Heat Engine

Combustion: Combustion or burning is a complex sequence of chemical reactions between a fuel and an oxidant accompanied by the production of heat or both heat and light in the form of either a glow or flames.

Heat engine: A heat engine is a system that converts heat or thermal energy—and chemical energy—to mechanical energy, which can then be used to do mechanical work. It does this by bringing a working substance from a higher state temperature to a lower state temperature.

There are two main types of heat engines: external combustion and internal combustion:

- In an **external combustion engine**, the fuel burns outside and away from the main bit of the engine where the force and motion are produced. A steam engine is a good example: there's a coal fire at one end that heats water to make steam. The steam is piped into a strong metal **cylinder** where it moves a tight-fitting plunger called a **piston** back and forth. The moving piston powers whatever the engine is attached to (maybe a factory machine or the wheels of a locomotive). This is an external combustion engine because the coal is burning outside and some distance from the cylinder and piston.
- In an **internal combustion engine**, the fuel burns *inside* the cylinder. In a typical car engine, for example, there are something like four to six separate cylinders inside which gasoline is constantly burning with oxygen to release heat energy. The cylinders "fire" alternately to ensure the engine produces a steady supply of power that drives the car's wheels.

Spark-ignition engine: A **spark-ignition engine** (**SI engine**) is an internal combustion engine, generally a petrol engine, where the combustion process of the air-fuel mixture is ignited by a spark from a spark plug. This is in contrast to compression-ignition engines, typically diesel engines, where the heat generated from compression together with the injection of fuel is enough to initiate the combustion process, without needing any external spark.

Spark-ignition engines are commonly referred to as "gasoline engines" in North America, and "petrol engines" in Britain and the rest of the world. However, these terms are not preferred, since spark-ignition engines can (and increasingly are) run on fuels other than petrol/gasoline, such as autogas (LPG), methanol, ethanol, bioethanol, compressed natural gas (CNG), hydrogen, and (in drag racing) nitromethane.

The working cycle of both spark-ignition and compression-ignition engines may be either two-stroke or four-stroke.

A four-stroke spark-ignition engine is an Otto cycle engine. It consists of following four strokes: suction or intake stroke, compression stroke, expansion or power stroke, exhaust stroke. Each stroke consists of 180 degree rotation of crankshaft rotation and hence a four-stroke cycle is completed through 720 degree of crank rotation. Thus for one complete cycle there is only one power stroke while the crankshaft turns by two revolutions.

Combustion, also known as burning, is the basic chemical process of releasing energy from a fuel and air mixture. In an internal combustion engine (ICE), the ignition and combustion of the fuel occurs within the engine itself. The engine then partially converts the energy from the combustion to work. The engine consists of a fixed cylinder and a moving piston. The expanding combustion gases push the piston, which in turn rotates the crankshaft. Ultimately, through a system of gears in the powertrain, this motion drives the vehicle’s wheels.

The Petrol is ignited in the cylinder by the help of SPARK PLUG by which air fuel mixture burns and thus produces power. This is the reason why these engines are called SPARK IGNITION engines.

Ignition systems have two circuits that result in a spark being fired at the end of a spark plug. The primary circuit is between the battery and the ignition coil. The secondary circuit is between the ignition coil and the spark plug.

A secondary ignition circuit consists of three components and is the basis for newer variations of the ignition system. The three components are:

- The ignition coil
- The distributor
- The spark plug

HOW DOES AN INTERNAL COMBUSTION ENGINE WORK? (4-stroke engines)

There are two kinds of internal combustion engines currently in production: the spark ignition gasoline engine and the compression ignition diesel engine. Most of these are four-stroke cycle engines, meaning four piston strokes are needed to complete a cycle. The cycle includes four distinct processes: intake, compression, combustion and power stroke, and exhaust.

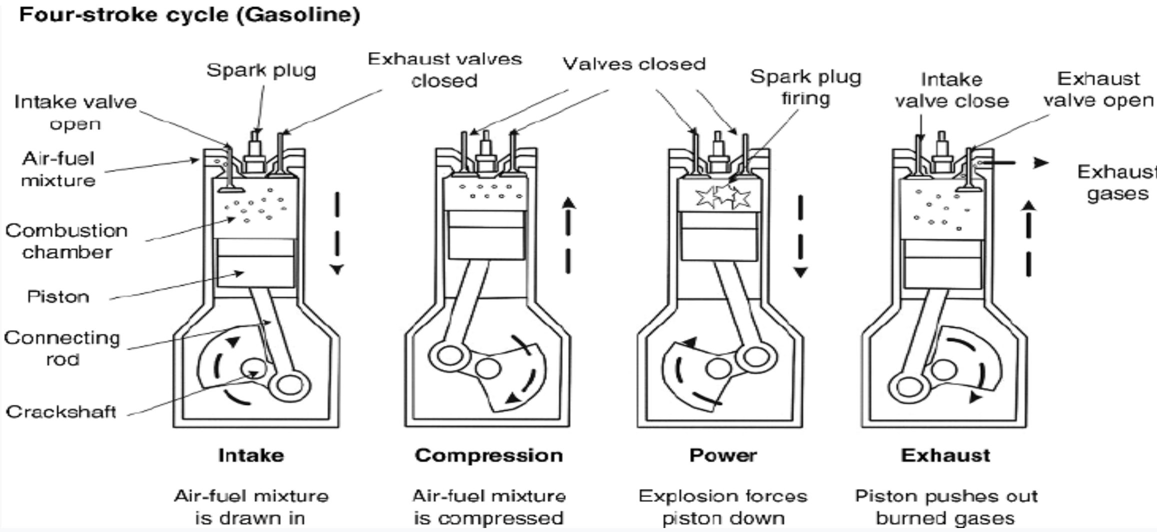

Diagram showing the operation of a 4-stroke SI engine. Labels:

1 - Intake
2 - Compression
3 - Power
4 - Exhaust

The *top dead center* (TDC) of a piston is the position where it is nearest to the valves; *bottom dead center* (BDC) is the opposite position where it is furthest from them. A *stroke* is the movement of a piston from TDC to BDC or vice versa, together with the associated process. While an engine is in operation, the crankshaft rotates continuously at a nearly constant speed. In a 4-stroke ICE, each piston experiences 2 strokes per crankshaft revolution in the following order. Starting the description at TDC, these are:

1. **Intake**, **induction** or **suction**: The intake valves are open as a result of the cam lobe pressing down on the valve stem. The piston moves downward increasing the volume of the combustion chamber and allowing air to enter in the case of a CI engine or an air fuel mix in the case of SI engines that do not use direct injection. The air or air-fuel mixture is called the *charge* in any case.
2. **Compression**: In this stroke, both valves are closed and the piston moves upward reducing the combustion chamber volume which reaches its minimum when the piston is at TDC. The piston performs work on the charge as it is being compressed; as a result its pressure, temperature and density increase; an approximation to this behavior is provided by the ideal gas law. Just before the piston reaches TDC, ignition begins. In the case of a SI engine, the spark plug receives a high voltage pulse that generates the spark which gives it its name and ignites the charge. In the case of a CI engine the fuel injector quickly injects fuel into the combustion chamber as a spray; the fuel ignites due to the high temperature.

3. **Power** or **working stroke**: The pressure of the combustion gases pushes the piston downward, generating more work than it required to compress the charge. Complementary to the compression stroke, the combustion gases expand and as a result their temperature, pressure and density decreases. When the piston is near to BDC the exhaust valve opens. The combustion gases expand irreversibly due to the leftover pressure—in excess of back pressure, the gauge pressure on the exhaust port—; this is called the *blowdown*.
4. **Exhaust**: The exhaust valve remains open while the piston moves upward expelling the combustion gases. For naturally aspirated engines a small part of the combustion gases may remain in the cylinder during normal operation because the piston does not close the combustion chamber completely; these gases dissolve in the next charge. At the end of this stroke, the exhaust valve closes, the intake valve opens, and the sequence repeats in the next cycle. The intake valve may open before the exhaust valve closes to allow better scavenging.

Compression Ignition Engine:

Compression ignition engine or CI engine is an internal combustion engine in which ignition of the fuel takes place with the help of hot compressed air. As the air is compressed, it gets hot and its heat is used for the ignition and burning of the fuel. In this engine the air is sucked during suction stroke and then this air is compressed while compression stroke. At the end of the compression stroke, fuel is injected into the cylinder and it gets ignited from the heat of compressed air and burning process begins. Diesel is used as fuel for the working of this engine. It works on the principle of Diesel Cycle. The compression ratio of this type of engine is usually ranges from 14:1 to 22:1. It is used in heavy duty vehicles like buses, trucks, ships, etc.

The main components of compression ignition (CI) engine are:

1. **Injector:** It is used to inject the fuel into the cylinder during compression of air.
2. **Inlet valve:** The air inside the cylinder is sucked through inlet valve during suction stroke.
3. **Exhaust Valve:** The whole burnt or exhaust from the cylinder thrown out through exhaust valve.
4. **Combustion chamber:** It is a chamber where the combustion of fuel takes place.
5. **Piston:** It is reciprocating part of CI engine which does reciprocating motion inside the cylinder. Its main function is to transmit the thrust force generated during power stroke to the crankshaft through connecting rod.
6. **Connecting rod:** It connects piston to the crankshaft.
7. **Crankshaft:** It is used to convert the reciprocating motion of the piston into rotary motion.

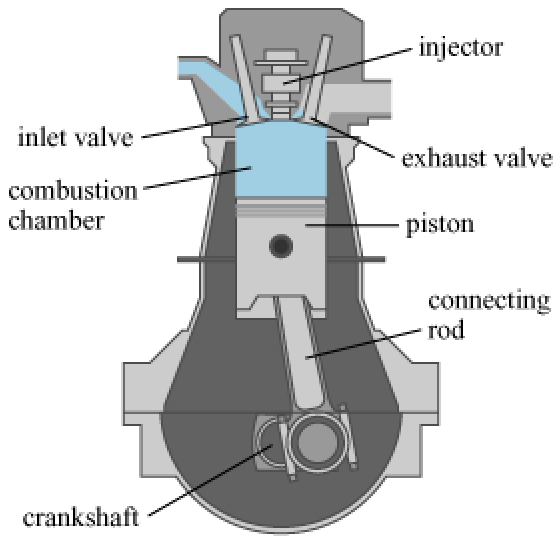

Figure: Compression ignition (CI) engine

Difference between SI and CI engine

Spark ignition gasoline and compression ignition diesel engines differ in how they supply and ignite the fuel. In a spark ignition engine, the fuel is mixed with air and then inducted into the cylinder during the intake process. After the piston compresses the fuel-air mixture, the spark ignites it, causing combustion. The expansion of the combustion gases pushes the piston during the power stroke. In a diesel engine, only air is inducted into the engine and then compressed. Diesel engines then spray the fuel into the hot compressed air at a suitable, measured rate, causing it to ignite.

Topics	**CI Engine**	**SI Engine**
Intake	Only air.	Air and Fuel.
Mode of combustion	Highly pressurized fuel spray and Highly pressurized air.	Pressurized air-fuel mixture and Spark.
Fuel supply	Injector.	Carburetor.
Fuel properties	High viscous, low auto-ignition temperature, less mixing property. Ex: Diesel.	Less viscous, high auto-ignition temperature, better mixing property. Ex. Petrol.

Engine type	Low speed engine, high Compression ratio.	High speed engine, less compression ratio.
Application	Heavy duty vehicles.	Light commercial vehicles.

Why are diesel engines more efficient than gasoline engines?

We all know that diesel engine is the most appropriate choice of the engineers when it comes to drive heavy automobile like trucks, aircraft, ships etc.

Following are the reasonable points that conclude the high torque and efficiency of diesel engine.

Diesel engine uses simple mechanism for combustion unlike in gasoline engine. Removal of ignition system not only makes the mechanism simpler but also reduces the risk of improper combustion due to damage in ignition system. In short burning of the fuel is easy and always accessible. This results in higher efficiency diesel engine.

Diesel fuel is a heavier hydrocarbon in which carbon and hydrogen are strongly bonded with each other. And when energy is supplied in form of heat it gets explode releasing much higher energy then gasoline. In short diesel fuel has higher energy density then gasoline which results in huge explosion.

One more factor for higher efficiency in diesel engine is its property of lubrication. Although all fuel has property of lubrication but diesel fuel has much higher lubrication then gasoline fuel.

The compression ratio is much higher in diesel as compared to gasoline because in diesel engine air is alone compressed inside the cylinder and it’s a known fact that gas easily compresses then liquid. This is not so in gasoline engine because air-fuel mixture is compressed inside the cylinder. This higher compression gives higher heat and simultaneously higher torque.

We can’t use Carnot cycle to get 100% efficiency but can use its principle to attain maximize efficiency. In diesel engine heat is added at constant pressure which results in higher utilization of heat energy to get maximize work output.

These were the advantageous features of diesel engine but it has some demerits as well like ***it releases highly toxic gases, noisy, higher maintenance cost and starting problem to heat the engine before ignition.***

It is costlier than gasoline engine but with optimum operation and good maintenance resolve all these problems.

Knocking: Knocking, in an internal-combustion engine, sharp sounds caused by premature combustion of part of the compressed air-fuel mixture in the cylinder. In a properly functioning engine, the charge burns with the flame front progressing smoothly from the point of ignition across the combustion chamber.

Effect of Knocking

The impact of knock on the engine components and structure can cause engine failure.

In addition, the noise from engine vibration is always objectionable. The pressure difference in the combustion chamber causes the gas to vibrate and scrub the chamber walls causing increased loss of heat to the coolant. Fuel consumption of engine increases drastically as heat energy is lost during knocking. The same reason also affects the power output which is observable at the time of acceleration.

Factors Affecting Knock

From the above discussion on knock, it may be seen that four major factors are involved in either producing or preventing knock. These are the temperature, pressure, density of the unburned charge and the time factors.

Temperature factor includes inlet temperature of the mixture and temperature of the combustion chamber walls. Increase in inlet temperature of the mixture makes the charge more vaporized than the required at the end of compression. This increases the tendency of knocking. Temperature of the combustion chamber walls plays a predominant role in knocking. In order to prevent knocking the hot spot in the combustion chamber should be avoided. Since, the spark plug and exhaust valve are two hottest parts in the combustion chamber; they mostly converted in to sources of auto ignition after a long run. Furthermore, most of the two wheelers use air cooling which is not at all efficient to cool these two hottest parts. This is the main reason because of which a single cylinder engine could also have knocking problem.

Pressure factor includes the final pressure of fresh charge that it can reach after completion of compression stroke. Obviously, high pressure again converted in to high temperature factor and boosts the knocking process. No doubt, pressure factor is not at possible to control externally. It depends only on design parameters of engine.

Density factor comprises mass of inducted charge and fuel-air ratio. A reduction in the mass of the inducted charge into the cylinder of an engine by throttling reduces both temperature and density of the charge at the time of ignition. This decreases the tendency of knocking.

The flame speeds are affected by fuel-air ratio. Also the flame temperature and reaction time are different for different fuel-air ratios. So tendency of fresh charge to reach up to its self-ignition temperature directly depends on the composition of that charge. As the carburetor or injection systems are the only responsible components for fuel-air ratios, it is advisable to keep them cleaned and tuned to avoid knocking.

Time factors consist of engine speed and spark timing. An increase in engine speed increases the turbulence of the mixture considerably resulting in increased flame speed, and reduces the time available for pre-flame reactions. Hence knocking tendency is reduced at higher speed. Adversely, prolonged high speed increases working temperature of engine and increases amount of hot spots, so prolonged and constant high speed should be avoided to minimize the knocking. Wrong spark timing always leads to incomplete combustion. This incomplete combustion can be possible either as pre-ignition or post-ignition. Both these incomplete combustion increases knocking tendency.

Miscellaneous factors include location of spark plug and octane value of the fuel. In order to have a minimum flame travel, the spark plug is located at proper place in the combustion chamber. DTSI, DTS-SI and now three spark plugs (Pulsar 200) are few of the examples where efforts have been made to reduce flame travel by igniting the fresh charge from different locations, of course in proper manner. High octane fuel has the higher self-ignition temperature and low pre-flame reactivity which reduces the tendency of knocking.

How to Recognize Knock

Following are some symptoms which can help to identify the knock.

- Metallic sound in harmony with engine firing
- Sound comes out after long running
- Sound disappears at idle speed
- Drastic drop in fuel efficiency
- Drop in power output
- Engine run with high temperature and noise

Refrigeration, or cooling process, is the removal of unwanted heat from a selected object, substance, or space and its transfer to another object, substance, or space. Removal of heat lowers the temperature and may be accomplished by use of ice, snow, chilled water or mechanical refrigeration.

Mechanical refrigeration, is the utilization of mechanical components arranged in a **"*refrigeration system*"** for the purpose of transferring heat.

Refrigerants, are chemical compounds that are alternately compressed and condensed into a liquid and then permitted to expand into a vapor or gas as they are pumped through the mechanical refrigeration system to cycle.

STATES OF MATTER

All known matter exists in one of three physical forms or states: solid, liquid, or gaseous. There are distinct dissimilarities among these physical states namely:

- Matter in a liquid state will retain its quantity and size but not its shape. The liquid will always conform to the occupying container. If a cubic foot of water in a container measuring 1 foot on each side is transferred to a container of different rectangular dimensions, the quantity and volume of the water will be the same although the dimension will change.

- Matter in solid state will retain its quantity, shape, and physical dimensions. A cubic foot of wood will retain its weight, size, and shape even if moved from place to place.

- Matter in gaseous state does not have a tendency to retain either its size or its shape. If a one foot cylinder containing steam or some other gas is connected to a 2-cubic foot cylinder on which a vacuum has been drawn, the vapor will expand to occupy the volume of the large cylinder. Although these specific differences exist in the three states of matter, quite frequently, under changing conditions of pressure and temperature, the same substance may exist in any one of the three states, such as a solid, a liquid, or vapor (ice, water, and steam, for example). Solids always have some definitive shape, whereas liquids and gases have no definitive shape of their own, but will conform to the shape of their containers.

MOLECULAR MOVEMENT

All matter is composed of small particles known as molecules, for the present we will concern ourselves only with the molecule, the smallest particle into which any matter or substance can be broken down and still retain its identity. Molecules vary in shape, size, and weight. In physics we learn that molecules have a tendency to cling together. When heat energy is applied to a substance it increases the internal energy of the molecules, which increase their motion or velocity of movement. With this increase in the movement of the molecules, there is also rise or increase in the temperature of the substance. When heat is removed from a substance, it follows that the velocity of the molecular movement will decrease and also that there will be a decrease or lowering of the internal temperature of the substance.

CHANGE OF STATE

When a solid substance is heated, the molecular motion is chiefly in the form of rapid motion back and forth, the molecules never moving far from their normal or original position. But at some given temperature for that particular substance, further addition of heat will not necessarily increase the molecular motion within the substance; instead, the additional heat will cause some solids to liquefy (change into a liquid). Thus the additional heat causes a change of state in the material.

The temperature at which this change of state in a substance takes place is called its ***melting point***. Let us assume that a container of water at 70 deg F, in which a thermometer has been placed, is left in the freezer for hours. When it is taken from the freezer, it has become a block of ice - ***solidification*** has taken place. Let us further assume that the thermometer in the ice block indicates a temperature of 20 deg F.

If it is allowed to stand at room temperature, heat from the room air will be absorbed by the ice until the thermometer indicates a temperature of 32 deg F, when some of the ice will begin to change into water. With heat continuing to transfer from the room air to the ice, more ice will change back into the water; but the thermometer will continue to indicate a temperature a temperature of 32 deg F until all the ice has melted. ***Liquefaction*** has now taken place.

As mentioned, when all the ice is melted, the thermometer will indicate a temperature of 32ºF, but the temperature of the water will continue to rise until it reaches or equals room temperature. If sufficient heat is added to the container of water through outside means such as a burner, the temperature of the water will increase until it reaches 212ºF, at this temperature, and under "standard" atmospheric pressure, another change will take place - ***vaporization***. Some of the water will vaporize into steam and, with the addition of more heat, all of the water will vaporize into steam; yet the temperature of the water will not increase above 212ºF.

Thus far we have learned how solids can change into liquid, and how a liquid can change in to a vapor but it is possible for a substance to undergo a physical change through which solid will change directly into a gaseous state without first melting into a liquid. This is known as a ***sublimation***. As an example, dry ice (CO_2) at atmospheric conditions sublimes directly into vapor. Let us review these changes of state: a) SOLIDIFICATION - a change from a liquid to a solid. LIQUEFACTION - a change from a solid to a liquid. VAPORIZATION - a change from a liquid to a vapor. CONDENSATION - a change from a vapor to a liquid. SUBLIMATION - a change from a solid to a vapor without passing through the liquid state.

WHY DO WE USE THE TERM "COMPRESSION"?

The **Vapor Compression Refrigeration Cycle involves four components:** compressor, condenser, expansion valve/throttle valve and evaporator.

It is a compression process, whose aim is to raise the refrigerant pressure, as it flows from an evaporator. The high-pressure refrigerant flows through a condenser/heat exchanger before attaining the initial low pressure and going back to the evaporator. A more detailed explanation of the steps is as explained below.

STEP 1: COMPRESSION

The refrigerant enters the compressor at low temperature and low pressure. It is in a gaseous state. Here, **compression takes place to raise the temperature and refrigerant pressure**. The refrigerant leaves the compressor and enters to the condenser. Since this process requires work, an electric motor may be used. Compressors themselves can be scroll, screw, centrifugal or reciprocating types.

STEP 2: CONDENSATION

The condenser is essentially a heat exchanger. **Heat is transferred from the refrigerant to a flow of water.** This water goes to a cooling tower for cooling in the case of water-cooled condensation. Note that seawater and air-cooling methods may also play this role. As the refrigerant flows through the condenser, it is in a constant pressure.

One cannot afford to ignore condenser safety and performance. Specifically, pressure control is paramount for safety and efficiency reasons. There are several pressure-controlling devices to take care of this requirement

STEP 3: THROTTLING AND EXPANSION

When the refrigerant enters the throttling valve, it expands and releases pressure. **Consequently, the temperature drops at this stage.** Because of these changes, the refrigerant leaves the throttle valve as a liquid vapor mixture, typically in proportions of around 75 % and 25 % respectively.

Throttling valves play two crucial roles in the vapor compression cycle. First, they maintain a pressure differential between low- and high-pressure sides. Second, they control the amount of liquid refrigerant entering the evaporator.

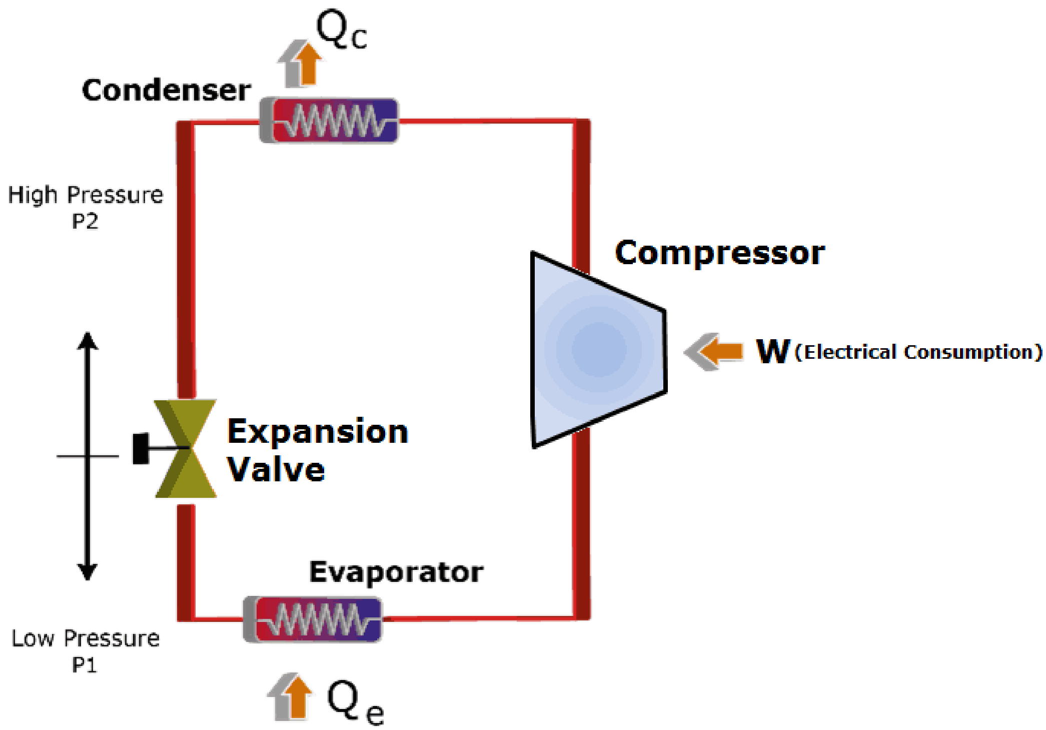

Fig 1: Schematic Representation of the Steps

STEP 4: EVAPORATION

At this stage of the Vapor Compression Refrigeration Cycle, the refrigerant is at a lower temperature than its surroundings. Therefore, **it evaporates and absorbs latent heat of vaporization**. Heat extraction from the refrigerant happens at low pressure and temperature. Compressor suction effect helps maintain the low pressure.

Impact on agriculture and food production

Agriculture's role in developed countries has drastically changed in the last century due to many factors, including refrigeration. Statistics from the 2007 census gives information on the large concentration of agricultural sales coming from a small portion of the existing farms in the United States today. This is a partial result of the market created for the frozen meat trade by the first successful shipment of frozen sheep carcasses coming from New Zealand in the 1880s. As the market continued to grow, regulations on food processing and quality began to be enforced. Eventually, electricity was introduced into rural homes in the United States, which allowed refrigeration technology to continue to expand on the farm, increasing output per person. Today, refrigeration's use on the farm reduces humidity levels, avoids spoiling due to bacterial growth, and assists in preservation.

1) Demographics

The introduction of refrigeration and evolution of additional technologies drastically changed agriculture in the United States. During the beginning of the 20th century, farming was a common occupation and lifestyle for United States citizens, as most farmers actually lived on their farm. In 1935, there were 6.8 million farms in the United States and a population of 127 million. Yet, while the United States population has continued to climb, citizens pursuing agriculture continue to decline. Based on the 2007 US Census, less than one percent of a population of 310 million people claim farming as an occupation today. However, the increasing population has led to an increasing demand for agricultural products, which is met through a greater variety of crops, fertilizers, pesticides, and improved technology. Improved technology has decreased the risk and time involved if agricultural management and allows larger farms to increase their output per person to meet society's demand.[36]

2) Meat packing and trade

Prior to 1882, the South Island of New Zealand had been experimenting with sowing grass and crossbreeding sheep, which immediately gave their farmers economic potential in the exportation of meat. In 1882, the first successful shipment of sheep carcasses was sent from Port Chalmers in Dunedin, New Zealand, to London. By the 1890s, the frozen meat trade became increasingly more profitable in New Zealand, especially in Canterbury, where 50% of exported sheep carcasses came from in 1900. It wasn't long before Canterbury meat was known for the highest quality, creating a demand for New Zealand meat around the world. In order to meet this new demand, the farmers improved their feed so sheep could be ready for the slaughter in only seven months. This new method of shipping led to an economic boom in New Zealand by the mid 1890s.

In the United States, the Meat Inspection Act of 1891 was put in place in the United States because local butchers felt the refrigerated railcar system was unwholesome.[38] When meat packing began to take off, consumers became nervous about the quality of the meat for consumption. Upton Sinclair's 1906 novel *The Jungle* brought negative attention to the meat packing industry, by drawing to light unsanitary working conditions and processing of diseased animals. The book caught the attention of President Theodore Roosevelt, and the 1906 Meat Inspection Act was put into place as an amendment to the Meat Inspection Act of 1891. This new act focused on the quality of the meat and environment it is processed in.[39]

3) Electricity in rural areas

In the early 1930s, 90 percent of the urban population of the United States had electric power, in comparison to only 10 percent of rural homes. At the time, power companies did not feel that extending power to rural areas (rural electrification) would produce enough profit to make it worth their while. However, in the midst of the Great Depression, President Franklin D. Roosevelt realized that rural areas would continue to lag behind urban areas in both poverty and production if they were not electrically wired. On May 11, 1935, the president signed an executive order called the Rural Electrification Administration, also known as REA. The agency provided loans to fund electric infrastructure in the rural areas. In just a few years, 300,000 people in rural areas of the United States had received power in their homes.

While electricity dramatically improved working conditions on farms, it also had a large impact on the safety of food production. Refrigeration systems were introduced to the farming and food distribution processes, which helped in food preservation and kept food supplies safe. Refrigeration also allowed for production of perishable commodities, which could then be shipped throughout the United States. As a result, the United States farmers quickly became the most productive in the world,[40] and entire new food systems arose.

4) Farm use

In order to reduce humidity levels and spoiling due to bacterial growth, refrigeration is used for meat, produce, and dairy processing in farming today. Refrigeration systems are used the heaviest in the warmer months for farming produce, which must be cooled as soon as possible in order to meet quality standards and increase the shelf life. Meanwhile, dairy farms refrigerate milk year round to avoid spoiling.

Impact on nutrition

The introduction of refrigeration allowed for the hygienic handling and storage of perishables, and as such, promoted output growth, consumption, and the availability of nutrition. The change in our method of food preservation moved us away from salts to a more manageable sodium level. The ability to move and store perishables such as meat and dairy led to a 1.7% increase in dairy consumption and overall protein intake by 1.25% annually in the US after the 1890s.

People were not only consuming these perishables because it became easier for they themselves to store them, but because the innovations in refrigerated transportation and storage led to less spoilage and waste, thereby driving the prices of these products down. Refrigeration accounts for at least 5.1% of the increase in adult stature (in the US) through improved nutrition, and when the indirect effects associated with improvements in the quality of nutrients and the reduction in illness is additionally factored in, the overall impact becomes considerably larger. Recent studies have also shown a negative relationship between the number of refrigerators in a household and the rate of gastric cancer mortality

Application of Refrigeration:

Probably the most widely used current applications of refrigeration are for air conditioning of private homes and public buildings, and refrigerating foodstuffs in homes, restaurants and large storage warehouses. The use of refrigerators in kitchens for storing fruits and vegetables has allowed adding fresh salads to the modern diet year round, and storing fish and meats safely for long periods. The optimum temperature range for perishable food storage is 3 to 5 °C (37 to 41 °F).

In commerce and manufacturing, there are many uses for refrigeration. Refrigeration is used to liquefy gases – oxygen, nitrogen, propane, and methane, for example. In compressed air purification, it is used to condense water vapor from compressed air to reduce its moisture content. In oil refineries, chemical plants, and petrochemical plants, refrigeration is used to maintain certain processes at their needed low temperatures (for example, in alkylation of butenes and butane to produce a high-octane gasoline component). Metal workers use refrigeration to temper steel and cutlery. When transporting temperature-sensitive foodstuffs and other materials by trucks, trains, airplanes and seagoing vessels, refrigeration is a necessity.

Dairy products are constantly in need of refrigeration, and it was only discovered in the past few decades that eggs needed to be refrigerated during shipment rather than waiting to be refrigerated after arrival at the grocery store. Meats, poultry and fish all must be kept in climate-controlled environments before being sold. Refrigeration also helps keep fruits and vegetables edible longer.

One of the most influential uses of refrigeration was in the development of the sushi/sashimi industry in Japan. Before the discovery of refrigeration, many sushi connoisseurs were at risk of contracting diseases. The dangers of unrefrigerated sashimi were not brought to light for decades due to the lack of research and healthcare distribution across rural Japan. Around mid-century, the Zojirushi corporation, based in Kyoto, made breakthroughs in refrigerator designs, making refrigerators cheaper and more accessible for restaurant proprietors and the general public.