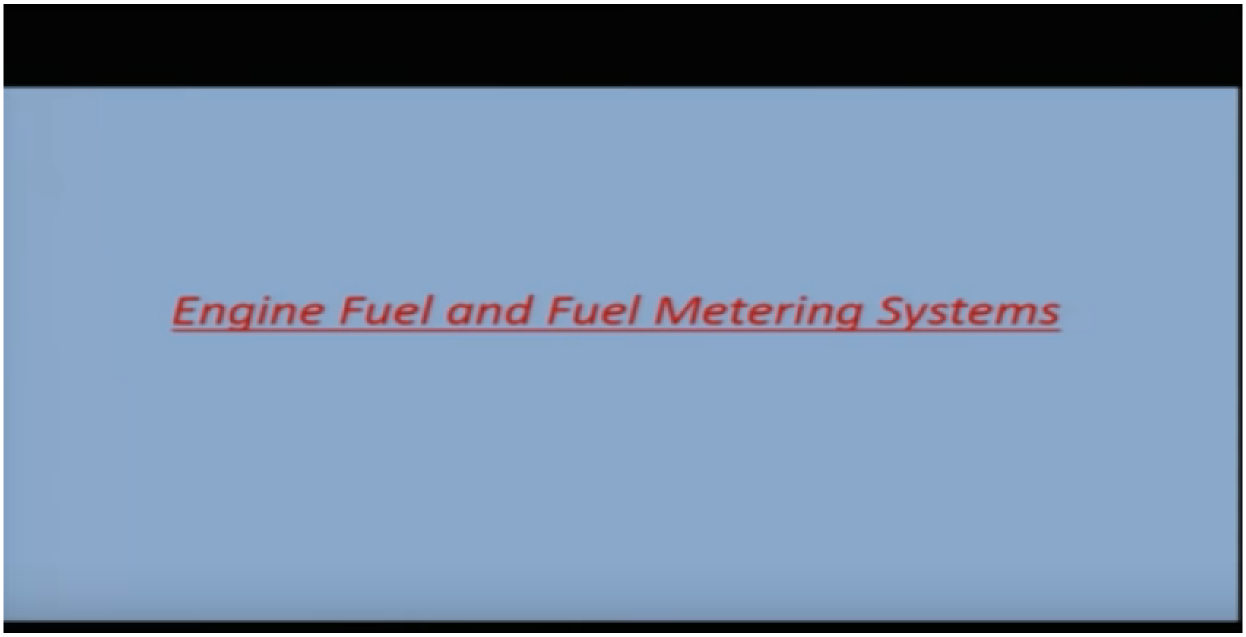
Lecture 14
Engine fuel and Fuel Metering Systems

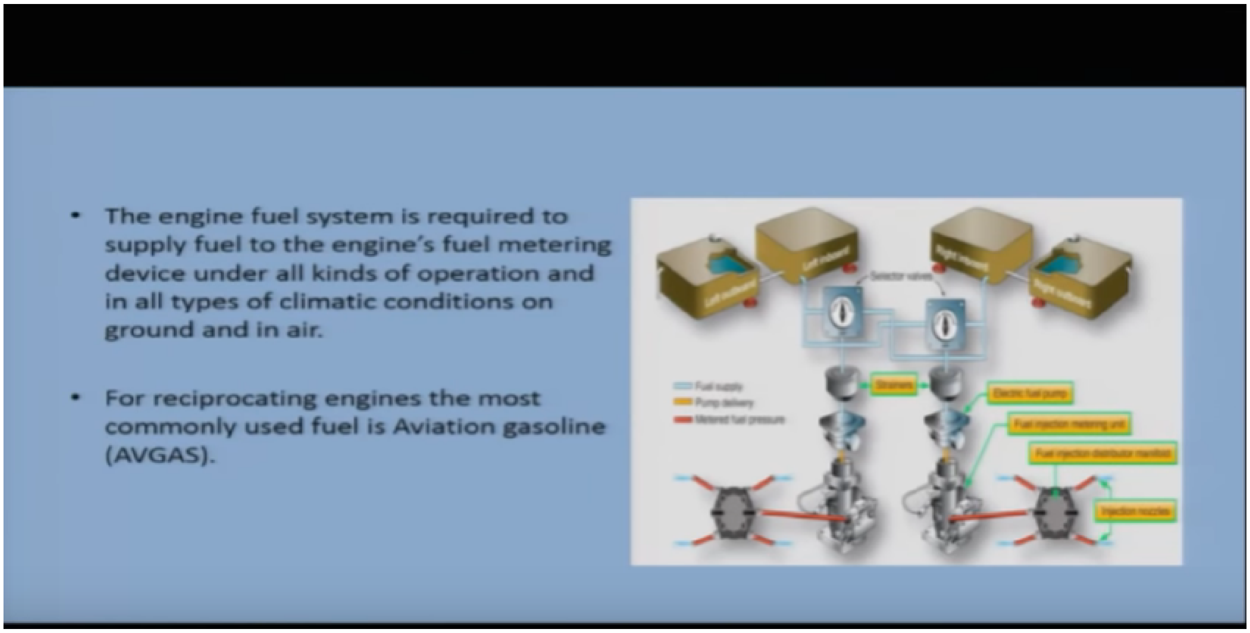
So, today, we are going to, look into the Engine Fuel and Fuel Metering System.

Refer slide time :(0:19)



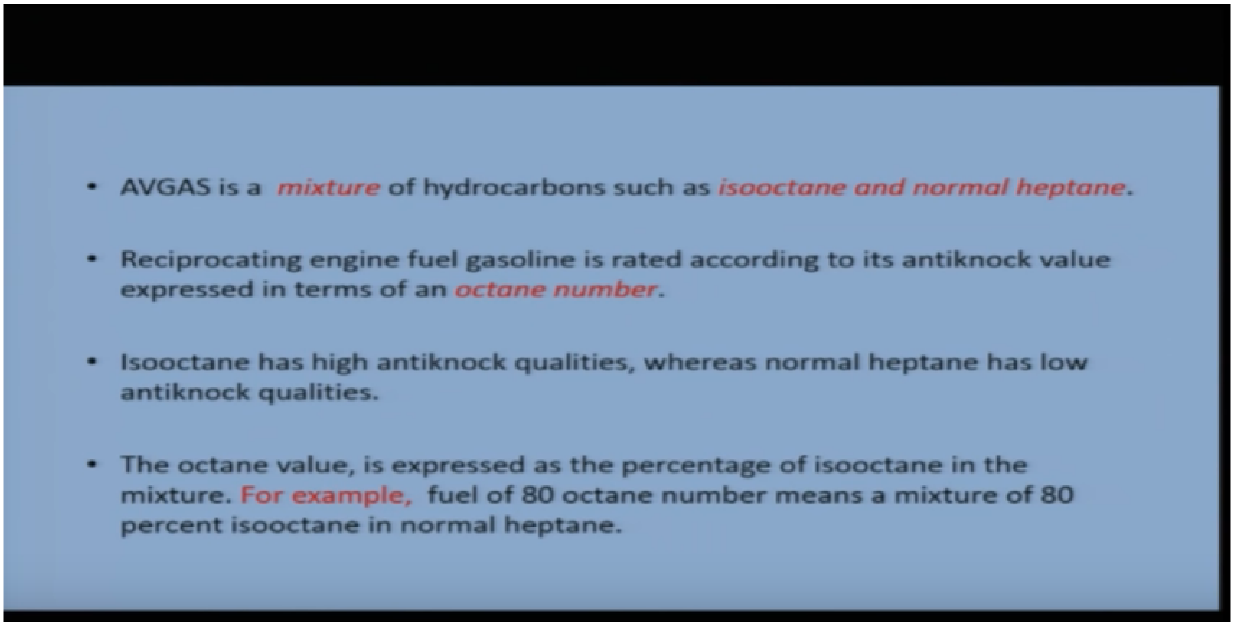
The fuel system of an aircraft is the fuel system, for the airframe and the engine fuel system together. Now the airframe fuel system, is the fuel system which starts, from the fuel tanks, from the fuel tanks, the fuel comes to the selector valve to the collector tank, to the fuel pumps, filters and then to the engine driven fuel pump, up till the filter, the fuel system, is the airframe fuel system and from the engine driven fuel pump, it is the engine fuel system. So, let us see what the engine fuel and fuel metering system is all about.

Refer slide time :(0:19)



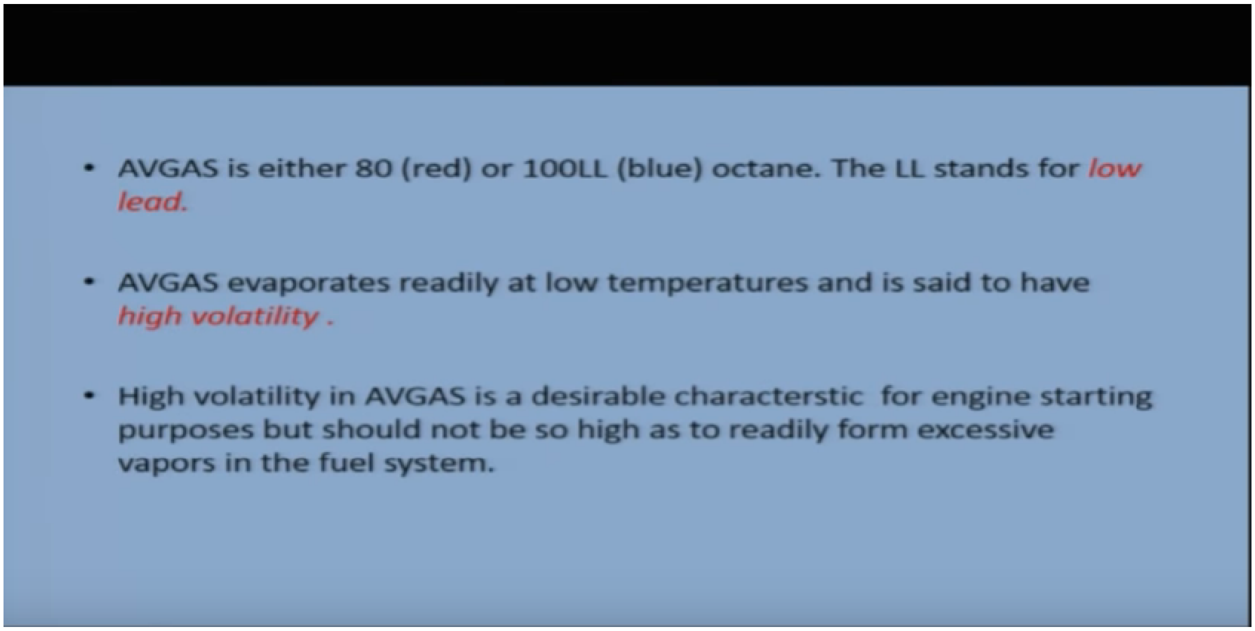
So, the engine fuel system is required, to supply fuel to the engines, fuel metering device, under all kinds of operation and in all types of climatic conditions, on ground and in air. So, the fuel system, the engine fuel system, it is required to supply fuel, under all climatic conditions and under all kinds of operation, whether the operation is on ground, whether the operation is on air. So, in all types of conditions, the fuel system, is supposed to supply fuel, in reciprocating engines the most commonly used, fuel is aviation gasoline, we call it f gas aviation gasoline, which is the most common type of fuel, used in the reciprocating engines. Now you can see the figure, tanks have been shown, the fuel tanks, the fuel is stored in the fuel tanks, you can see here the fuel tanks, for the right wing and the left wing, then you have the fuel tanks, which are coming to the selector wall you can see the selector, valve here from the selector ball, it is coming to the filter, from the filter, it is coming to the electrical fuel pump. Now till this point till the electrical fuel pump, this is your airframe fuel system, the engine fuel system starts, from the engine driven fuel pump although the engine driven fuel pump is not shown, in this figure the engine fuel system starts from the engine driven fuel pump. And from the engine driven fuel pump, it goes to the fuel injector or the fuel air control unit, from the fuel air control unit, it is going to the fuel manifold and then to the nozzles, we will study, about the system in our further slides, but the idea behind this slide, is to tell you, that the airframe fuel system, is up to the electrical fuel pump and the engine fuel system starts from the engine, driven fuel pump.

Refer slide time :(02:58)



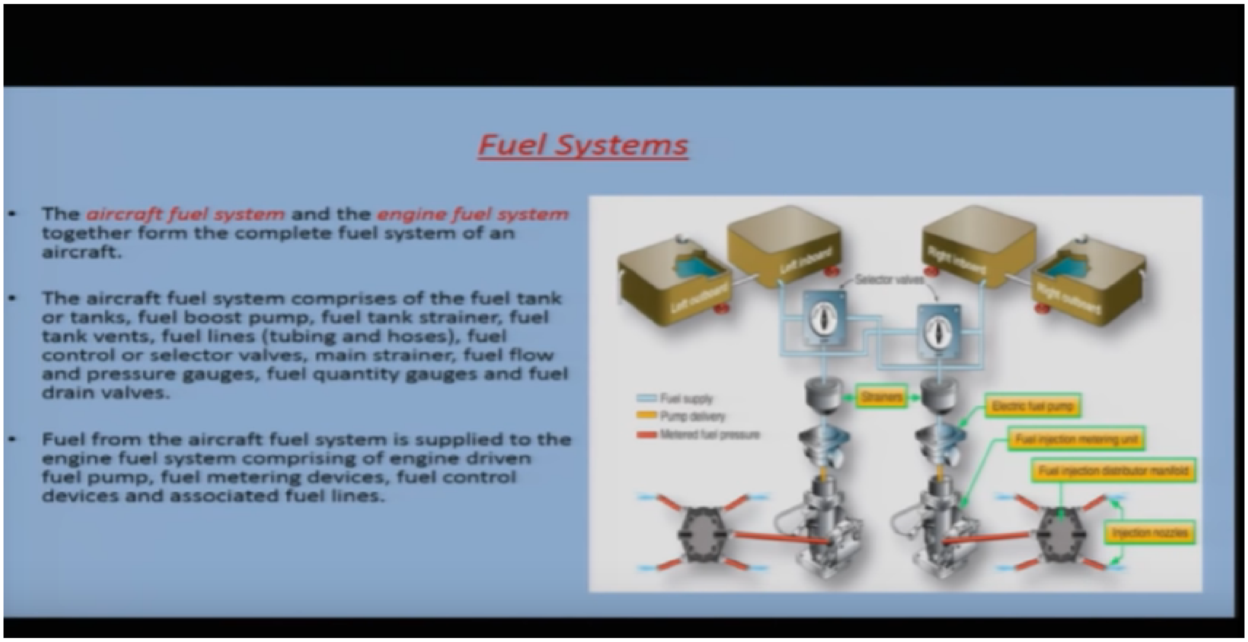
Coming to any aviation gasoline, emulation gasoline is a mixture of hydrocarbons such as, ISO octane and normal Heptanes. So, the aviation gasoline it is a mixture of hydrocarbons, which has isooctane and normal Heptane, the reciprocating engine fuel gasoline is rated according to its antiknock value, expressed in terms of an octane number. So, the fuel which is being used, in the aircraft engine is rated in terms of an octane number and this octane number, is on the basis of the antiknock value of the fuel, we will see in our another slide, that what is antiknock what is knocking? So, as per the antiknock value, the fuel is designated an octane number, isooctane has high antenna quality, now whereas normal hot pain has low antiknock qualities. So, the since the gasoline, is a mixture of hydrocarbons, with isooctane and normal Heptanes, isooctane has got high antiknock quality, whereas normal Heptane has low antiknock quality. So, high antiknock quality is desirable. So, we will see the octane value, how is it expressed the octane value is expressed as the percentage of isooctane in the mixture. So, the percentage of isooctane in the mixture, is expressed as the octane value, for example fuel of 80 octane number means, a mixture of 80 percent isooctane, in normal Heptane. So, 80 octane fuel means, it has 80% isooctane, in normal Heptane.

Refer slide time :(04:36)



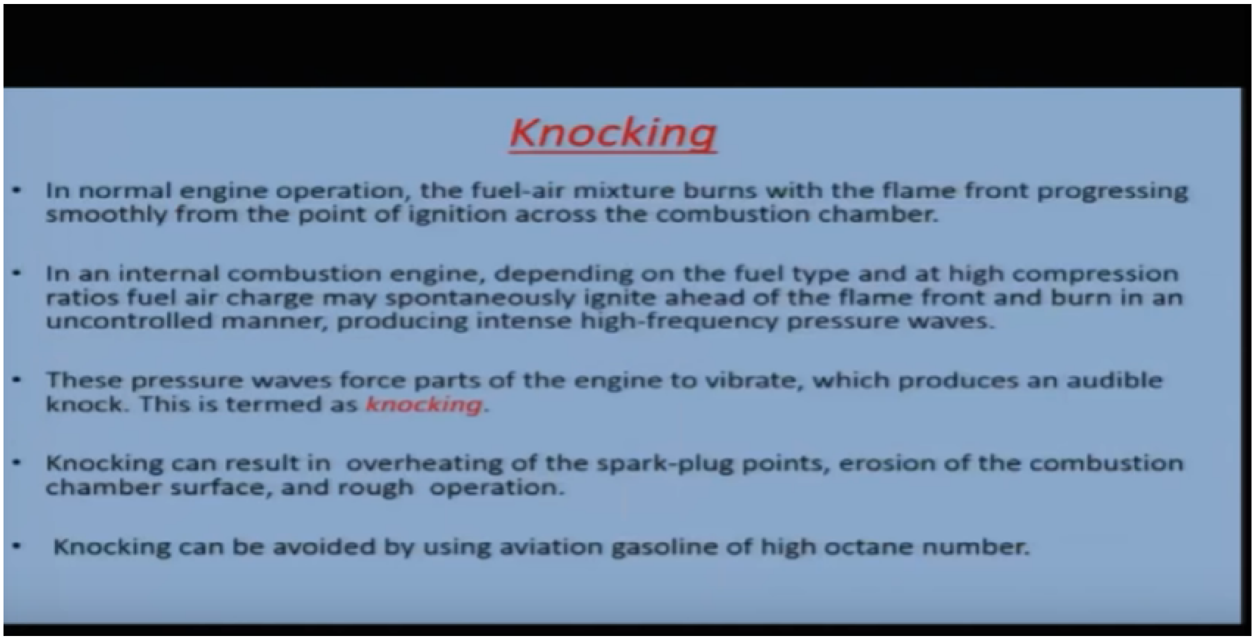
Aviation gasoline it can be either colored, red or it can be in color the red-colored is has an octane number, of 80 whereas the blue colored aviation gasoline has hundred octane number it is termed as 100 LL and the LL stands for low lead, aviation gasoline has the property, of evaporating, readily at low temperatures and is said to have high volatility. Now this aviation gasoline this evaporates very easily, at low temperatures and is said to be highly volatile highly welled high volatility, is in aviation gasoline, is a desirable characteristic, it is a desirable characteristic, for engine starting purposes because, it helps in combustion, but it should not be so, high as to readily form excessive, vapors in the fuel system. Now in case if the fuel is highly volatile, that it may cause a negative effect also it may vaporize, very easily in the fuel lines and cause vapor pockets, which may finally result in fuel starvation. So, the aviation gasoline should have high volatility, but it should not be so, high that it forms excessive vapors in the system.

Refer slide time :(05:57)



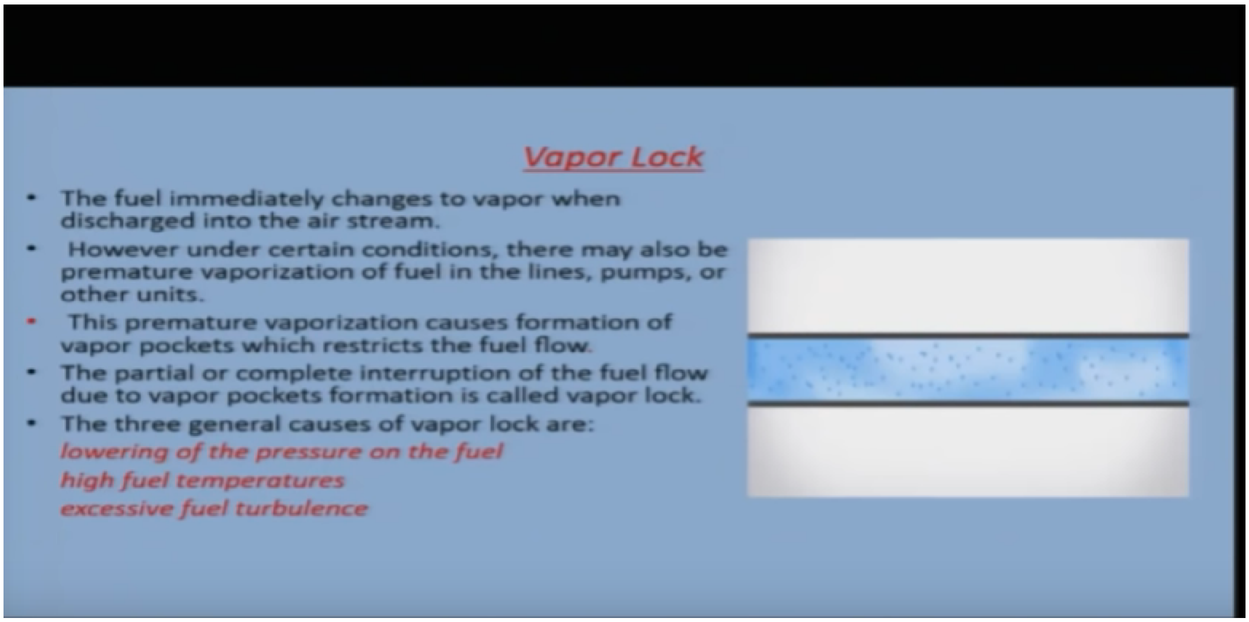
Now again coming to the fuel system, the aircraft fuel system and the engine fuel system here, it is the same diagram, you can see the aircraft fuel system and engine fuel system, they together form the complete fuel system, of an aircraft, the aircraft fuel system comprises, of the fuel tank or tanks fuel booster pumps, fuel strainers fuel tank, vents lines control or selector bolts, main strainers fuel flow and pressure gauges, fuel quantity gauges and fuel drain valves. Now the aircraft fuel system, it has got fuel tanks, to store the fuel, the fuel tanks, will store the fuel the fuel booster pump, it is a pump to boost the fuel, to provide positive pressure to the fuel, fuel tanks trainers are required to filter the fuel, in the tank, that fuel which is coming out, of the tank, is filtered. So, every tank has got a strainer a filter. So, that filtered fuel is coming out of the tank, fury tank two tanks. Now the tanks are vented to the atmosphere. So, that positive pressure is acting on the fuel, so, all the tanks are wintered. So, they have the vent lines, fuel lines, now the proper fuel lines are required, to transfer fuel from one place to another. So, fuel lines are their fuel, control or selector valve. So, fuel selector valve are required the main strainer, that is your main filter, it's just at the lowest point of the system, it is required to filter, out the fuel which is coming out of the system, then you have gauges you have instruments, you have the fuel flow gauge, you have the pressure gauge, edge to measure the, fuel flow to measure the fuel pressure, in the system, you have fuel quantity gauges, to measure the quantity of fuel in each tank and you have fuel drain valves. So, all these things they comprise, the aircraft fuel system, but all these things, may not be there, in every system, in every aircraft fuel system, it depends on type 2 type on aircraft type on aircraft, manufacturer, you may have some of these things, but ideally in an ideal system, you'll have all these things. Now from the aircraft fuel system, fuel is supplied, to the engine fuel system so, the fuel from the a aircraft system, is being supplied to the engine fuel system, which consists of the engine driven fuel pump, the fuel metering devices, it can be fuel metering devices, it can be a carburetor, it can be a injector, we will read about these metering devices, in our further slides, fuel control devices and the associated fuel lines. So, you have seen the airframe fuel system, the aircraft fuel system and the engine fuel system, together this forms the fuel system of the complete aircraft.

Refer slide time :(08:47)



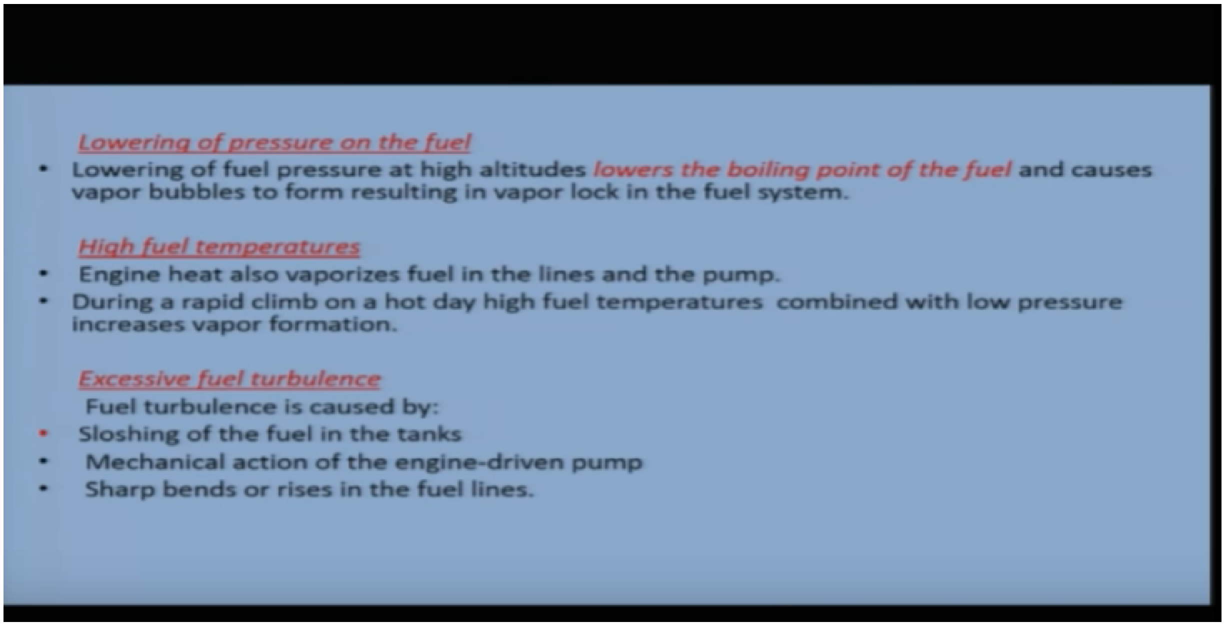
Now what is knocking, we have seen in our previous slide, that aviation gasoline it is rated in terms, of octane number and high octane number fuel is required. So, let us see what is knocking? Because high octane number fuel is required as, it has knocking qualities, anti knocking properties. So, let us see what is knocking? In normal engine operation, the fuel air mixture burns, with the flame front progressing smoothly, from the point of ignition, across the combustion chamber. So, in the normal operation, the fuel burns is smoothly, the flame front progresses smoothly, from the ignition point and all across the combustion chamber. So, this is your normal operation, now in an internal combustion, engine depending on the fuel type and at high compression ratios. So, in case if the fuel type is of a different, type or your engine is of a very high compression ratio, then the fuel may burn spontaneously, the fuel layer charge may burn spontaneously, ahead of the flame front. So, just ahead of the flame, front the fuel may burn spontaneously and in an uncontrolled manner. So, in normal operation, the fuel was burning smoothly and the flame front was progressing smoothly, from the point of ignition, but in this case the flame, the ignition may be spontaneous, maybe, in an uncontrolled manner, it may be ahead of the flame front and it will produce, intense high-frequency pressure, we these pressure waves, will cause the engine to vibrate, which will produce an audible knock, this is termed as knocking. So, because of these pressure waves, there will be severe vibration in the engine, which will produce an audible, knock and it is termed as knocking, it can result, in overheating of the spark plug points. So, spark plug points, can be overheated, the combustion chamber surfaces may be eroded and the engine may operate roughly. So, knocking has got so, many disadvantages, overheating of the spark plug points, erosion of the combustion chamber, surface and rough operation, knocking can be avoided by using aviation gasoline of high octane number. So, high octane number, fuel is desirable and it has anti knocking qualities.

Refer slide time :(11:18)



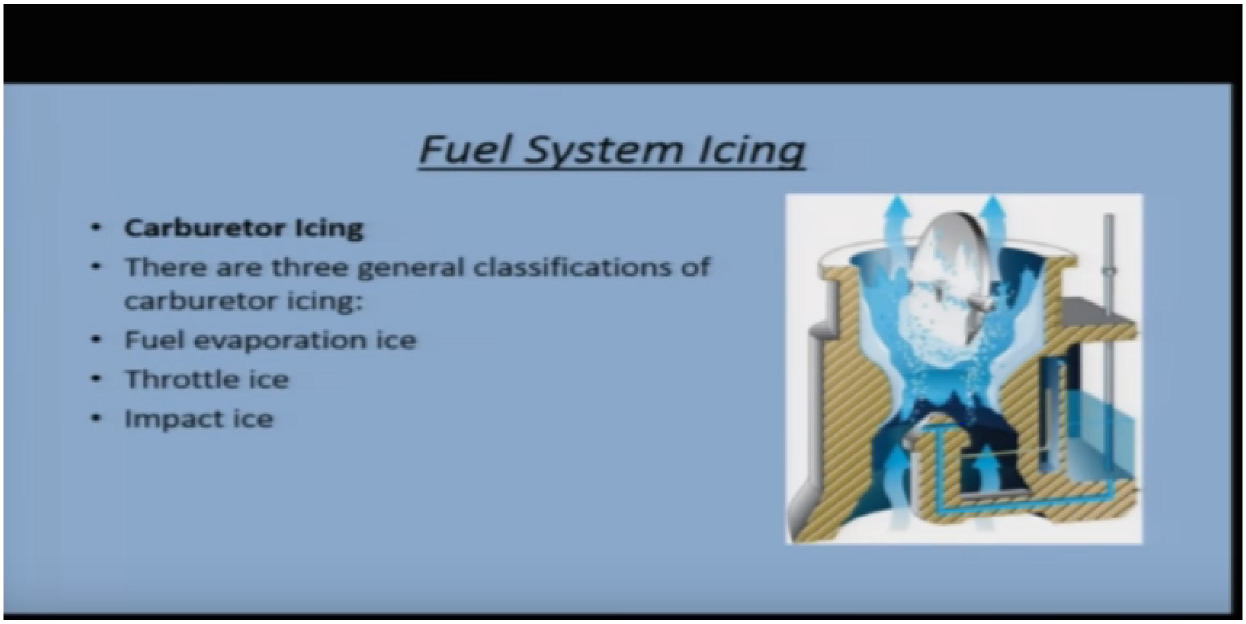
Now what is vapor lock, the fuel immediately changes to vapor when it is discharged into the airstream? So, as soon as the fuel, is discharged into the Airstream, it vaporizes it forms into vapor, however under certain conditions, there may also be premature by vaporization of fuel in the lines, pumps or other units, but in some cases, the fuel may be price prematurely, in the lines in the pumps or in other units this premature vaporization, will cause formation of vapor pockets, which restricts, the fuel flow. Now if the fuel, prematurely it will cause vapor pockets, in the lines and will restrict the, fuel flow. So, the partial or complete interaction, interruption of fuel flow, due to vapor pockets, formation is called,' Vapor Lock'. So, this formation of vapor pockets, in the lines, this partial or complete interruption of fuel flow, this is called,' Vapor Lock'. And this is this may lead to fuel starvation, we have problems, we encounter lot of problems because of vapor lock, especially in hot climatic conditions. So, there are issues, with the vapor lock. So, we need to be careful, this is premature vaporization of the fuel, causing vapor pockets, in the lines or the pumps and resulting in fuel starvation, there are various reasons, of vapor locks the main reasons are lowering of pressure on the fuel, the pressure may be lowered, on the fuel, high fuel temperatures and excessive fuel turbulence. So, there may be low pressure on the fuel, fuel temperature may be high and there should there may be fuel turbulence. So, because of these reasons, vapor lock formation, can take place.

Refer slide time :(13:08)



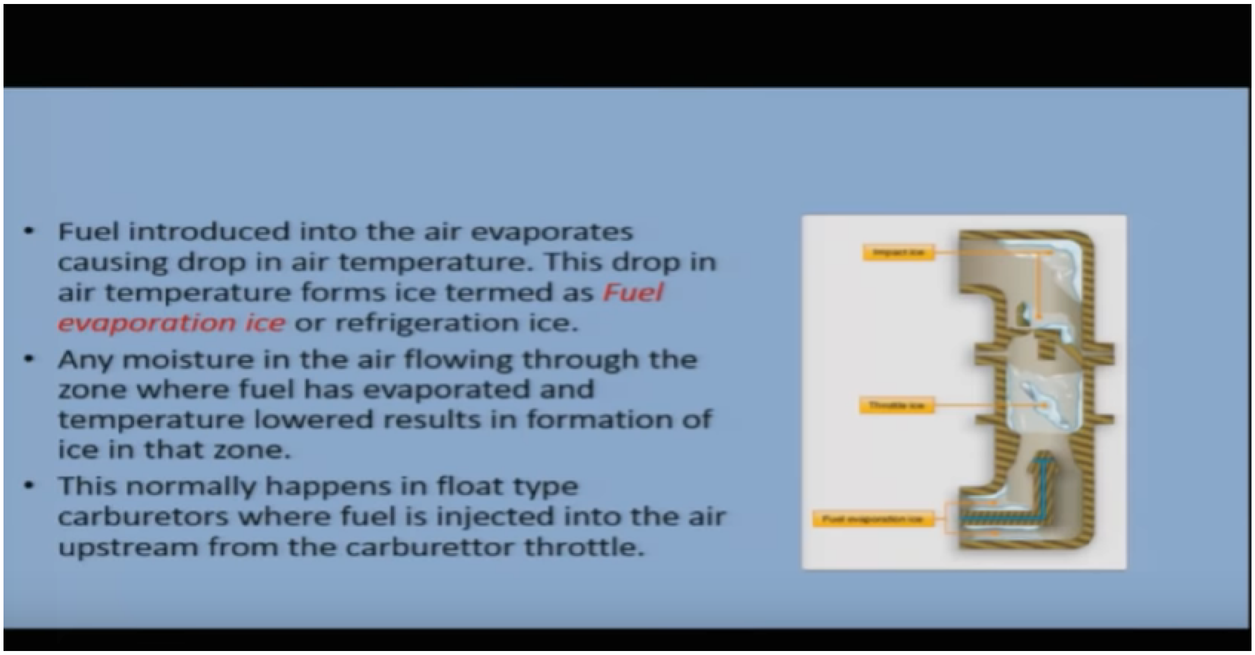
Lowering of pressure on the fuel, now lowering of fuel pressure at high altitudes lowers the boiling point of the fuel. So, at high altitudes, when the fuel pressure is lowered, it lowers the boiling point of view and causes vapor bubbles, to form resulting in vapor lock in the fuel system. So, at high altitudes, due to reduced fuel pressure, the boiling point reduces, the boiling point is Lord it, causes the vapor bubbles to form and resulting in vapor lock in the fuel system. Because, of high fuel temperature, injure heat also vaporizes fuel in the lines and the pumps, during a rapid climb, on a hot day high fuel temperature, combined with low pressure increases vapor formation. so because, of high temperature, also the fuel in the fuel line vaporizes and forms vapor pockets, on hot days during the rapid climb, there is again, vapor formation, because, it is a hot day so, you have high fuel temperature and since it is a rapid trying you encounter low pressure, also. So, this low pressure combined with high fuel temperature, forms vapors excessive fuel turbulence, now fuel turbulence, this is also the reason for vapor formation, the reasons for fuel turbulence in, a sloshing of fuel in the tanks, in the tanks fuel sloshing happens, mechanical action of the engine driven pumps, in the engine driven pumps also there is mechanical action and in the fuel lines, there are sharp bends or Rises, which help in formation of vapors. So, these are the reasons, of vapor formation lowering of pressure on the fuel, high fuel temperatures excessive, fuel turbulence.

Refer slide time :(14:58)



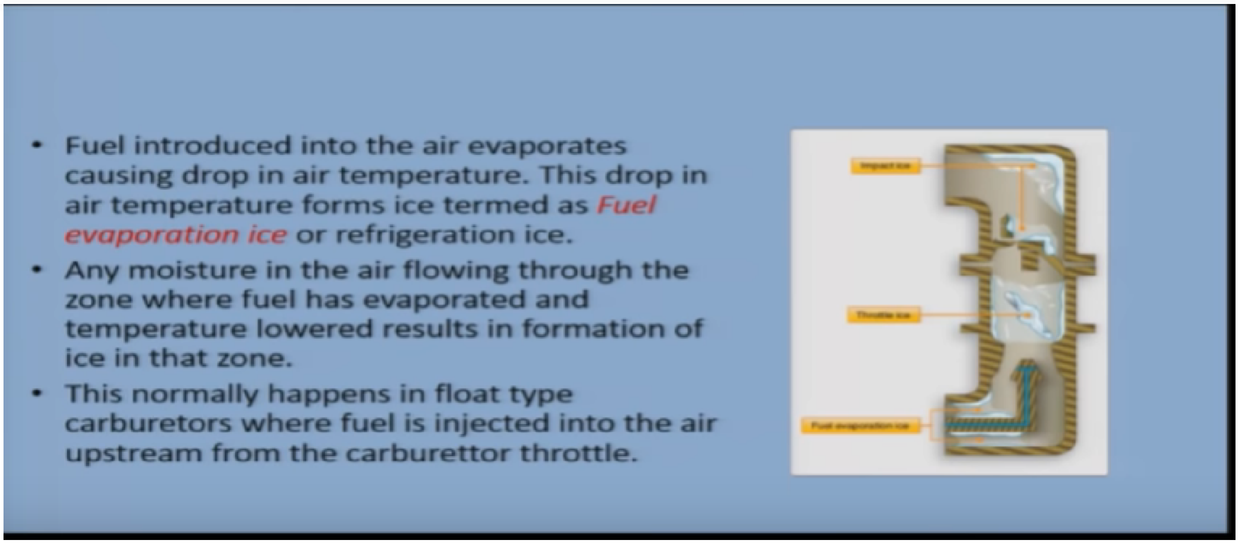
Now another serious, problem or another disadvantage, of the carburetors, of the fuel metering devices that is seen, is fuel system icing. Now since the aircraft is operating, in we're in different types of climatic conditions, it is prone to icing. So, let us see what are the different types of icing, that take place in the fuel system, in the fuel system, the fuel air metering unit, carburetor is used, in a carburetor fuel the ice forms and it is of generally three types, fuel evaporation ice, fertilize and impact ice. So, fuel evaporation ice, throttle ice and impact ice this is different types of ice formation.

Refer slide time :(15:45)



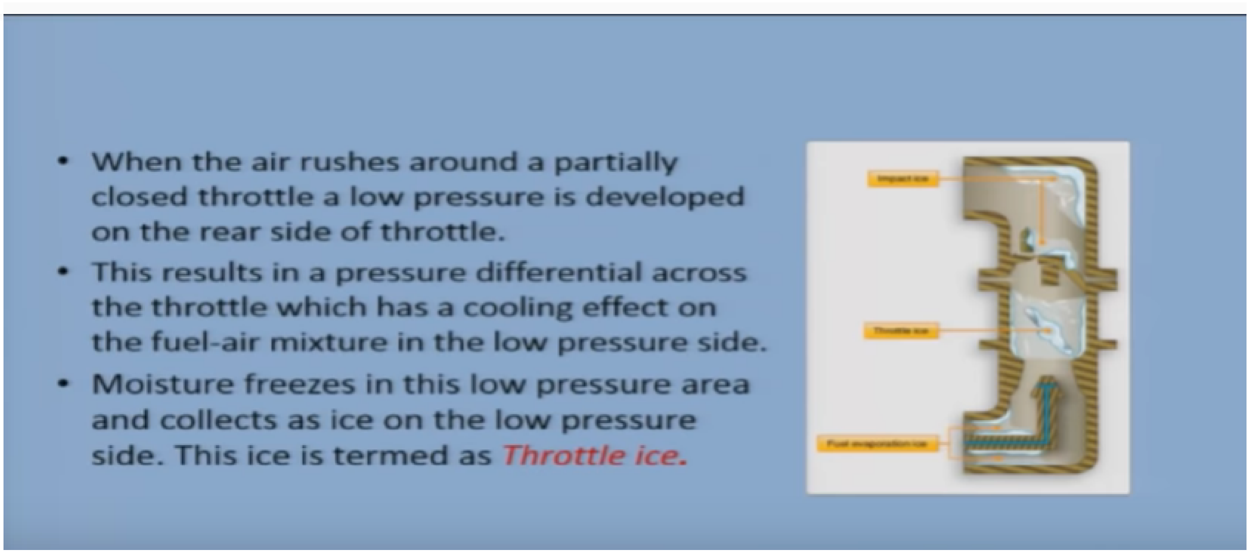
So, here in the picture, you can see there is ice formation, at various places. So, let us see, the first type of ice fuel evaporation ice, this fuel evaporation ice is also called as the,' Refrigeration Ice'. Now when the fuel is introduced, into the air which evaporates it causes drop in air temperature, now fuel, when it evaporates it causes a drop in temperature, this drop in air temperature, forms ice which is termed, as fuel evaporation ice or refrigeration any moisture in the air, flowing through the zone, where fuel has evaporated and temperature lowered, results in formation of ice in that zone. So, when air is flowing through this zone, where the temperature is lowered, because of fuel evaporation and this flowing, air has got moisture in it then, ice formation, will take place in that zone, this normally happens, in float type of carburetors, where fuel is injected into the air, upstream from the carburetor throttle. So, we will read about the throttle, in our further slides. So, this is generally happening in carburetors, where the air, is flowing, upstream, from the carburetor throttle.

Refer slide time :(16:52)



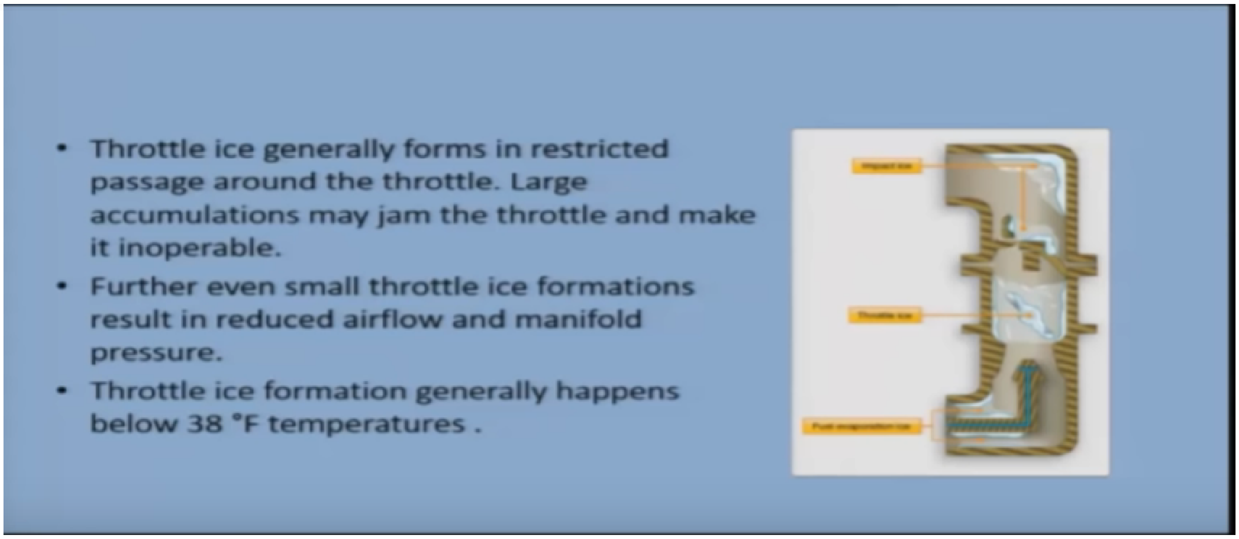
Fuel evaporation ice is normally formed, at a fuel discharge nozzle, in the carburetor. So, in the figure you can see, here this is your fuel discharge nozzle here and the fuel evaporation ice, is forming, at the discharge nozzle this fuel evaporation ice or refrigeration ice, can form over a wide range of temperatures and humidity conditions, since the engine is operating, in various types of climatic conditions. So, over a wide range of temperatures, over a wide range of humidity conditions, the fuel evaporation ice, will form, this type of ice, formed can lower the manifold pressure, it can interfere with the fuel, flow and can also affect mixture distribution. So, it has so, many disadvantages it can lower the manifold pressure, it can interfere with the fuel flow, it can also affect the mixture distribution. So, again this is not a desirable quality, coming to.

Refer slide time :(17:58)



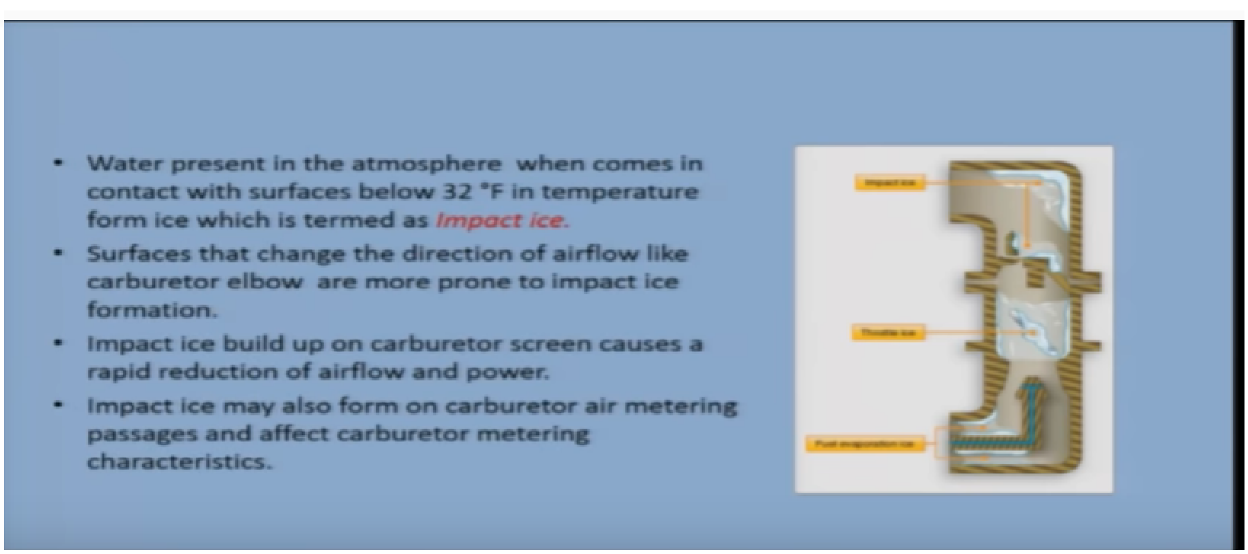
Next type of ice, the total ice, now when the air she's around a partially closed throttle, a low-pressure is developed, on the rear side of the throttle. Now on this diagram you see, this was your fuel discharge nozzle and you can see here this is your total, we will study how the throttle functions, now when this throttle is partially closed, when the air rushes around, the opening that is a low-pressure, which develops on the rear side of the throttle. So, when the air is passing, this air is rushing, to the restricted openings, there is a low pressure, formation on the rear side of the throttle, because of this low pressure, information there is a pressure differential, which acts across the throttle and it results in the cooling effect, on the fuel air mixture in the low pressure side. so, this pressure differential, there is a pressure differential across the throttle, this pressure differential has a cooling effect, on the fuel air mixture, now the fuel air mixture is coming out of this discharge nozzle this fuel air mixture is going, through this side and this fuel-air mixture experiences, a cooling effect on the low pressure side of the throttle. Now the moisture, if present will freeze because, of this low temperature and will form on the low pressure side of the throttle. So, this ice which forms around the throttle is termed as the throttle ice.

Refer slide time :(19:23)



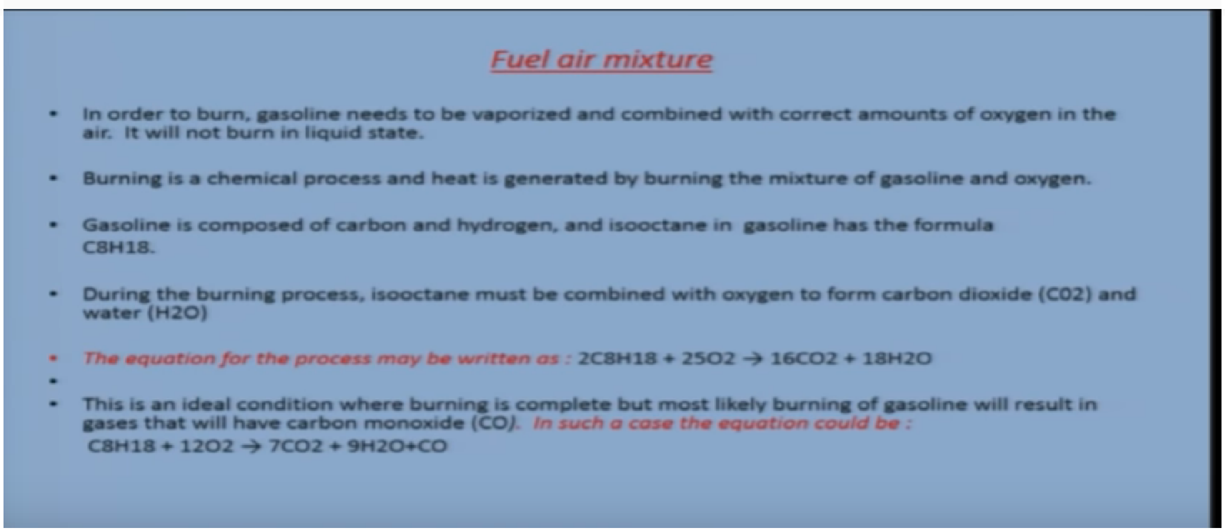
Throttle ice generally forms, in restricted passage around the throttle. So, there are restricted passages, around the throttle, you can see here there are restricted passages, around the throttle it generally forms, around the restricted passages. Now if there is large accumulation, of ice around the throttle, equals Jam this throttle, it will not let it open and will make it in operable, further even small throttle ice formations result in reduced air, flow and manifold pressure. Now even if the ice formation is small, then also it will reduce the air flow, it will cause obstruction for air flow and it will also reduce manifold pressure, throttle ice formation generally happens below 38 degrees Fahrenheit temperatures. So, generally below 38 degrees Fahrenheit temperatures, throttle ice formation takes place.

Refer slide time :(20:15)



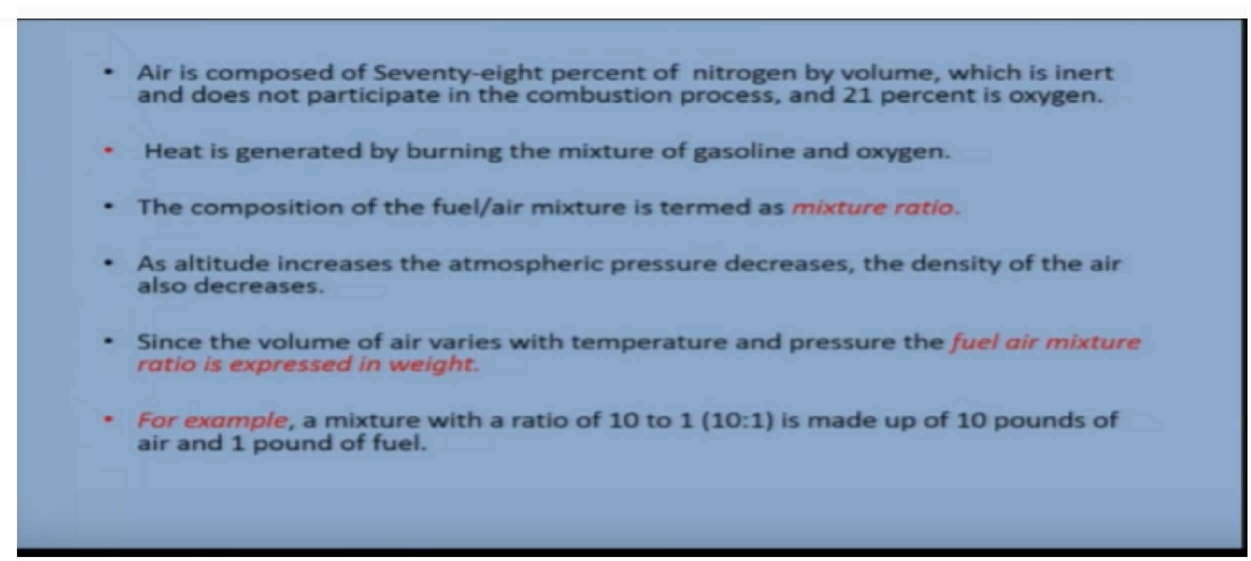
Now what is impact ice, this is a third type of ice that is impact ice. Now water is present in the atmosphere, which when it comes in contact with the surfaces below 32 degrees Fahrenheit in temperature, forms ice, this is termed as impact ice. So, when the air is flowing, over the surfaces which are below 32 degrees Fahrenheit in temperature ice, will form over these surfaces, because of the moisture present, in atmosphere and this is known as impact ice, surfaces that change the direction, of air flow are more prone to impact ice formation. So, you can see here in this diagram, there are tanks here, now these bands are more prone to impact ice formation, impact ice buildup on carburetor, screen causes a rapid reduction, of air flow and power. Now in case if the impact ice formation, is taking place on carburetor screen, then there will be rapid reduction of air flow and finally there will be, rapid power loss, impact ice may also form on carburetor air metering passages and affect the carburetor meeting characteristics. So, impact ice, it can also form on the carburetor metering, devices metering units and it will form, it will affect, the carburetor metering characteristics.

Refer slide time :(21:41)



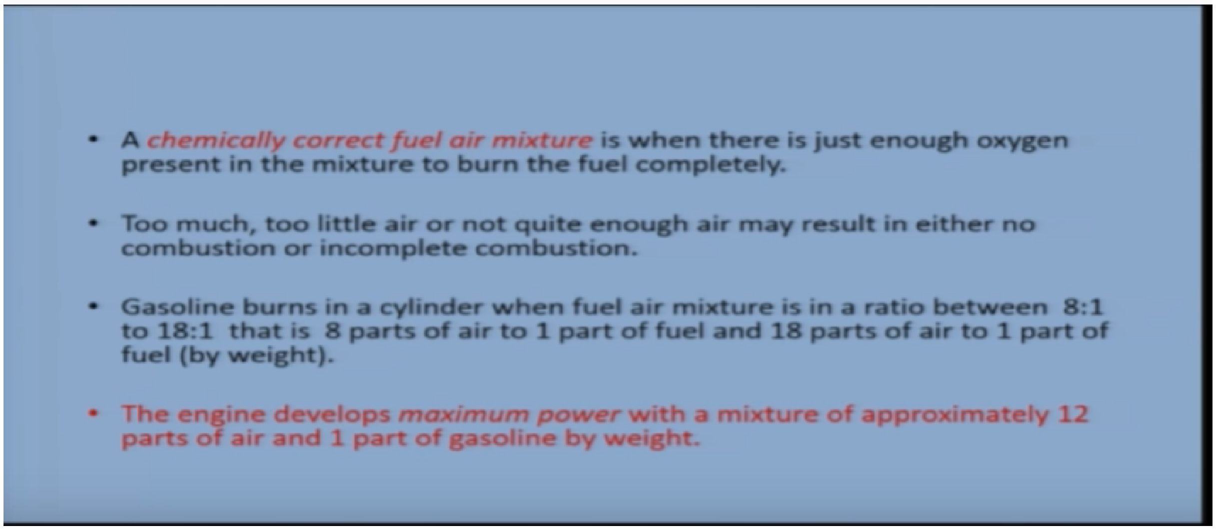
Now for combustion fuel and air are mixed and a fuel air mixture is formed, which enters the engine cylinders and combustion takes place. So, let us see what is fuel air mixture, in order to burn gasoline needs to be vaporized and combined with correct amounts of oxygen in air; it will not burn in liquid state. So, gasoline it is not going to burn in liquid state, it has to be vaporized and it should combine with oxygen in the air. So, that combustion can make place, now burning is a chemical process and heat is generated by burning the mixture of gasoline and oxygen, yes we all know that burning is a chemical process and in combustion, heat is generated, gasoline is calm of carbon and hydrogen and isooctane in gasoline has the formula c8h18. Now in a previous slide, we have read that gasoline is a mixture of hydrocarbons, it has isooctane and normal Heptane. So, it is given by the formula c8h18, during the burning process isooctane, must be combined with oxygen, to form carbon dioxide and water. So, when combustion takes place, during the combustion gasoline, combines with oxygen, in the air to form carbon dioxide and water. So, the combustion process, the combustion equation, is shown here, it has two c8h18 it is gasoline plus, combining with oxygen, it gives you carbon dioxide and water. Now in combustion, when you get carbon dioxide and water, this is an ideal condition, when burning is complete, complete gasoline has burned, this is an ideal condition, but generally incomplete combustion is not taking place, the burning of gasoline results in formation of carbon monoxide, gases. So, another equation you can see, gasoline combines with oxygen, it forms carbon dioxide, water and carbon monoxide. So, the equation is shown here c8h18 plus 1202 gives you seven co2 plus nine h2o plus co so, you are getting combustion, after combustion you are getting carbon dioxide water and carbon monoxide, gas.

Refer slide time :(24:41)



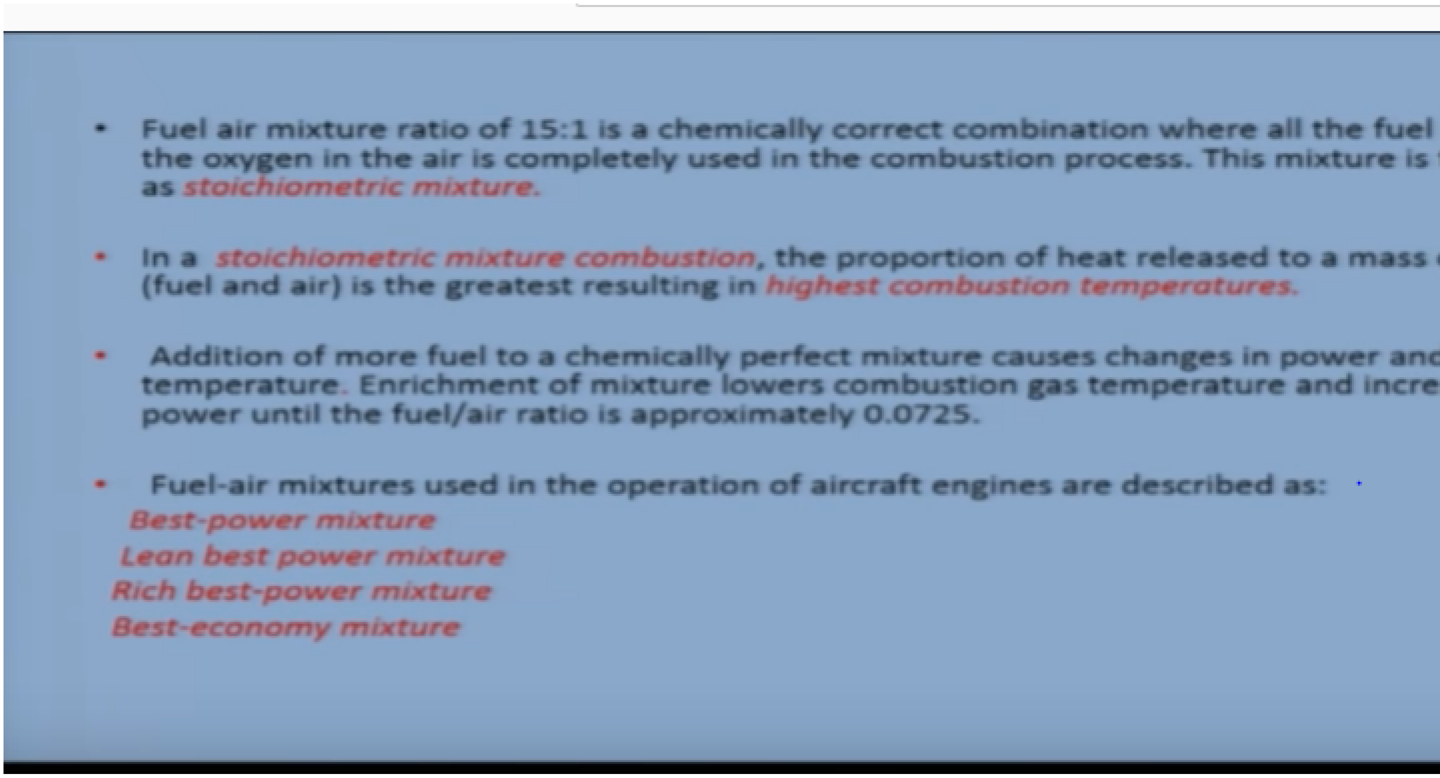
We all know, that air is composed of 78% of nitrogen, by volume, which is inert and it does not participate in the combustion process, in combustion oxygen participates and the percentage of oxygen, in air is 21%. So, the combustion mixture ,which is to burn comprises, of fuel and air and this ratio, of fuel and air mixture, is known as the mixture ratio, as altitude increases, the atmospheric pressure decreases, we know that as we go up that must be pressure will decrease, the density of air will also decrease, now since the volume of air, varies with temperature and pressure, the fuel air mixture ratio is expressed in weight, for example or mixture with a ratio of 10 to 1 10 raised to 1 is made up of 10 pounds of air and one pound of fuel. So, 10 raise to 1 ratio fuel air mixture, has 10 pounds of air and one pound of fuel a chemically correct fuel air mixture is when there is just enough oxygen present in the mixture to burn the fuel completely.

Refer slide time :(25:06)



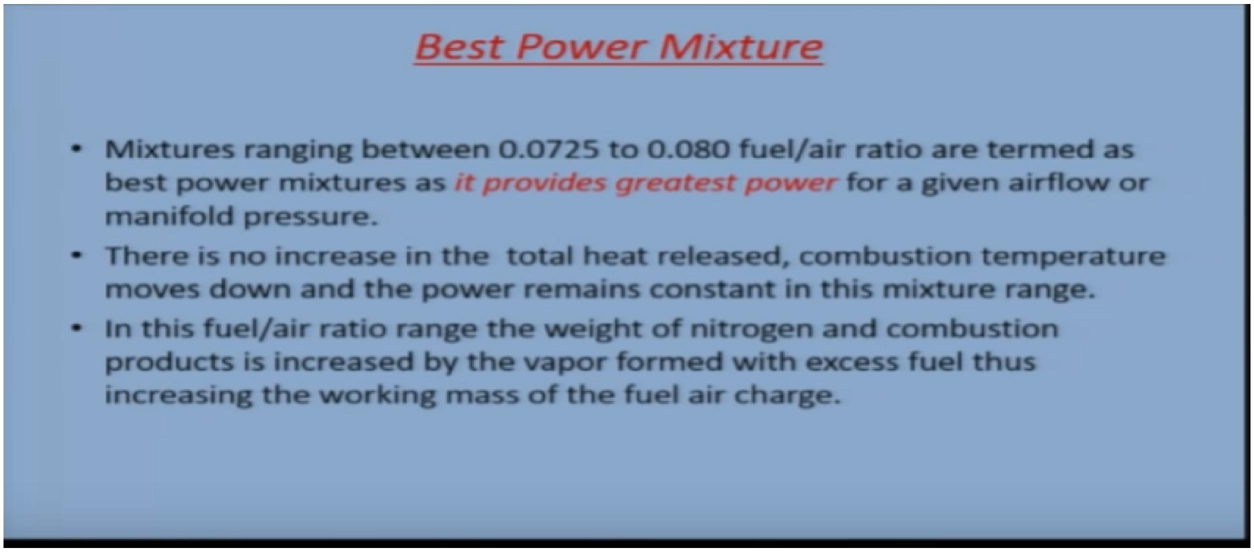
So, chemically correct fuel air mixture, is when there just enough oxygen, present in the to mixture burn the fuel off completely, too much or too little air or not quite enough air, may result in either no combustion or incomplete combustion. So, if you have too much of air, that means your mixture is lean, you have too much of air as compared to fuel or you have too little air, as compared to full fuel that means your mixture is rich, this may result in either no combustion or incomplete combustion. Now gasoline will burn in the cylinder the fuel air mixture will burn in the cylinder, only when the fuel air mixture, is in a certain ratio range, gasoline burns in a surrender, when fuel air mixture is in a ratio between, 8 raise to 1 to 18 raise to 1. So, if the fuel air mixture is in the ratio is in the range of a trace to 1, to 18 raise to 1, then only your combustion is going to take place and we all know that these mixture ratios, are expressed in weight, the engine develops maximum power with a mixture of approximately 12 parts of air and 1 parts of gasoline by weight. So, maximum power is achieved, when you have a fuel air mixture of, 12 raise to 1 12 parts of air and 1 part of gasoline by weight. So, your combustion is taking place, when you have the mixture ratio of 8 raise to 1 to 18 raise to 1 at maximum power, is achieved when you have a fuel air mixture of 12 raise to 1 ratio,

Refer slide time :(26:53)



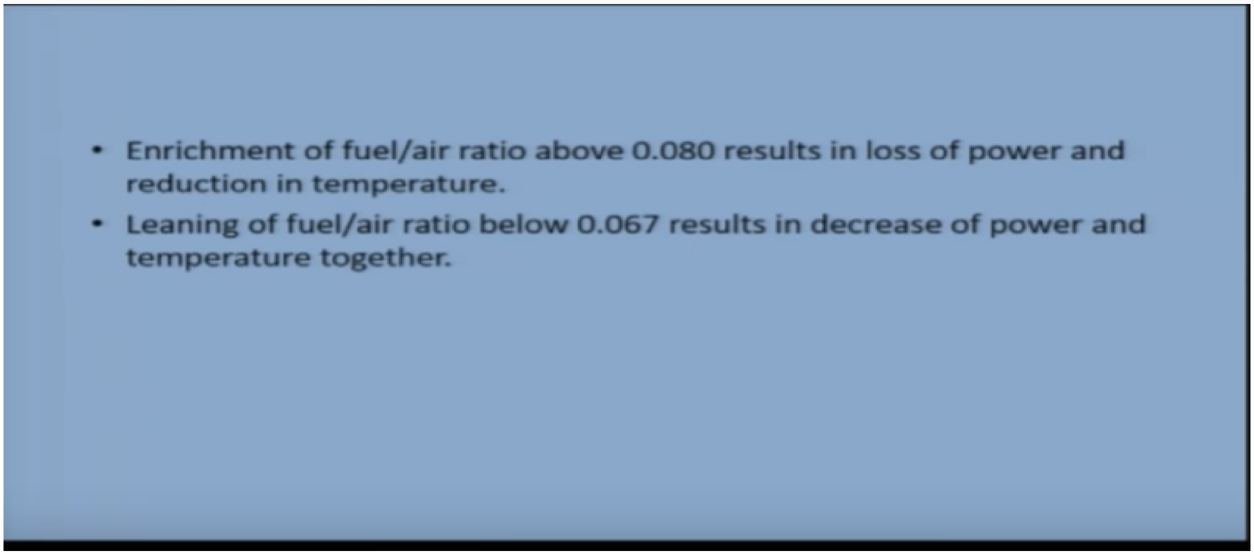
fuel air mixture of 15 raised to 1 is a chemically correct combination, where all the fuel and all the oxygen in the air is completely used in the combustion process. So, when complete combustion, is taking place, where all the fuel and all the oxygen in the air is getting burnt, that is you're chemically correct combination, which is around 15 raise to 1 this mixture is termed as the Stoichiometric mixture, in a Stoichiometric mixture, combustion the proportion, of heat released to mass or for charge, fuel and air is the greatest resulting in highest combustion temperatures. Now since this is a chemically correct combination, complete combustion is taking place. So, maximum heat is generated and you have the highest combustion, temperatures, addition of more fuel to a chemically perfect mixture, causes changes in power and temperature. So, when you add more fuel to the chemically correct combination, you have lower temperatures and you have changes in power also, enrichment of mixture lowers the combustion gas temperature. So, when you are making the mixture more rich, from the chemically correct combination, you have lower gas temperatures, you have lower combustion gas temperatures and power is also increased, until the fuel air ratio, is approximately 0.07 to 5. So, there is a ratio till which you may have more power, when you and rich in the mixture, now in a reciprocating engine, we are using different types of mixture ratios, the different fuel air mixture ratios, they are used in operation and are described as best power mixture, lean best power mixture, rich best power mixture and best economy mixture. So, different types of mixtures, best power, lean best power, rich best power and best economy mixture.

Refer slide time :(28:50)



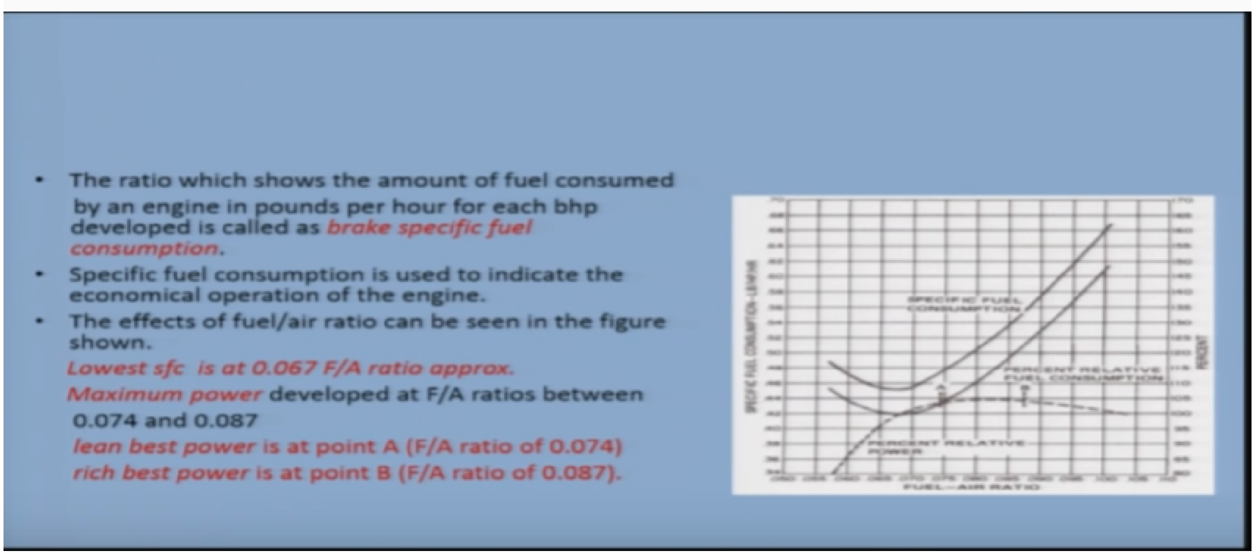
Now let us see what is best power mixture, mixture is ranging between 0.072 five two point zero eight zero fuel a ratio or termed as best power mixtures, as it provides greatest power, for a given airflow or manifold pressure, now for a given airflow or manifold pressure, this ratio is providing the greatest power. So, this is termed as best power mixture, since you are getting, greatest power, for a given airflow. So, this is termed as best power mixture, there is no increase, in the total heat released, combustion temperature moves, down and the power remains constant in this mixture range, in this fuel-air ratio range, the weight of nitrogen and combustion products is increased, by the vapor formed, with excess fuel thus increasing the working mass, of the fuel air charge. Now because of the excess fuel the weight of nitrogen and combustion products, it is increased and finally you're working mass, your fuel air charge working mass, is increased.

Refer slide time :(29:50)



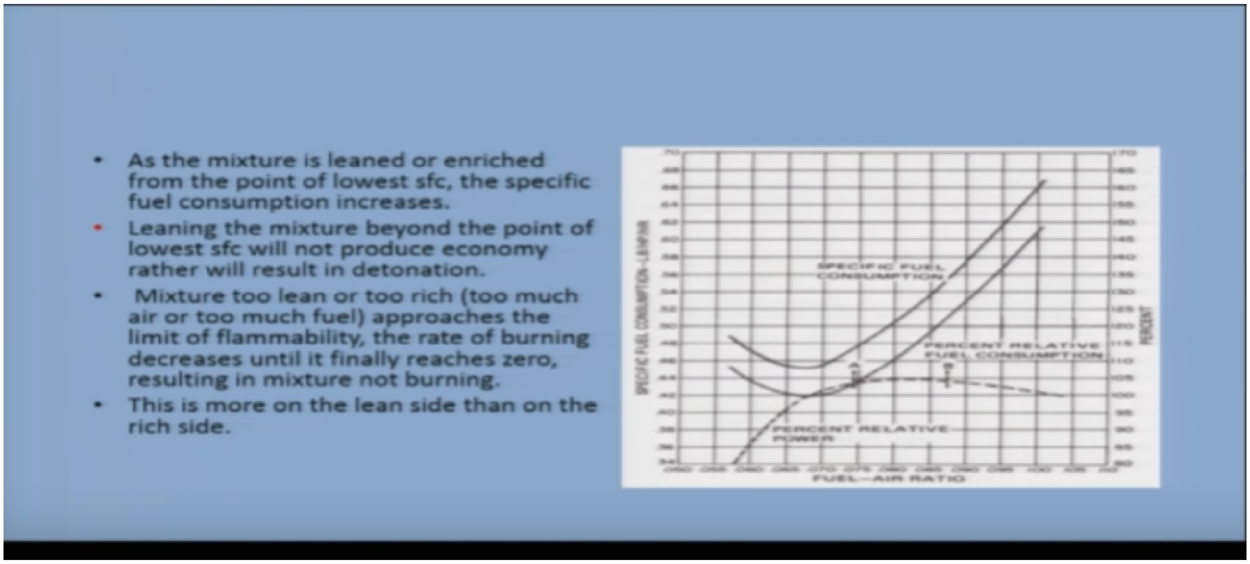
Enrichment of fuel air ratio, above point zero eight zero, results in loss of power and reduction in temperature. Now further enrichment of the fuel air mixture will result in loss of power and reduction in temperature. So, we have seen that from the chemically correct fuel mixture. Further enrichment increased the power to a certain extent and reduce the combustion temperature, further enrichment has resulted in loss of power and reduction in temperature ,leaning of fuel a ratio below point zero six seven results in decrease of power and temperature together. So, we have seen that when the fuel air ratio, is leaned below point zero six seven in that condition also, your power is decreasing and your temperature is also decreasing, power and temperature are decreasing together. So, there are purely air mixture ranges and above point zero eight zero fuel air ratio, when you enrich in the mixture, then also your power is dropping and when the fuel air mixture is leaned, below point zero six seven then also your power is dropping.

Refer slide time :(31:01)



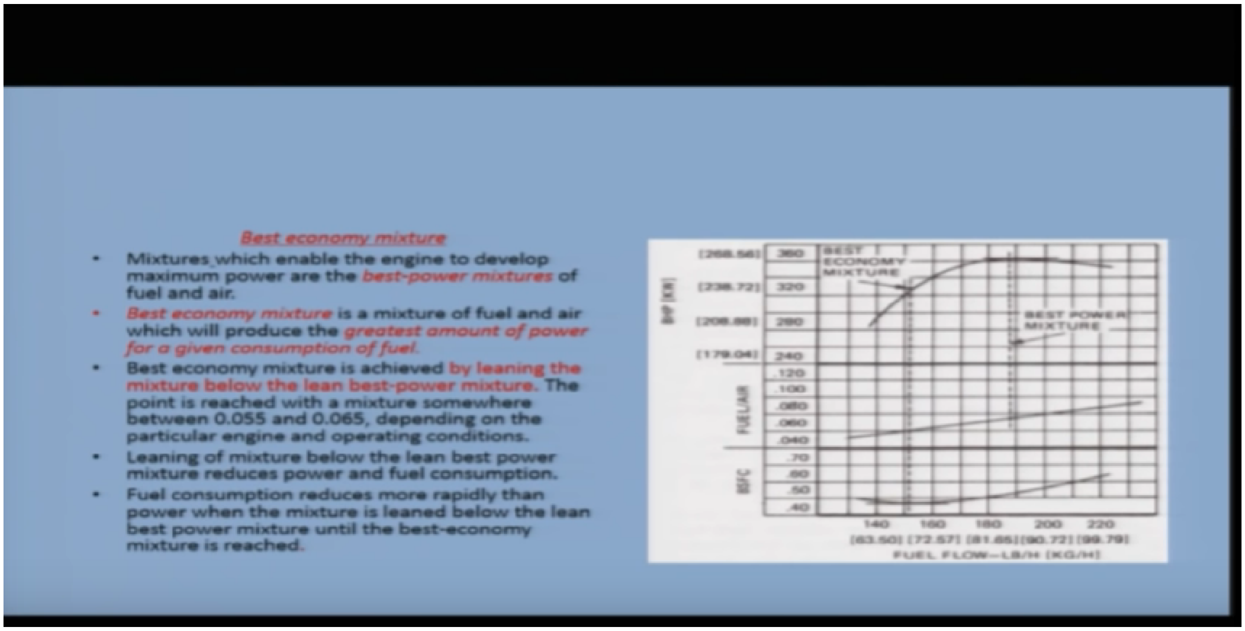
The ratio which shows the amount of fuel consumed by an engine, in pounds per R for each brake horsepower developed, is called as,' Brake Specific Fuel Consumption'. Now brake specific fuel consumption, it shows the amount of fuel consumed by an engine, in pounds per R for each BHP developed. So, for each BHP developed, the amount of fuel consumed by an engine, in pounds per are is termed as the brake specific fuel consumption, it indicates the economical operation of the engine. So, with the brake specific fuel consumption, we can understand whether or engine is operating economically or not. So, this is a very important term, brake specific fuel consumption. So, here in this diagram, you can see there is a graph, this is on the extreme left if you see this is specific fuel consumption, which is in pounds per horsepower per R then in the extreme bottom, you see it has fuel a ratio and on the extreme right side, it is percentage the graph shown is specific fuel consumption. Now if you see this autumn side, the fuel air ratio at point zero six seven fuel in issue if you see at point zero six seven, this is point zero six, five and this is point zero seven zero point zero six seven is somewhere here this gives you the lowest specific fuel consumption. So, point zero six seven fuel a ratio, is giving you, the lowest specific fuel consumption this is your few specific fuel consumption, graph at point zero six seven, you are getting the lowest specific fuel consumption, this graph here you see this is your power graph, this dotted line and in this if you see that maximum power is developed at, point zero seven four and point zero eight seventh. So, this is your fuel a ratio, point zero seven four, somewhere here, the A point and the B point is point zero eight seven. So, the maximum power is being generated between this A to B between 0.074 and point zero eight seven fuel air ratio. So, we have seen that Oh point zero seven four two, point zero eight seven mixture rage, gives us the maximum power, point zero six seven fuel a ratio, is giving us the lowest specific fuel consumption. Now this point zero seven four, fuel a ratio that is at a point this is termed as the lean best power, since we have seen that A to B this is your best power a is on the leaner side. So, this is termed as the lean, best power and B is on the richer side. So, this is termed as the rich best power, so, in this graph, we have seen the lowest specific fuel consumption, is at around point zero six seven, fuel air ratio the best power is being achieved between point zero seven four and point zero, eight seven fuel air ratio and point zero seven four is termed as the lean best power this thing, a in the figure the system as, the lean best power and be point zero, eight zero, point zero, eight seven sorry this is termed as the rich best power mixture.

Refer slide time :(34:09)



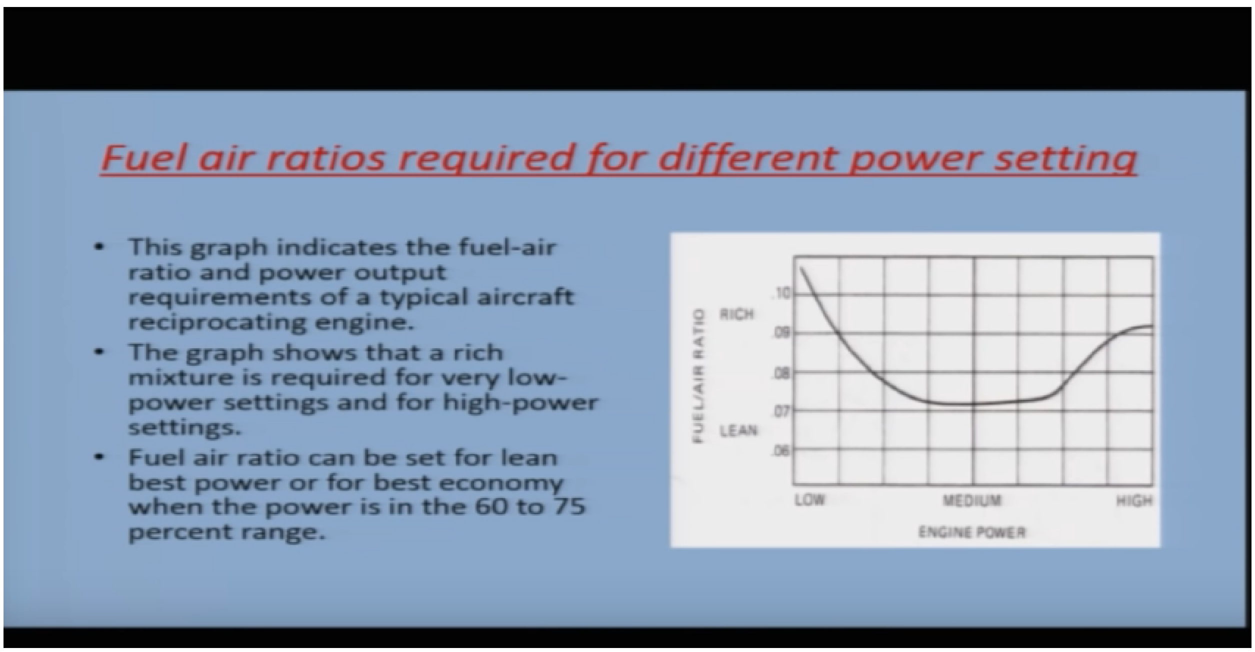
Now as the mixture is leaned or enriched, from the point of lowest specific fuel consumption, the specific fuel consumption increases, now seeing this diagram, we have seen that at around point zero six seven, we had the lowest specific fuel consumption. Now if we lean the mixture, beyond point zero six seven that means we are reducing, we are moving on the left side your specific fuel consumption is increasing, in this graph you can see, that the specific fuel consumption is increasing and if we reach the fuel air mixture, that is we move on the right side then also your specific fuel consumption is increasing. So, leaning or reaching the fuel air mixture, the lowest specific fuel consumption point, will increase the specific fuel consumption, leading the mixture beyond the point of lowest specific fuel consumption, will not produce economy, but will result in detonation. So, beyond specific fuel consumption, point if we lean the mixture, it does not give us economy, it will not help us in economizing, the fuel rather it can result in determination, which can be very harmful, mixture to lean, lean or to rich approaches, the limit of flammability, the rate of burning decreases, until it finally reaches zero, resulting in mixture not burning. So, we know that the combustion takes place, in a certain range. So, if the mixture is lead or enriched beyond this range, then the flammability the limit, of flammability is reached, the rate of burning is decreased and until it finally reaches zero and the mixture stop burning, this is more on the lean side, then on the rich side.

Refer slide time :(35:58)



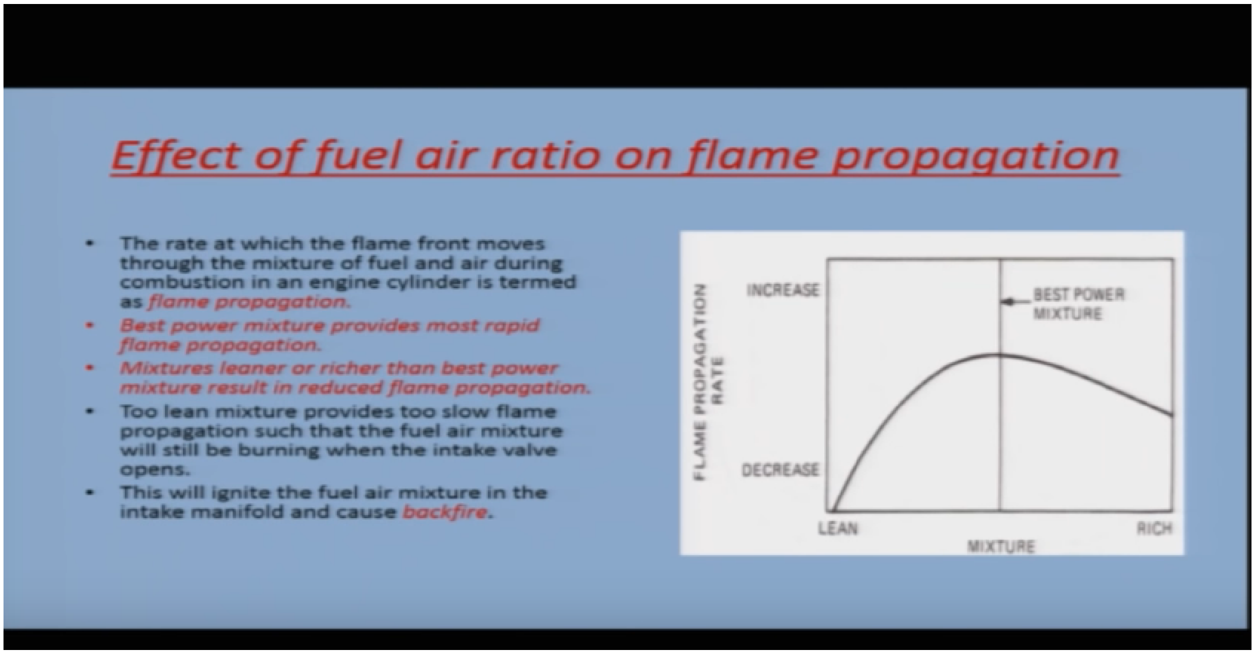
Now let us see what is best economy mixture, mixtures which enable the engine, to develop maximum, power are the best power mixtures of fuel and air, we have seen that mixtures which help us in getting, in developing, the maximum power they are termed, as the best power mixtures, best economy mixture is a mixture of fuel and air, which will provide the greatest amount of power, for a given consumption of fuel. So, for a given consumption of fuel, if we are able to generate, the maximum power greatest amount of power, that is termed as the best economy mixture. So, best economy mixture is achieved, by leaning the mixture, below the lean best power mixture. So, we have seen what is the lean best power mixture in a previous slide and if we lean the mixture below, the lean best power mixture, our best economic mixture can be achieved, in this graph, if we see that this is your best economy mixture, this is the graph, this is the plot, for the best economy mixture and this is your best power mixture, rather I can say that this is your lean, best bomber mixture, when we lean the mixture beyond the best power mixture, beyond the lean best power mixture, this is your lean best power mixture, if we move on the left side, if your mixture is reduced, if your mixture is leaned, further beyond the best power mixture, beyond the lean best power mixture, then the best economic mixture, can be achieved, in this graph you can see, this is your brake horsepower, in the first half, in the second half you can see this is your fuel air ratio and in the third half you have the brake specific fuel consumption. So, now this is your power curve and this condition, was your lean best power. So, when we have leaned, in the mixture, the mixture is leaned from the lean best power, further this gives us the best economy mixture, best make economic mixture, is achieved by leaning the mixture, below the lean best power mixture, the mixture the point is reached with a mixture, somewhere between point zero five, five and point zero six five. So, this is you can see here this point, this is between point zero five, five and point zero six five, depending on the particular engine and operating condition, meaning of mixture below the lean best power mixture, reduces power and fuel consumption. So, when we lean the mixture below the best power mixture, in that case power is reduced and fuel consumption is reduced, although we are getting the best economic mixture, but our power is getting reduced, fuel consumption reduces, more rapidly than the power, when the mixture is leaned below the lean best power mixture, until the best economy mixture is reached. So, leaning the mixture from the, lean best power mixture, to the best economy mixture, reduces our fuel consumption more rapidly, than the power, until your best economy mixture is reached. So, to sum up, about this slide, this is your best power mixture, this is your lean best power mixture, when the fuel air ratio, is leaned further beyond the lean best power mixture, the power reduces the fuel consumption reduces, fuel consumption reduces, at a rapid rate as compared to power and we achieve a best economy mixture. So, leaning of the fuel air mixture, beyond the best power mixture gives us the best economic mixture.

Refer slide time :(39:26)



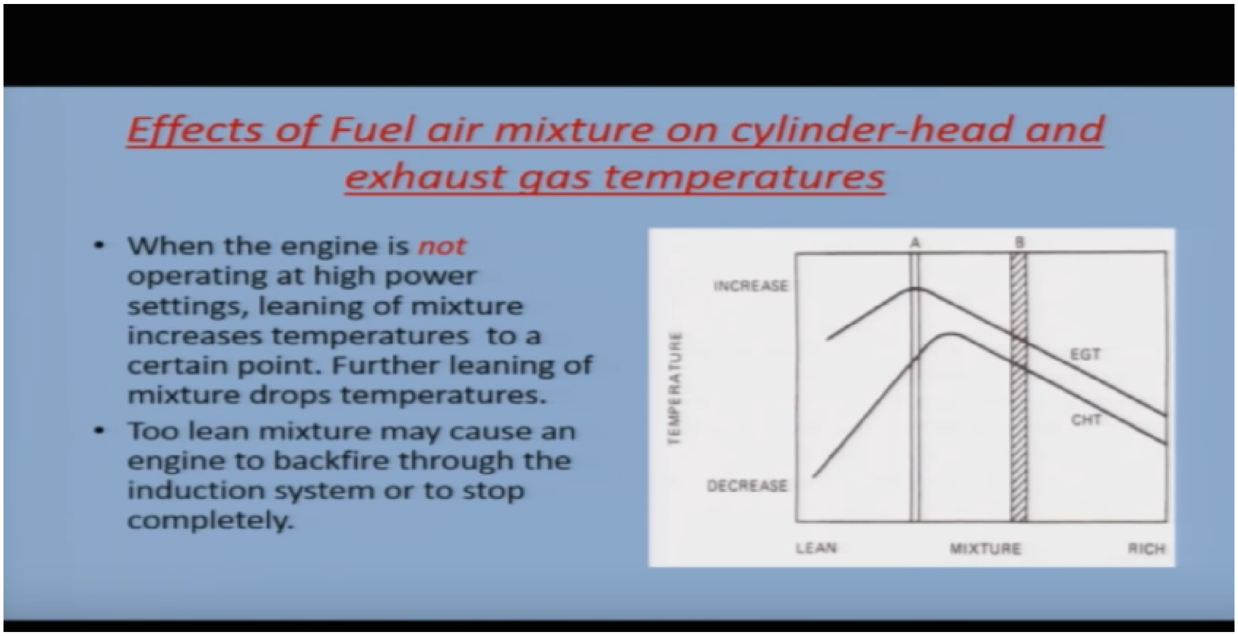
Now let us see what are the fuel air ratio is required for different power settings. This graph indicates the fuel, air ratio and power output requirements, for a typical aircraft reciprocating engine, the graph shows that a rich mixture is required, for very low power settings and for high power settings. So, here in the graph you can, see on the extreme left this is your fuel air ratio, this is your mixture, alright this is your power. So, at high power conditions, also and when you have high power, then also you need a rich mixture and when you I have low power in that condition, also you require a rich mixture. So, in low power conditions and in high power conditions or rich mixture is required fuel, ratio can be set for lean best power or for best economy, when the power is in the sixty to seventy-five percent range. So, see when the is in this range something around 60 to 75 range, then we can get, the lean best power mixture or the best economic mixture, otherwise in both the low power condition and the high power condition or rich mixture is required.

Refer slide time :(40:34)



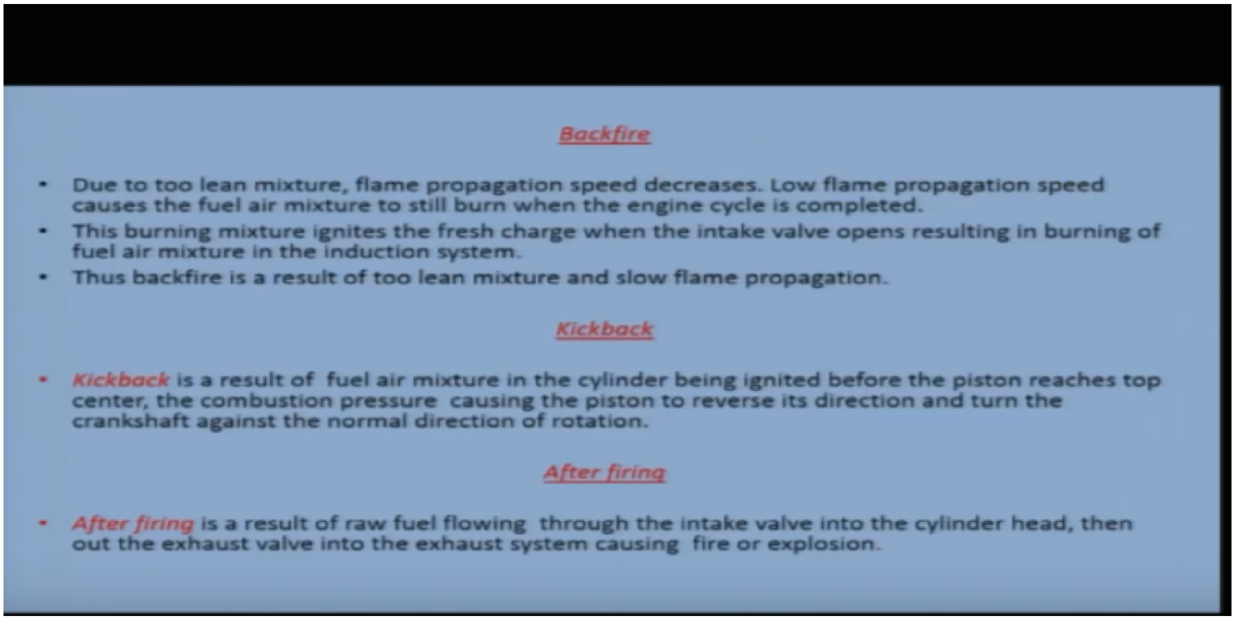
Now effect of fuel-air ratio on flame propagation, let us see what is the effect of fuel a ratio on flame propagation, here in the graph you can see this is the flame propagation rate, on the left side on the bottom side, is the mixture, the rate at which the flame front moves, through the mixture, of fuel and air during combustion in an engine cylinder is termed as flame propagation. So, the movement of flame front, during combustion, is termed as flame propagation, the best power mixture provides, the most rapid flame propagation. So, here you can see this is your best power mixture and this best power mixture provides the most rapid flame propagation, mixtures leaner or Richard and best power mixture result in reduced stream propagation. So, when your mixture is leaned or the mixture is in the rich condition, from the best power mixture, then your flame propagation rate is less, it reduces, you have the most rapid flame propagation, at the best power mixture, anything leaner or richer from this position, gives you reduced flame propagation, to lean mixture provides, to slow flame propagation such that the fuel air mixture, will still be burning when, the intake valve opens. So, to lean mixture, will have to slow flame propagation, such that the fuel air mixture, will continue to burn when the intake valve is open this can result in English' of the fuel air mixture, in the intake manifold and can cause backfire.

Refer slide time :(42:13)



Now let us see what is the effect of fuel air mixture on cylinder head temperature and exhaust gas temperature when the engine is not operating at high power settings leaning of mixture increases temperatures to a certain point. So, now in case when your engine is not operating, at high power settings, if we lean the mixture, we have higher temperatures, we counter high temperatures on leaning the mixture, further leaning of mixture drops temperature. So, here you see in the graph, this is your temperature on the left side and this is your mixture at the bottom, this curve is for the CH T and this curve is for the EGT the exhaust gas temperature, when the mixture is leaned, that means we are moving on the left side and the mixture is leaned in that case, the temperature increases, when the mixture is leaned the temperature the cylinder, head temperature is increasing and exhaust gas temperature is also increasing. Now further leaning it, it reaches to a certain point, to a maximum point and further leaning will drop the temperature, to lean mixture may cause an engine to backfire through the induction system or to stop completely. So, two leaning of the mixture has some disadvantages, it can cause backfiring through, the induction system and can result in complete stoppage of the engine.

Refer slide time :(43:33)



Let us see, what is backfire? What is kickback? What is after firing due to? Two lean mixture, flame propagation speed decreases, we have just now seen in our previous slide, that lean mixture, to lean mixture, gives a reduced plane propagation speed, low flame propagation speed, causes the fuel air mixture to still burnt, when the engine cycle is completed. So, when the engine cycle is completed still the fuel air mixture is burning, this burning fuel a mixture, will ignite the fresh air charge, when the intake valve opens, resulting in burning of fuel air mixture in the induction system. So, your fresh fuel air charge, can burn in the induction system, because of the continued burning, because of the low flame propagation speed, this causes a backfire in the induction system. And it is due to a too lean mixture and slow flame propagation, next is kickback, kickback is a result of fuel air mixture in the cylinder, being ignited before the piston reaches top center. Now since the ignition takes place at just before the top dead center. Now if the fuel air mixture gets ignited, in the cylinder, much before that the combustion, pressure will cause the to reverse its direction and it will turn the crankshaft against, the normal direction of rotation. So, this is your kick back and after firing after, firing is a result of raw fuel through, the intake valve into the cylinder head, now the fuel is coming from the intake, wall it is flowing from the intake valve into the cylinder, head and then goes to the exhaust valve into the exhaust system and causes fire or explosion. So, fuel coming from the intake valve, into the cylinder, head and into the exhaust system, it causes fire or explosion. So, we have seen, backfiring, after firing and kickback.