Spent acid from a nitrating process contains 21% H_2SO_4, 55% HNO_3 and 24% H_2O by weight. This stream is to strengthened by the addition of

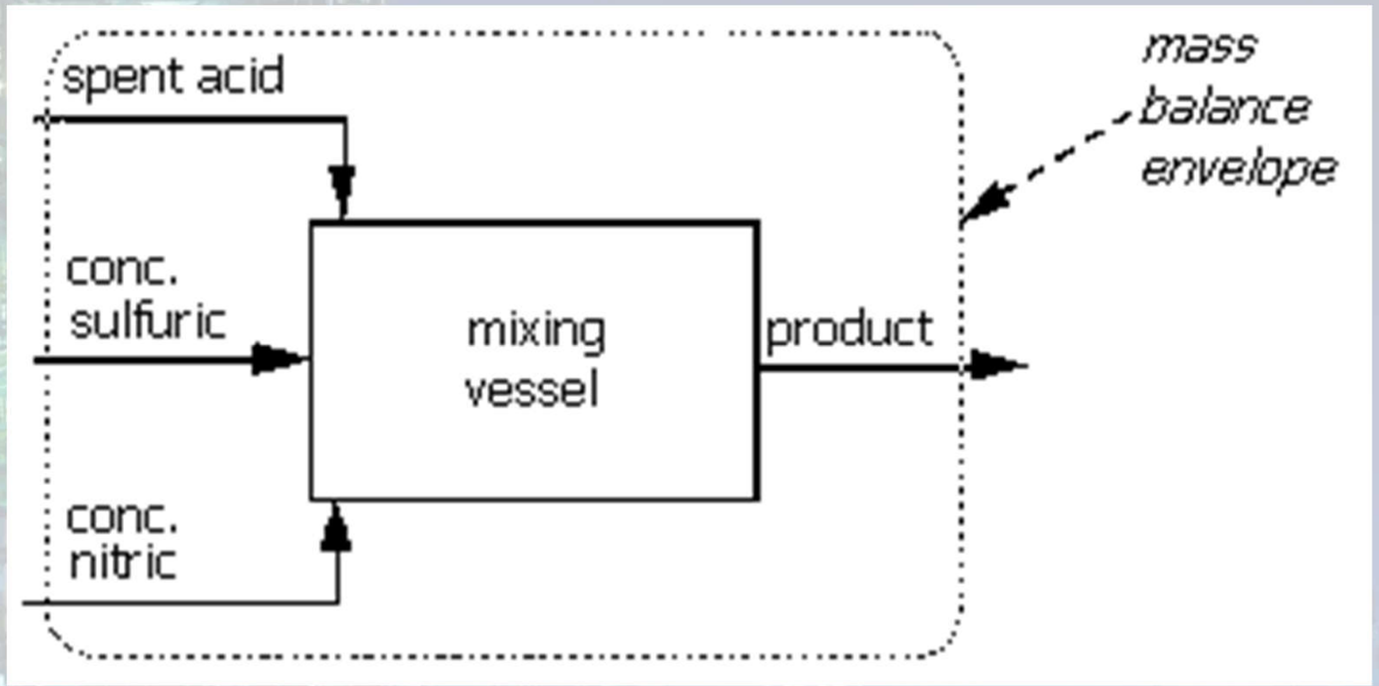
1) concentrated sulfuric acid containing 93% H_2SO_4 and 7% H_2O

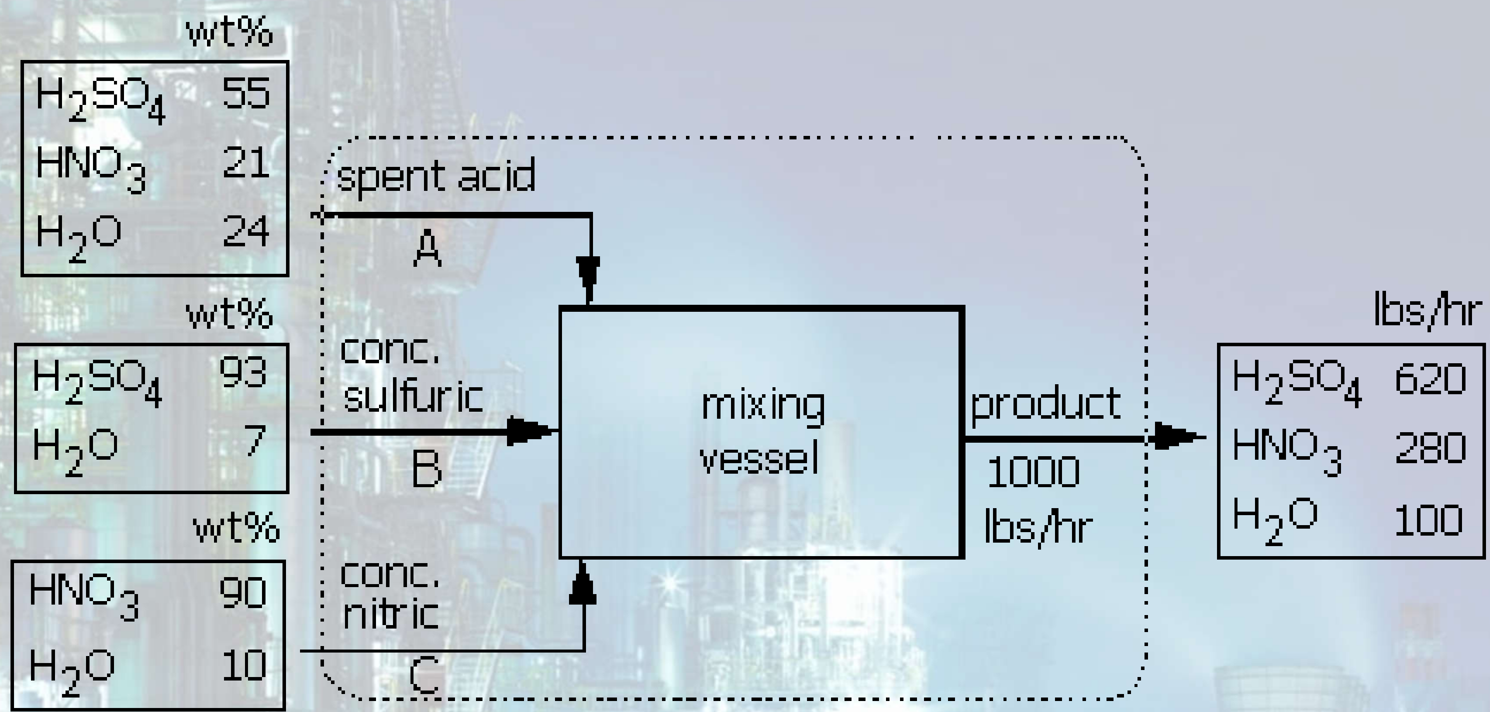
and

2) concentrated nitric acid containing 90% HNO_3 and 10% H_2O

to form a stream whose composition is 62% H_2SO_4, 28% HNO_3 and 10% H_2O.

If 1000 lbs/hour of the product stream is desired, find the flow rates of the other three streams.


spent acid
conc.
sulfuric
conc.
nitric
mixing
vessel
product
mass
balance
envelope


wt%
H2SO4 55
HNO3 21
H2O 24
spent acid
A
wt%
H2SO4 93
H2O 7
conc.
sulfuric
B
wt%
HNO3 90
H2O 10
conc.
nitric
C
mixing
vessel
product
1000
lbs/hr
lbs/hr
H2SO4 620
HNO3 280
H2O 100

The process is at steady-state and involves no chemical reaction, so the equation

rate of input = rate of output

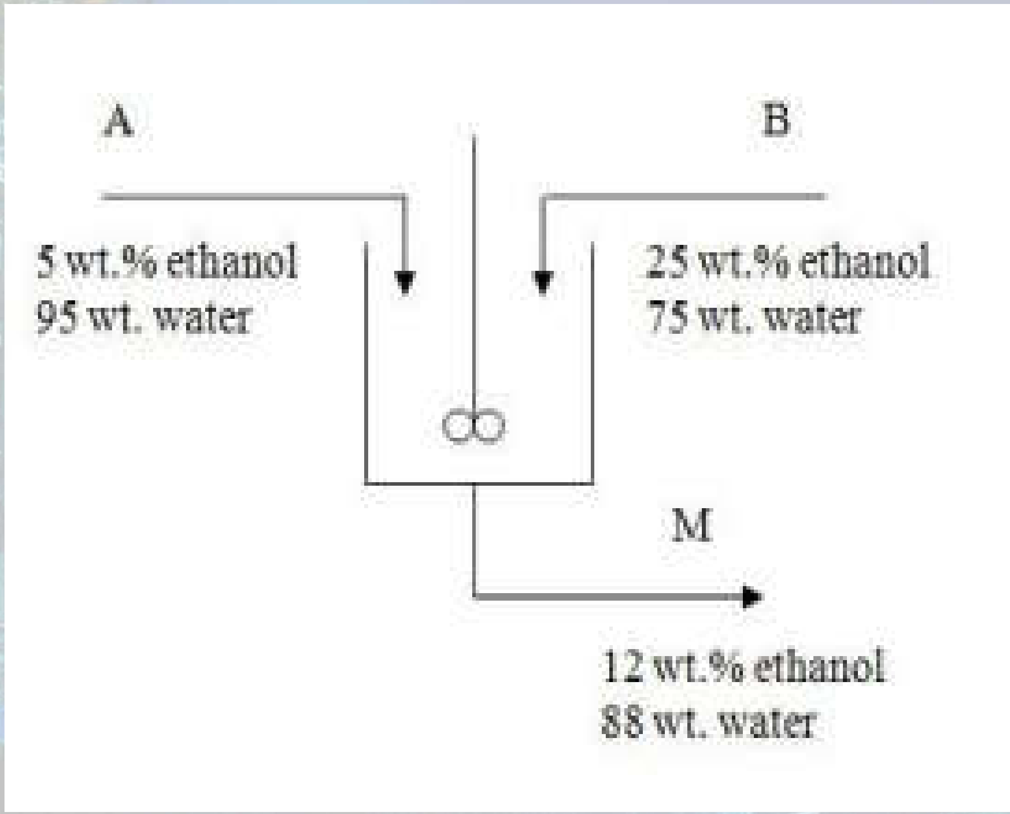
$$\begin{array}{llllll} H_2SO_4 & 0.55A & + \ 0.93B & & = 620 \\ HNO_3 & 0.21A & + & 0.90C & = 280 \\ H_2O & 0.24A & + \ 0.07B & + \ 0.10C & = 100 \end{array}$$

A+B+C = 1000 lbs/hours

A=**126.8** lbs/hr, B=**591.6** lbs/hr, and C=**281.6** lbs/hr

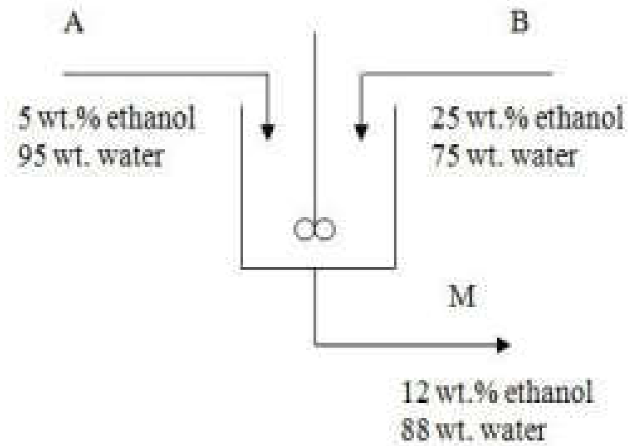
It is required to prepare 1250 kg of a solution composed of 12 wt.% ethanol and 88 wt.% water. Two solutions are available, the first contains 5 wt.% ethanol, and the second contains 25 wt.% ethanol. How much of each solution are mixed to prepare the desired solution?

It is required to prepare 1250 kg of a solution composed of 12 wt.% ethanol and 88 wt.% water. Two solutions are available, the first contains 5 wt.% ethanol, and the second contains 25 wt.% ethanol. How much of each solution are mixed to prepare the desired solution?



Solution:

1. **Ethanol balance**



Input = output

$$A\left(\frac{5}{100}\right) + B\left(\frac{25}{100}\right) = M\left(\frac{12}{100}\right)$$

$$0.05\,A + 0.25\,B = 0.12\,M$$

$$A = \left(\frac{150 - 0.25\,B}{0.05}\right) = 3000 - 5\,B \ldots\ldots\ldots..(1)$$

2. Water balance

Input = output

0.95 A + 0.75 B = 0.88 M = 0.88 (1250) = 1100

0.95 A + 0.75 B = 1100 … … … . . (**2**)

Sub. (1) in (2)

0.95(300-5 B) + 0.75 B = 1100

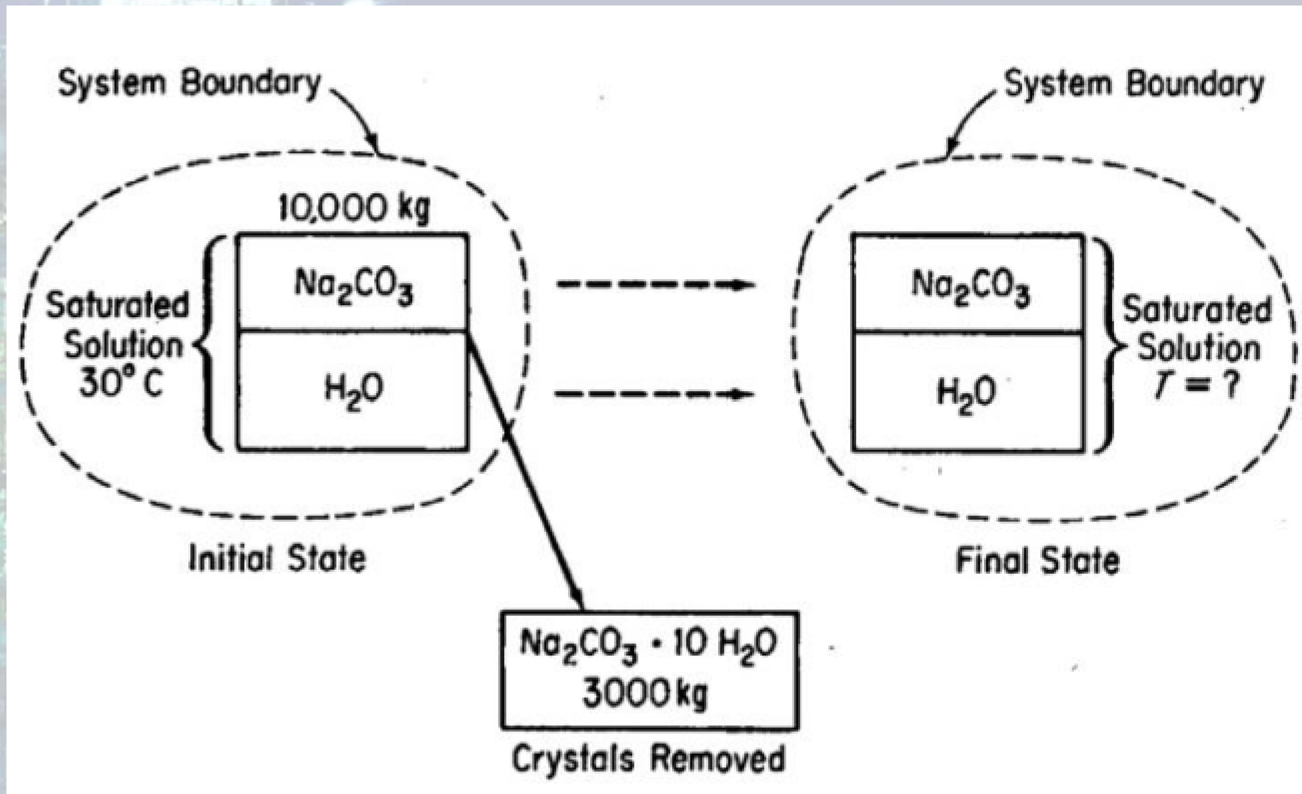
2850 - 4.75 + 0.75 B =1100

4 B =1750 …………………… B= 437.5 kg

Sub. B in (1) : A= 3000 – 5(437.5) = 812.5 kg

A tank holds 10,000 kg of a saturated solution of Na_2CO_3 at 30 °C. You want to crystallize from this solution 3000 kg of $Na_2CO_3.10H_20$ without any accompanying water. To what temperature must the solution be cooled? The solubility data of Na_2CO_3 as a function of the temperature is given as below:

Temp. (^oC)	Solubility (g Na_2CO_3 / 100 g H_2O)
0	7
10	12.5
20	21.5
30	38.8


System Boundary
System Boundary
10,000 kg
Saturated Solution 30° C
Na_2CO_3
H_2O
Na_2CO_3
H_2O
Saturated Solution T = ?
Initial State
Final State
$Na_2CO_3 \cdot 10\ H_2O$
3000 kg
Crystals Removed

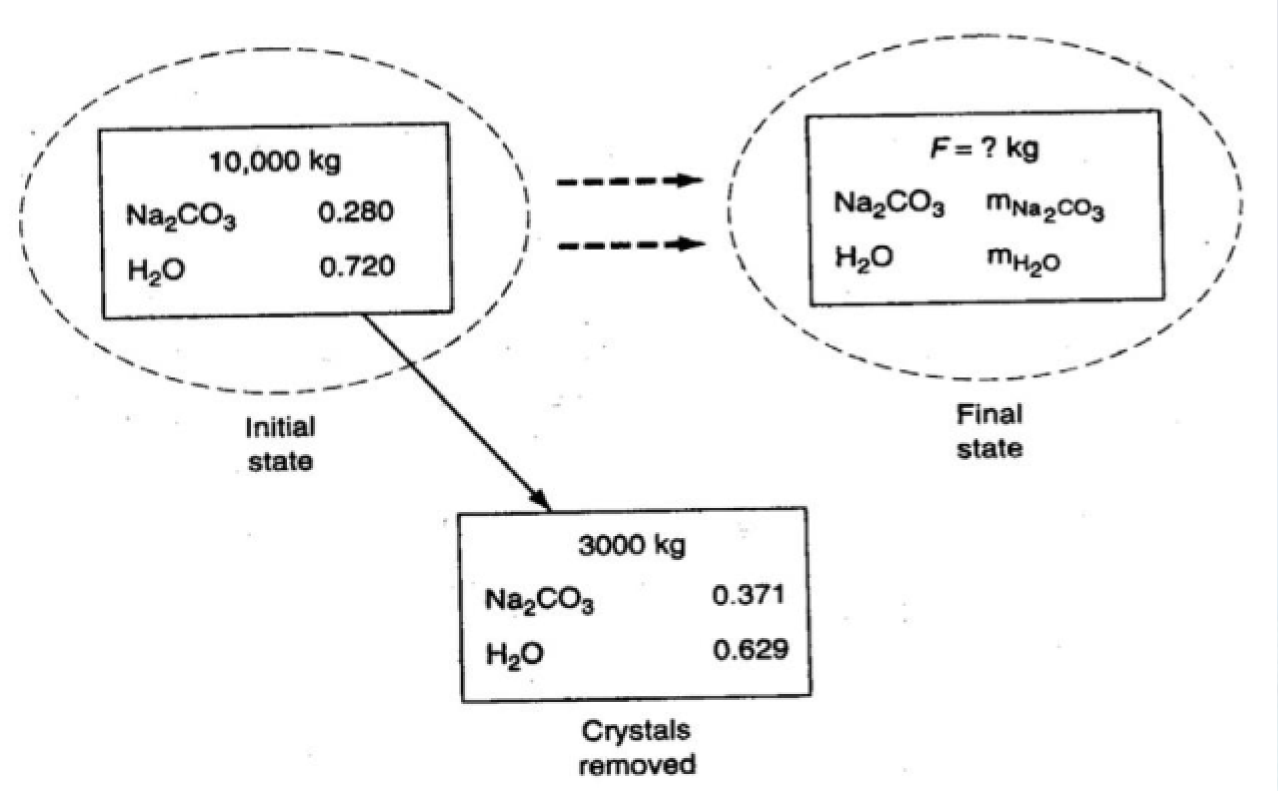
Since the initial solution is saturated at 30°C, you can calculate the composition of the initial solution:

$$\text{Mass fraction of } Na_2CO_3 = \frac{38.8 \text{ g } Na_2CO_3}{38.8 \text{ g } Na_2CO_3 + 100 \text{ g } H_2O}$$

Basis: 1 mol of $Na_2CO_3.10H_20$

Comp.	Mol	Mol wt.	Mass	Mass fraction
Na_2CO_3	1	106	106	0.371
H_20	10	18	180	0.629
Total			286	1.0

Basis: 10000 kg of saturated solution at 30°C



Because we are treated this problem as an unsteady-state problem (the flow = 0), the mass balance reduces to:

<u>Overall material balance:</u>

Initial state – Final state = Crystal removed

$10000 - F = 3000 \quad \Rightarrow \quad F = 7000$ kg

Na$_2$CO$_3$ material balance:

(0.28) (10000) - ($\mathbf{M}_{Na_2CO_3}$) (F) = (0.371) (3000) , where: **M**=mass fraction

(0.28) (10000) - ($\mathbf{M}_{Na_2CO_3}$) (7000) = (0.371) (3000)

$\mathbf{M}_{Na_2CO_3}$ = 0.241

Mass of Na_2CO_3 in the final state = ($\mathbf{M}_{Na_2CO_3}$) (F) = (0.241) (7000) = **1687 kg**

H_2O material balance:

(1-0.28) (10000) - ($\mathbf{M}_{H_2O}$) (F) = (0.629) (3000)

(0.72) (10000) - ($\mathbf{M}_{H_2O}$) (7000) = (0.629) (3000)

$\mathbf{M}_{H_2O}$ = 0.759

Mass of H_2O in the final state = ($\mathbf{M}_{H_2O}$) (F) = (0.759) (7000) = **5313 kg**

To find the temperature of the final solution, calculate the composition of the final solution in terms of (g Na_2CO_3. / 100 g H_2O) so that you can use the tabulated solubility data listed above.

$$\frac{1687\ \text{kg}\ Na_2CO_3}{5313\ \text{kg}\ H_2O} = \frac{31.8\ \text{g}\ Na_2CO_3}{100\ \text{g}\ H_2O}$$

Na_2CO_3	H_2O
1687 kg	5313 kg
X	100 g

⇒ X = 31.8

Thus, the temperature to which the solution must be cooled lies between 20°C and 30°C. By linear interpolation:

$$(30^oC) - \left[\frac{38.8 - 31.8}{38.8 - 21.5}\right](10^oC) = 26^oC$$

Slope 1 $(m1)$ = Slope 2 $(m2)$,

where, $m = \frac{y_2 - y_1}{x_2 - x_1}$

$$\left[\frac{38.8-31.8}{30-X}\right] = \left[\frac{38.8-21.5}{30-20}\right] \Rightarrow x = 26^oC$$

Energy balance:

The increasing cost of energy has caused the industries to examine means of reducing energy consumption in processing. Energy balances are used in the examination of the various stages of a process, over the whole process and even extending over the total production system from the raw material to the finished product.

Just as mass is conserved, so is energy conserved in operations. The energy coming into a unit operation can be balanced with the energy coming out and the energy stored.

Energy In = Energy Out + Energy Stored

$\Sigma E_R = \Sigma E_P + \Sigma E_W + \Sigma E_L + \Sigma E_S$

where

$\Sigma E_R = E_{R1} + E_{R2} + E_{R3} + \ldots\ldots =$ Total Energy Entering

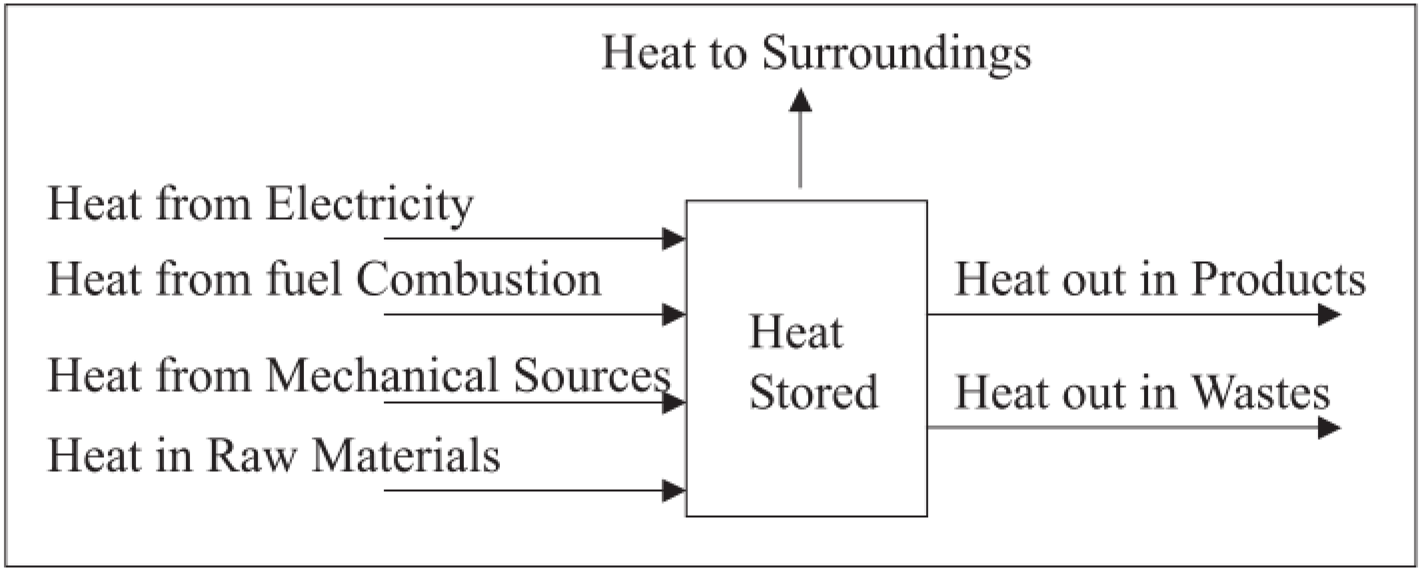
$\Sigma E_p = E_{P1} + E_{P2} + E_{P3} + \ldots\ldots =$ Total Energy Leaving with Products

$\Sigma E_W = E_{W1} + E_{W2} + E_{W3} + \ldots =$ Total Energy Leaving with Waste Materials

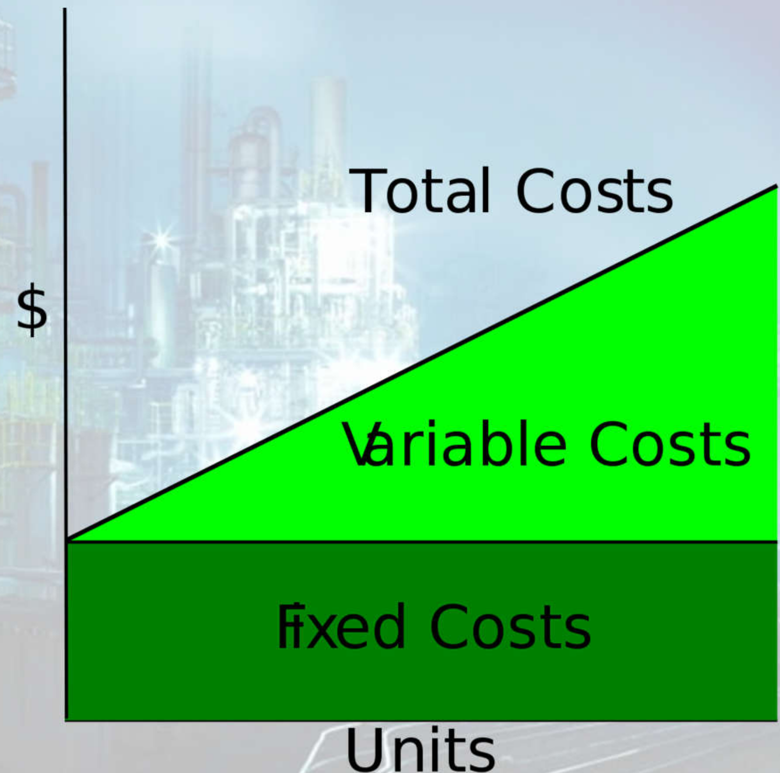
$\Sigma E_L = E_{L1} + E_{L2} + E_{L3} + \ldots\ldots =$ Total Energy Lost to Surroundings

$\Sigma E_S = E_{S1} + E_{S2} + E_{S3} + \ldots\ldots =$ Total Energy Stored

Energy balances are often complicated because forms of energy can be interconverted, for example mechanical energy to heat energy, but overall the quantities must balance.


Heat to Surroundings
Heat from Electricity
Heat from fuel Combustion
Heat from Mechanical Sources
Heat in Raw Materials
Heat
Stored
Heat out in Products
Heat out in Wastes

Variable costs comprise those factors which are only consumed (and therefore only charged to the operation) as product is being manufactured. As a result the total variable cost during an operating period-day, quarter, year-will vary directly as the plant output during that period.



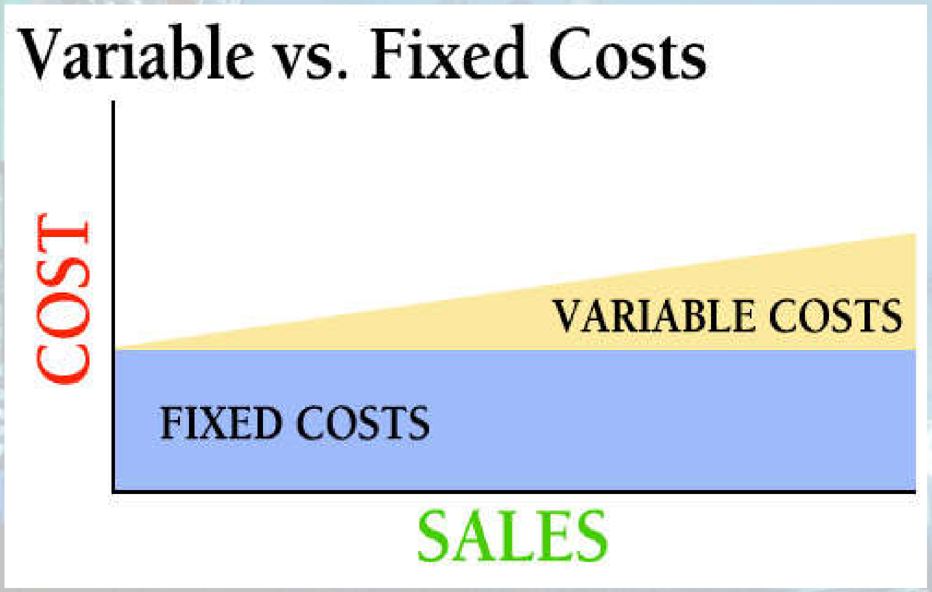

FIXED COSTS
Fixed costs remain the same regardless of sales.
VARIABLE COSTS
Variable costs change based on your sales activity.

Variable costs:

Raw material costs Energy input costs Royalty and licence payments	Variable cost elements (total sum £000/year varies with plant output)

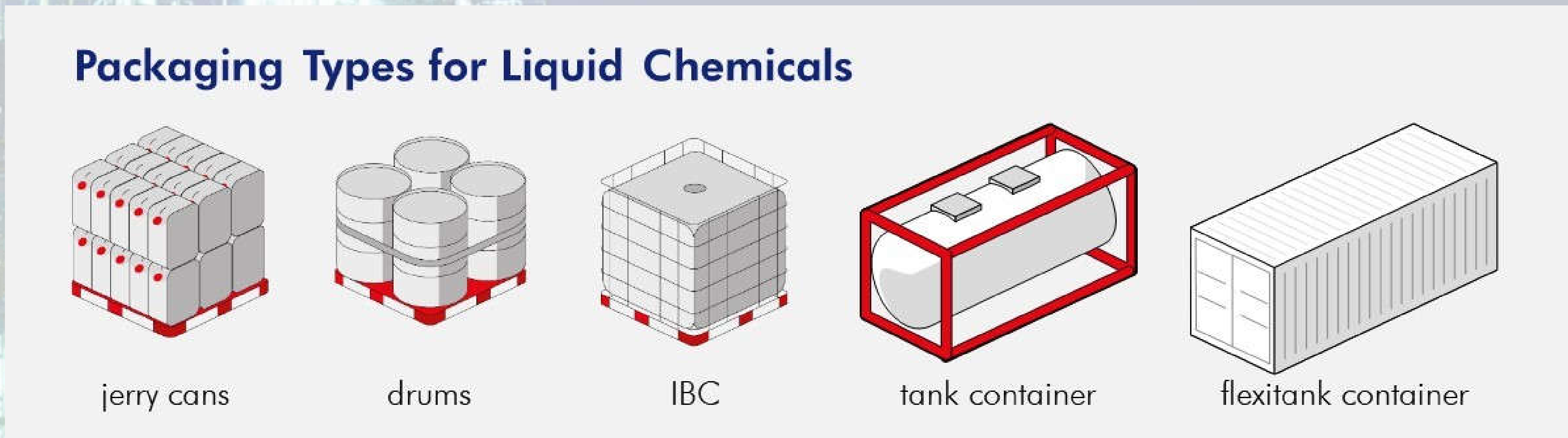
Effect of production rate on variable cost:

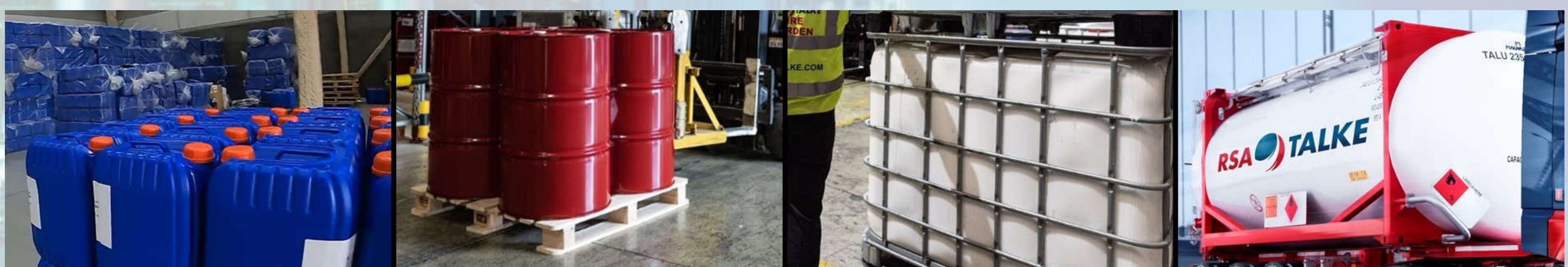
In the case of a continuously-operating process-the type of process used widely in the chemical industry-operation at low output rates or, conversely, higher than design rates can lead to process inefficiencies and an increase in the variable cost/unit of production.



Packaging and transport:

The costs involved in packaging and transport of a chemical product to the consumer are largely variable costs. However, such factors are not regarded as forming part of the production cost/income comparison.


Packaging Types for Liquid Chemicals
jerry cans
drums
IBC
tank container
flexitank container


RSA TALKE

Drums

Chemical drums, also referred to as barrels, are cylindrical shaped containers which comes in either fiber, metals or plastics materials. They are the most attractive products in the bulk container segment and known to be sustainable due to their ability to be reconditioned or reused. Chemical drums have a capacity of approx. 200 liters and are used to store almost all classes of chemicals including pharmaceutical liquids.

Intermediate Bulk Containers (IBC)

Intermediate Bulk Containers, popularly referred to as IBCs, are specialized units with capacity of holding up to 1,000 liters of liquid substances. These cube shaped containers either made of plastic, metals, or a combination of both are commonly used in handling (storing) dangerous chemicals such as edible liquids, lubricating and essential oils.

Jerry Cans

Jerry Cans are another secured and reliable medium for bulk liquid/chemicals packaging and transportation. They are specially designed containers that hold up to standard 20 liters (5 gallons) of liquids and come in two forms, steel metal (10 liters) and plastic (5 liters). History reveals that these cans originated from Germany back in the 1930s during the WWII.

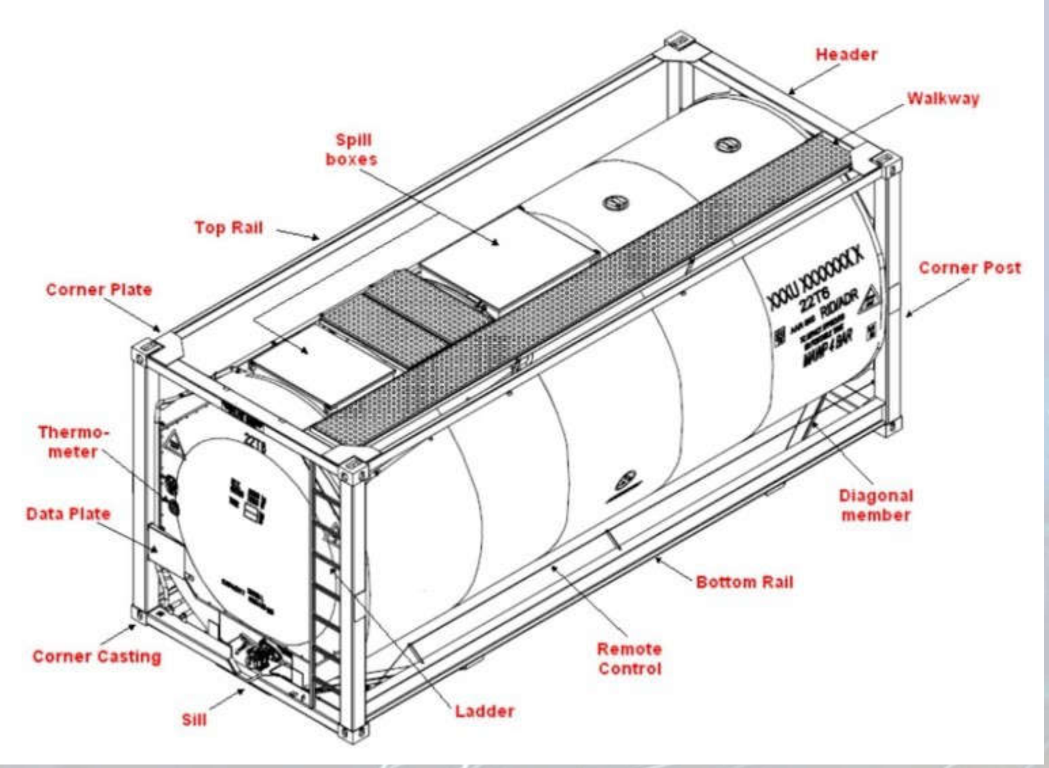
Flexi tank containers

Flexi tank containers are standard 20ft containers used for shipping bulk non-hazardous liquid such as edible oils. It is estimated that more than 800,000 flexi tank containers were transported in 2017. Flexi tank containers have become the alternative for shippers (transportation) as the tanks can be cost effective.



ISO tank containers

It is the most economical packaging for bulk usage. The cylindrical shaped containers primarily produced from stainless steel with strong metallic layers have gained popularity for most chemical and bulk liquid packaging. This is due to many producers and distributors shifting to the usage of eco-packaging as a solution to waste reduction and therefore opting for the usage of recyclable ISO tank containers. Sustainability is one of the biggest concerns of all global stakeholders.



Fixed costs:

The second category in the cost table, the fixed costs, can be divided as follows:

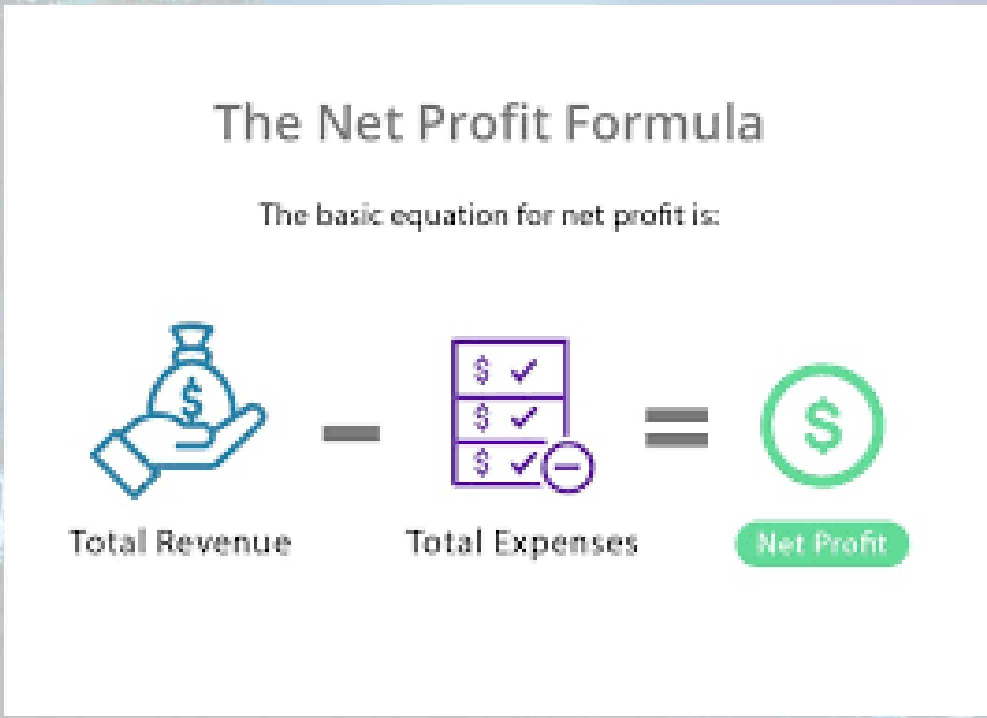
Operating labour and supervision Maintenance labour and supervision Analytical and laboratory staff Maintenance materials Depreciation Rates and insurance Overheads—works overhead charges —general company overheads	Fixed-cost elements (total sum £'000/year is fixed irrespective of plant output)

Table 6.2 Relationship between variable and fixed, and direct and indirect, costs

Variable or fixed		*Direct or indirect*
V	Materials cost	D
V	Energy inputs	D
V	Royalty payments	D
F	Process and maintenance labour	D
F	Process and maintenance supervision	D
F	Maintenance materials	D
F	Rates and insurance	Capital-related
F	Works overhead	I
F	Site and company overhead	I
F	Depreciation	Capital-related

Profit:

Profit can be measured in a variety of ways but two measures which are commonly used by accountants are gross profit and net profit.



Factors Affecting Plant Location-Industries:

1. Nearness to Raw Material:

It will reduce the cost of transporting raw material from the vendor's end to the plant. Especially those plants, which consume raw material in bulk, or raw material is heavy, is cheap but loses a good amount of its weight during processing (trees and saw mills), must be located close to the source of raw material.

2. Transport Facilities:

A lot of money is spent both in transporting the raw material and the finished goods. Depending upon the size of raw material and finished goods, a suitable method of transportation like roads, rail, water or air is selected and accordingly the plant location is decided. One point must be kept in mind that cost of transportation should remain fairly small in proportion to the total cost.

3. Nearness to Markets:

It reduces the cost of transportation as well as the chances of the finished products getting damaged and spoiled in the way (especially perishable products). Moreover a plant being near, to the market can catch a big share of the market and can render quick service to the customers.

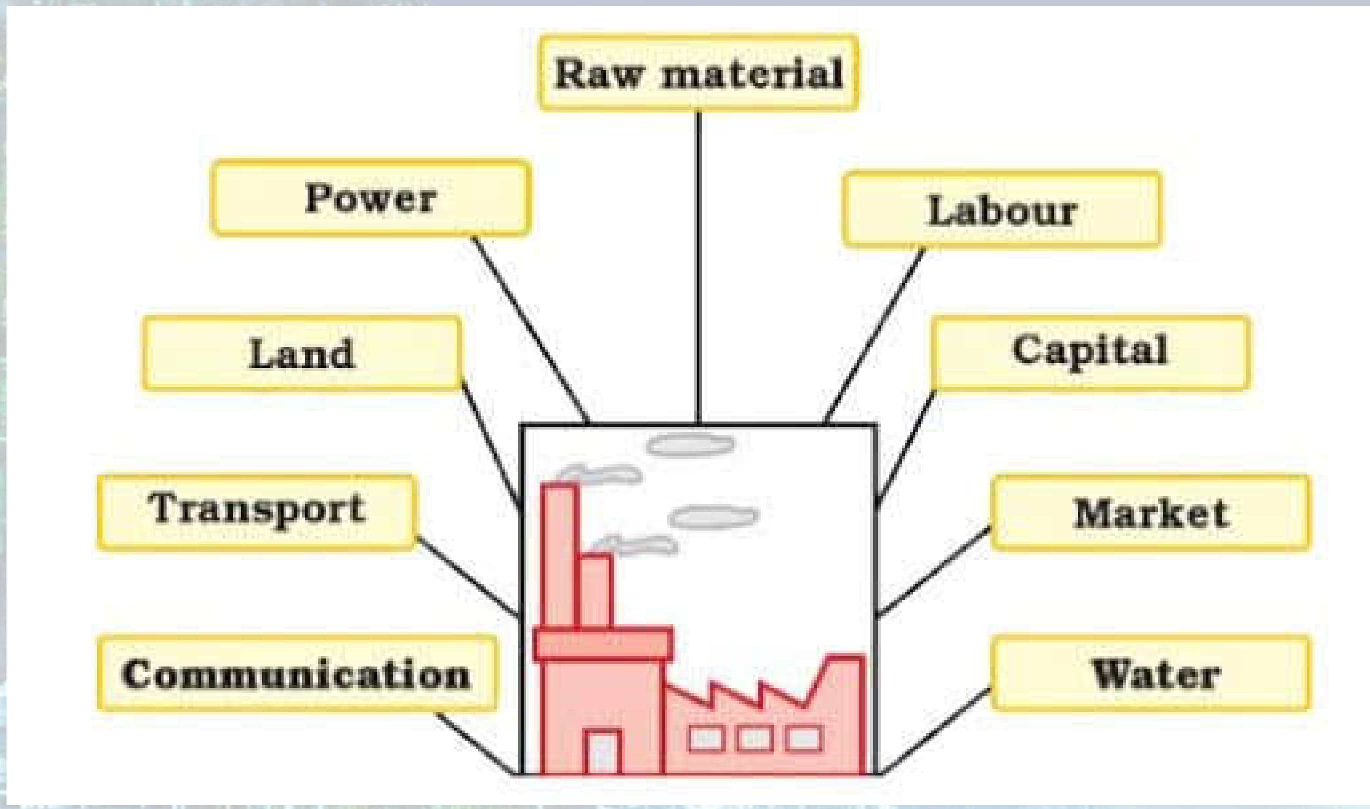
4. Availability of Labor:

Stable labor force, of adequate size (number), and at reasonable rates with its proper attitude towards work are a few factors which govern plant location to a major extent.

5. Availability of Fuel and Power:

Because of the wide spread use of electric power, in most cases fuel (coal, oil, etc.) has not remained a deciding factor for plant location. Even then steel industries are located near source of fuel (coal) to cut down the fuel transportation costs.

It is of course essential that electric power should remain available continuously, in proper quantity and at reasonable rates.


Raw material
Power
Labour
Land
Capital
Transport
Market
Communication
Water

6. Availability of Water:

Water is used for processing, as in paper and chemical industries, and is also required for drinking and sanitary purposes. Depending upon the nature of plant, water should be available in adequate quantity and should be of proper quality (clean and pure).

A chemical industry should not be set up at a location which is famous for water shortage.

7. Climatic Conditions:

With the developments in the field of heating, ventilating and air-conditioning, climate of the region does not present much problem.

Of course, control of climate needs money.

8. Financial and Other Aids:

Certain states give aids as loans, feed money, machinery, built up sheds, etc., to attract industrialists.

9. Land:

Topography, area, the shape of the site, cost, drainage and other facilities, the probability of floods, earthquakes (from the past history) etc., influence the selection of plant location.

10. Community Attitude:

Success of an industry depends very much on the attitude of the local people and whether they want work or not.

11. Presence of related industries.

12. Existence of hospitals, marketing centers, schools, banks, post offices, etc.

13. Local bye-laws, taxes, building ordinances, etc.

14. Housing facilities.

15. Security.

16. Facilities for expansion.