Textile Finishing
Prof. Kushal Sen
Department of Textile Technology
Indian Institute of Technology - Delhi

Module - 8
Lecture - 19
Fire Retardant Finishing

Welcome back to this class on textile finishing. Just to recall, till the last time, what did we learn.

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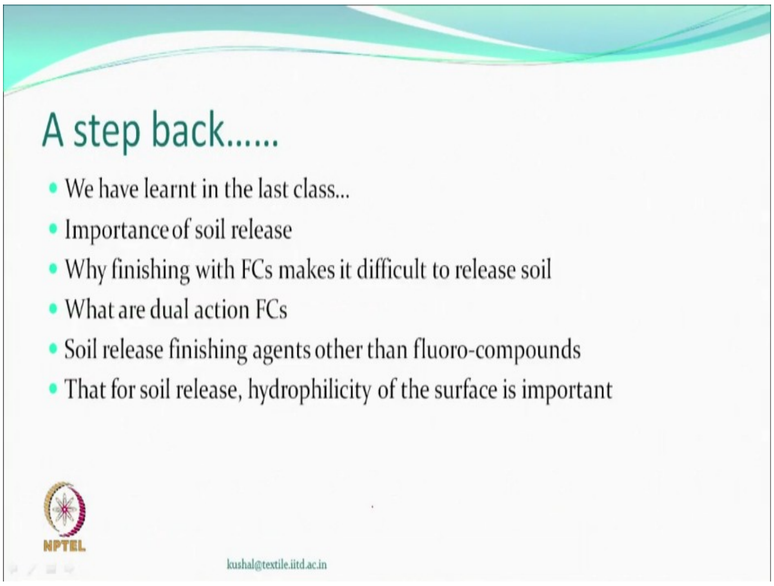

We understood the importance of soil release vis-a-vis soil repellency. We also understood and discussed while the common fluorochemical compounds are very good soil repellent, but it is difficult to release soil from these finished garments. And therefore, one had to synthesize a new type of smart compounds, called the dual action fluorochemicals, which would not only repel the soil, but also help in the release of the soil.

We also learned about some other compounds as soil releasing agents or finishes, other than the fluoro compounds. So, it is clear that, for soil release, hydrophilicity of the surface is also very important.

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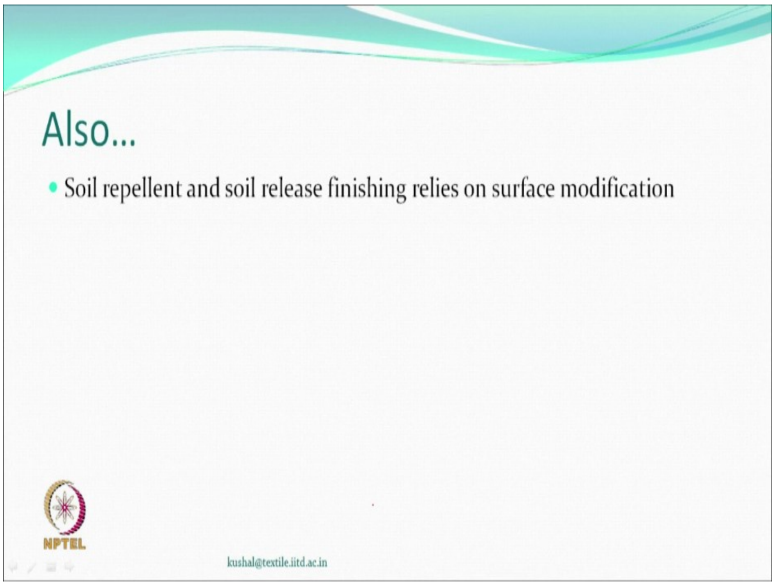

We also must remember that soil repellent and soil release finishes basically rely on surface modification and not bulk modification. Right. So, let us move on and look at another interesting finishing treatment.

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That is fire retardant finishing.

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This is one of the very important textile finishing treatments.

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Today, in this interaction that we are having, we shall be defining what do we understand by this flame retardancy; approximately, what is the burning process; what does it involve; and just some fundamental approaches for rendering a textile fire or flame retardant. Okay. That is what we intend to do in this lecture.

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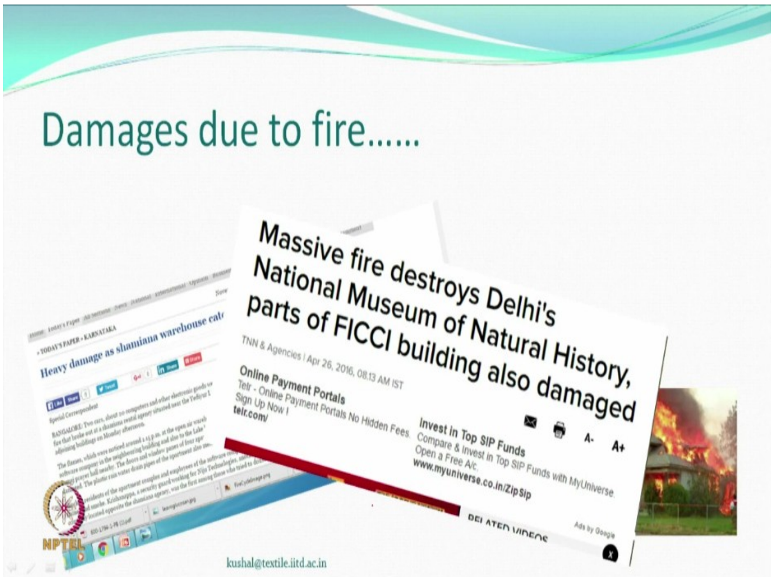

Damages: You may be hearing a lot of news once in a while, that the building has caught a fire; that a tent arranged for a certain function caught fire; a fire in a cinema hall. All these things are very difficult news to digest. So, there are damages which happens due to fire; tragedies happen. And that actually becomes an important safety consideration for any, let us say a legislative body. When a fire occurs in any environment, so, there is definitely damage to life which we are quite bothered.

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There is definitely damage to property, valuable property. And so, that is permanent. These days, we hear lot of natural calamities like forest fire. Recently, you may have heard fires in Amazon forest. Before that, many other such forest areas, particularly in dry season, get fire and there is a lot of damage. And vis-a-vis that you have a city fires, where the buildings, the temporary structures, they catch fire.

And these are generally, we will consider as a man made disasters. Then, industrial fires which happen in various industries due to flash fires, flammable compounds. And in some sense, the fire department is always kept on their toes, because you get keep getting calls at odd hours, that something wrong has happened somewhere and it has caught fire. So, fire and damage to the fire is a common place. And one would obviously like to avoid it. So, where do the textiles come into this picture?

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Textiles are everywhere. Starting from the apparel that we wear; the household textiles which may be curtains, carpet, rugs, wall hangings, upholstery. Then, the structural tents. These days, lot of temporary structures are created for, generally for some function. But these structures can actually be quite permanent also. And then, protective textiles. Where someone is actually working in industry where fire hazards are more common.

So, textiles are everywhere. And what is the problem? The problem is, textiles may also burn. You may have seen them. Can we solve all these problems, starting some natural disaster to the industrial fires and everything else; as a textile person? Well, we may not be able to handle other things. But we can render the textiles more safe from the fire hazards and prevent some of these losses.

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Textile mills themselves can sometimes get fires. Lot of news keeps coming that the whole store in a spinning mill containing bales of cotton got destroyed. Otherwise, in finishing departments and various other things you may have, let us say pigment printing; and you are doing, using a water oil mixture as a thickening agent, there are chances that there are flash fires.

So, the fires can happen in daily life; in the house, outside the house and in the mills. Any kind of environment can actually get fires. And so, one must be concerned about them. In fact, lot of legislation has come up in different countries. For example, baby wear.

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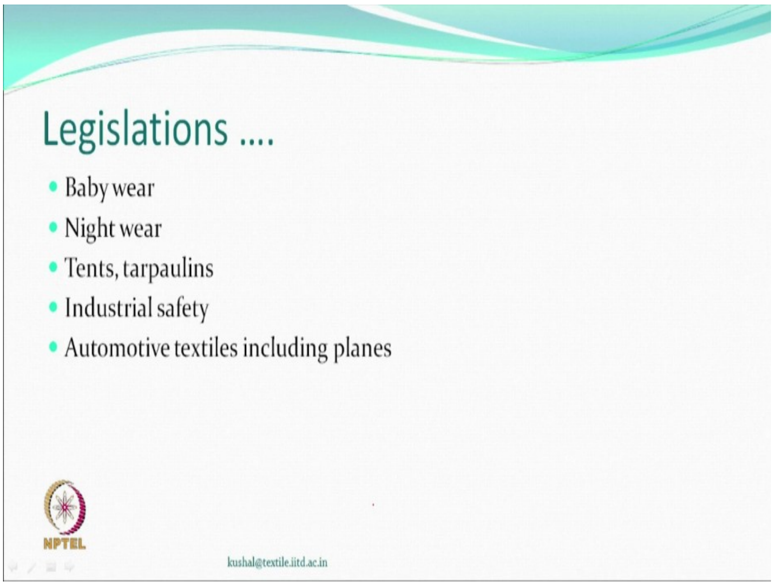

People would want it to be definitely flame retardant. Similarly, night wears, where persons are sleeping. They must be fire retardant, flame retardant. And of course, tents, tarpaulins, industrial safety garments. For example, a fireman's clothing, automotive textiles including those which are used in upholstery in aeroplanes, rails, trains, etcetera. So, there will be legislation which will help the user to become little more safer, if some treatments have been given. So therefore, what we are discussing today becomes an important finishing treatment, which is flame or fire retardants.

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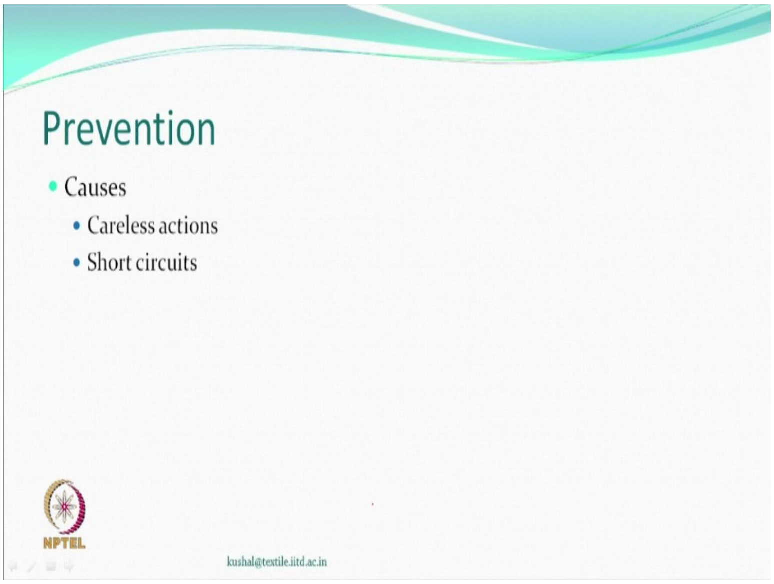

The cause, generally would be a carelessness. A cigarette or something thrown at in a forest for example, or where the flammables are stored, could become one of the cause. Another cause which normally people find is some electric short circuiting. And so, that also starts the fire. And once the fire starts, it continues and damages lot of property and sometimes lives also. So, what is the primary goal of fire retardant finishing treatment?

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Is it to save textiles? Obviously, no. Our aim would be save lives, save property.

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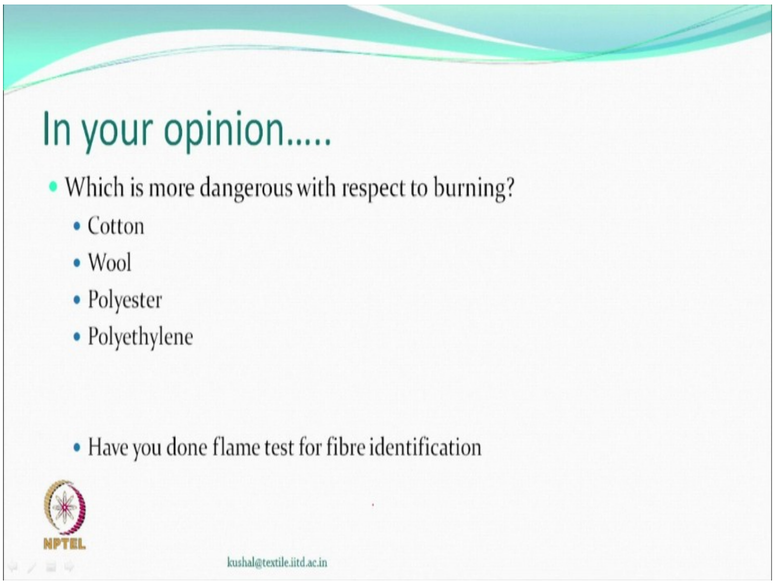

In your opinion, which of the following in your opinion burns more rapidly or is more dangerous with respect to burning? Cotton, wool, polyester, polyethylene. Have you faced any time? Let us say in your earlier classes, you may have done a flame test for identification of fibers. Do you remember the flame test for cotton? When you take it near the flame, what happened?

Does it burn or not? It burns. What kind of smell does it give? Yeah, paper burning smell. Wool, does it burn? When you take it near the flame, it does burn, but differently. What smell? Something like burning hair. It is a protein fiber. Polyester, a common fabric. What happens here? Well, it shrinks. That is one thing which we normally notice, that a synthetic fiber shrinks, which is thermoplastic.

So, polyester also thermoplastic and it shrinks; and it melts; and then it burns. So, shrinking, melting, burning could be reasons. And something similar you may see in polyethylene also, which burns rapidly.

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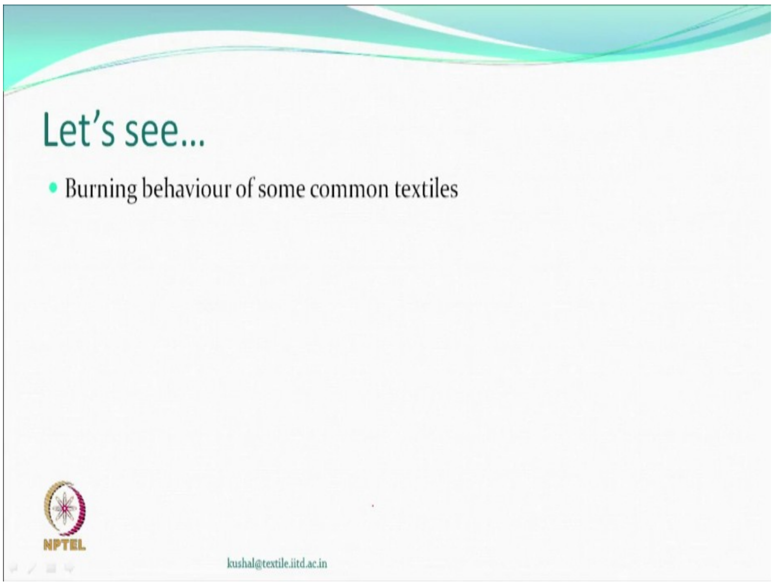

Let us see the burning behavior of some of the common textiles. So, here is a short video clip. **(Video Starts: 13:34)** Flammability of textiles. Let us look at the burning behavior of some textile fabrics. Why not cotton first? See, what happens when the cotton fabric is burnt from the bottom? The flame spreads rapidly. And the sample burns completely. Do you see any char and some glow at the edges?

Okay. Let us see what happens if we ignite the fabric from the top. Rate of burning is slower than the previous case right. But the sample does burn completely. And of course, we see the glow at the edges. It is there, is not it? The takeaway from this is, in the vertical flame test, when the fabric is ignited from the bottom, the burning is very severe. Now, let us look at the wool fabric.

When ignited from the bottom, burns completely. Surprised? Wool is supposed to be more resistant to flame compared to cotton. Right. Let us see what happens if we burn from the top. It extinguishes. What about cotton? It was completely burnt. So, it is true that wool is inherently more flame retardant compared to cotton. Polyester is one of the most important synthetic fibers.

Let us see its burning behavior, first from the bottom. It melts and burns completely. And when ignited from the top, again burns completely. Not safe, right? Okay. What about the blends, say polyester cotton. When burnt from bottom, it burns completely. It burns completely even when ignited from the top. Is any textile in common use, safe from the point of view burning? The answer is no, in bold. To make these safe, we would need to impart flame retardancy. **(Video Ends: 18:04)** So, what did you see? So, most of the fibers that you saw were burning.

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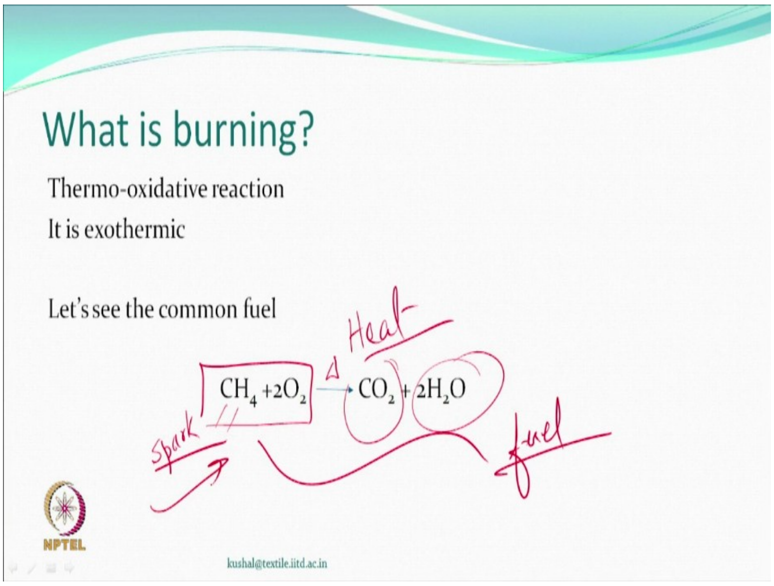

Right. So, what is burning? So, burning in short is a thermo-oxidative reaction. It is oxidative. That means oxygen is required. An exothermic, that actually it generates heat. So, this burning in a way is an exothermic process. For example, let us say a methane gas. What does it do? Well, you provide oxygen. And of course, you have to provide some heat. And then, you will see, it burns and also it gives heat.

So, there may be that if you just have these 2 compounds, very rapidly they can burn. But maybe, if you have some spark, then the flame will be instantaneous. And after that, it produces heat. And therefore, this can be considered as a fuel. And during this process of burning, obviously, the carbon and hydrogen will get converted to finally water and carbon dioxide. So, what are textiles?

Do they have carbon? That is a cellulose. Do they have hydrogen? Yes, they have. Some of them may have oxygen. Some of them may also have nitrogen. Some of them may have sulphur. But all of them, at the end of the day, if ignited; now, the ignition conditions may be different. Some of the gases for example, like methane; or the gas that you have in the kitchen, which is LPG; or natural gas.

When you switch on, the gas comes out. It does not burn by itself. Is dangerous, but does not burn by itself. So, you need a spark. You show, create a spark; and suddenly there is a flame. After that, it is all heat. And that is what is fuel.

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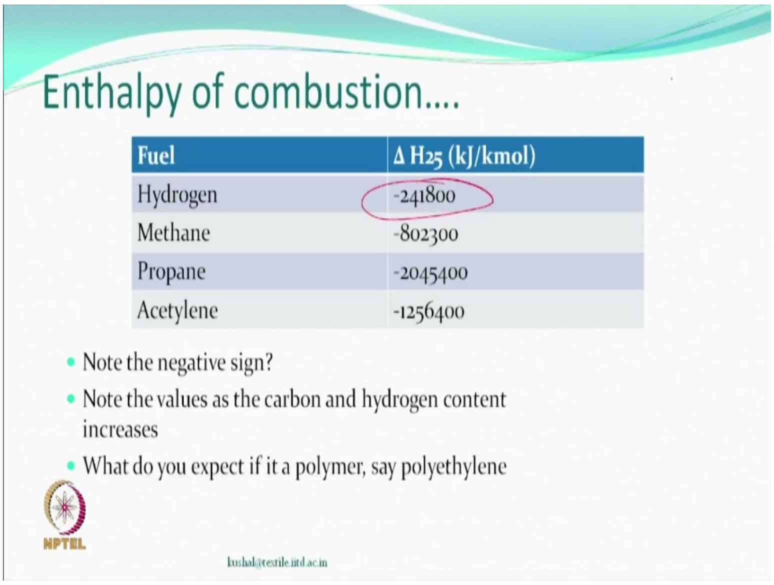

So, we look at some of the gases which can be considered as fuel. The hydrogen catches fire rapidly and actually is dangerous. But if you look at the total amount of heat produced per kilomole is 241800. Alright. We go to the next one, which is the methane we just saw before. It will be give you something like a 802300. That is the heat enthalpy. The propane is gives you like 2045400, larger. Alright.

And then, acetylene is also similar like 1256400 kilo joules per kilomole. What do we see here? A negative sign in all of these. That means, heat is being evolved, released. And so, they can act as fuel. Okay. We also notice that more is the number of carbon, more is the number of hydrogen. So, per mole of the compound or per kilomole of the compound; the enthalpy is higher. Okay.

That means what? If we have more carbon, more hydrogen, its fuel of course. When you have a polymer like polyethylene, it has got only carbon, hydrogen, carbon, hydrogen, carbon, hydrogen. So, it is a hydrocarbon. The whole of the polymer is ready to be burnt. So, shall we say that higher is the molecular weight, higher is the heat generated. Yes, of course. It will be, per mole.

If you look at it, of course, it will be. But the gases obviously get ignited faster than the liquids, than the solids. But once it starts, then there is no looking back. So, people do talk about something called a fire triangle. What is a fire triangle?

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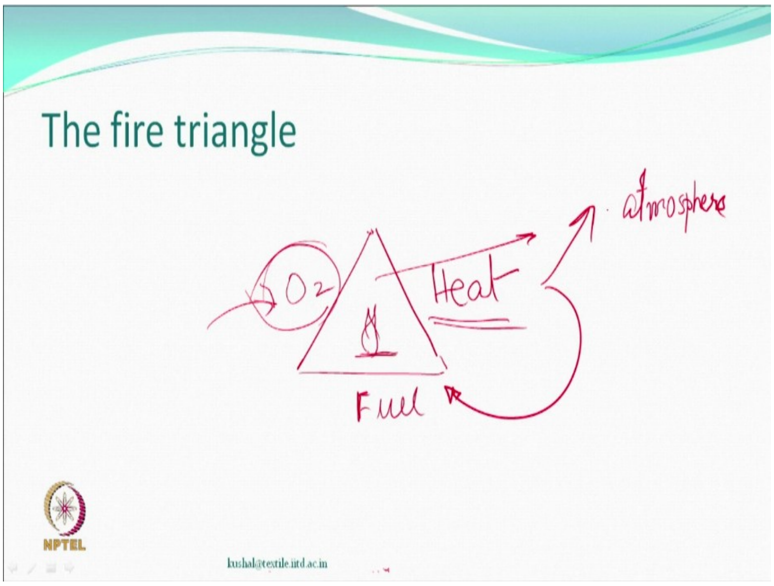

So, you have a fuel. And you give some amount of ignition by, let us say a Bunsen burner. And you; it will start reacting. And you supply oxygen. And if you supply oxygen, it is available. Then the exothermic process will start. So, you are doing some initiation. Then, the oxygen can come. And then, after that, this flame will be there. And the flame will generate heat. Some heat to give in the beginning, to be given in the beginning.

Oxygen, if is available, will react to go for a thermo-oxidative process. After that, the burning will start and heat will be released. This heat can go to the atmosphere or come back to the fuel itself. Let us say the fuel is textile or any other polymer for that matter. So, this becomes a continuous process. Oxygen keep supplying. The heat is being fed back. And so, the process continues till the fuel is finished. Alright.

Interesting thing can happen if you cut off the oxygen supply somehow. If you somehow ensure that most of the heat goes to the atmosphere does not come back, any of these things can give a clue as to what a fire retardant may do.

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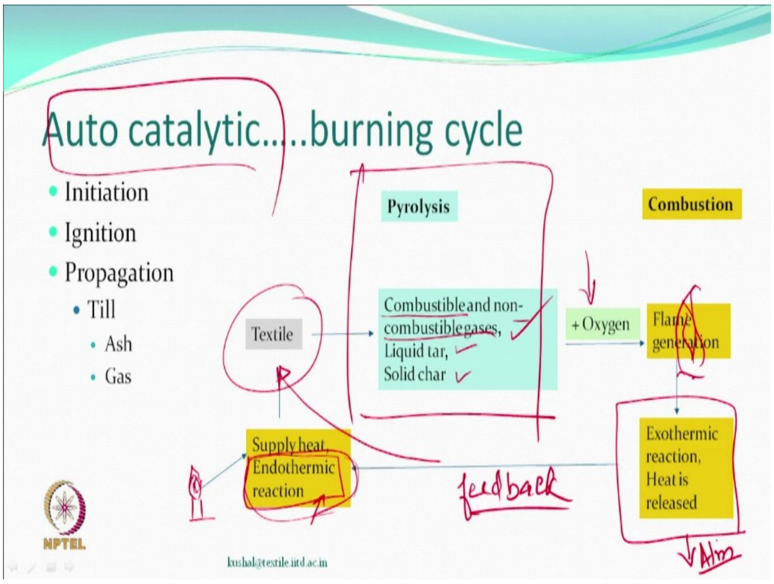

So, the burning is an autocatalytic process. It is a thermo-oxidative. It is an exothermic process. And is an autocatalytic. This burning fire triangle that you saw, autocatalytic. So, all you have to do is initiate. How do you initiate a spark? A Bunsen burner, a matchstick, take it near the fuel, so it will start. This initiation will start, what we call as ignition. So, the polymer, the fiber, the fuel will start ignite.

After it ignites, then obviously, this whole reaction, flaming reaction will propagate; keep on doing this. Autocatalytic because part of the heat may come back, then start burning on itself. You then do not have to initiate again. That means, once you start burning, you can remove the source of ignition. It will burn on its own, till it is completely finished. What will be left is, let us say an ash, if complete burning is taking place or has been converted to gases.

Gas we said could have been, could be carbon dioxide, could be water. If there are sulphur and nitrogen also present, then obviously oxides of sulphur and nitrogenous gases also will go away. And finally, we will be left with something called an ash. So, what happens? We are just revising again. So, you supply initially some heat. So, there is, you can say this is an endothermic reaction.

Because, unless you do this initiation, it may not start burning. For example, we are sitting with textiles on the classroom. For example, all upholstery on the chairs; and the table which are wood. Nothing is burning. Right. Because they are stable. But if you initiate, then they will start a reaction. So, this will be an endothermic process. And this heat for example, when it actually interacts with this, is generate some type of endothermic reaction.

And this endothermic reaction can generate combustible or non-combustible gases; can generate some liquidish material called tar; or can produce a carbonaceous material called char. And this whole thing can be considered as pyrolysis. Things are happening because we supply the heat. And this all is in some way endothermic process. The exothermic process or the combustion starts when there is a supply of oxygen.

When oxygen is supplied, then the combustion process starts and the flame gets generated; lot of flaming. And this exothermic process releases a lot of heat. This heat, as we said could go to the atmosphere or can be fed back to the textile. So, the heat can come from external source or by this autocatalytic mechanism and keep burning this, let us say the textile till it has finished. So, you have pyrolytic reactions; you have combustion reactions; and then this cycle is complete. Is it clear? So, textiles and polymers, they are fuels. They all burn.

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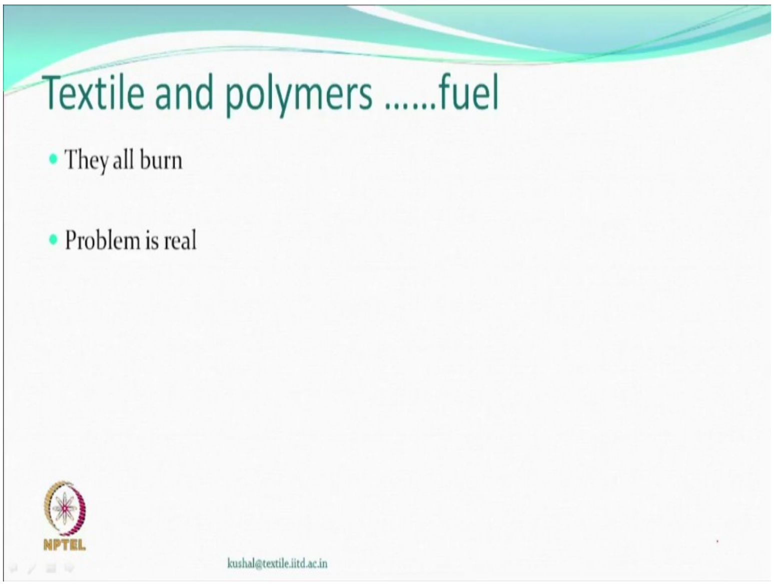

So, this is a real problem.

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So, let us say you want to solve this problem. Before that, let us look at some of the definitions. Like a flame resistant finish or a flame resistant textile, what it will be? A textile will be considered as a flame resistant when it extinguishes after the source of ignition has been removed. So, there is a textile. For example, this textile is not burning. But if you take a flame near this, which you saw in that video; if you take a flame near this, it starts the ignition, initiation of reactions.

And then it starts burning. So, you remove the source of ignition, what happens then? If it is extinguishes itself, the flame stops by itself. Then it will be considered as a frame resistant or a flame retardant fabric or a textile. Is it clear? That is, when you, after removal of, after removal of the source of ignition, the flame must extinguish by itself. So, that is the flame retardant.

Or, the another term which people use is fire resistant or fire retardant. Now, this includes 2 things. One is the flame, other is glow. Okay. So, the fire resistant fabric should be able to stop the flame as well as stop the glow. You remember the glow? Did you saw in that video? Okay. After the source of ignition has been removed. This is important. So, glow show so would not take place on its own.

The flame will also extinguish. And therefore, this whole cycle of burning will be stopped. So, a fire retardant or a fire resistant fabric would extinguish the flame one; and would not glow once the source of ignition is removed. So remember, we are not claiming that if you keep having a source of ignition, take the burner and continuously keep burning and that the textile will not burn.

That is not is the claim here. The claim is, remove the source of ignition, it will stop burning. That is one's claim. Fireproof is a textile which is really special, that you actually keep on burning and it still resists. For example, a glass fiber fabric, any other ceramic fabric; it will not catch flame, because it does not act like a fuel. So, can we do something like this? Well, that is what will, if you can.

That you keep burning, it will still not burn. Those things will be fireproof. So, they will be inherently different types of fibers having different kinds of chemistry. So, but normally we will be quite satisfied with our work if you have done fire resistant of fire retardant fabrics. Flame and glow:

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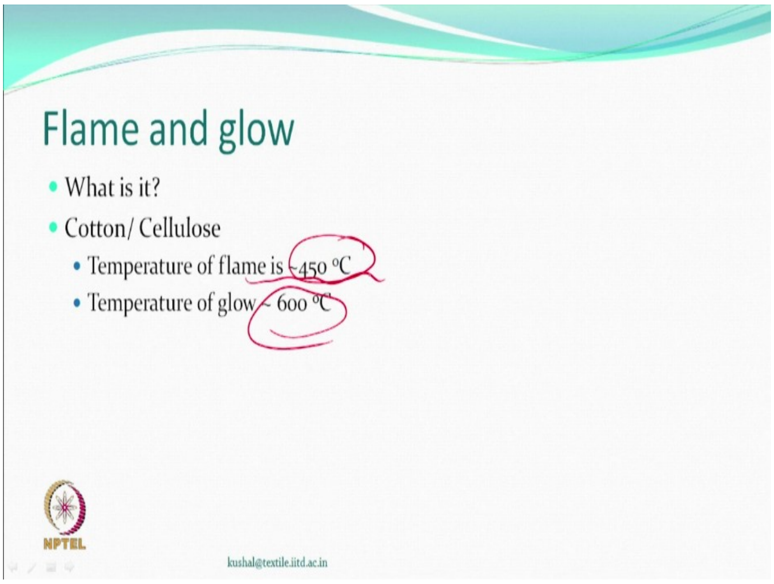

Flame is very rapid. You see that? You saw in the video, that the moment you start igniting, the flame just grows, keeps on growing up and up. Yeah, up and up means that, if you burn from the bottom, the heat generated obviously has the tendency to go up. The gases which are hot, have the tendency to go up. So, the fuel that the fiber, the polymer which is in the top, again gets the heat very easily; the feedback of the heat is easy.

If you burn from the top, the all gases and hot gases and heat is going let us say more in upper direction. So, the rate of burning becomes slow. But as such, the flame is very rapid. It grows in volume, envelopes the whole polymer and the fiber; and then the burning starts. But interestingly, in the case of cotton for example, where you have seen the glow. Okay. The temperature of the flame may be around 450 degree centigrade.

Obviously, it is ready to completely burn the system, burn the fiber, burn the polymer. No issues on that. The glow on the other hand is a very slow process, very slow. But if the glow continues, the polymer can completely finish. Because the temperature at the point of glow is actually higher than even the flaming temperature, although flaming temperature is higher enough to burn everything.

But glow which is a very slow process can also finish if the favorable conditions are there, enough oxygen is there; it will continue to burn and finish in a slow manner, but definitely finish.

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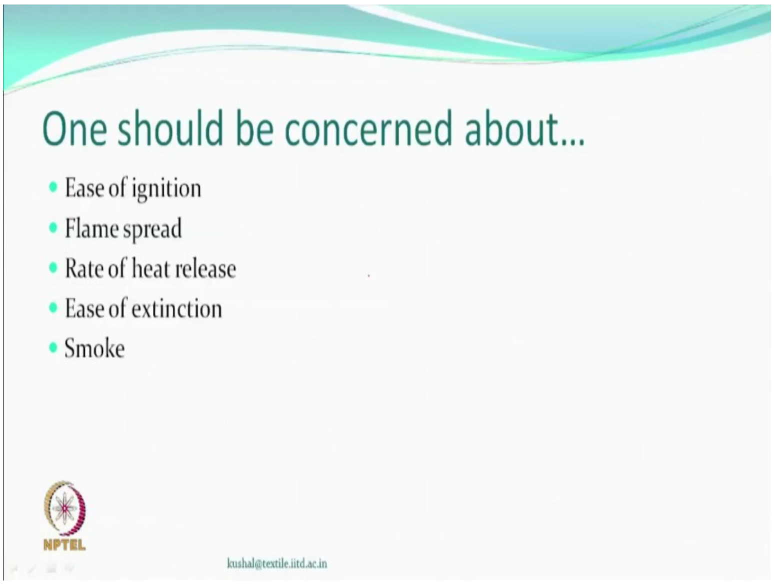

So, when we say we are going to do fire retardant, flame retardant, what are we supposed to be concerned? Ease of ignition: How easy it is to ignite? Okay. How easy? Like this textile is easy compared to let us say this wooden material. The gas, for example of methane is much easy to ignite. So, when somebody says, well, I want to make it difficult. So, you say, well, we will do something, so that it becomes difficult to ignite.

Some of the pyrolytic reactions will be difficult or will be made difficult to happen. And so, ease of ignition. So, we make it difficult. Flame spreads. How fast the flame spreads and how is it being helped? Can that be reduced? For example, if you cut the oxygen supply, the flame will not progress that fast. It is quite possible, if the air is blowing, the wind is blowing. For example, in a forest fire, when the wind blows, a large amount of area gets burned.

Because more oxygen is available, the flame keeps on growing everywhere. So, can that be restricted? So, if it is easy spreading condition, then burning will be rapid. More oxygen for that matter. That is the kind of reaction that we are talking about. Then, the rate of heat release: What is burning; how much is burning; per unit time; and how much heat is being released; all they are going to be important.

If you can cut this down, reduce this rate, then also one may get into a favorable position. So, that is the way the logic might work. Ease of extinction: That means how fast some compounds are being formed, which do not want to burn. Or you have created a condition that oxygen cannot penetrate is not apply available around the point where the fuel actually is. You can do.

One of the way is what, that is you, let us say, people say wrap blanket for example. Or you create gases, let us say carbon dioxide environment all around; something like that. Smoke: We should be bothered about the smoke that is produced. Carbon, carbon soot, all those things can be harmful. One should be concerned about it. And one should also be concerned about toxic gases.

So, it is quite possible that you treat a fabric with some compound which does all those things which we just talked about, but produces gases which are toxic in nature. If that happens, it is not good for us. So, we should be concerned about how easy it is to ignite; what is the rate of flame spread; what is the rate of heat release; is it easy to extinguish or difficult to extinguish; how much smoke is being produced.

So, people may like to measure the amount of smoke. What kind of gases are being produced; are they toxic or just like that. So, all that, somebody will have to bother. It is not just apply a chemical and say everything is alright. So, let us see in this small video clip; can we make a cotton fabric flame or let us say fire retardant. This is the short clip you may like to see.

(Video Starts: 43:39) Flame retardant cotton fabrics. Let us see what happens if we have flame retardant treated cotton fabrics. Do you remember the burning behavior of untreated cotton fabrics ignited from the bottom; ignited from the top? When imparted flame retardancy, it extinguishes when ignited from the top. It extinguishes even when ignited from the bottom. So, yes, it is possible to impart flame and fire retardancy. Does this not give motivation to learn more about this subject? It does. **(Video Ends: 44:50)**

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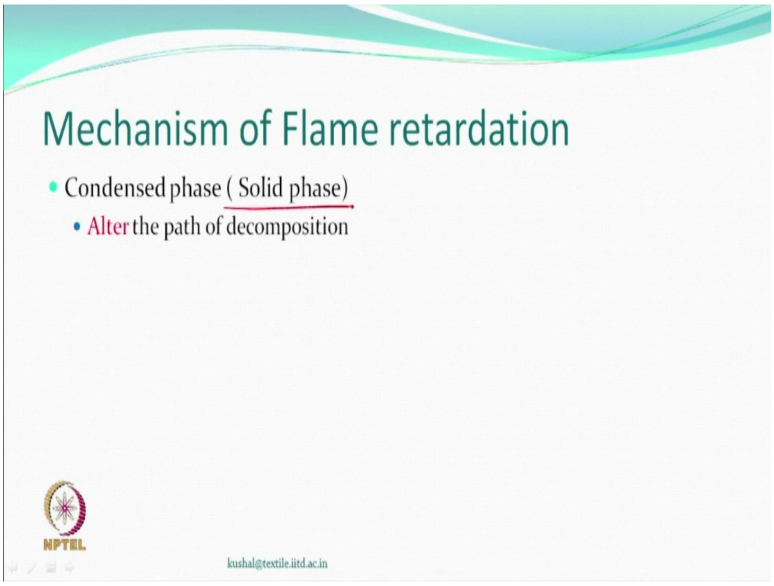

Roughly, we will discuss what we call as a mechanism of flame retardancy. We just saw some factors before. And what do we do? What actually the chemicals, if at all we apply, will be doing? So, there are one mechanism which is called a condensed phase mechanism or sometimes also referred as solid phase. Because most of the changes that will happen by this chemical would be in the solid phase.

That is, the pyrolytic path of the decomposition of this polymer will be changed. So, these chemical which will be called the fire retardants, would work in the solid phase. Let us say, you wanted; earlier the pyrolytic product was a tarry product, was a gaseous product. So, you will say, well, we reduce the production of tarry products; we reduce the production of gases. And so, alter the path of decomposition, so that they will be acting. Let us say there is a cross linking happening. The ignition time is increased, because it does not burn. So, that is how the solid phase can be changed.

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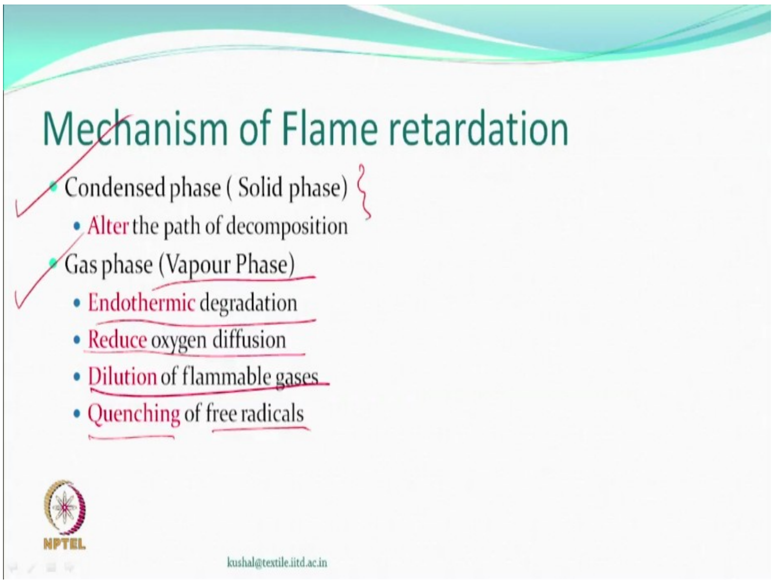

The other is called a gas phase mechanism; were sometime also referred to as a vapour phase mechanism. So, it does not work at the solid state so much. But itself degrades and become a gas. And in the flame starts acting in a vapour phase. All these flaming reactions in some sense are radical, free radical reactions that are happening around that area of the flame; very quick reactions.

But these type of flame retardants which work in the gas phase, by themselves will also degrade and work around in many ways. Their degradation may be an endothermic process. So, whatever heat gets generated by an exothermic flaming process is absorbed by these and they degrade. Or they change their phase. For example: Something is burning and you throw water. So, what happens?

The heat that was being produced has been used by water to become steam. So, the heat has gone out. So, that could be one mechanism. So, they also evaporate and everything else up so. They are not change anything on the polymer, they themselves have used the heat. They can degrade in a way, they can reduce the oxygen diffusion. For example, they degrade simultaneously and make an envelope around the burning area.

So, oxygen cannot diffuse. And so, it is in the gas phase, the oxygen wanted to come, so that the combustion could take place. And combustion does not take place. So, they have not altered anything on the polymer. They themselves have degraded to create an envelope. Interesting. They can do dilution of flammable gases. A dilution of flammable gases. That means, they themselves degrade and produce gases.

Let us say a compound degrades and produces lot of ammonia, which in a way dilutes the concentration of the flammable gases which were being generated by the pyrolysis. If that happens, then the autocatalytic thing is reduced. Afterall, you always know need certain amount of, a certain critical concentration of a flammable gas before it can catch fire. If you reduce this concentration, it may not catch fire. Alright.

And then, the whole process, the cycle stops, the burning stops. So, it is the cycle that you are talking about, you know. There is a polymer; it degrades; forms gases; the gases get oxygen; thermo-oxidative process; flame; heat is fed back; and this process continues. You stop anywhere. At the solid phase you stop, no gas is produced; no tarry liquid produced or very less produced.

In the gas phase, they themselves degrade and do certain things like this. Or another way is quenching of the free radical with themselves make, react with the radicals. Free radicals that are, say instead of the free radical reacting with the, let us say the gaseous fuel that is coming out. They are so smart, small molecules go and react with the free radical themselves. It is not available for that other thermo-oxidative process which is the flame.

So, 2 basic mechanisms. One is condensation phase. The other is the gas phase mechanism. So, some of the compound that we will study later would be acting either in the first phase or the second. In some cases, they may act in both phases. So, in this whole thing, one is thus that I reduce the burning, I reduce the oxygen, I increase the other non-flammable gases; and all that can happen.

What is important is, in what period it happens? The flaming is very quick. You saw some of the videos, right? Flaming is very quick. So, you have to do everything in very short period; short span of time. Okay. So that, the gases which can burn, diffuse out. And the oxygen, by the time it comes, they are already gone. Or the gases that the flame retardant is producing hss produced quickly, the dilution has taken place. So, there is something called a sphere of influence.

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So, the burning is taking place here. And this burning; so there are some gases being produced. The oxygen is coming. How much delay can you do in this reaction? How much, how fast can this diffusion take place? This sphere of influence is an important thing. If the diffusion takes place early, then the concentration keeps on diluting as it keeps on getting out. And the burning will not take place.

So, time; how quickly one acts and how quickly the diffusion takes place. All of them will be important. That is, you should get away as early as possible from the so called fuel. So, this sphere of influence is an important point which may note.

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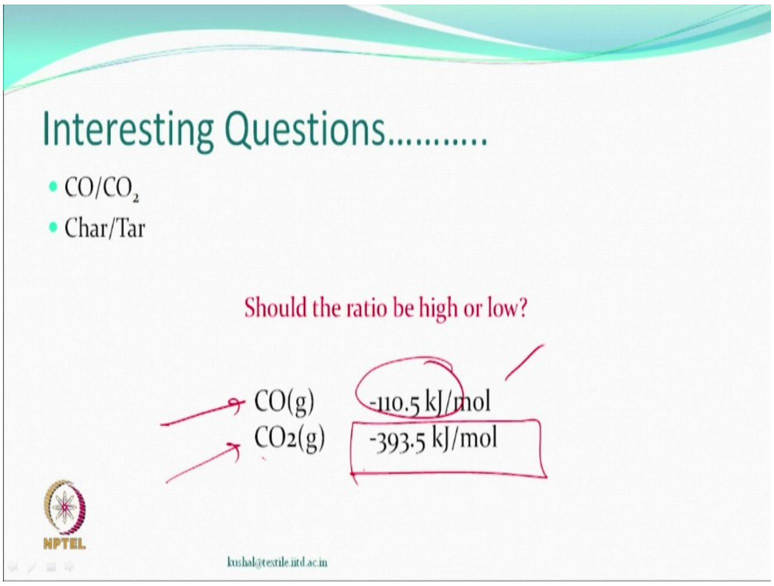

Some of the questions you may like to answer. People talk about carbon monoxide to carbon dioxide ratio. Would you like this ratio of carbon monoxide to carbon dioxide to be high or low? High or low? Similarly, another thing, char. Char, we said was a carbonaceous material. You know, something which blackish, carbonaceous material left out after the flame has been extinguished; versus tar which is liquidish material.

What would you expect a flame retardant should do? Increase the char to tar ratio or decrease. Well, obviously, it is quite clear. Char obviously can only glow. Rate of burning will be very slow. And so, tarry material will become to catch fire; it can get converted to gas easily. And so, you would like char to tar ratio to be high. What about carbon monoxide to carbon dioxide?

Want more carbon dioxide or more carbon monoxide? It is always a confusion. Finally, carbon will get to carbon monoxide and then to carbon dioxide. There is no doubt about that. Which will we want more to be there as a ratio is concerned? What do we think? Let us look at this. When you produce carbon dioxide from carbon, so much heat is generated; 110, approximately, kilojoules per mole.

When you convert carbon to carbon dioxide, so much heat is generated, which is almost 4 times. So, what will your conclusion? The conclusion should be, I want to produce less heat. So, I may be interested that carbon monoxide forms. And before it becomes carbon dioxide, it diffusers out from this sphere of influence. Okay. If it goes out of the sphere of influence, well, it can become carbon dioxide later.

But it has got out of this zone, where the fuel was there, which is the polymer or a textile and gone out. Of course, at a later stage, this can become carbon dioxide. But then, the heat is somewhere else in the atmosphere. So, the autocatalytic reaction may not take place. So, what do we want? Carbon monoxide to carbon dioxide ratio to be high. Char to tar ratio to be high. This is what we will like. Just before we wind up, the flame retardants can be classified in many ways.

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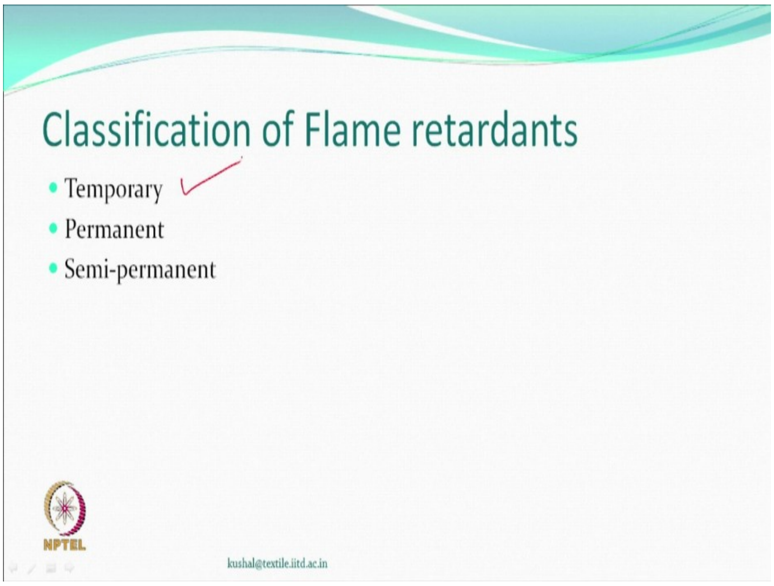

But from the permanency point of view, they have been classified as temporary. Temporary is, that means to washing; once you give the finish, it is there, it works. You wash it off, it goes off. So, every time you want to apply, let us say curtain. After washing, apply the flame retardant and use the curtain. Alright. Every, after every wash, you apply a temporary finish. So, that will be temporary.

But it will work till the time the chemical is on the textile. Permanent, obviously it means. But permanent also a relative term. It is nothing like eternal, right? It is only a relative term. So, there is another class of the chemical which has been defined as semi-permanent, which is very interesting. There some of the chemicals would last up to a few washes. And then, the effect fades out.

So, this permanent and semi-permanent type of classification only means, if the fabric can withstand up to 15 laundry cycles, well, it is in the range of permanent, in the category of permanent. But is less than that, we will say, well, semi-permanent. So, it was lasted to 5, to 5, 7, 8, 10 cycles; and after that it did not. So, some permanency, but not complete. Why would this happen?

We shall learn about it later. Another question that we like to answer now. This fire retardancy, is it a surface finishing treatment or a bulk finishing treatment? A surface finish or a bulk finish? This is burning, completely every part of the polymer is ready to burn. So, if you just treat a surface, it is not going to work. So, it is a bulk finish. Unlike the ones which we did as a soil repellent, water repellent.

They were surface finishes. You just had to change the surface. In fact, not only this, the total amount of chemical required, is much higher. And let us say, we might require a fluorochemical for water repellency or soil repellency. Very high, sometimes 8 to 15% on the weight of the fabrics may have to be added before you can say, this is fire retardant. So, it is not only bulk, but requires more amount of chemicals which must protect you; protect the building; protect the property; protect the life.

That is more important. And so, you may have to add more chemicals, of course. People are looking at various types of chemicals which can be more efficient, so that less amount of add-on is required to get the right property, the right flame retardancy, as per the definitions that we just talked about. So, what have we learnt today?

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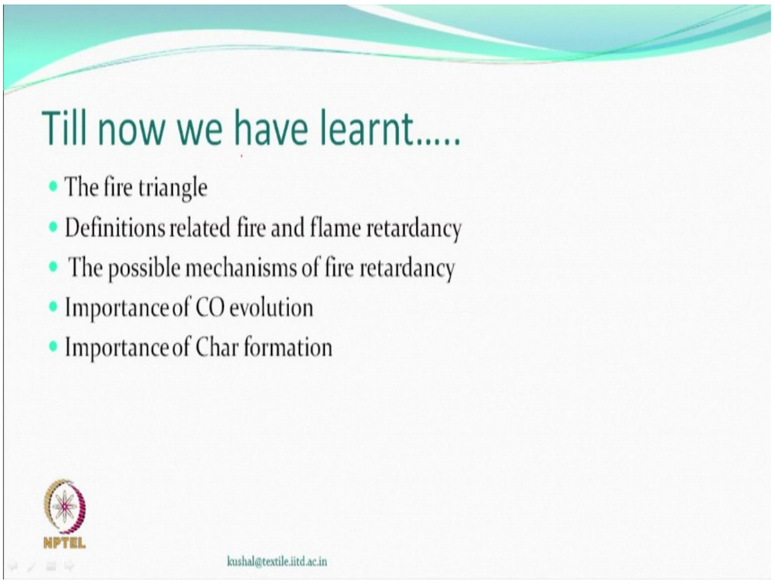

We have learnt that there is something called a fire triangle, where pyrolysis, combustion and feedback of the heat generated to the polymer itself takes place. Definitions, we tried to understand. Possible mechanisms and also importance of more carbon monoxide formation and importance of more char formation also, we talked about. In the next class, we shall talk about the chemistry of some of the fire retardants. Till then, enjoy. Thank you. See you later.