Recent Advances in Transmission Insulators
Prof.B. Subba Reddy
Department of Electrical Engineering
Indian Institute of Science – Bangalore

Module No # 01
Lecture No # 02
Manufacturing process for Ceramic / glass Insulator

So good morning we were discussing about the history of transmission insulators which are used for outdoor applications. As mentioned we have 3 main types of insulators which are used for overhead transmutations. First being the ceramic or porcelain the other is glass the third is the non-ceramic or composite or polymer insulators which are being used widely for the transmission.

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So we will look into the various manufacturing process of all the three types of insulators. So this is how the story happens for the ceramic insulators or the porcelain insulators a way back in 1880's the insulators technology was initially being used for the telegraphic communication application used for telegraphic lines. So this insulators which are the develop somewhere around 1880's which are known as pin type of insulators basically used for telegraphic conductor isolation there.

Later on these were tried for their electrical insulations it so happen up to certain voltage the problem does not exist later on when the voltage levels increased there used to be flashover on the surface and this is how the insulator how the technology has been come and so this is how various types of insulators you can see several pin type of insulators since inception. So various models various crepe age lens various types were developed across by various manufactures.

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And they were been used for several decades so these are again improve mental aspects for the porcelain insulator as mentioned these are the two important these are the important people which have contributed to the development of ceramic or porcelain insulators Edward Hewlett and Harold Buck these two engineers who were working in Niagara falls and (()) (02:32) electric contributed to the recent designs of porcelain or the ceramic insulators.

Further several designs based on the crepe age based on the usage like the insulator there being used for under desert conditions or without (()) (02:50) which is known as the hydrofoil normal conditions and also an fog and anti-fog type this was developed to cater the needs for the conditions where the contamination is more severe. So various types of insulators have been developed over the period so these are of the recent origin or recent being used for the extra high voltage ultrahigh voltage regions.

So you can see ceramic insulators or a glass insulators again the glass is popularly used in Europe because of the material availability mechanically and electrical performance of

ceramic and glass insulators are being the same. So we will be looking into briefly about the manufacturing process the due course and so these are again the various types of ceramic insulators which are used for railway traction, bushings for the equipment's and several so on and hence so forth.

So this is the recent polymeric insulation we will be trying to cover the ceramic, a porcelain or a porcelain and glass and the recent polymer or a silicon rubber insulators in detail in the coming lectures.

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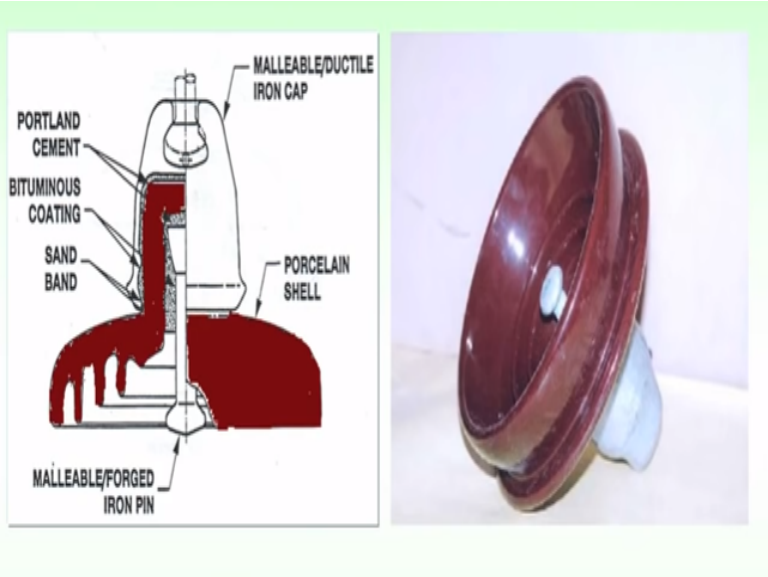

So how the porcelain insulator looks when you typically see the insulator cut section and the porcelain insulator or a ceramic insulator is made up of cap which is known as made by valuable or a duck tail material. So this is a cap of the insulator you have a shell this is a porcelain or ceramic shell which has a different petty coats has mentioned this petty coats or used depending upon the conditions.

So this will crepe age distance what we call will be from this junction that is cement we have again a sand which is ceramic is a metal pin here. So this metal pin is of valuable or a forged iron material. So you have a metal cap and a metal pin in between you have a ceramic shell so this ceramic shell is being integrated with the help of the cement that is the Portland cement. The Portland cement which helps in having the contact between the cap and pin we

can see a portion of the program cement on the cap which will be mechanically coupling with the ceramic shell.

Again here the pin gets coupled with the porcelain Portland cement here so basically cap, a ceramic shell and a malleable or iron pin. So these are the important components you have in between to fix properly mechanically you have a sand that is Portland cement with the help of a sand band for a mechanical grip.

Then you also have a bituminous coating here on this to see that the corrosion is not a the similarly here is the pin junction the zinc sleeve is sometimes being adopted to see the corrosion does not occur and because of the cement junction here this could see the cement broth and further the pin and the ceramic shell and getting detached. So these are the basically important information about the ceramic insulators, this is the cap, this is the pin and this is the shell of the insulator or the crepe age from the pin to the cap from here near the cement junction.

Cement is not usually connected with the crepe age so immediately after the cement junction the entire length from here forms a crepe age up to this junction. So this inside junction from the cement portion here to the end portion here forms the protective crepe age what we call and up to this is the total crepe age. So this is how the crepe age length of a ceramic or a glass insulator is defined.

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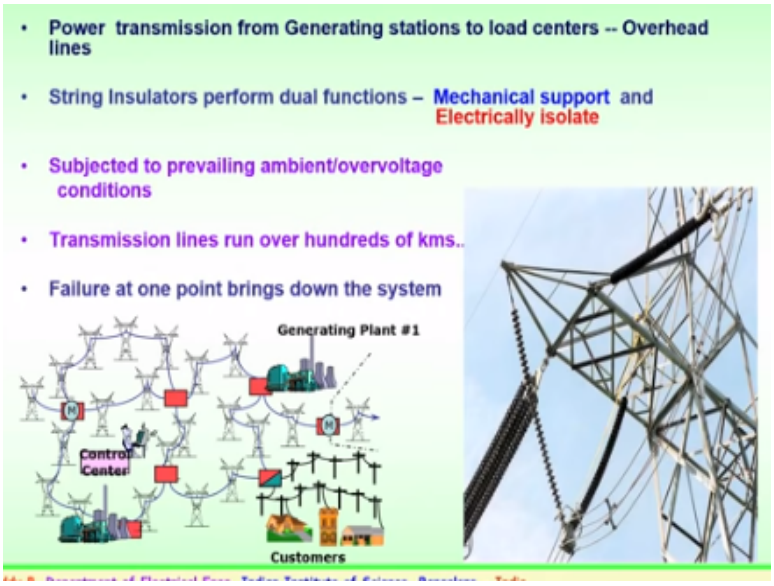

So we have a known that the transmission power transmission occurs from the generating stations. So transmission is very important component so generation as mentioned earlier it could be of thermal and nuclear or hydro-electric or renewables. So from the generating stations to the load centers again I repeat the load centers could be industrial loads, agricultural loads it could be domestic or it could be several for traction and so on and hence for forth.

So to reach the required customers or the required load we use the transformation and this high voltage transmission consist of as mentioned the tower conductors, the foundation for the tower various types of accessories which are used insulators so on and hence so forth. So as mentioned the power transmission from the generating stations to the load centers load places is essentially though overhead lines.

Where I mentioning the string insulators again these are all the insulators string insulators could be of as a ceramic or porcelain glass or a recent type of polymer insulators. So these insulators usually perform two important functions you can see that mechanical support to the tower. So these either in the tension mode or in the suspension mode you have to have a mechanical connection that is the mechanical support to the tower.

The second being electrically isolating the tower to the conductor so these are the conductors here for an example we can see four bundle conductor with several accessories like space

corona control ring and several of these. So these conductors which are at very high voltages so could be around 400 KV or 765KV or 800 KV levels. So these have this potential which are at the transmission voltages have to be isolated from the metal tour.

So for the transmission you use the insulator so basically the number of insulators again depends upon the voltage level that we will be discussing in the future lectures. So this performance of string insulators or the insulator mainly depends or it support to important causes one is the mechanical to the tower and other is to isolate this conductor so that the flash over should not occur.

So these insulators are mentioned are in the environment or at outdoor so most of the transmission line you see there are outdoor towers which this insulators are been subjecting to various conditions like some times over voltage conditions. This over voltages could be because of the lighting natural lightning which occur during the raining conditions or a monsoon conditions where the over voltages should not cause the damage to the power equipment's and the substations or at the nearby distribution stations.

So this have to be protected so this insulators also have to sub or also have to be subjected to the ambience conditions. This ambient conditions it could be environmental conditions like long term performance have to be done this have to be performed in the field like environmental it could be UV ultra violet radiation it could be the dust which is going to set, it could be the contamination, it could be the rain, it could be the fog, it could be the ice loading on the insulators.

So several of this are conditions are being prevailing on this insulators to this insulators have to with stand all this stresses which are in the field apart from the electrical stresses. And these transmission towers are transmission lines depending upon the voltage level and also the generating station to the load centers the transmission lines run over a few hundreds and sometimes few thousands of kilometers in case of HVDC.

In case of HVAC few hundreds of kilo meters so HVDC few thousands of kilometers so why I mentioning this point is you have several towers. You have insulators all over the line length so these are subjected in case there is a failure at any point in the system that is from the

generating to the transmission to the distribution stations. So the entire system could be brought down so this is so important the insulations has to be maintained the insulted should perform for all the conditions which are mentioned.

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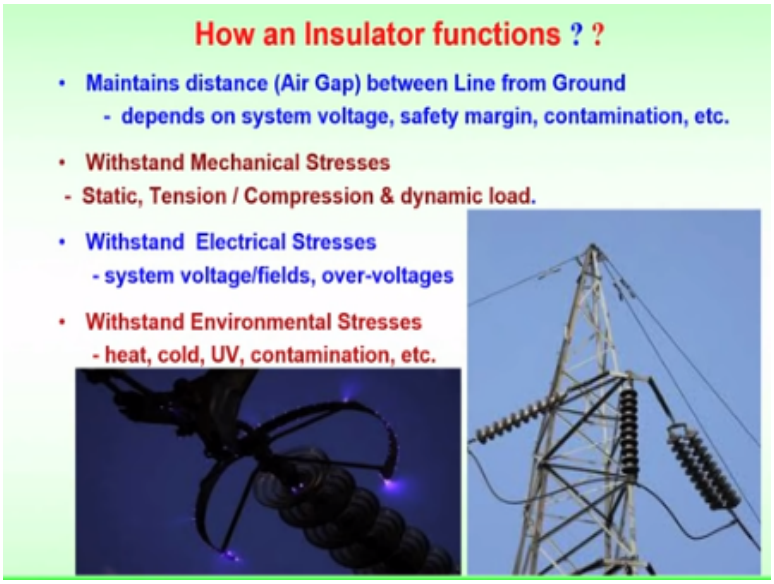

So how this sign later functions so we have mentioned the important of mechanical and electrical importance as mentioned. So the insulators again here I would like to stress it could be glass, it could be polymer, it could be porcelain these area essentially used to maintain the distances particularly a what we called between the line conductors that is the high voltage conductors to the ground it could be to the ground or it could go to the conductors.

So here it has to see that the safety margin is maintained and also the system voltages depending upon the voltage level this clearances or the gap distances levels which are defined by the standards have to be always maintained apart from the environmental condition could be of which are trace nearby or any other metallic objects which are nearby to be seen that the clearances are to be maintained. So proper safety margin as per the standards have to be done are to be maintained and contamination as I mentioned contamination or pollution conditions.

So these contamination is a very a series threat in particular for this outdoor installation so we will be discussing in more detail about the contamination or a pollution effects on this insulators how the performance is disturbed at the normal working voltages which is very

serious matter the performance of this insulators or integrity of the insulators will be low will be designed based on the contamination or a pollution aspect we will be looking into that aspect.

So further they have to with stand the mechanical stresses the mechanical stresses it is not only the support to the tower. So these could be because of the dynamic variation there could be a static loads or attention loads because when the insulators are in tension modes again insulators could be of double tension or a quadruple tension load depending upon the voltages 200 to 400 KV or 765 KV loads.

So because of this dynamic changes both compression and tension forces are exerted on conductors and these insulators which support have to be with stand this mechanical stresses. So mechanical stresses as mentioned again electrical stresses this electrical stresses apart from mechanical stresses have to with stood by the insulators here what are the electrical stresses? Electrical stresses could be the normal system voltages or the feels because of the voltage levels and over voltages.

So what over voltages? So over voltages again it could be because of the lighting effect where the lighting strike and the tower a proper shielding or a ground wire is protected in case that is not able to protected the entire in case of the lighting strikes. So over voltages because of lightning could be reduced and these travel to the sub stations and the equipment in the substation could be damaged or the insulator string could flash over because of lighting effect.

Apart from lightning we have the voltages which are developed because of switching effect because the switching of circuit brake is closing or opening of the circuit breakers. So switching are also developed apart from lightning over voltages, switching over voltages, normal working for frequency over voltages also to happen because of the some of the conditions where the line gets disturbed.

So it could be because of the normal conditions there is a power frequency over voltages switching lighting and the over and performance to various environmental stresses. So here again there are typical performs or typical conditions in case of lightning happens. So the

typical way forms being 1.2 micro second by 15 micro second 1.25 / 50 we called the front time and the tail times of the lightning waves have to (()) (16:50) on this insulators and try to see that whether they can with stand for the lightning effects.

Similarly for switching there is a two way forms which are defined and the laboratory experimentation 250 / 2500 micro seconds the front is 250 and the tail is 2500 of these again we will be discussing during the high voltage testing aspects for the insulators string. Apart from this lower voltages lightning, switching, normal power frequency over voltages the insulator strings or insulator has to with stand the environmental stresses.

Again these environmental stresses mentioned could be due to the temperature of the area where there is transmission towers are erected. It could be because of the cold climatic conditions again in case of higher altitudes and the cold countries where the temperature goes much before below the sub 0 range. So the ice formation or the contamination which is happening on the insulators sees that it conducts and there could be flash happen.

So this have to be withstand on the stresses not only to the very high temperatures the cold conditions ultra violet radiations which are coming from the sun continuously these are exposed to over continuously did so this during the day time and contamination. So contamination or pollution is whatever was mentioned is a serious threat to the insulation of any kind it could be polymer or glass or a ceramic type of insulator.

So contamination again we will be looking in to the phenomena of the contamination how it happens what is the physics behind this out of flash that could happen and how some of the design aspects are being considered for extra high voltage and ultrahigh voltage transmission why the contamination are the pollution plays and important role in the insulator functioning so this we will be also looking into that.

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Factors determining insulation design [IEEE-report]

Sl. No	Voltage levels	Factors responsible for Insulation design
1	0 - 4 kV	Mechanical clearances
2	4 - 34.5 kV	Corona and surges
3	69 – 220 kV	Lightning and switching surges
4	345 - 765 kV	Switching surges & Contamination / Pollution
5	765 - 1500 kV	Contamination

=> For EHV/UHV pollution / contamination performance is very important

So before going into the details of further details of the insulations there are important factor which determines the insulation design. So when we look into the hydro poly technical report which is available this report clearly demonstrates voltage levels up to of 4 kilo volts. So 0 to 4 kilo volts the factors which are mainly responsible for the insulation design are the mechanical clearances.

So the tower to the conductor clearances or the ground clearances, so these are designed basically with the clearances and any other equipment or any other material or a metal which is nearby to do that. So when the voltage levels above 4 to 33 KV the corona and the lightning surges apply a role in design of insulation aspects. So the corona again being the discharges which are happening near the vicinity of the high voltage conductor basically it is a near break down near the conductor or the metal or the aspect near the high voltage area.

So this break down near the vicinity of the conductor opposes the threat and the clearances are important in this aspects and lighting surges. So lightning because of lightning effects the installation design as to be looked into and the factors both have to considered up to 33 KV or 34 KV. Similarly when the voltage level is above 33 to 220 kilovolts both apart from this corona lightning surges switching surges take the importance here.

So switching surges of the opening and closing of the circuit breakers in the sub stations this surges could cause or flash over or could cause damage to the insulation aspects. So proper

protection or proper insulation design for the equipment's as well as the production system as to be done. So up to 220 KV lightening and switching surges play a dominant role in the design of line insulation further to 220 KV level up to 765 KV or you can see that apart from switching.

So lightning is also considered apart from lightning a switching surges play much more role in the line design. And you can see the contamination or a pollution so contamination pollution dominates above 400 KV and higher voltage levels which we called EHP extra high voltage or ultrahigh voltage range.

So where switching surges apart lightning surges apart from lightning switching and contamination flash over or a pollution flash over phenomena which dominates the saying and this pollution or a contamination further to 800 KV. Again the major portion or a major responsible of factor for design insulation is the contamination or pollution. So the contamination or pollution has seen above the high voltage levels takes an important role and this are responsible for the this factor as to be considered for the proper insulation design at this voltage levels.

So you can see that for extra high voltage or ultrahigh voltage pollution is or contamination is very important factor which is responsible for insulation design. So design engineers have to consider this so how series is that how it happens why it is so important the reason being this contamination or the pollution flash over occurs at the normal working voltages.

So this phenomena which occurs at normal working voltages it is not due to the over voltages as to the very important design in criteria which has to be linked to several lines I have been noticed and several lines have been seen that tripping or failure accordance at the working voltages particularly in during the rainy seasons.

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So the design is very important at EHP and UHP level for pollution so that is the basic information about the stresses to be which are encountered by the insulators outdoor insulators again various insulators in the field and important aspects to be considered before the designed for a certain voltage levels now. We will look into the manufacturing of various outdoor insulators which are used for high and very high voltages extra high voltage and ultrahigh voltage ranges.

So as mentioned again like to repeat we use porcelain or a ceramic insulators glass and recently developed composite or polymeric insulators for outdoor application up to EHP and in the country we are also using for EHP and UHP or composite type of insulators. So you can see this is the ceramic insulator has mentioned as the cap and the pin arrangement. Similarly you will see the glass insulators you have a cap and pin again to have a glass shell instead of porcelain or ceramic shell.

So these are the recent developed polymeric composite silicon rubber so several names which are being used for high voltage extra high voltage and voltage transmission and also for the traction and insulating for distribution levels. So manufacturing of these outdoor insulators gives us an idea as what could cause the issues or what could lead to somehow the processes how important is the manufacturing of each and every type we will be briefly looking into this.

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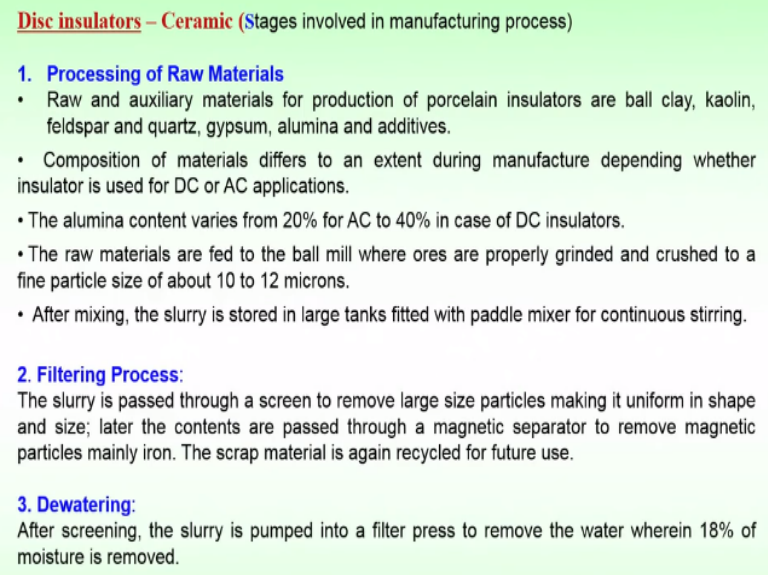

So first we will look into the manufacturing of the disk insulators basically the ceramic or porcelain insulators which are more than it century old and which have reasonably provided the performance up to UHP and it is also being used for ultrahigh voltages and these insulators have to been origin over the century and several types of insulators for normal conditions and contaminated condition have been developed by various manufacturers across the globe.

And are being used for transmission system so we would like to see or focus on disk insulators again ceramic insulators different types it could be bushings it could be long rod insulators. So there are other types which there are being manufacturing we will focus on the disk insulators which are basically used for transmission. So disk insulators there are several stages of manufacturing this porcelain or ceramic insulators we look into the steps which are being followed.

So initially processing of raw materials so what are the raw materials raw and axillary materials which are used for the manufacturing of this porcelain or ceramic insulators are basically clay. Clay is mud so this clay which is normally available in the country and abroad are being used for the porcelain manufacturing. Apart from clay we they use kaolin, kaolin is again a clay type of material along with the clay it is being used or some portion of quartz, gypsum, alumina and additives.

These are the main ingredients and the raw materials or auxiliary materials apart from the major clay, kaolin, feldspar, quartz, gypsum, alumina and additives are used. The composition of these materials. So whatever the materials which are been mentioned could differ to an extent particularly this has to be noted here during manufacturing we can depending upon whether the insulator is for DC or AC application.

So it is not that AM insulators which are being used for AC could be used for DC yes to an extent it could be used. But during the manufacturing there is an extent which differs during the manufacturing process in particularly for the DC application rare the alumina content for the DC various from 20% in case of AC to 40% in case of DC insulators. So this as to be noted it is not the same material or the same mixture of materials which have been mentioned.

So the alumina content particularly in case of DC where (()) (29:47) could be same the raw materials which are mentioned are fed to the ball mill which tries to mix up the materials where ores of the material properly grinded and crushed to fine particle here the ball milling what we called in the initial stages is done to see that the particle size is drop down somewhere 10 to 12 microns so where is small size the material is being crushed after mixing.

This slurry which is obtained it contains against water + the clay and the other axillary materials so this is made in the form of slurry or fine liquid slurry which is stored in large tanks which are fitted with mixture for continuous stirring. So the continuous stirring is being same in the initial stage further filtering of process happens slurry which is obtained by the raw material is passed through the screen and to move into a large size particle making it uniform in shape and size.

So later and the contents are passed through a magnetic separator why magnetic separator basically to remove magnetic particles mainly iron and so on. So the scrap material which is obtained that is which is removed is again recycle for future use after the filtering process. So further to the filtering process dewatering is being done. So these dewatering is basically after screening the slurry which is obtained is pumped into the filter where mainly the

intention is to remove the water where in 18% of the moisture is removed in this process during the dewatering.

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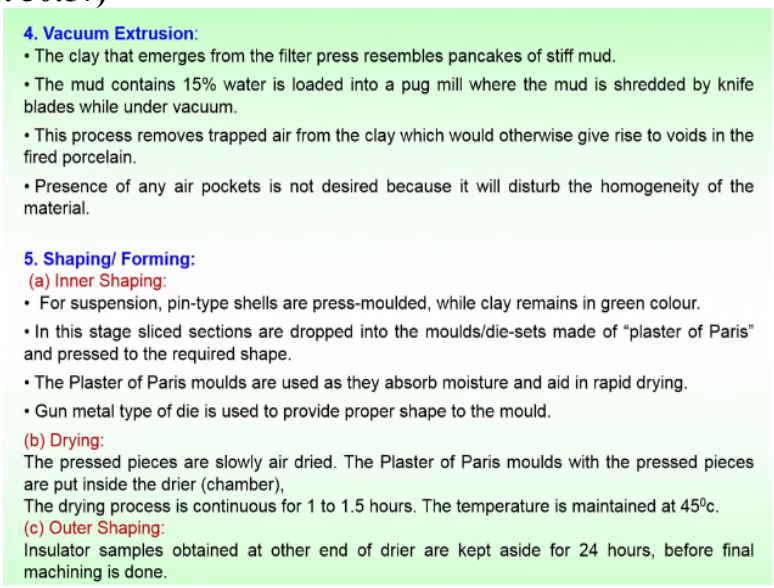

So the slurry the paste which is being formed the 18% of the moisture is removed in the dewatering stage further the clay emerges from the after the dewatering is passed through the filter press further similar to the pan cakes with a stiff mud is obtained this stiff mud which contains again 15% water this is loaded into what is known as pug mill where the mud is shredded by the knife blades and the vacuum conditions.

So this process of vacuum extrusion is mainly removes the trapped air from the clay which is would otherwise give rise to voids during the manufacturing. So air bubbles or void do not present during the manufacturing process so this process of vacuum extrusion sees that this voids or air bubbles are removed. So presence of any air pockets is not desired as mentioned it will disturb the homogeneity of the material which is being used when what are the manufacturing this could cause the failure in the field.

So further to the vacuum extrusion this material goes for or the material which has obtained goes for the shaping or forming the cycle what is known as. So here again it as three sub divisions for inner shape drawing an outer shaping inner shaping again consist for a suspension or a pin type shell are basically done using the press moulds type of arrangements while clay remains in green color.

So this stage this molds which are used are sliced sections are dropped into the moulds or dye sets what we call these dye sets or moulds is basically made of plaster of Paris and pressed into the regular shape. So this plaster of Paris and mould which are used as a absorb water moisture and aid in rapid drain. So importance of using this plaster of Paris is moulding sued to see that the drying should faster and also the moisture should be removed.

So usually gun type metal gun metal type of dye set is employed to provide a proper shape to the mould, So this is again for the inner shaping further it goes for drying where this pressed pieces of the inner shape are slowly air dried and the plaster of Pairs mould with pressed pieces are put inside the dryer chamber which is known see that the mould with the content gets dried over the period of time.

So this drying process is continuous it could be for 1 to 1.5 hours during this process of drying the temperature is maintained anywhere around 45 degrees continuously. So further the outer shaping so outer shaping of this samples are done at the other end of the dryer and this are normally kept for 24 hour before final machining is done to the insulators samples. So this undergoes shaping inner shaping the dry and the outer shaping in the formation of the insulator and samples.

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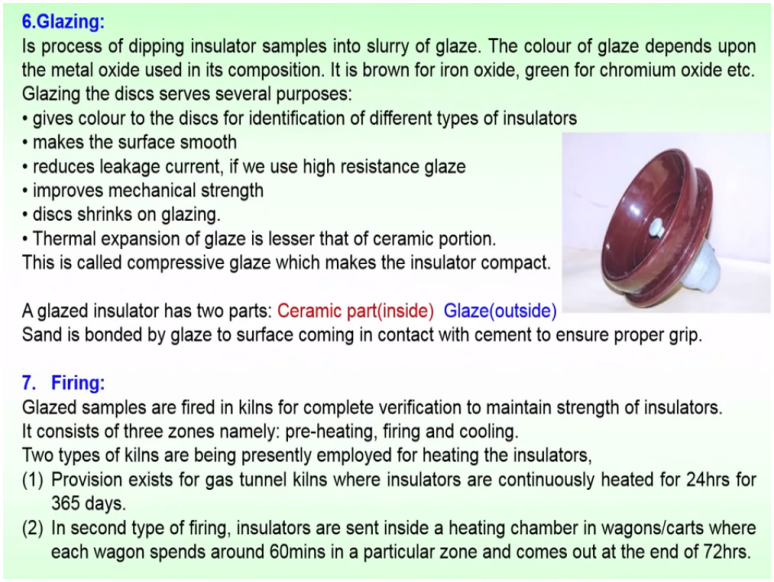

Further to this it insulator process the glazing have to be done so the glazing which is done on the surface of the insulator is mainly to see that during this process the insulator which are

obtained are dipped into the slurry of glaze. So glaze is again the color of glaze is depends on the metal oxide and it is composition so it could be brown for iron oxide green for chromium oxide etc., So the glazing serves several purposes the intention is to see that this glazing gives color to the devices or disc basically disc for identification of different type insulators makes the surface very smooth reduces the leakage current in case of using the high resistive glaze.

It improves the mechanical performance of the insulator and these disk shrinks disk on glazing and the glazing also helps in a thermal expansion of glaze is lesser and compare to the ceramic portion. So thus is also called as compressive glaze which makes the insulator compact so very important so insulator have to act in compression also the tension modes a glaze insulator usually has two important that is the ceramic part and the glaze which is coated outside.

So consist of two parts which inside the ceramic outside is ceramic coated with the glaze so the sand which is bonded by the glaze to the surface coming in contact with the cement is to ensure proper grip that is the sand which is used after a below the cap and pin, pin and cap have to be arranged to the ceramic cell. So this ensures proper bonding between the metal and the ceramic shell.

So the final stage is the firing very important stage in manufacturing of ceramic disc insulators here the glazed samples which are obtained or sent into the kilns, hot kilns or high temperature kilns for complete verification to maintain the strength of insulations. This firing zone usually consists of three zones one is the free hitting, firing and cooling zones. So two types of kilns are usually employed for hitting this insulators. So provision is also made for gas tunnels kilns where insulators are continuously heated for more than 24 hours up to 365 days.

The second type of firing depends on the insulator where sent inside and hitting chamber in the wagons or the carts where each wagon consisting of several insulators spends more than 60 minutes in a particular zones. So several zones and comes out by the end of 72 hours so each

60 minutes that is 1 hour to 72 hours. So this a process involves in firing which is very important process manufacturing of insulator or a ceramic insulator.

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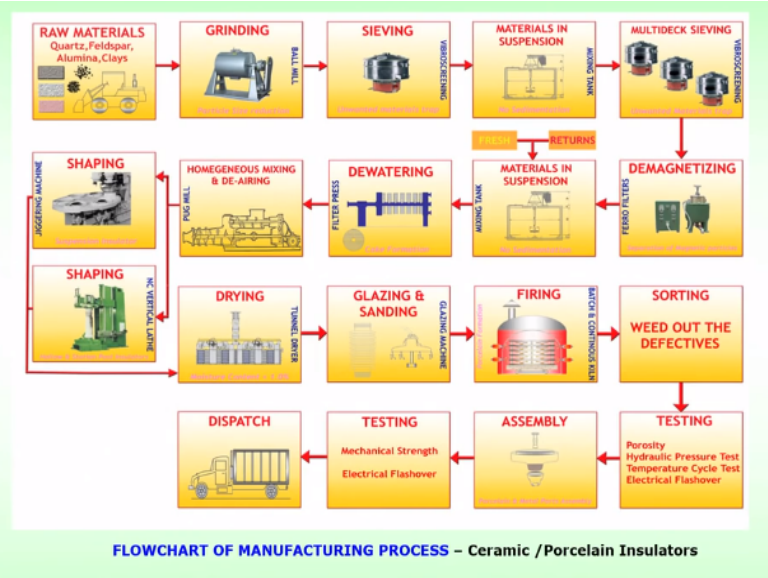

FLOWCHART OF MANUFACTURING PROCESS – Ceramic /Porcelain Insulators

So this gives the entire flow chart or the manufacturing process whatever we tried to discuss. So we can see that raw materials as mentioned it could be quartz, Feldspar. Alumina, clays several of this things are mixed using the ball milling and this slurry is passed on to the further grinding to a fine particles then this grinded the fine particle are sieve to the certain using the blade type of arrangement and the materials which are still available like iron and other particle are removed with the magnetic separators.

Further this materials in suspension are to send to dewatering where the 18% of watering is removed and the homogenous mix and the drying or the hearing of samples are done. Further the shaping using the moulds as mentioned using the plaster of Paris moulds are dye sets or the shaping is done it could be disk insulators or it could be of bushing or whatever we were discussing further this goes for drying over a certain period then as mentioned the glazing of the insulators again it could be of bushing or the disk insulator where the glazing is properly done and sent for firing.

So firing has mentioned there are two types of firing methods which have different zones where heating, cooling and firing zones each I have to spends some certain time and by the time it leads out also the defective insulator samples are removed by sorting then further to the

obtained after the firing the samples are being sent for the testing that is what is known as the internal or routine type of arrangement testing which are done in factories.

So this testing mainly looks into the porosity whether any particular voids are present in the samples in the manufacturing process or whether they could with stand the hydraulic pressure at temperature cycle and electrical flash over test. These test are preformed after the firing and further the assembly of the insulator is done assembly in the sense the pin, the cap and the shell are connected with the help of a Portland cement and the sand which is on the mechanically to support.

So this assembly is further after the assembly the testing for the mechanical and electrical flashover are carried out. So this involved the factory testing for both mechanical and electrical. Again if we are the mechanical test are depending upon the insulator strength it could be for typical crepe age or typical usage so the mechanical strength could be 70 kilo, 90, 120, 210, 420.

So depending upon the mechanical strength required the insulators are manufactured this have to undergo the mechanical strength and the electrical flash over. So after this the dispatch of the insulators in the crags is done and it is sent to the utility centers. So this is how the flow chart of the manufacturing process for ceramic or a porcelain disk is carried down. So we will further look into the service experience in the next class so thank you.