**Chemical Process Utilities**
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**Lecture - 18**
**Steam**

Welcome to the new topic under the aegis of chemical process utilities: steam. Now steam is very important in all the chemical process industries because it can be used for power generation. It can be used for making slurries. It can be used to impart heat to any equipment, etc, because it offers a wide spectrum of uses. Apart from this, steam can be used for mixing and agitation purposes, and steam finds it is a very vast spectrum in various operations of chemical engineering.

So, we are starting this steam concept. In this particular lecture, we are going to cover what is steam why we are using this steam and what is the phenomena through which we can generate steam, and how do we can identify the steam properties based on the various concepts is about the latent heat about the enthalpy about the entropy steam can be of a very various use in all spectrum.

Now steam is a vapor form of water, and it is colorless, tasteless, and odorless, but apart from this, it carries heat energy. So, steam transfers heat energy from one location to another one.

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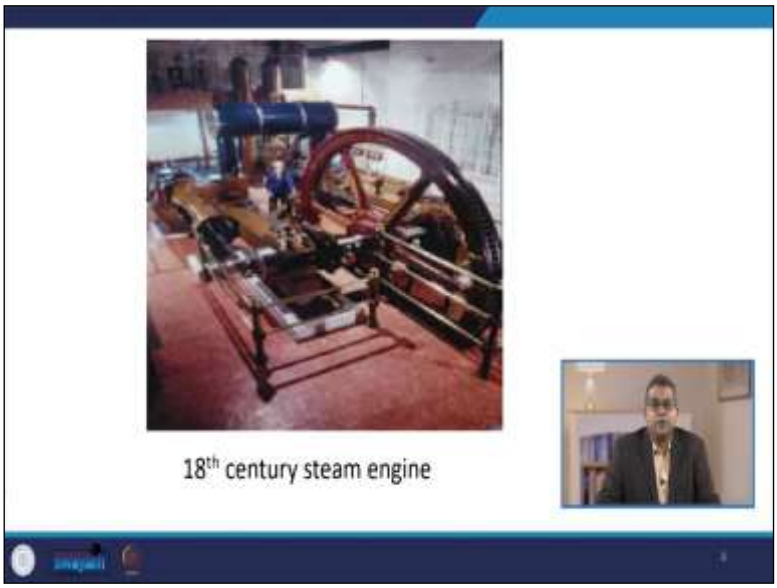

Now you see that steamed engines duly backed the Industrial Revolution back in the 18th century, and that was the first industrial revolution. It completely transformed the entire way of think of people, and it has a phenomenal effect on the day-to-day affair of any human being.

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Now a question arises that why one should use steam. In this particular slide, we have enlisted a couple of things that give you an idea of why we should use steam or why we are using steam in such a broad spectrum in any processing industry. Now steam is a very efficient heat transfer media. See by the latent heat under the other properties, and steam is a very good heat transfer media.

We have already developed equipment and expertise to design and install the steam-oriented system. I told you that way back in the 18th century, the generation of this team attributed the entire industrial revolution. So, since then, we have already developed we have already designed so many types of equipment to utilize the properties of this steam. Now we have a lot of knowledge concerning steam.

Trust me, and we have a steam table. If you go to the stream table, we have enlisted all the properties which one can imagine in this team. So, we know a broad spectrum of knowledge concerning steam. Above all, because of the variety of things and the cost effectiveness and the

other variety with respect to the properties steam one can easily control, we will discuss this particular aspect in due course of time.

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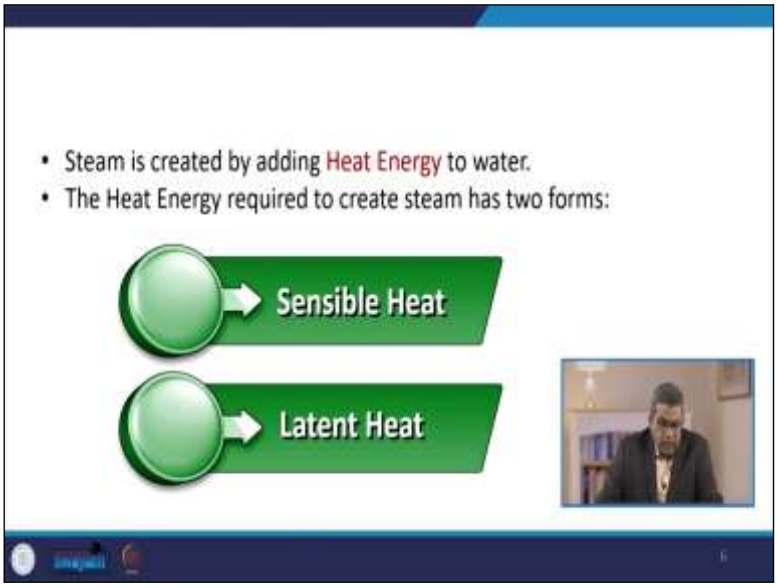


The question arises about how we can create steam and generate steam. So, steam is created by adding heat energy to water. Now the heat energy required to create steam is two forms. One is the sensible heat. The second one is latent heat very common because it carries the heat and can be used to transfer the heat from one station to another station.

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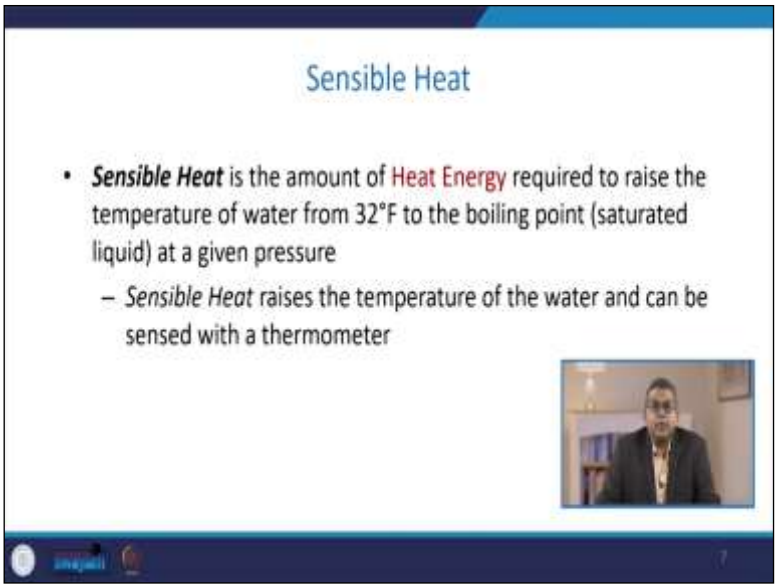

Let us have a brief look at the sensible heat. Now sensible heat is the amount of heat energy required to raise the temperature of water from 32 degrees Fahrenheit to the boiling point, and that is called the saturated liquid at a given pressure. So, sensible heat raises the temperature of the water and can be sensed with any kind of temperature measuring device.

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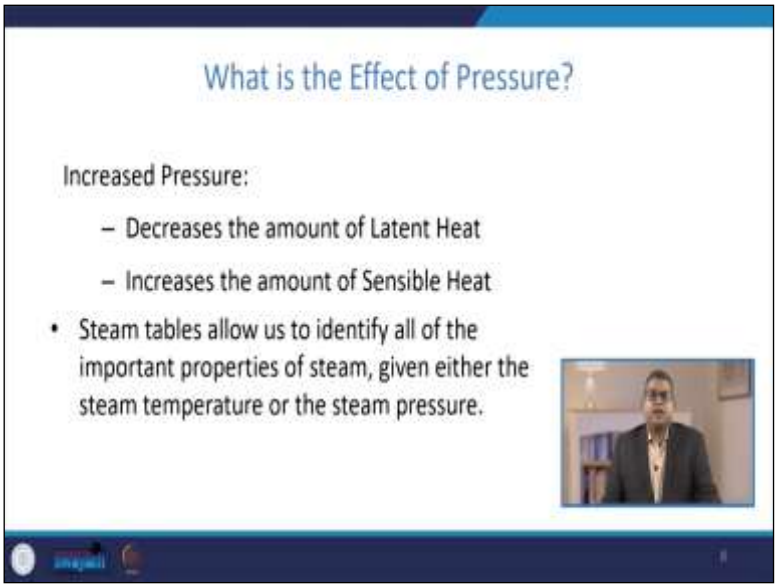


Now, certain questions arise: what is the effect of various parameters attributed to any steam generation process? So, let us take that what the effect of pressure is? Now see if there is increased pressure, then there is a decrease in latent heat and an increase in the amount of sensible heat. Usually, this is the smarter phenomenon that is called the steam table. Knowing the steam tables allows us to identify all the important properties of steam given either the steam temperature or steam pressure.

And we have ready-made mathematical correlation through which we can analyze or predict or calculate the other properties of steam.

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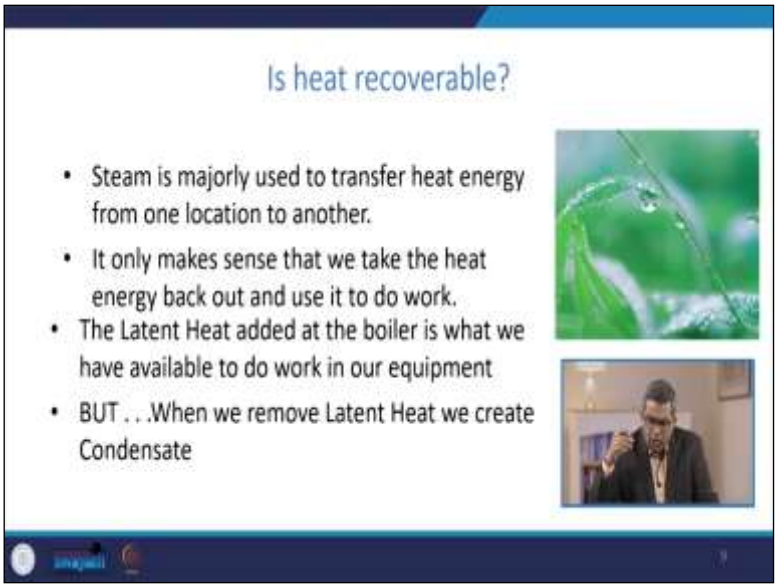


Now, when we discuss the heat carrying capacity of steam, the question may arise about heat recoverability. Now steam is mostly used to transfer the heat energy from one station to another. It only makes sense that we take the heat energy back out and use it to work. So, first, you create you apply a certain quantity of energy to create the steam, then you extract the work, and sometimes it discharges the energy, and you grab this energy and collect the condensate, and then again you can reuse all those things.

So, the latent heat is usually added at the boiler level, and that is what we have available to do work in any kind of equipment, but when we remove the latent heat, we create the condensate. Remember, condensate always possesses an extensive amount of economical value because whenever we generate steam through the water, we need to have the water in the purified form. That does cost us to perform the demineralization operation deionization operation just to prevent the scaling formation.

So, when we remove the latent heat we cannot create, we cannot discharge the water as such, it needs to be collected, and again it needs to be recirculated. Still, apart from this, when we form the condensate, there may be a chance of pressure disturbance within the system.

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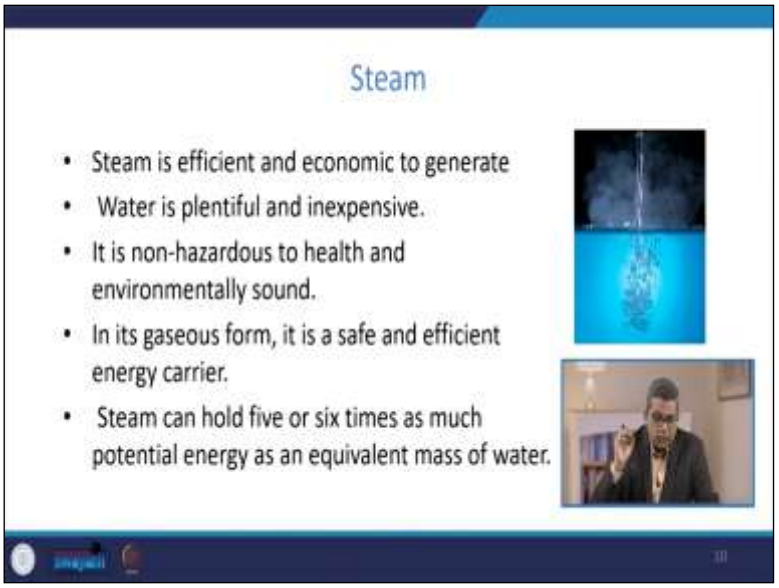


So, steam is efficient and economical to generate because water is plentiful, inexpensive, and available in abundance in several locations. It is non-hazardous to health and environmentally sound. In its gaseous form, it is a safe and efficient energy carrier, and trust me, and it is very economical. Above all, steam can hold five or six times as much potential energy as an equivalent mass of water, courtesy of latent heat.

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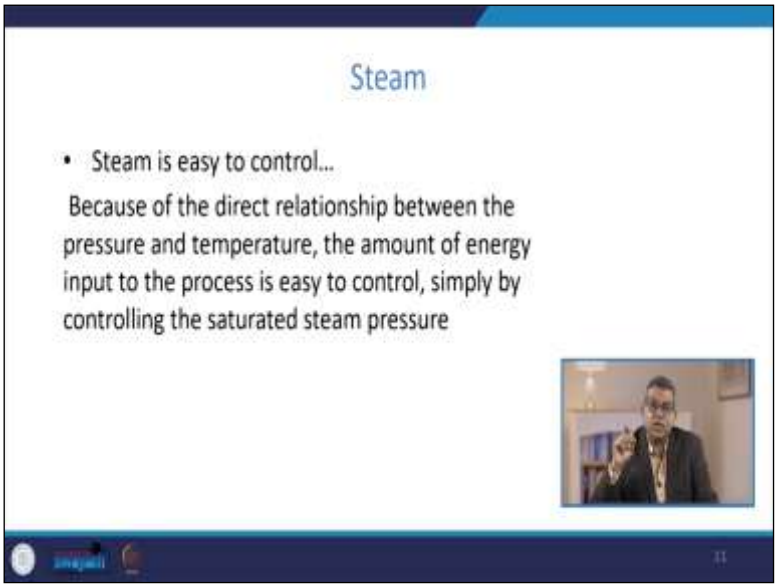


Steam is always easy to control because we have a direct relationship between pressure and temperature. You can easily control the amount of energy input to the process simply by controlling the saturated steam pressure.

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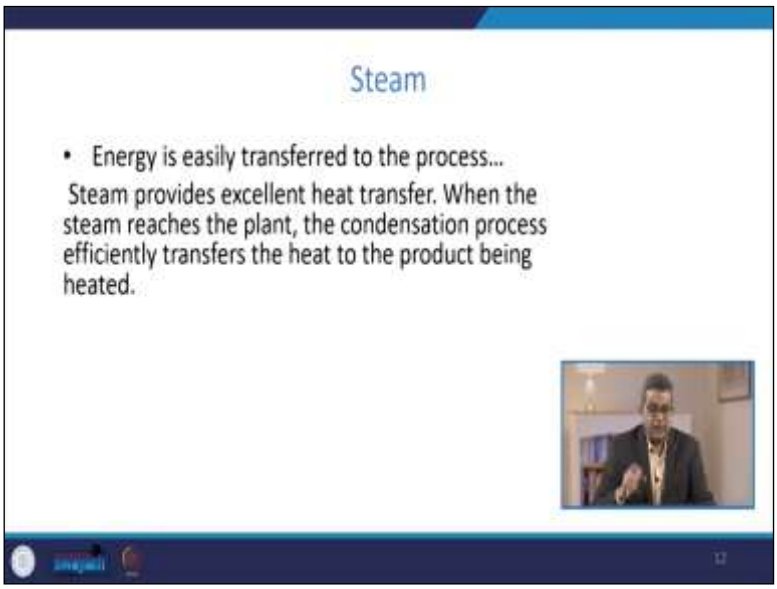


Now this energy, whatever you created by the formation of steam, this energy you can easily transfer to any process. So, steam provides excellent heat transfer. When the steam reaches the plant, the condensation process efficiently transfers the heat to the heated product.

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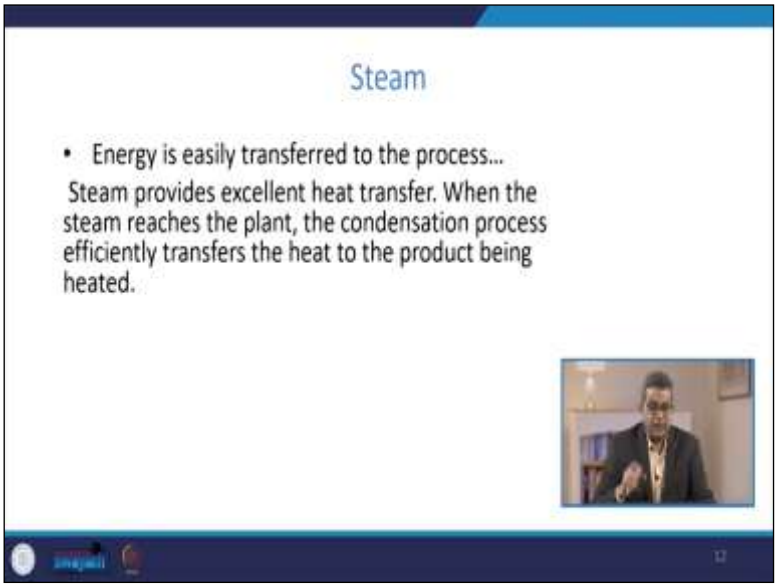


The question arises: What is an integral part of any steam plant because steam generation is not an easy task concerning the theoretical approach. We need the purified form of water or the purest form of water when we are manufacturing or preparing this pure form of water again. The

economic aspect involves. The generation may take place in a boiler. The boiler needs some external energy source through which the water can be heated.

There must be certain safety norms. Once the steam is generated, there must be a steam distribution network to the point of use and whatever condensate because earlier told you that steam condenses once it condenses into water, and water carries some economic aspect. So, you need to collect the condensate for its reuse, and there must be a certain blowdown system.

So, all these things make a complete steam modern steam plant. Now, these modern steam plants, because of this direct relationship mathematical correlation which are easily established apart from this all the properties of steam we know increasingly the industrial energy users they are always looking for maximization of energy efficiency and minimization of a product cost and overheads.

And that is why they are always intended to recover the condensate whatever is formed in due time. We will discuss this condensate recovery aspect in due course of time. Now here, you can see that this is the modern steam plant; we have a feedwater supply. Now, this feed water supply is again kept with certain sort of pre-heaters because usually, the boiler runs at a very high temperature.

So, if we supply the normal water to the boiler, there may be a chance that a thermal breakdown or thermal shock may occur. To prevent this, these feed water supply tanks must be equipped with preheat preheating devices. Now, this preheating may be either through the heat recovery aspect or through some external heat sources. This is the main boiler assembly. We will discuss the anatomy of this main boiler assembly in due course of time.

Here you see the distribution steam distribution network, which distributes the steam to the point of use; this is the blowdown valve or blowdown tank. Now the blowdown tank's role is that repeated water use may create scale or sludge formation. Now this scale or sludge does not possess any heat value or heat transfer facilitation aspect.

So, these need to be removed intermittently to improvise the energy efficiency and the boiler efficiency. So, intermittently these sludge or scales are being removed through this blowdown wall. We will discuss this thing in a later part.

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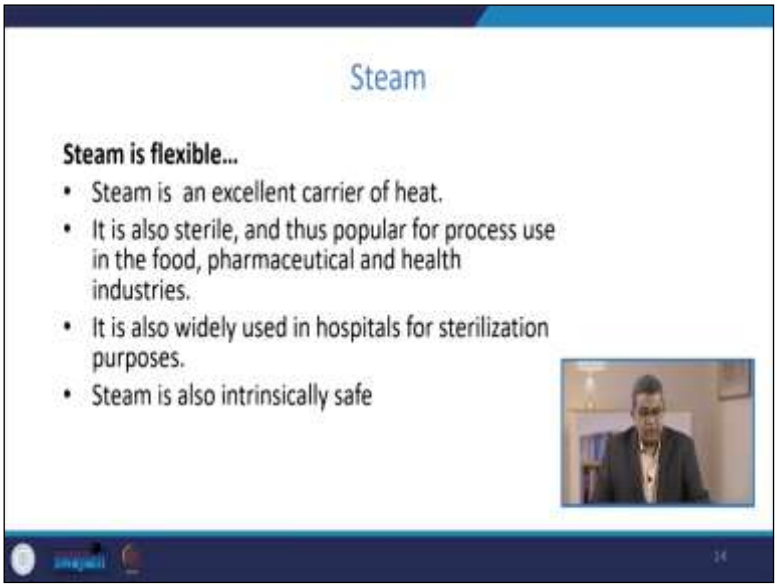


Now steam is flexible. Now steam is an excellent carrier of heat we have already discussed it is also sterile and thus popular for process use in the food pharmaceutical and health industries sterilization process is one of the examples of the health industries it also widely used in hospitals for various aspect including the sterilization, and it is also intrinsically safe.

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When we talk about the industrial energy source, the primary industrial energy source is either process heating process control some sort of mechanical drive to generate the power space heating, etc. So, these are some of the industrial energy sources.

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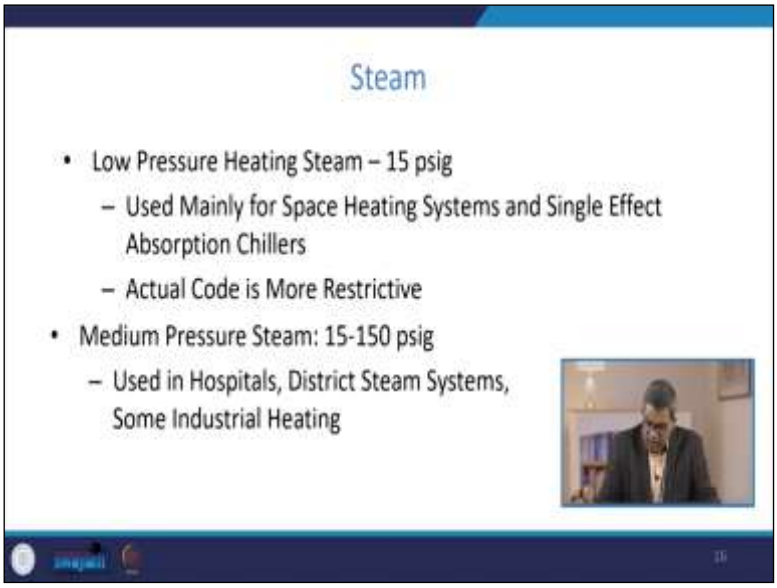


Now sometimes, the question arises of how we can classify the steam. Few people say it is that ok we may have some low-pressure heating steam maintained at 15 PSIG. This is used mainly for space heating systems, and the single effect absorption chiller actual code is more restrictive in this particular aspect. Then we may have medium pressure steam from 15 to 150 PSIG used in the hospital steam systems, some of the industrial heating.

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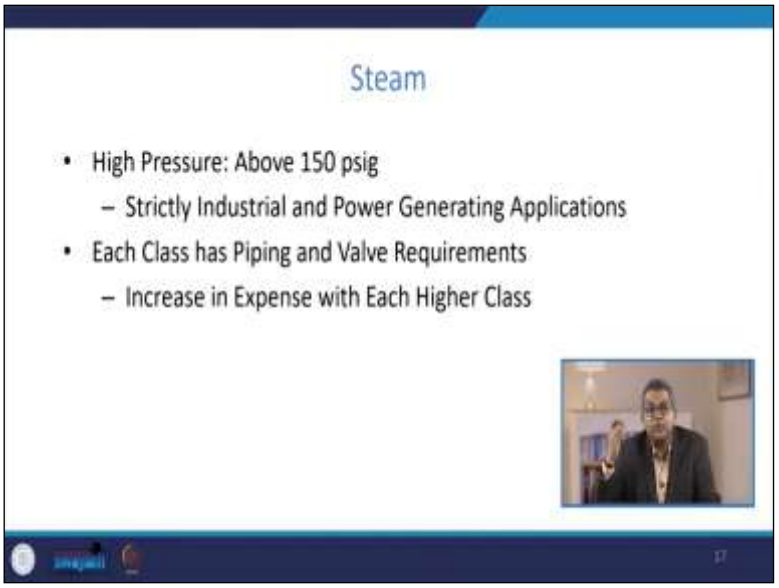


Then there is a high-pressure category which is above 150 PSIG. Now, this is strictly industrial and power generation application. Now each class has piping and wall requirements separately. Now, whenever we go for the high-pressure stream, certain attributing expenses may go on the higher side. So, increase in expenses with each higher class of the system.

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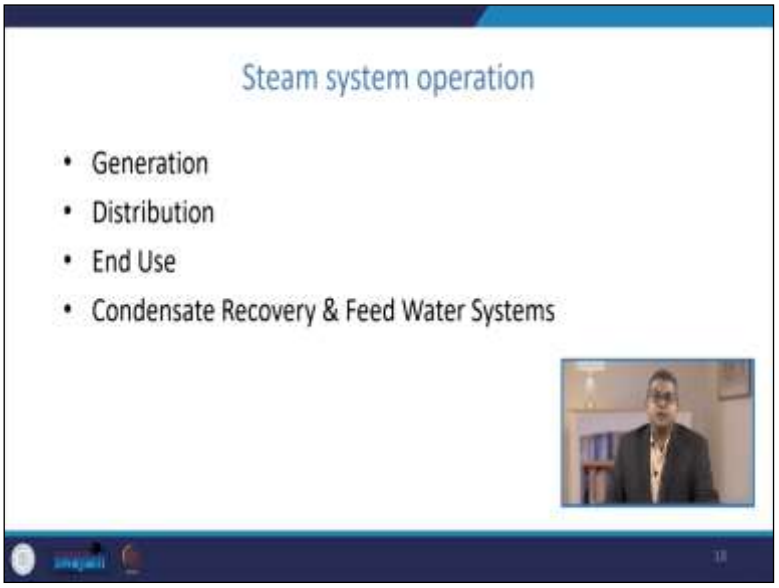


When we talk about the steam system operation, as we discussed earlier, there are four different integral parts. One is how we generate the steam, the boiler, and the feedwater supply system. They are part and parcel. Then there must be a distribution network through which we can distribute whatever steam is being formed in due course of time through the boiler to the point of

use. Then end-use, where we are using the steam, maybe for the power generation, the heating, the mixing, the agitation, etc.

Then the condensate recovery and the feedwater system. Now condensate recovery I told you that it is again very important because of water's value or precious value.

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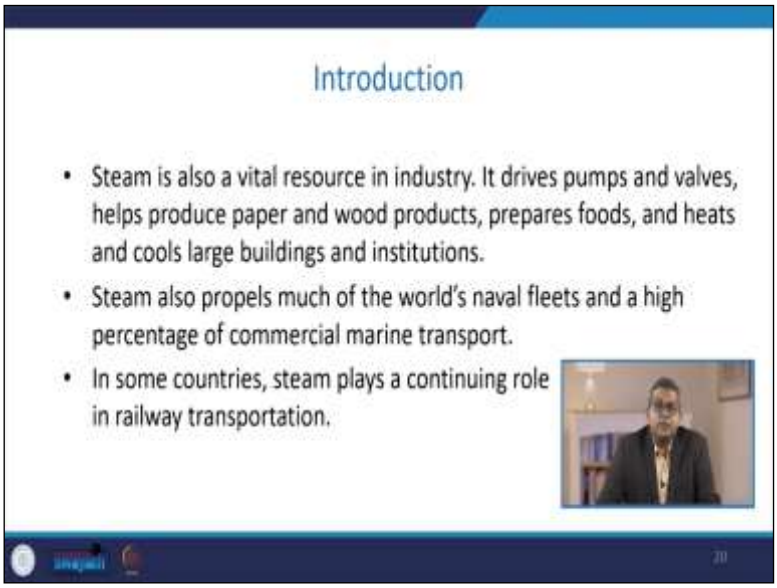


Now steam is again when we talk about the vital source of mechanical power in various industries. It drives pumps sometimes walls this help to produce the paper, and wooden products prepare food, heat and cool large building and institution. It also propelled much of the world's naval fleet and a high percentage of commercial marine transport, and remember it is it was also being used for the locomotive purpose. So, still, steam plays a continuing role in railway transportation in some countries.

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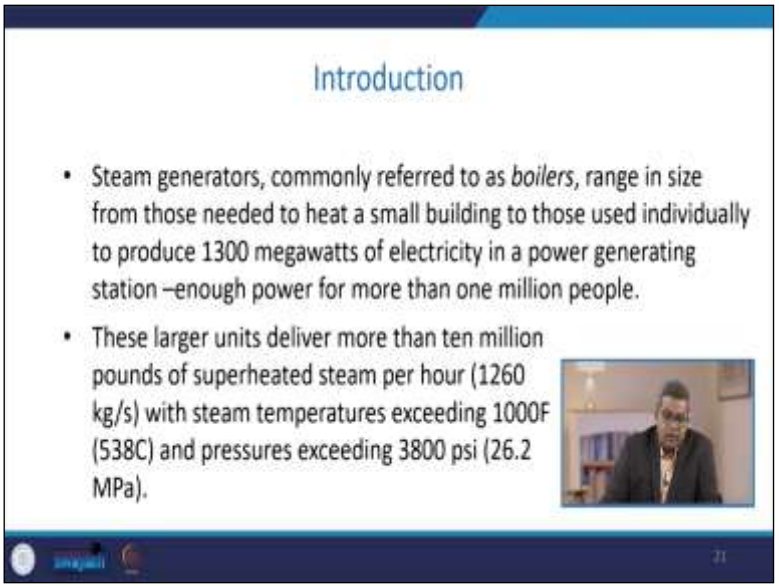


Now steam generators are usually called boilers because they boil the water and generate the steam. This ranges in size from those needed to heat a small building or use in industrial operations. Sometimes they may produce even 1300 megawatt to 1800 megawatt of electricity in the power generation system, so enough power for more than 1 million people. These larger units deliver more than 10 million pounds of superheated steam per hour.

It is roughly 1260 kilogram per second with steam temperature exceeding 1000 Fahrenheit or sometimes 538 degrees Celsius and pressure exceeding 26.2 mega Pascal.

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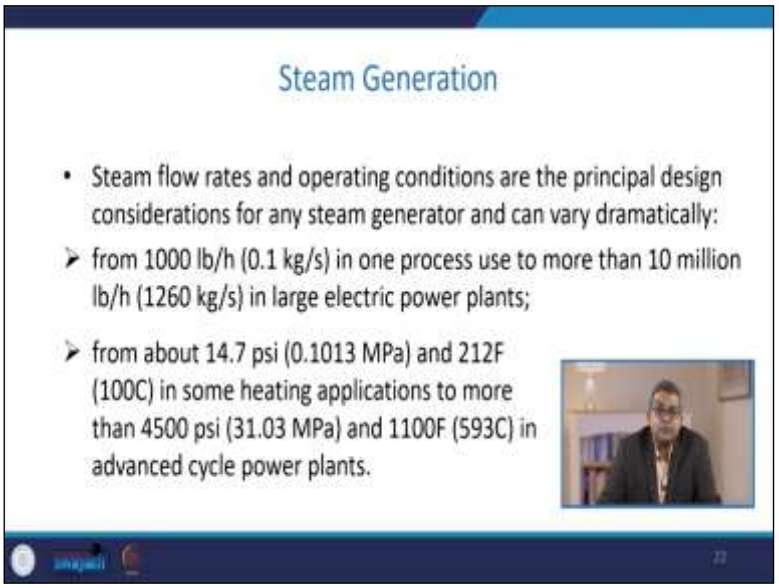

Streamflow rate and operating conditions are again crucial, and while designing the steam distribution network, it is the main candidate of design consideration. Now say from 1000 pounds per hour, that is 0.1 kilogram per second in one process sometimes use more than 10 million pounds per hour in a large electric power plant. Sometimes from about 14.7 PSIG and 212 degrees Fahrenheit in some heating applications to more than 4500 psi and 1100 Fahrenheit in advanced cycle power plants. So, you can see the wide spectrum of steam uses.

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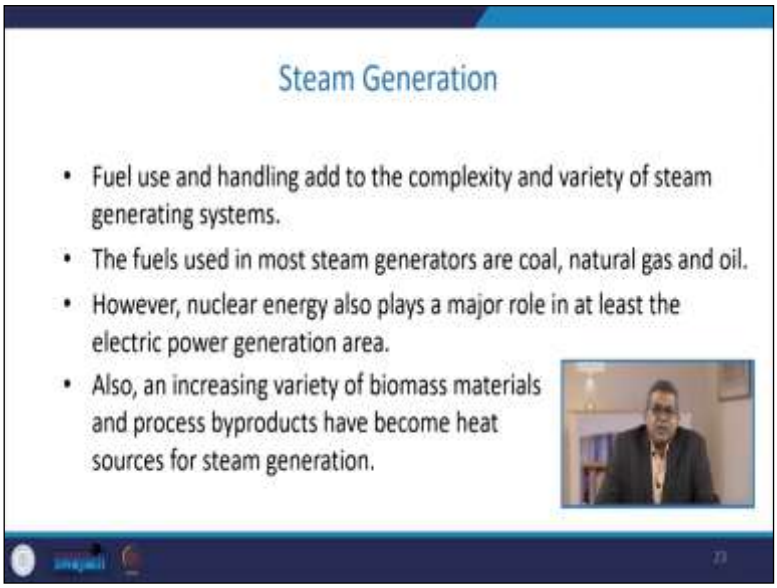


There is certain complexity associated with the steam generation attributed to the choice of fuel used like oil or gas or coal and the handling of these fuels, oil. These add to the complexity and variety of steam-generating systems. We will discuss this thing in due course of time. The fuels used in the most steam generator are mainly coal, oil, or natural gas. Sometimes nuclear energy also plays a major role in at least the electric power generation area.

Because of the excessive amount of energy being liberated in nuclear reactions and that can be capitalized for the generation of steam. This steam can be used for power generation. Also, an increasing variety of biomass materials and a process by the product have become the heat source for steam generation.

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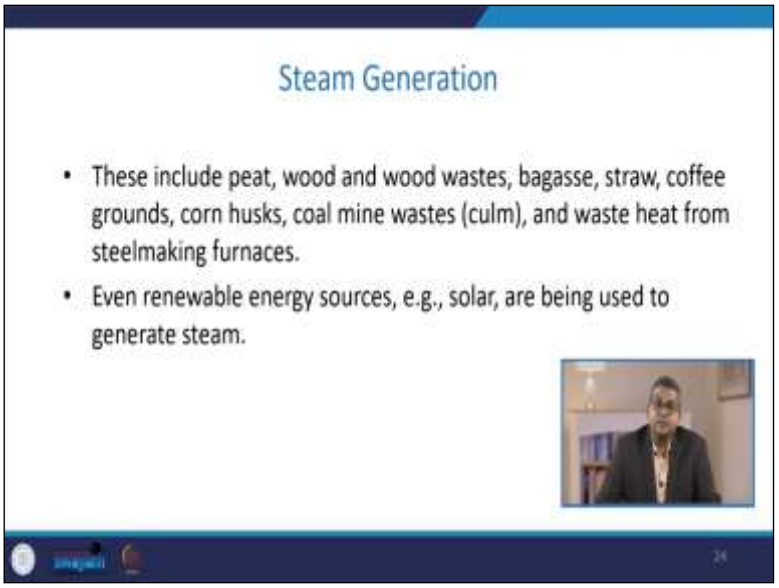


These include peat, wood and wood waste, bagasse, straw coffee grounds, cornhusk, coal mine waste, and waste heat from steel-making furnaces. Even renewable energy sources like solar are being used to generate steam. Sometimes hospital waste incineration of hospital waste is also being used for a steam generation because it offers excessive heat liberation that can be utilized to generate steam through the boiler.

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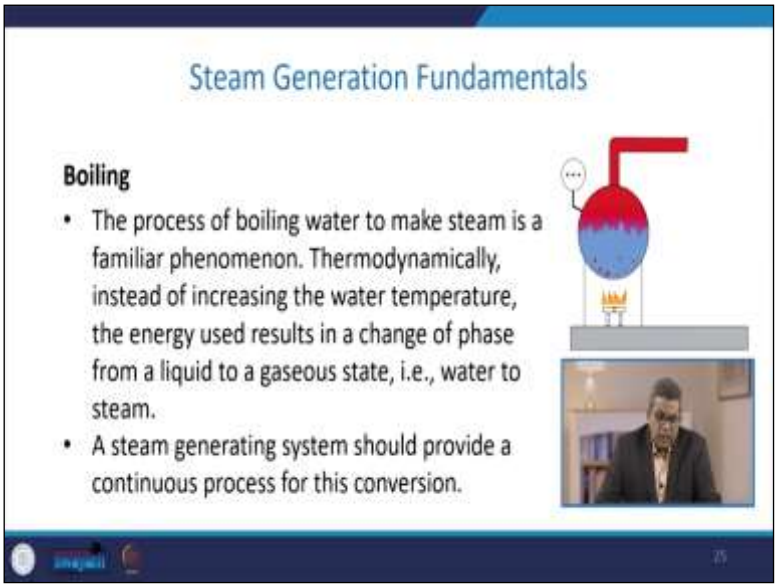


Now let us have some fundamentals about steam generation. The basic fundamental associated with steam generation is boiling. The process of boiling water to make steam is a well-known phenomenon. Thermodynamically instead of increasing the water temperature, the energy used

results in a phase change from liquid to gas versus state water to steam. The steam generating system should provide a continuous process for this conversion.

Here you can see that is the small steam generator where we are supplying the heat, and this is the water level, and this is the steam chest, and you are getting steam, and we are equipped with the pressure measuring device; This is the basic form of boiling equipment.

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Now keeping, given this particular fact, let us go into the details of the boilers. You may recall that these are the locomotive engines used for transportation, but in some countries, they are in use. You can see this graphic. This is the small amount of steam generator where the steam is being generated at a step specified pressure, and it can be used for various domestic purposes.

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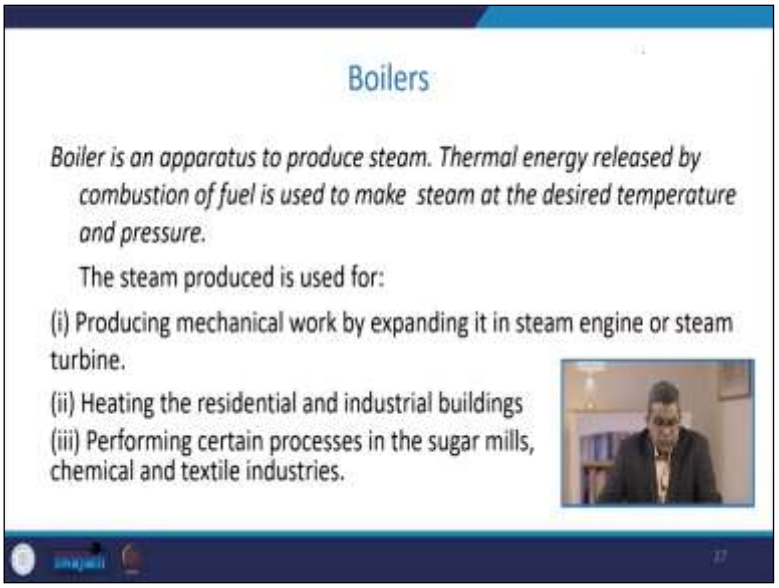


So, what is a boiler? Does the question arise of how we can define the boiler? The boiler is an apparatus to produce steam thermal energy released by fuel combustion. This is used to make steam at the desired temperature and pressure. Now whatever steam is being produced, it can be used to produce mechanical work by expanding it in steam engine or steam turbine. We can utilize this steam to heat residential and industrial buildings very common in developed countries.

They perform certain processes in sugar mills, chemical plants, textile industries, pulp, paper, pharmaceutical industries, etc.

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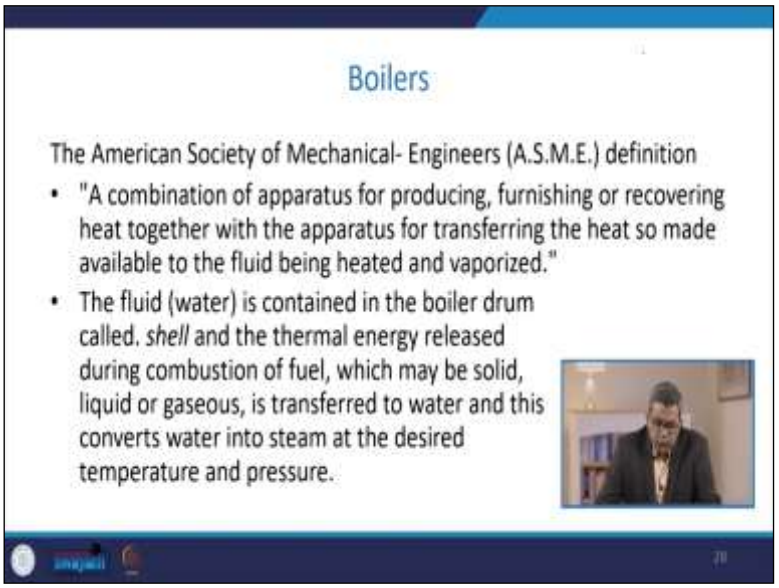

When we talk about the specific definition, the American society of mechanical engineers popularly known as ASME gives us a broad scientific definition. Now, this is a combination of apparatus for furnishing or recovering the heat and the apparatus for transferring the heat to the fluid being heated and vaporized. Now fluid usually is the water. In this case, fluid is heat contained in the boiler drum called a shell.

And the thermal energy is released during the combustion of fuel which may be solid liquid or gaseous. This thermal energy is transferred to water, converting water into steam at the desired temperature and pressure. Remember, there is a co-relationship between the temperature and the pressure concerning the steam, a well-known phenomenon has been discussed thoroughly in the steam tables.

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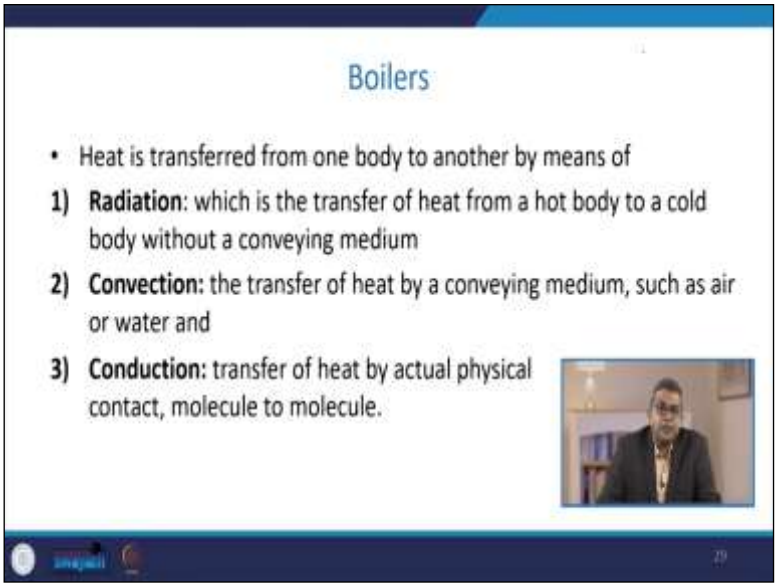


Now the heat is transferred from one body to another using radiation convection and conduction. It is our heat transfer phenomenon. Now radiation is the transfer of heat from one hot body to cold body without a conveying media convection. The heat can transfer heat by conveying media such as air or water and conduction transfer of heat by actual physical contact molecule to molecule. These three are phenomena.

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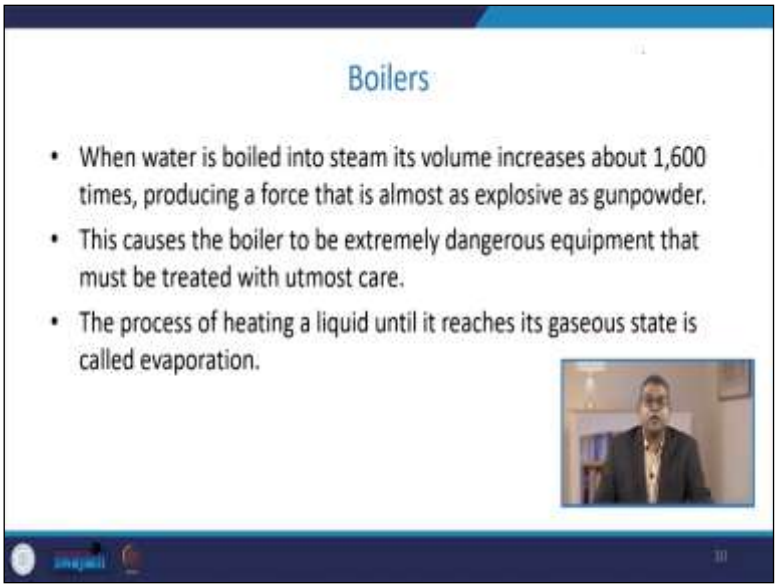


Now when water is boiled into steam, its volume increases about 1600 times, producing a force that is almost as explosive as gunpowder. Now, this causes the boiler to be extremely dangerous equipment, which must be treated with the most care, and that is why it is called the pressure vessel sometimes; it is referred to as the pressure vessel. Accelerating a liquid until it reaches its gaseous state is called evaporation.

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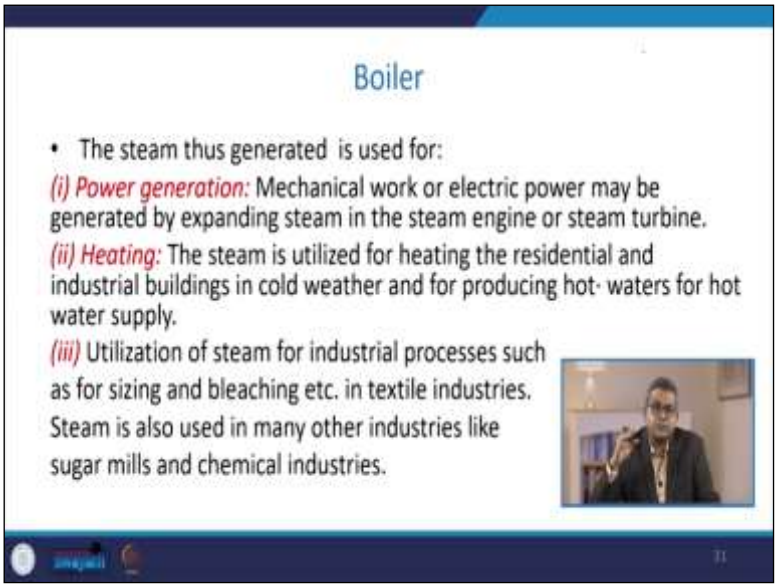


So, the steam generated by this means can be used for mechanical work or electric power generation. This can be generated by expanding steam in the steam engine or steam turbine heating this can be utilized for heating the residential, industrial building, various chemical processes, etc.

Utilization of steam for industrial processes such as; sizing and bleaching in textile industries. Steam is also used in many other industries like sugar mills, paper mills, chemical industries, etc.

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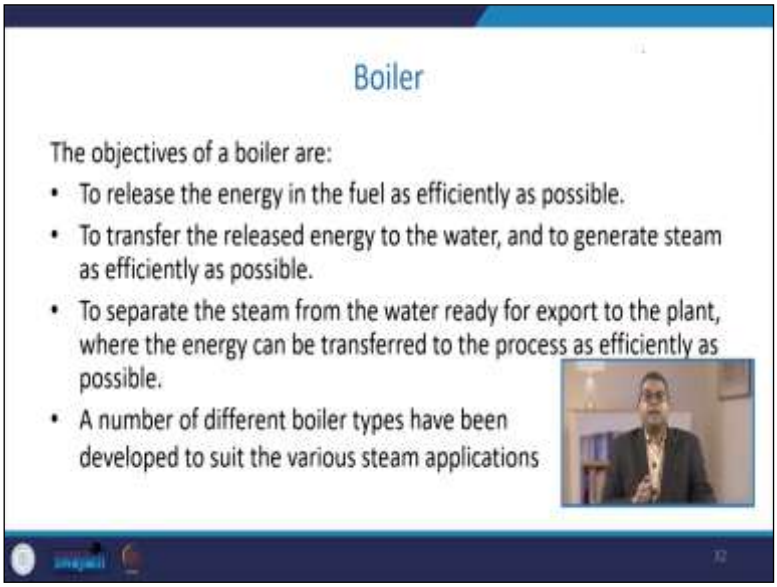


So, the thing is that when we call the boiler pressure vessels, a lot of operations are being carried out within the boiler; then one may ask that, what is the objective of the boiler? Because see it acquires the heat from some source delivered to the water generate the steams at high-temperature high pressure distributed then what is the objective of boiler? The objective of the boiler is to release the energy in the fuel as efficiently as possible.

To transfer whatever the released energy occurred to the water and generate steam as efficiently as possible. Now see, if there is a chest steam chest in intimate contact with the water, then there is a need to separate the steam from the water that needs to be exported to the plant. Now, this is again one of the objectives of the boiler. Now, where does this need to be exported? The energy can be transferred to the process as efficiently and as quickly as possible. So, many different boiler types have been developed to suit the various steam applications.

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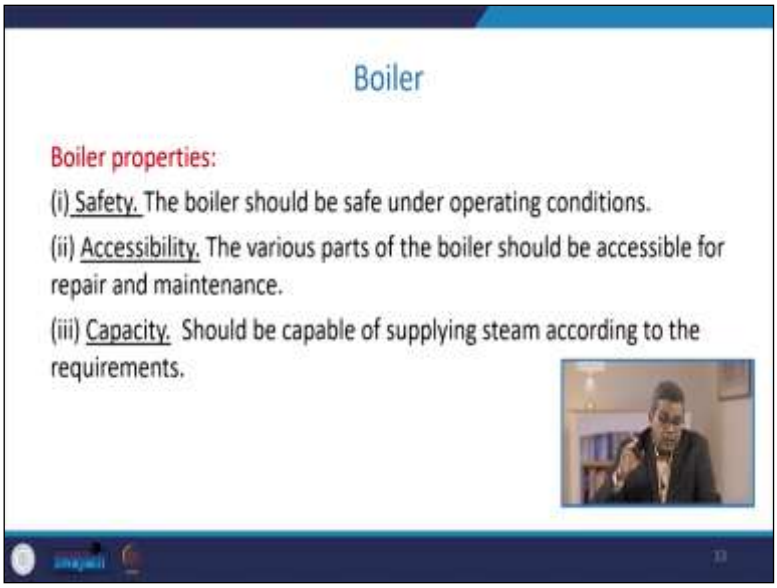


Certain things are essential in the boiler that we will discuss in due course of time. One is safety because, as I told you, the boiler is sometimes called the pressure vessel. So, the boiler should be safe under operating conditions because it can build excessive pressure and temperature. So, it should be safe accessibility the various parts because the boiler contains various parts, including the safety wall stream distribution network, water level indicator temperature sensors, etc.

And sometimes, because the repeated use of water may create the problem of scaling, you need to maintain all these points repeatedly or intermittently. So, the accessibility of the various part of the boiler should be accessible for repairing and maintenance. Then the capacity should be capable of supplying steam according to the requirement because some processes may require superheated steam some processes may require saturated steam. So, these boilers should be capable of supplying as per the requirement.

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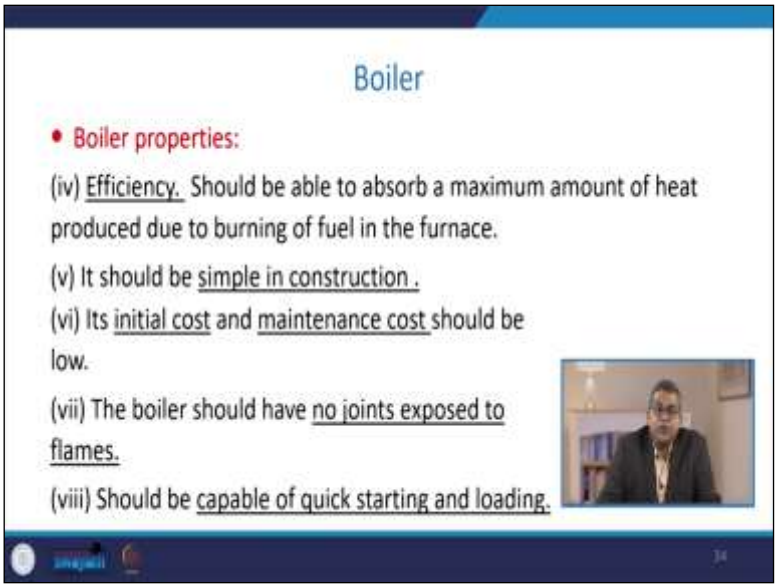


Apart from this, efficiency is again a very crucial thing. Now, this should be able to absorb a maximum amount of heat produced due to the burning of fuel in the furnace. Now, remember this is again very crucial because per unit cost of steam is always dependent on these types of things, which is quite essential that it should be simple in construction. So, that maintenance and repairing may be easy, its initial cost and maintenance cost should be as low as possible because, ultimately, it will produce by this way it can produce steam at a lower cost.

The boiler should have no joints exposed to the flame because sometimes the thermal expansion may create a problem. The boiler may explode, and serious accidents in the past occurred just because of this particular hiatus. Now, these boilers should be capable of quick starting and loading, which is always desirable to maintain the boiler's efficiency. When we talk about the boiler, they are specifically the pressure vessels.

So, every country has its boiler regulations. These boiler regulations are attributed to the safety of the workers to the safety of the nearby people to the safety of other people who may directly or indirectly may get in touch with these kinds of things. So, in India, we have boiler regulations and boiler act again in our country. So, the Indian Boiler Act was enacted to consolidate and amend the law related to the steam boiler.

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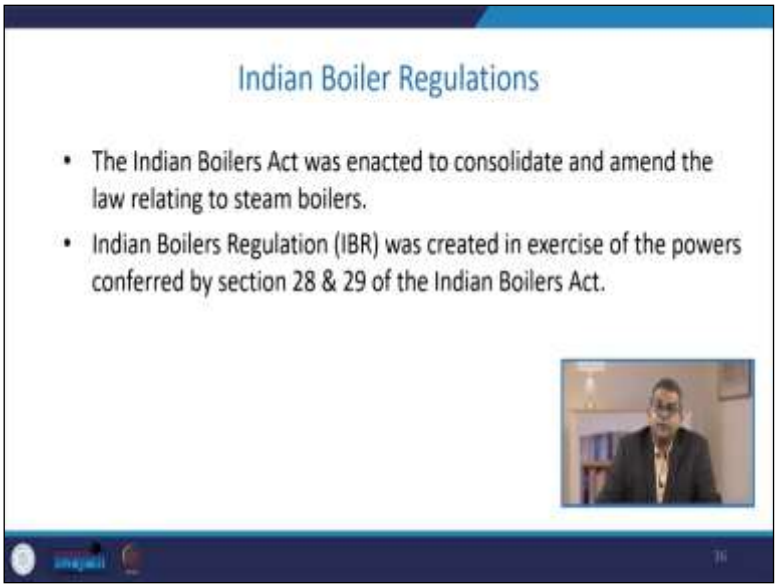


This Indian boiler regulation was created to exercise power conferred by sections 28 and 29 of the Indian Boiler Act. Now there are certain advantages of this Indian boiler regulation approval as to complete the manufacturing system; they need to have an IBR approved material. So, the risk of explosion again reiterates that the boiler is a pressure vessel. So, the risk of an explosion can be minimized.

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Now, as approved by IBR, there will not be the legal complication that ensures the peace of mind that is the broad spectrum of IBR. The IBR design and construction compliance ensures longer tube life and lesser breakdown. Sometimes, because of repeated use, scale formation, and corrosive

material involvement, the tube may get brittle or deformed, creating a problem. It may lead to a boiler explosion.

So, the IBR approval is essential concerning the design and construction. The overall safety assurance is the Indian government-certified third-party inspection under the aegis of IBR.

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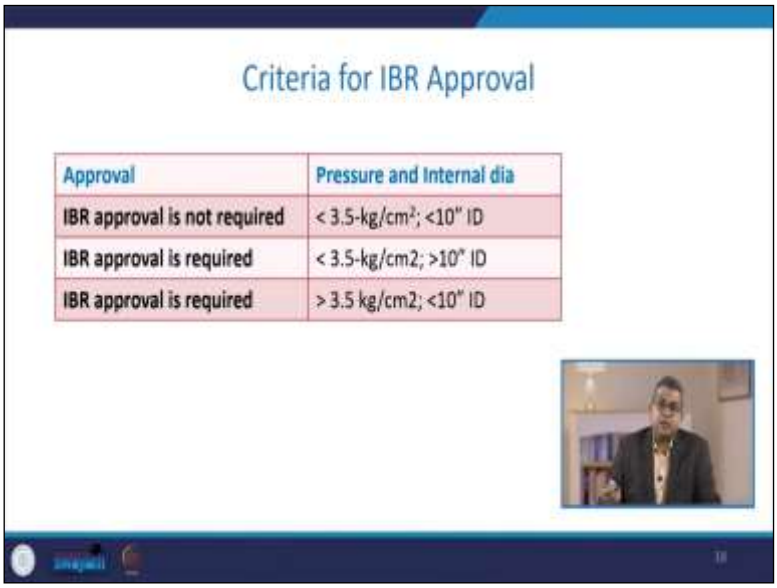


There are various criteria for Indian boiler regulation approval; not every boiler needs IBR approval. If we have 3.5 kilograms per centimeter square and less than 10 inches internal diameter, the IBR approval is not required. But if you have between 3.5 kilograms per centimeter square and greater than 10 inches id, then IBR approval is required.

So, these are the conditions concerning the pressure and internal dia which IBR approval is required or not required.

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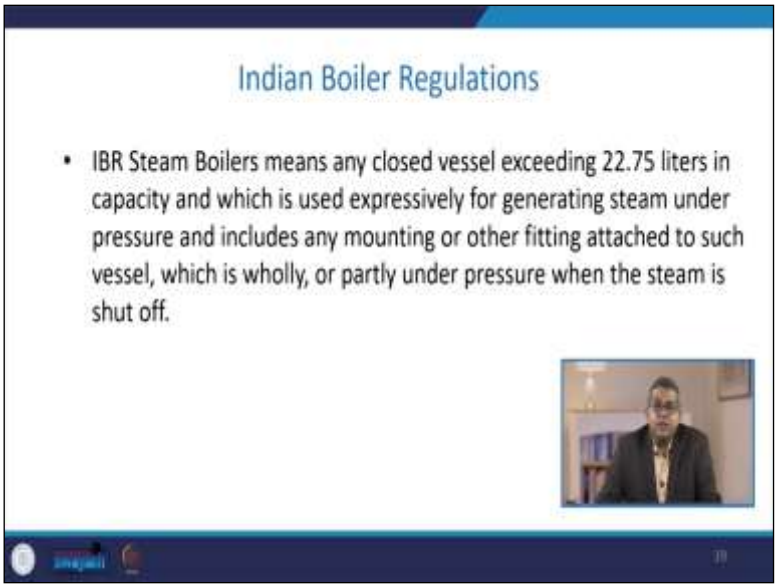


Now IBR steam boilers mean any closed vessel exceeding 22.75 liters in capacity and are used expressively for generating steam under pressure and including any mounting or other fitting attached to such vessel that is wholly or partially under pressure when the steam is shut off.

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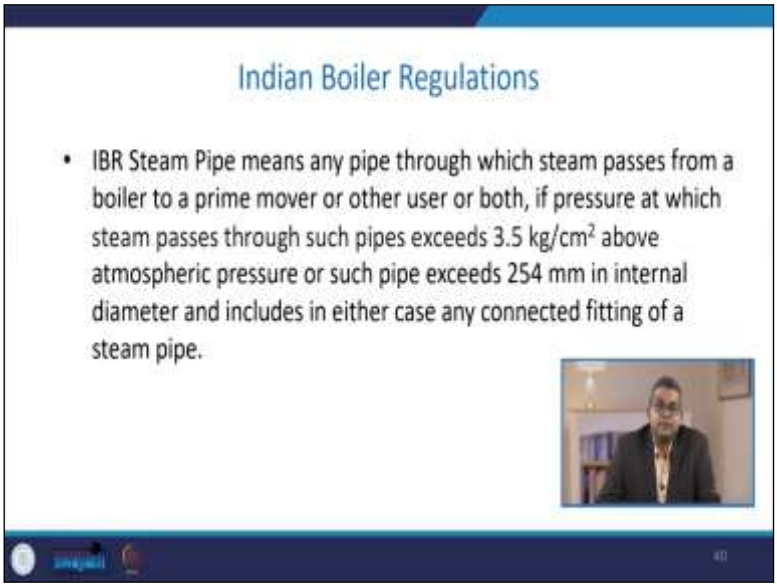


Now IBR steam pipe means any pipe through which steam passes from a boiler to the prime mover or other user or both if the pressure at which the steam passes through such pipe exceeds 3.5 kilograms per centimeter square above atmospheric pressure or such pipe exceeds 254 mm in internal diameter and includes, in either case, any connected fitting of a steam pipe.

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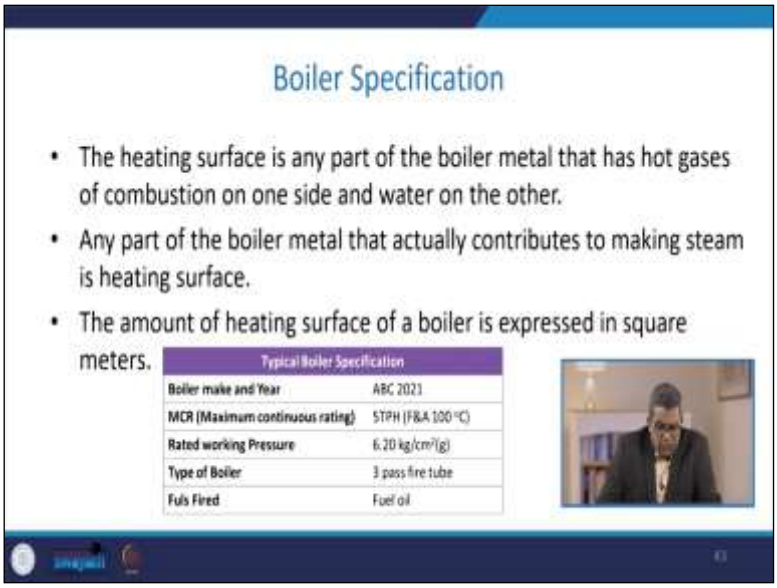


Now let us talk about some boiler specifications. The heating surface is any part of the boiler metal with hot gas of combustion on one side and water on the other side. Now any part of the boiler metal that contributes to making the steam is the heating surface. So, the boiler's heating surface is expressed in square meters. This is the typical boiler rating or boiler specification.

Like its mandatory to make the mention that a boiler makes a year maximum, continuous rating rated working pressure which kind of the boiler it is and which kind of the fuel you are using may be fuel oil may be gas, natural gas, or maybe some other materials like coal, etc. The larger the boiler's heating surface, the more efficient it becomes. The quantity of the steam produced is indicated in tons of water evaporated to steam per hour.

The maximum continuous rating is the hourly evaporation that can be maintained for 24 hours. Now let us take it because we have various choices based on the Indian boiler regulation. In this lecture, we have discussed the various aspects of different steam properties of the steam and how we can produce the steam. How is steam beneficial? What is an integral part of the steam generation system?

As well as a small amount of detailed knowledge about the boilers what are the boilers basic definitions of boilers as per the ASME standards. And for your convenience, we have enlisted a couple of references.

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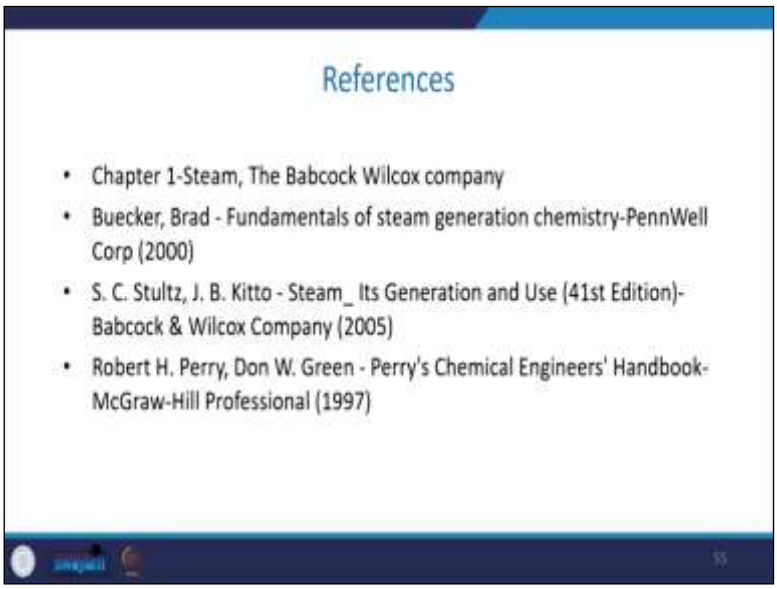


You can go through all these references for further studies; thank you very much.