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COURSE GUIDE

INDUSTRIAL PROPCESSES & APPLICATIONS

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MODULE 1

UNIT 1: INDUSTRIAL CHEMICAL PROCESSES: HABER PROCESS

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1.0 INTRODUCTION

We can look at an industry from different perspective. Some people think of it in terms of huge factories or oil refining plants giving out smoke and pollution to the environment. Others see it in terms of facts and figures, profits and loss. In our daily lives we cannot help but make use of chemical substances. They are the food we eat, the clothes we wear, the medicines we take and the immense variety of articles we use.

In this module we are going to learn some of the industrial process involved in the production of some certain commodities we use in our daily lives.

2.0 OBJECTIVES

At the end of this course unit, you should be able to:

1. Explain what is meant by industrial process
2. Explain how industries operations

3.0 MAIN CONTENT

WHAT ARE INDUSTRIAL PROCESSES?

Industrial processes are procedures involving chemical, physical, electrical or mechanical steps to aid in the manufacture of an item or items, usually carried out on a very large scale. Industrial processes are the key components of heavy industry.

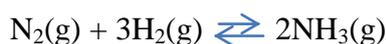
There are several examples of different processes involved when producing or manufacturing products chemically. This processes includes:

- Haber Process (ammonia manufacture)
- Contact Process (manufacture of sulphuric acid)
- Ostwald Process (Nitric acid manufacture etc)
- Bayer Process

- Bessemer Process
- Hall Heroult Process
- Kroll Process
- Siemens Process

3.1 HABER PROCESS

It is made through the reaction of nitrogen with hydrogen. Nitrogen is obtained by the liquefaction of air. The major use of nitrogen in the Haber process which takes the gas straight from the air is production of ammonia. The reaction between nitrogen and hydrogen involves equilibrium



The Haber process involves 3 main stages

- Supply and purification of the reacting gas
- Compression of the gases and conversion into ammonia
- Recovery of the ammonia

The following are necessary conditions for the production of ammonia:

The catalyst

The catalyst is actually slightly more complicated than pure iron. It has potassium hydroxide added to it as a promoter - a substance that increases its efficiency.

The pressure

The pressure varies from one manufacturing plant to another, but is always high. You can't go far wrong in an exam quoting 200 atmospheres.

Recycling

At each pass of the gases through the reactor, only about 15% of the nitrogen and hydrogen converts to ammonia. (This figure also varies from plant to plant.) By continual recycling of the unreacted nitrogen and hydrogen, the overall conversion is about 98%.

Explaining the conditions

The proportions of nitrogen and hydrogen

The mixture of nitrogen and hydrogen going into the reactor is in the ratio of 1 volume of nitrogen to 3 volumes of hydrogen.

Avogadro's Law says that equal volumes of gases at the same temperature and pressure contain equal numbers of molecules. That means that the gases are going into the reactor in the ratio of 1 molecule of nitrogen to 3 of hydrogen.

That is the proportion demanded by the equation.

In some reactions you might choose to use an excess of one of the reactants. You would do this if it is particularly important to use up as much as possible of the other reactant - if, for example, it was much more expensive. That doesn't apply in this case.

There is always a down-side to using anything other than the equation proportions. If you have an excess of one reactant there will be molecules passing through the reactor which can't possibly react because there isn't anything for them to react with. This wastes reactor space - particularly space on the surface of the catalyst.

The temperature

Equilibrium considerations

You need to shift the position of the equilibrium as far as possible to the right in order to produce the maximum possible amount of ammonia in the equilibrium mixture.

The forward reaction (the production of ammonia) is exothermic.



According to Le Chatelier's Principle, this will be favoured if you lower the temperature. The system will respond by moving the position of equilibrium to counteract this - in other words by producing more heat.

In order to get as much ammonia as possible in the equilibrium mixture, you need as low a temperature as possible. However, 400 - 450°C isn't a low temperature!

Rate considerations

The lower the temperature you use, the slower the reaction becomes. A manufacturer is trying to produce as much ammonia as possible per day. It makes no sense to try to achieve an equilibrium mixture which contains a very high proportion of ammonia if it takes several years for the reaction to reach that equilibrium.

You need the gases to reach equilibrium within the very short time that they will be in contact with the catalyst in the reactor.

The compromise

400 - 450°C is a compromise temperature producing a reasonably high proportion of ammonia in the equilibrium mixture (even if it is only 15%), but in a very short time.

The pressure

Equilibrium considerations



Notice that there are 4 molecules on the left-hand side of the equation, but only 2 on the right.

According to Le Chatelier's Principle, if you increase the pressure the system will respond by favouring the reaction which produces fewer molecules. That will cause the pressure to fall again.

In order to get as much ammonia as possible in the equilibrium mixture, you need as high a pressure as possible. 200 atmospheres is a high pressure, but not amazingly high.

Rate considerations

Increasing the pressure brings the molecules closer together. In this particular instance, it will increase their chances of hitting and sticking to the surface of the catalyst where they can react. The higher the pressure the better in terms of the rate of a gas reaction.

Economic considerations

Very high pressures are very expensive to produce on two counts.

You have to build extremely strong pipes and containment vessels to withstand the very high pressure. That increases your capital costs when the plant is built.

High pressures cost a lot to produce and maintain. That means that the running costs of your plant are very high.

The compromise

200 atmospheres is a compromise pressure chosen on economic grounds. If the pressure used is too high, the cost of generating it exceeds the price you can get for the extra ammonia produced.

The catalyst

Equilibrium considerations

The catalyst has no effects whatsoever on the position of the equilibrium. Adding a catalyst doesn't produce any greater percentage of ammonia in the equilibrium mixture. Its only function is to speed up the reaction.

Rate considerations

In the absence of a catalyst the reaction is so slow that virtually no reaction happens in any sensible time. The catalyst ensures that the reaction is fast enough for a dynamic equilibrium to be set up within the very short time that the gases are actually in the reactor.

Separating the ammonia

When the gases leave the reactor they are hot and at a very high pressure. Ammonia is easily liquefied under pressure as long as it isn't too hot, and so the temperature of the mixture is lowered enough for the ammonia to turn to a liquid. The nitrogen and hydrogen remain as gases even under these high pressures, and can be recycled.

Application/Uses of Ammonia:

1. Manufacture of fertilizers
2. Manufacture of Nitric acid
3. Manufacture of polymers

4.0 CONCLUSION

The Haber process is an example of industrial chemical process involving the production of ammonia. Ammonia has so many uses some of which include manufacture of fertilizers, polymers and nitric acid.

5.0 SUMMARY

The Haber process combines nitrogen from the air with hydrogen derived mainly from natural gas (methane) into ammonia. The reaction is reversible and the production of ammonia is exothermic.

6.0 TUTOR MARKED ASSIGNMENT

1. Explain the conditions necessary for the production of ammonia.
2. Why is the Haber process an exothermic reaction?

7.0 REFERENCES AND FURTHER READING

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UNIT 2

INDUSTRIAL CHEMICAL PROCESSES: CONTACT PROCESS

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- 2.0 Objectives
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- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor Marked Assignment (TMA)
- 7.0 References and Further Reading

1.0 INTRODUCTION

2.0 OBJECTIVES

3.0 MAIN CONTENT

3.1 Contact Process (manufacture of Sulphuric acid)

The contact process is the process used in the manufacture of sulphuric acid. The quantity of sulphuric acid made or consumed by a country has been used as a measure of the state of its economy. If the economy is striving, then the industry needs huge quantities of the acid. There are three main stages in the process:

- Burning sulphur to make sulphur dioxide
- Converting sulphur dioxide and oxygen into sulphur trioxide
- Absorbing sulphur trioxide in sulphuric acid to give high concentrated sulphuric acid

The details of these processes are as follows:

Making the sulphur dioxide

This can either be made by burning sulphur in an excess of air:



or by heating sulphide ores like pyrite in an excess of air:



In either case, an excess of air is used so that the sulphur dioxide produced is already mixed with oxygen for the next stage.

Converting the sulphur dioxide into sulphur trioxide

This is a reversible reaction, and the formation of the sulphur trioxide is exothermic.



A flow scheme for this part of the process looks like this:

The reasons for all these conditions will be explored in detail further in this section.

Converting the sulphur trioxide into sulphuric acid

This can't be done by simply adding water to the sulphur trioxide - the reaction is so uncontrollable that it creates a fog of sulphuric acid. Instead, the sulphur trioxide is first dissolved in concentrated sulphuric acid:



The product is known as *fuming sulphuric acid* or *oleum*.

This can then be reacted safely with water to produce concentrated sulphuric acid - twice as much as you originally used to make the fuming sulphuric acid.



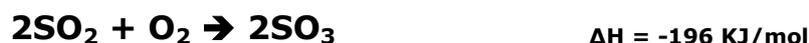
Explaining the conditions

The proportions of sulphur dioxide and oxygen

The mixture of sulphur dioxide and oxygen going into the reactor is in equal proportions by volume.

Avogadro's Law says that equal volumes of gases at the same temperature and pressure contain equal numbers of molecules. That means that the gases are going into the reactor in the ratio of 1 molecule of sulphur dioxide to 1 of oxygen.

That is an excess of oxygen relative to the proportions demanded by the equation.



According to Le Chatelier's Principle, Increasing the concentration of oxygen in the mixture causes the position of equilibrium to shift towards the right. Since the oxygen comes from the air, this is a very cheap way of increasing the conversion of sulphur dioxide into sulphur trioxide.

Why not use an even higher proportion of oxygen? This is easy to see if you take an extreme case. Suppose you have a million molecules of oxygen to every molecule of sulphur dioxide.

The equilibrium is going to be tipped very strongly towards sulphur trioxide - virtually every molecule of sulphur dioxide will be converted into sulphur trioxide. Great! But you aren't going to produce much sulphur trioxide every day. The vast majority of what you are passing over the catalyst is oxygen which has nothing to react with.

By increasing the proportion of oxygen you can increase the percentage of the sulphur dioxide converted, but at the same time decrease the total amount of sulphur trioxide made each day. The 1:1 mixture turns out to give you the best possible overall yield of sulphur trioxide.

The temperature

Equilibrium considerations

You need to shift the position of the equilibrium as far as possible to the right in order to produce the maximum possible amount of sulphur trioxide in the equilibrium mixture.

The forward reaction (the production of sulphur trioxide) is exothermic.



According to Le Chatelier's Principle, this will be favoured if you lower the temperature. The system will respond by moving the position of equilibrium to counteract this - in other words by producing more heat.

In order to get as much sulphur trioxide as possible in the equilibrium mixture, you need as low a temperature as possible. However, 400 - 450°C isn't a low temperature!

Rate considerations

The lower the temperature you use, the slower the reaction becomes. A manufacturer is trying to produce as much sulphur trioxide as possible per day. It makes no sense to try to achieve an equilibrium mixture which contains a very high proportion of sulphur trioxide if it takes several years for the reaction to reach that equilibrium.

You need the gases to reach equilibrium within the very short time that they will be in contact with the catalyst in the reactor.

The compromise

400 - 450°C is a compromise temperature producing a fairly high proportion of sulphur trioxide in the equilibrium mixture, but in a very short time.

The pressure

Equilibrium considerations



Notice that there are 3 molecules on the left-hand side of the equation, but only 2 on the right.

According to Le Chatelier's Principle, if you increase the pressure the system will respond by favouring the reaction which produces fewer molecules. That will cause the pressure to fall again.

In order to get as much sulphur trioxide as possible in the equilibrium mixture, you need as high a pressure as possible. High pressures also increase the rate of the reaction. However, the reaction is done at pressures close to atmospheric pressure!

Economic considerations

Even at these relatively low pressures, there is a 99.5% conversion of sulphur dioxide into sulphur trioxide. The very small improvement that you could achieve by increasing the pressure isn't worth the expense of producing those high pressures.

The catalyst

Equilibrium considerations

The catalyst has no effect whatsoever on the position of the equilibrium. Adding a catalyst doesn't produce any greater percentage of sulphur trioxide in the equilibrium mixture. Its only function is to speed up the reaction.

Rate considerations

In the absence of a catalyst the reaction is so slow that virtually no reaction happens in any sensible time. The catalyst ensures that the reaction is fast enough for a dynamic equilibrium to be set up within the very short time that the gases are actually in the reactor.

3.2 Uses of Sulfuric Acid :

1. Making superphosphate fertilizer
2. Making aluminum sulphate fertilizer
3. Processing of metal ores
4. Manufacturing of detergents
5. Manufacture of paper
6. Manufacture of Rayon and other polymers
7. Manufacture of paints and pigments

8. Electrolytes in heavy duty vehicles
9. Industrial treatment of metals
10. Laboratory reagents

4.0 CONCLUSION

The contact process is also another example of industrial chemical process use in the manufacturing of sulfuric acid. Sulfur acid has many uses, it used in making superphosphate fertilizers, processing of metal ores, manufacturing of detergents, manufacture of paper, manufacture of Rayon and other polymers, manufacture of paints and pigments and electrolytes in heavy duty vehicles

5.0 SUMMARY

The Contact Process makes sulphur dioxide; converts the sulphur dioxide into sulphur trioxide (the reversible reaction at the heart of the process); converts the sulphur trioxide into concentrated sulphuric acid.

6.0 TUTOR MARKED ASSIGNMENT (TMAS)

1. Distinguish between physical and chemical processes.
2. Briefly explain the conditions necessary for the production of sulfuric acid by contact process .
3. State five economic importance of sulfuric acid.

7.0 REFERENCES/FURTHER READING

Ernest , C. (March 20, 1926) "Peregrine Phillips, the inventor of the contact process for sulphuric acid," *Nature*, **117** (2942) : 419-421. en.wikipedia.org/wiki/contact_process

George, L., *Theoretical and Practical Treatise on the Manufacture of Sulphuric Acid and Alkali, with the Collateral Branches*, 3rd ed., vol. 1, part 2 (London, England: Gurney and Jackson, 1903), page 975. en.wikipedia.org/wiki/contact_process

UNIT 3: APPLICATION OF ELECTROPLATING

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- 3.0 Main content
 - 3.1 The concept of electroplating
 - 3.2 Common uses of electroplating
 - 3.3 Benefits and hazard of electroplating
 - 3.4 Process of electroplating
- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor Marked Assignment (TMAs)
- 7.0 References/Further reading

1.0 INTRODUCTION

Study of science without its application to industry is meaningless. On one hand, it may not prepare the learners for what they are likely to witness in the labour market. On the other hand, it prepares them to develop interest in applied sciences such as engineering, medicine, food technology, etc. Electroplating is one of such concepts that have direct industrial applications. For better understanding, the unit examines the concept of electroplating, its common uses, benefits and hazards as well as the processes of electroplating.

2.0 OBJECTIVES

It is expected that upon going through this unit you should be able to:

1. Explain the concept of electroplating
2. Identify common uses of electroplating
3. Itemise benefits and hazards of electroplating
4. List and discuss processes of electroplating

HOW TO STUDY THIS UNIT:

In this unit you are expected to :

1. Read through the course contents on your own
2. First attempt the activities, then the TMA without looking at the hints provided by the author
3. Make observations on all your difficulties to your facilitator
4. Confirm your work on the activities after you have done your best to get all correct

3.0 MAIN CONTENT

3.1 Concept of Electroplating

Also known as electrode position, electroplating is using a small sheet of metal in an electrolytic cell to coat another object. It is used to protect objects from damage against rusting and corrosion of metals. The Chemistry behind electroplating is this: the item to be plated by the metal gets the negative charge and is put into a salt solution of the metal being used to plate the object. The metal being used to plate the item has a positive charge and is placed in the same solution. Therefore, the object to be plated is the cathode, and the metal being used to plate the item is the anode. Because of this, electroplating is an electrolytic cell since the electrons are flowing from positive to negative, where the metal to be plated is being reduced and the metal being used in the process is being oxidized. With the electrons flowing, it is just the law of attraction. The positive ions from the salt solution and the metal being used to plate "stick" onto the object being plated since it has a negative charge. The thickness of the metal plating depends on how long you leave it in the solution, and the flow of electrons.

Self Assessment 1

What is another name for electroplating? What in your understanding is electroplating?

Solution: Another name for electroplating is electrode position. Electroplating is using a small sheet of metal in an electrolytic cell to coat another object.

3.2 Common uses of Electroplating and the Metals Used

Metal	Anode	Electrolyte	Application
Cu	Cu	20% CuSO ₄ , 3% H ₂ SO ₄	electrotype
Ag	Ag	4% AgCN, 4% KCN, 4% K ₂ CO ₃	jewelry, tableware
Au	Au, C, Ni-Cr	3% AuCN, 19% KCN, 4% Na ₃ PO ₄ buffer	jewelry
Cr	Pb	25% CrO ₃ , 0.25% H ₂ SO ₄	automobile parts
Ni	Ni	30% NiSO ₄ , 2% NiCl ₂ , 1% H ₃ BO ₃	Cr base plate
Zn	Zn	6% Zn(CN) ₂ , 5% NaCN, 4% NaOH, 1% Na ₂ CO ₃ , 0.5% Al ₂ (SO ₄) ₃	galvanized steel
Sn	Sn	8% H ₂ SO ₄ , 3% Sn, 10% cresol-sulfuric acid	tin-plated cans

Electroplating is commonly used for plating jewelry which uses silver or gold, silverware which is most commonly uses silver, and vehicle parts which uses chromium. Each reaction includes a salt solution containing ions from the metal to be used, and the salt solution allowing the two to connect.

Self Assessment 2

In jewelry and table ware making what kind of metal should be used as the anode and why?

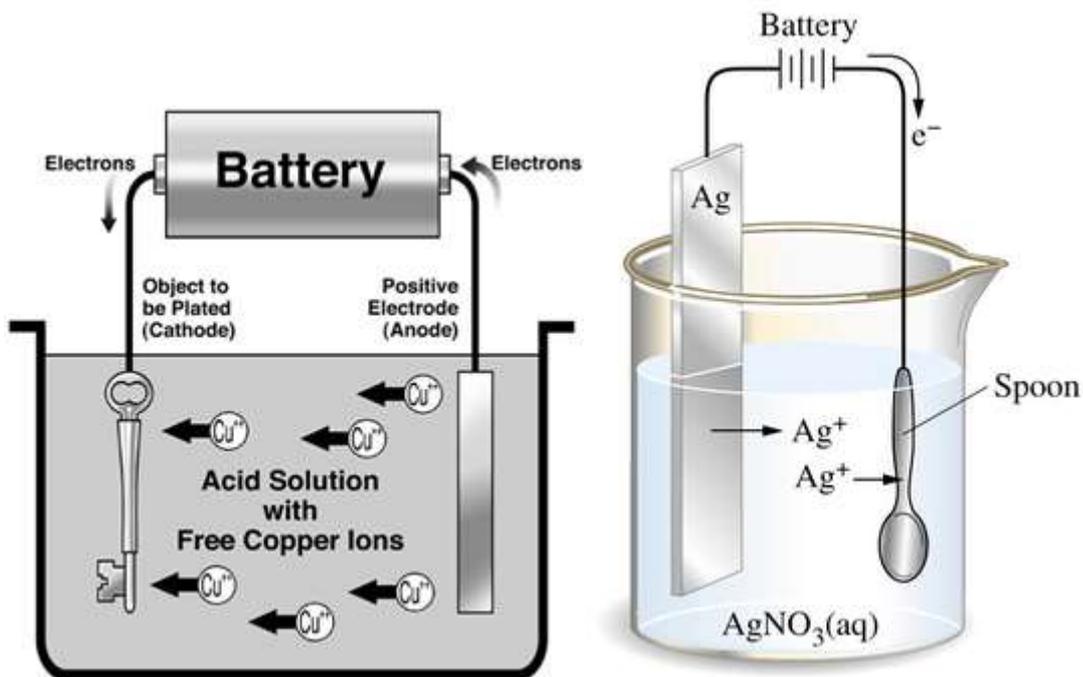
Solution/Hints on Self Assessment Questions

In jewelry and table ware electroplating we can use gold metal as the anode. The reason for this choice is to allow it dissolve into the electrolyte and eventually deposited on the cathode, the material you wish to portray on the outside as gold

3.3 Benefits and Hazards of Electroplating

Electroplating has so many real-world applications that it is invaluable to modern society. Sometimes, it is impractical or impossible to manufacture a product out of a metal with certain properties. With electroplating, however, one is able to coat the surface of an object with a rare or otherwise impractical metal in order to bestow the properties of that metal onto said object. Tin is used to coat cans in order to prevent corrosion, while a chromium coating will increase a metal's resistance to wear. Similarly, silver and gold are used to coat silverware and jewelry to prevent corrosion and increase value. Another application of electroplating is the thickening of an object.

However, although this process is very useful, it can also be dangerous. In the real world, electroplating is done in a large scale, and so a large amount of waste is produced. The resulting waste is called wastewater in the industry, and must be treated before it is suitable for the sewage system. The wastewater is very corrosive, and contains very toxic heavy metals. Therefore, dispensing it untreated into water sources would harm wildlife and potentially contaminate drinking water. Treating the wastewater, however, must also be done with much care due to its toxicity and corrosiveness. Proper procedure must be followed or else the industrial chemist responsible for this treatment could undergo chemical burns or poisoning.



Electroplating - What It Is and How It Works



Trophies are shiny and resist corrosion because of electroplated chromium.

Electroplating is the application of electrolytic cells in which a thin layer of metal is deposited onto an electrically conductive surface. Here's a closer look at what electrochemistry is, how it works, and what metals and anodes are used.

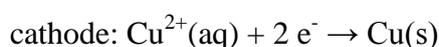
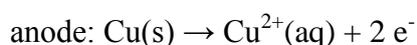
3.4 Processes of Electroplating

There are several reasons why you might want to coat a conductive surface with a metal. Silver plating and gold plating of jewelry or silverware typically is done to improve the appearance and value of the items. Chromium plating improves the appearance of objects and also improves its wear. Zinc or tin coatings may be applied to confer corrosion resistance. Sometimes electroplating is done simply to increase the thickness of an item.

Electroplating works like a galvanic cell in reverse. An electrical current reduces cations from a solution so that they can coat a conductive material with a thin layer.

In one form of electroplating, the metal to be plated is located at the anode of the circuit, with the item to be plated located at the cathode. Both the anode and the cathode are immersed in a solution which contains a dissolved metal salt (e.g., an ion of the metal being plated) and other ions which act to permit the flow of electricity through the circuit. Direct current is supplied to the anode, oxidizing its metal atoms and dissolving them in the electrolyte solution. The dissolved metal ions are reduced at the cathode, plating the metal onto the item. The current through the circuit is such that the rate at which the anode is dissolved is equal to the rate at which the cathode is plated.

A simple example of the electroplating process is the electroplating of copper in which the metal to be plated (copper) is used as the anode and the electrolyte solution contains the ion of the metal to be plated (Cu^{2+} in this example). Copper goes into solution at the anode as it is plated at the cathode. A constant concentration of Cu^{2+} is maintained in the electrolyte solution surrounding the electrodes:



5.0 Common Electroplating Processes

Metal	Anode	Electrolyte	Application
Cu	Cu	20% CuSO_4 , 3% H_2SO_4	electrotype
Ag	Ag	4% AgCN , 4% KCN , 4% K_2CO_3	jewelry, tableware
Au	Au, C, Ni- Cr	3% AuCN , 19% KCN , 4% Na_3PO_4 buffer	jewelry
Cr	Pb	25% CrO_3 , 0.25% H_2SO_4	automobile parts
Ni	Ni	30% NiSO_4 , 2% NiCl_2 , 1% H_3BO_3	Cr base plate
Zn	Zn	6% $\text{Zn}(\text{CN})_2$, 5% NaCN , 4% NaOH , 1% Na_2CO_3 , 0.5% $\text{Al}_2(\text{SO}_4)_3$	galvanized steel
Sn	Sn	8% H_2SO_4 , 3% Sn, 10% cresol-sulfuric acid	tin-plated cans

6.0 TUTOR-MARKED ASSIGNMENT

1. Identify any six common uses of electroplating, metal used and their applications.
2. Explain any 4 benefits of electroplating and any one hazard of it also.

7.0 REFERENCES/FURTHER READINGS

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UNIT 4: SOUND AND ITS APPLICATIONS

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1.0 INTRODUCTION

Sound is a form of wave and its transmission is unique. Its study is wide; its daily and industrial applications are numerous. As we study sound and its applications, mention must be made of echoes and its advantages and disadvantages; echo sounding, ultrasound, properties of ultrasound, acoustic impedance and general applications of ultrasound. It is envisaged that such study will make learners conversant with life applications of what is learnt at the class room level and develop interest in areas to specialize in further studies.

2.0 OBJECTIVES

It is expected that after going through this unit, you will be able to:

Explain the relationship between sound and echo

1. List advantages and disadvantages of echoes
2. Explain what is mean by echo sounding
3. Define echo ranging
4. Discuss what is mean by ultrasound
5. Outline ultrasound and its properties
6. Discuss acoustic impedance interaction of ultrasound with tissues
7. Outline applications of ultrasound
8. Explain what is mean by a room acoustics.

HOW TO STUDY THIS UNIT:

In this unit you are expected to :

1. Read through the course contents on your own
2. First attempt the activities, then the TMA without looking at the hints provided by the author
3. Make observations on all your difficulties to your facilitator
4. Confirm your work on the activities after you have done your best to get all correct

3.0 MAIN CONTENTS

3.1 Echoes

Like all waves, sound waves can be reflected. Sound waves suffer reflection from the large obstacles. As a result of reflection of sound wave from a large obstacle, the sound is heard which is named as an echo. Ordinarily echo is not heard as the reflected sound gets merged with the original sound. Certain conditions have to be satisfied to hear an echo distinctly (as a separate sound).

The sensation of any sound persists in our ear for about 0.1 seconds. This is known as the persistence of hearing. If the echo is heard within this time interval, the original sound and its echo cannot be distinguished. So the most important condition for hearing an echo is that the reflected sound should reach the ear only after a lapse of at least 0.1 second after the original sound dies off. As the speed of sound is 340 m/s, the distance travelled by sound in 0.1 second is 34 m. This is twice the minimum distance between a source of sound and the reflector. So, if the obstacle is at a distance of 17 m at least, the reflected sound or the echo is heard after 0.1 second, distinctly.

Further, for reflection of any wave to take place, the size of the reflector should be large compared to the wavelength of the sound, which for ordinary sound is of the order of 1 metre. A large building, a mountain side, large rock formation etc. are good reflectors of sound for producing an echo. Also, for the reflected sound to be heard, it must have enough intensity or loudness. Moreover, if the echo is to be distinguished from the original sound the two should not mix or overlap. For this, the original sound should be of very short duration, like a clap or shout.

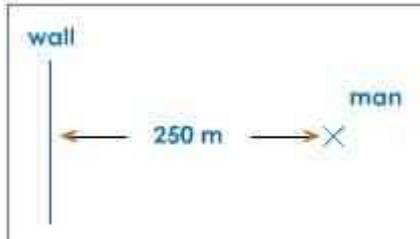
So, following conditions could be listed for formation of echo:

- The size of the obstacle/reflector must be large compared to the wavelength of the incident sound (for reflection of sound to take place).
- The distance between the source of sound and the reflector should be at least 17 m (so that the echo is heard distinctly after the original sound is over).
- The intensity or loudness of the sound should be sufficient for the reflected sound reaching the ear to be audible. The original sound should be of short duration.

Example 1:

A man stands 250 m from a wall and hears the echo of his gunshot after 1.5 s. Calculate the velocity of sound under the circumstances.

Suggested answer:



Distance travelled by sound = $2 \times 250 \text{ m}$

= 500 m

Velocity of sound = $\frac{\text{distance travelled}}{\text{time taken}}$

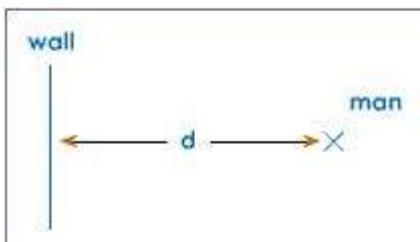
$$= \frac{500}{1.5}$$

= 333.3 m/s

Example 2:

A man stands at a certain distance from a wall and sets up a simple pendulum which makes three vibrations per second. He claps his hands and hears the echo exactly after five complete vibrations of the pendulum. If the velocity of sound in air is 350 m/s, calculate the distance between the man and the wall.

Suggested answer :



3 vibrations - 1 s

5 vibrations - $\frac{1}{3} \times 5 = \frac{5}{3} \text{ s}$

distance = velocity x time

$$2d = 340 \times \frac{5}{3}$$

$$d = \frac{340}{2} \times \frac{5}{3}$$

$$= 283.3 \text{ m}$$

Self learning question 1

Identify any three conditions that are necessary for echo to take place.

Answer: Conditions necessary for echo to take place are:

1. The size of the obstacle/reflector must be large compared to the wavelength of the incident sound (for reflection of sound to take place).
2. The distance between the source of sound and the reflector should be at least 17 m (so that the echo is heard distinctly after the original sound is over).
3. The intensity or loudness of the sound should be sufficient for the reflected sound reaching the ear to be audible. The original sound should be of short duration.

3.2 Advantages and Disadvantages of Echoes

Echoes can be useful or a nuisance. In a concert hall, echoes can ruin a performance if the walls and ceiling are not properly designed. If the walls are too hard, or too flat, they make good reflecting surfaces for the sound waves.

Echoes can be used to give vital information. A sonar (Sonar stands for sound navigation ranging) device sends out high frequency sound waves from a ship to find out how close the vessel is to the sea bed. An ultrasound scanner, particularly known for giving images of the unborn baby, works in roughly the same way.

Bats use echoes to navigate as they fly in the night. This works on the same principle as sonar and ultrasound scanner. The bat sends out tiny, high pitched squeaks, which bounce off the objects in the bat's flight path. The echoes reach the bat, which then adjusts its course to avoid the obstacles. Many bats have very large ears to catch as much of the reflected sound as possible.

When animals such as bats and dolphins use echoes, it is called echo location. They use it to find their way around or to locate prey. Echo location describes the way of how some animals detect the size and position of objects around them.



At night, bats use echolocation to guide them in flight. They send out tiny 'clicks', which bounce off objects and return to the bat. It builds up a 'sound' picture of its surroundings.

3.3 Echo Sounding

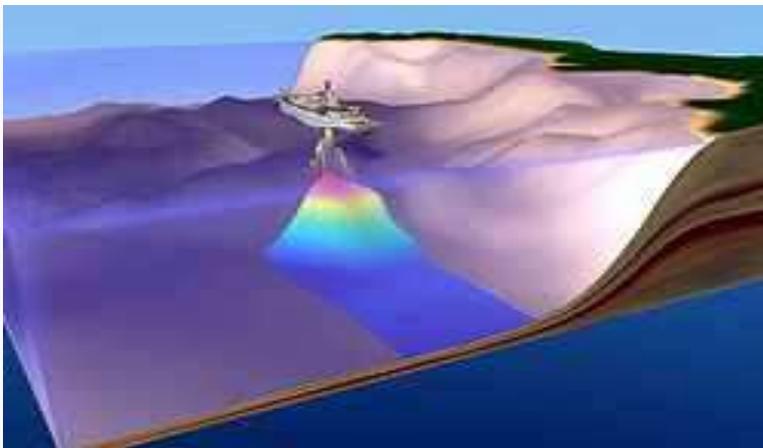


Illustration of echo sounding using a multibeam echosounder.

Echo sounding is a type of SONAR used to determine the depth of water by transmitting sound pulses into water. The time interval between emission and return of a pulse is recorded, which is used to determine the depth of water along with the speed of sound in water at the time. This information is then typically used for navigation purposes or in order to obtain depths for charting purposes. Echo sounding can also refer to hydroacoustic "echo sounders" defined as active sound in water (sonar) used to study fish. Hydroacoustic assessments have traditionally employed mobile surveys from boats to evaluate fish biomass and spatial distributions. Conversely, fixed-location techniques use stationary transducers to monitor passing fish.

The word sounding is used for all types of depth measurements, including those that don't use sound, and is unrelated in origin to the word sound in the sense of noise or tones. Echo sounding is a more rapid method of measuring depth than the previous technique of lowering a sounding line until it touched bottom.

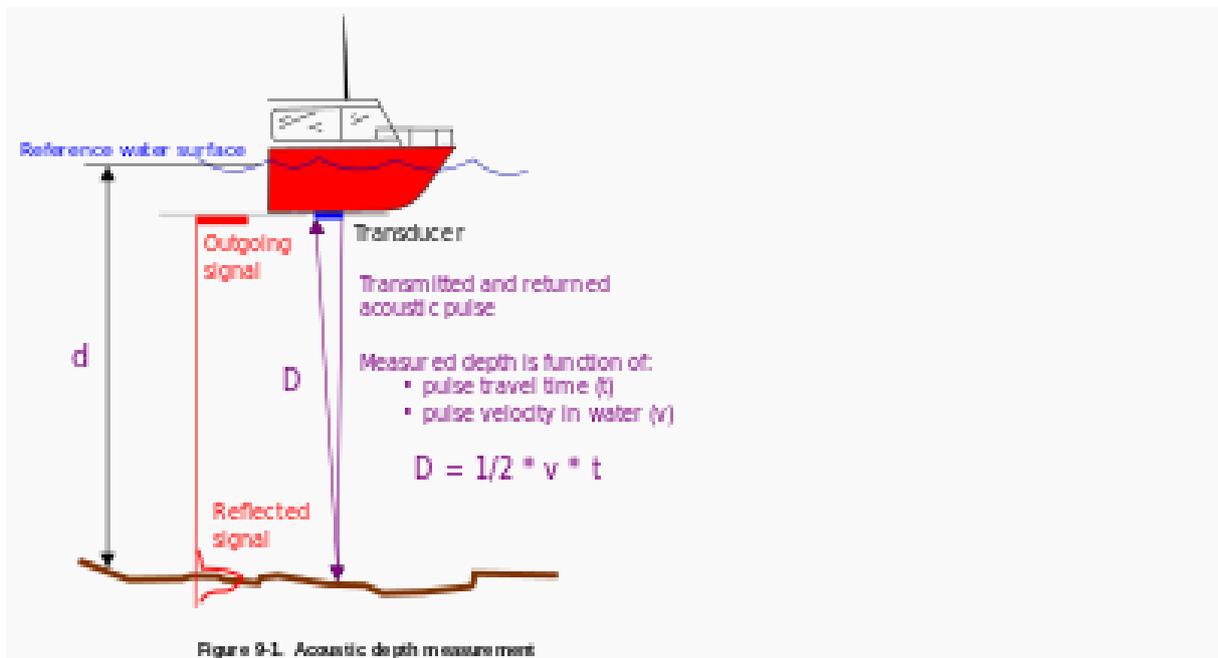


Diagram showing the basic principle of echo sounding

Distance is measured by multiplying half the time from the signal's outgoing pulse to its return by the speed of sound in the water, which is approximately 1.5 kilometres per second. For precise applications of echosounding, such as hydrography, the speed of sound must also be measured typically by deploying a sound velocity probe into the water. Echo sounding is effectively a special purpose application of sonar used to locate the bottom. Since a traditional pre-SI unit of water depth was the fathom, an instrument used for determining water depth is sometimes called a *fathometer*.

Most charted ocean depths use an average or standard sound speed. Where greater accuracy is required average and even seasonal standards may be applied to ocean regions. For high accuracy depths, usually restricted to special purpose or scientific surveys, a sensor may be lowered to measure the temperature, pressure and salinity. These factors are used to calculate the actual sound speed in the local water column. This latter technique is regularly used by US Office of Coast Survey for navigational surveys of US coastal waters. As well as an aid to navigation (most larger vessels will have at least a simple depth sounder), echo sounding is commonly used for fishing. Variations in elevation often represent places where fish congregate. Schools of fish will also register. A fish finder is an echo sounding device used by both recreational and commercial fishers.

In areas where detailed bathymetry is required, a precise echo sounder may be used for the work of hydrography. There are many considerations when evaluating such a system, not limited to the vertical accuracy, resolution, acoustic beamwidth of the transmit/receive beam and the acoustic frequency of the transducer.



An example of a precision dual frequency echosounder, the Teledyne Odom MkIII

The majority of hydrographic echosounders are dual frequency, meaning that a low frequency pulse (typically around 24 kHz) can be transmitted at the same time as a high frequency pulse (typically around 200 kHz). As the two frequencies are discrete, the two return signals do not typically interfere with each other. There are many advantages of dual frequency echosounding, including the ability to identify a vegetation layer or a layer of soft mud on top of a layer of rock.

Most hydrographic operations use a 200 kHz transducer, which is suitable for inshore work up to 100 metres in depth. Deeper water requires a lower frequency transducer as the acoustic signal of lower frequencies is less susceptible to attenuation in the water column. Commonly used frequencies for deep water sounding are 33 kHz and 24 kHz.

The beamwidth of the transducer is also a consideration for the hydrographer, as to obtain the best resolution of the data gathered a narrow beamwidth is preferable. This is especially important when sounding in deep water, as the resulting footprint of the acoustic pulse can be very large once it reaches a distant sea floor.

In addition to the single beam echo sounder, there are echo sounders that are capable of receiving many return "pings". These systems are detailed further in the section called multibeam echosounder.

The required precision and accuracy of the hydrographic echo sounder is defined by the requirements of the International Hydrographic Organization (IHO) for surveys that are to be undertaken to IHO standards. These values are contained within IHO publication.

In order to meet these standards, the surveyor must consider not only the vertical and horizontal accuracy of the echo sounder and transducer, but the survey system as a whole. A motion sensor may be used, specifically the heave component (in single beam echosounding) to reduce soundings for the motion of the vessel experienced on the water's surface. Once all of the uncertainties of each sensor are established, the hydrographer will create an uncertainty budget to determine whether the survey system meets the requirements laid down by IHO.

Different hydrographic organisations will have their own set of field procedures and manuals to guide their surveyors to meet the required standards.

3.4 Echo Ranging

Echo ranging is a technique used to determine the distance of an object from the transducer.

This technique relies on reflection.

The echo ranging equation is $z=ct$.

z = distance c = speed of ultrasound in tissue t = time

A sound beam is transmitted into a medium and is reflected back from an object. The elapsed time between the transmitted pulse and the received echo is converted into the total distance traveled. (The z value is only half of the distance traveled away and back to the transducer.)

Sound speed (c) is equal to one over the square root of the density times compressibility. OR $c = \text{square root compressibility} / \text{square root density}$. This indicates that if the density of a material is increased the speed of sound in that material will also be increased. Sound travels faster in media that are denser than air because of reduced compressibility. The velocity of ultrasound remains constant for a particular medium. Where $c = \text{frequency} \times \text{wavelength}$. Indicating that for a constant velocity as the frequency is increased the wavelength is reduced. Ultrasonic waves are reflected at boundaries where there is a difference in acoustic impedance (Z) of the materials on each side of the boundary. This difference in Z is commonly referred to as the impedance mismatch. The greater the impedance mismatch, the greater the percentage of energy that will be reflected at the interface or boundary between one medium and another. The fraction of the incident wave intensity that is refracted can be derived because particle velocity and local particle pressures must be continuous across the boundary. When the acoustic impedances of the materials on both sides of the boundary are known, the fraction of the incident wave intensity that is reflected can be calculated with the equation below. The value produced is known as the reflection coefficient. Multiplying the reflection coefficient by 100 yields the amount of energy reflected as a percentage of the original energy. Reflection - sound is reflected at an interface regardless of the thickness of the material from which it is reflected. The reflection coefficient:

$$R = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1} \right)^2$$
 The equations for transmission and reflection of ultrasound intensity are independent of frequency for specular reflection. Therefore changing the transducer frequency does not alter the fraction of intensity transmitted/reflected at an interface. Transmission coefficient - $\%T = 4 Z_2 Z_1 / (Z_2 + Z_1)^2$.

Nature of ultrasound

Ultrasound uses high frequency (above 20 kHz) mechanical vibrations or pressure waves that the human ear cannot detect. Typical diagnostic sonographic scanners operate in the frequency range of 2 to 18 megahertz, hundreds of times greater than the limit of human hearing. The choice of frequency is a trade-off between spatial resolution of the image and imaging depth: lower frequencies produce less resolution but image deeper into the body.

Superficial structures such as muscles, tendons, testes, breast and the neonatal brain are imaged at a higher frequency (7-18 MHz), which provides better axial and lateral resolution. Deeper structures such as liver and kidney are imaged at a lower frequency 1-6 MHz with lower axial and lateral resolution but greater penetration.

Wave parameters

PERIOD: time taken for one particle in the medium through which the wave travel, to make one complete oscillation (cycle) about its rest position, in response to the wave

FREQUENCY: the number of oscillations per second of the particle in the medium responding to the wave passing through it

WAVELENGTH: the distance between 2 consecutive, identical positions in the pressure wave

VELOCITY: the speed of propagation of a sound wave, determined by a combination of the density and compressibility of the medium through which it is propagating

PHASE: the stage at which a wave is within a cycle

AMPLITUDE: a measure of the degree of change within a medium, caused by the passage of a sound wave and relates to the severity of the disturbance

POWER: rate of flow of energy through a given area

INTENSITY: the power per unit area

Properties of interfaces

An interface is the junction of two media with different acoustic properties.

It does not matter which impedance is the larger or smaller for two materials composing an interface; the difference between them squared is the same. This means that the same amount of reflection occurs at an interface going from high impedance to low impedance or vice versa

3.5 Ultrasound

Ultrasound refers to a cyclic sound pressure in the form of waves that has a frequency greater than the upper limit of human hearing. The highest human beings can detect is 20 thousand cycles per second (20,000 Hz).

3.5.1 Ultrasound and Properties

Defining Ultrasound: Ultrasound is *high frequency mechanical vibrations* or pressure waves above a frequency the human ear can hear.

Ultrasound uses sound waves:

Audible 20Hz and 20 000Hz.

Infra sound Below 20Hz

Ultrasound Above 20 000Hz

Ultrasound uses a pulse-echo technique of imaging the body.

Pulses transmitted into patient and give rise to echoes when they encounter interfaces/reflectors.

These interfaces/reflectors are caused by variations in the "**acoustic impedance**" between different tissues.

Echo signals are amplified electronically and displayed on a monitor using shades of grey (from black to white), **stronger reflectors = brighter shades of grey and appear white in an image**. Those with **no echoes will appear black**, such as a full bladder.

Tissues with **multiple interfaces** are termed **echogenic**, solid organs: spleen, liver and kidneys.

Structures with **no internal interfaces** are **hypoechoic** and return no echoes. characteristics of liquid filled structures such as gall bladder and the urinary bladder.

Properties of an ultrasound wave

- Frequency higher than 20 000Hz (20kHz)
- Propagation of sound waves longitudinal, the mechanical displacement being in the same direction as propagation.
- A medium is needed for sound waves to go through, no medium = no sound waves
- This propagation is whereby the particles of the medium which the sound is going through oscillate (move) back and forth from their original rest positions, in the same line as the wave. This is also known as Simple Harmonic Motion
- The motion of these particles is caused by 2 factors; the pressure of the wave (which forces them to move in the beginning) and the forces of the restoring molecules (also known as the elasticity of the medium)
- The sound waves are transmitted as an alternation series of compressions (zones of high pressure) and rarefactions (zones of low pressure).
- The physical disturbance can be shown in a diagram (the dot diagram), and the individual movement of each particle in the diagram is/ can be described mathematically by the wave equation
- Also the amount of particle movement is dependent on the pressure change associated with the wave, therefore the increased pressure change equals the increased particle movement, and therefore louder sound

3.5.2 Interactions of ultrasound with soft tissues

When an ultrasound wave passes through tissues

- **Attenuation:** Reduction in amplitude and intensity of wave
- **Refraction:** Change in direction & velocity of wave

Attenuation is the rate at which intensity wave diminishes with the depth it covers or its penetration.

Types:

- Reflection.
- Scattering
- Absorption

Affecting attenuation:

Frequency of wave - Higher the frequency, higher the attenuation and less penetration of the wave

Type of tissue the wave is traveling

Depth the wave travels - more distance wave has to travel the more energy is lost.

Reflection

When a sound wave is incident on a interface between two tissues, part of it is reflected back into the original medium. The amount of energy reflected back depends on impedance.

The greater the difference in impedance between the tissues forming the interface the greater the amount of energy that is reflected back.

Impedance is a property of a tissue defined as density of tissue and velocity of sound in that tissue.

Denoted as $Z = d \text{ (kg/m}^3\text{) } \times c \text{ (m/s)}$

Reflection co-efficient (R) is the ratio of the intensity of the reflected wave to the incident wave.

$$R = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

The greater R, the greater the degree of reflection. i.e. R for a soft tissue interface such as liver and kidney is 0.01, i.e. only 1% of the sound is reflected. Muscle/bone interface 40% is reflected and for a soft tissue/air interface 99% is reflected.

This is the basis of ultrasound as different organs in the body have different densities and acoustic impedance and this creates different reflectors. In some cases the acoustic impedance can be so great that all the sound waves energy can be reflected, this happens when sound comes in contact with bone and air. This is the reason why ultrasound is not used as a primary imaging modality for bone, digestive tract and lungs.

Absorption

Absorption is the main form of attenuation. Absorption happens as sound travels through soft tissue, the particles that transmit the waves vibrate and cause friction and a loss of sound energy occurs and heat is produced. In soft tissue sound intensity decreases exponentially with depth.

Diffuse Scatter

Diffuse scatter when an objects size relative to the wave length becomes smaller. Imagine placing a thin stick upright in large rippling puddle or lake shore. The waves striking the stick

will barely change course. The same applies to sound when the wave length of the sound waves are much larger than the object they are striking little or no sound waves will be reflected back. Because of this no strong reflections are seen as the sound, if reflected at all does not go directly back to the transducer. An example of this can be seen as speculation of an ultrasound image.

3.6 Acoustic impedance interactions of ultrasound with tissue

Acoustic Impedance (Z) is a measure of the resistance to sound passing through a medium. $Z = \text{density} \times \text{speed of sound}$. It is similar to electrical resistance.

Unit - $\text{kg/m}^2/\text{s}$ called rayl

Materials with a higher density have increased c which therefore means the acoustic impedance is higher. eg bone.

Gases have low acoustic impedance.

Impedance mis-match - a difference in acoustic impedances cause some portion of the sound to be reflected at the interface. Therefore we want the acoustic impedance of two different materials to be as similar as possible to ensure that the beam is reflected at a specula reflector.

Whenever a sound wave encounters a material with a different density (acoustical impedance), part of the sound wave is reflected back to the probe and is detected as an echo. The greater the difference between acoustic impedance, the larger the echo is. If the pulse hits gases or solids, the density difference is so great that most of the acoustic energy is reflected and it becomes impossible to see deeper.

Huygen's Principle

A source of sound acts as if it is composed of an infinite number of point sources of sound. The waves from these point sources combine with each other to form a wavefront which then determines the direction of wave travel. The intensity at any point within the beam is determined by the sum of the contributions from all the point sources. Interferences occur between the waves from the point sources, leading to variation in intensity within the beam.

Attenuation

As an ultrasound beam passes through a medium, it loses energy and therefore undergoes a reduction in amplitude and intensity... this loss of energy is determined by the characteristics of the medium. Attenuation is frequency dependent thus dictating the limit of penetration of an ultrasound beam at a given frequency, resulting in the resolution/penetration trade-off in diagnostic sonography. Five processes responsible for attenuation of an ultrasound beam... reflection/scattering/absorption/refraction/beam divergence

Intensity

Is a physical parameter that describes the amount of energy flowing through a unit cross-sectional area of a beam each second or the rate at which the wave transmits the energy over a small area

unit - watt per square cm or joule per second per square cm.

- it can be used to describe the loudness of sound, in dB.

Amplitude

Indicates the strength of the detected echo or the voltage induced in a crystal by a pressure wave.

Is a measure of the degree of change within a medium, caused by the passage of a sound wave, relates to the severity of the disturbance

Distance measurement

distance (z) is equal to the product of speed of sound times the time of travel. $z=ct$

Echo ranging is used to determine the distance travelled by the sound beam. If the velocity of the ultrasound in the medium and the elapsed time from the original transmitted pulse are known echo ranging principle states that the distance to an interface can be determined.

3.7 Applications of Ultrasound

3.7.1 Night Club Isolation

The Structure

Concrete walls, concrete floor, concrete ceiling with suspended ceiling tiles 18" down. While the client noticed less-than-ideal sound in the club, the main problem he wished to combat was the structure borne transmission of sound to the apartment upstairs.

Ceiling

Roll out 6" unfaced insulation over the top of the suspended ceiling grid, then roll out a layer of SheetBlok over the top of the insulation (or at least back each ceiling tile with SheetBlok). Alternately, roll out 12" of insulation over the top of the suspended ceiling if it is determined that the ceiling cannot support the additional weight of SheetBlok even with reinforcement. Seal the juncture where the rolled out SheetBlok meets the structure by using the aforementioned tape.

Stage

Pull back the carpet and pad on the stage. Pull up the layer of plywood over the framing members (joists). Insulate between the joists with 6" of insulation to cut down the reflected sound under the stage. Line the bottoms of the joists with SheetBlok to isolate the stage from the structural concrete floor. Install a layer of SheetBlok on the floor of the stage itself, or at least a layer of ¾" MDF and then a layer of ¾" particle board, cross-seamed. Then lay the padding and carpet back down. If the pad is not rebound, replace it with this type or ComfortWear-200, which will offer 5-7dB of additional sound isolation. The stage should be kept as physically separate from the structure as possible. For maximum control, build new walls adjacent to the existing walls as outlined earlier or at least add additional layers of gypsum board to the existing walls with a layer of SheetBlok then a layer of 5/8" gypsum board. The club owner was unwilling to do either of these, so we recommended he apply 4" Studio foam, realizing that it would alleviate at least some of the low frequency sound that is offending the apartment upstairs.

3.7.2 Garage Isolation and Treatment

A one-car 13'x19' garage; carpeted floor; gypsum board walls; no windows; 1 36" solid-core door; acoustical tile ceiling at 8' height. The room is used to teach guitar and rehearse with guitar, bass, drums and drum machine.

The Problem

Excessive slap echo and reverb along with excessive low-end buildup due to drum kit being located in one corner. Owner not overly worried about sound transmission

to/from the outside, but would like some additional transmission control.

:What to do

- Roll out unfaced insulation over the top of the suspended ceiling tiles, thus increasing transmission loss through the ceiling while adding low frequency control to the room.
- Treat all four vertical corners with LENRD Bass Traps.
- Treat the walls with 2" Studiofoam, preferably cut into 2'x2' panels and applied in a staggered checkerboard pattern with space between panels, easily adapted so no two parallel walls are mirror-images of each other. This method yields improved absorption and diffusion without costing any more money. Coverage minimum for a room of this size and with this intended usage is 45%; 60-75% is more appropriate.

The customer originally thought he wanted to purchase Venus Bass Traps and 12" Corner Fills for all four (4) wall/ceiling junctures, but we recommended LENRDs instead because of his room's size. We advised 2" Studiofoam for the walls instead of 4" because the slap echo and excessive reverb dictate more coverage, not thicker foam. If the budget allowed, 4" Studiofoam would be a welcome substitution.

Architectural Acoustics

From Wikipedia, the free encyclopedia



Symphony Hall, Birmingham, an example of the application of architectural acoustics.

Architectural acoustics (also known as room acoustics and **building acoustics**) is the science and engineering of achieving a good sound within a building and is a branch of acoustical engineering. The first application of modern scientific methods to architectural acoustics was carried out by Wallace Sabine in the Fogg Museum lecture room who then applied his new found knowledge to the design

of Symphony Hall, Boston.

Architectural acoustics can be about achieving good speech intelligibility in a theatre, restaurant or railway station, enhancing the quality of music in a concert hall or recording studio, or suppressing noise to make offices and homes more productive and pleasant places to work and live in. Architectural acoustic design is usually done by acoustic consultants.

After determining the best dimensions of the room, using the modal density criteria, the next step is to find the correct reverberation time. The reverberation time depends on the use of the room. Times about 1.5 to 2 seconds are needed for opera theaters and concert halls. For broadcasting and recording studios and conference rooms, values under one second are frequently used. The recommended reverberation time is always a function of the volume of the room. Several authors give their recommendations. A good approximation for Broadcasting Studios and Conference Rooms is: $TR[1 \text{ kHz}] = [0,4 \log (V+62)] - 0,38$ TR in seconds and V =volume of the room in m^3 . The ideal RT60 must have the same value at all frequencies from 30 to 12,000 Hz. Or, at least, it is acceptable to have a linear rising from 100% at 500 Hz to 150% down to 62 Hz

To get the desired RT60, several acoustics materials can be used as described in several books. A valuable simplification of the task was proposed by Oscar Bonello in 1979. It consists of using standard acoustic panels of 1 m^2 hung from the walls of the room (only if the panels are parallel). These panels use a combination of three Helmholtz resonators and a wooden resonant panel. This system gives a large acoustic absorption at low frequencies (under 500 Hz) and reduces at high frequencies to compensate for the typical absorption by people, lateral surfaces, ceilings, etc.

Reverberation, in terms of psychoacoustics, is the interpretation of the persistence of sound after a sound is produced. A reverberation, or **reverb**, is created when a sound or signal is reflected causing a large number of reflections to build up and then decay as the sound is absorbed by the surfaces of objects in the space – which could include furniture and people, and air. This is most noticeable when the sound source stops but the reflections continue, decreasing in amplitude, until they reach zero amplitude. Reverberation is frequency dependent. The length of the decay, or reverberation time, receives special consideration in the architectural design of spaces which need to have specific reverberation times to achieve optimum performance for their intended activity. In comparison to a distinct echo that is a minimum of 50 to 100 ms after the initial sound, reverberation is reflections that arrive in less than approximately 50ms. As time passes, the amplitude of the reflections is reduced until it is reduced to zero. Reverberation is not limited to indoor spaces as it exists in forests and other outdoor environments where reflection exists.

An **anechoic chamber** (an-echoic meaning non-reflective, non-echoing or echo-free) is a room designed to completely absorb reflections of either sound or electromagnetic waves. They are also insulated from exterior sources of noise. The combination of both aspects means they simulate a quiet open-space of infinite dimension, which is useful when exterior influences would otherwise give false results.

Anechoic chambers, a term coined by American acoustics expert Leo Beranek, were originally used in the context of acoustics (sound waves) to minimize the reflections of a room. More recently, rooms designed to reduce reflection and external noise in radio frequencies have been used to test antennas, radars, or electromagnetic interference.

Anechoic chambers range from small compartments the size of household microwave ovens to ones as large as aircraft hangars. The size of the chamber depends on the size of the objects to be tested and the frequency range of the signals used, although scale models can sometimes be used by testing at shorter wavelengths (higher frequencies).

4.0 CONCLUSION

Echo, a variant of sound has a number of applications in daily life and in industries. While it is used in distance/depth measurement, position determination as we have for birds like bat, at the manufacturing level ultrasound equipments are useful in hospitals for scanning and so on. Architectures use echo phenomenon extensively to in designing room acoustics and in studios sound proofs rooms are made to restrict interference, reflection, etc.

5.0 SUMMARY

In this unit a lot of sound related applications both in daily life and in industries are discussed. Sound has applications mainly in the echo form for depth determination and sound enhancement in architectural halls. Ultrasound is used at industrial level to produce scan machines used extensively in hospitals to examine babies in fetus, bone fracture, tissue or lung cancer, and so on.

6.0 TUTOR-MARKED ASSIGNMENT

1. List any six properties of ultrasound
2. Explain the form of industrial application of sound in [a] sound enhancement in concert halls [b] baby scan in pregnant women

7.0 REFERENCES

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UNIT 5: APPLICATIONS OF TOTAL INTERNAL REFLECTION

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 - 3.2 Total internal reflection
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- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor Marked Assignment (TMAs)
- 7.0 References/Further Readings

1.0 INTRODUCTION

Today total internal reflection as a phenomenon has gone beyond its observation as we find on tarred roads as mirage to industrial applications in areas such as optical fibres, productions of prisms and diamonds. It is one thing to study light its reflection and refraction but it is another thing to know application of the knowledge beyond the class room. Doctors now depend greatly on use of optical fibres to reduce how many people they need to open up in the name of surgical operation. In this unit natural and industrial applications of total internal reflections are explained.

3.0 OBJECTIVES

In this unit it is expected that after studying it you should be able to answer questions related to:

-
1. Refractive index
 2. How total internal reflection takes place
 3. What is optical fibre and its advantages
 4. Listing and explaining 4 applications of total internal reflection
-

HOW TO STUDY THIS UNIT:

In this unit you are expected to :

1. Read through the course contents on your own
2. First attempt the activities, then the TMA without looking at the hints provided by the author
3. Make observations on all your difficulties to your facilitator
4. Confirm your work on the activities after you have done your best to get all correct

3.1 Refractive Index

We know the speed at which a wave travels is dependent upon the medium it travels through. A number called the refractive index of a substance is a measure of how much the speed of a wave changes compared to the speed in a reference medium i.e. air or a vacuum.

For light waves the refractive index is given as

$$\text{Refractive Index} = \frac{\text{Speed of light in air}}{\text{Speed of light in medium}}$$

The refractive index for glass is approximately 1.5; this means the speed of light in glass is approximately 1.5 times slower than the speed of light in air. Similarly, the refractive index of water is 1.33. This implies that light rays will not be bent as much in water as they are in glass as they are not slowed down as much in water.



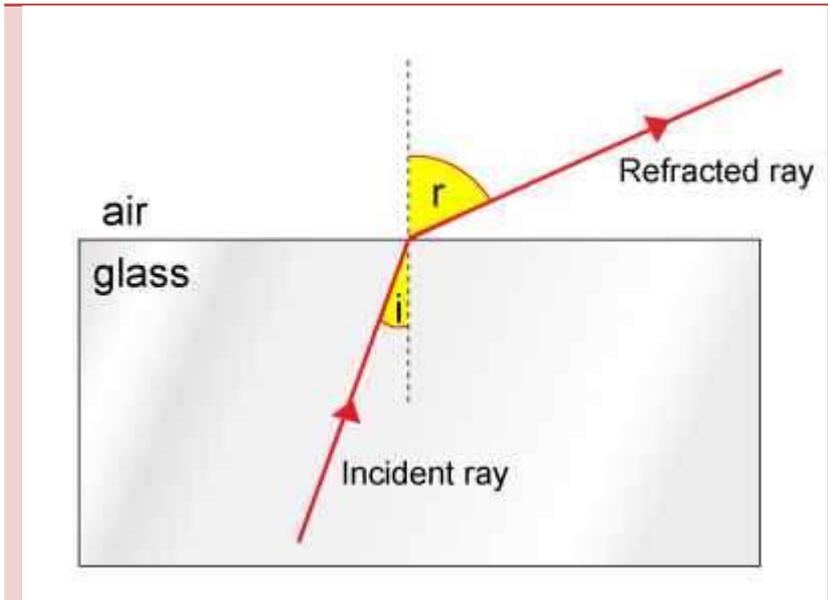
3.2 Total Internal Reflection

When light travels from one medium to another it changes speed and is refracted. If the light rays are travelling from a less dense material to a dense medium they are refracted towards the normal and if they are travelling from a dense to less dense medium they are refracted away from the normal.

For total internal reflection to occur the light must travel from a dense medium to a less dense medium (e.g. glass to air or water to air).

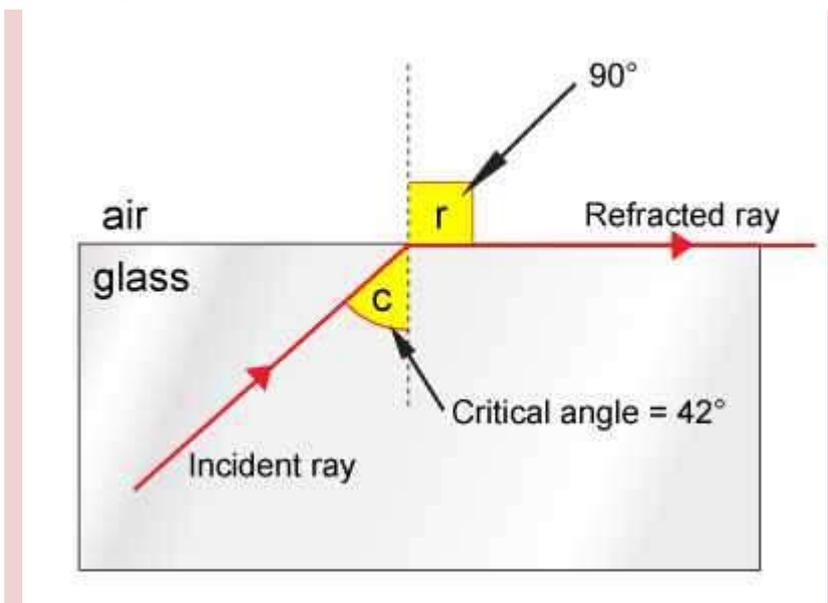
As the angle of incidence increases so does the angle of refraction. When the angle of incidence reaches a value known as the **critical angle** the refracted rays travel along the surface of the medium or in other words are refracted to an angle of 90°. The critical angle for the angle of incidence in glass is 42°.

1. ANGLE OF INCIDENCE LESS THAN THE CRITICAL ANGLE



When the angle of incidence of the light ray leaving the glass is less than the critical angle, the light ray speeds up on leaving the glass and is refracted away from the normal.

2. ANGLE OF INCIDENCE EQUAL TO THE CRITICAL ANGLE



When the angle of incidence of the light ray reaches the critical angle (42°) the angle of refraction is 90° . The refracted ray travels along the surface of the denser medium in this case the glass.

3. ANGLE OF INCIDENCE GREATER THAN THE CRITICAL ANGLE



When the angle of incidence of the light ray is greater than the critical angle then no refraction takes place. Instead, all the light is reflected back into the denser material in this case the glass. This is called total internal reflection.

In order for total internal reflection to take place;

1. The rays of light must travel from a dense medium to a less dense medium.

2. The angle of incidence must be greater than the critical angle.

3.3 Optical Fibres and Advantages

Optical fibres are used extensively in the field of telecommunications and medicine. In the telecommunication field they are used as an alternative signal carrier to copper wires in the telephone system. They are used to carrier digital signals in the form of light pulses over long distances.

OPTICAL FIBRE

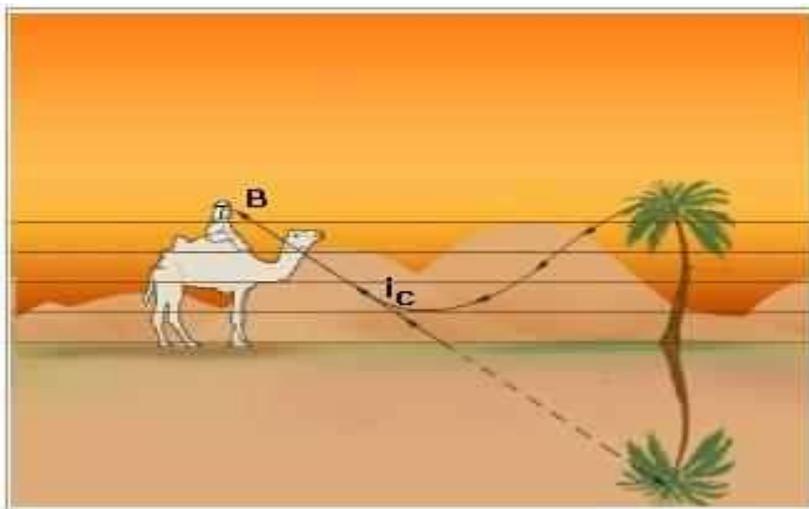
An optical fibre consists of a very thin core of high purity glass. The core is covered by a second layer (cladding) also made from high purity glass. The cladding is less dense than the core and has a lower refractive index. **Remember, for total internal reflection to occur the light rays must travel from a dense medium to a less dense medium.** Thus light rays passing along the core at an angle greater than the critical angle are totally internally reflected. The surface of the high purity glass core acts like a perfect mirror and the light ray is continuously reflected along the length of the optical fibre core. The cladding is covered with a protective plastic buffer coating.

Advantages of Optical Fibres

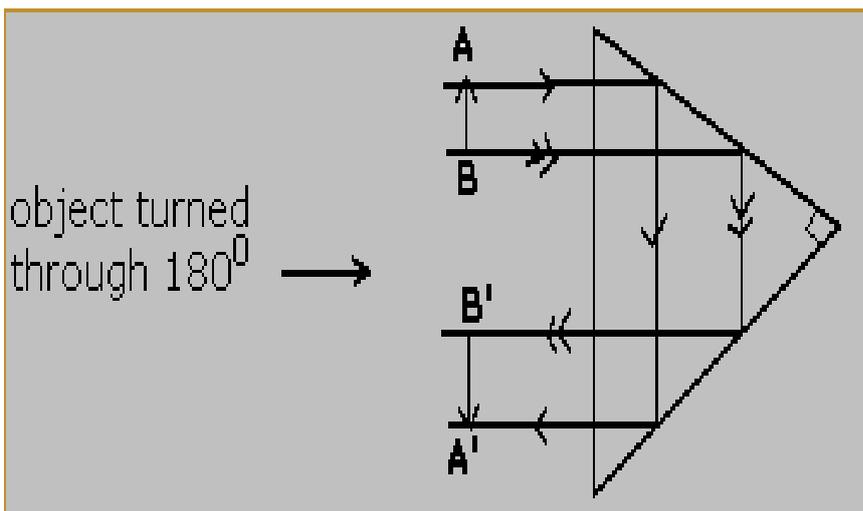
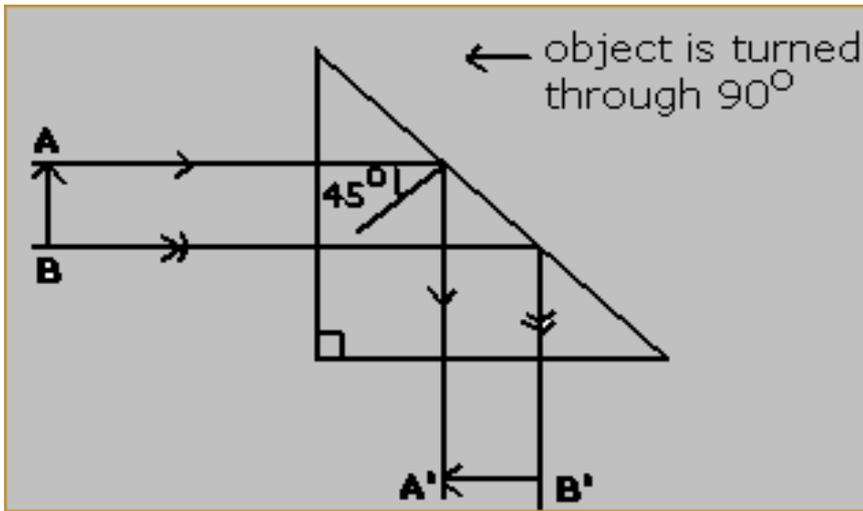
1. Optical fibres are less expensive than copper wires.
2. Optical fibres are thinner than copper wires allowing more fibres to be bundled together in a given cable diameter. This allows for more information be it telephone conversations or television channels to be passed through the cable.
3. Electrical signals in copper wires interfere with other copper wires bundled in the same cable. As optical fibres carry light signals there is no interference between fibres bundled in the same cable resulting in a clearer signal.
4. Due to little degradation of the optical fibre signal the signal only needs to be boosted after long distances approximately 100km whereas for copper cables this needs to be done a lot more often after approximately 8km. Thus optical fibres require less power for transmission.

3.4 Applications of Total Internal Reflection

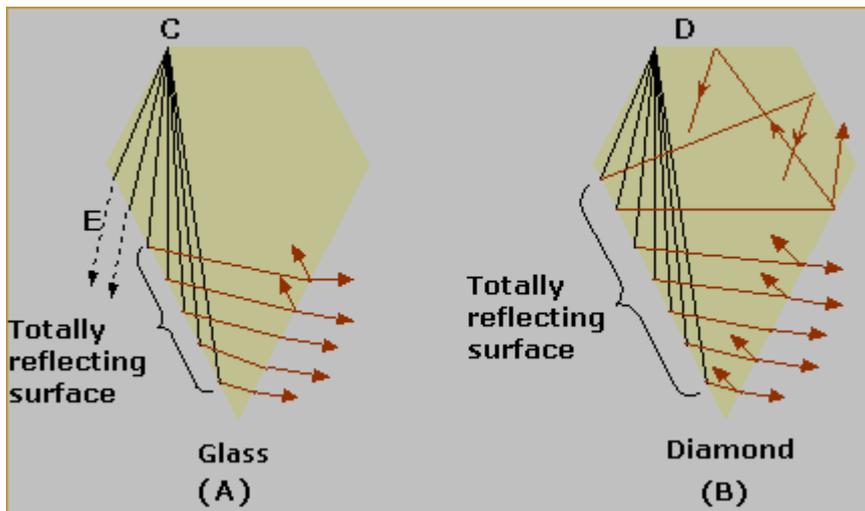
- Mirage is an optical illusion, which occurs usually in deserts on hot summer days. On such a day, temperature of air near the earth is maximum and hence is rarer or lighter. The upper layers of air, which are relatively cool, are denser. A ray of light from the top of a tree travels from denser to rarer and bend away from the normal. At a particular layer, if the angle of incidence is greater than 'c', total internal reflection occurs. To far away observer, this ray i.e., AE appears to be coming from I i.e., mirror image of O. Thus inverted image of tree creates an optical illusion of reflection from a pond of water.



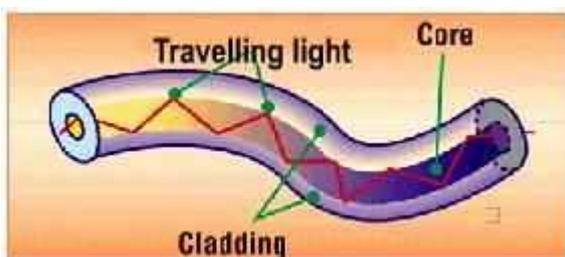
- Right angled isosceles prism can turn light through 90° or 180° . This is based on total internal reflection. Since n for glass-air is 1.5, the value of 'C' is 42° . In such a prism, the angle of incidence in the denser medium is $45^\circ (>C)$ and hence light suffers total internal reflection.



- The brilliance of diamond is due to total internal reflection. Now n for diamond is 2.42° and c (the critical angle) is 24.4° for diamond-air interface. The faces of the diamond are so cut that a ray of light entering the diamond falls at angle greater than 24.4° . This results in multiple, total internal reflections at various angles and remains within the diamond. Hence diamond sparkles.



- Optical Fibres: Optical fibres consist of a very fine quality of glass or quartz fibres. They are coated with thin layer of material of lower refractive index than that of the fibre. The thickness of the strand is 10^{-4} . The optical fibre works on the principle of total internal reflection.



The word total means that reflection in the above case occurs with no loss of intensity. This phenomena enables doctors to inspect many internal body sites.

A Bundle of fibres transmit an image that can be inspected visually outside the body.

Optic fibres are as thick as a human hair. If a beam of light is sent down a thin glass rod, total internal reflection traps the light inside the rod. This technique is called 'fibre optics'.

Fibre optics finds its use in the medical field too. Endoscopes use fibre optics technique. A patient can swallow a tube containing a fine glass fibre through which a doctor can examine the internal stomach parts and hence unnecessary surgeries can be avoided. 'Fibre optics' is used to destroy tumors. If a fibre optic cable is passed into the organ laser light can be directed along it. The laser is directed at the tumor cells and kills them.

The red plastic reflector on the back of a bicycle uses total internal reflection.

Self Assessment Question

Describe briefly how optical fibres are useful to doctors in the hospital.

Answer: Fibre optics finds its use in the medical field too. Endoscopes use fibre optics technique. A patient can swallow a tube containing a fine glass fibre through which a doctor

can examine the internal stomach parts and hence unnecessary surgeries can be avoided. 'Fibre optics' is used to destroy tumors. If a fibre optic cable is passed into the organ laser light can be directed along it. The laser is directed at the tumor cells and kills them.

4.0 CONCLUSION

In this unit it is seen that total internal reflection has its applications in our daily life as we find on roads, deserts and bicycle rear light. The phenomenon is also extended by application to optical fibres which is widely used in hospitals to see around corners in human stomach or system, production of prisms for laboratory use and diamonds as fine and valued asset.

5.0 SUMMARY

Having gone through this unit we can now itemize what learnt briefly thus:

- i. Refraction takes place when light passes from one medium to another of different density
- ii. Beyond a critical angle reflection could be within a medium and does not cross to the other and therefore referred to total internal reflection
- iii. Naturally total internal reflection can be observed as mirage on tarred roads and deserts.
- iv. Prisms, diamonds and optical fibres are produced with application of total internal reflections
- v. Optical fibres are used in medical diagnosis, in place of surgery, passing laser light through for treatment of cancer and tumor cells. The red plastic reflector on the back of a bicycle uses total internal reflection.

6.0 TUTOR-MARKED ASSIGNMENT

Unit 3 Question 1

List any four applications of total internal reflection and describe each briefly

Unit 3 Question 2

What is optical fibre? With aid of diagram demonstrate how total internal reflections takes place in optical fibre.

7.0 REFERENCES/FURTHER READINGS

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UNIT 6: BREWING

TABLE OF CONTENT

- 1.0 Introduction
- 2.0 Objectives
- 3.0 How to study this unit
- 4.0 Main Content
 - 4.1 What is Brewing
 - 4.1.1 Yeast
 - 4.2 What is Biotechnology
 - 4.3 Formation of Alcohol during Anaerobic respiration
- 5.0 Conclusion
- 6.0 Summary
- 7.0 Tutor Marked Assignment (TMA)
- 8.0 References and Further Reading

1.0 INTRODUCTION

The word brewing is always associated with fermentation. Fermentation is the process by which certain organisms such as yeast derive energy from breaking down sugar in the complete absence of oxygen through a process known as anaerobic respiration or anaerobiosis.

In this unit you are going to learn how this process is used in the industry to produce alcoholic drinks such as beer, wine, other alcoholic drinks, and insulin.

2.0 OBJECTIVES

By the end of the unit you should be able to:

1. Define brewing;
2. Explain the term biotechnology,
3. Explain the formation of alcohol during anaerobic respiration.
4. State the chemical composition of alcohol
5. List other materials associated with brewing

3.0 HOW TO STUDY THIS UNIT

1. You should look at samples of different alcoholic drinks to appreciate what they look like. Most of you are familiar with alcoholic drinks.
2. Review your knowledge of aerobic and anaerobic respiration.
3. Visit any brewery around your area
4. Familiarize yourself with terms which are new to you.
5. Carry out all the activities and assignments giving to you.

NOTE: ALL ANSWERS ARE AT THE END OF THIS BOOK

4.0 MAIN CONTENT

4.1 What is Brewing?

Brewing is the production of beer through steeping a starch source (commonly cereal grains) in water and then fermenting with yeast. It is commonly done in a brewery by a brewer.

The basic ingredient of beer are water, a starch source such as malted barley which is able to be fermented (converted to alcohol), a brewers yeast to induce fermentation and a flavouring such as hops. A secondary starch source may be used such as maize, rice, sugar, millet, sorghum, cassava, and potato.

Activity I

What are the steps involved in brewing

The steps involved in brewing include: malting, milling, mashing, lautering, boiling, fermenting, conditioning, filtering and packaging

There are three main fermentation methods, namely warm, cool and wild or spontaneous. Fermentation may take place in open or closed vessel. There may be secondary fermentation that can take place in the brewery, in the cask or in the bottles.

Activity 2

Pay a visit to a brewery and observe the steps involved in brewing. Write short notes on the different steps involved in brewing.

Beer is brewed from barley grain which has been partially germinated to convert its starch store to sugars such as maltose, the process is called malting. Gibberellins are used to speed up the reaction and amylase added to increase the amount of sugar which leads to production of more alcohol. The grain is killed by slow roasting. The grain is then crushed between rollers and added to hot water to extract the sugars.

The liquid obtained is called wort. Hops are added for their bitter flavor and anti microbial properties. The mash is boiled and then cooled to a suitable temperature for fermentation. It is then added to a large batch fermentator where it is inoculated with brewer's yeast. Two commonly used yeasts are Saccharomyces cerevisiae and Saccharomyces carlsbergensis. Fermentation is anaerobic.

During this process sugar is converted to alcohol and carbon dioxide. After 2 – 5 days, the alcohol reaches a final concentration of 3.5 -8%.

Wine

The source of sugar for fermentation, which lasts for several days, is grapes. Different grape varieties and different yeasts are responsible for different flavours of wine Red wine get their colour from the skin of the grapes used. White wines are made from grapes whose skin has been removed. Fermentation starts while the grapes are crushed to form 'must'. A second fermentation by lactic acid is converted to lactic acid and carbondioxide. This reduces the acidity of the wine.

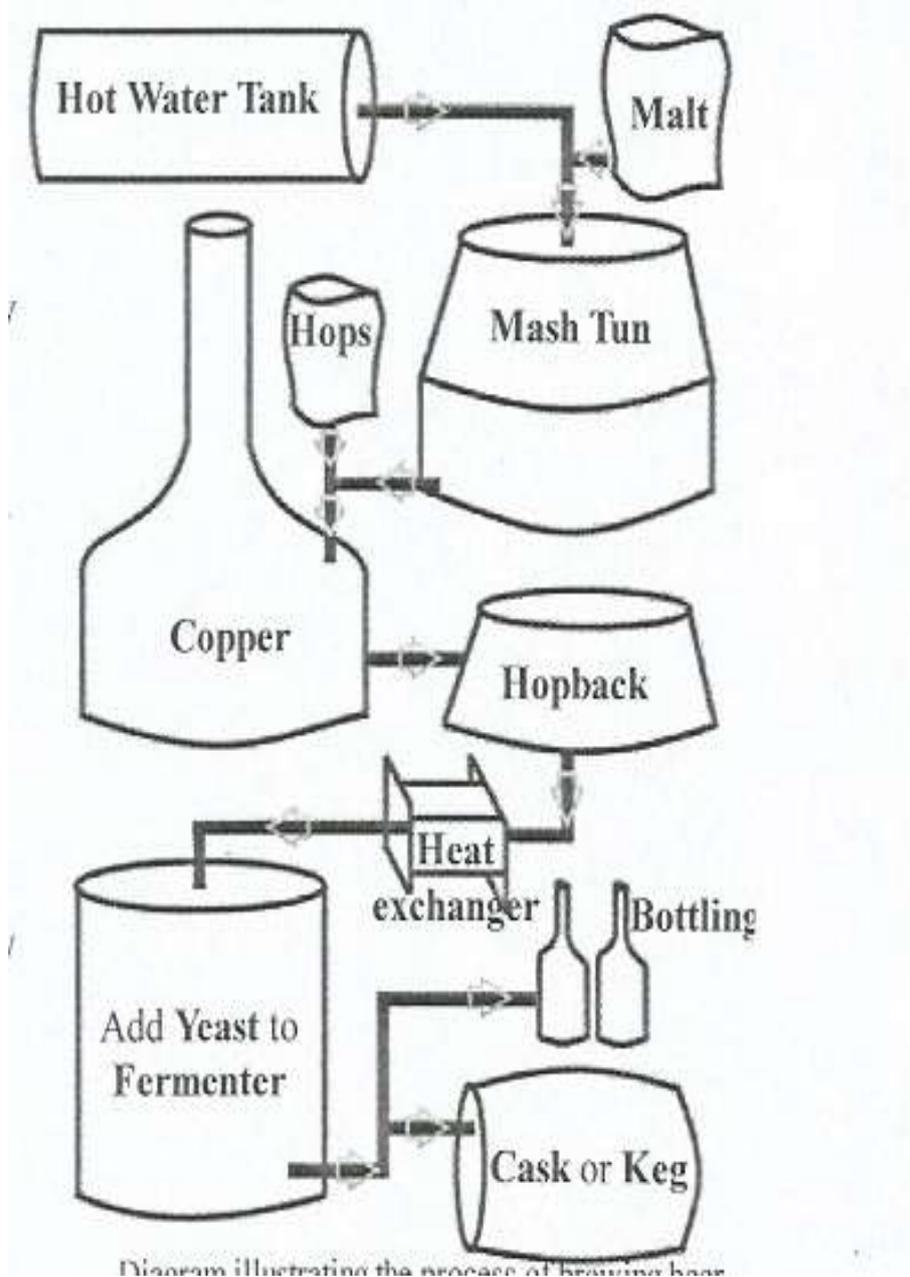


Fig 3.2: Diagram illustrating the brewing of beer

4.1.1 Yeast

Yeast is the microorganism that is responsible for the fermentation in beer. Yeast metabolises the sugars extracted from grains which produce alcohol and carbon dioxide. The dominant types of yeast used in making beer are Saccharomyces cerevisias known as ale yeast and Saccharomyces uvarum known as lager yeast.

4.2 What is Biotechnology?

Biotechnology has been defined as the application of organisms, biological systems or biological processes to manufacturing and servicing industries.

Activity 3

List some biological processes in a manufacturing process that could be regarded as biotechnology.

The use of any biological process in a manufacturing process could be regarded as biotechnology.

These include genetic engineering and cloning of plants in agriculture, horticulture and forestry, breeding and improvement of domesticated animals

Fig 3.1 Below shows examples of biotechnology.

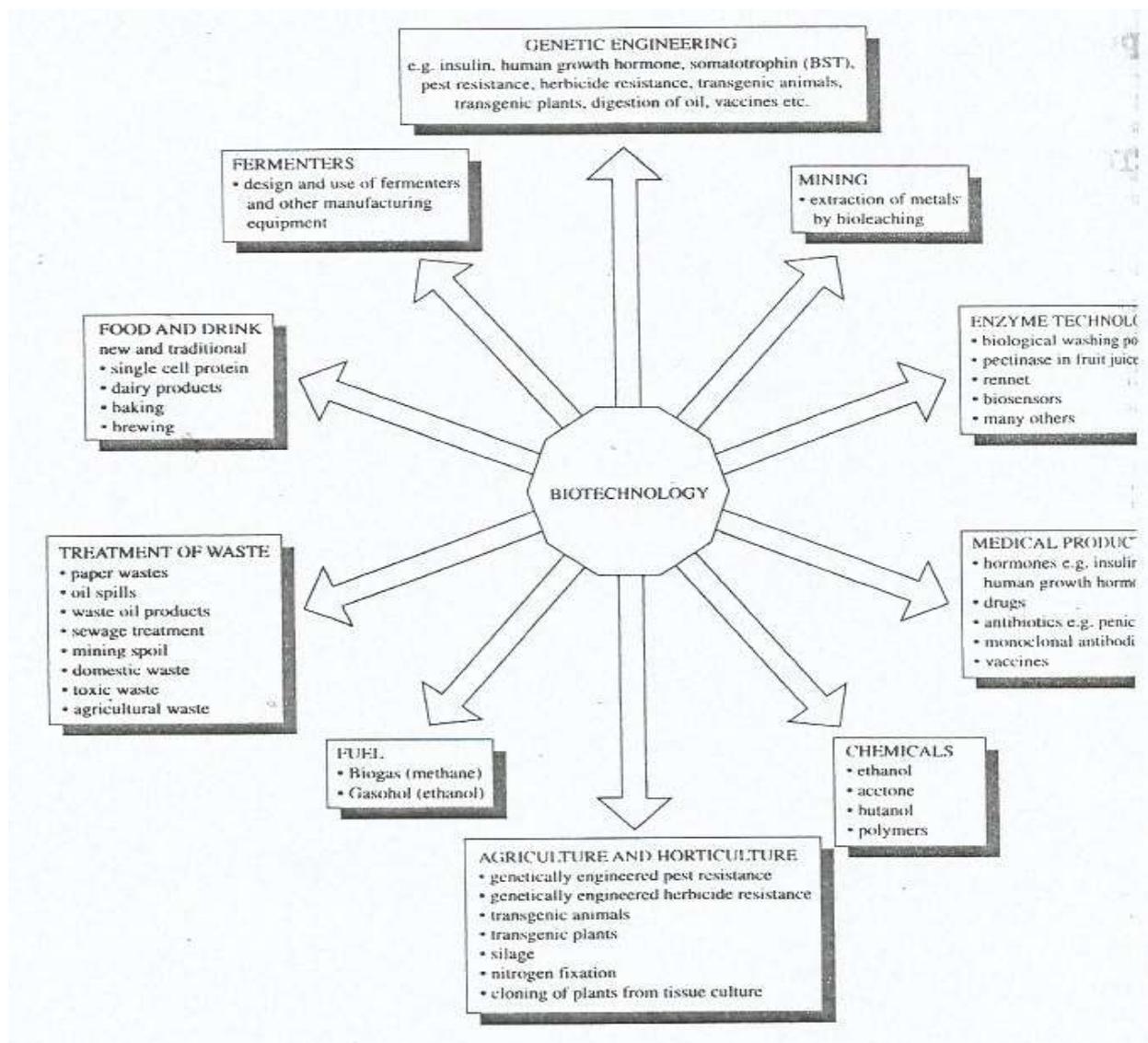


Fig 3.1: some of the application of biotechnology

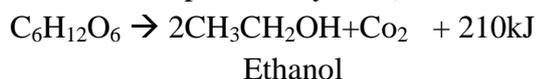
Biotechnology provides both products and services.

Examples of products are alcohol in the brewing industry, and human insulin from genetically engineered bacteria. Examples of services are treatment of sewage or detection of pollution using a biosensor.

4.3 Formation of alcohol during anaerobic respiration.

Anaerobic respiration is the type of respiration that occurs without oxygen. In this type of respiration sugar is partially broken down. Instead of being oxidized to carbon dioxide and water, it is converted into either ethanol (ethyl alcohol) or lactic acid. Ethanol is the end product of anaerobic in plants, and yeast, and lactic acid in animals.

Anaerobic in plant and yeast (alcoholic fermentation):



Anaerobic in animals:



The usefulness of anaerobiosis in the brewing industry is through fermentation of yeast. The fact that yeast can respire anaerobically to produce ethanol has long been used by man in brewing. But in fact yeast grows much better in aerobic conditions. Therefore if too little oxygen is present the ethanol concentration rises so much and the yeast cells are destroyed. The secret in brewing is therefore not to let conditions become too anaerobic. The work of microbiologist working in brewery companies is to develop new strains of yeast that are tolerant to high concentrations of ethanol.

5.0 SUMMARY

In this unit you learned that:

- Brewing is the production of beer through steeping a starch source in water and then fermenting with yeast
- The application of organisms, biological systems or biological processes to manufacturing and servicing industries is known as biotechnology
- Examples of products of biotechnology are alcohol in brewing industry and human insulin.
- Alcohol is produced during anaerobic respiration. It is this process that is utilized in the brewing industries for the production of beer and other alcoholic drinks.
-

6.0 TEACHER MARKED ASSIGNMENT (TMA)

1. a. What is genetic engineering?
b. Give examples of genetic engineering
2. Explain the terms 'want' 'must' and malt

7.0 REFERENCES/FURTHER READING

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ANSWERS TO ASSIGNMENT

1. (a) Genetic engineering is the technique available to study and change genetic instructions of an organism. Genetic engineering involves inserting a new gene into an organism.
b. Examples are the transfer of genes for human insulin, human growth hormone and bovine somatotrophin (BST)
2. ‘Wart’ – this is the liquid obtained when grain is crushed and added to hot water to extract the sugars
‘Must’ – This is the name given to the products that result when grapes are crushed during wine making.
‘Malt’ is the product produced when barley grain is partially germinated to convert its starch stores to sugars such as maltose.

UNIT 7: SMELTING

TABLE OF CONTENT

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main content
 - 3.1 Process
 - 3.1.1 Reduction
 - 3.1.2 Fluxes
 - 3.2 Tin and Lead
 - 3.3 Copper and Bronze
 - 3.4.1 Early iron smelting (Ferrous metallurgy)
 - 3.4.2 Later iron smelting (Blast furnace)
 - 3.5 Base metals
- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor Marked Assignment (TMAs)
- 7.0 References/Further reading

1.0 Introduction

Smelting is a form of extractive metallurgy; its main use is to produce a metal from its ore. This includes production of silver, iron, copper and other base metals from their ores. Smelting uses heat and a chemical reducing agent to decompose the ore, driving off other elements as gasses or slag and leaving just the metal behind. The reducing agent is commonly a source of carbon such as coke, or in earlier time's charcoal. The carbon (or carbon monoxide derived from it) removes oxygen from the ore, leaving behind elemental metal. The carbon is thus oxidized in two stages, producing first carbon monoxide and then carbon dioxide. As most ores are impure, it is often necessary to use flux, such as limestone, to remove the accompanying rock gangue as slag.

2.0 Objectives

It is expected that upon going through this unit you should be able to:

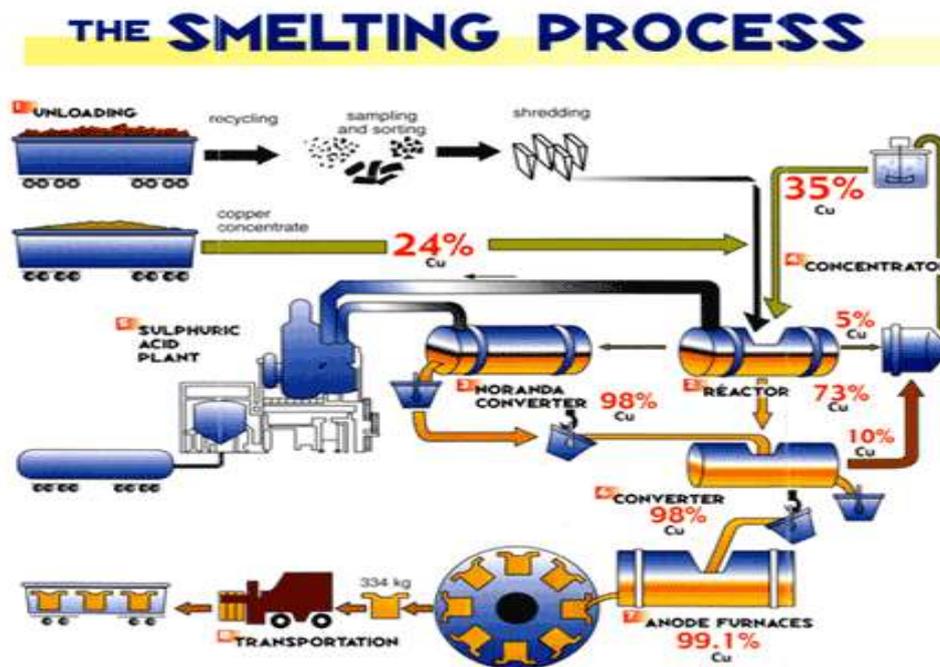
1. Explain the concept of smelting
2. List and explain some of the processes involve in smelting
3. Explain the smelting of Tin and lead
4. Describe the smelting of blast furnace

3.0 Main content

Of the seven metals known in antiquity only gold occurred regularly in native form in the natural environment. The others – copper, lead, silver, tin, iron and mercury – occur primarily as minerals, though copper is occasionally found in its native state in commercially significant quantities. These minerals are primarily carbonates, sulfides, or oxides of the metal, mixed with other components such as silica and alumina. Roasting the carbonate and sulfide minerals in air converts them to oxides. The oxides, in turn, are smelted into the metal. Carbon monoxide was (and is) the reducing agent of choice for smelting. It is easily produced during the heating process, and as a gas comes into intimate contact with the ore.

In the Old World, humans learned to smelt metals in prehistoric times, more than 8000 years ago. The discovery and use of the "useful" metals — copper and bronze at first, then iron a few millennia later — had an enormous impact on human society. The impact was so pervasive that scholars traditionally divide ancient history into Stone Age, Bronze Age, and Iron Age.

3.1 Process



Smelting involves more than just melting the metal out of its ore. Most ores are a chemical compound of the metal with other elements, such as oxygen (as an oxide), sulfur (as a sulfide) or carbon and oxygen together (as a carbonate). To produce the metal, these compounds have to undergo a chemical reaction. Smelting therefore consists of using suitable reducing substances that will combine with those oxidizing elements to free the metal.

3.1.1 Roasting

In the case of carbonates and sulfides, a process called "roasting" drives out the unwanted carbon or sulfur, leaving an oxide, which can be directly reduced. Roasting is usually carried out in an oxidizing environment. A few practical examples:

- Malachite, a common ore of copper, is primarily copper carbonate (CuCO_3). This mineral undergoes thermal decomposition to CuO and CO_2 in several stages between 250°C and 350°C . The carbon dioxide is expelled into the atmosphere, leaving copper oxide which can be directly reduced to copper as described in the following section titled Reduction.
- Galena, the most common mineral of lead, is primarily lead sulfide (PbS). The sulfide is oxidized to a sulfite (PbSO_3) which thermally decomposes into lead oxide and sulfur dioxide gas. (PbO and SO_2) The sulfur dioxide is expelled (like the carbon dioxide in the previous example), and the lead oxide is reduced as below.

3.1.2 Reduction

Reduction is the final, high-temperature step in smelting. It is here that the oxide becomes the elemental metal. A reducing environment (often provided by carbon monoxide, made by incomplete combustion, produced in an air-starved furnace) pulls the final oxygen atoms from the raw metal. The required temperature varies over a very large range, both in absolute terms and in terms of the melting point of the base metal. A few examples:

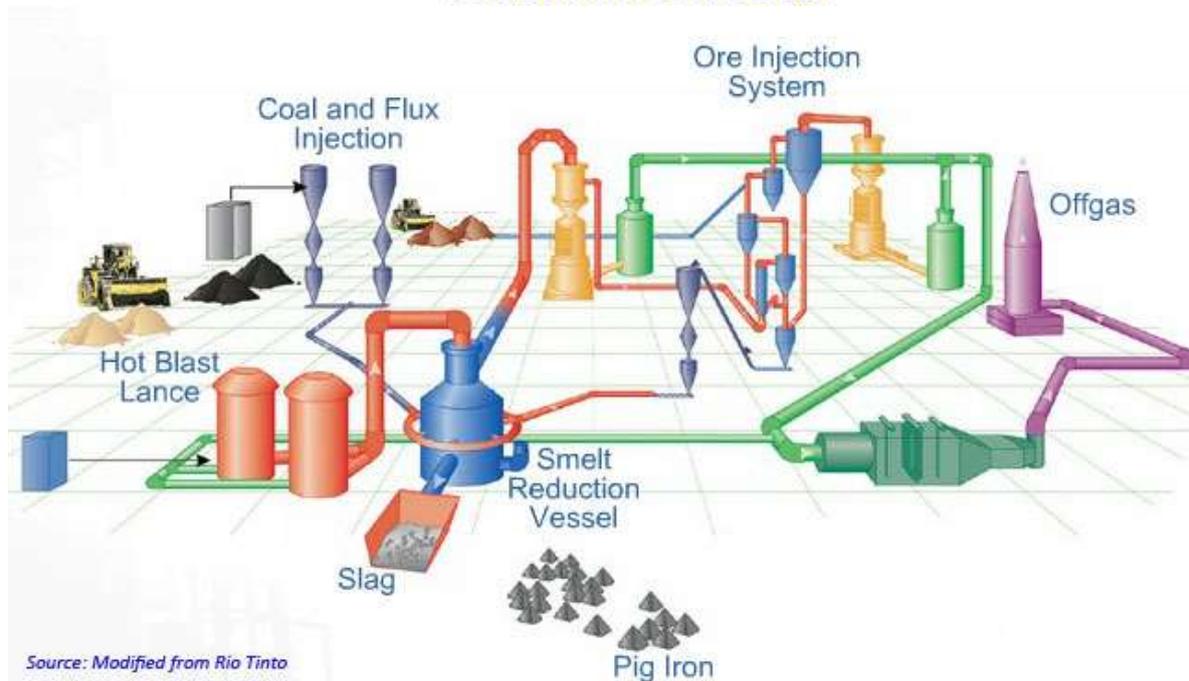
- iron oxide becomes metallic iron at roughly 1250°C , almost 300 degrees *below* iron's melting point of 1538°C
- mercuric oxide becomes vaporous mercury near 550°C , almost 600 degrees *above* mercury's melting point of -38°C

Flux and slag can provide a secondary service after the reduction step is complete: They provide a molten cover on the purified metal, preventing it from coming into contact with oxygen while it is still hot enough to oxidize readily.

3.1.3 Fluxes

Fluxes are used in smelting for several purposes, chief among them catalyzing the desired reactions and chemically binding to unwanted impurities or reaction products. Calcium oxide, in the form of lime, was often used for this purpose, since it could react with the carbon dioxide and sulfur dioxide produced during roasting and smelting to keep them out of the working environment.

Smelting Reduction Plant Layout (Using Hismelt Technology)



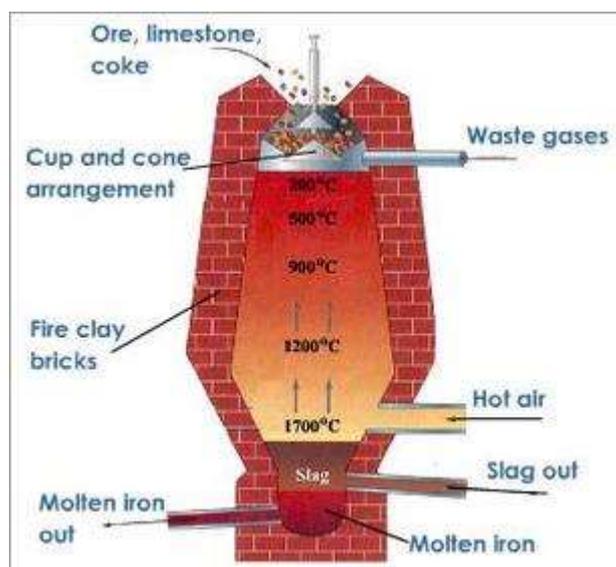
3.2 Tin and lead

In the Old World, the first metals smelted were tin and lead. The earliest known cast lead beads were found in the Çatal Höyük site in Anatolia (Turkey), and dated from about 6500 BC, but the metal may have been known earlier.

Since the discovery happened several millennia before the invention of writing, there is no written record about how it was made. However, tin and lead can be smelted by placing the ores in a wood fire, leaving the possibility that the discovery may have occurred by accident.

Although lead is a common metal, its discovery had relatively little impact in the ancient world. It is too soft to be used for structural elements or weapons, excepting for the fact that it is exceptionally heavy, making it ideal for sling projectiles. However, being easy to cast and shape, it came to be extensively used in the classical world of Ancient Greece and Ancient Rome for piping and storage of water. It was also used as a mortar in stone buildings.

Tin was much less common than lead and is only marginally harder, and had even less impact by itself.



3.3 Copper and bronze

After tin and lead, the next metal to be smelted appears to have been copper. How the discovery came about is a matter of much debate. Campfires are about 200 °C short of the temperature needed for that, so it has been conjectured that the first smelting of copper may have been achieved in pottery kilns. The development of copper smelting in the Andes, which is believed to have occurred independently of that in the Old World, may have occurred in the same way. The earliest current evidence of copper smelting, dating from between 5500 BC and 5000 BC, has been found in Pločnik and Belovode, Serbia. A mace head found in Can Hasan, Turkey and dated to 5000 BC, once thought to be the oldest evidence, now appears to be hammered native copper.

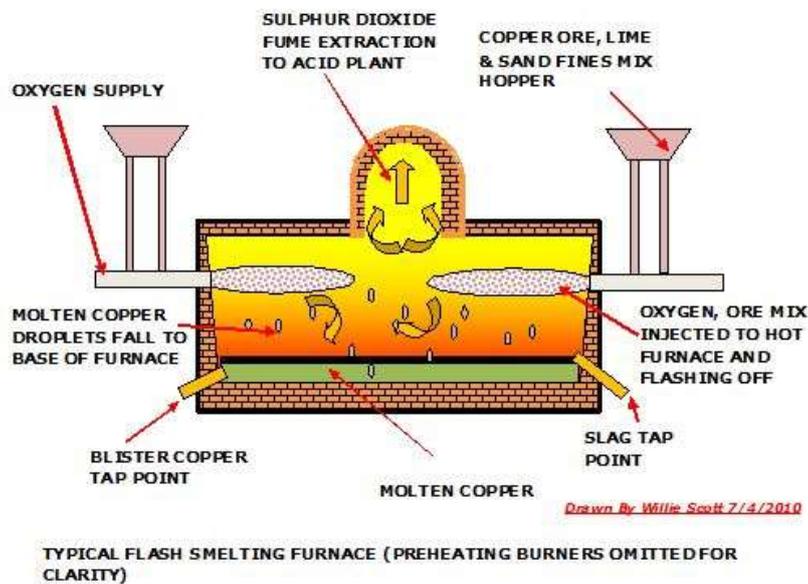
By combining copper with tin and/or arsenic in the right proportions one obtains bronze, an alloy which is significantly harder than copper. The first copper/arsenic bronzes date from 4200 BC from Asia Minor. The Inca bronze alloys were also of this type. Arsenic is often an impurity in copper ores, so the discovery could have been made by accident; but eventually arsenic-bearing minerals were intentionally added during smelting.

Copper–tin bronzes, harder and more durable, were developed around 3200 BC, also in Asia Minor.

The process through which the smiths learned to produce copper/tin bronzes is once again a mystery. The first such bronzes were probably a lucky accident from tin contamination of copper ores, but by 2000 BC, we know that tin was being mined on purpose for the production of bronze. This is amazing, given that tin is a semi-rare metal, and even a rich cassiterite ore only has 5% tin. Also, it takes special skills (or special instruments) to find it and to locate the richer lodes. But, whatever steps were taken to learn about tin, these were fully understood by 2000 BC.

The discovery of copper and bronze manufacture had a significant impact on the history of the Old World. Metals were hard enough to make weapons that were heavier, stronger, and

more resistant to impact-related damage than their wood, bone, or stone equivalents. For several millennia, bronze was the material of choice for weapons such as swords, daggers, battle axes, and spear and arrow points, as well as protective gear such as shields, helmets, greaves (metal shin guards), and other body armor. Bronze also supplanted stone, wood, and organic materials in all sorts of tools and household utensils, such as chisels, saws, adzes, nails, blade shears, knives, sewing needles and pins, jugs, cooking pots and cauldrons, mirrors, horse harnesses, and much more. Tin and copper also contributed to the establishment of trade networks spanning large areas of Europe and Asia, and had a major effect on the distribution of wealth among individuals and nations.



3.4.1 Early iron smelting

Ferrous metallurgy

Where and how iron smelting was discovered is widely debated, and remains uncertain due to the significant lack of production finds. Nevertheless, there is some consensus that iron technology originated in the Near East, perhaps in Eastern Anatolia.

In Ancient Egypt, somewhere between the Third Intermediate Period and 23rd Dynasty (ca. 1100–750 BC), there are indications of iron working. Significantly though, no evidence for the smelting of iron from ore has been attested to Egypt in any (pre-modern) period. There is

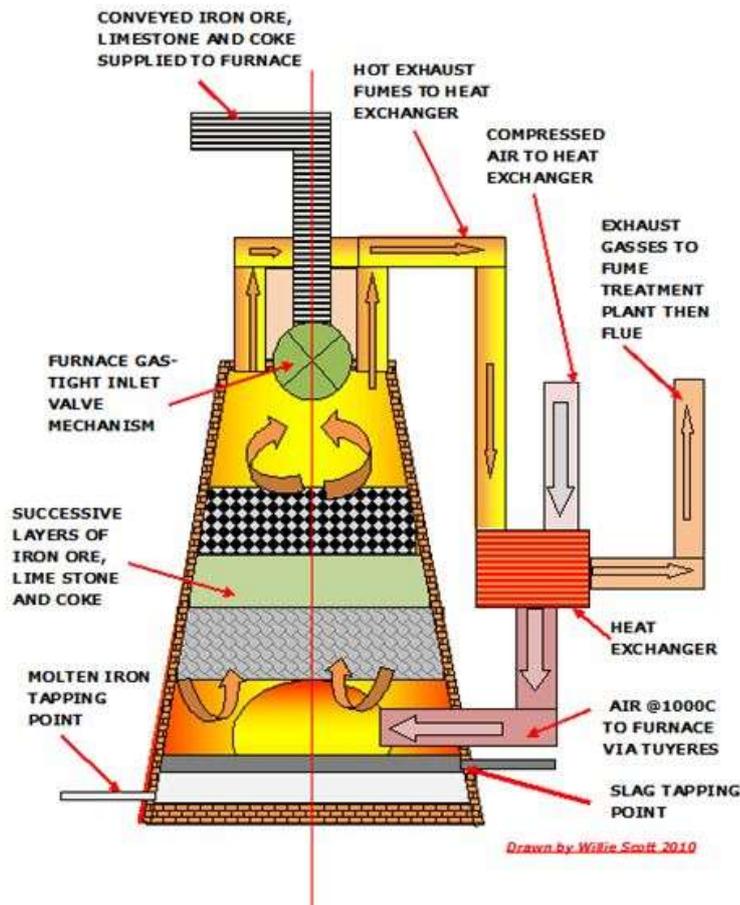
a further possibility of iron smelting and working in West Africa by 1200 BC In addition, very early instances of carbon steel were found to be in production around 2000 years before the present in northwest Tanzania, based on complex preheating principles. These discoveries are significant for the history of metallurgy.

Most early processes in Europe and Africa involved smelting iron ore in a bloomery, where the temperature is kept low enough so that the iron does not melt. This produces a spongy mass of iron called a bloom, which then has to be consolidated with a hammer. The earliest evidence to date for the bloomery smelting of iron is found at Tell Hammeh, Jordan, and dates to 930 BC (C14 dating).

3.4.2 Later iron smelting

Blast furnace

From the medieval period, the process of direct reduction in bloomeries began to be replaced by an indirect process. In this, a blast furnace was used to make pig iron, which then had to undergo a further process to make forgeable bar iron. Processes for the second stage include fining in a finery forge and, from the Industrial Revolution, puddling. However both processes are now obsolete and wrought iron is now hardly made. Instead, mild steel is produced from a Bessemer converter or by other means including smelting reduction processes such as the Corex Process.

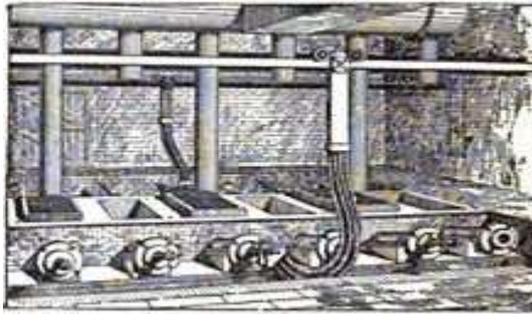


3.5 Base metals

The ores of base metals are often sulfides. In recent centuries, reverberatory furnaces have been used. These keep the fuel and the charge being smelted separate. Traditionally these were used for carrying out the first step: formation of two liquids, one an oxide slag containing most of the impurity elements, and the other a sulfide matte containing the valuable metal sulfide and some impurities. Such "reverberatory" furnaces are today about 40 m long, 3 m high and 10 m wide. Fuel is burned at one end and the heat melts the dry sulfide concentrates (usually after partial roasting), which are fed through the openings in the roof of the furnace. The slag floats on top of the heavier matte, and is removed and discarded or recycled. The sulfide matte is then sent to the converter. The precise details of the process will vary from one furnace to another depending on the mineralogy of the ore body from which the concentrate originates.

While reverberatory furnaces were very good at producing slags containing very little copper, they were relatively energy inefficient and produced a low concentration of sulfur dioxide in their off-gases that made it difficult to capture, and consequently, they have been supplanted by a new generation of copper smelting technologies. More recent furnaces have been designed based upon bath smelting, top jetting lance smelting, flash smelting and blast furnaces. Some examples of bath smelters include the Noranda furnace, the Isasmelt furnace, the Teniente reactor, the Vunyuikov smelter and the SKS technology to name a few. Top

jetting lance smelters include the Mitsubishi smelting reactor. Flash smelters account for over 50% of the world's copper smelters. There are many more varieties of smelting processes, including the Kivset, Ausmelt, Tamano, EAF, and BF.



4.0 Conclusion

Of the seven metals known in antiquity only gold occurred regularly in native form in the natural environment. The others – copper, lead, silver, tin, iron and mercury – occur primarily as minerals, though copper is occasionally found in its native state in commercially significant quantities. These minerals are primarily carbonates, sulfides, or oxides of the metal, mixed with other components such as silica and alumina. Roasting the carbonate and sulfide minerals in air converts them to oxides. The oxides, in turn, are smelted into the metal. Carbon monoxide was (and is) the reducing agent of choice for smelting. It is easily produced during the heating process, and as a gas comes into intimate contact with the ore.

5.0 Summary

In this unit a lot have been discuss on smelting. Smelting is a form of extractive metallurgy; its main use is to produce a metal from its ore. This includes production of silver, iron, copper and other base metals from their ores.

Smelting process involve the roasting, reduction and fluxes.

Some of the metals smelted discussed under this unit are Tin and lead, Copper and bronze and the melting of Iron as well as metal base.

6.0 Tutor Marked Assignment (TMAs)

1. Explain the smelting of Tin and lead
2. Describe the smelting of blast furnace

7.0 References/Further reading

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MODULE 2

UNIT 1: PAINT

TABLE OF CONTENT

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
- 3.1 What is Paint
- 3.2 Raw Materials used in the Production of Paint
- 3.3 Production Process
- 3.4 Diagram of a Paint Mill
- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor Marked Assignment (TMA)
- 7.0 References and Further Reading

1.0 INTRODUCTION

To most people, paint is just the colour on the walls of their homes, the colour of their car, boat or caravan. Also most people often think that paint is made or produced by just mixing one or two and more colours. In this unit we will be able to understand the step by step systematic process involved in the production or manufacture of paint.

2.0 OBJECTIVES

At the end of this course unit, you should be able to:

1. Explain what is meant by paint
2. List the applications of paints
3. Outline the raw materials used in the manufacture of paint
4. Explain the step by step process involved in the manufacture of paint

3.0 MAIN CONTENT

3.1 WHAT IS PAINT?

Paint is a term used to describe a number of substances that consist of a pigment suspended in a liquid or paste vehicle such as oil or water. With a brush, a roller, or a spray gun, paint is applied in a thin coat to various surfaces such as wood, metal, or stone. Although its primary purpose is to protect the surface to which it is applied, paint also provides

1. Decoration
2. Protection
3. Identification
4. Sanitation

3.2 RAW MATERIALS USED IN THE PRODUCTION OF PAINT

Paint typically consists of

1. Pigment
2. Resin
3. Solvent and
4. Additives

Pigment- to Provide Colour, Hiding and Control gloss

Pigments are usually divided into two groups. One called 'Prime Pigments' includes pigments such as Titanium Dioxide (white), Chrome Green Oxide, Yellow and Red Iron Oxides, etc. The other group of pigments is called 'Extender Pigments' and includes Calcite (Calcium Carbonate), Talc (Magnesium Silicate), Mica, Barytes (Barium Sulphate), etc.

Resin- the binder to hold the pigment particles together and provide adhesion to the surface

Waterborne paints most often use acrylic emulsion polymers as binders. These come in a wide variety of types and combinations. Common acrylic polymer types are based on monomers such as methyl methacrylate and butyl methacrylate. Traditionally, lower cost paints have been formulated on PVA (Poly Vinyl Acetate) binders.

Solvent based resins come in a very wide range of types. The most common solvent based resins are termed 'alkyd resins' that are normally used in enamel paints. Urethane alkyds often used in clear varnishes. Protective coating resins include types such as Epoxy, Urethane, Polysiloxane and Moisture Cured Urethane.

Solvent – to act as a carrier for the pigments and resin – the solvent may be organic (such as Mineral Turps) or water.

Additives – to enhance certain properties such as ease of brushing, mould resistance, scuff resistance, drying and sag resistance.

3.3 PRODUCTION PROCESSES

Making the paste

Pigment manufacturers send bags of fine grain pigments to paint plants. There, the pigment is premixed with resin (a wetting agent that assists in moistening the pigment), one or more solvents, and additives to form a paste.

Dispersing the pigment

The paste mixture for most industrial and some consumer paints is now routed into a sand mill, a large cylinder that agitates tiny particles of sand or silica to grind the

pigment particles, making them smaller and dispersing them throughout the mixture. The mixture is then filtered to remove the sand particles.

Instead of being processed in sand mills, up to 90 percent of the water-based latex paints designed for use by individual homeowners are instead processed in a high-speed dispersion tank. There, the premixed paste is subjected to high-speed agitation by a circular, toothed blade attached to a rotating shaft. This process blends the pigment into the solvent.

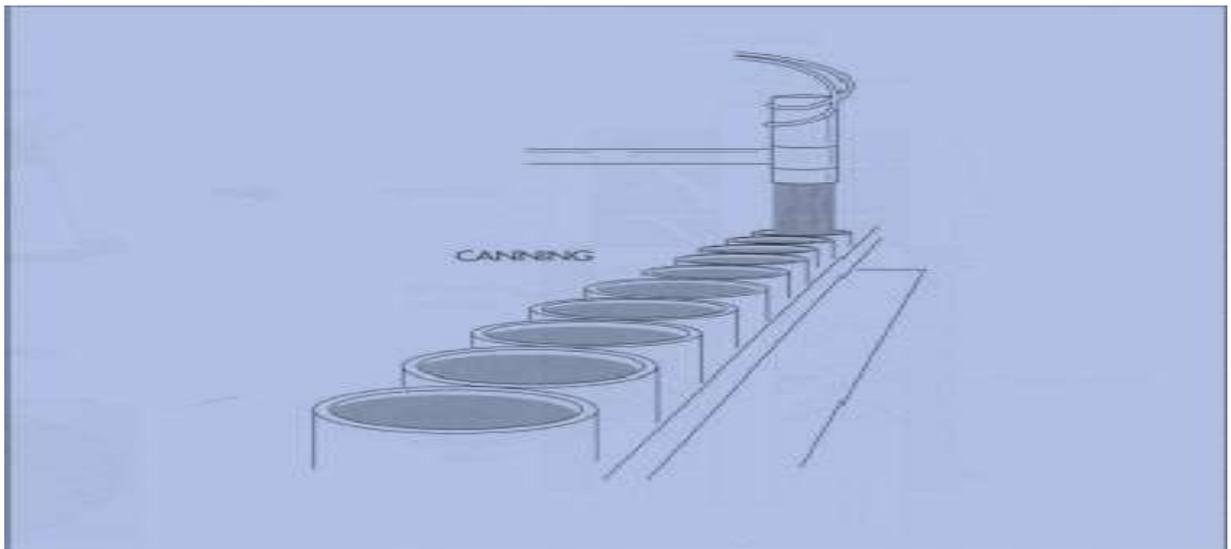
Thinning the paste

Whether created by a sand mill or a dispersion tank, the paste must now be thinned to produce the final product. Transferred to large kettles, it is agitated with the proper amount of solvent for the type of paint desired.

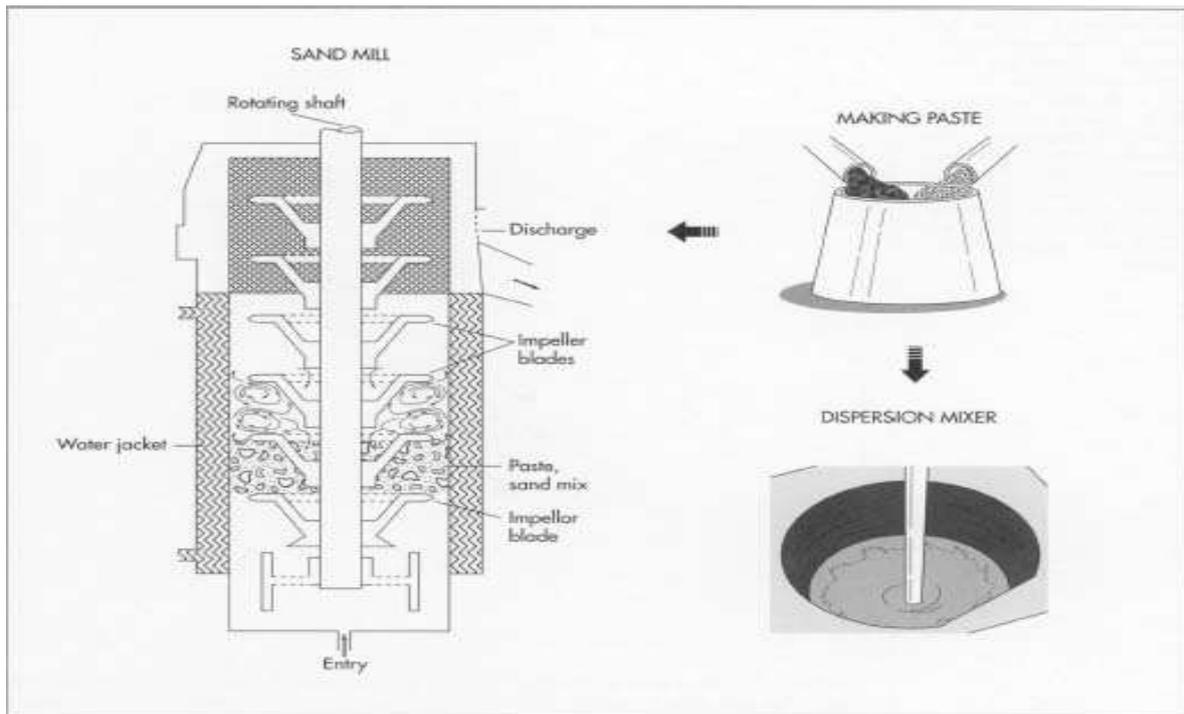
Canning the paint

The finished paint product is then pumped into the canning room. For the standard 8 pint (3.78 liter) paint can available to consumers, empty cans are first rolled horizontally onto labels, then set upright so that the paint can be pumped into them. A machine places lids onto the filled cans, and a second machine presses on the lids to seal them. From wire

that is fed into it from coils, a bailometer cuts and shapes the handles before hooking them into holes precut in the cans. A certain number of cans (usually four) are then boxed and stacked before being sent to the warehouse.



3.4 Diagram of a paint mill



4.0 CONCLUSION

Paint is a chemical substance that consists of a pigment suspended in a liquid or paste vehicle such as oil or water. Its primary purpose is to protect the surface to which it is applied, paint, however, it also provides decoration, protection, identification, sanitation to objects.

5.0 SUMMARY

In this unit you have learnt that

1. Paint is a term used to describe a number of substances that consist of a pigment suspended in a liquid or paste vehicle such as oil or water.
2. The primary purpose is to protect the surface to which it is applied; paint also provides Decoration, Protection, and Identification Sanitation.
3. Paint typically consists of Pigment, Resin, Solvent, and Additives.
4. The process involved in the production of paint includes: making the paste, dispersing the pigment, thinning the paste and canning the paint.

6.0 TEACHER MARKED ASSIGNMENT

1. Explain five uses of cement.
2. What are the raw materials necessary for the production of cement?
3. Describe the processes involved in the production of cement.

7.0 REFERENCES/FURTHER READING

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UNIT 2: TEXTILES

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- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main content
- 3.1 Uses
- 3.2 Sources and Types
- 3.3 Production methods
- 3.4 Treatment
- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor Marked Assignment (TMAs)
- 7.0 References/Further reading

1.0 INTRODUCTION

A textile or cloth is a flexible woven material consisting of a network of natural or artificial fibres often referred to as thread or yarn. Yarn is produced by spinning raw fibres of wool, flax, cotton, or other material to produce long strands. Textiles are formed by weaving, knitting, crocheting, knotting, or pressing fibres together (felt).

The words **fabric** and **cloth** are used in textile assembly trades (such as tailoring and dressmaking) as synonyms for textile. However, there are subtle differences in these terms in specialized usage. Textile refers to any material made of interlacing fibres. Fabric refers to any material made through weaving, knitting, spreading, crocheting, or bonding that may be used in production of further goods (garments, etc.). Cloth may be used synonymously with fabric but often refers to a finished piece of fabric used for a specific purpose (e.g., table cloth).

2.0 OBJECTIVES

It is expected that upon going through this unit you should be able to:

1. Explain the concept of textile.
2. Describe some uses of textile.
3. List and explain the types of textile.
4. Discuss briefly the method of textile manufacturing
5. Describe the treatment of textile.

3.0 MAIN CONTENT

The word 'textile' is from Latin, from the adjective *textilis*, meaning 'woven', from *textus*, the past participle of the verb *texere*, 'to weave'.

The word 'fabric' also derives from Latin, most recently from the Middle French *fabrique*, or 'building, thing made', and earlier as the Latin *fabrica* 'workshop; an art, trade; a skillful production, structure, fabric', which is from the Latin *Faber*, or 'artisan who works in hard materials', from PIE *dhabh-*, meaning 'to fit together'.

The word 'cloth' derives from the Old English *clað*, meaning a cloth, woven or felted material to wrap around one, from Proto-Germanic *kalithaz* (compare O.Frisian 'klath', Middle Dutch 'cleet', Dutch 'kleet', Middle High German 'kleit', and German 'kleid', all meaning "garment"). There are several different types of fabric from two main sources: manmade and natural. Inside natural, there are two others, plant and animal. Some examples of animal textiles are silk and wool. An example of a plant textile is cotton.

3.1 USES

Textiles have an assortment of uses, the most common of which are for clothing and for containers such as bags and baskets. In the household they are used in carpeting, upholstered furnishings, window shades, towels, coverings for tables, beds, and other flat surfaces, and in art. In the workplace they are used in industrial and scientific processes such as filtering. Miscellaneous uses include flags, backpacks, tents, nets, handkerchiefs, cleaning rags, transportation devices such as balloons, kites, sails, and parachutes; textiles are also used to provide strengthening in composite materials such as fibre glass and industrial geotextiles. Using textiles, children can learn to sew and quilt and to make collages and toys.

Textiles used for industrial purposes, and chosen for characteristics other than their appearance, are commonly referred to as technical textiles. Technical textiles include textile structures for automotive applications, medical textiles (e.g. implants), geotextiles (reinforcement of embankments), agro textiles (textiles for crop protection), protective clothing (e.g. against heat and radiation for fire fighter clothing, against molten metal's for welders, stab protection, and bullet proof vests). In all these applications stringent performance requirements must be met. Woven of threads coated with zinc oxide nanowires, laboratory fabric has been shown capable of "self-powering nanosystems" using vibrations created by everyday actions like wind or body movements.

3.2 SOURCES AND TYPES

Textiles can be made from many materials. These materials come from four main sources: animal (wool, silk), plant (cotton, flax, jute), mineral (asbestos, glass fibre), and synthetic (nylon, polyester, acrylic). In the past, all textiles were made from natural fibres, including plant, animal, and mineral sources. In the 20th century, these were supplemented by artificial fibres made from petroleum.

Textiles are made in various strengths and degrees of durability, from the finest gossamer to the sturdiest canvas. The relative thickness of fibres in cloth is measured in deniers. Microfibre refers to fibres made of strands thinner than one denier.

Animal textiles

Animal textiles are commonly made from hair, fur, skin or silk (in the silkworms case).

Wool refers to the hair of the domestic goat or sheep, which is distinguished from other types of animal hair in that the individual strands are coated with scales and tightly crimped, and the wool as a whole is coated with a wax mixture known as lanolin (sometimes called wool grease), which is waterproof and dirt proof. Woollen refers to a bulkier yarn produced from carded, non-parallel fibre, while worsted refers to a finer yarn spun from longer fibres which have been combed to be parallel. Wool is commonly used for warm clothing. Cashmere, the hair of the Indian Cashmere goat, and mohair, the hair of the North African Angora goat, are types of wool known for their softness.

Other animal textiles which are made from hair or fur are alpaca wool, vicuña wool, llama wool, and camel hair, generally used in the production of coats, jackets, ponchos, blankets, and other warm coverings. Angora refers to the long, thick, soft hair of the Angora rabbit. Qiviut is the fine inner wool of the muskox.

Wadmal is a coarse cloth made of wool, produced in Scandinavia, mostly 1000~1500 CE.

Silk is an animal textile made from the fibres of the cocoon of the Chinese silkworm which is spun into a smooth fabric prized for its softness. There are two main types of the silk: 'mulberry silk' produced by the *Bombyx Mori*, and 'wild silk' such as Tussah silk. Silkworm larvae produce the first type if cultivated in habitats with fresh mulberry leaves for consumption, while Tussah silk is produced by silkworms feeding purely on oak leaves. Around four-fifths of the world's silk production consists of cultivated silk.

Plant textiles

Grass, rush, hemp, and sisal are all used in making rope. In the first two, the entire plant is used for this purpose, while in the last two, only fibres from the plant are utilized. Coir (coconut fibre) is used in making twine, and also in floor mats, doormats, brushes, mattresses, floor tiles, and sacking.



Traditional textile making tools from 14th century Persia

Straw and bamboo are both used to make hats. Straw, a dried form of grass, is also used for stuffing, as is kapok.

Fibres from pulpwood trees, cotton, rice, hemp, and nettle are used in making paper.

Cotton, flax, jute, hemp, modal and even bamboo fibre are all used in clothing. Piña (pineapple fibre) and ramie are also fibres used in clothing, generally with a blend of other fibres such as cotton. Nettles have also been used to make a fibre and fabric very similar to hemp or flax. The use of milkweed stalk fibre has also been reported, but it tends to be somewhat weaker than other fibres like hemp or flax.

Acetate is used to increase the shininess of certain fabrics such as silks, velvets, and taffetas.

Seaweed is used in the production of textiles: a water-soluble fibre known as alginate is produced and is used as a holding fibre; when the cloth is finished, the alginate is dissolved, leaving an open area.

Lyocell is a man-made fabric derived from wood pulp. It is often described as a man-made silk equivalent; it is a tough fabric that is often blended with other fabrics – cotton, for example.

Fibres from the stalks of plants, such as hemp, flax, and nettles, are also known as 'bast' fibres.

Mineral textiles

Asbestos and basalt fibre are used for vinyl tiles, sheeting, and adhesives, "transit" panels and siding, acoustical ceilings, stage curtains, and fire blankets.

Glass fibre is used in the production of spacesuits, ironing board and mattress covers, ropes and cables, reinforcement fibre for composite materials, insect netting, flame-retardant and protective fabric, soundproof, fireproof, and insulating fibres.

Metal fibre, metal foil, and metal wire have a variety of uses, including the production of cloth-of-gold and jewellery. Hardware cloth (US term only) is a coarse woven mesh of steel wire, used in construction. It is much like standard window screening, but heavier and with a more open weave. It is sometimes used together with screening on the lower part of screen doors, to resist scratching by dogs. It serves similar purposes as chicken wire, such as fences for poultry and traps for animal control.

Synthetic textiles



A variety of contemporary fabrics. From the left: even weave cotton, velvet, printed cotton, calico, felt, satin, silk, hessian, polycotton.



Woven tartan of Clan Campbell, Scotland.



Embroidered skirts by the Alfaro-Nunez family of Cochas, Peru, using traditional Peruvian embroidery methods.

All synthetic textiles are used primarily in the production of clothing.

Polyester fibre is used in all types of clothing, either alone or blended with fibres such as cotton.

Aramid fibre (e.g. Twaron) is used for flame-retardant clothing, cut-protection, and armor.

Acrylic is a fibre used to imitate wools, including cashmere, and is often used in replacement of them.

Nylon is a fibre used to imitate silk; it is used in the production of pantyhose. Thicker nylon fibres are used in rope and outdoor clothing.

Spandex (trade name Lycra) is a polyurethane product that can be made tight-fitting without impeding movement. It is used to make active wear, bras, and swimsuits.

Olefin fibre is a fibre used in active wear, linings, and warm clothing. Olefins are hydrophobic, allowing them to dry quickly. A sintered felt of olefin fibres is sold under the trade name Tyvek.

Ingeo is a polylactide fibre blended with other fibres such as cotton and used in clothing. It is more hydrophilic than most other synthetics, allowing it to wick away perspiration.

Lurex is a metallic fibre used in clothing embellishment.

Milk proteins have also been used to create synthetic fabric. Milk or casein fibre cloth was developed during World War I in Germany, and further developed in Italy and America during the 1930s. Milk fibre fabric is not very durable and wrinkles easily, but has a pH similar to human skin and possesses anti-bacterial properties. It is marketed as a biodegradable, renewable synthetic fibre.

Carbon fibre is mostly used in composite materials, together with resin, such as carbon fibre reinforced plastic. The fibres are made from polymer fibres through carbonization.

3.3 PRODUCTION METHODS

Weaving is a textile production method which involves interlacing a set of longer threads (called the warp) with a set of crossing threads (called the weft). This is done on a frame or machine known as a loom, of which there are a number of types. Some weaving is still done by hand, but the vast majority is mechanized.

Knitting and crocheting involve interlacing loops of yarn, which are formed either on a knitting needle or on a crochet hook, together in a line. The two processes are different in that knitting has several active loops at one time, on the knitting needle waiting to interlock with another loop, while crocheting never has more than one active loop on the needle.

Spread Tow is a production method where the yarns are spread into thin tapes, and then the tapes are woven as warp and weft. This method is mostly used for composite materials; Spread Tow Fabrics can be made in carbon, aramide, etc.

Braiding or plaiting involves twisting threads together into cloth. Knotting involves tying threads together and is used in making macrame.

Lace is made by interlocking threads together independently, using a backing and any of the methods described above, to create a fine fabric with open holes in the work. Lace can be made by either hand or machine.

Carpets, rugs, velvet, velour, and velveteen are made by interlacing a secondary yarn through woven cloth, creating a tufted layer known as a nap or pile.

Felting involves pressing a mat of fibres together, and working them together until they become tangled. A liquid, such as soapy water, is usually added to lubricate the fibres, and to open up the microscopic scales on strands of wool.

Nonwoven textiles are manufactured by the bonding of fibres to make fabric. Bonding may be thermal or mechanical, or adhesives can be used.

Bark cloth is made by pounding bark until it is soft and flat.

3.4 TREATMENTS

Textiles are often dyed, with fabrics available in almost every colour. The dyeing process often requires several dozen gallons of water for each pound of clothing. Coloured designs in textiles can be created by weaving together fibres of different colours (tartan or Uzbek Ikat), adding coloured stitches to finished fabric (embroidery), creating patterns by resist dyeing methods, tying off areas of cloth and dyeing the rest (tie-dyeing), or drawing wax designs on cloth and dyeing in between them (batik), or using various printing processes on finished fabric. Woodblock printing, still used in India and elsewhere today, is the oldest of these dating back to at least 220 CE in China. Textiles are also sometimes bleached, making the textile pale or white.



Brilliantly dyed traditional woven textiles of Guatemala, and woman weaving on a back strap loom.

Textiles are sometimes finished by chemical processes to change their characteristics. In the 19th century and early 20th century starching was commonly used to make clothing more resistant to stains and wrinkles. Since the 1990s, with advances in technologies such as permanent press process, finishing agents have been used to strengthen fabrics and make them wrinkle free. More recently, nanomaterials research has led to additional advancements, with companies such as Nano-Text and NanoHorizons developing

permanent treatments based on metallic nanoparticles for making textiles more resistant to things such as water, stains, wrinkles, and pathogens such as bacteria and fungi.

More so today than ever before, textiles receive a range of treatments before they reach the end-user. From formaldehyde finishes (to improve crease-resistance) to biocidal finishes and from flame retardants to dyeing of many types of fabric, the possibilities are almost endless. However, many of these finishes may also have detrimental effects on the end user. A number of disperse, acid and reactive dyes (for example) have been shown to be allergenic to sensitive individuals. Further to this, specific dyes within this group have also been shown to induce purpuric contact dermatitis.

Although formaldehyde levels in clothing are unlikely to be at levels high enough to cause an allergic reaction, due to the presence of such a chemical, quality control and testing are of utmost importance. Flame retardants (mainly in the brominated form) are also of concern where the environments, and their potential toxicity, are concerned. Testing for these additives is possible at a number of commercial laboratories; it is also possible to have textiles tested for according to the Oeko-tex certification standard which contains limits levels for the use of certain chemicals in textiles products.

4.0 CONCLUSION

A textile or cloth is a flexible woven material consisting of a network of natural or artificial fibres often referred to as thread or yarn. Yarn is produced by spinning raw fibres of wool, flax, cotton, or other material to produce long strands. Textiles are formed by weaving, knitting, crocheting, knotting, or pressing fibres together (felt).

The words fabric and cloth are used in textile assembly trades (such as tailoring and dressmaking) as synonyms for textile. However, there are subtle differences in these terms in specialized usage. Textile refers to any material made of interlacing fibres. Fabric refers to any material made through weaving, knitting, spreading, crocheting, or bonding that may be used in production of further goods (garments, etc.). Cloth may be used synonymously with fabric but often refers to a finished piece of fabric used for a specific purpose (e.g., table cloth).

5.0 SUMMARY

In this unit we are able to deal with a lot on textile as: A textile or cloth is a flexible woven material consisting of a network of natural or artificial fibres often referred to as thread or yarn.

Textiles have an assortment of uses, the most common of which are for clothing and for containers such as bags and baskets. In the household they are used in carpeting, upholstered furnishings, window shades, towels, coverings for tables, beds, and other flat surfaces, and in art.

The main sources of textile are animal (wool, silk), plant (cotton, flax, jute), mineral (asbestos, glass fibre), and synthetic (nylon, polyester, acrylic).

Weaving is a textile production method which involves interlacing a set of longer threads (called the warp) with a set of crossing threads (called the weft). This is done on a frame or machine known as a loom, of which there are a number of types. Some weaving is still done by hand, but the vast majority is mechanized.

Treatment of textiles is often dyed, with fabrics available in almost every colour. The dyeing process often requires several dozen gallons of water for each pound of clothing.

6.0 TUTOR MARKED ASSIGNMENT

1. Discuss briefly the method of textile manufacturing
2. Describe the treatment of textile.

7.0 REFERENCES/FURTHER READING

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UNIT 3: PETROLEUM

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 - 3.2 Processing Units Used in Refineries
 - 3.3 Auxiliary Facilities Required in Refineries
 - 3.4 Schematic Flow Diagram of a Typical Petroleum Refinery
 - 3.5 Refining End Products
- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor Marked Assignment (TMA)
- 7.0 References and Further Reading

INTRODUCTION

Prior to the nineteenth century, petroleum was known and utilized in various fashions in Babylon, Egypt, China, Persia, Rome and Azerbaijan. However, the modern history of the petroleum industry is said to have begun in 1846 when Abraham Gessner of Nova Scotia, Canada discovered how to produce kerosene from coal. Shortly thereafter, in 1854, Ignacy Lukasiewicz began producing kerosene from hand-dug oil wells near the town of Krosno, now in Poland. The first large petroleum refinery was built in Ploesti, Romania in 1856 using the abundant oil available in Romania.^{[4][5]}

In North America, the first oil well was drilled in 1858 by James Miller Williams in Ontario, Canada. In the United States, the petroleum industry began in 1859 when Edwin Drake found oil near Titusville, Pennsylvania.^[6] The industry grew slowly in the 1800s, primarily producing kerosene for oil lamps. In the early twentieth century, the introduction of the internal combustion engine and its use in automobiles created a market for gasoline that was the impetus for fairly rapid growth of the petroleum industry. The early finds of petroleum like those in Ontario and Pennsylvania were soon outstripped by large oil "booms" in Oklahoma, Texas and California.

To understand how refineries use energy and what the possibilities are for more efficient use of such energy, it is useful to review the principal processes in the refining of petroleum of a modern refinery.

2.0 OBJECTIVES

At the end of this course unit, you should be able to:

1. Explain petroleum refining process
2. List some end products gotten after the refining of petroleum
3. Explain the step by step process involved in the production of petroleum

3.0 MAIN CONTENT

3.1 PETROLEUM REFINING PROCESS

Petroleum refining processes are the chemical engineering processes and other facilities used in petroleum refineries (also referred to as oil refineries) to transform crude oil into useful products such as liquefied petroleum gas (LPG), gasoline or petrol, kerosene, jet fuel, diesel oil and fuel oils.

Petroleum refineries are very large industrial complexes that involve many different processing units and auxiliary facilities such as utility units and storage tanks. Each refinery has its own unique arrangement and combination of refining processes largely determined by the refinery location, desired products and economic considerations. There are most probably no two refineries that are identical in every respect.

Some modern petroleum refineries process as much as 800,000 to 900,000 barrels (127,000 to 143,000 cubic meters) per day of crude oil.

3.2 PROCESSING UNITS USED IN REFINERIES

To understand how refineries use energy and what the possibilities are for more efficient use of such energy, it is useful to review the principal processes of a modern refinery.

The processes include

1. Crude Oil distillation Unit/Atmospheric Distillation
2. Vacuum Distillation
3. Fluid Catalytic Cracking
4. Catalytic Reforming
5. Alkylation
6. Hydrocracking
7. Hydrotreating
8. Residuum Desulfurizing
9. Cooking

Crude Oil Distillation Unit/Atmospheric Distillation

The crude oil distillation unit (CDU) is the first processing unit in virtually all petroleum refineries. The CDU distills the incoming crude oil into various fractions of different boiling ranges, each of which are then processed further in the other refinery processing units. The CDU is often referred to as the *atmospheric distillation unit* because it operates at slightly above atmospheric pressure.

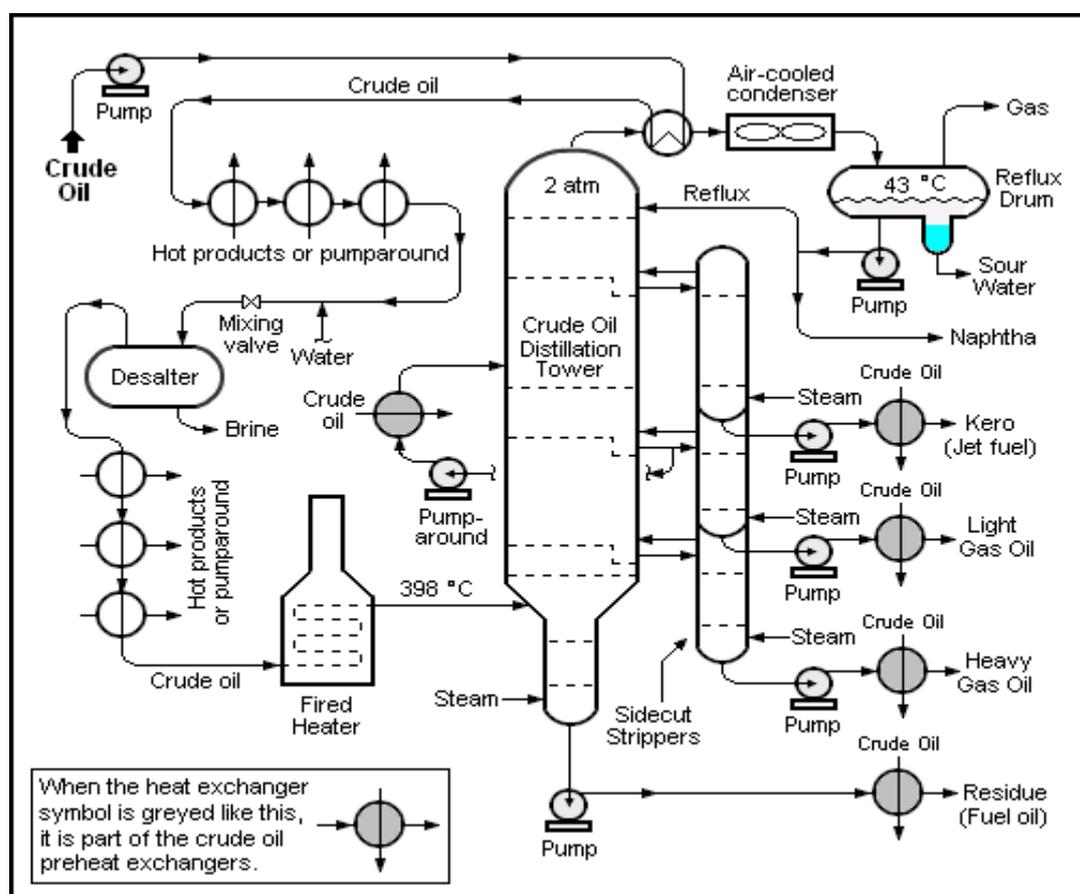
Below is a schematic flow diagram of a typical crude oil distillation unit. The incoming crude oil is preheated by exchanging heat with some of the hot, distilled fractions and other streams. It is then desalted to remove inorganic salts (primarily sodium chloride).

Following the desalter, the crude oil is further heated by exchanging heat with some of the hot, distilled fractions and other streams. It is then heated in a fuel-fired furnace (fired

heater) to a temperature of about 398 °C and routed into the bottom of the distillation unit.

The cooling and condensing of the distillation tower overhead is provided partially by exchanging heat with the incoming crude oil and partially by either an air-cooled or water-cooled condenser. Additional heat is removed from the distillation column by a pumparound system as shown in the diagram below.

As shown in the flow diagram, the overhead distillate fraction from the distillation column is naphtha. The fractions removed from the side of the distillation column at various points between the column top and bottoms are called *sidecuts*. Each of the sidecuts (i.e., the kerosene, light gas oil and heavy gas oil) is cooled by exchanging heat with the incoming crude oil. All of the fractions (i.e., the overhead naphtha, the sidecuts and the bottom residue) are sent to intermediate storage tanks before being processed further.



Schematic flow diagram of a typical crude oil distillation unit as used in petroleum crude oil refineries.

Vacuum Distillation

Some crude oil components are too heat-sensitive or have boiling points that are too high to be distilled at atmospheric pressure. In such cases the so-called “topped crude” (material from the bottom of the atmospheric column) must be further distilled in a column operating under a vacuum. This operation lowers the boiling point of the material

and thereby allows distillation of the heavier fractions without excessive thermal decomposition.

Fluid Catalytic Cracking

Through fluid catalytic cracking, crude petroleum whose lighter fractions were removed by atmospheric or vacuum distillation is entrained in a hot, moving catalyst and chemically converted to lighter materials. The catalyst is then separated and regenerated, while the reaction products are fractionated into their various components by distillation. This is one of the most widely used refinery conversion techniques.

Catalytic Reforming

Reforming is a catalytic process that takes low octane materials and raises the octane number to approximately 100. Although several chemical reactions take place, the predominant reaction is the removal of hydrogen from naphthenes (hydrogen-saturated, ring-like compounds) and the conversion of naphthenes to aromatics (benzenoid compounds). In addition to markedly increasing the octane number, the process produces hydrogen that can be used in other refinery operations.

Alkylation

In the alkylation process, isobutane, a low molecular-weight gas is chemically added to the

Carbon-to-carbon double bonds that occur in certain hydrocarbons. The resulting product, now containing many isobutyl side groups, has a much higher octane number compared to the original straight-chained substance, and is therefore a better motor fuel. Branched-chain hydrocarbons, such as those with isobutyl side groups, are able to have their octane rating increased even further with lead additives, but with the increasing consumer need for unleaded gasoline, this type of alkylation will be less and less used.

Hydrocracking

Hydrocracking is a catalytic, high-pressure process that converts a wide range of hydrocarbons to lighter, cleaner, and more valuable products. By catalytically adding hydrogen under very high pressure, the process increases the ratio of hydrogen to carbon in the feed and produces low-boiling material. Hydrocracking is especially adapted to the processing of low-value stocks that are not suitable for catalytic cracking or reforming because of their high content of trace metals, nitrogen, or sulfur, such feedstocks are used to produce gasoline, kerosene, middle-distillate fuels, and feedstocks for other refining and petrochemical processes.

Hydrotreating

A number of hydrotreating processes use the catalytic addition of hydrogen to remove sulfur compounds from naphthas and distillates (light and heavy gas oils). Removal of sulfur is essential for protecting the catalyst in subsequent processes (such as catalytic reforming) and for meeting product specifications on certain “mid-barrel” distillate fuels. Hydrotreating is the most widely used treating process in today’s refineries. In addition to removing sulfur, it can eliminate other undesirable impurities (e.g., nitrogen and oxygen),

decolonize and stabilize products, correct odor problems, and improve many other deficiencies. Fuel products so treated range from naphthas to heavy burner fuels.

Residuum Desulfurizing

With the increasing need to use the heavier, higher boiling components of crude oils (the “bottom of the barrel”), a number of processes are being offered for the desulfurization of residuum, the material remaining after atmospheric and vacuum column distillation. These processes operate at pressures and temperatures between low-severity hydrotreating and the much more severe hydrocracking previously described. Depending on the market, the desulfurized “resid” can be used as a blending component of low-sulfur fuel oils or as a feedstock to a coke producing unit (if a low-sulfur coke is to be made).

Coking

In the past, the residual bottoms from the crude unit have been blended with lighter oils and marketed as fuel oils of low-quality and often high sulfur content. These residues do, however, contain lighter fractions (naphthas and gas oils) that can be recovered if the residual oil is “coked” at high temperatures. It is becoming economically worthwhile to recover these remaining light ends for further processing. Petroleum coke is used principally as a fuel. Coke derived from untreated residues may have a high sulfur content and hence be of limited commercial value.

3.3 AUXILIARY FACILITIES REQUIRED IN REFINERIES

Steam reformer unit: Converts natural gas into hydrogen for the hydrotreaters and/or the hydrocracker.

Sour water stripper unit: Uses steam to remove hydrogen sulfide gas from various wastewater streams for subsequent conversion into end-product sulfur in the Claus unit.

Utility units such as cooling towers for furnishing circulating cooling water, steam generators, instrument air systems for pneumatically operated control valves and an electrical substation.

Wastewater collection and treating systems consisting of API separators, dissolved air flotation (DAF) units and some type of further treatment (such as an activated sludge biotreater) to make the wastewaters suitable for reuse or for disposal.

Liquified gas (LPG) storage vessels for propane and similar gaseous fuels at a pressure sufficient to maintain them in liquid form. These are usually spherical vessels or *bullets* (horizontal vessels with rounded ends).

Storage tanks for crude oil and finished products, usually vertical, cylindrical vessels with some sort of vapour emission control and surrounded by an earthen berm to contain liquid spills.

3.5 REFINING END PRODUCT

The primary end-products produced in petroleum refining may be grouped into four categories: light distillates, middle distillates, heavy distillates and others.

Light distillates

Liquid petroleum gas (LPG)
Gasoline (also known as petrol)
Heavy Naphtha
Light Naphtha

Middle distillates

Kerosene
Automotive and rail-road diesel fuels
Residential heating fuel
Other light fuel oils

Heavy distillates

Heavy fuel oils
Bunker fuel oil and other residual fuel oils

4.0 CONCLUSION

Petroleum is the main source of hydrocarbons, but could be obtained from coal and natural gases. Petroleum refining processes are the chemical engineering processes and other facilities used in petroleum refineries (also referred to as oil refineries) to transform crude oil into useful products such as liquefied petroleum gas (LPG), gasoline or petrol, kerosene, jet fuel, diesel oil and fuel oils

5.0 SUMMARY

In this unit you have learnt that

1. Petroleum refining processes are the chemical engineering processes and other facilities used in petroleum refineries.
2. The process involved in the production of petroleum includes: Atmospheric Distillation, Vacuum Distillation, fluid catalytic cracking, catalytic reforming, alkylation, hydrocracking, hydrotreating, residuum desulphuring and coking.
3. End Products derived from the refining of Petroleum include: Liquid petroleum gas (LPG), Gasoline (also known as petrol), Heavy Naphtha, Light Naphtha, Kerosene, Automotive and rail-road diesel fuels, Residential heating fuel, Other light fuel oils, Heavy fuel oils, Bunker fuel oil and other residual fuel oils

6.0 TEACHER MARKED ASSIGNMENT

1. Explain petroleum refining process.
2. List some end products gotten after the refining of petroleum.

3. Explain the step by step process involved in the production of petroleum.

7.0 REFERENCES/ FURTHER READING

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UNIT 4: CEMENT

TABLE OF CONTENT

- 1.0 Introduction
- 2.0 Objectives
- 3.0 How to Study the Unit
- 4.0 Main Content
 - 4.1 Definition and Historical Background
 - 4.2 Raw Materials Used in the Production of Cement
 - 4.3 Production Process/Basic components of cement
 - 4.4 Flow Chart of Manufacturing Process
 - 4.5 Chemistry of Cement
 - 4.6 Uses of Cement
 - 4.7 Environmental and Safety risk involved in Cement Production
 - 4.8 Safety Measures to be taken by Cement Companies
 - 4.9 Cement Companies in Nigeria
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- 5.0 Conclusion
- 6.0 Summary
- 7.0 Tutor Marked Assignment (TMA)
- 8.0 References and Further Reading

1.0 INTRODUCTION

Cement is seen as a powder when mixes with water is used to smooth a surface of the wall. Here we to look in the Cement as it is produce, the raw materials needed and processes in the manufacture of the cement.

2.0 OBJECTIVES

After studying this unit, you should be able to:

1. Explain the concept cement
2. Outline the raw materials for the production of cement
3. Explain the process involved in the manufacture of cement
4. Write some chemical equation depicting reactions during cement production;
5. List the types of cement
6. Mention the use of cement
7. Mention some cement companies in Nigeria

3.0 HOW TO STUDY THIS UNIT

1. Look at samples of cement available in cement shops around you.
2. Go through the unit step by step
3. Visit a cement plant, interact with the workers and ask questions.
4. Go back and read the unit again
5. Carry out all the activities and assignment given to you

NOTE: ALL ANSWERS ARE AT THE END OF THIS BOOK

4.0 MAIN CONTENT

4.1 DEFINITION AND HISTORICAL BACKGROUND

The term **cement** is commonly used to refer to powdered materials which develop strong adhesive qualities when combined with water. These materials are more properly known as hydraulic cements. Gypsum plaster, common lime, hydraulic limes, natural pozzolana, and Portland cements are the more common hydraulic cements, with Portland cement being the most important in construction.

Cement was first invented by the Egyptians. Cement was later reinvented by the Greeks and the Babylonians who made their mortar out of lime. Later, the Romans produced cement from pozzolana, an ash found in all of the volcanic areas of Italy, by mixing the ash with lime.

Cement is a fine grayish powder which, when mixed with water, forms a thick paste. When this paste is mixed with sand and gravel and allowed to dry it is called **concrete**.

About ninety-nine percent of all cement used today is Portland cement. The name Portland cement is not a brand name. This name was given to the cement by Joseph Aspdin of Leeds, England who obtained a patent for his product in 1824. The concrete made from the cement resembled the color of the natural limestone quarried on the Isle of Portland in the English Channel. The balance of cement used today consists of masonry cement, which is fifty percent Portland cement and fifty percent ground lime rock. The first cement manufactured in the United States was produced in 1871 by David Saylor of Coplay, Pennsylvania.

Activity 1

Visit a cement shop. Request to touch the cement they sell in plates. How does it feel?

4.2 RAW MATERIALS USED IN THE PRODUCTION OF CEMENT

There are two types of raw materials which are combined to make cement:

1. Lime-containing materials, such as limestone, marble, oyster shells, marl, chalk, etc.
2. Clay and clay-like materials, such as shale, slag from blast furnaces, bauxite, iron ore, silica, sand, etc.

It takes approximately 3,400 lbs. of raw materials to make one ton (2,000 lbs.) of Portland cement. The mixture of materials is finely ground in a raw mill. The resultant raw mix is burned in a rotary kiln at temperatures around 4482 degrees Celsius to form clinker. The clinker nodules are then ground with about 3 % gypsum to produce cement with a fineness typically of less than 90 micrometers.

4.3 PRODUCTION PROCESSES

The production of cement takes place with several steps:

1. Quarrying of limestone and shale
2. Dredging the ocean floor for shells
3. Digging for clay and marl
4. Grinding
5. Blending of components
6. Fine grinding

7. Burning
8. Finish grinding
9. Packaging and/or shipping

Quarrying, Dredging, and Digging

Quarrying of limestone and shale is accomplished by using explosives to blast the rocks from the ground. After blasting, huge power shovels are used to load dump trucks or small railroad cars for transportation to the cement plant, which is usually nearby. The ocean floor is dredged to obtain the shells, while clay and marl are dug out of the ground with power shovels. All of the raw materials are transported to the plant.

Grinding

After the raw materials have been transported to the plant, the limestone and shale which have been blasted out of the quarry must be crushed into smaller pieces. Some of the pieces, when blasted out, are quite large. The pieces are then dumped into primary crushers which reduce them to the size of a softball. The pieces are carried by conveyors to secondary crushers which crush the rocks into fragments usually no larger than 3/4 inch across.

Blending

After the rock is crushed, plant chemists analyze the rock and raw materials to determine their mineral content. The chemists also determine the proportions of each raw material to utilize in order to obtain a uniform cement product. The various raw materials are then mixed in proper proportions and prepared for fine grinding.

Fine Grinding

When the raw materials have been blended, they must be ground into a fine powder. This may be done by one of two methods:

1. Wet process, or
2. Dry process

The wet process of fine grinding is the older process, having been used in Europe prior to the manufacture of cement in the United States. This process is used more often when clay and marl, which are very moist, are included in the composition of the cement. In the wet process, the blended raw materials are moved into ball or tube mills which are cylindrical rotating drums which contain steel balls. These steel balls grind the raw materials into smaller fragments of up to 200 of an inch. As the grinding is done, water is added until a slurry (thin mud) forms, and the slurry is stored in open tanks where additional mixing is done. Some of the water may be removed from the slurry before it is burned, or the slurry may be sent to the kiln as it is and the water evaporated during the burning.

The dry process of fine grinding is accomplished with a similar set of ball or tube mills; however, water is not added during the grinding. The dry materials are stored in silos where additional mixing and blending may be done.

Burning

Burning the blended materials is the key in the process of making cement. The wet or dry mix is fed into the kiln, which is one of the largest pieces of moving machinery in the industry. It is generally twelve feet or more in diameter and 500 feet or more in length, made of steel and lined with firebrick. It revolves on large roller bearings and is gradually slanted with the intake end higher than the output end.

As the kiln revolves, the materials roll and slide downward for approximately four hours. In the burning zone, where the heat can reach 3,000 degrees Fahrenheit, the materials become incandescent and change in color from purple to violet to orange. Here, the gases are driven from the raw materials, which actually change the properties of the raw materials. What emerges is **“clinker”** (Four basic oxides in the correct proportions make cement clinker: calcium oxide (65%), silicon oxide (20%), alumina oxide (10%) and iron oxide (5%). These elements mixed homogeneously (called “raw meal” or slurry)) which is round, marble-sized, glass-hard balls which are harder than the quarried rock. The clinker is then fed into a cooler where it is cooled for storage.

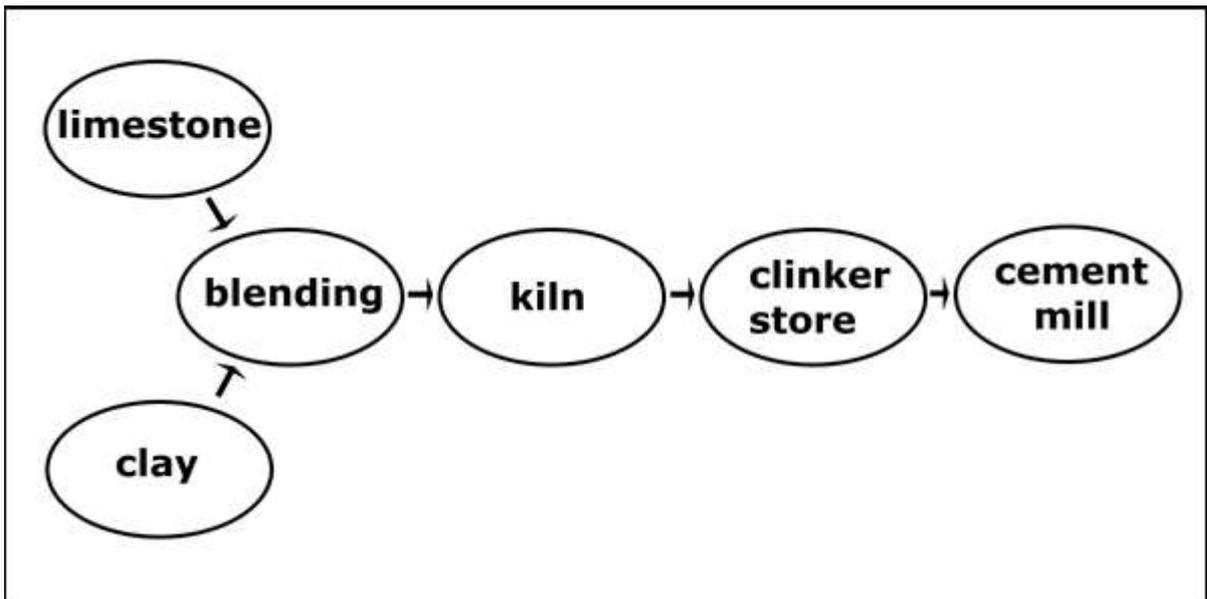
Finish Grinding

The cooled clinker is mixed with a small amount of gypsum, which will help regulate the setting time when the cement is mixed with other materials and becomes concrete. Here again there are primary and secondary grinders. The primary grinders leave the clinker, ground to the fineness of sand, and the secondary grinders leave the clinker ground to the fineness of flour, which is the final product ready for marketing.

Packaging/Shipping

The final product is shipped either in bulk (ships, barges, tanker trucks, railroad cars, etc.) or in strong paper bags which are filled by machine. In the United States, one bag of Portland cement contains 94 pounds of cement, and a “barrel” weighs four times that amount, or 376 pounds. In Canada, one bag weighs 87 1/2 pounds and a “barrel” weighs 350 pounds.

Masonry cement bags contain only seventy pounds of cement. When cement is shipped, the shipping documents may include “sack weights.” This must be verified by the auditor since only the cement is taxable. “Sack weights” must be excluded.



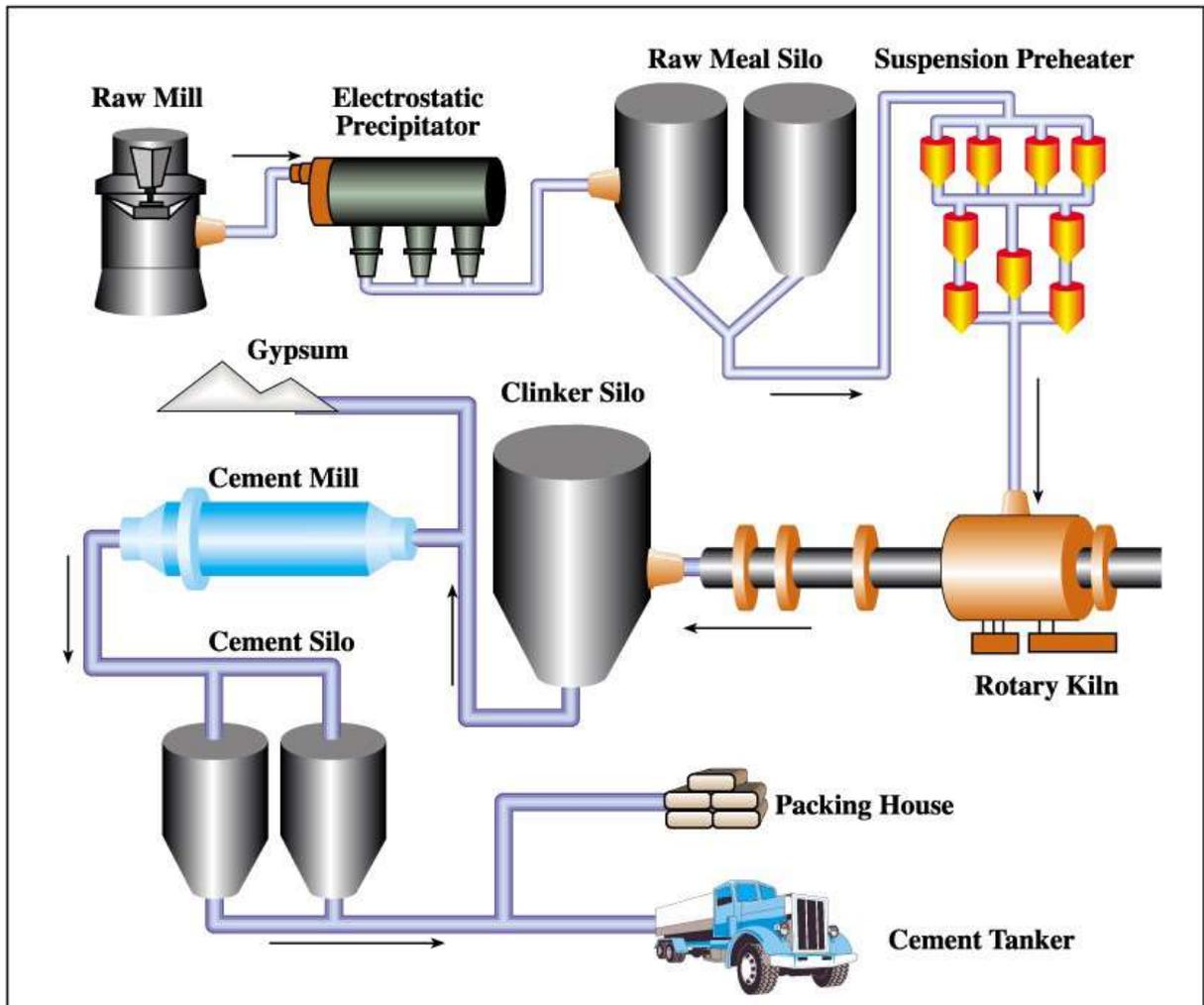
The basic components of the cement production process.

Activity 2

Make an educational visit to a cement factory. Observe all the stages involved in the production of cement

4.4 FLOW CHART OF MANUFACTURING PROCESS

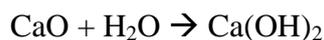
Cement Production Process



4.5 Chemistry of Cement

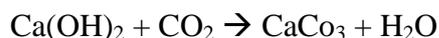


This is the breakdown of calcium carbonate (CaCO_3), into calcium oxide (CaO) and carbon dioxide (CO_2). The calcium oxide is then spent (slaked) mixing with water to make slaked lime.



Once the water from the slaked lime is completely evaporated (setting)

Carbonation starts:



The reaction of carbonation requires air to be in contact with the dry cement, hence the slaked lime is a non hydraulic cement. The whole process is called the lime cycle. Conversely the chemistry underlying the action of hydraulic cement is hydration.

Hydraulic cement e.g Portland cement are made of a mixture of silicates and oxides.

The four main components are:

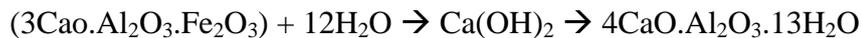
Belite ($2\text{CaO} \cdot \text{SiO}_2$);

Alite ($3\text{CaO} \cdot \text{SiO}_2$);

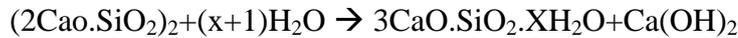
Celite ($3\text{CaO}\cdot\text{Al}_2\text{O}_3$); and

Brown millerite ($4\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot\text{Fe}_2\text{O}_3$).

The reactions during the setting of cement are as follows:



The reactions during hardening is



The silicates are responsible for the mechanical properties of cement.

The celite and brown millerite are essential to allow the liquid phase during the cooking.

The chemistry of the reaction is not completely clear and is still the object of research.

4.6 Uses of Cement

Cement is used for the production of several structures. Two of the most popular ones are production of mortar and production of concrete.

Activity 3

Mention other uses of cement that you know

4.7 Environmental, Health and Safety Risk Involved in Cement Production

Cement is highly alkaline and the setting process is exothermic. As a result, wet cement is strongly caustic and can easily cause severe burns if not properly washed off with water. Dry cement powder in contact with mucous membranes can cause severe eye or respiratory irritation, some ingredients in cement can cause allergic dermatitis.

Carcinogen chromate can be formed in cement. This is prevented by adding some reducing agents.

Cement users are always advised to wear protective clothing.

Most cement bags bear safety measures on them to create awareness on safety issues of cement.

4.8 Safety Measures to be taken by Cement Companies

Safety measures include

- Implementation of an environmental, health and safety management system
- Regular inspection of plant to prevent leakage and product loss
- Enclose conveyers and storage areas to reduce dust.
- Isolate noisy equipment and rotate tasks to minimize time spent with noisy equipment
- Regulate exposure times by workers
- Train workers in correct use of machinery and safety devices
- Install automatic alarms and shut off systems
- Install firefighting and first aid equipment.

4.9 Cement Companies in Nigeria

Some of the most popular Cement Companies in Nigeria are Dangote Cement, Lafarge Nigeria, Unicem, Sokoto Cement and Ibeto Cement.

4.10 Location of Cement Factories

Cement production facilities are often located in rural areas and close to quarries where the raw materials are present e.g. limestone and shale.

5.0 SUMMARY

- The term **cement** is commonly used to refer to powdered materials which develop strong adhesive qualities when combined with water.
- There are two types of raw materials which are combined to make cement:
 - i. Lime-containing materials, such as limestone, marble, oyster shells, marl, chalk, etc.
 - ii. Clay and clay-like materials, such as shale, slag from blast furnaces, bauxite, iron ore, silica, sand, etc.
- The production of cement takes place with several steps:
Quarrying of limestone and shale, Dredging the ocean floor for shells, Digging for clay and marl, Grinding, Blending of components, Fine grinding, Burning, Finish grinding and Packaging and/or shipping.

6.0 TUTOR MARKED ASSIGNMENT (TMAS)

1. List the processes involved in the production of cement and describe any five.
2. What are the raw materials for the production of cement?
3. Discuss the importance of cement in the economic development of Nigeria.
4. List other hazards involved in Cement Production
5. Mention some of the safety measures that can be taken

7.0 REFERENCES/FURTHER READING

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ANSWERS TO ACTIVITIES AND ASSIGNMENT

Activity I

The cement feels very fine like powder

ASSIGNMENT

1. Other hazards involved in cement production are:
 - a. Hearing loss due to noise. People working around grinders and conveyor systems can suffer hearing loss
 - b. Dust arising from production activities may have significant effect on neighboring locations
 - c. Waste water with high PH may affect surrounding waters and contaminate them.
 - d. Additives to the cement process can be harmful and toxic.
 - e. Explosion – raw materials are often stored in silos. A silo may rupture due to over pressurization in the tank.
 - f. Collision – people may be hit by moving, flying or falling objects
 - g. Road noise and traffic congestion. Have you ever travelled through a road, leading to a cement factory/plant .e.g. Obajana Plant; you will notice the heavy traffic of trailers causing congestion on the road.
2. Safety measures include:
 - a. Implementation of an environmental, health and safety management system
 - b. Regular inspection of plant to prevent leakage and product loss
 - c. Enclose conveyers and storage areas to reduce dust.
 - d. Isolate noisy equipment and rotate tasks to minimize time spent with noisy equipment
 - e. Regulate exposure times by workers
 - f. Train workers in correct use of machinery and safety devices
 - g. Install automatic alarms and shut off systems
 - h. Install firefighting and first aid equipment.

UNIT 5: FERTILIZER

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3.2	Raw Materials used for Production
3.3	Production Process/Manufacturing Process
3.4	Flow Chart Of Manufacturing Process
4.0	Conclusion
5.0	Summary
6.0	Tutor Marked Assignment (TMA)
7.0	References and Further Reading

1.0 INTRODUCTION

Fertilizer is a substance added to soil to improve plants' growth and yield. First used by ancient farmers, fertilizer technology developed significantly as the chemical needs of growing plants were discovered. In this unit, we are going to discuss on the raw materials used in the production as well as the process involved in the manufacture of fertilizer.

2.0 OBJECTIVES

After studying this unit, you should be able to:

1. Explain fully the meaning and its importance of fertilizer to life
2. Itemize the raw materials used in the production of fertilizer
3. List and explain the processes involved.

3.0 MAIN CONTENT

3.1 DEFINITION AND HISTORICAL BACKGROUND

Fertilizer is a substance added to soil to improve plants' growth and yield. First used by ancient farmers, fertilizer technology developed significantly as the chemical needs of growing plants were discovered. Modern synthetic fertilizers are composed mainly of nitrogen, phosphorous, and potassium compounds with secondary nutrients added. The use of synthetic fertilizers has significantly improved the quality and quantity of the food available today, although their long-term use is debated by environmentalists. Fertilizers replace the chemical components that are taken from the soil by growing plants. However, they are also designed to improve the growing potential of soil, and fertilizers can create a better growing environment than natural soil. They can also be tailored to suit the type of crop that is being grown. Typically, fertilizers are composed of nitrogen, phosphorus, and potassium compounds. They also contain trace elements that improve the growth of plants.

3.2 RAW MATERIALS

The fertilizers outlined here are compound fertilizers composed of primary fertilizers and secondary nutrients. These represent only one type of fertilizer, and other single nutrient types are also made. The raw materials, in solid form, can be supplied to fertilizer manufacturers in bulk quantities of thousands of tons, drum quantities, or in metal drums and bag containers.

Primary fertilizers include substances derived from nitrogen, phosphorus, and potassium (NPK). Various raw materials are used to produce these compounds. When ammonia is used as the nitrogen source in a fertilizer, one method of synthetic production requires the use of natural gas and air. The phosphorus component is made using sulfur, coal, and phosphate rock. The potassium source comes from potassium chloride, a primary component of potash.

Secondary nutrients are added to some fertilizers to help make them more effective. Calcium is obtained from limestone, which contains calcium carbonate, calcium sulphate, and calcium magnesium carbonate. The magnesium source in fertilizers is derived from dolomite. Sulfur is another material that is mined and added to fertilizers. Other mined materials include iron from ferrous sulfate, copper, and molybdenum from molybdenum oxide.

3.3 PRODUCTION/MANUFACTURING PROCESSES

Fully integrated factories have been designed to produce compound fertilizers. Depending on the actual composition of the end product, the production process will differ from manufacturer to manufacturer.

Nitrogen fertilizer component

1. Ammonia is one nitrogen fertilizer component that can be synthesized from inexpensive raw materials. Since nitrogen makes up a significant portion of the earth's atmosphere, a process was developed to produce ammonia from air. In this process, natural gas and steam are pumped into a large vessel. Next, air is pumped into the system, and oxygen is removed by the burning of natural gas and steam. This leaves primarily nitrogen, hydrogen, and carbon dioxide. The carbon dioxide is removed and ammonia is produced by introducing an electric current into the system. Catalysts such as magnetite (Fe_3O_4) have been used to improve the speed and efficiency of ammonia synthesis. Any impurities are removed from the ammonia, and it is stored in tanks until it is further processed.
2. While ammonia itself is sometimes used as a fertilizer, it is often converted to other substances for ease of handling. Nitric acid is produced by first mixing ammonia and air in a tank. In the presence of a catalyst, a reaction occurs which converts the ammonia to nitric oxide. The nitric oxide is further reacted in the presence of water to produce nitric acid.
3. Nitric acid and ammonia are used to make ammonium nitrate. This material is a good fertilizer component because it has a high concentration of nitrogen. The two materials are mixed together in a tank and a neutralization reaction occurs, producing ammonium nitrate. This material can then be stored until it is ready to be granulated and blended with the other fertilizer components.

Phosphorous fertilizer component

4. To isolate phosphorus from phosphate rock, it is treated with sulfuric acid, producing phosphoric acid. Some of this material is reacted further with sulfuric acid and nitric

acid to produce a triple superphosphate, an excellent source of phosphorous in solid form.

5. Some of the phosphoric acid is also reacted with ammonia in a separate tank. This reaction results in ammonium phosphate, another good primary fertilizer.

Potassium fertilizer component

6. Potassium chloride is typically supplied to fertilizer manufacturers in bulk. The manufacturer converts it into a more usable form by granulating it. This makes it easier to mix with other fertilizer components in the next step.

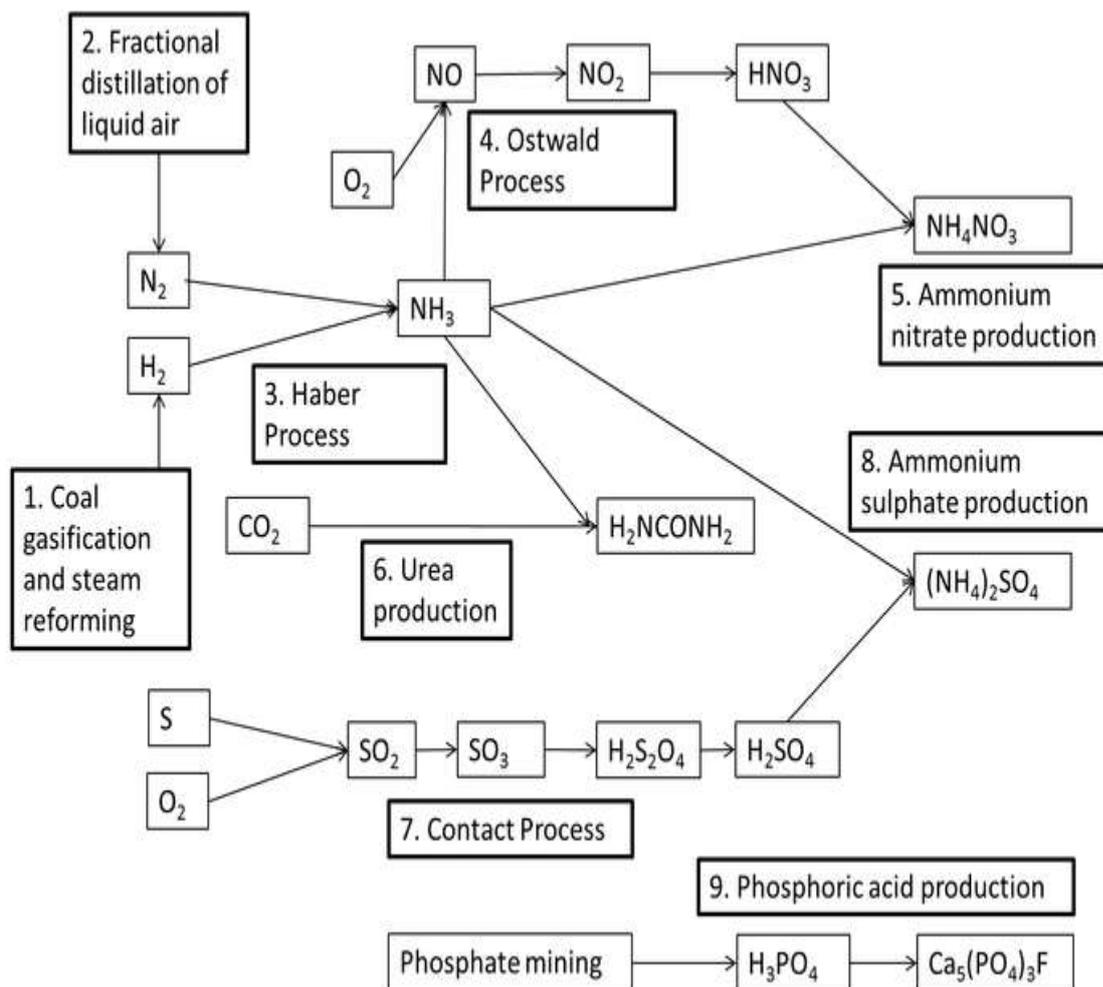
Granulating and blending

7. To produce fertilizer in the most usable form, each of the different compounds, ammonium nitrate, potassium chloride, ammonium phosphate, and triple superphosphate are granulated and blended together. One method of granulation involves putting the solid materials into a rotating drum which has an inclined axis. As the drum rotates, pieces of the solid fertilizer take on small spherical shapes. They are passed through a screen that separates out adequately sized particles. A coating of inert dust is then applied to the particles, keeping each one discrete and inhibiting moisture retention. Finally, the particles are dried, completing the granulation process.
8. The different types of particles are blended together in appropriate proportions to produce a composite fertilizer. The blending is done in a large mixing drum that rotates a specific number of turns to produce the best mixture possible. After mixing, the fertilizer is emptied onto a conveyor belt, which transports it to the bagging machine.

Bagging

9. Fertilizers are typically supplied to farmers in large bags. To fill these bags the fertilizer is first delivered into a large hopper. An appropriate amount is released from the hopper into a bag that is held open by a clamping device. The bag is on a vibrating surface, which allows better packing. When filling is complete, the bag is transported upright to a machine that seals it closed. The bag is then conveyed to a palletizer, which stacks multiple bags, readying them for shipment to distributors and eventually to farmers.

3.4 Flow Chart of Manufacturing Process



The industrial manufacturing of fertilisers

4.0 CONCLUSION

Fertilizer is a chemical substance added to soil to improve plants' growth and yield. Fertilizer technology developed significantly as the chemical needs of growing plants were discovered. The use of synthetic fertilizers has significantly improved the quality and quantity of the food available today, although their long-term use an issue that is being debated by environmentalists.

5.0 SUMMARY

Fertilizer is a substance added to soil to improve plants' growth and yield. Typically, fertilizers are composed of nitrogen, phosphorus, and potassium compounds. The fertilizers outlined here are compound fertilizers composed of primary fertilizers and secondary nutrients. The process involved the steps as Nitrogen fertilizer component, the phosphorus fertilizer component, potassium fertilizer component, granulating and blending and bagging.

6.0 TEACHER MARKED ASSIGNMENT

1. Discuss the importance of fertilizer to life.
2. What are the raw materials necessary for the production of fertilizer?
3. Explain the processes involved in the production of fertilizer.

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UNIT 6: FOOD PROCESSING AND CONFECTIONERIES

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- 3.2 Confectionery
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1.0 INTRODUCTION

Food processing is the transformation of raw ingredients, by physical or chemical means into food, or of food into other forms.

Food processing involves activities such as Mincing and macerating, Liquefaction, Emulsification, Cooking (such as boiling, broiling, frying, or grilling), Pickling and preservation, Canning or jarring (primary-processing such as Dicing or slicing, Freezing or drying when leading to secondary products are also included). These activities or a combination thereof, result in the manufacture of ready-to-cook or precooked food products like confectionery, instant foods, flavored and health drinks, pickles, jams, flakes, juices, purees, canned foods, powders and mixes, jellies, sauces, oils, etc.

2.0 OBJECTIVES

1. Explain the concept food processing
2. Discuss the benefit of food processing
3. Analyze some of the problems associated with food processing
4. Highlight some performance parameters of food processing

5. List and explain the modern development of food processing
6. Explain the term confectionery
7. Itemize and discuss the sweating agents giving examples each.

3.0 MAIN CONTENT

Food processing typically takes clean, harvested or culled crops or butchered animal products and processes these produce attractive, marketable and often long shelf-life manufactured food products. After fresh produce undergoes such food processing, most nations require that the resultant food items be affixed with a label listing the ingredients and a use-by or expire-by date.

Food processing should not be confused with the nominal process fresh produce is subject to, before transport and marketing, such as trimming, grading, washing and packaging, as well the process of controlled ripening of fruits. These procedural activities do not transform the raw produce into another food item or add ingredients, and such packages will not require labeling with fixed expiry dates.

Food processing dates back to the prehistoric ages when crude processing incorporated fermenting, sun drying, preserving with salt, and various types of cooking (such as roasting, smoking, steaming, and oven baking). Such basic food processing involved chemical enzymatic changes to the basic structure of food in its natural form, as well served to build a barrier against surface microbial activity that caused rapid decay. Salt-preservation was especially common for foods that constituted warrior and sailors' diets until the introduction of canning methods. Evidence for the existence of these methods can be found in the writings of the ancient Greek, Chaldean, Egyptian and Roman civilizations as well as archaeological evidence from Europe, North and South America and Asia. These tried and tested processing techniques remained essentially the same until the advent of the industrial revolution. Examples of ready-meals also date back to before the preindustrial revolution, and include dishes such as Cornish pasty and Haggis. Both during ancient times and today in modern society these are considered processed foods.

Modern food processing technology developed in the 19th and 20th centuries was developed in a large part to serve military needs. In 1809 Nicolas Appert invented a hermetic bottling technique that would preserve food for French troops which ultimately contributed to the development of tinning, and subsequently canning by Peter Durand in 1810. Although initially expensive and somewhat hazardous due to the lead used in cans, canned goods would later become a staple around the world. Pasteurization, discovered by Louis Pasteur in 1864, improved the quality of preserved foods and introduced the wine, beer, and milk preservation.



Industrial cheese production



3.1.1 Benefits

Benefits of food processing include toxin removal, preservation, easing marketing and distribution tasks, and increasing food consistency. In addition, it increases yearly availability of many foods, enables transportation of delicate perishable foods across long distances and makes many kinds of foods safe to eat by de-activating spoilage and pathogenic micro-organisms. Modern supermarkets would not exist without modern food processing techniques, and long voyages would not be possible.

Processed foods are usually less susceptible to early spoilage than fresh foods and are better suited for long distance transportation from the source to the consumer. When they were first introduced, some processed foods helped to alleviate food shortages and improved the overall nutrition of populations as it made many new foods available to the masses.

Processing can also reduce the incidence of food borne disease. Fresh materials, such as fresh produce and raw meats, are more likely to harbour pathogenic micro-organisms (e.g. Salmonella) capable of causing serious illnesses.

The extremely varied modern diet is only truly possible on a wide scale because of food processing. Transportation of more exotic foods, as well as the elimination of much hard

labour gives the modern eater easy access to a wide variety of food unimaginable to their ancestors.

Mass production of food is much cheaper overall than individual production of meals from raw ingredients. Therefore, a large profit potential exists for the manufacturers and suppliers of processed food products. Individuals may see a benefit in convenience, but rarely see any direct financial cost benefit in using processed food as compared to home preparation.

Processed food freed people from the large amount of time involved in preparing and cooking "natural" unprocessed foods. The increase in free time allows people much more choice in life style than previously allowed. In many families the adults are working away from home and therefore there is little time for the preparation of food based on fresh ingredients. The food industry offers products that fulfill many different needs: e.g. fully prepared ready meals that can be heated up in the microwave oven within a few minutes.

Modern food processing also improves the quality of life for people with allergies, diabetics, and other people who cannot consume some common food elements. Food processing can also add extra nutrients such as vitamins.

3.1.2 Disadvantage

Any processing of food can affect its nutritional density. The amount of nutrients lost depends on the food and processing method. For example the heat destroys the Vitamin C. Therefore, canned fruits possess less vitamin C than their fresh alternatives. The USDA conducted a study in 2004, creating a nutrient retention table for several foods. A cursory glance of the table indicates that, in the majority of foods, processing reduces nutrients by a minimal amount. On average this process reduces any given nutrient by as little as 5%-20%.

New research highlighting the importance to human health of a rich microbial environment in the intestine indicates that abundant food processing (not fermentation of foods) endangers that environment.

Using food additives represents another safety concern. The health risks of any given additive vary greatly from person to person; for example using sugar as an additive endangers diabetics. In the European Union, only European Food Safety Authority (EFSA) approved food additives (e.g., sweeteners, preservatives, stabilizers) are permitted at specified levels for use in food products. Approved additives receive an E number (E for Europe), simplifying communication about food additives included in the ingredients' list for all the different languages spoken in the EU. Certain additives can also result in an addiction to a particular food item. As effects of chemical additives are learnt, changes to laws and regulatory practices are made to make such processed foods safer.

Food processing is typically a mechanical process that utilizes large mixing, grinding, chopping and emulsifying equipment in the production process. These processes inherently introduce a number of contamination risks. As a mixing bowl or grinder is used over time the food contact parts will tend to fail and fracture. This type of failure will introduce into the product stream small to large metal contaminants. Further processing of these metal fragments will result in downstream equipment failure and the risk of ingestion by the consumer. Food manufacturers utilize industrial metal detectors to detect and reject automatically any metal fragment. Large food processors will utilize many metal detectors within the processing stream to reduce both damage to processing machinery as well as risk to consumer health.

3.1.3 Performance parameters for food processing

When designing processes for the food industry the following performance parameters may be taken into account:

- Hygiene, e.g. measured by number of micro-organisms per mL of finished product
- Energy efficiency measured e.g. by “ton of steam per ton of sugar produced”
- Minimization of waste, measured e.g. by “percentage of peeling loss during the peeling of potatoes”
- Labour used, measured e.g. by “number of working hours per ton of finished product”
- Minimization of cleaning stops measured e.g. by “number of hours between cleaning stops.

3.1.4 De-agglomerating batter mixes in food processing

Problems often occur during preparation of batter mixes because flour and other powdered ingredients tend to form lumps or agglomerates as they are being mixed during production. A conventional mixer/agitator cannot break down these agglomerates, resulting in a lumpy batter. If lumpy batter is used to enrobe products, it causes an unsatisfactory appearance with misshapen or oversize products that do not fit properly into packaging. This can force production to a standstill. Furthermore batter mix is generally recirculated from an enrobing system back to a holding vessel; lumps then have a tendency to build up, reducing the flow of material and raising potential sanitation issues.

Using a high shear in-line mixer in place of a conventional agitator or mixer can quickly solve problems of agglomeration with dry ingredients. A single pass through a self-pumping, in-line mixer adds high shear to batter, which de-agglomerates the mix, resulting in a homogeneous, smooth batter. With a consistent, smooth batter, finished product appearance is improved; the effectiveness and hygiene of the recirculation system is increased; and a better yield of raw materials is achieved. By increasing overall product quality, the amount of raw materials needed is decreased, thereby lowering manufacturing costs.

High shear in-line mixers process food to be made faster and cheaper while increasing consistency of the finished food. Powder and liquid mixing systems are capable of rapidly incorporating large quantities of powders at high concentrations – agglomerate free and fully hydrated. Advances in technology have made processing equipment easy to clean, leading to a much safer processed food.

3.1.5 Development in modern food processing

Health

- Reduction of fat content in final product by using baking instead of deep-frying in the production of potato chips, another processed food.
- Maintaining the natural taste of the product by using less artificial sweetener than was used before.

Hygiene

The rigorous application of industry and government endorsed standards to minimise possible risk and hazards. The international standard adopted is HACCP.

Efficiency

- Rising energy costs lead to increasing usage of energy-saving technologies,^[9] e.g. frequency converters on electrical drives, heat insulation of factory buildings and heated vessels, energy recovery systems, keeping a single fish frozen all the way from China to Switzerland.
- Factory automation systems (often Distributed control systems) reduce personnel costs and may lead to more stable production results.

3.2 CONFECTIONERY

Confectionery is the art of making confections, which are food items that are rich in sugar and carbohydrates. Exact definitions are difficult. In general, though, confectionery is divided into two broad and somewhat overlapping categories, bakers' confections and sugar confections.

Bakers' confectionery, also called flour confections, includes principally sweet pastries, cakes, and similar baked goods. In the Middle East and Asia, flour-based confections are more dominant.

Sugar confectionery includes sweets, candied nuts, chocolates, chewing gum, sweetmeats, pastillage, and other confections that are made primarily of sugar. In some cases, chocolate confections (confections made of chocolate) are treated as a separate category, as are sugar-free versions of sugar confections. The words candy (US and Canada), sweets (UK and Ireland), and lollies (Australia and New Zealand) are common words for the most common varieties of sugar confectionery.

The confectionery industry also includes specialized training schools and extensive historical records. Traditional confectionery goes back to ancient times, and continued to be eaten through the middle ages into the modern era.

3.2.1 Sweetening agents

Confections are defined by the presence of sweeteners. These are usually sugars, but it is possible to buy sugar-free sweets, such as sugar-free peppermints. Most common is the disaccharide sucrose. Hydrolysis of sucrose gives a mixture called invert sugar, which is sweeter and is also a common ingredient. Finally confections, especially commercial ones, are sweetened by a variety of syrups obtained by hydrolysis of starch, these include corn syrup.

3.2.2 Bakers' confectionery

Bakers' confectionery includes sweet baked goods, especially those that are served for the dessert course. Bakers' confections are sweet foods that feature flour as a main ingredient and are baked. Major categories include cakes, sweet pastries, doughnuts, scones, and cookies.^[6]

3.2.3 Sugar confectionery

Sugar confections include sweet, sugar-based foods, which are usually eaten as snack food. This includes sugar candies, chocolates, candied fruits and nuts, chewing gum, and sometimes ice cream.

3.2.4 Examples

List of candies



Peeps

Rock candy



Brittles



Chocolate

Sugar confectionery items include sweets, lollipops, candy bars, chocolate, cotton candy, and other sweet items of snack food. Some of the categories and types of sugar confectionery include the following:

- Caramels: Derived from a mixture of sucrose, glucose syrup, and milk products. The mixture does not crystallize, thus remains tacky.
- Chocolates: Bite-sized confectioneries generally made with chocolate.
- Divinity: A nougat-like confectionery based on egg whites with chopped nuts.
- Dodol: A toffee-like food delicacy popular in Indonesia, Malaysia, and the Philippines
- Dragée: Sugar-coated almonds and other types of sugar panned candy.
- Fondant: Prepared from a warm mixture of glucose syrup and sucrose, this is partially crystallized. The fineness of the crystallites results in a creamy texture.
- Fudge: Made by boiling milk and sugar to the soft-ball stage. In the US, it tends to be chocolate-flavored.
- Halvah: Confectionery based on tahini, a paste made from ground sesame seeds.
- Hard candy: Based on sugars cooked to the hard-crack stage. Examples include suckers (known as *boiled sweets* in British English), lollipops, jawbreakers (or gobstoppers), lemon drops, peppermint drops and disks, candy canes, rock candy, etc. Also included are types often mixed with nuts such as brittle. Others contain flavorings including coffee such as Kopiko.
- Ice cream: Frozen, flavoured cream, often containing small pieces of chocolate, fruits and/or nuts.
- Jelly candies: Including those based on sugar and starch, pectin, gum, or gelatin such as Turkish delight (lokum), jelly beans, gumdrops, jujubes, gummies, etc.
- Liquorice: Containing extract of the liquorice root. Chewier and more resilient than gum/gelatin candies, but still designed for swallowing. For example, Liquorice allsorts. Has a similar taste to star anise.
- Marshmallow: "Peeps" (a trade name), circus peanuts, fluffy puff, Jet-Puffed Marshmallows etc.
- Marzipan: An almond-based confection, doughy in consistency, served in several different ways.
- Mithai: A generic term for confectionery in India typically made from dairy products and/or some form of flour. Sugar or molasses are used as sweeteners.

- Tablet: A crumbly milk-based soft and hard candy, based on sugars cooked to the soft-ball stage. Comes in several forms, such as wafers and heart shapes. Not to be confused with tableting, a method of candy production.
- Taffy or chews: A candy that is folded many times above 50 °C, incorporating air bubbles thus reducing its density and making it opaque.

3.2.5 Risks

Excessive consumption of confectionery has been associated with increased incidences of type 2 diabetes, obesity, and tooth decay.

Contaminants and coloring agents as well as toys and other non-nutritive products in confectionery can be particularly harmful to children. This non-nutritive material can cause injury or pose choking hazards. Therefore, confectionery contaminants such as high levels of lead have been restricted to 1 ppm in the US. There is no specific maximum in the EU.

Candy colorants, particularly yellow colorants such as E102 Tartrazine, E104 Quinoline Yellow and E110 Sunset Yellow FCF, do have many restrictions around the world. Tartrazine, for example, can cause allergic and asthmatic reactions and was once banned in Austria, Germany, and Norway. Some countries such as the UK have asked the food industry to phase out the use of these colorants, especially for products marketed to children.

Non-nutritive toy products such as chocolate eggs containing packaging with a toy inside are banned from sale in the US. If the material attached to confectionery does have a function and will not cause any injury to the consumer, it is allowed to be marketed. In the EU however, the Toy Safety Directive 2009/48/EC specifies that toys contained in food only need separate packaging that cannot be swallowed.

4.0 CONCLUSION

Food processing involves activities such as Mincing and macerating, Liquefaction, Emulsification, Cooking (such as boiling, broiling, frying, or grilling), Pickling and preservation, Canning or jarring (primary-processing such as Dicing or slicing, Freezing or drying when leading to secondary products are also included). These activities or a combination thereof, result in the manufacture of ready-to-cook or precooked food products like confectionery, instant foods, flavored and health drinks, pickles, jams, flakes, juices, purees, canned foods, powders and mixes, jellies, sauces, oils, etc.

5.0 SUMMARY

Food processing is the transformation of raw ingredients, by physical or chemical means into food, or of food into other forms.

Benefits of food processing include toxin removal, preservation, easing marketing and

distribution tasks, and increasing food consistency.

Any processing of food can affect its nutritional density. The amount of nutrients lost depends on the food and processing method. For example the heat destroys the Vitamin C.

The performance parameters in food processing includes hygiene, energy efficiency measured, and minimization of waste, labour used, minimization of cleaning stops measured.

Problems often occur during preparation of batter mixes because flour and other powdered ingredients tend to form lumps or agglomerates as they are being mixed during production. A

Confectionery is the art of making confections, which are food items that are rich in sugar and carbohydrates.

Confectionery is divided into two broad and somewhat overlapping categories, bakers' confections and sugar confections.

Confections are defined by the presence of sweeteners. These are usually sugars, but it is possible to buy sugar-free sweets, such as sugar-free peppermints.

Sugar confectionery items include sweets, lollipops, candy bars, chocolate, cotton candy, and other sweet items of snack food.

6.0 Tutor Marked Assignment (TMAs)

1. Explain the concept food processing
2. Discuss the benefit of food processing
3. Analyze some of the problems associated with food processing
4. Highlight some performance parameters of food processing
5. List and explain the modern development of food processing

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UNIT 7: FOOD PRESERVATION

1.0 INTRODUCTION

Micro – organisms are always affecting the food we eat thereby causing food decay and food spoilage. The microbes or their spores most times survives heat and cold better than other advanced life forms. Thus the problems of food storage and preservation is central. In this unit you will learn about the various ways in which food can best be stored and preserved.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

1. explain the rationale for preserving food;
2. describe some methods of preserving food;
3. list and describe at least 3 techniques of storing required foods;
4. carry out some small scale projects on food preservation.

3.0 HOW TO STUDY THIS UNIT

1. Read through the whole unit to familiarize yourself with the topic
2. Reflect on the issues raised through the topic
3. Read the unit, now step by step
4. Carry out the suggested activities
5. Summarize the main ideas of the topic

NOTE: ALL ANSWERS ARE AT THE END OF THIS BOOK

4.0 MAIN CONTENT

4.1 WHY PRESERVE FOOD

ACTIVITY I

Take a trip to a farm in your area. Ask the farmer whether he incurs any losses of his products before selling them in the market.

Discuss with him, methods, he uses in preserving his food stuff.

Every year farmers lose a lot of their harvested food stuff to pest attack, fungi and bacteria activities

The decomposition of the food makes the food unusable by humans or animals throughout the years, man has learnt to preserve food in one way or another. Most of the foods preserved then were of poor quality. Food preserving improved with the introduction of freeze drying techniques which retained more of the nutritional value.

Many crops are seasonal and most are harvested at a particular time of the year. To ensure all year round supply of food, there is need for efficient preservation and storage of food. Many of our farm produce in Nigeria are not adequately preserved and stored. There is over production during the harvest period and scarcity after that. Such crops include yams, tomatoes, onions.

Another reason for preserving food is to reduce the damages that could be done to food by pest during storage. For example beans and maize.

Farmers lose a lot of money every year due to losses incurred through attack by pests.

Activity 2

Why do we preserve food?

4.2 METHODS OF PRESERVING FOOD

There are many ways of preserving food. These include:

1. Salting or adding sugar to food
2. Smoking and drying the food
3. The use of vinegar (acetic acid) to preserve food
4. Canning and bottling of food
5. Freezing of food and
6. The use of chemical preservatives.

4.2.1 Salting and Adding Sugar

Salt and sugar are often used to preserve traditionally. The principles used in both cases is the same. This involves eliminating micro-organisms from the food by dehydrating them by the process of osmosis.

Activity 3

Describe what happens during osmosis

The microbes consequently lose their water and dehydrate to death. This is why salt is rubbed into meat and sugar is added to fruit for jam making.

4.2.2 Smoking and Drying Process

The principle of smoking and drying is to eliminate moisture from the food, and so make fungal and bacterial life on the food impossible. Air drying is used to preserve foods such as beans, fruits, and fish but vitamin C is lost in the process.

Without water in the food, bacteria cannot grow so the food remains fresh. The taste of the food is sometimes affected by the drying.

Other foods that can be preserved by drying include powdered milk, processed potatoes and soups.

Water is just added when these food are required for food.

Activity 4

Which method is used in preserving fish in Lake Chad area

4.2.3 The use of Vinegar (acetic acid)

Vinegar (acetic acid) is a liquid preservative and food flavouring agent containing about 5% ethanoic acid.

It is made by oxidation of ethanol formed by fermentation of carbohydrates. When vinegar is added to food, it destroys many of the microbes. Some vegetables e.g onions are pickled to preserve them.

4.2.4 Canning and bottling of food

Canning and bottling employ the principle of excluding air from the food after it has been strongly heated to destroy all the micro organisms. Fresh or new organisms cannot enter the sealed containers. Therefore the food remains preserved for quite sometimes. Canning machines can produce thousands of cans at a time. Cans are made of steel plated with tin, to prevent rusting.

Vitamins in canned food are often preserved since the heating time can be reduced.

Activity 5

Are all canned foods safe at all times?

Canned foods may not be safe at all times. In exceptional cases “blown” tins are produced due to faulty preparation as the bacteria have not been destroyed. Carbon dioxide evolved by the respiring micro – organisms causes the “blown” appearance. The gas is known as the toxin of botlinus. Such tins are very dangerous because of the bacteria and the poisons which they may reproduce which causes food poisoning.

Activity 5

Visit a food processing industry or a bottling company near you.

During your visit ask as many questions as you can on their scientific operations.

4.2.5 Freezing of food to preserve it

For thousands of years people have preserved food by packaging it in ice. The ice was never enough when needed and it always melts away.

Freezing food uses the principle of making the microbes absolutely inactive due to very low temperature. The low temperature prevents the multiplication of the microbes and so slows their growth.

The disadvantage of this technique is that micro – organisms are not killed. They are only made inactive for a while. One advantage of freezing process is that the original flavor and the freshness of the preserved foods are retained.

Have you a freezer and a refrigerator in your house? They are used for freezing food.

In industries, food is preserved in cold rooms kept at very low temperatives

4.2.6 The use of Chemical Preservatives

Some chemicals can be used to preserve food sometimes. Cereals are often preserved by spraying them with non – toxic chemicals. Monosodium glutamate helps to preserve dried foods and is often used in pre-packaged food. Sulphur dioxide is often used to preserve fruit juices and soft drinks, because it forms a reducing agent which kills micro – organisms. Common food additives such as Maggi cubes or knor are preserved using chemicals.

4.3 FOOD STORAGE

Whereas preservation is concerned with the elimination of microbes from the food, storage is concerned with keeping the preserved food undisturbed over a long period of time.

Farmers have ways in which to store their agricultural produce for a long period. Yam is stored in yam barns, traditional silos (“Rumbus”) are used to store cereals and legumes. They also use air-tight containers.

Proper food storage is important to prevent pests from destroying the food while in storage.

Rats, house flies, weevils and other insects bring about storage problems to the farmer.

Pesticides are also used to store food. Cereals such as maize and beans are often preserved with pesticides.

Some pesticides can be very toxic and pose danger to humans.

5.0 SUMMARY

In this unit you have learn that:

- Micro – organisms are responsible for food decay or decomposition.
- Micro – organisms can survive heat and cold better than more advanced organisms
- Preservation techniques centre on eliminating the microbes in one way or another.
- Smoking, salting, adding sugar and freezing are methods of food preservation.
- Canning and bottling employ the principle of excluding air from the preserved food
- Pest causes a lot of destruction to products in storage.

6.0 ASSIGNMENT

1. What are micro – organisms
2. Name any 3 common storage pests
3. State 3 ways of storing produce by Nigeria farmers

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ANSWERS TO ACTIVITIES AND ASSIGNMENT

ACTIVITY 2

We preserve food to prevent them from decaying or decomposing through the action of micro – organisms

ACTIVITY 3

Osmosis is the passage of water molecules from a region of their high concentration to a region of their low concentration through a partially permeable membrane.

ACTIVITY 4

The method used in preserving food in Lake Chad area is smoking and drying.

ACTIVITY 5

All canned foods are not safe at all times. In exceptional cases ‘blow’ tins are produced due to faulty preparation. This can cause botulism which is food poisoning.

Assignment

1. Micro – organisms are the smallest organisms in living things. They are also called microbes. They include bacteria (prokaryotes) viruses, fungi and protoctists. They cause decay of organic material. Some cause diseases and some are useful in many biotechnological processes.
2. Any 3 common storage pests are weevils, house flies and rats
3. Three ways of storing produce in Nigeria are:
 1. Storage in yam barns
 2. Use of traditional silos
 3. Use of pesticides.

ANSWERS TO TUTOR MARKED ASSIGNMENTS IN MODULE 1 UNITS 3, 4 & 5.

Unit 3 Question 1

Any six uses in the table mentioned with metals to be used and electrolyte contents are okay.

Common uses of Electroplating and the Metals Used

Metal	Anode	Electrolyte	Application
Cu	Cu	20% CuSO ₄ , 3% H ₂ SO ₄	Electrotype
Ag	Ag	4% AgCN, 4% KCN, 4% K ₂ CO ₃	jewelry, tableware
Au	Au, C, Ni-Cr	3% AuCN, 19% KCN, 4% Na ₃ PO ₄ buffer	Jewelry

Cr	Pb	25% CrO ₃ , 0.25% H ₂ SO ₄	automobile parts
Ni	Ni	30% NiSO ₄ , 2% NiCl ₂ , 1% H ₃ BO ₃	Cr base plate
Zn	Zn	6% Zn(CN) ₂ , 5% NaCN, 4% NaOH, 1% Na ₂ CO ₃ , 0.5% Al ₂ (SO ₄) ₃	galvanized steel
Sn	Sn	8% H ₂ SO ₄ , 3% Sn, 10% cresol-sulfuric acid	tin-plated cans

Unit 3 Question 2

2. Tin is used to coat cans in order to prevent corrosion
3. Chromium coating will increase a metal's resistance to wear.
4. Similarly, silver and gold are used to coat silverware and jewelry to prevent corrosion and increase value.
5. Another application of electroplating is the thickening of an object.

However, although this process is very useful, it can also be dangerous. In the real world, electroplating is done in a large scale, and so a large amount of waste is produced. The resulting waste is called wastewater in the industry, and must be treated before it is suitable for the sewage system. The wastewater is very corrosive, and contains very toxic heavy metals. Therefore, dispensing it untreated into water sources would harm wildlife and potentially contaminate drinking water. Treating the wastewater, however, must also be done with much care due to its toxicity and corrosiveness. Proper procedure must be followed or else the industrial chemist responsible for this treatment could undergo chemical burns or poisoning.

Unit 4 Question 1

Answer to question one:

- Frequency higher than 20 000Hz (20kHz)
- Propagation of sound waves longitudinal, the mechanical displacement being in the same direction as propagation.
- A medium is needed for sound waves to go through, no medium = no sound waves
- This propagation is whereby the particles of the medium which the sound is going through oscillate (move) back and forth from their original rest positions, in the same line as the wave. This is also known as Simple Harmonic Motion
- The motion of these particles is caused by 2 factors; the pressure of the wave (which forces them to move in the beginning) and the forces of the restoring molecules (also known as the elasticity of the medium)

- The sound waves are transmitted as an alternation series of compressions (zones of high pressure) and rarefactions (zones of low pressure).
- The physical disturbance can be shown in a diagram (the dot diagram), and the individual movement of each particle in the diagram is/ can be described mathematically by the wave equation
- Also the amount of particle movement is dependent on the pressure change associated with the wave, therefore the increased pressure change equals the increased particle movement, and therefore louder sound

Unit 4 Question 2

Answer/hints:

- 1) Application of echo in concert hall is planned for and executed by architectures. The building especially the roofing and ceiling will be done in such a way that the hall it is possible for reverberation to take place. This helps to make the original sound appear prolonged and in the event of multiple reverberations the sound becomes enhanced in the room. A poor concert hall makes musician become disconcerted.
- 2) In baby scan, sound of high frequency above the audible frequency (20,000 Hz) are passed unto the position of the baby in the womb. However, because of differences in tissue density or thickness, reflections from different parts of the woman's body differ and in so doing will be able to make interpretations concerning the baby. There are special ultrasound machines in hospitals and other places where such scan are carried out.

Unit 5 Question 1

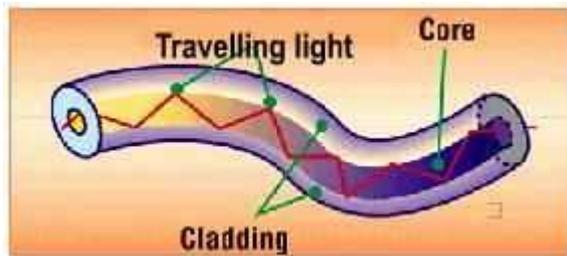
Four applications of total internal reflection are:

- a. Mirage
- b. Production of right angle prism
- c. Production of diamond
- d. Optical fibre production and uses in hospital and communication.
- e. Rear light of bicycle

Any four explained briefly is okay.

Unit 5 Question 2

Optical fibres consist of a very fine quality of glass or quartz fibres. They are coated with thin layer of material of lower refractive index than that of the fibre. The thickness of the strand is 10^{-4} . The optical fibre works on the principle of total internal reflection.



The word total means that reflection in the above case occurs with no loss of intensity. This phenomena enables doctors to inspect many internal body sites. A Bundle of fibres transmit an image that can be inspected visually outside the body. Through a series of reflections the light ray travel through bent tube until it comes out on the other end.