Technical Textiles
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Lecture No- 38
Additional Lecture on Composites

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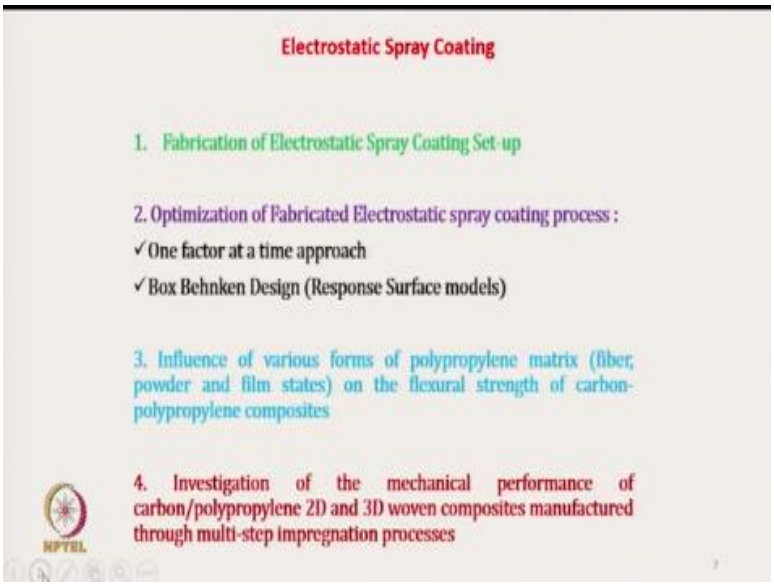

Hello everyone. Today's topic is composite by electrostatic spray coating. So electrostatic spray coating we have already discussed. Today in the discussion what we will do, we will cover few studies which has been carried out, so fabrication detail we will discuss then we will try to see the optimization process. So different parameters which affect the efficiency of electrostatic spray coating process will study will discuss in detail.

After that in next class subsequently will discuss the influence of various forms of polymeric matrix here specifically we have used polypropylene. So forms of matrix are fiber form, powder form and film form. We used the polypropylene in this forms and we have studied mainly flexural properties then we have developed fabrics made of carbon polypropylene preform and the fabrics are of 2D and 3D woven structure. So let us start with the;

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Fabrication of electrostatic spray coating process. So we will discuss here details of design and development process including all the individual components and their functions.

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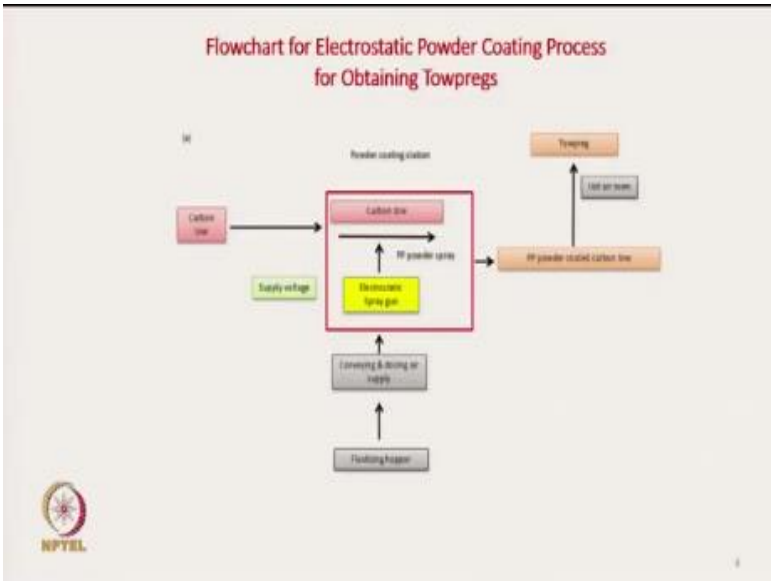

So this schematic diagram we have seen earlier also here in our present setup, we have used carbon fiber tow as the reinforcing material, so here carbon the filament tow is used which is entering into the powder coating station where powder is being supplied through fluidizing hopper and electrostatic spray gun. So once the powders once the polypropylene powder is coated.

So fluidizing hopper that generates cloud of polypropylene powder and this spray gun coats the carbon tow with the polypropylene powder and immediately after that this PP powder coated carbon tow is passed through the hot air oven. So let us see details.

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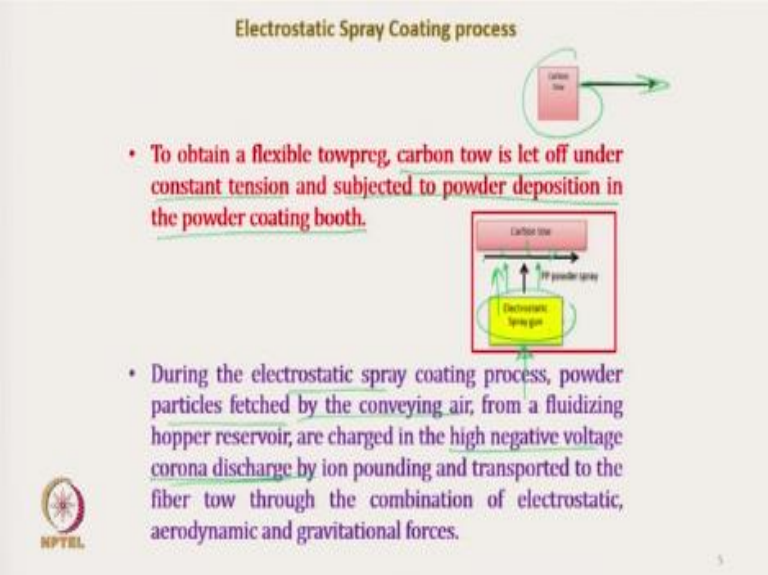

So to obtain a flexible towpreg, carbon tow is let off so this is the carbon tow, which is so carbon tow here carbon tow let off under constant tensions, so constant tension is important and subjected to powder deposition in the powder coating. So carbon tow is delivered here, then during the electrostatics spray coating, so here electrostatics spray coating is there as I have mentioned powder particles faced by conveying air.

So from here conveying air is coming and the electrostatics spray gun charges the powder. So highly negative charge corona discharge is there. So which charges the polypropylene powder and it is attracted by the carbon tow which is neutral which is earthed. So it is deposited carbon the powder is deposited on the carbon tow.

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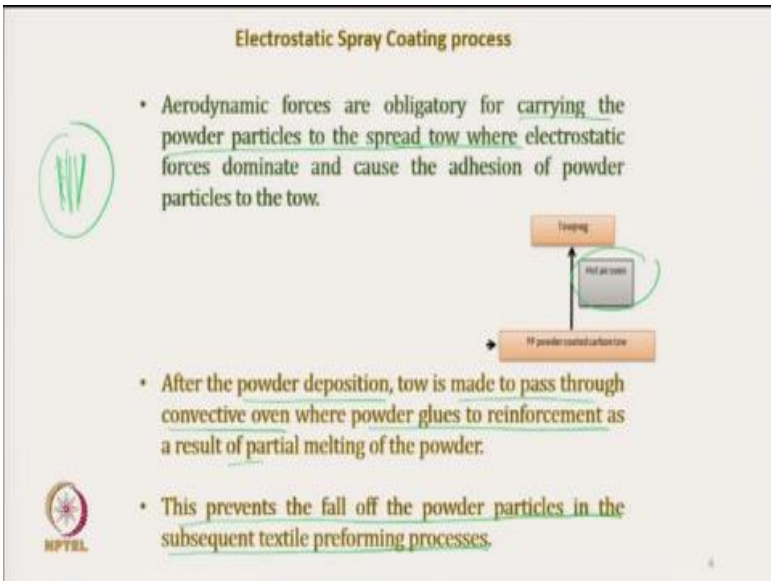

So air dynamic forces are important to carry the powder particle to the on the sprayed tow, so the carbon tow is it is not the single filament it is a multi filament large number of filaments are there. So we need to spray it, so that the particles are deposited on almost individual carbon filament. So after powder deposition, tow is made to pass through the convective oven so this is a convective oven is there where powder glues to reinforce the carbon tow.

So this hot air oven melting partial melting is important, otherwise the carbon tow cannot hold the polypropylene powder, it will the powder will get separated from the surface of the carbon tow, so that is why we need to partially melt. So this prevents the fall of powder particle in subsequent textile performing process, like we can use weaving. So this tow is used for making the fabric or any sort of preform system.

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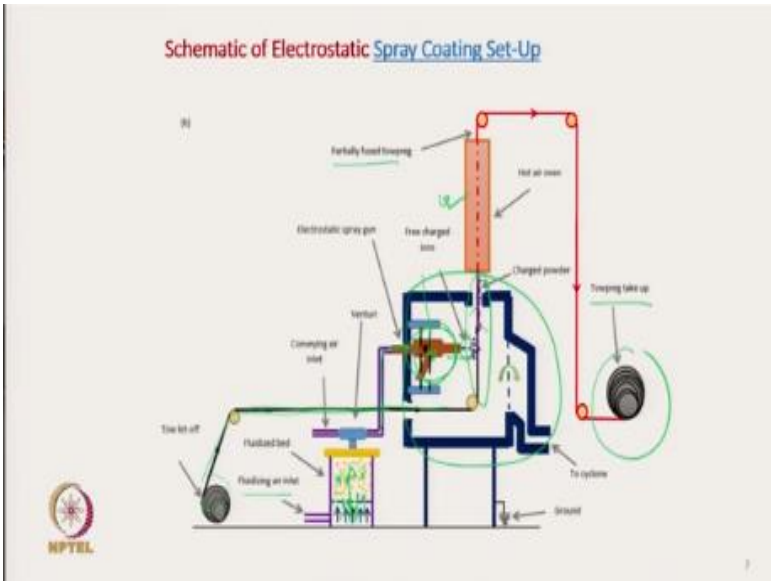

So this is the spray coating set up, here the let-off of the carbon tow is there and then the carbon tow is entering into the spray coating chamber, this is spray coating chamber and this is the electrostatic spray gun and polypropylene powder is coming from the fluidizing bed, where fluidizing air inlet is there in the plenum chamber and this pressure, this pressure there is a perforated base and as air enters inside this fluidizing bed.

So the curve polypropylene powder acts as a fluid liquid and it gets separated and then through the conveying air and with the use of venturi this air laden with the polypropylene particle enters into the electrostatic spray gun and in this spray gun the particles are charged with the corona discharging system and this charged particle is coming out from the spray gun and deposited on the carbon tow.

And at this point the attraction force is very low so there is a chance of separation of the polypropylene powder from the tow that is why immediately after that hot air oven is used where the polypropylene particles melted and then partially fused towpreg is then owned on a package which is finally it is a towpreg is formed. Now let us see the video of this system.

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So this is the running of this equipment, here this one is a carbon tow its feed so here let-off system is there you can see the let-off system here this is the let-off system, okay, and now through the centering device and spreading arrangement this carbon tow is entering into the

powder coating chamber. So this is the powder coating chamber here. Now where the carbon tow is entering and this is a spray gun is there which is coating the carbon tow with the polypropylene powder charged powder is there.

And after coating this carbon tow coated with the polypropylene powder is entering into the this is the oven, convective oven where partial melting of the polypropylene powder takes place and after cooling, here it is a cooling zone is there then the carbon towpreg that is the carbon filament covered with the matrix here, matrix is the polypropylene and which is now its wound on a package. Finally this will be used for making composite.

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Now we will discuss the individual component of this setup.

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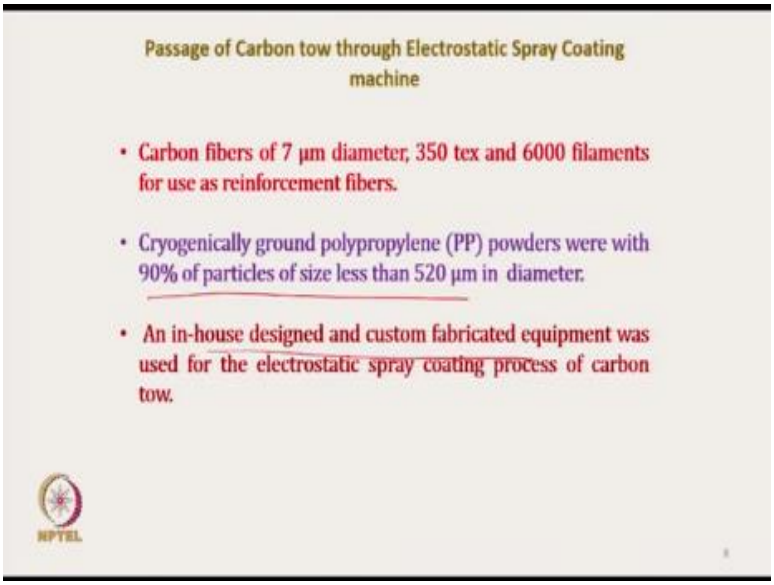

So where the carbon filaments, which we have used is 7 micron diameter with 350 tex and 6000 filaments are there for reinforcement use and polypropylene is a cryogenically ground powder is which maximum diameter typically it is a 520 micron. So more than 90% particles are less than 520 micron. So this then the in house designed and fabricated equipment is used for this electrostatic spray coating. So this we have already discussed.

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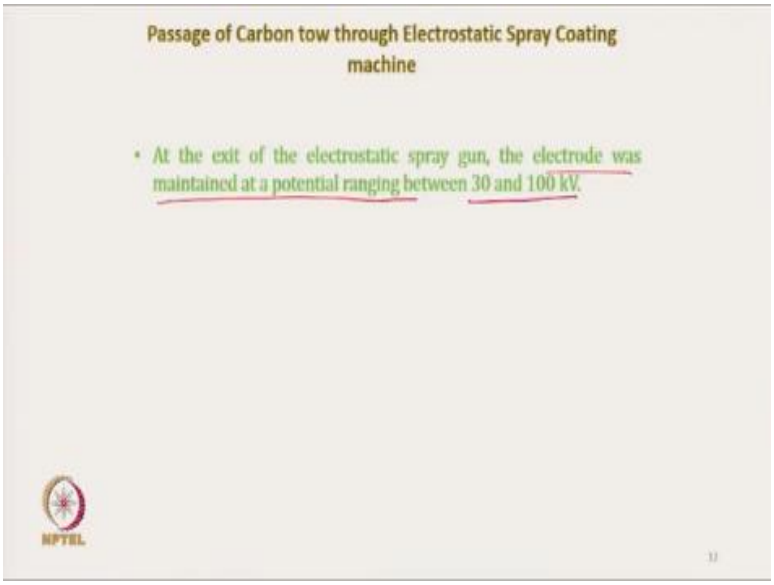

In the machine the carbon tow is let-off from the unwinding device. So this is the unwinding device. So after that the carbon tow is made to pass through powder coating chamber. The powder coating chamber consists of electrostatic spray gun which course the particle on the carbon tow. This is the place we have discussed and at the exit of the electrostatic spray gun, the electrode was maintained at potential range between 30 to 100 kilovolt. So this we can change okay and that actually charges the particle. So here is the charge it is used.

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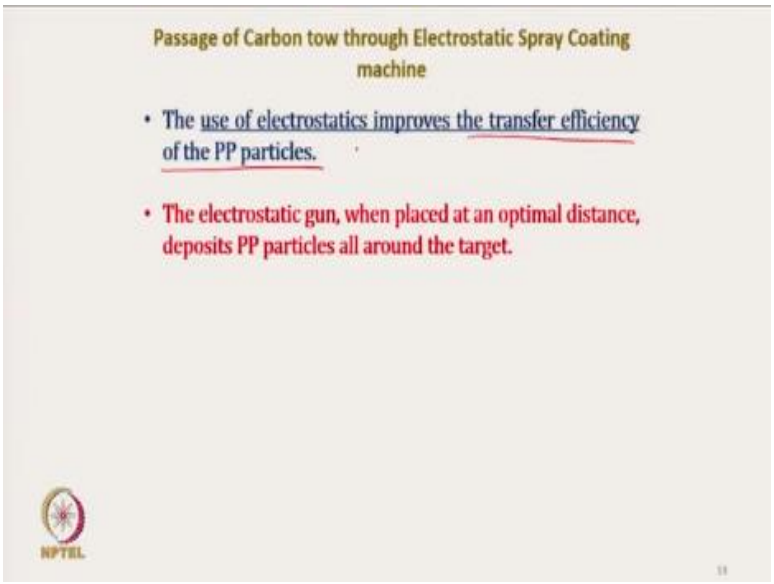

So this powder particles acquire electrostatic charge and deposited on the conductive tow, which is important. So here it is a deposited on the conductive tow. The use of electrostatic improved the transfer efficiency of PP particle, which is important, so without the electrostatic charge the

spray gun will throw the particle. But as there is no charge the adherence of the charge on the carbon tow, the efficiency of the adherence will be low.

The electrostatic gun then placed at an optimal distance so based on the distance the efficiency of coating changes, so that we will discuss in separate study.

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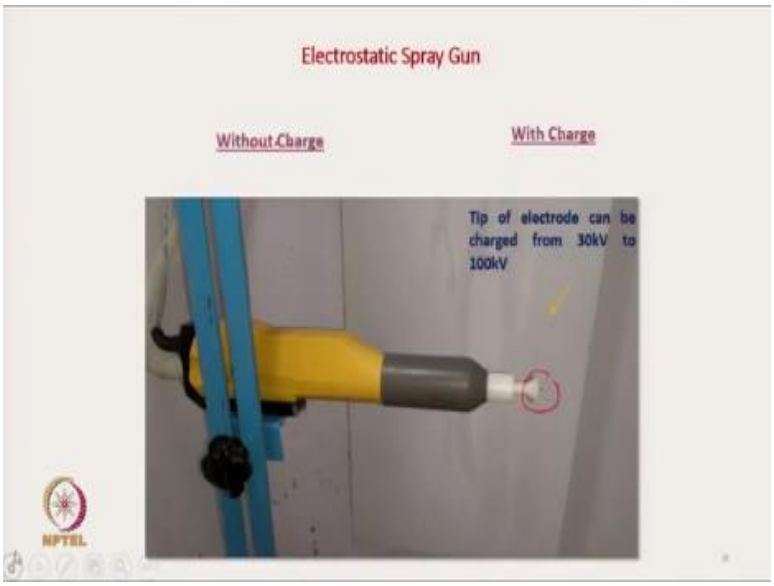

Now let us see the effect of charging on powders on the powder coating performance. So if there is no charge in the particle, so the powder will be only pushed with the help of compressed air.

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So here we can see here, there is no charge so powder is coming out. So the coating efficiency is very poor, so the powder is not coated properly and effectively, this powders will get separated.

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Now once there is a charge let us see what is happening.

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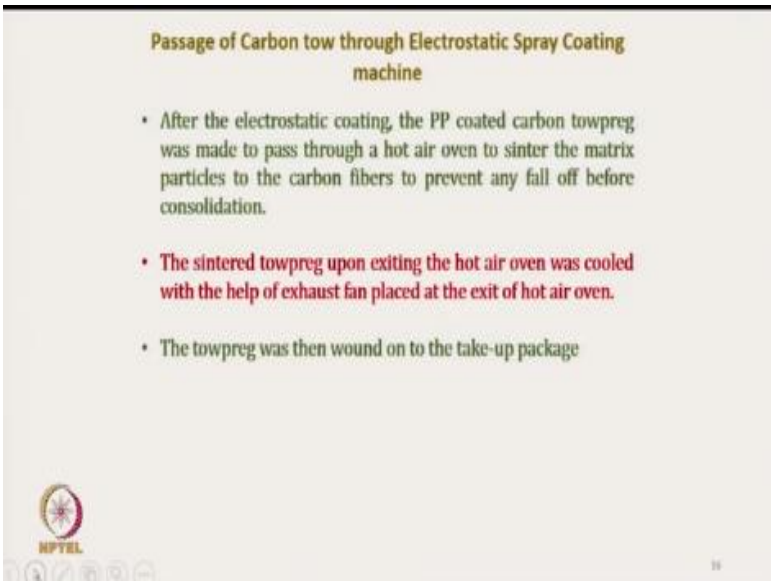

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So now charges applied here. Now we will see the coating efficiency is very good. So this charged particle highly charged particle is coming out through this spray gun here and once the carbon tow is placed you can see very clearly the coating its becoming white fully coated with the polypropylene powder. So this is the total it is a black carbon tow this fully coated with the polypropylene powder.

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So charging helps in proper coating. So after electrostatic coating the PP coated carbon towpreg was made to pass through hot air oven as I have already mentioned the sintered towpreg upon exiting the hot air oven was cooled. It was cooled with the help of exhaust fan placed at the exit of the hot air oven. This helps in eliminating any sticking on the rollers. So the towpreg was then wound on to the take up package. So this is the winding is taking place here.

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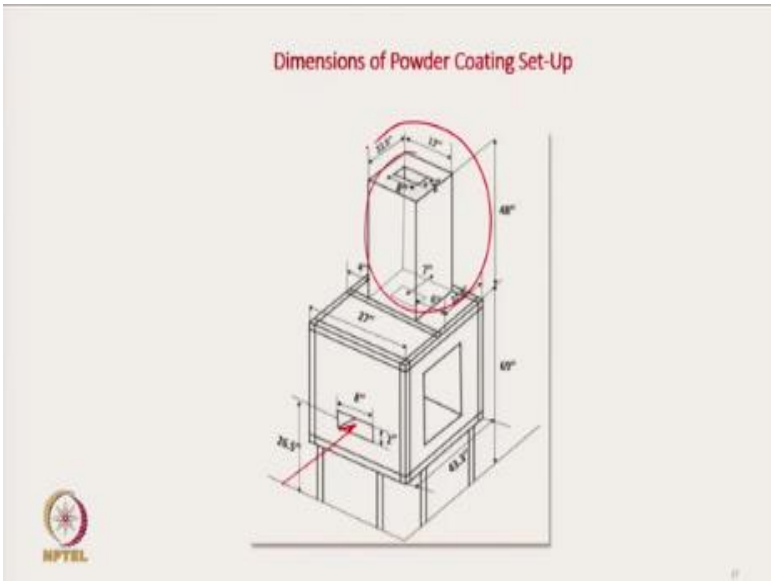

Now if we see the dimension of the system, so this is the dimension here, this is the entry point and this one is the hot air oven and this is the chamber. This chamber is the coating chamber.

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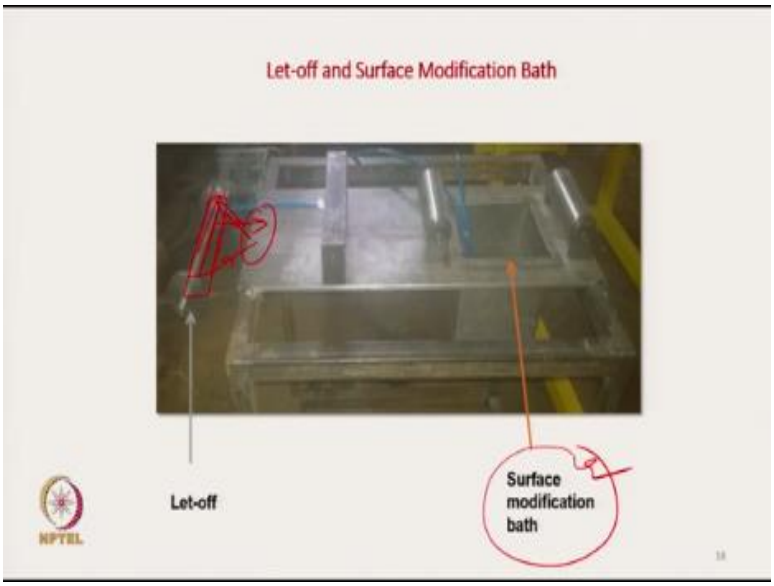

Now let us see each and individual component from the back side of the instrument, this is the let-off system where the carbon tow is placed the package is placed feed package is placed here and with the centering devices there and here it is a surface modification bath. If we need surface modification, we need we have to use this surface modification bath. Now initially the placement of the let off system was at the top, close to the centering device but finally what we found that lot of tension variation due to the traversing of the filament.

So lot of tension variation was there and also there was a high tension variation at the entry point the, to avoid this the let-off system has been brought down close to ground, so that the tension variation was reduced.

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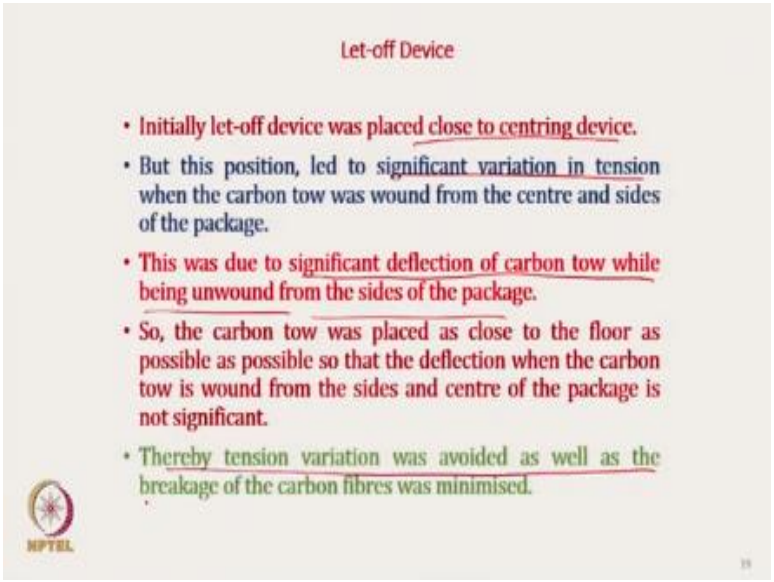

Close to centering device significant variation in tension was observed. This was due to significant deflection of carbon tow while being unwound from the side of the package so that we have already seen. So carbon tow is placed close to the ground and what we have found that the tension variation was not that significant. So that tension variation was avoided as well as the breakage of carbon fiber was minimized due to the high tension variation at the entry point.

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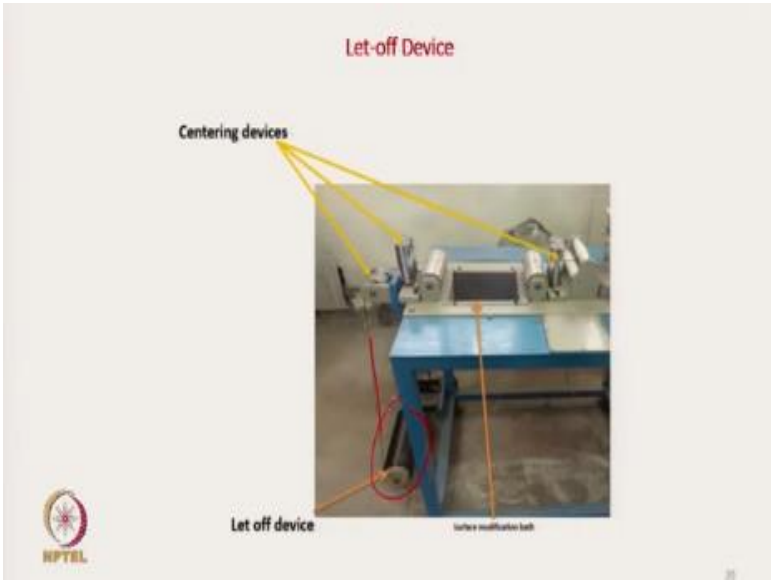

So now you can see the modified let-off device is at this point and here it is a centering device, these are the centering point and tension variation was minimum at this point.

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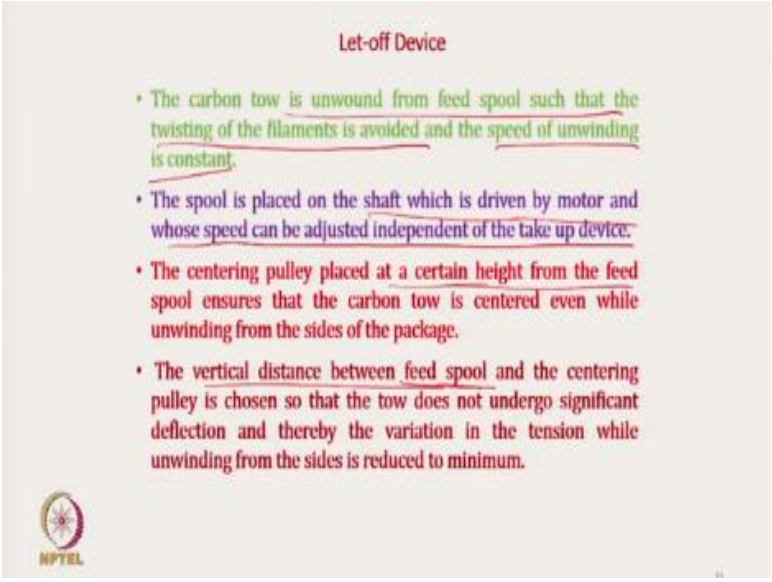

So carbon tow is unwound from the spool such that twisting of the filament is avoided and speed of unwinding is constant. So that is important if the twisting is there then during the unwinding process, if twisting at the carbon filament is there then there would not be any spreading and proper coating of polypropylene powder on the carbon tow or carbon filaments will not be there. The spool is placed on the shaft which is driven by motor.

So this motor is driving the takeoff spool which is so let-off spool which is the speed can be adjusted independent of the take up device, so this speed the let-off speed we can adjust. The centering pulley is placed at the certain height as already been mentioned, the vertical distance between the feed spool, the feed spool and the centering device its the distance is selected in such a fashion to minimize the unwinding tension variation.

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And after the centering device the material enters into the surface modification bath, where if we need any finish to be applied on the surface of the that fiber so in that case we can use this surface modification bath. So this immersion time here can be adjusted based on the requirement. But in our present study as we have used carbon fiber, so we do not need any modification so this this is for general purpose for some certain fiber we may need.

Certain surface finish like natural fiber, like flax if we want to coat with the polypropylene in that case we can use some surface modification.

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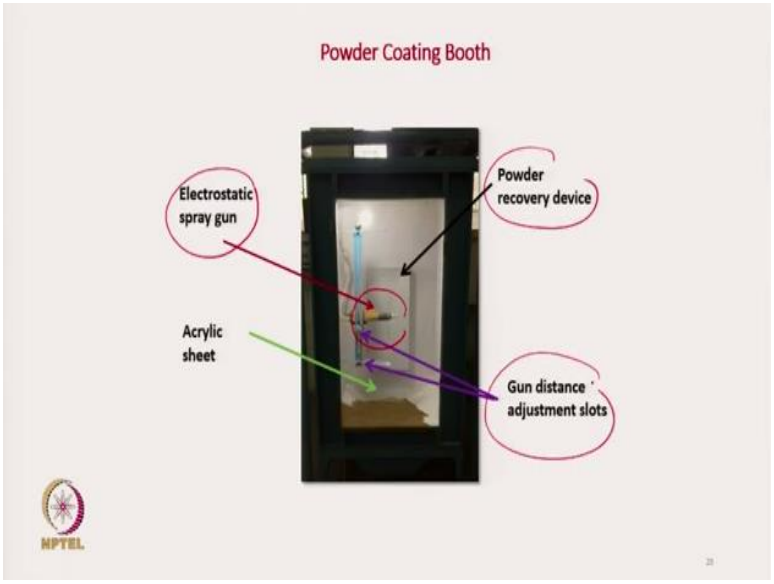

Then after that it comes to the powder coating booth. This powder coating booth consists of acrylic sheet, which helps in proper viewing. Electrostatics spray gun, here there is a powder recovery device. So during powder coating what we have observed the effective powder, take up by the tow is very very low, it is typically 4 to 5% maximum majority 90, 95, 96% powders are not being used.

So we have to take, recover this powder for reuse it again, we cannot actually, throw this powder its expensive and this gun distance can be adjusted. And gun height also can be adjusted using this adjustment slot.

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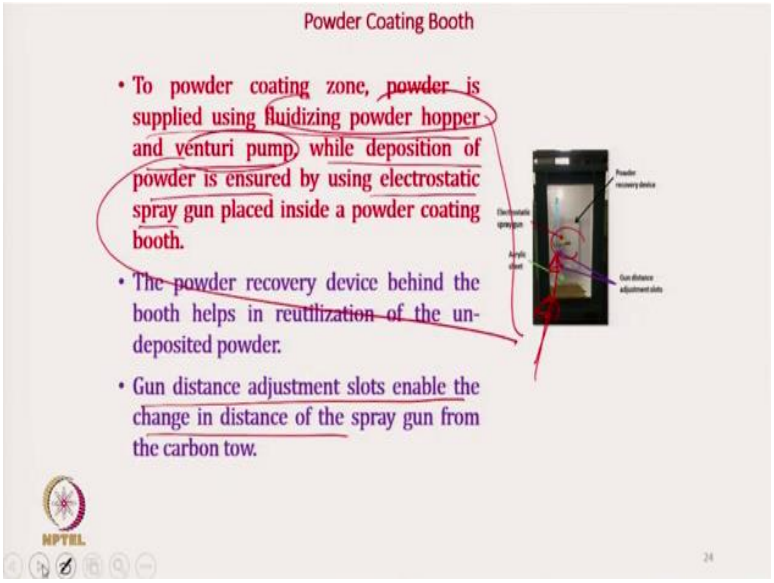

The powder is supplied using fluidizing powder hopper and venturi pump so this I will discuss in detail. While deposition of powder is ensured by electrostatic spray guns, so electrostatic spray. So it is the powder is supplied here from the fluidizing powder hopper, and it has come through the density pump, so it has been supplied here. So powder recovery is system we have discussed. This gun distance adjustment slot enables to change the distance.

So there are significant effect of distance of the gun from the towpreg on the powder coating performance. This study we will discuss in next class. So acrylic sheet enables proper viewing.

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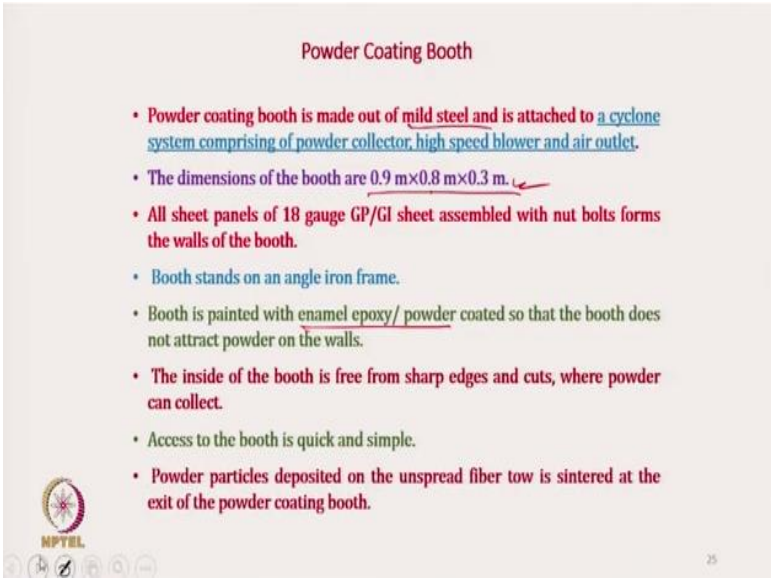

So powder coating it is made of the mild steel dimension is given here 0.9 meter by point 0.8 meter by point 0.3 meter this is dimension which has been used, we can change at readjusted dimension. Angle iron, booth is painted with enamel, epoxy or powder. So this is important we cannot keep the both rough surface because otherwise it will attract the powder. These are the features of the powder coating booth; access should be quick.

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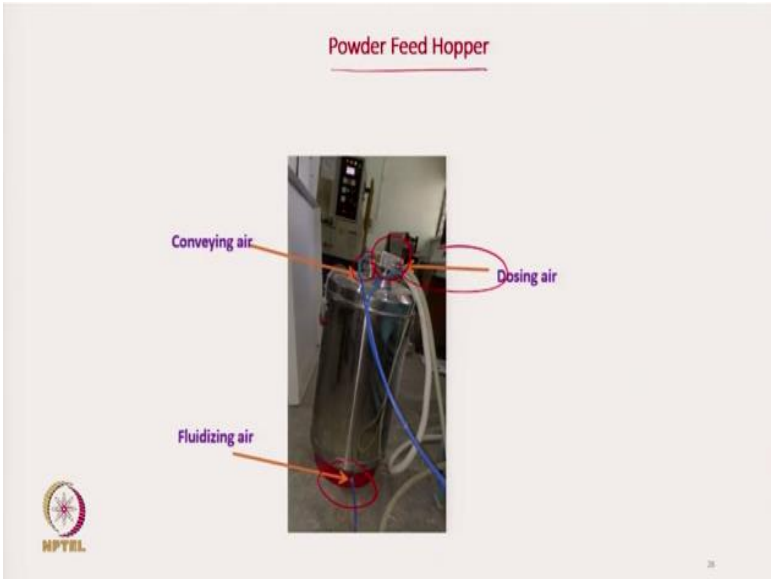

Now coming to the supply of powder to the spray gun, so it is done by the powder feed hopper, so here this hopper consists of fluidizing air inlet. And this is the chamber, conveying air and dosing air, I will discuss and here this is the venturi.

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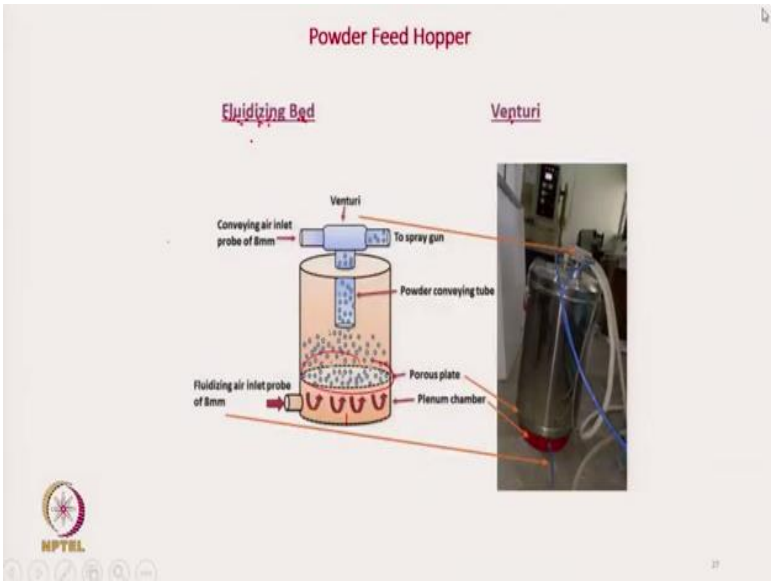

Now this fluidizing bed the powder feed hopper it consists of fluidizing bed and venturi. This fluidizing bed consists of fluidizing air inlet, plenum chamber, porous plate. And this fluidizing bed when the air enters from the bottom of the porous plate. And here there are powder is placed here. And with the air pressure powder becomes actually starts boiling like a fluid that is why it is called fluidizing bed. So let us see the running of the fluidizing bed.

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Here the powder is kept here, now the compressed air is coming from the bottom and we can see where clearly the powder its acting like a fluid like any fluid which is boiling and gradually the powder will start escaping and form cloud now it is forming cloud. And this powder cloud is taken by the venturi pump and then it is supplied to the spray gun, so this is it is powder cloud is formed powder is coming out from the bed and its mixed with the air.

And like it is just like a boiling water any boiling fluid. So this is the fluidizing of the powder.

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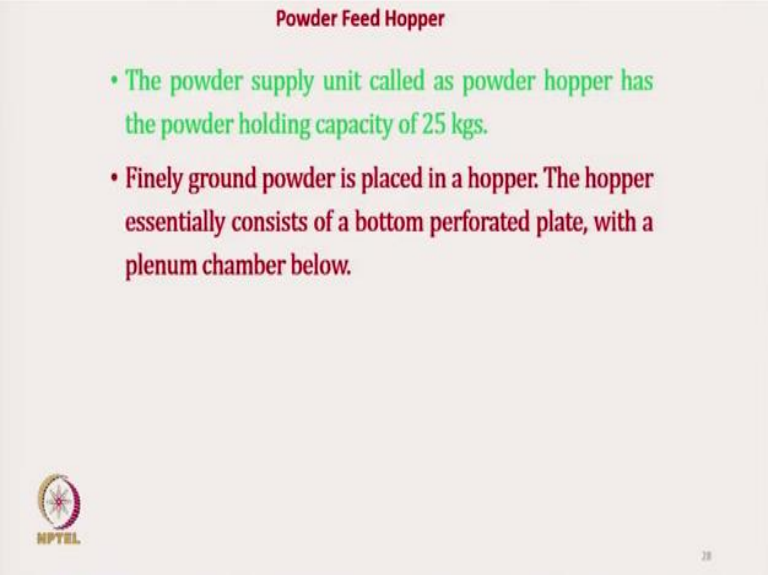

Now let us see the venturi;

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This is the venturi here okay and where the powder is coming from the bottom, this is the powder from the fluidizing bed, it is coming. And one is the compressed air inlet another is the, this is the dosing air and it controls dosing air, it controls the powder, here the gun will be placed.

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Which controls the powder, so powder supply unit called as powder hopper, it has a in this experimental set up its 25 kg size. So finely ground powder is placed on the hopper as I have mentioned.

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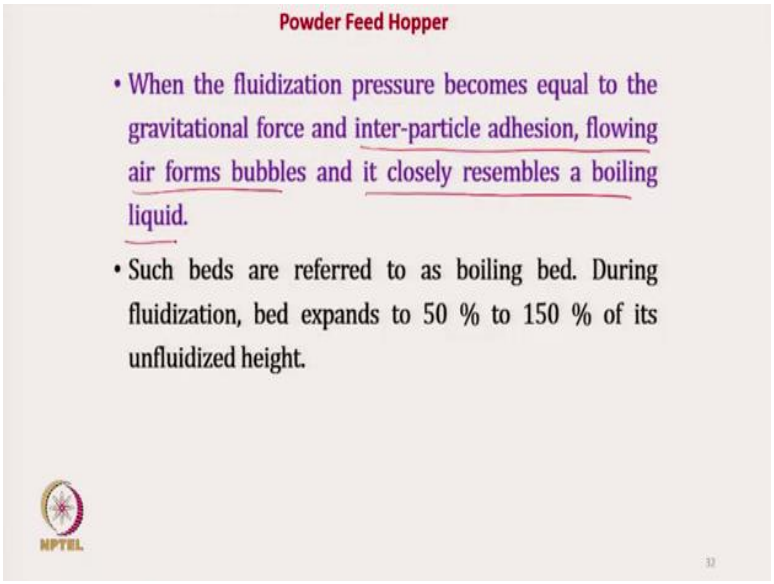

So this is the hopper here we are placing dried and filtered air is allowed to move in upward direction in the plenum chamber so that we can see here this is the plenum chamber. So the air should be dry otherwise it will the agglomeration of the powder will be there, it will not get separated easily. When the fluidization pressure becomes equal to or equal to the gravitational force. The inter-particle adhesion and flowing air forms bubble.

It is closely resemble the boiling liquid that we have seen. Here just like a boiling liquid powder is formed here.

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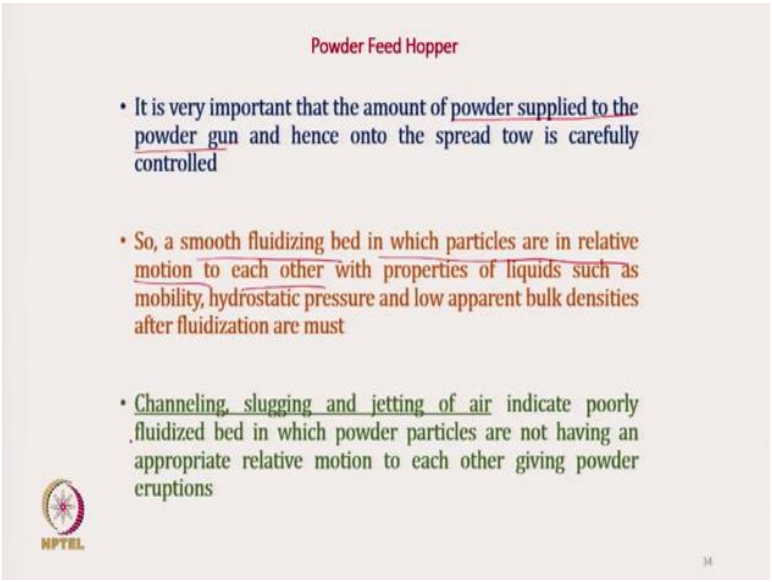

Here it is very important that the amount of powder supplied to the powder gun is controlled. We have to very carefully control, if it is very high then clogging of the air gun will take place. And that amount we have to control. So it ensure the smooth fluidization bed is required in which particles are in relative motion to each other. So that particle should have their relative motion. So agglomeration is avoided. So channeling, slugging and jetting of air indicates poorly formed fluidized bed. Okay?.

In which the powder particles are not having an appropriate relative motion.

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So this is the venturi pump as I have already mentioned here, this is here from at this entry point the cloud powder is supplied, this is the conveying pressure which actually press the push the powder particle to the spray gun, which is exit spray gun, it is to the spray gun. Here spray gun is placed and this dozing air, it is important just to control the supply of the powder. So and this conveying air what conveying air does while moving from this left to right side, it creates vacuum. And this vacuum helps in shocking this powder from the hopper.

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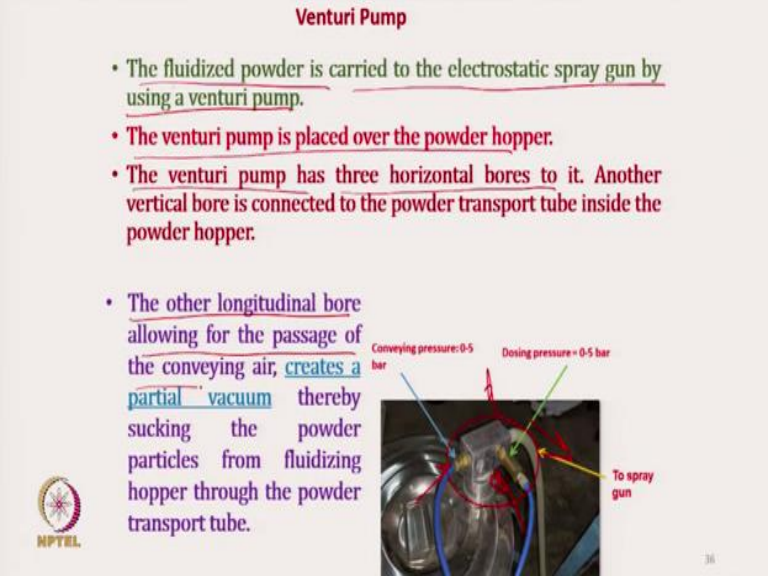

So the fluidizing, the fluidized powder is carried to the electrostatic spray gun by using the venturi pump, as this is the venturi pump we have seen here. The venturi pump is placed over the powder hopper, the venturi pump has three horizontal bores, as I have mentioned, one is conveying air for conveying air another is the spray gun and third one is for dosing. The other longitudinal bore allowing for the passage of the conveying air creates partial vaccum, so this is the, it creates partial vacuum as I have mentioned.

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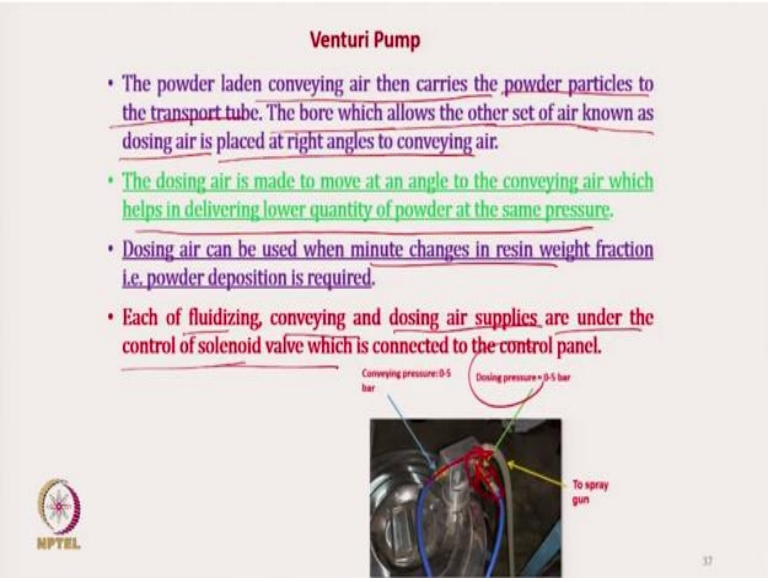

So the powder laden conveying air then carries the powder particle to the transport tube, this is the transport tube, the bore which allows the other set of air known as dosing air. So this is the transport tube here it is the dosing air is placed at right angle to the conveying air. So this is the

conveying air and at right angle we place the dosing air. So which controls the, so this dozing air is made to move at right angle to the conveying air which helps delivering lower quantity of power.

So if we want to control the level of powder, so we have to use this dosing air. So minute change in the weight fractions, if we want to change minute have minute change in the weight fraction, so we can use this dosing air. So each of fluidizing, conveying and dozing air supply are used to control this is actually the pressure is controlled by solenoid valve which is controlled by a control panel. So that we can control the dosing air pressure the conveying air pressure.

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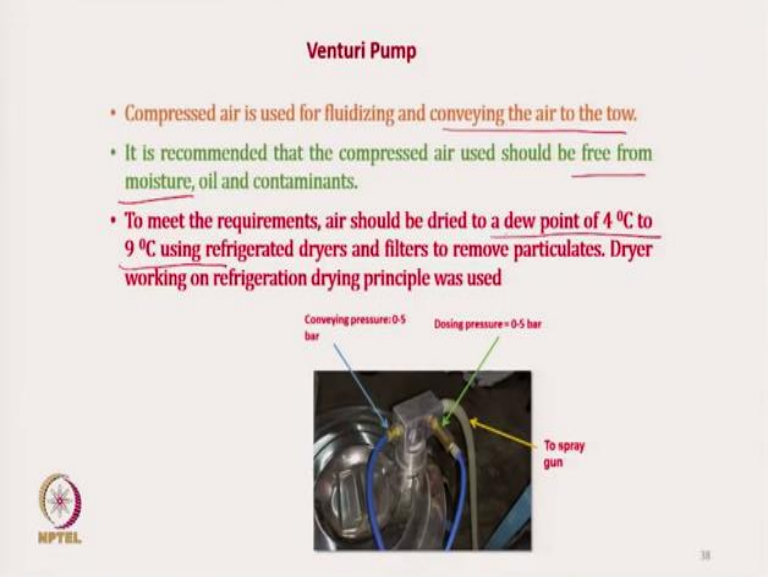

So the compressed air is used for fluidizing and conveying the air, so this compressed air has to be dry. So it should be free from moisture oil and so otherwise there as I have mentioned the clogging, agglomeration of particles will be there. And it is tried at the below dew point so the dew point temperature 4 to 9 degree, the represented dryer is used then its filtered to remove any moisture.

This we have already seen the electrostatic spray gun. So at the tip of the spray gun, there is a voltage. So, 30 to 100 kilo volt we can use, can change accordingly.

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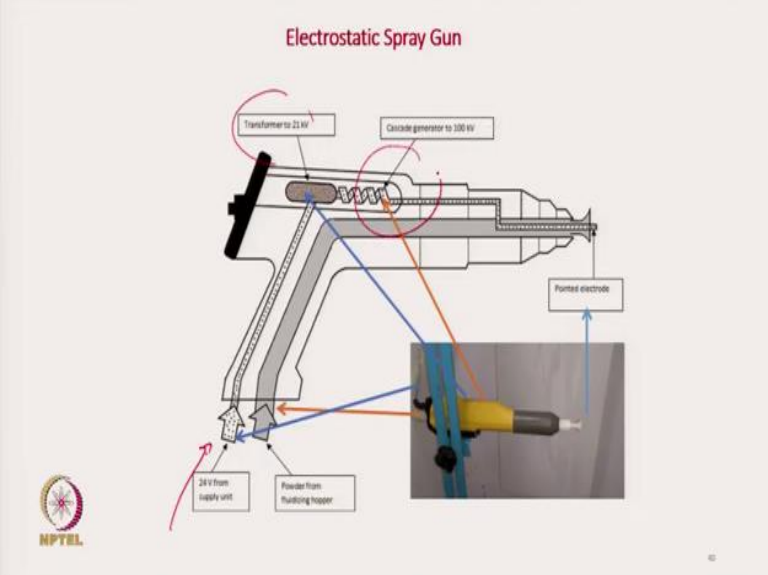

Here the supply is the 24 volt, So 24 volt okay and this 24 volt you with the help of transformer it is actually increased upto 100 kilovolt. It is a very high charge which actually helps in charging the particle.

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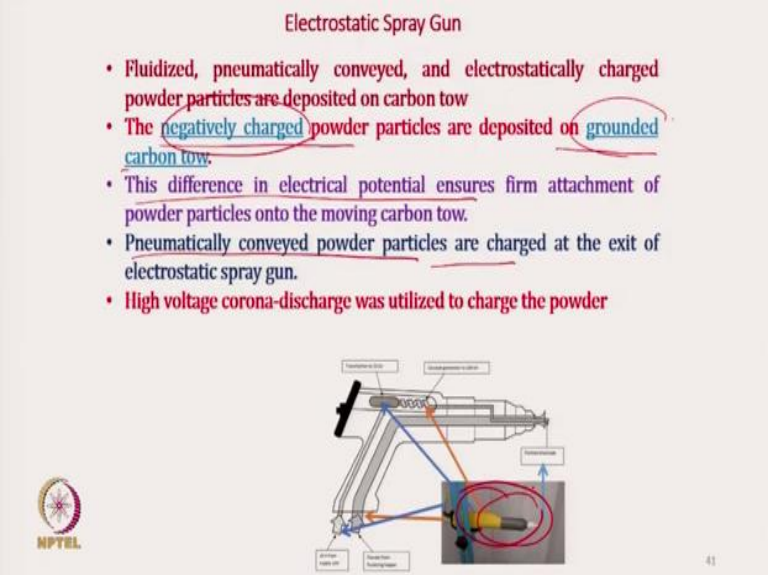

So the spray gun if we see, it actually generates here it is a negatively charged powder particle and which are deposited on the grounded carbon tow, why is it grounded because to have zero charge there is no charge. This difference in electrical potential that is the grounded carbon tow and negatively charged powder which helps in deposition of the powder on the carbon tow. So pneumatically conveyed powder with the help of the conveying pressure are then charged at this point.

This is the charging device and then it is deposited on the carbon tow. So here high voltage corona discharge was utilized.

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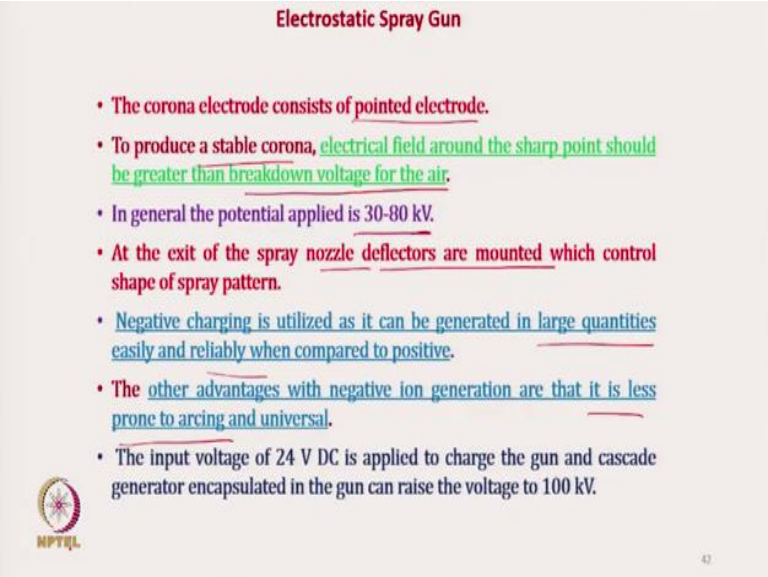

It is a pointed electrode is used here to produce a stable corona. So electrical field around the sharp point should be greater than the breakdown voltage of air, it is a 32 to 80 kilovolt are used here. At the exit of the spray nozzle deflectors are mounted. So here at the exit the deflectors are mounted to act to spread the particles. Otherwise there will be pointed exit of the powder.

So proper powder cloud will form so negative charge we have used here. Because it can be generated in large quantities and reliably it is easily and reliably compared to positive. So large quantity we can generate here. And the other advantages of negative ion generation is that it is less prone to arcing and it is universal. So that is why we have selected negative charging one can select the positive charging also. 24 volt DC supply as I have mentioned. This is the setup we have discussed already.

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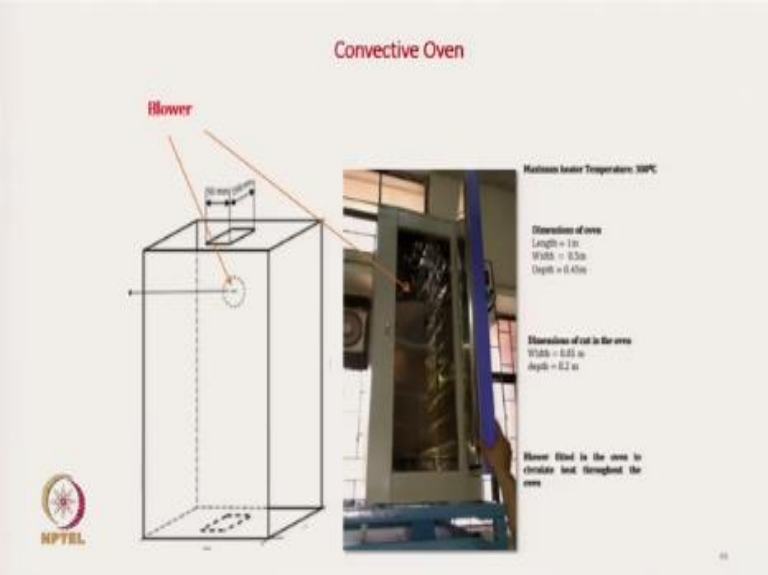

And after that the after coating the towpreg**,** the carbon tow is a covered with the powder polypropylene powder enters into the convective oven chamber.

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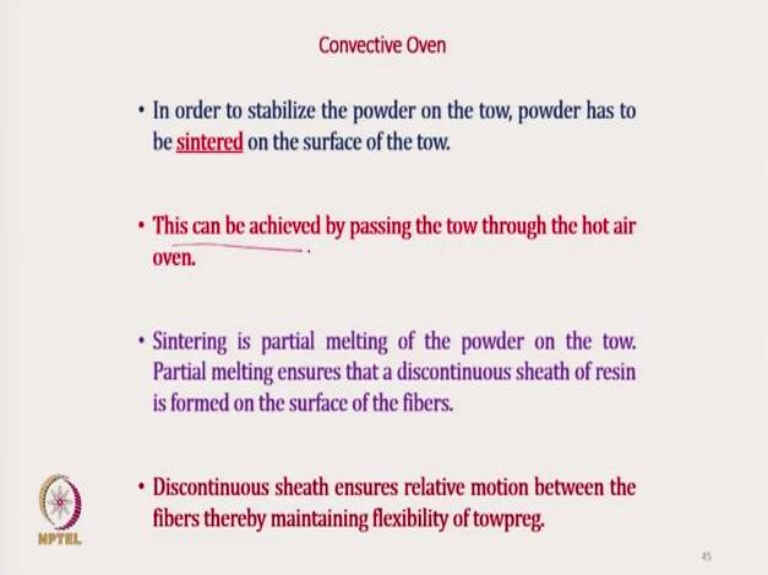

So in order to stabilize the powder on the tow, the powder has to be sintered. This can be achieved by passing through the hot air where partial melting of powder takes place. And partial melting is important.

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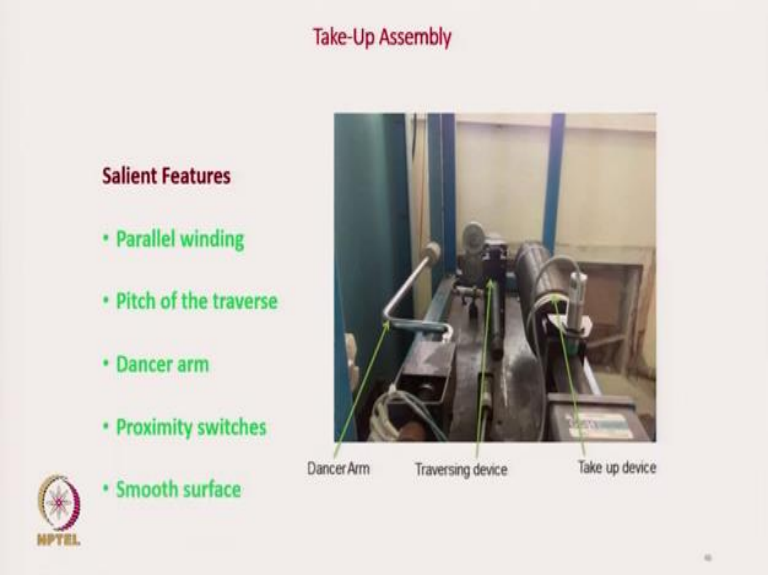

The last component of this setup is that the take up assembly which consists of dancer arm, traversing device and take up device. So it's salient feature is of parallel winding is done. The pitch of traverse is maintained; it is basically depending on the thickness of the tow. Dancer arm here just to control the take up tension, proximity switch controls the end point of the package. And we need smooth surface.

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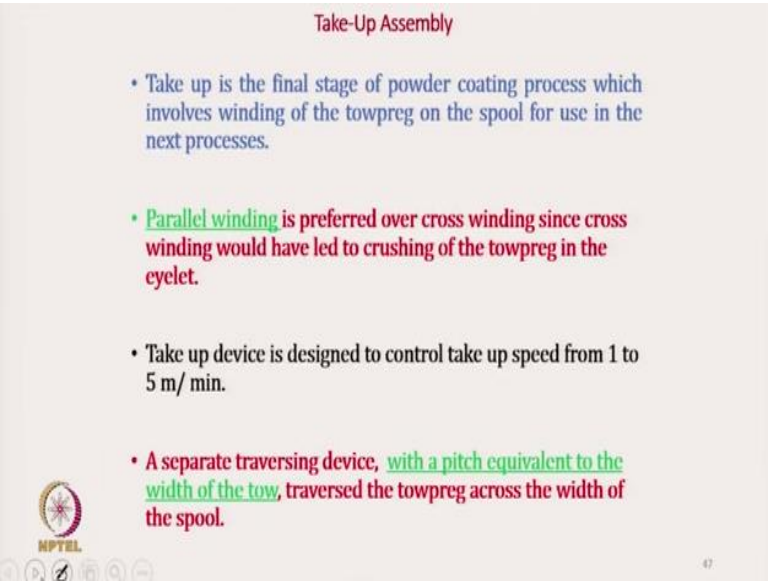

So as I have already mentioned we need a parallel winding is preferred over cross winding because otherwise the tension variation will be there. And which may damage the towpreg, a separate traversing arrangement is there.

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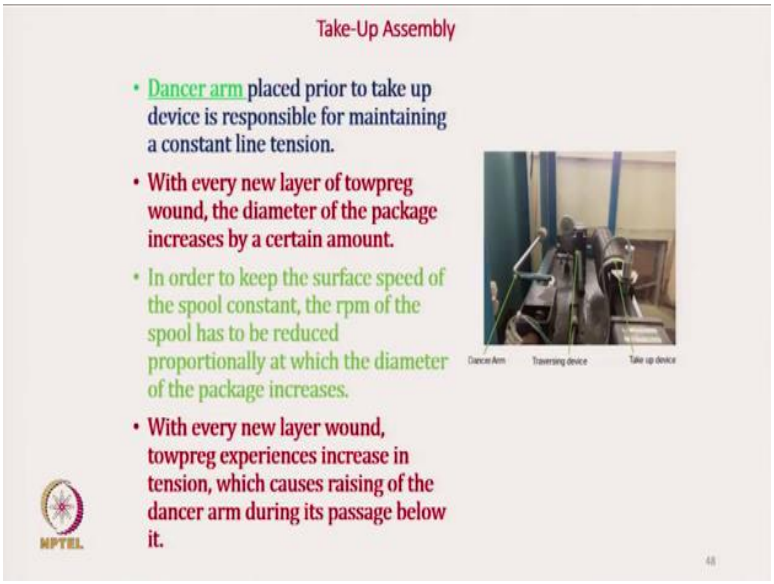

The dancer arm this is the dancer arm, which is placed here prior to take up device, is responsible to maintain the line tension. Now the material which is winding it is coming through below the dancer arm. In case of any tension change, increasing tension this dancer arm will be lifted and then the signal will go to the control system and it will change the speed. So with every new layer on towpreg in the take up package the diameter of the package increases in order to keep the surface speed of the spool constant.

The rpm of the spool has to be reduced proportionally and this is done by the help of this dancer arm, with every new layer towpreg experience increase in tension, increase in tension, okay, which causes rising of the dancer arm and then subsequently it controls the speed.

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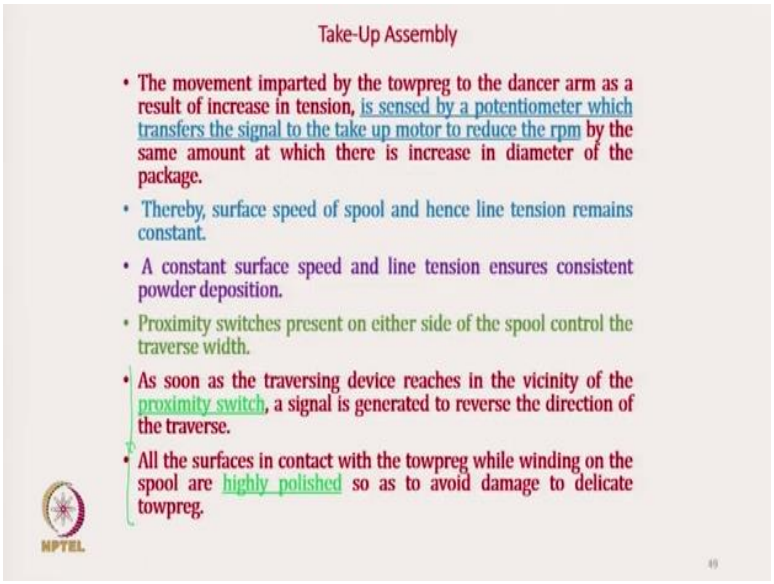

So that has been explained here and the proximity switch, it controls the, the width of the traverse. And all the surfaces has to be highly smooth polished surface otherwise it will damage the carbon flow.

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And there is a powder recovery system as I have already mentioned and it is a filter bag is that so recovery system has got two components.

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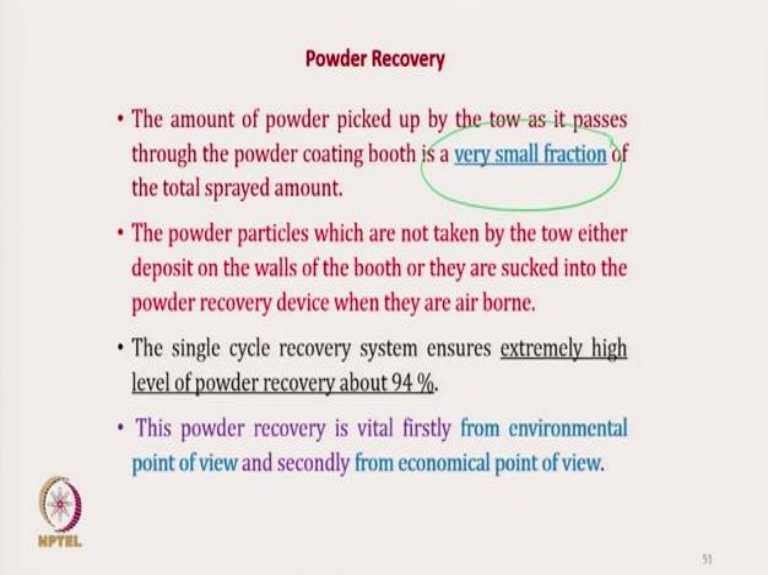

One is the, this is the as I have mentioned its very small fraction is used and typically 95% powder has to be recovered. Otherwise there will be it will go to environment and economically there will be loss.

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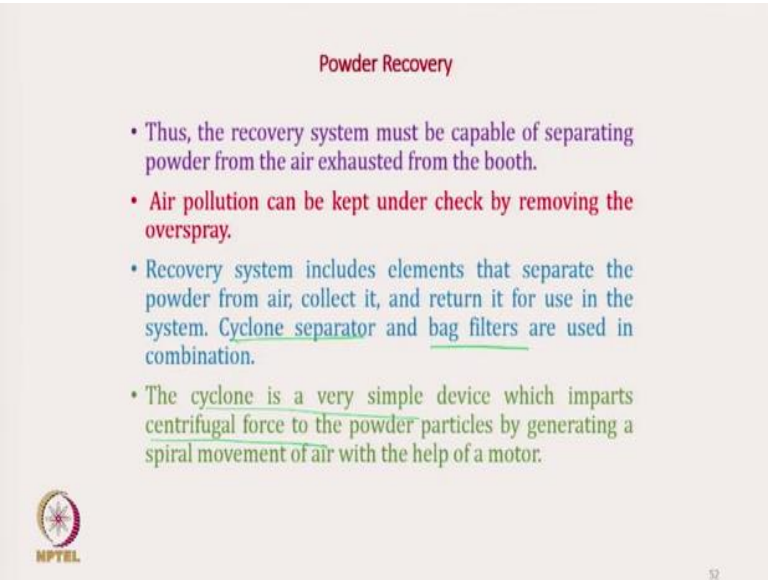

So it has got two types of particles one is coarse particle another is the fine particle coarse particle is separated using the cyclone separator. And fine particle is separated using the filter. So the cyclone is very simple device which imparts centrifugal force on the powder so heavy particle will get separated from the air stream and will deposit will get deposited, at the back of the machine.

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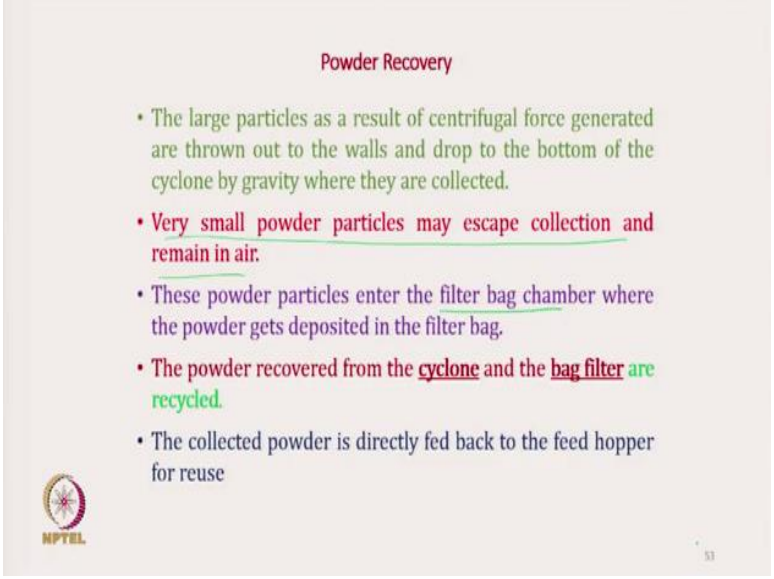

And the fine particle will be separated by the filter bag. It is small particles may escape collection and remain in the air and there the filter bag is used at the filter chamber. And this powder is collected and again reused in the feed hopper.

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So air dryer is the very important as we have mentioned otherwise the particles will get clogged.

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So, this is the whole setup as we have already seen.

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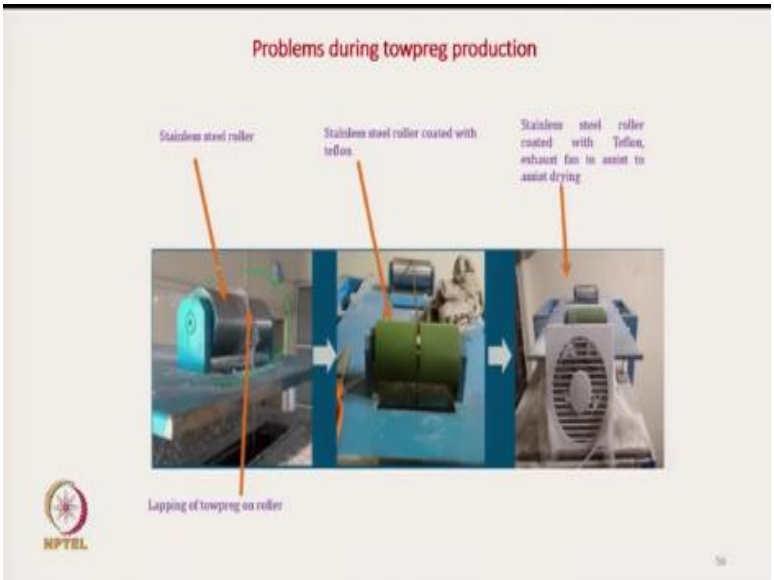

And basic problem was there small problem we faced once the towpreg coming out of that oven it gets stick to the roller, roller lapping took place. So to avoid that we have used the teflon coating and immediate cooling systems were there. Teflon coating and exhaust fan was used for drying.

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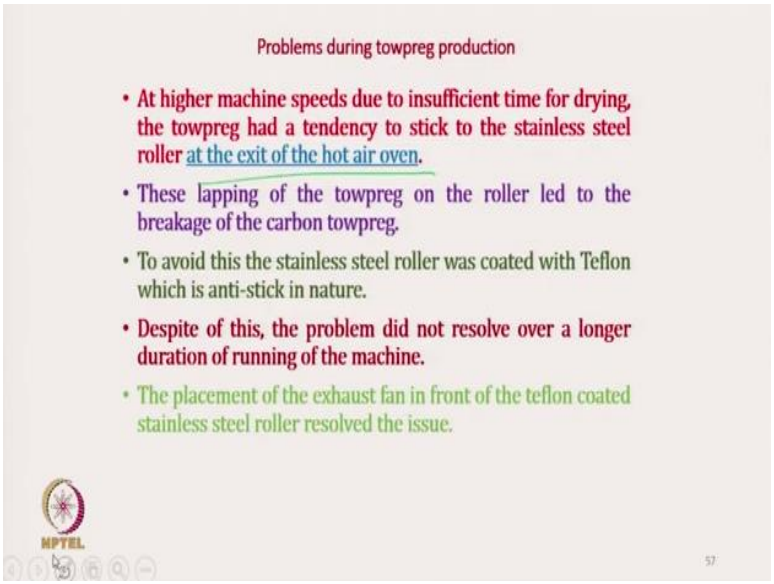

So at the exit of the hot air oven, so this we have used so to avoid the roller lapping.

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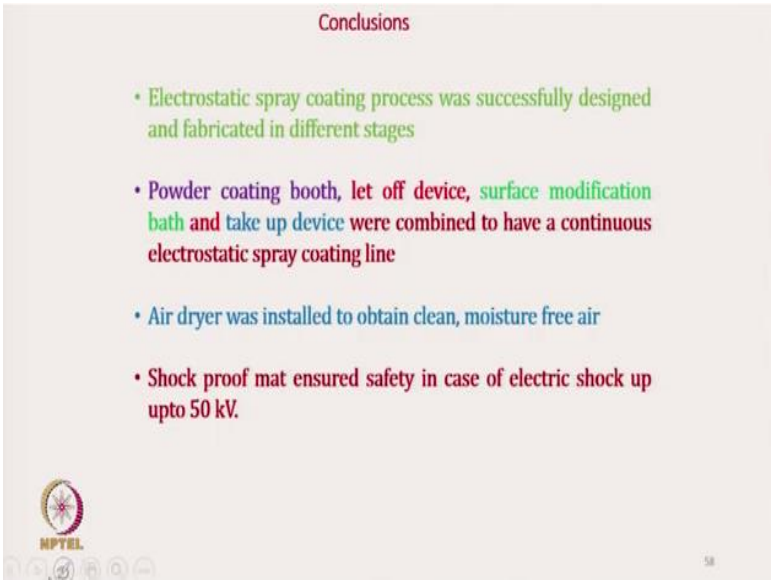

So in the conclusion we have we could develop one complete system of the powder coating. And shock proof mat was used to ensure safety in case of electrical shock. And we will stop here and in the next class we will discuss the optimization of different parameters. Till then thank You.