



## CHAPTER 2

### LITERATURE REVIEW AND THEORETICAL CONSIDERATION

#### 2.1 General

Many variations are possible in the design of plants for evaporation to crude glycerine. Readers unfamiliar with the unit operation of evaporation may find it uses to consult one of the standard chemical engineering textbooks, or the book *Efficient Use of Steam* by Oliver Lyle (originally published by Her Majesty's Stationery Office in 1947; the new edition, edited by P.M. Goodall, published by Butterworth Scientific Ltd, 1980). A short, but comprehensive, review by the present author, (Edger Wcollatt, 1982) may also be helpful.

Points to be considered in the design of an evaporation plant to produce crude glycerine include:

:the capacity required in terms of water to be evaporated, crude glycerine produced, and, for soap lyes, salt to be separated.

: thermal efficiency and maximum consumption of steam.

: arrangements for separation of salt, when relevant.

: avoidance of undue losses of glycerol.

: vacuum equipment and other auxillaries.

: method of control.

: materials of construction.

#### 2.2 Water to be evaporated, salt to be separated, and crude glycerine produced

A simple procedure for the estimation of the relationships between the relevant quantities is illustrated by an example of a soap lye containing 4% glycerol, 11% salt and 85% water. Minor ingredients and losses are neglected.

	Lye	Crude Glycerine	Lye to produce 100 parts of crude glycerine contains	To be separate
Glycerol	4	83	83	-
Salt	11	8	$\frac{11 \times 83}{4} = 228$	$228 - 8 = 220$
Water	85	9	$\frac{85 \times 83}{4} = 1764$	$1764 - 9 = 1755$
Total	100	100	2075	1975

Hence, to produce 1 part of 100 % glycerol in crude :

- use  $\frac{2075}{83} = 25.0$  parts lye
- make  $\frac{100}{83} = 1.2$  parts crude
- evaporate  $1755 = 21.1$  parts water
- separate  $\frac{220}{83} = 2.7$  parts salt

The results of similar calculations for lyes containing 4, 6, 10 and 15 %glycerol respectively, plus 11% salt, evaporated to give a crude glycerine containing 83% glycerol, 8% salt and 9% water are shown in Table 1.1 It shows that a small increasing in lye strength reduces the quantity of water to be evaporated, and consequently the amount of steam uses in the proce with consequent reduction in steam usage and ss being also small. The quantity of salt in recycling stream is deminished .The estimated quantities for evaporation of treated lyes of semi-crude strength (see later), or of sweet waters can be calculated.

Table 2.1 - Quantities required and/or separated to produce 1 part of 100% glycerol in crude glycerine at 83% glycerol

% glycerol in lye	Parts lye used	Water evaporated	Salt separated	Crude glycerine produced
4	25.0	21.1	2.7	1.2
6	16.65	13.7	1.75	1.2
10	10.0	7.8	1.0	1.2
15	6.65	4.8	0.65	1.2

## 2.3 Thermal efficiency

In addition to steps to reduce the quantity of water to be evaporated methods are available to minimize the usage of steam required to carry out the necessary evaporation. One kg of steam will evaporate approximately 1 kg of water fed at its boiling point, but less than 1 kg when the feed is at a lower temperature and sensible heat, which does not immediately produce vapour, has to be supplied before boiling commences. The boiling point of water, or any other liquid, falls as the pressure under which the thermal efficiency of an evaporation system can be improved. Thermal efficiency is often and conveniently expressed in terms of kg of water evaporated per kg of steam supplied (called 'kg/kg', or in 'lb/lb').

The main procedures in which thermal efficiency can be improved :

: multiple effect operation in which the vapour from one evaporating vessel, or 'effect', becomes the heating steam in another effect operating under a lower pressure. In this way, the latent heat is used more than once

: vapour recompression in which the vapour from a vessel is compressed, by a steam jet or by mechanical compressor, and returned as heating steam to the same evaporating unit. It will be appreciated that for the latent heat to be re-usable the pressure must be increased; and that a simple addition of superheat to the vapour will not do.

: selection of the optimum method of feeding the liquor to the evaporator; and/or the use of the heat exchangers. As discussed later, heat exchangers can be used internally between effects, or to recover heat from outgoing streams of vapour, condensate, or product.

: integration with other plants in the factory.

Before these procedures are considered, it is necessary to discuss about boiling point elevation and temperature differences of solution. Boiling point elevation is the temperature difference between the boiling point of the solution in an effect and the boiling point of water under the pressure in the vapour space of the effect. It is due to two causes:

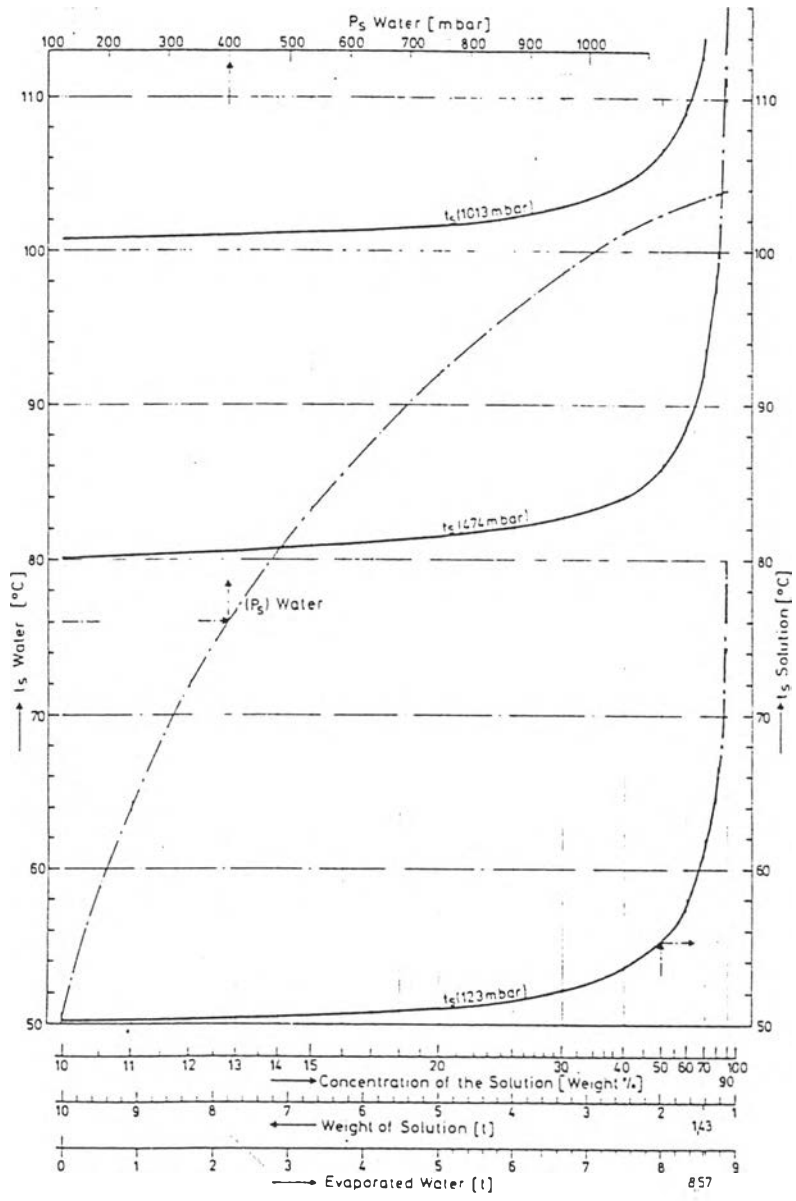


Fig. 2.1 Boiling diagram for sweet water solutions.(Edger Woollatt, 1982)

: boiling point elevation due to the amount of dissolved substances(in relation to fatty acidin distillation unit)increase.For exsample : in semi-crude soap lye glycerine of 40 - 45% glycerol ,the boiling point elevated about 15C; and for soap lye crude of 83% glycerolis about 37C. Fig 2.1, Courtesy Lurgi, gives similar information in a different form for concentrated sweet waters.

: boiling point elevation due to hydrostatic head. When a liquid is heated at a distance below its surface, the pressure is that in the vapour space plus that equivalent to the head of liquid above the point at which the heat is supplied. 3 ft of glycerine of specific gravity 1.2 is equivalent to a hydrostatic pressure of  $3 \times 12 (1.2 / 13.4) = 3.2$  inches of mercury, so that with a pressure of 2 inches Hg. in the vapour space, the pressure at a depth of 3 feet is equal to 5.2 inches Hg. The relative effect is clearly smaller when the pressure in the vapour space is higher. Boiling only occurs when the temperature reaches the boiling point under the prevailing pressure, but it is possible for the liquid to be heated to above its boiling point at the pressure in the vapour space and for it to flash when the liquid is circulated to a zone of lower pressure.

The apparent temperature difference,  $t_{ap}$ , is defined as the difference between condensing temperature of steam in heater and the temperature at which water boils under the pressure in vapour space. For example, a single effect evaporator in which the heating steam condenses at 5 psig 109C, and the vapour space has a pressure of 2 inches mercury at which water boils at 38C. The apparent temperature difference is  $109-38=71$ C. If the liquid being boiled is crude glycerine with a boiling point elevation,  $bp_{lev}$  including any hydrostatic head effect, of 37C, it will boil at  $38+37=75$ C; and the actual temperature difference,  $\Delta t_{act}$ , is  $109-75=34$ C (or, alternatively,  $71-37=34$ C, the apparent temperature difference minus the boiling point elevation). This situation is depicted as case 1 in Fig.2.2. If a double effect evaporator is used in which vapour from the first effect, which contains partially concentrated liquor with a boiling point elevation of 10C boiling at 91C, is used to boil crude glycerine under a pressure of 2 inches Hg in the second effect, the condition are as shown as case 2 in Fig.2.2 .

A positive  $\Delta t_{act}$  is essential in each effect in order to achieve heat flow and evaporation. With a natural circulation heater, particularly when the liquid is viscous, a  $\Delta t_{act}$  is

required larger than the minimum which can be used with a forced(pump) circulation type of heater.

Case 3 (in Fig.2.2) shows approximate conditions for evaporation from lye to semi-crude glycerine in double effect using low pressure steam, a system which is widely used.

Case 4 shows possible conditions for evaporation from lye to crude glycerine in triple effect using steam which condenses at 30 psig, 133C.

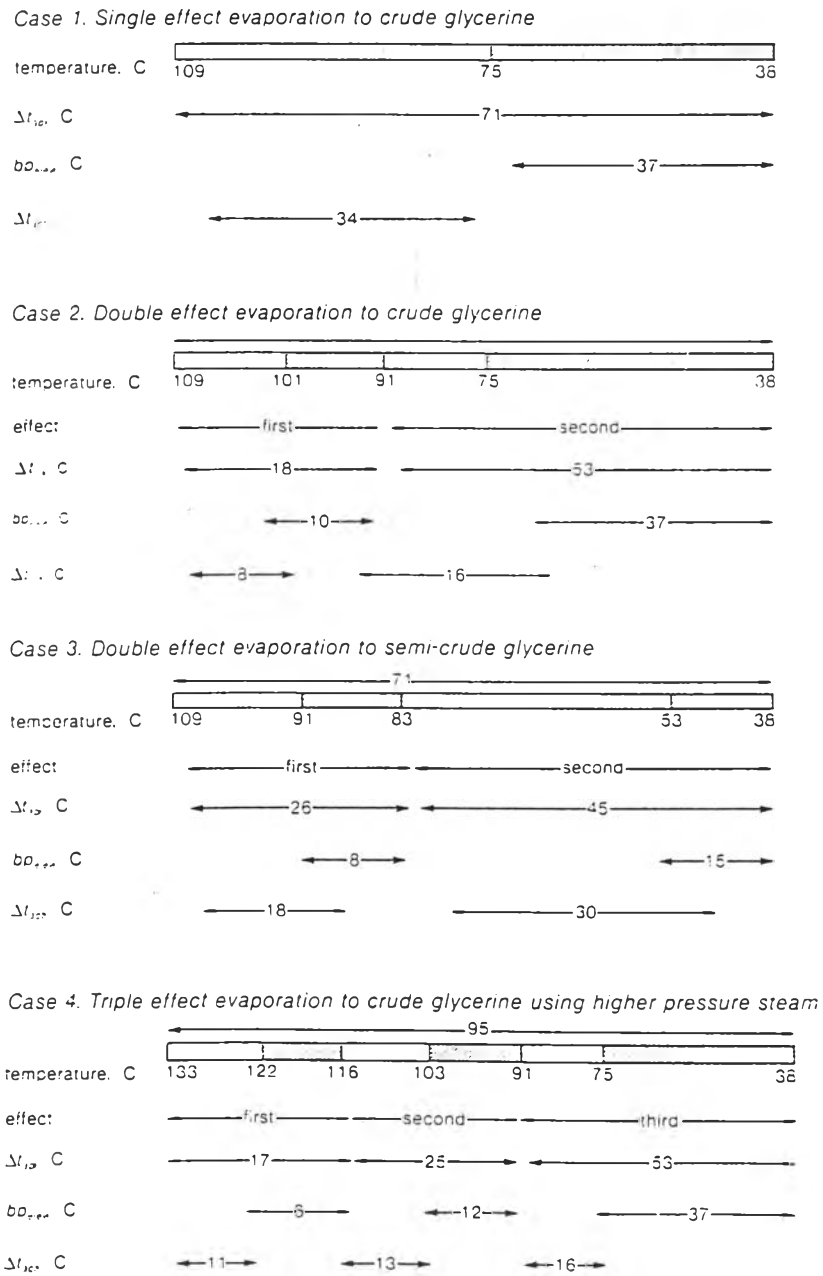


Fig 2.2 Temperature condition for single , double and triple effect evaporation to soap lye crude or semi-crude ,glycerine.(Edger Woollatt, 1982)



Some general points related to these topics are:

: boiling point elevation due to hydrostatic head varies with the design of the heaters and is assumed to be included in the figures for  $bp_{elev}$  used in Fig 2.2. It does, however, reduce the effective temperature difference, even if the liquor is heated without boiling and only flashes when it arrives near to the liquor surface.

: boiling point elevation due to dissolved substances depends only on the composition of the liquor. It is high for crude glycerine; and this is a disadvantage of continuous operation in which the liquor in the effect from which the product leaves must be maintained at the product concentration. If an evaporator is operated semi-batch, that is the unit is fed with fresh liquor but the bulk of the product is not discharged until its concentration reaches the desired level, the average boiling point elevation is lower and the average  $t_{act}$  higher, other things equal, than with continuous operation. At one time semi-batch operation to concentrate lye to semi-crude and, separately, semi-crude to crude glycerine was normal, but the usual advantages of continuous operation are now commonly considered to outweigh this disadvantage.

: forced circulation heaters, now often used in all effects, are particularly valuable for effects in which crude glycerine concentration is reached, as they permit operation with a low  $t_{act}$  even when the liquid is quite viscous.

: the need for an adequate  $t_{act}$  in each effect limits the number of effects which are physically possible with given terminal conditions. In general, an increase in the number of effects leads to a reduction in steam consumption, but to an increase in capital cost. There is an economic optimum which may well use less than the maximum number of effects physically possible.

Double effect evaporators to concentrate lye to semi-crude were traditional for many years; and further concentration to crude glycerine was carried out in a separate single effect

finisher, or in the second effect of the double effect unit operated either as a single effect using a connection directly to the steam supply, or as a double effect using water in the first effect. These plants used steam at only just above atmospheric pressure; and the supply commonly included exhaust from steam pumps and small steam engines. Increased emphasis on fuel economy around the 1940s and 1950s led to the construction of at least one quadruple effect natural circulation evaporator to produce semi-crude glycerine from soap lyes. This was fed with steam at 90 psig and the pressure in the first effect heater rose to 30-50 psig depending upon conditions. Initially, this unit was operated semi-batch like its double effect predecessors, but it was found preferable to work it continuously. Triple effect evaporators have been, and are, also used for soap lyes and sweet waters. They now commonly use forced circulation and take the concentration to crude glycerine strength. The concentration of glycerol in the lye, or sweet water, to be evaporated is an important factor in the design of the plant.

Vapour recompression evaporation with an electrically driven mechanical compressor is only likely to be economical when the compression ratio (that is, the ratio of the pressure of the heating steam to that of the vapour it produces by evaporation) is low, which means a low  $t_{app}$ . A low  $t_{act}$  can be achieved by the use of a forced circulation heater with a generous area of heating surface, but  $bp_{elev}$  is inevitably high if the unit is to produce crude glycerine; and mechanical recompression is not suitable for this duty. Jet recompression, combined with multiple effect operation, is valuable; and is now widely used when steam at boiler pressure, rather than steam including low pressure exhaust, is to be the heating medium. Fig 2.3 show the main features of triple effect system with jet recompression of part of the vapour leaving the first effect. Again, recompression is most effective when the pressure ratio is small, as it can be when the liquor concentration in the first effect is fairly low. When conditions permit satisfactory recompression, a useful improvement in thermal efficiency is achieved without increase in other costs and for only a very small additional capital cost for

the jet.

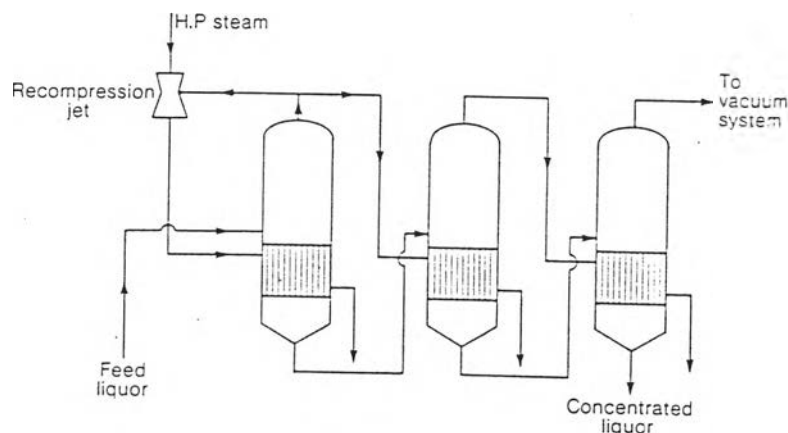


Fig 2.3-Principle of triple effect evaporation with vapour recompression (Edger Woollatt, 1982)

Parallel feed, that is separate feed to each effect, is suitable for the evaporation of brine to produce salt, but not for glycerine liquors in which the concentration of glycerol increases very substantially as the evaporation proceeds. Feed can be forward, that is 1-2-3 etc., the effects being numbered in the direction of heat flow; or backward which is the reverse direction, for example 3-2-1. The direction of feed often has an important influence upon steam consumption, depending upon the temperature of the feed liquor. If the feed is cold, it has to be heated to its boiling point under the pressure in the effect to which it goes. With forward feed, the temperature of the whole of the feed must be raised to the relatively high boiling point in the first effect by new steam and this sensible heat does not produce any vapour in that effect, although the heat in the partly concentrated liquor does produce some vapour by flashing when it is transferred to the second and subsequent effects which operate under lower pressures than the first effect. With backward feed, a cold liquor is heated in stages as the unevaporated portion is transferred from effect to effect. Only the final portion which reaches the first effect is heated with new steam, and the sensible

heating in the second and subsequent effects is done by vapours from an earlier effect; that is by latent heat which has already been used one, or more, times in the evaporator. If the feed liquor is very hot, for example above the boiling point in the first effect, no sensible heat is required even with forward feed; and flash vapour is produced in each effect and forms part of the steam used in the next effect. With backward feed, the hot liquor flashes to the pressure in the last effect and the latent heat is not used again, at least in the evaporator. The residual liquor then has to be re-heated to the temperature in its next effect, as for cold feed. These considerations show that it is beneficial thermally to use forward feed with hot liquor and backward feed with cold liquor; at some intermediate temperature the factors balance and there is no difference between backward and forward feed. The thermal advantage of backward feeding with relatively cold feed liquor can nearly be achieved by the use of forward feed with interstage preheaters as indicated in Fig 2.4. The feed is preheated stage by stage with vapour at as low a temperature as possible to make the maximum re-use of latent heat. A preheater cannot operate without a positive temperature difference in the required direction; and with modern vacuum equipment it is often not possible to use a preheater in the vapours from the final vapours is clear gain. Heat transferred to the feed in interstage preheaters is not available for use in the next effect, but the overall result is beneficial with cool feed for the reasons discussed in relation to forward and backward feed. Heat can also often be recovered from other streams leaving the effects, particularly the condensates. These condensates can be handled in several ways, bearing in mind the fact that condensate leaves the first effect heater at a higher temperature than that from the second effect, and so on;

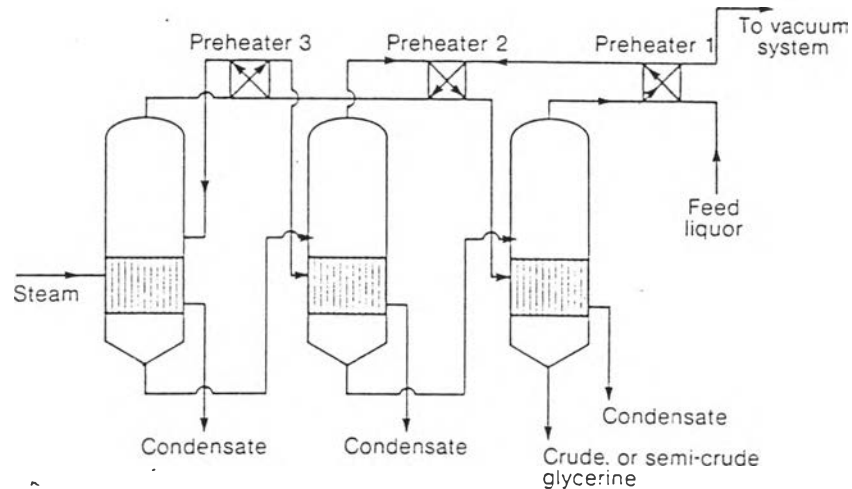


Fig2.4 Evaporation with forward feed and interstage preheaters.(Edger Woollatt, 1982)

:condensates can be allowed to flash on reduction in pressure on transfer from one effect heater to the next, or in separate vessels. The flashed vapour is used as steam at a suitable point in the system, and the residual hot, or warm, water remains available. This condensate can be re-used as process water in the soapmaking or fat-splitting process, as well as a source of heat.

: unflashed, or flashed, condensate can be used in a heat exchanger.

Other factors to be considered in the selection of a system of feeding are :

:with forward feed the most concentrated liquor is evaporated at the lowest temperature, so that its viscosity is higher than that of the fully concentrated liquor using backward feed. This adversely affects heat transfer, particularly with natural circulation heaters.

: more sensible heat leaves in the crude, or semi-crude, with backward than with

forward feed; but some of this may be recoverable in heat exchangers.

: liquor can normally be transferred from effect to effect by pressure difference with forward feed, although a pump may be needed to introduce the feed liquor into the first effect. With backward feed it is normally possible to suck the feed liquor into the last effect, but pumps are needed for transfer from effect to effect, unless unusual levels are adopted which provide sufficient gravity head to more than offset the adverse pressure differences between the vapour spaces.

: the salt crystals which separate during the evaporation of soap lyes are rather fine; and they tend to become finer with rise in the temperature at which they are separated and with increase in the glycerol content of the liquor. Fine crystals are more difficult to wash effectively than coarser ones. The same factors also tend to induce 'salting' of the heater tubes, a phenomenon discussed later. Salting can be a serious problem with natural circulation soap lye evaporators under some conditions and forward feed may then be advisable.

When the feed liquor is relatively cool it is usual to use forward feed with interstage preheaters. For special reasons, it is also possible to use other arrangements. For example, the quadruple effect evaporator mentioned earlier was for many years fed 1-2-4-3.

As mentioned earlier, and for the reasons just discussed in relation to methods of feeding, it is commonly a serious error to assume 1 kg of live steam will evaporate  $n$  kg of water in an  $n$ -effect evaporator, unless the feed is exceptionally hot or a recompression jet is used. A good estimate of the performance to be expected from an evaporator, including its evaporative capacity, can be made with the aid of detailed heat balances over each stage of the process. Because of the dynamic equilibria maintained within a unit, the temperatures and pressures adjust themselves automatically to meet both heat balance and heat transfer criteria in each section of the plant. For a plant which does not exist, it may be necessary to

make provisional assumptions as to intermediate temperatures, or likely heat transfer coefficients; and to make adjustments, if necessary, to reconcile the two sets of criteria. Such calculations are not difficult, but manual calculation can be tedious, particularly when several effects are involved. Plant manufacturers will provide estimates in response to serious enquiries, doubtless by the use of computer programmes, but it is sometimes useful for an operator to estimate what is likely to result from changes such as the inclusion of an additional heat exchanger, or a different feed arrangement. In making such estimates, it must be remembered that any change is likely to induce other changes to maintain the dynamic equilibria.

As a first approximation it is sometimes assumed that an  $n$ -effect evaporator costs  $n$  times as much as single effect plant for the same duty, because the overall temperature difference is split between the effects with a consequent need for additional heating surface. This is also subject to considerable error. Estimates obtained some years ago from a well-known plant manufacturer for single and double effect units for the same, rather small, duty showed that the cost of the double effect was substantially less than twice that for the single effect. At least in part this was because of the larger final entrainment separator, condenser, and vacuum equipment needed for the single effect unit in which the whole of the water evaporated passes to the condenser.

The discussion of thermal efficiency has so far considered the evaporator alone, but it is sometimes worthwhile to involve other plant. Steam from another unit which is not at high enough pressure to be used as first effect steam may be able to be introduced between effects. Similarly, vapour can sometimes be bled between effects for use elsewhere. Different plant units commonly do not synchronize at all times, so that it is usually necessary to provide an alternative steam supply, probably through a reducing valve. Surplus heat from a high pressure fat splitting plant can often be used in the evaporation of the sweet water.

## 2.4 Minimization of losses of glycerol

During evaporation, liquor containing glycerol and salt can be lost by being carried out in liquid/solid form with the vapours and discharged in a condensate. The carry-over can be as droplets, foam, or, if a serious prime occurs, as bulk liquid. To minimize this loss:

- :adequate vapourspace should be provided above the level of the boiling liquid.

- : suitable separators, and external "catchalls", usually cyclonic, should be included in the system. It is useful to provide sight-glasses in external separators, and/or the return lines, so that the plant operator can see immediately when any serious carry-over occurs and take remedial action.

- : the liquor levels in the effects should be controlled with care, automatically or manually.

- : the treatment of the lyes, or sweet water, should ensure that the liquors have no undue tendency to foam.

External catchalls are sometimes fitted only to the effect in which the concentration of glycerol is highest. Devices which measure roughly the electrical conductivity of the condensate from the evaporated vapours are very useful indicators of carry-over. They actually indicate the presence of salt, or other electrolyte, but this is relevant as salts and glycerol are carried over together. The main problem is to obtain a continuous flow of condensed vapour from the last effect when, as is common, a direct contact condenser is used in the vacuum system; and the condensate is mixed with cooling water. It is not essential to obtain a representative sample of the vapours plus any entrained liquor; all that is necessary is to get a sample which will indicate when any abnormal amount of salt is present in the vapours, and this can often be achieved by the use of a small partial condenser in the vapour line. For example, a ring carrying cold water placed above a



collecting tray, in a vertical vapour main, as shown in Fig 2.5, can be used. There is a continuous flow of condensate through the box containing the electrodes which are connected to a suitable low AC voltage and a measuring instrument or, better, recorder. An audible alarm can be included to draw immediate attention to any substantial increase in conductivity.

Losses of glycerol during evaporation can occur in other ways, for example, if a leak develops in a calandria. The effects are normally left containing water during shut-downs (to dissolve deposited salt) and, if a leak is present, some salt solution can be drained from the steam chest of the calandria after the plant has stood for a period of time.

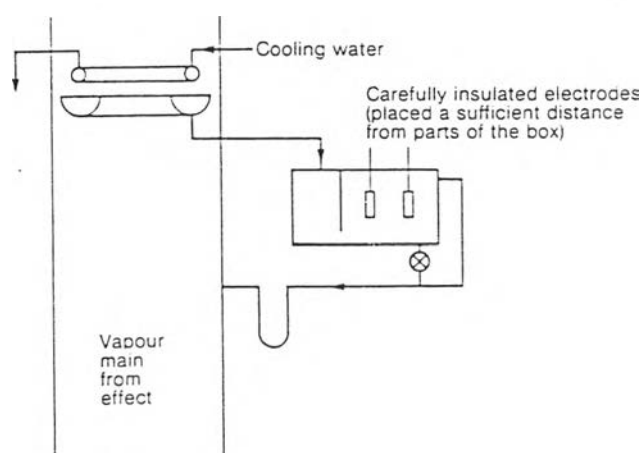


Fig 2.5 Partial condenser for entrainment indicator.

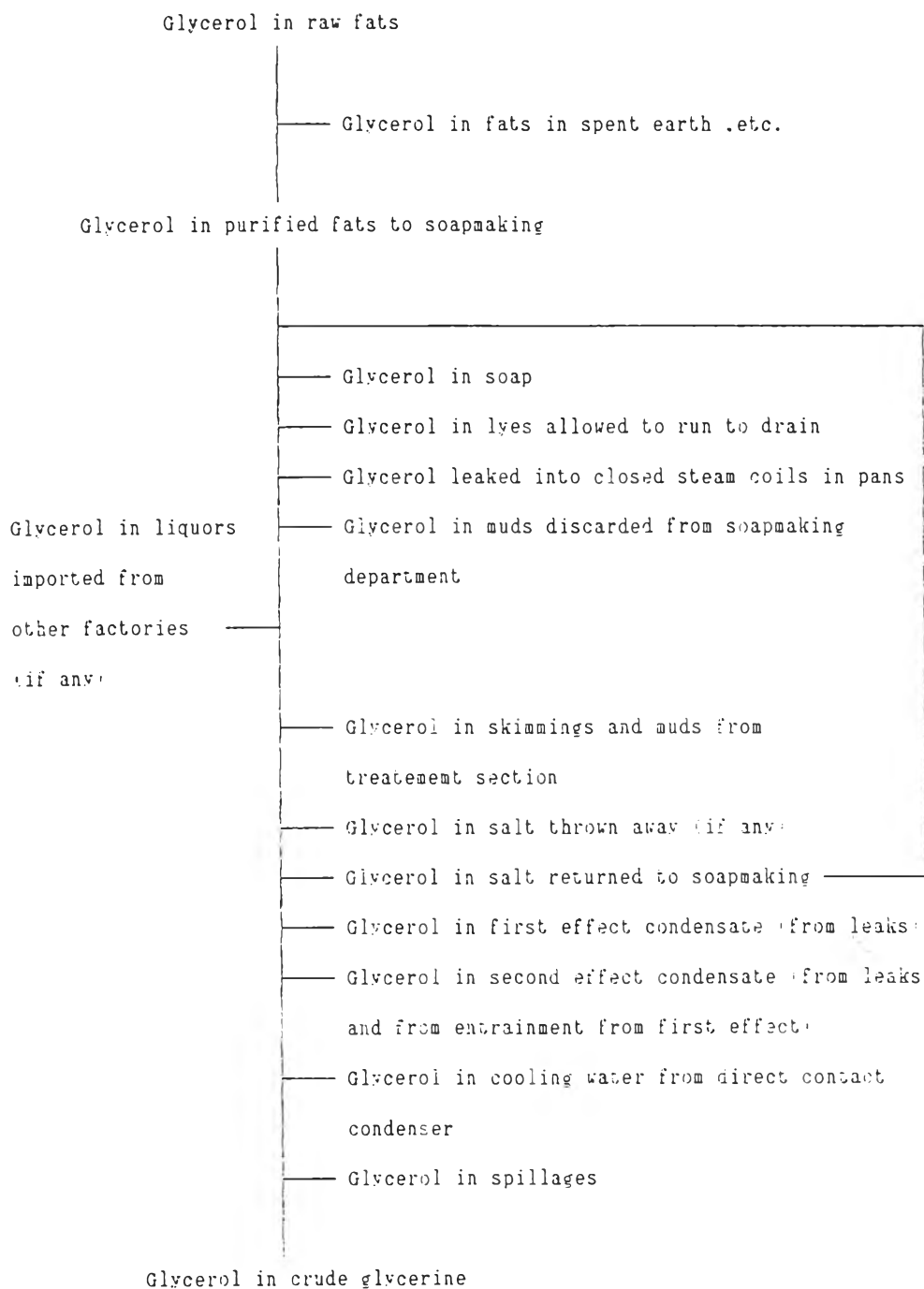


Fig 2.6 Flow of glycerol through a soap and glycerine factory  
(Edger Woollatt, 1982)

Fig 2.6 shows the flow of glycerol through a soap factory with glycerine recovery; and indicates the sources of loss. The diagram is drawn for a double-effect evaporator with direct contact condenser; and refers to closed coils in soap pans. Such coils are now obsolete, but they can be a serious source of loss if present. The diagram can readily be modified to suit other plant arrangements and similar ones prepared for the splitting route. It is useful to determine the recovery in each section of the factory, particularly if the overall loss is high., but, this is usually not done easily; and, for routine purposes, those with limited resources may find it best to concentrate on checks on the controllable losses, and the important glycerol in re-cycled salt. Care is necessary to ensure that truly average samples of materials such as muds are tested. Misleading samples of treatment mud can be taken from near the point at which water is introduced into the filter presses.

## 2.5 Vacuum maintenance

Principles of vacuum maintenance are discussed in Appendix A. Glycerine evaporators now normally operate at 22-4 inches Hg. absolute pressure (28-26 inches Hg vacuum with 30 inches Hg barometric pressure); and a high-level direct contact condenser with barometric leg is commonly used. The noncondensable gas can be removed with a two-stage ejector system, with an intermediate condenser, or by a mechanical vacuum pump. Because of the level of pressure needed in a glycerine evaporator, no booster jets are normally installed. The direct contact main condenser can be replaced by a surface condenser if the condensate from the last effect is required, for example, for use with other condensates in the splitting section of a fatty acid plant.

## 2.6 Evaporator control

Traditionally glycerine evaporators were controlled manually, but standard instrumental control techniques are now used to make operation increasingly automatic. Possible difficulties due to dissolved and solid salt must be remembered with soap lye evaporators.

Also, the influence of vapour on the apparent density of boiling liquid in, for example, a natural circulation evaporator.

A reliable indication of the concentration of glycerol in the material being discharged from an effect producing crude glycerine is required. This is frequently based upon the relationship between boiling point elevation and concentration; in other words, between boiling point under a known pressure and concentration. A very simple way for a plant operator to control a manually operated finisher, or other unit producing crude glycerine, is to provide:

: a barometer to measure atmospheric pressure (b inches Hg.)

: a Mercury U-tube with an open end to the atmosphere and the other end connected to the vapour space in the effect. This gives the vacuum under which the liquor is boiling. x inches Hg; that is the difference between the atmospheric pressure and the pressure in the vapour space. The absolute pressure in that vapour space is thus (b - x) inches Hg. Alternatively, gauges which measure this absolute pressure directly can be used.

: a thermometer set to measure the temperature of the boiling liquid. Because of the effect of hydrostatic head, this temperature will vary somewhat with the quantity of liquor in the effect and the point at which the thermometer is placed.

Because of the influence of hydrostatic head, and of impurities in the crude glycerine being produced, it is necessary to calibrate the system by the analysis of samples taken in relation to various sets of reading. Roughly, a boiling temperature of about 77°C with an absolute pressure of 2 inches Hg indicates 83% glycerol in a soap lye crude glycerine. It has also been found that an extra 0.1 inch Hg pressure requires an extra 1°C in boiling liquor temperature. Hence, if 77°C is found to be correct for 22.0 inches Hg, 79°C will be about right for 2.2 inches Hg pressure, and 74°C for 1.7 inches Hg pressure.

## 2.7 Complete evaporation plants

It will be appreciated that many combinations of plant elements are possible. Fig 2.7a,b,c,d,e outlines some examples from recent plant manufacturers brochures but, as in others fields, most manufacturers offer alternative designs to suit various requirements.

Fig 2.7a shows a Wurster and Sanger backward feed, double-effect, evaporator, for soap lyes, directly connected to single-effect finisher. Heating is in natural circulation calandrias; and extraction of salt slurry in a batch centrifuge, or centrifuges.

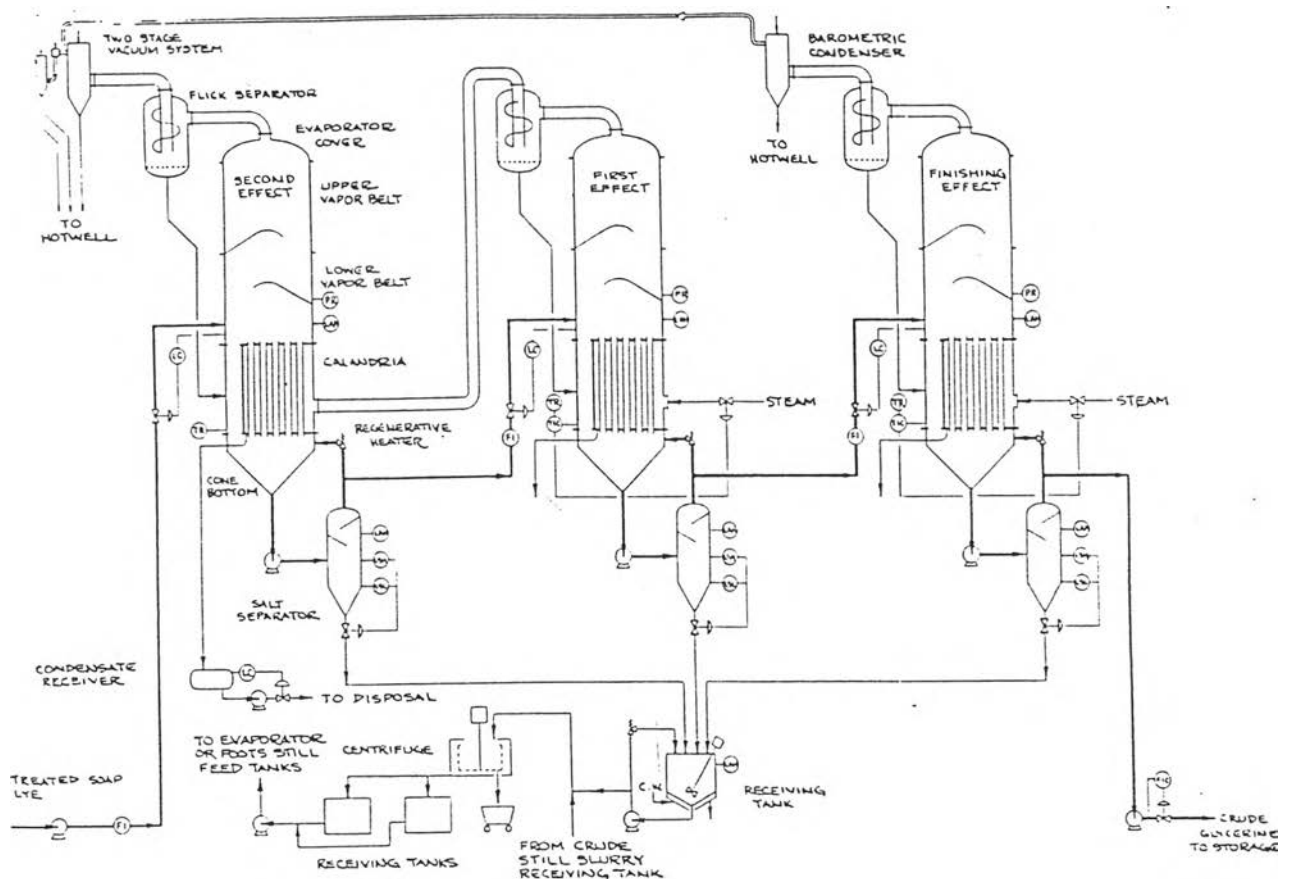


Fig 2.7a Wurster and Sanger evaporator for soap lyes.

(Edger Woollatt, 1982)

Fig 2.7b represents a Gianazza evaporator for soap lyes. This unit is double effect with forward feed and uses jet recompression of part of the vapour from the first effect. External condensers are used, with natural circulation for the first effect and forced for the second which produces crude glycerine. Salt slurry is extracted by pneumatically operated salt boxes, and from the crude glycerine in static separator, for separation in centrifuge. B01 is direct contact condenser with barometric leg and PV 01 a mechanical vacuum pump.

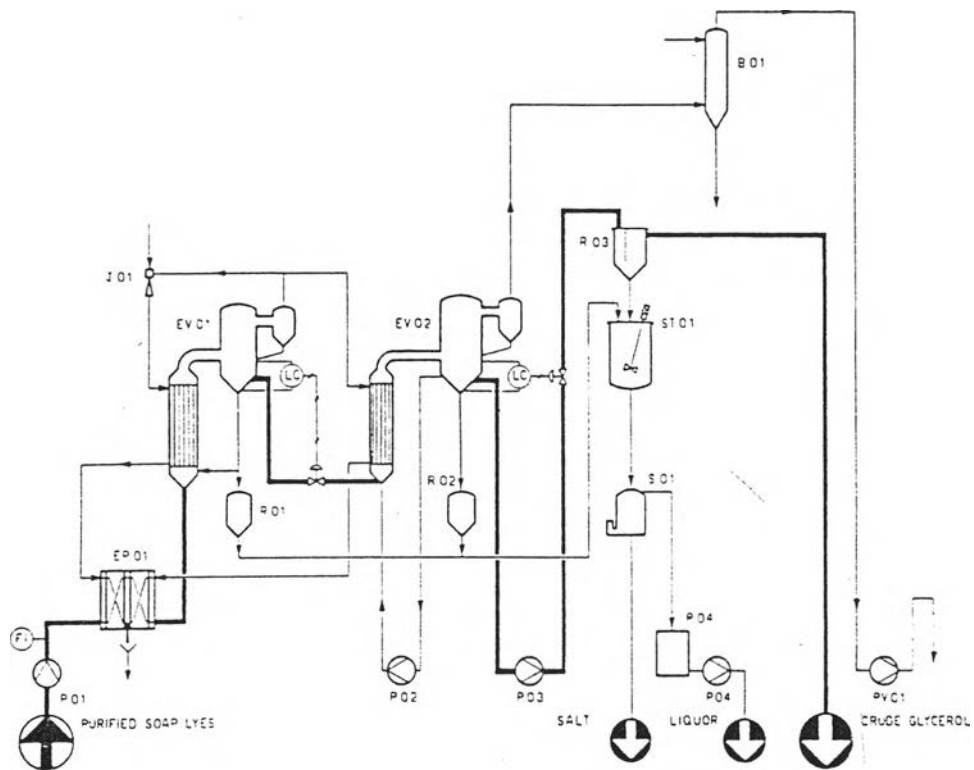


Fig 2.7b Gianazza evaporator for soap lyes.(Edger Woollatt, 1982)

Fig 2.7c shows a Lurgi double effect sweet water evaporator .Special features are :

: jet recompression of part of the vapour from the first effect .

: multi-compartment , long tube ,climbing film calendrias ,arranged so that the liquid flow is once through each compartment in series, with the vapour discharge from each into a single space . The last part of the second effect is separated from the rest and is fed with steam directly from the recompression jet;that is the final concentration is in single effect .As an example ,Lurgi quotes concentration from sweet water at about 10 % glycerol to 25 % in the first effect ,to 70 % in the second effect ,and to 88 % in the final stage .

: a surface condenser is used for the final vapours to increase the quantity of condensate available for re-use.

: the feed is preheated by the first effect condensates ( including that from the final stage).

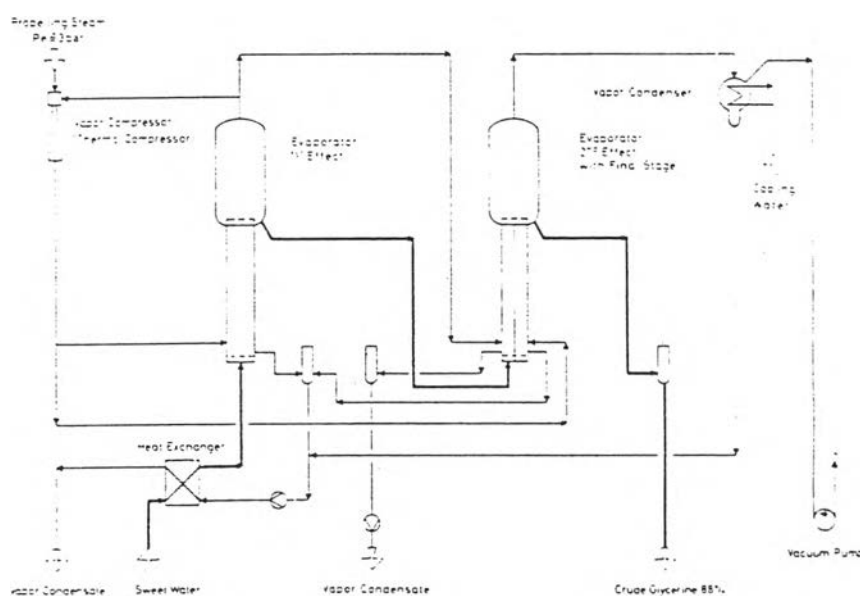


Fig 2.7c Lurgi double-effect sweet water evaporator.(Edger Woollatt, 1982)

Fig 2.7d shows a Lurgi triple effect plant for sweet water which is generally similar to the previous example. No recompression jet is shown, but one could be used if the available heating steam is at the suitable pressure. The feed is preheated by condensate, followed by live steam. A separate finishing section, operating in double effect, is included in the third effect shell.

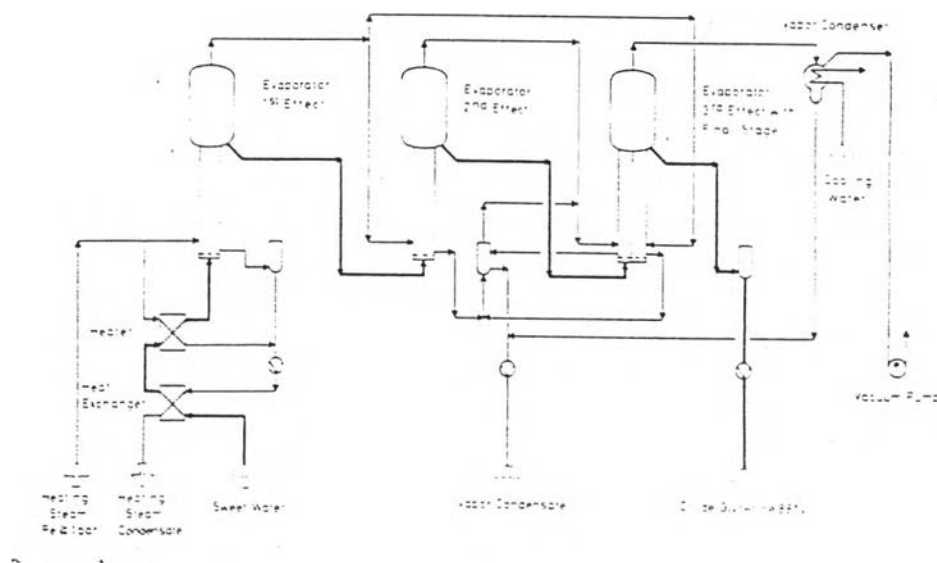


Fig 2.7d Lurgi triple-effect sweet water evaporator. (Edger Woollatt, 1982)



Fig 2.7e depicts a Wurster and Sanger quadruple effect evaporator for sweet waters. Feed is forward. External calandrias are used with natural circulation for the first three effects and forced circulation for the fourth effect.

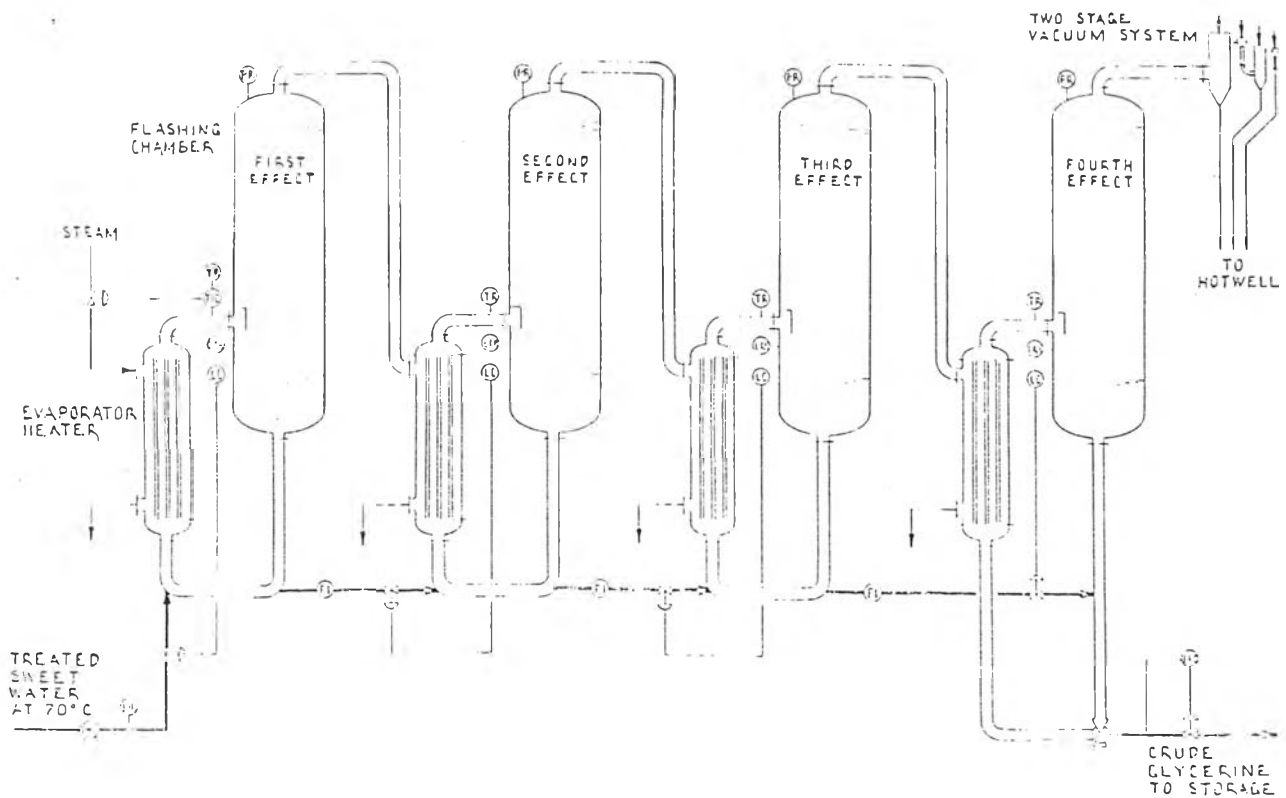


Fig 2.7e Wurster and Sanger quadruple-effect sweet water evaporator  
(Edger Woollatt, 1982)

## 2.8 Colgate Palmolive Soap Making Process

Colgate Palmolive use palm oil, palm stearin and coconut oil as raw material and the process is called "Continuous Process" that compose of reaction unit that the oil will react with caustic soda, extraction unit with four extraction columns and neutralization unit.

Soap from the neutralization unit is called "Wet Soap" that will pass through the dryer unit for drying to the standard formula moisture level. By product that come from the reaction unit is called "Spent Lye" which has 17-25 % glycerol. Spent lye has to be treated before the evaporation unit for the reason of avoiding the foaming problem at the evaporator. After the evaporation unit we will get the crude glycerine. The distillation unit is the last process that will purify the glycerine to meet the standard specification before sending to the toothpaste making plant. (See Figure 2.8)

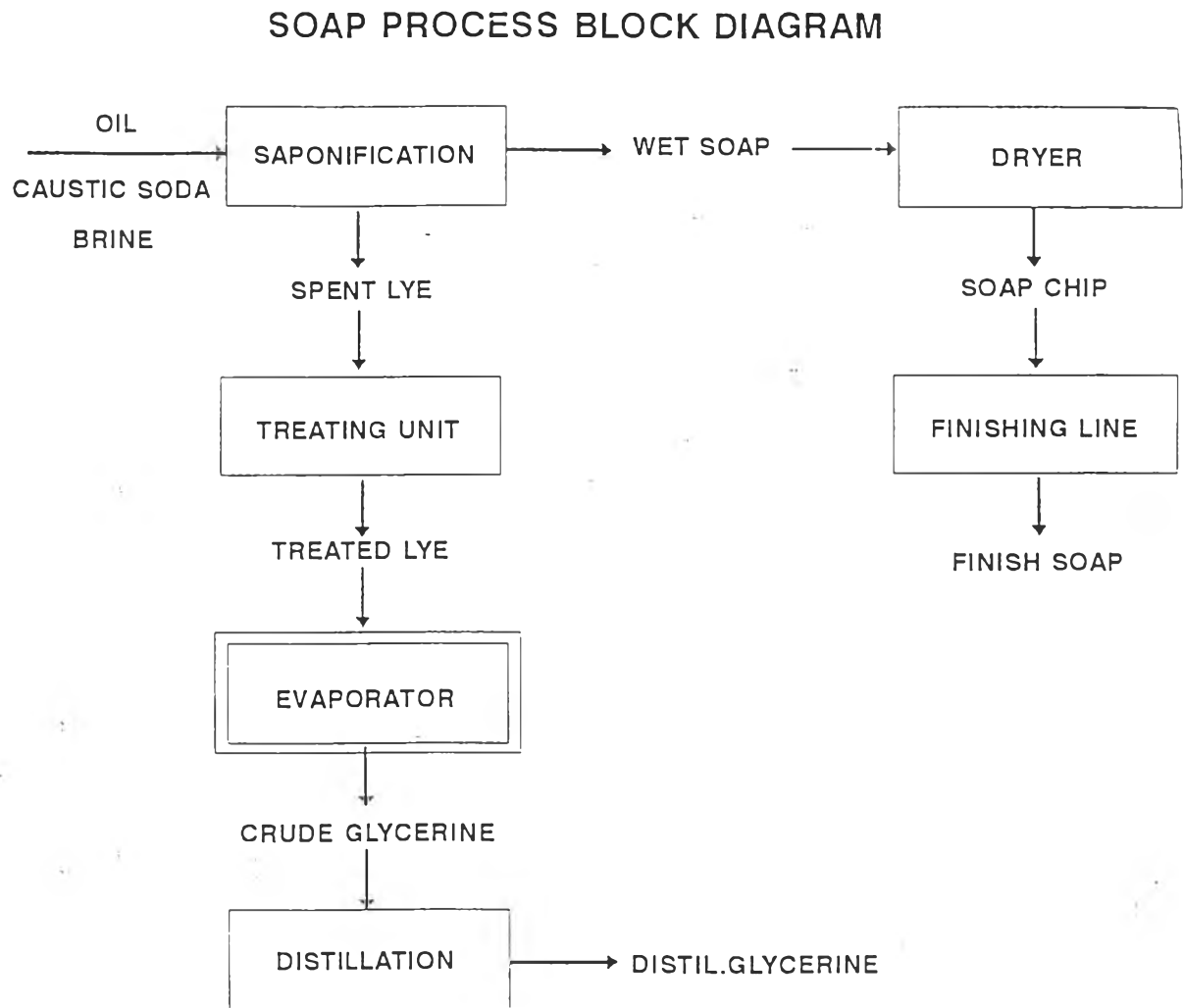


Fig. 2.8 Soap Process Block Diagram