Chemical Process Safety
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Lecture 29
Designs to Prevent Fire & Explosion: Static Electricity

Welcome to the next module of Design to Prevent Fire and Explosion. Up till now we have studied about the various purging methodologies through which we can inert any work place where the chances of flammable vapours are on the higher side.

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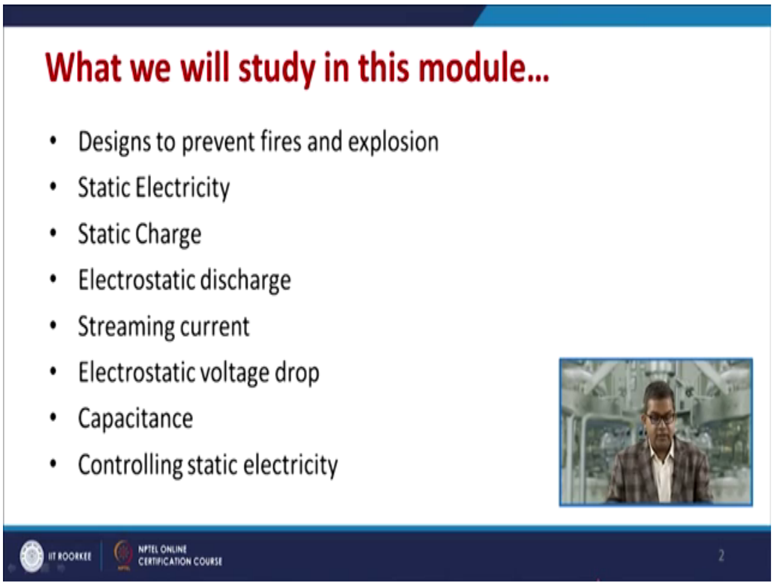

Now, in this particular module we will discuss about the static electricity, what is the static charge, electrostatic discharge, what is the impact of streaming current, electrostatic voltage drop, capacitance and how to control the static electricity.

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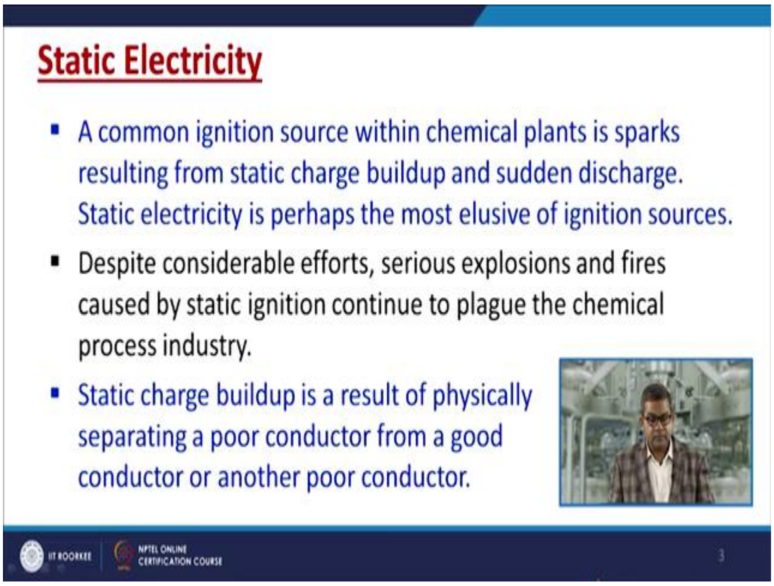

Now, let us have look about the static electricity. A common ignition source within chemical plant is spark resulting from static charge buildup and sudden discharge. Static electricity is perhaps the most elusive of ignition sources. And remember we cannot avoid the generation of ignition sources and the static electricity is one of the foremost destructive mode of ignition source.

So, despite considerable efforts, serious explosion and fires caused by static ignition continue to plague the chemical process industry. Now, static charge buildup is a result of physically separating a poor conductor from a good conductor or another poor conductor. So, this the brief outlay of the static electricity.

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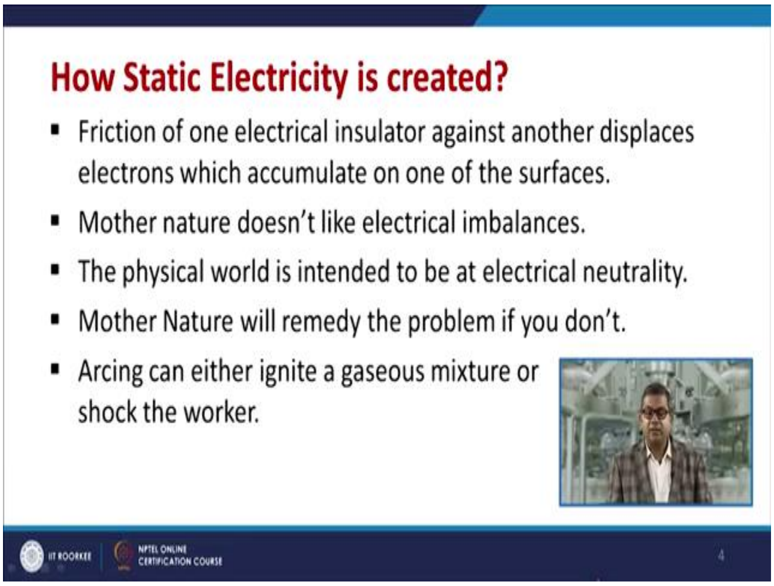

Now, question arises that how static electricity is created or generated? Now, friction is one of the foremost source of generation of static electricity. So, friction of one electrical insulator against another displaces of electron which accumulate on one of the surfaces. Mother nature does not like electrical imbalance and the physical world is intended to be at electrical neutrality. So, Mother Nature will adopt the process of remedy of the problem if you do not. So, arcing can either ignite or a gaseous mixture or a shock worker. So, mother nature definitely attempt to neutralize the any kind of charge imbalance within the system.

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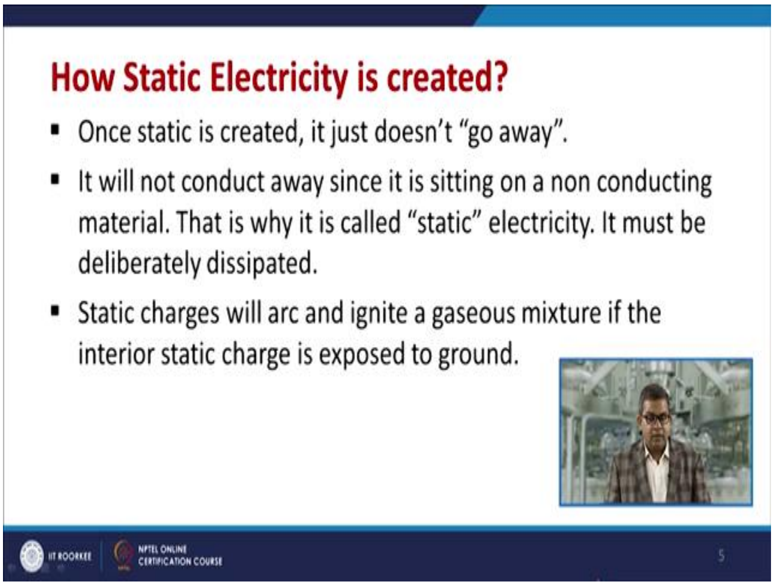

So, once static electricity or static charge is created, it does not go away. It will not conduct away since it is sitting on a non-conducting material. And that is why it is called the static electricity or static charge. So, it must be deliberately dissipated with the variety of tools available or otherwise the nature will do on its own.

So static charges will arc and ignite a gaseous mixture if the interior static charge is exposed to the ground and that is one of the most serious problem. Because sometimes this spark or arc they may have a sufficient energy to ignite any kind of flammable material provided they are within the LFL and UFL zone.

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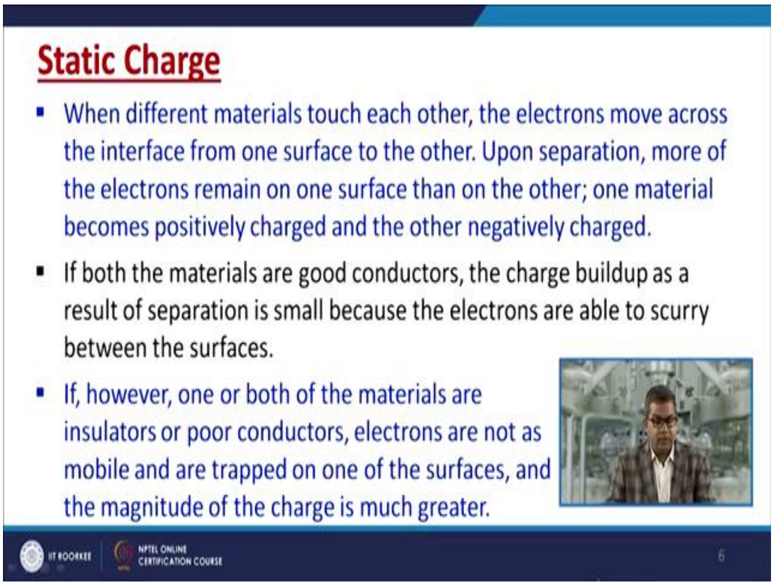

Now, let us discuss about the static charge. So, when different material touch each other, the electron moves across the interface from one surface to other. Upon separation, more of the electrons remain on one surface than on the other. So, one material becomes positively charged and other negatively charged. Now, if both materials are good conductor the charge build up as a result of separation is small because electrons are able to scurry between the surface.

Now if, however, one or both of the materials are insulator or poor conductors, electrons are not as mobile and are trapped on one of the surfaces and magnitude of the charge is much greater. So, if charge the charge density is on the higher side, then definitely whatever spark been generated or whatever arc is generated, must have a higher intensity.

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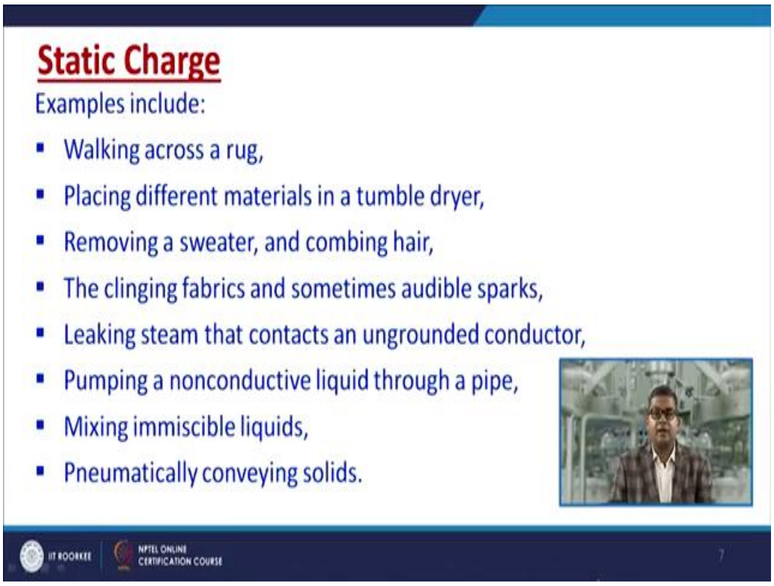

Now there are certain examples like walking across a rug, placing different materials in a tumbler dryer, removing sweater and combing hair, and specially the dry hair, so whenever there is a friction then the charge accumulation or a generation of a charge is on the proximity. The clinging fabric and sometimes audible spark especially applicable when you are wearing the silk cloths, etc leaking stream that contacts the underground conductors, pumping a nonconductive liquid through a pipe, mixing immiscible liquid, pneumatically conveying solids. So, these are some of the examples through which static charge may generate, may accumulate, may transfer.

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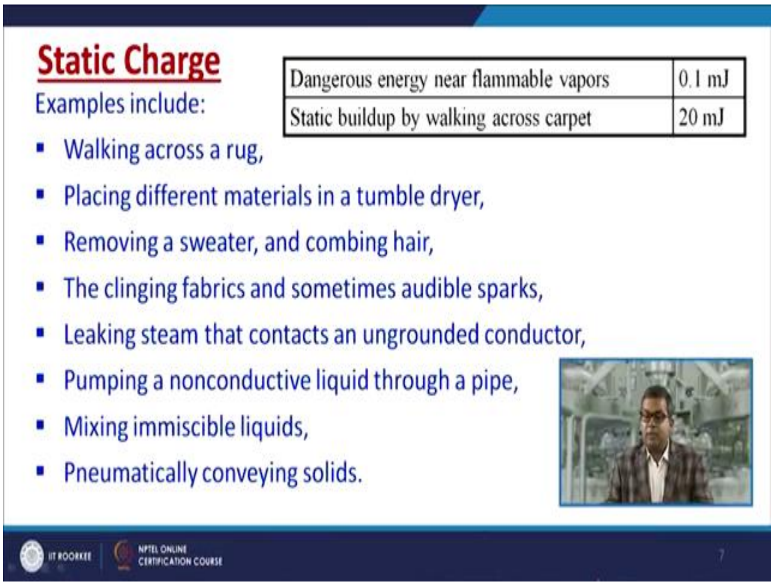

Now, you may have look that a dangerous energy near the flammable vapours is around 0.1 milli Joule. And if you walk across the carpet or you are simply walking across the floor then the generation of static charge is around 20 milli Joule. So, you can anticipate that how dangerous it is. So, it is the foremost requirement to remove whatever excess charge or static charge build up on the surface to avoid any kind of fire and explosion hazard.

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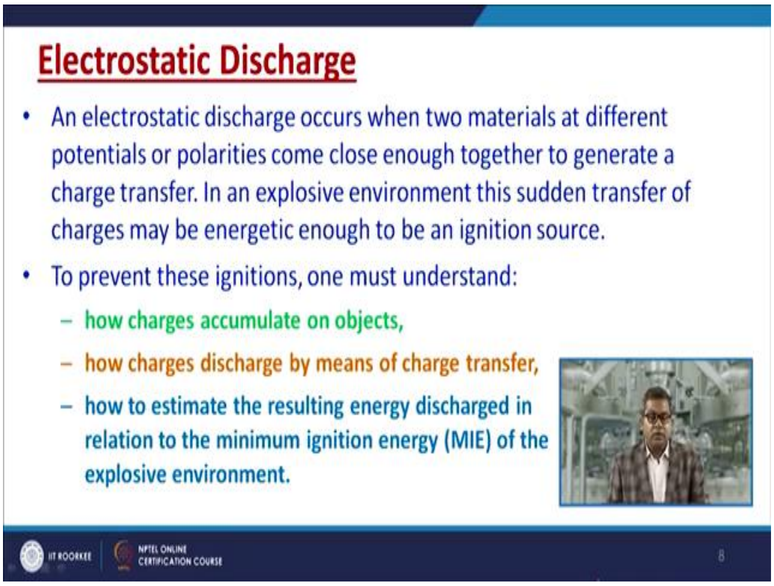

So, electrostatic discharge is usually an electrostatic discharge occurs when two materials at different potential or polarities come close enough together to generate a charge transfer. In an explosive environment this sudden transfer of charge maybe so energetic to be a source of ignition. So, remember we must aware this type of danger, because these are certain hidden dangers in our work place.

To prevent this ignition, one must understand that how charges accumulate on an object that is required. How charge is discharged by means of charge transfer. How to estimate the resulting energy discharge in relation to minimum ignition energy of the explosive environment. So, we must answer, and we must know the knowledge of these questions.

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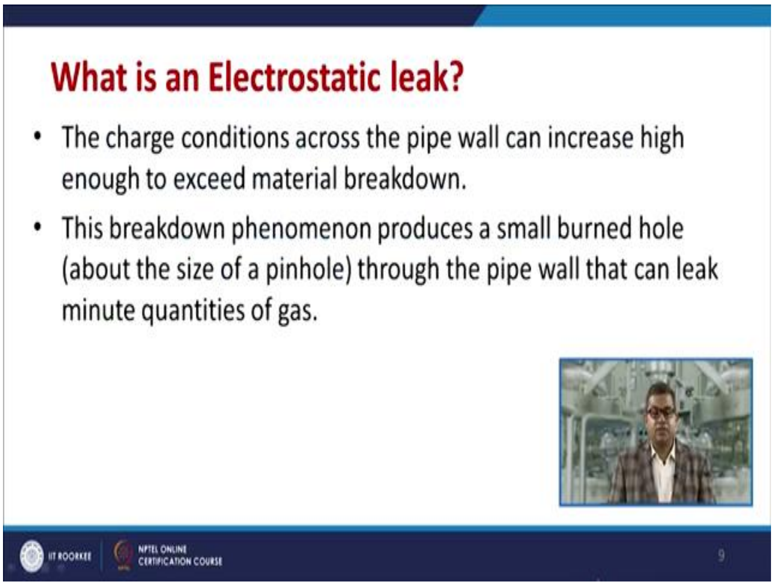

Now, sometimes we may experience the electrostatic leak. So, question arises that what is an electrostatic leak? The charge conditions across the pipe wall can increase high enough to exceed material breakdown. And this breakdown phenomenon produces a small burned hole about a size of a pinhole through a pipe wall that can leak the minute quantities of gases.

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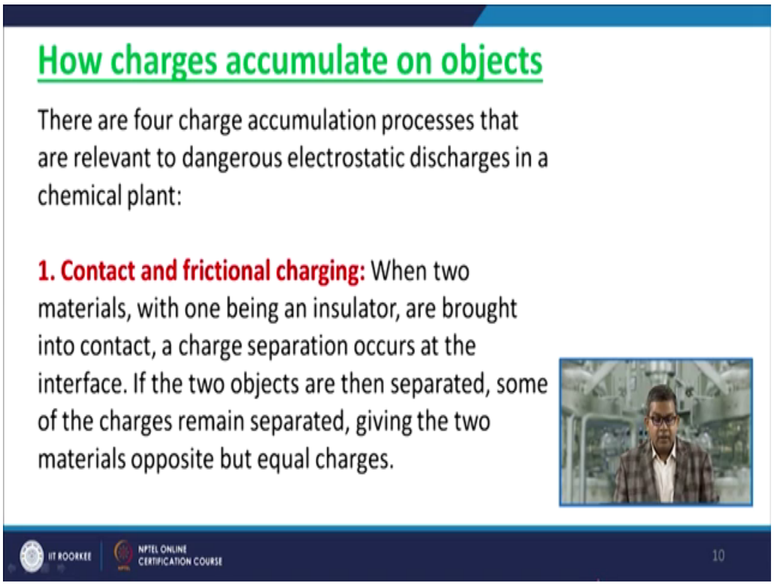

So, in the previous slides we have discussed that there is an accumulation of charges on an object. So, question arises that how charges are accumulate on an object. So there four charge accumulation processes that are relevant to the dangerous electrostatic discharge in a chemical plant. Number 1, the Contact and frictional charging. So, when two materials with one being an insulator are brought into contact, a charge separation occurs at the interface. If the two objects are then separated, some of the charge remain separated and giving the two materials opposite but equal charge. That means the neutralization of charge aspect.

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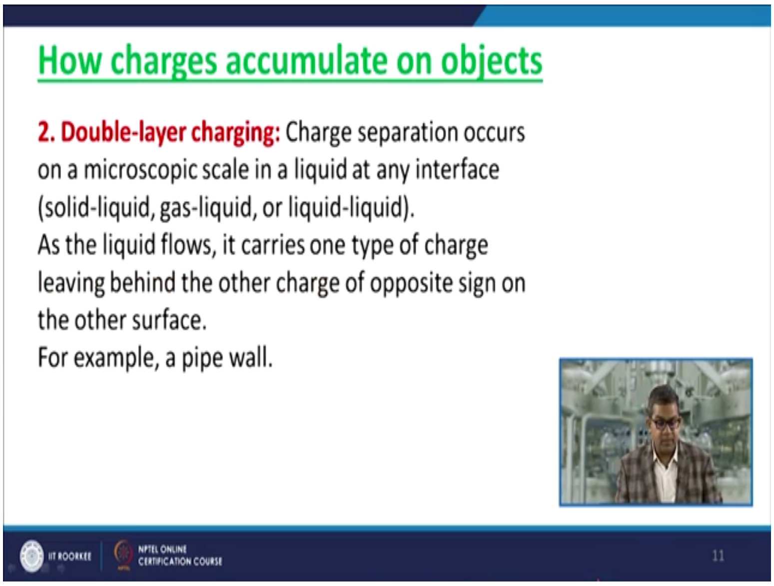

Second is the double layer charging. Charge separation occurs on a microscopic scale in a liquid at any interface maybe solid-liquid, gas-liquid or liquid-liquid. So, as the liquid flows, it carries one type of charge leaving behind the other charge of opposite sign on the other surface. The best example is a pipe wall.

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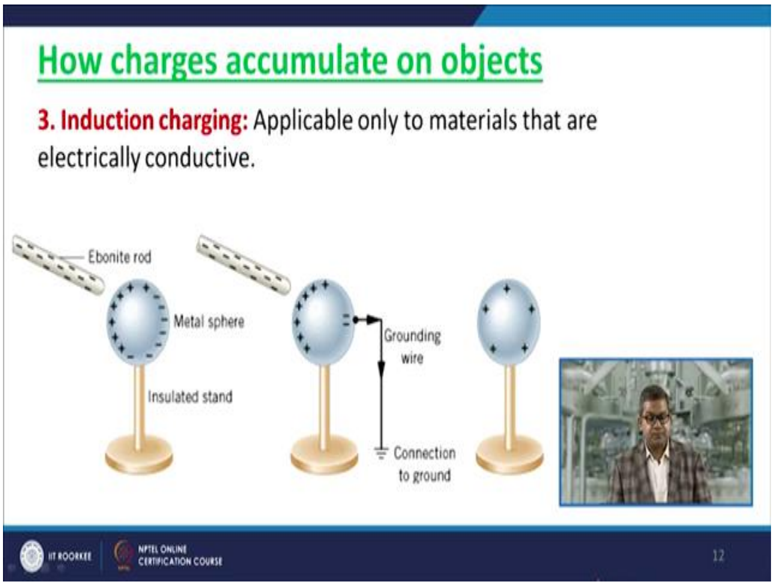

The third one is the induction charging. This is applicable only to the material that are electrically conductive. So, you can see that you are having one metal sphere over here. This is the insulated stand, and this is the Ebonite rod. So, the charge accumulation takes place in these three figures. So, first one is the charge accumulation and then if you provide the grounding wire. So, one charge that is negative charge is being transferred to the ground and then it remains the positively charged. So, sometimes it is in you may take the things in a positive manner, sometimes it is in negative manner.

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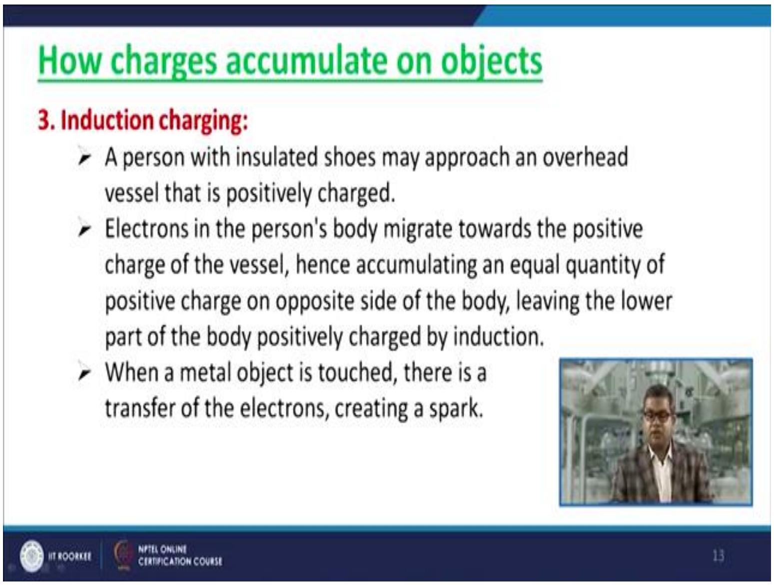

Now, induction charging, the person with insulated shoes may approach an overhead vessel that is positively charged. The electron in person’s body migrate towards the positive charge of the vessel. Hence, accumulating an equal quantity of positive charge on opposite side of the body, leaving the lower part of the body positively charged by induction. So, when a metal object is touched there is transfer of electrons creating a spark. Sometimes in our day to day affair you may experience this type of induction charging through your body.

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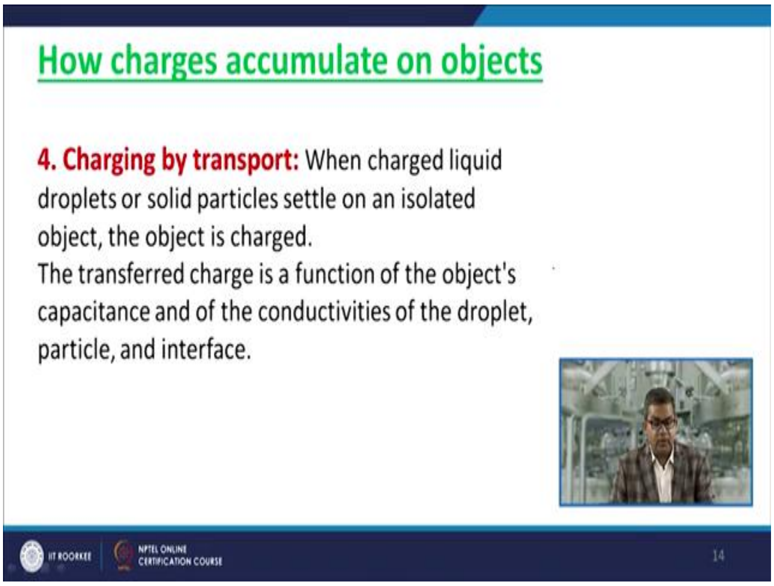

The last part is that charging by transport so when charged liquid droplets or solid particles settle on an isolated object the object is charged. The transferred charge is a function of the object's capacitance and of the conductivities of the droplet, particle and interfaces. So, this is again a very useful phenomenon and very common phenomenon in chemical engineering aspect.

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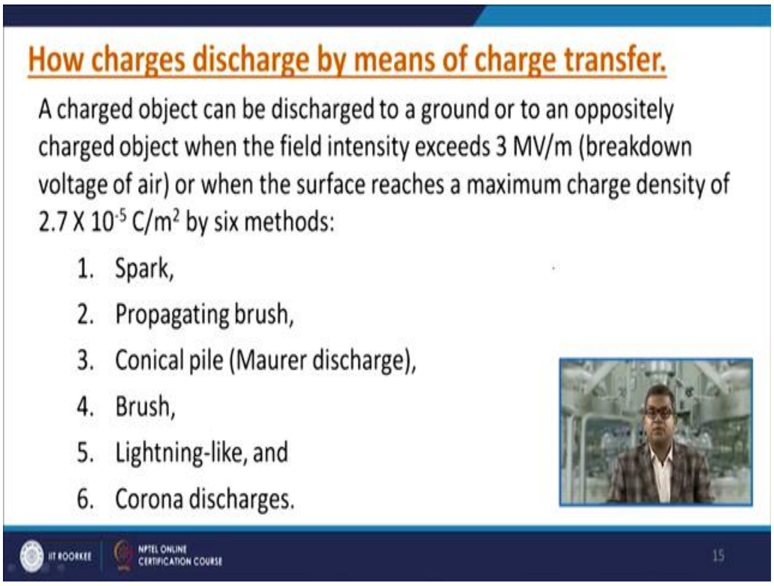

Now, another question is how charge is discharged by means of charge transfer? So, a charge can be discharged to a ground or to an oppositely charge object when the field intensity exceed by 3 mega volt per meter, breakdown voltage of air or when the surface reaches the maximum charge density by different six methods. So, there are six methods through which it reaches the maximum charge density, may be because of a Spark, Propagating brush, Conical pile, Brush, Lightning-like and Corona discharge.

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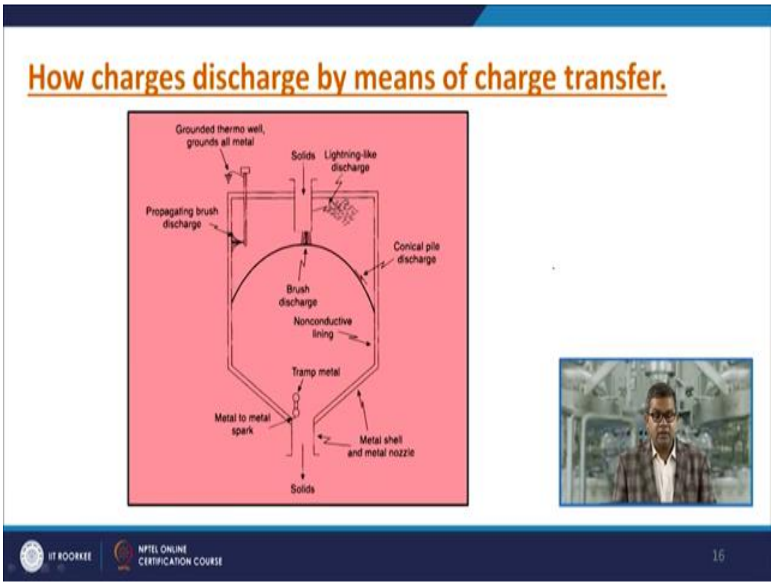

So, in this particular figure you can see that this is a typical filling operation when the solids are being filled in a vessel and they are passed through the hoppers because solid particles they by the friction or the by the transfer they may charge, they may generate the static electricity or static charge so this particular vessel is properly grounded like this, this grounded thermo wall to all metals.

Now, there are certain propagating brush discharge so that the charge density may not reach to the dangerous level. This is again the brush discharge, here the non-conductive linings so by this way you can adopt the methodology of charge transfer to some other place and through (which) this way you can discharge whatever charge being generated during the vessel filling operation or the transfer of the solid material to the ground so that you can neutralize the vessel or you can neutralize the things as per your requirement.

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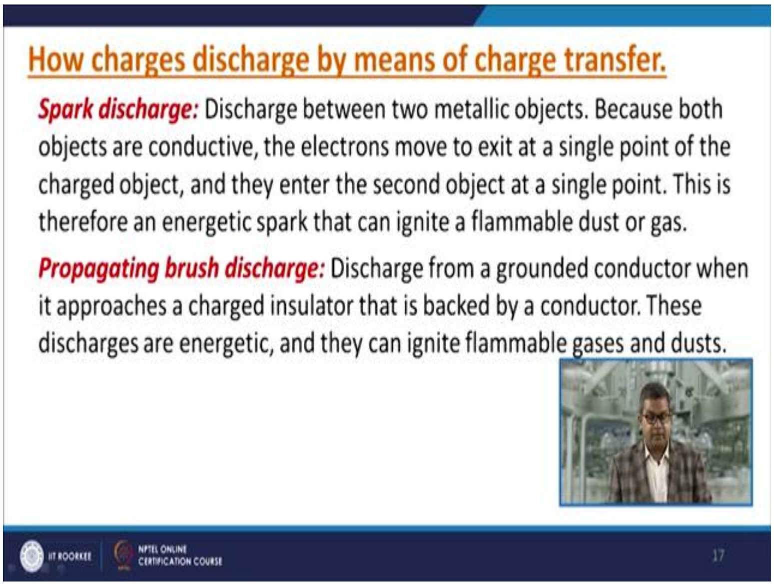

There is another aspect that is called the spark discharge that is the discharge between to metallic objects because both objects are conductive, the electrons move to exit at a single point of the charged object and they enter the second object at a single point and this is therefore an energetic spark that can ignite a flammable dust or a gas.

Another is a propagating brush discharge so discharge from grounded conductor when in approaches a charged insulator that is backed by a conductor. So these discharges are energetic, they can ignite the flammable gases and dust.

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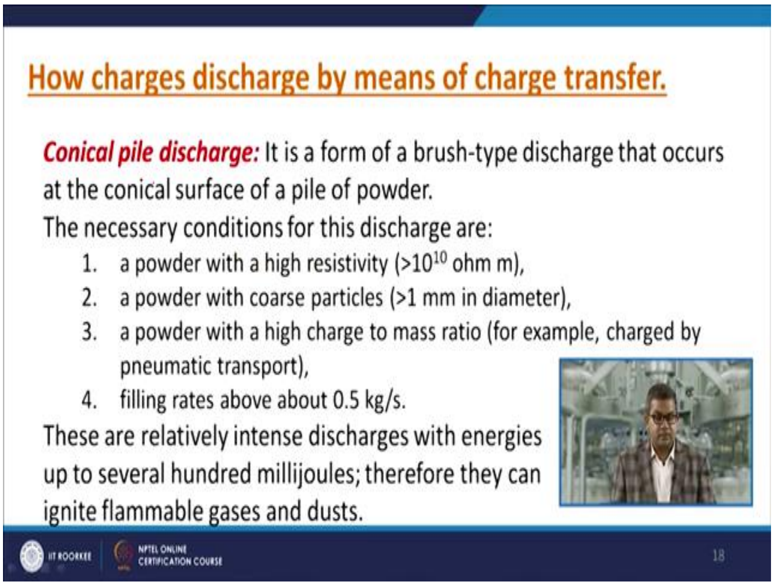

Another is the conical pile discharge. This is a form of a brush type discharge that occurs at the conical surface, like we have seen in the previous figure, of a pile of powder. The necessary condition for discharge are, a powder with a very high resistivity, a powder with the coarse particle, a powder with a charge to mass ratio, filling rates about 0.5 kilogram per second so these because the filling rate is on the higher side so the charge density or charge accumulation or generation of charge would be on the higher side. So, these are the relatively intense discharge with energies up to several hundred millijoules and therefore they can ignite flammable gases and dust.

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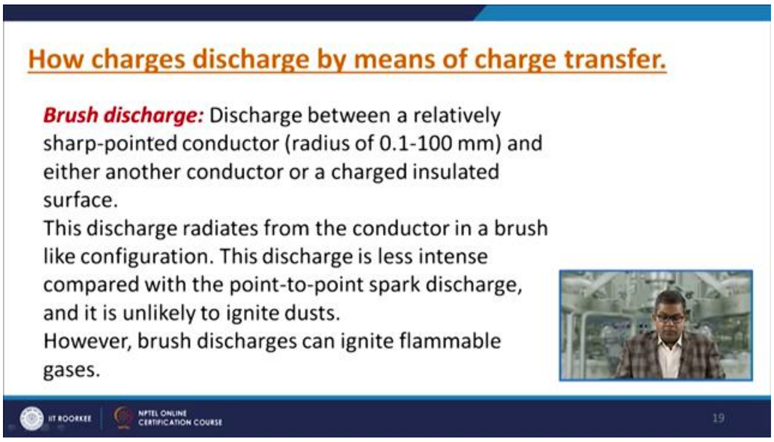

Now brush discharge, the discharge between a relatively sharp-pointed conductor usually the radius of about 0.1 to 100 millimetre and either another conductor or charged insulated surface. This discharge radiates from the conductor in a brush like configuration and this discharge is less intense compared with the point to point spark discharge and it is unlikely to ignite dusts. However, brush discharge can ignite flammable gases, so the gravity is on the higher side.

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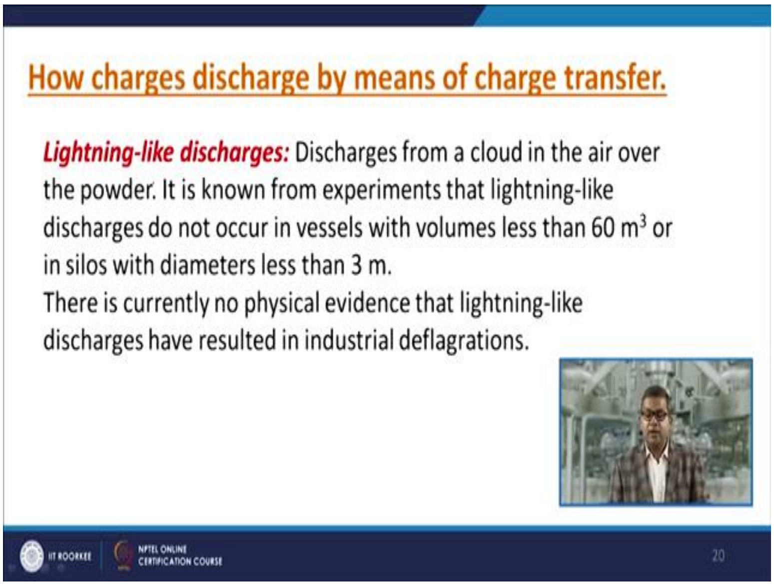

Another method is lightning like discharges that is discharge from a cloud in the air over the powder. It is known from the experiments like lightning-like discharge do not occur in vessel with volume less than 60 meter cube or in silos where diameter is less than 3 meters. There is currently no physical evidence that lightning like discharges have resulted in industrial deflagrations.

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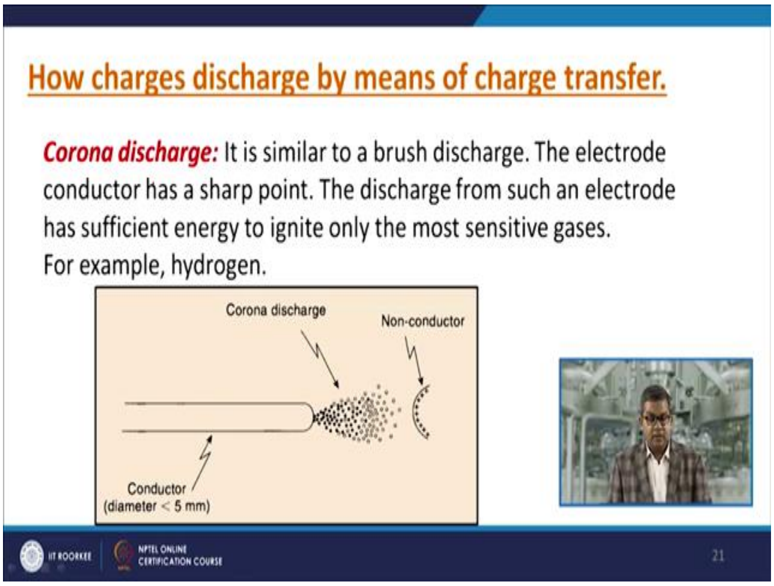

The Corona discharge, it is similar to the brush discharge. The electrode conductor has a sharp point. The discharge from such an electrode has sufficient energy to ignite only the most sensitive gases like Hydrogen so here you can see the accumulation of charges, so this is a non-conductor.

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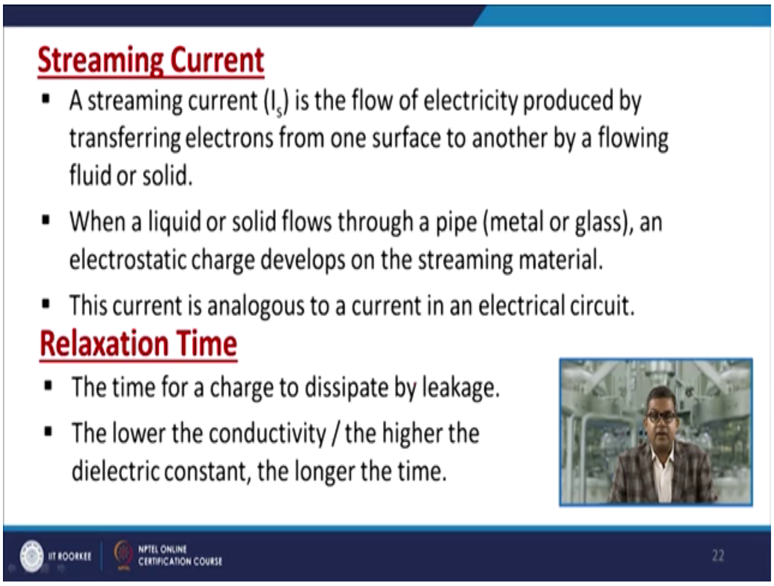

Another concept is the streaming current, especially when you are transferring an inflammable material from one place to another place, the concept of stream current plays a very vital role, so a streaming current is the flow of electricity produced by transferring electrons from one surface to another by flowing fluid or solid especially valuable when you are transferring hydrocarbon from one place to another place.

So, when a liquid or solid flows through a pipe like metal or a glass an electrostatic charge develops on the streaming material, so this current is analogous to a current in an electrical circuit. So, sometimes you may need to encounter the things related to the relaxation time the time for charge to dissipate by leakage, so the concept of this relaxation time is important. The lower the conductivity the higher the dielectric constant and the longer the time so that is the concept, and we will discuss this relaxation aspect in subsequent slides.

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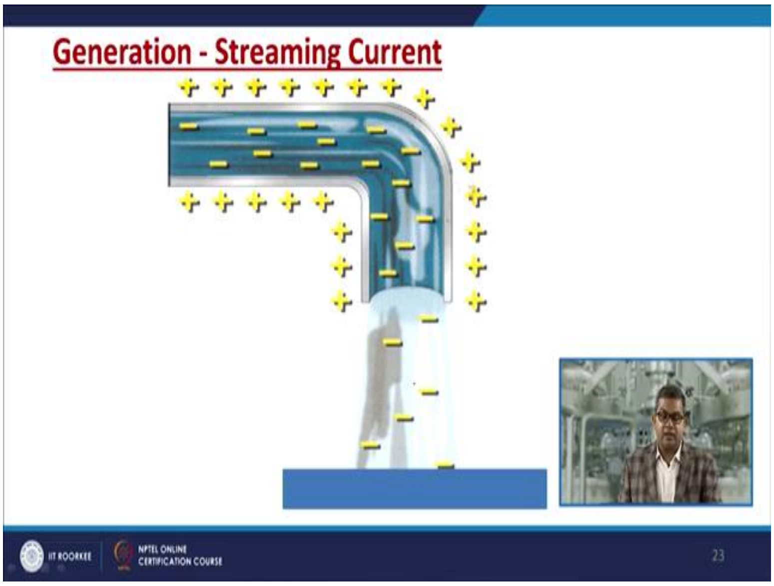

Now, this picture shows that how the generated charge is streaming just like current so this flow of material which is being flowing from one place to another place, you can take the example of vessel filling operation. Here positive and the both negative charges they are coming towards the vessel and sometimes if this vessel is not equipped with proper safety devices the spark may generate and the content may be blown up or if this is a flammable liquid or vapor then definitely the destructive aspect may occur in due course of time so due care must be taken.

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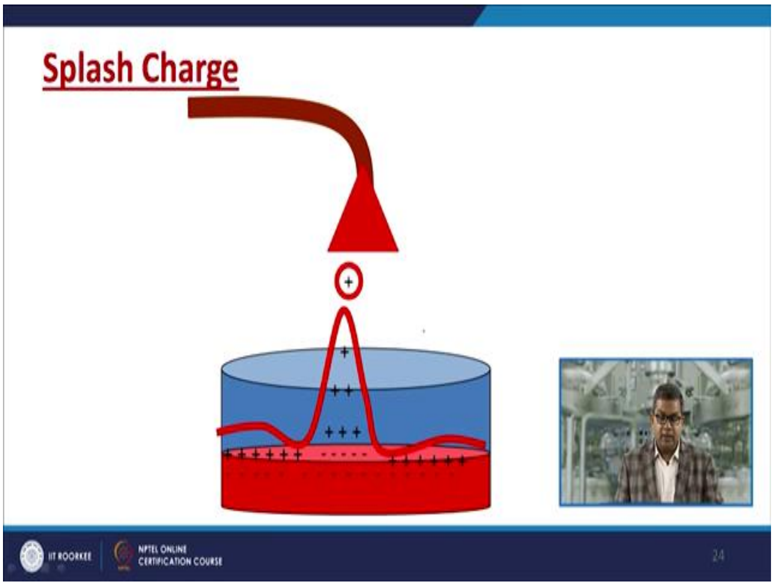

Another is the splash charge, especially it is applicable in the vessel filling application so you are filling a vessel and the discharge point or the outlet of this pipe is at this point so whenever the fluid moves or it fills to this particular vessel the charge may accumulate or charge may transfer to the various surfaces, sometimes at the upper part of the liquid and sometimes it may get deposited at the wall of this vessel.

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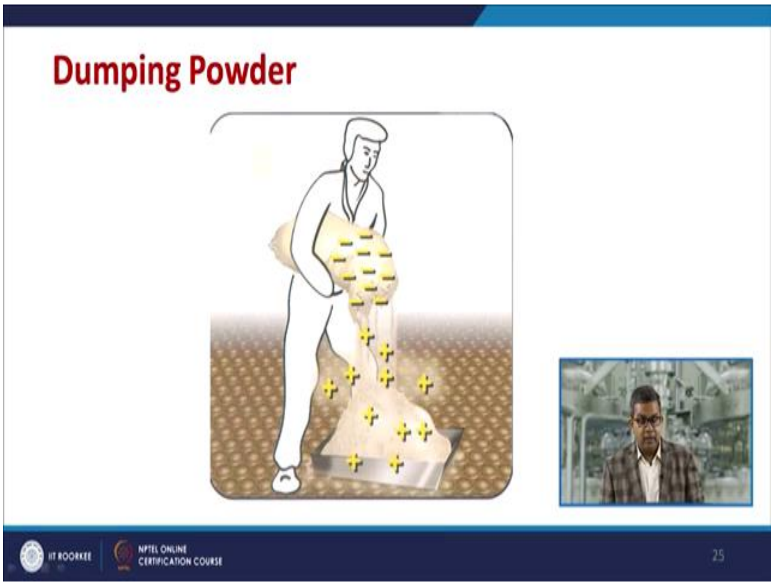

Sometimes this type of a problem when you are dumping the powder or bags to storage area or anywhere else then you may experience this type of problem, the negative charge particle and the positive charge particle so you have to take the due care while handling such type of scenario.

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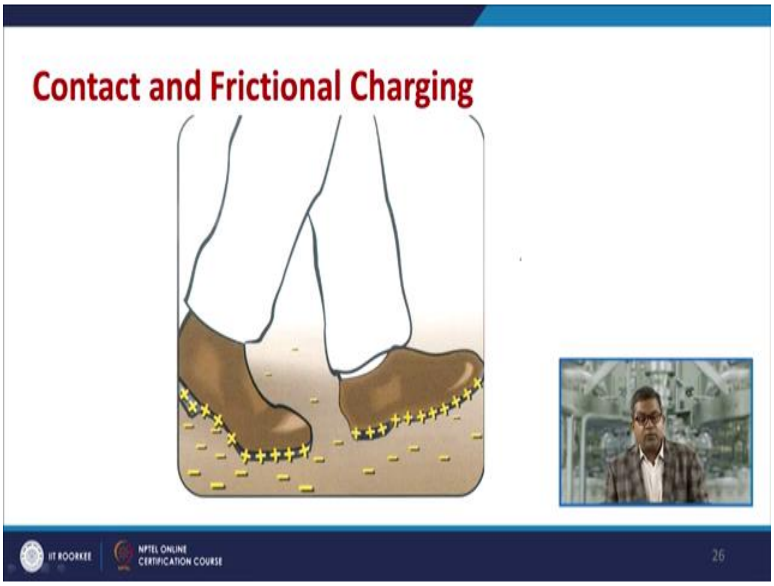

This is a very common aspect that is contact and frictional charging so you are moving across any surface, may be floor, may be carpet, may be grass, etc based on the material of your sole the charge may accumulate or charge may generate so when they find the favourable condition the spark may be created and that is why and if the chances are on the higher side when your shoe is equipped with iron shoe nails so be practical and be aware about such particular scenario.

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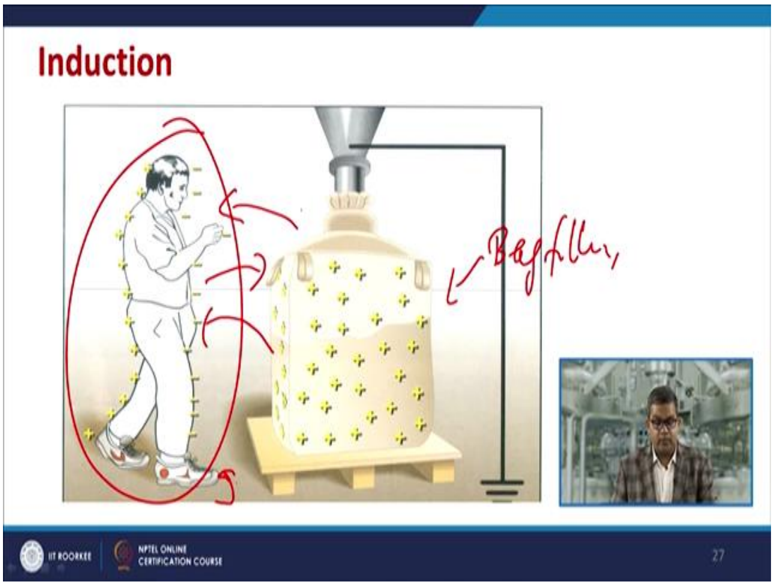

Sometimes you may experience that the charge may transfer from one surface to another surface through induction. It is just like this, this particular gentleman may be previously he was having the neutral charge, but since this is a bag filling operation and through which some positive charge is generated in due course of time and this charge gets transferred to this gentleman so sometimes he may experience the generation of a spark provided that sufficient neutralization or sufficient source is available at this particular point of time.

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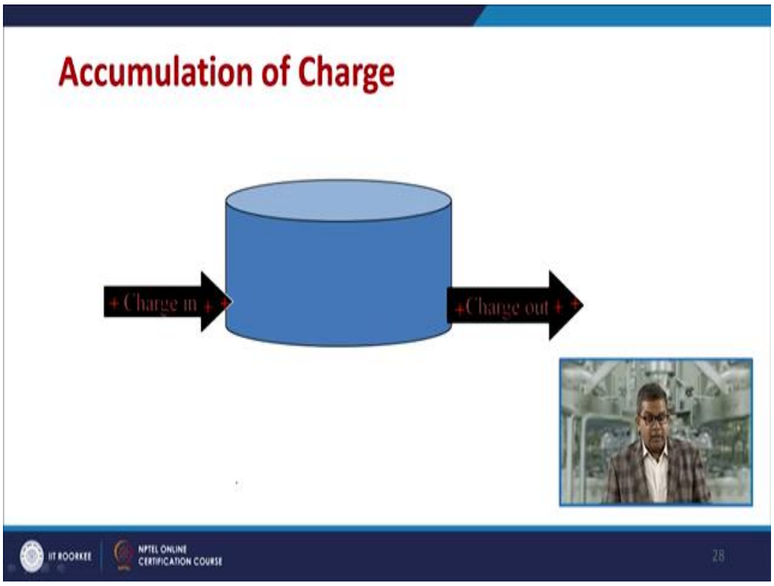

Sometimes the accumulation of charge may take place in static vessel where the charge in and the charge out may be in the neutral side so sometimes you may experience the accumulation of charge within the vessel without the reason unknown and sometimes it may pass on to some other surface.

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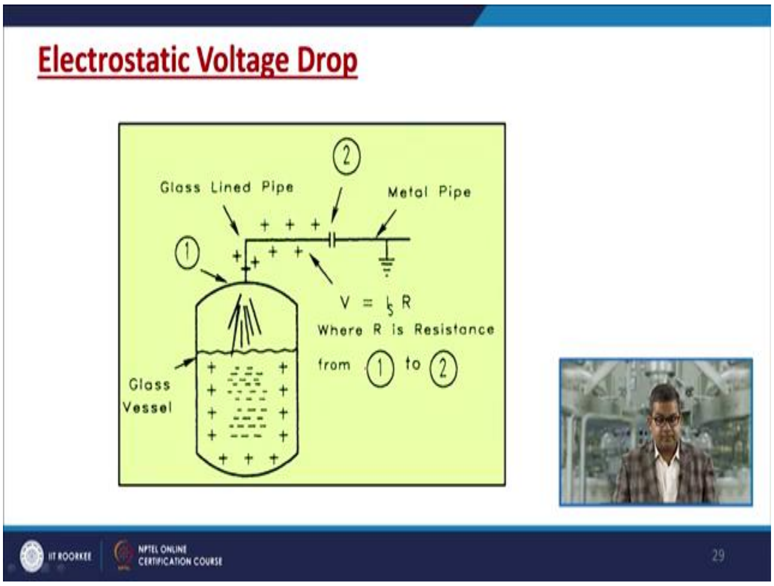

Now, this is again the electrostatic sometimes the electrostatic voltage drop may create a problem especially when you are adopting the concept of vessel filling operation. Now, this is the glass lined pipe with a certain fluid is flowing through this glass line pipe and this pipe is connected to this vessel where this vessel is being filled by this particular pipe.

Now, this is a glass lined or glass vessel and some positive charge being generated through the flow of this particular fluid and it is being transferred to this glass line vessel. Now, if you have taken the due care then this may be grounded or this may be bonded with some other for the neutralization and indeed you need to ground this particular glass line vessel also.

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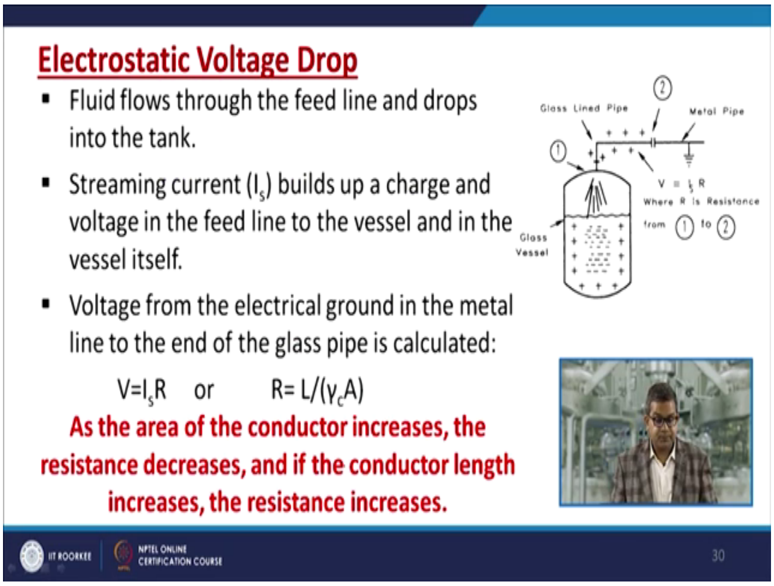

So, fluid flows through the feed line and drops into the tank and streaming current that is represented by Is builds up the charge and voltage in the feed line to the vessel and in the vessel itself. So, voltage from the electrical ground in the metal line to the end of the glass pipe is calculated through this formula:

$$V = IR$$

that is the common formula, so,

$$V = I_s R$$

or resistance is calculated through this formula. So as the area of the conductor increases, the resistance decreases and if the conductor length increases the resistance increases that is the common physics phenomenon.

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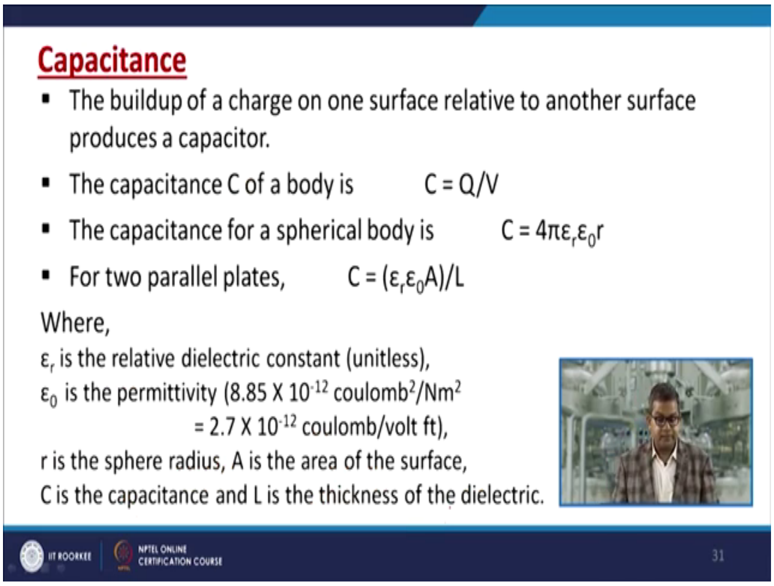

Let us have a discussion about the capacitance that is the buildup of charge on surface related to another surface produces a capacitor. The capacitance C of a body is denoted by:

$$C = Q/V$$

V is the voltage and Q is the charge, the capacitance of a spherical body is determined through this formula:

$$C = 4\pi\varepsilon_r\varepsilon_0 r$$

Now, for two parallel plates you can find out the capacitance with the help of this formula:

$$C = (\varepsilon_r\varepsilon_0 A)/L$$

where ε_r is the relative dielectric constant that is unitless, ε_0 is the permittivity usually at around ($8.85X10^{-12}$ coulomb^2 /Nm^2, r is the sphere radius, A is the area of the surface which is in question and C is the capacitance and L is the thickness of the dielectric.

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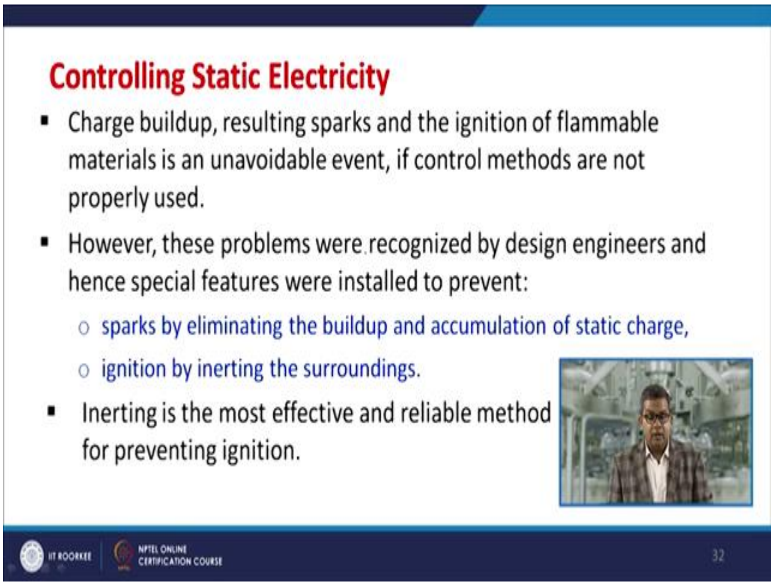

Now, we must discuss about controlling static electricity aspect. The charge build up, resulting spark and the ignition of inflammable material is an unavoidable event. Now, if control methods are not properly used then the results could be more destructive. However, these problems were recognized by design engineers and hence special features were installed to prevent sparks by eliminating the buildup and accumulation of static charge that is a key feature of designing of equipment, then ignition by inerting the surroundings.

So, we have discussed the inerting methodology in the previous module, in case you cannot avoid the generation of charge then you must adopt inerting methodology so that the LFL and UFL limits cannot be reached. Now, inerting is the most effective and reliable methods for preventing ignition because ultimately when you are walking, or you are flowing a fluid through a pipe you cannot avoid the generation of static charge.

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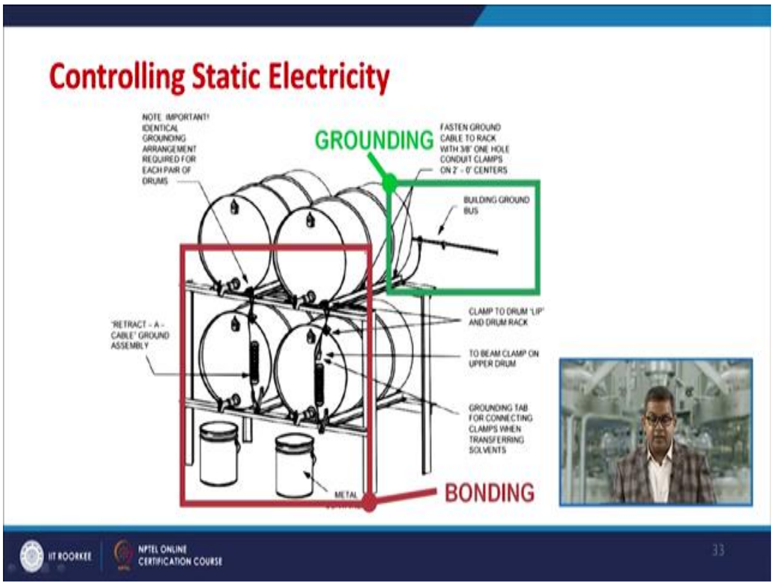

Now, how we can control the static electricity? This is one of the methodology and this rough diagram depicts that how we can control. Now here, there are certain vessels, they are stored, and you can connect these vessels through either grounding or a bonding, so you can see these are connected like this. So, this is the method of bonding through which you can bond each other and then adopt the grounding. This is the fasten ground cable to rack. Now this is, you can see, here is a grounding so bonding and grounding these two are very effective methodology to prevent the hazard of static electricity.

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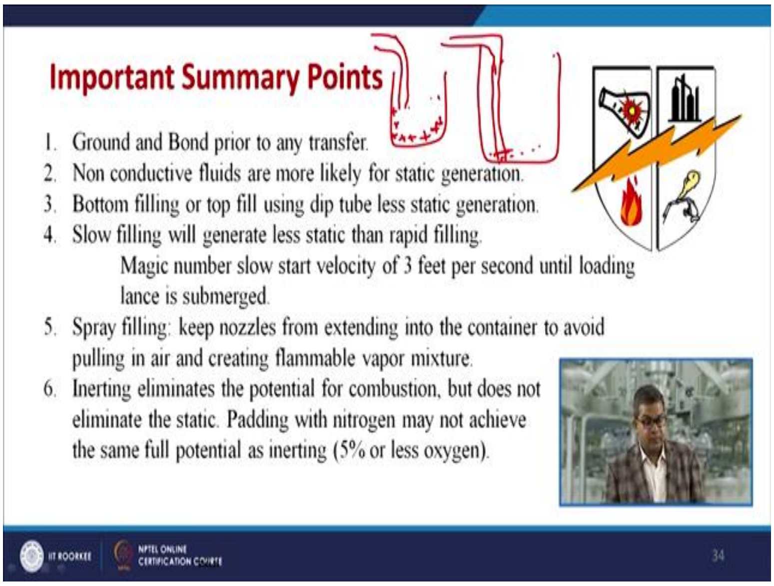

Now, there are certain important summary points which we have to look that ground and bond prior to any transfer because you do not have any clue about how much static charge is being accumulated over the surface. Non-conductive fluids are more likely for static generation. Bottom filling or top filling using dip tube less static generation. Dip tube is just like that, suppose you are filling any vessel so if you have a tube like this that may be just a few inche above the bottom of the vessel. So, it may create a less problem of generation of static electricity compared to this tube where you are having a tip at bit higher point, so the charge may find more larger area for generation.

Slow filling will generate less static electricity than rapid filling, it is quite obvious, we have discussed it in the previous slides. Magic number slow start velocity of 3 feet per second until loading lance is submerged. Spray filling keeps nozzles from extending into the container to avoid pulling in air and creating flammable vapor mixture.

Inerting eliminates the potential for combustion, but does not eliminate the static. So, you avoid the formation of combustible zone because you cannot eliminate the generation of static electricity charge. Padding with Nitrogen may not achieve the same full potential, sometimes it is effective, sometimes it is not. So, in this particular module we have discussed the static electricity generation, what are the theoretical aspects of this static electricity and how we can avoid the destructiveness of the static electricity.

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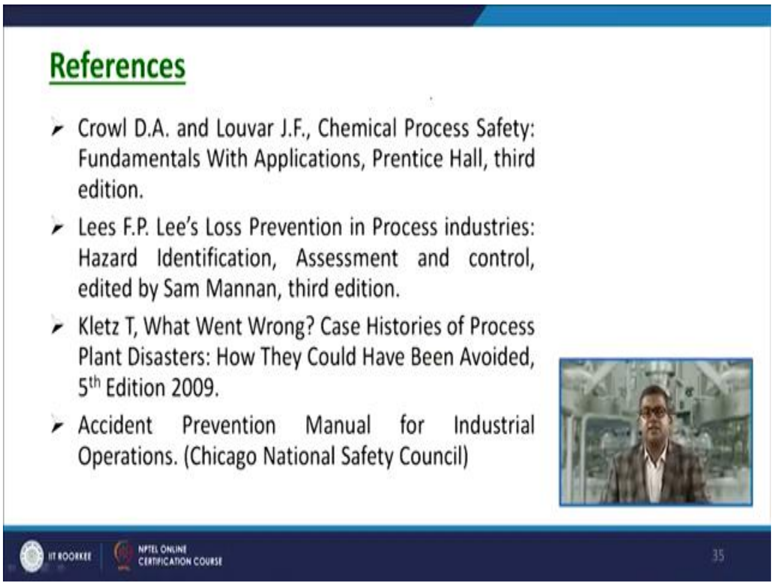

For more studies you can have a look of these references, thank you very much.