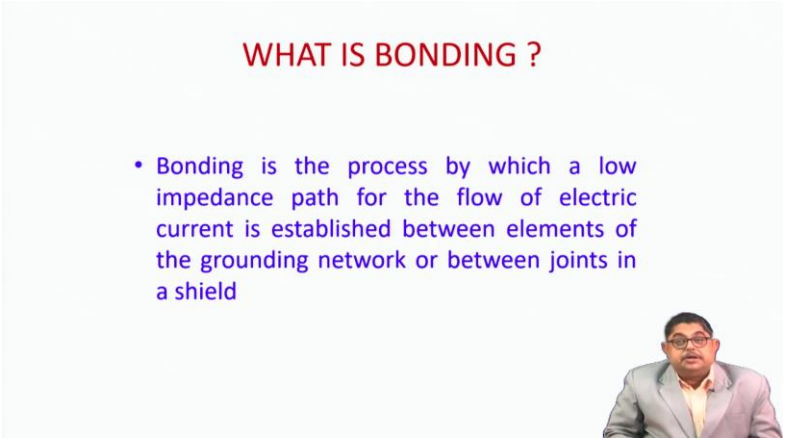
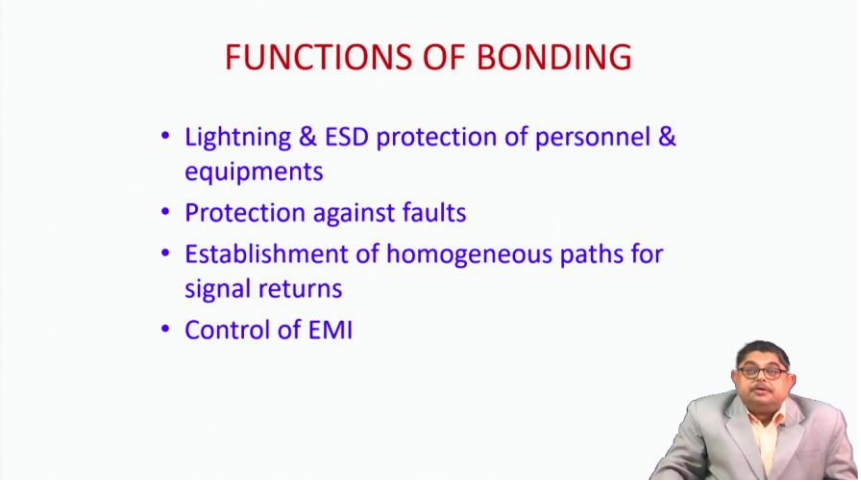
Course name: EMI /EMC and Signal Integrity: Principles, Techniques and Applications.
Professor name: Prof. Amitabha Bhattacharya
Department name: Electronics and Electrical Communication Engineering
Institute name: IIT Kharagpur
Week :12
Lecture 57: Bonds and Joints

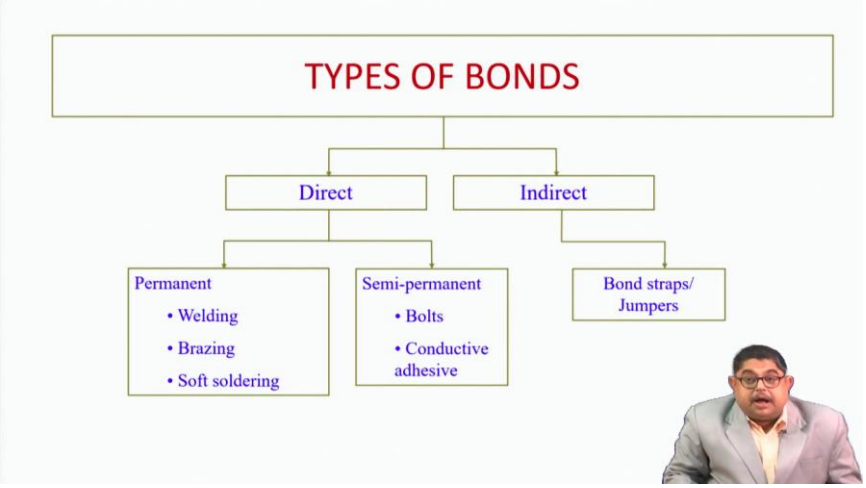
Welcome to the lecture of the course on EMIMC and Signal Integrity Principles, Techniques and Applications. We were discussing various practical aspects, system aspects of EMC. So, today we will discuss Bonds and Joints. Now, this lecture and the next lecture actually you see that I am an academician. So, these things are practical EMC aspects. So, I have taken these materials for this lecture and the next lecture from Dr. D. Subbaraw who is a senior scientist of SAMI which is a DST society for microwave research. So, they are specialist in EMC, EMI, EMC etcetera. So, I have taken the material from him, these are not mine material. Now, what is bonding? Bonding is the process by which you create a low impedance path for the flow of electric current between elements of the grounding network or between joints in a shield. So, you can see that that is also the job of grounding, bonding also provides a low impedance path, but here bonding means it is between elements of the grounding network it can be or between joints in a shield. So, in those cases they are not cannot be called ground they are called joints.



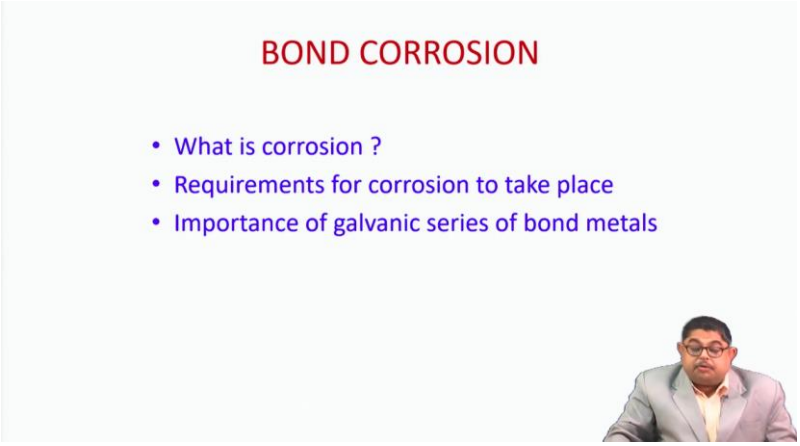
Elements of bonding, lightning and ESD protection of personnel and equipments, protection against fault, establishment of homogeneous paths for return of the signal, control of EMI actually same as the grounding things. So, these are same that will be same only thing to whom they are doing that providing the low impedance path based on that bonding and grounding are different.



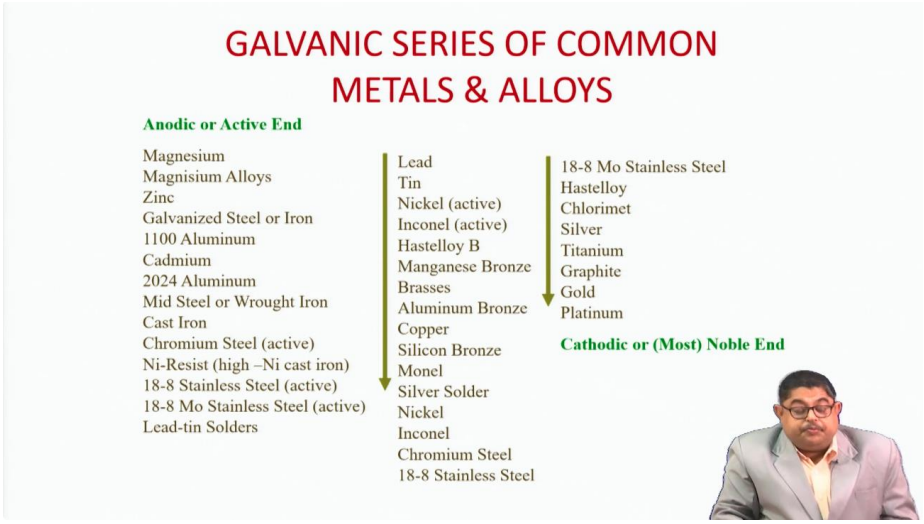
Now, types of bond there are direct bonds. So, permanent varieties either you through welding or through brazing or soft soldering we provide a bond between two dissimilar metals generally and if you do not want that permanent the semi permanent variety that is also direct bonding that is by bolts or conductive adhesive etcetera. Whereas, indirect means you are not putting the two togethers there is a bond strap or a jumper there. So, these are the various types of bonds.



Now, bonds get corroded because they are made of metal. So, corrosion is actually oxidation of the metallic thing. So, if there are water moisture at proper temperature they will try to oxidize. So, that is why it is very important to choose what two different metals you will bond. So, for that there is a series which is called galvanic series of bond materials.

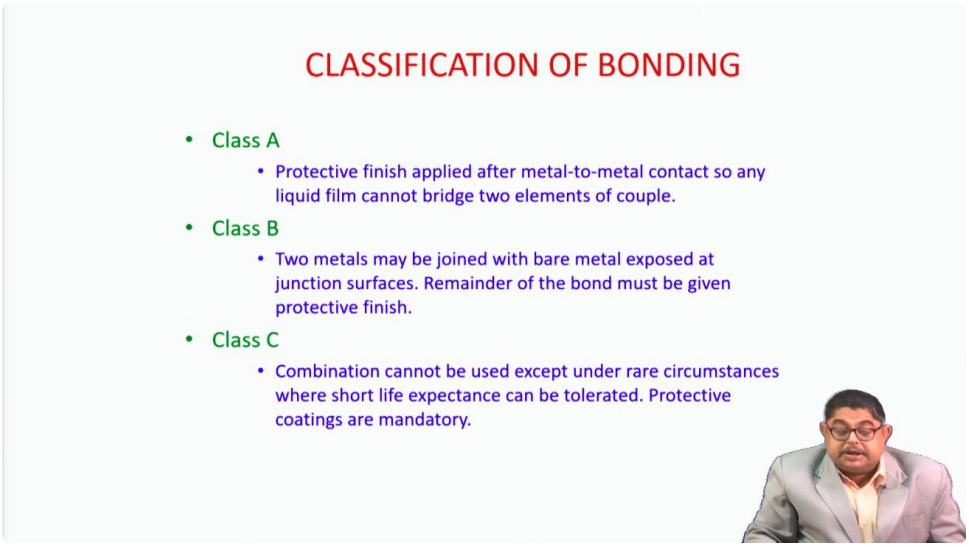


So, you see that anode is on the top and cathodic or most noble end is the bottom side. So, these gives you an way that which is most active and which is less or inner type of thing. So, you see platinum, but gold is available compared to platinum. So, you can see that gold is most inactive. So, cathodes are made of gold and magnesium, but amongst them there are many because the other ones the magnesium alloys, zinc they are more easily available they are less costly. So, how you will make that? So, this series will help you that which one we will make when you are joining which one you will make anode, which one we will make cathode, but exactly how will you pair that does not get determined from here.



So, proper selection is necessary and cleaning and protecting the surfaces to be joined is an important thing. Use of paints for protective finish because even after joining even after you have taken care that least corrosion takes place some corrosion will takes place. So, you put a paint so that the anti corrosion paint so that the moisture etcetera cannot come. And if required if you cannot have that joint you use proper jumper things.

Now, we close to this classification of bonding. So, class A is protective finish applied after metal to metal contact. So, any liquid film cannot bridge two elements of that couple, couple means the two metals that you are metals or metal alloys you are putting together. Class B is two metals may be joined with bare metal exposed as junction surface, remainder of the bond must be given protective finish that is the that conductive paint. And class C is combination cannot be used that means, combination of the above two except under rare circumstances where short life expect tends can be tolerated. So, these are mainly in some cases you cannot have those things, but protective coatings are mandatory, but these two class A and class B you can combine in some case they are not recommended, but it is done.

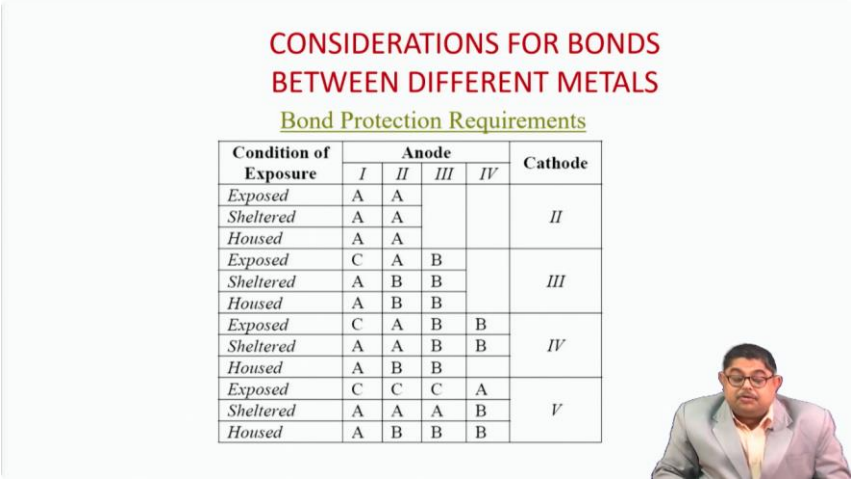


Now, consideration of galvanic series while bonding so there have been made five compatible groups. So, you see that in a group a member he can be amongst them they can be paired. So, in the first group is magnesium that means, magnesium with magnesium can be paired then in second group you see aluminium can be paired. Now,

which one will be made cathode which one will be made anode that you look from the galvanic series. Three you see carbon steel, iron, lead, tin, lead tin solder.So, you see that lead and tin they are combined to make the solder nickel, chromium, stainless steel etcetera. So, with this you this is a convenient way that by this grouping you can do the bonding.

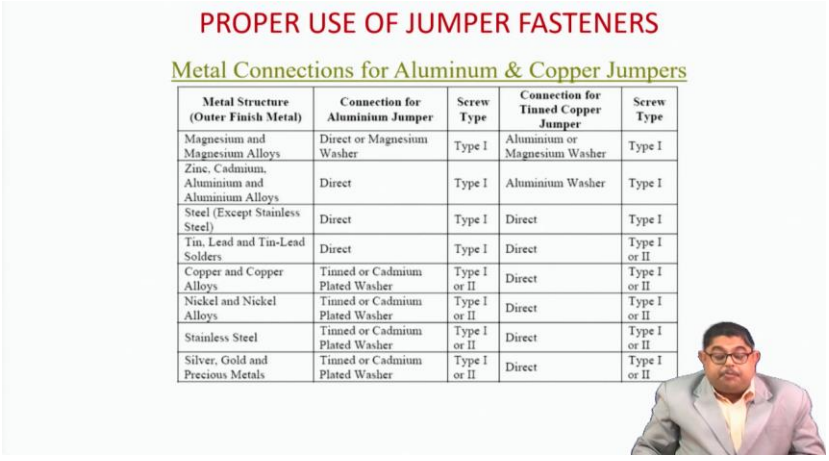
Now, also relative degrees of exposure to the moisture or outside environment. So, the first group is exposed. So, it is open unprotected exposure to weather then second variety is called sheltered where limited protection from direct action of weather locations in housings, sheds and vehicles of our sheltered exposure and housed means located in waterproof buildings where no water can come. So, exposed is one end housed is another end sheltered is in between where some form of outside environment is avoided, but still moisture etcetera can come.

Now, you with this bond protection you can different metals. So, in case of exposed you see how will you choose anode if you choose from class anode from group 1 and if you choose the A type bonding then you choose cathode from group 2 like that in a sheltered case if you choose from 2 type of metal 2 metal from the second group you then have to take the cathode from this. So, with this for every situation you have a guideline that which metals can be combined. So, this is a very very important table from which you can get that how will you make the bond which metals you will make the bond.



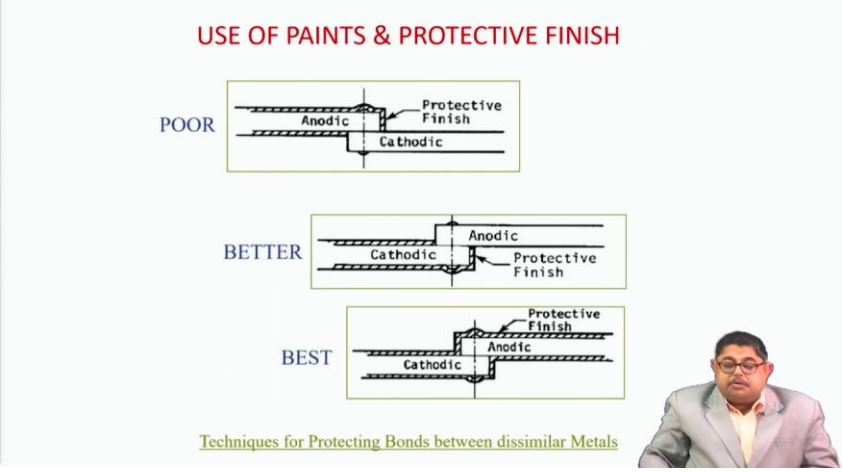
Condition of Exposure	Anode				Cathode
	I	*II*	*III*	*IV*	
Exposed	A	A			*II*
Sheltered	A	A			
Housed	A	A			
Exposed	C	A	B		*III*
Sheltered	A	B	B		
Housed	A	B	B		
Exposed	C	A	B	B	*IV*
Sheltered	A	A	B	B	
Housed	A	B	B		
Exposed	C	C	C	A	*V*
Sheltered	A	A	A	B	
Housed	A	B	B	B	

and now proper use of jumper fasteners that is an another class that is an indirect class there also metal connections for aluminum and copper jumpers there what is the outer finish metal connection for aluminum jumper. So, whether you will use a direct jumper or some washer you will use then what is the screw type. So, that is type 1 then connection for tinned copper jumper screw type. So, all these are covered here. So, for jumpers this is this table will guide you that which metal you will take for making the jumper and what are the screw etcetera you will use how will you make the connection.

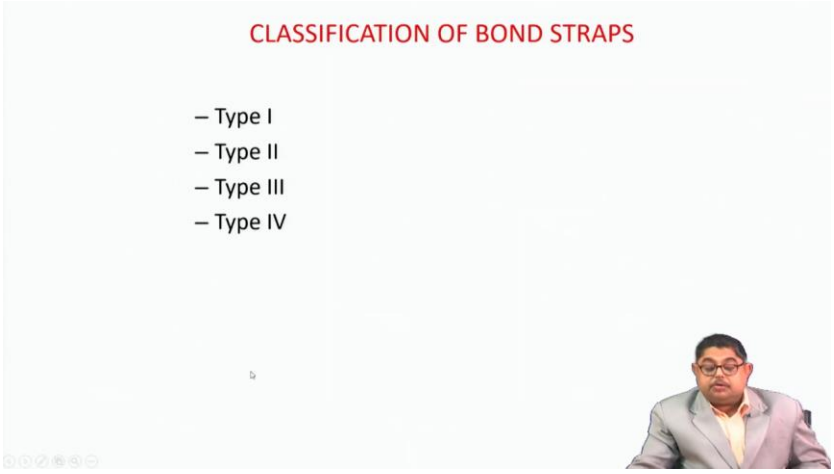


Metal Structure (Outer Finish Metal)	Connection for Aluminium Jumper	Screw Type	Connection for Tinned Copper Jumper	Screw Type
Magnesium and Magnesium Alloys	Direct or Magnesium Washer	Type I	Aluminium or Magnesium Washer	Type I
Zinc, Cadmium, Aluminium and Aluminium Alloys	Direct	Type I	Aluminium Washer	Type I
Steel (Except Stainless Steel)	Direct	Type I	Direct	Type I
Tin, Lead and Tin-Lead Solders	Direct	Type I	Direct	Type I or II
Copper and Copper Alloys	Tinned or Cadmium Plated Washer	Type I or II	Direct	Type I or II
Nickel and Nickel Alloys	Tinned or Cadmium Plated Washer	Type I or II	Direct	Type I or II
Stainless Steel	Tinned or Cadmium Plated Washer	Type I or II	Direct	Type I or II
Silver, Gold and Precious Metals	Tinned or Cadmium Plated Washer	Type I or II	Direct	Type I or II

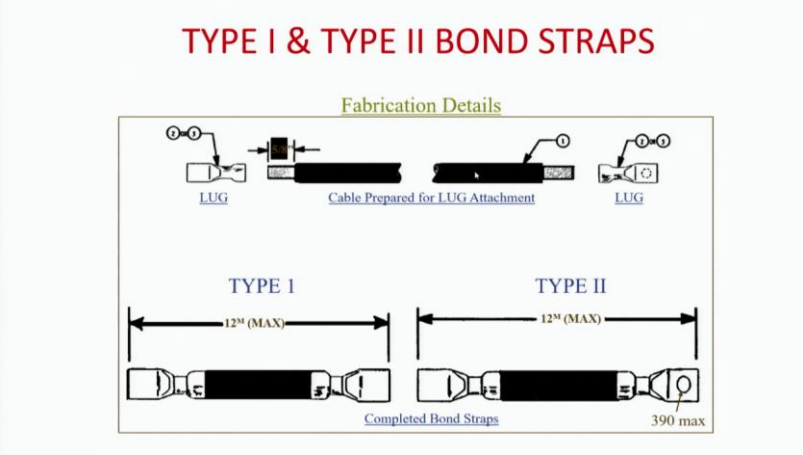
Use of paints and protective finish you see that this is a poor way of doing the conductive paint or protective paint why because you see that a large portion of the cathode is unexposed the here there is a bond, but the bond is. So, there up to that there is a there is a finish here here there is a finish, but this cathode is fully unexposed. So, from here moisture may come here a better way is you see that to certain exchange this paint is extended to cathode. So, it is a better way, but here you see that anode is comparatively paint is reduced from the start and up to the joint the paint is there on the cathode side, but not on anode side, but the best is if you cover the whole thing with conductive paint. Now, conductive paints are obviously, a bit costly, but if you do this that is the best way of protecting bond between the similar metals.



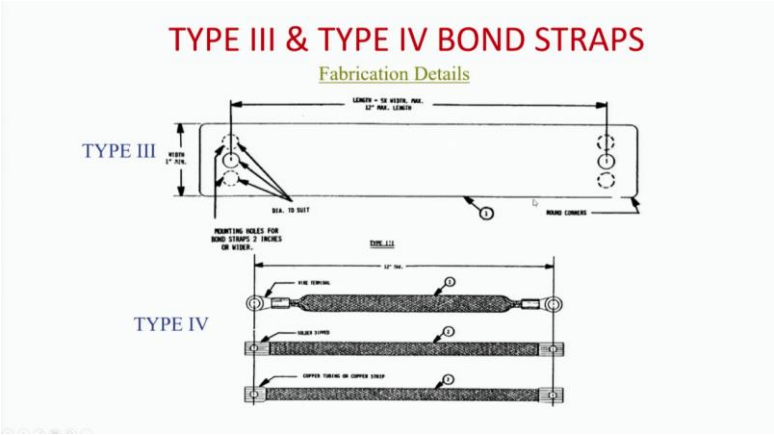
Now, classification of bond straps actually bond strap is another way. So, there are also four types of bond straps.



So, you see the bond strap that means there is a cable now with this you can attach two straps actually two cables you can attach. So, you see this is the type one bond strap. So, after making the bond strap that means after having this you can think this as a connector sort of thing. So, with the cable the black one is the cable. So, with the cable if you do it finally, you can join the two cables with them. Now, so this is the type one this is the type two the difference is you see here there is no hole here, here there is a hole for some purposes that hole may be used, but there from the there will be some type of environmental exposure can come.

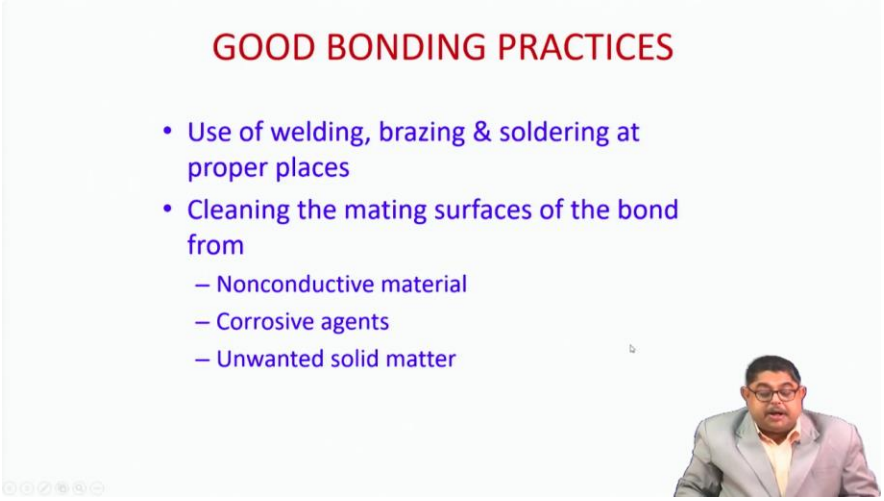


Then this is the third type here also the holes are there, but there is also a cover that bond cover and this is your type four. So, here you see that there are various types of holes and various thing this is wire terminal, this is solder dip, this is copper tubing or copper strap and same is here. So, this is the type four the most complicated, but the obviously that serves lot of purposes is type four.

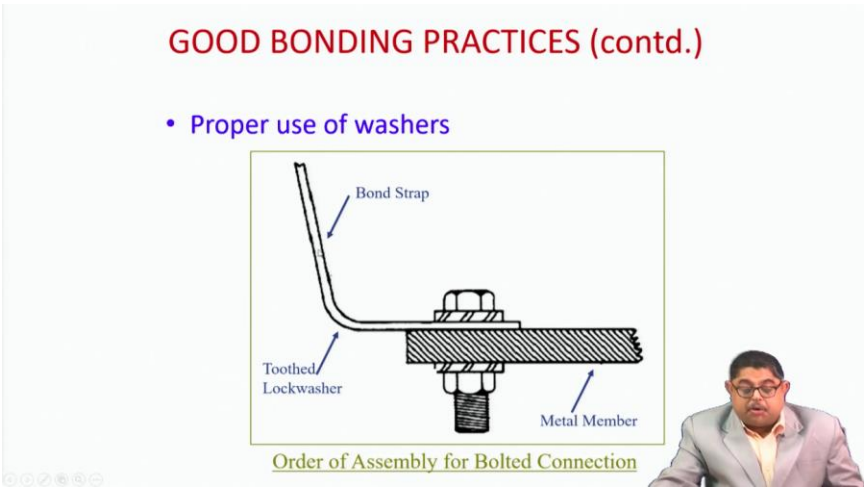


Now, general installation guidelines for bond straps is one is installation hardware, then contact surface you will have to prepare before bonding, then you install, then you will have to put the coating.

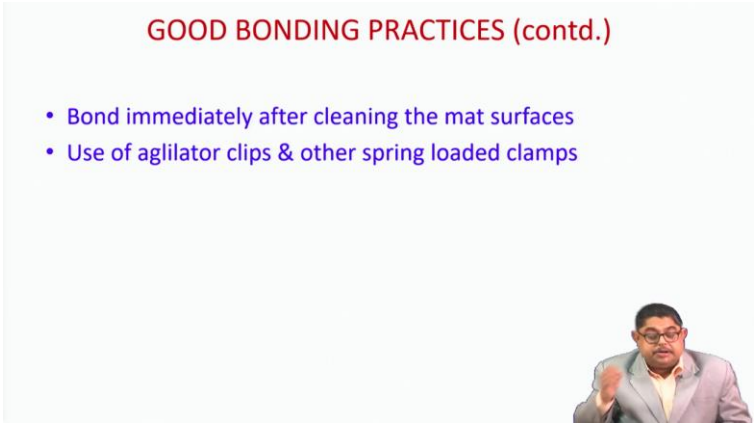
Now, good bonding practices use of welding brazing and soldering at proper places that means if you make direct bonding that is the best thing cleaning the mating surfaces of the bond from non conductive material corrosive agents unwanted solid matter.



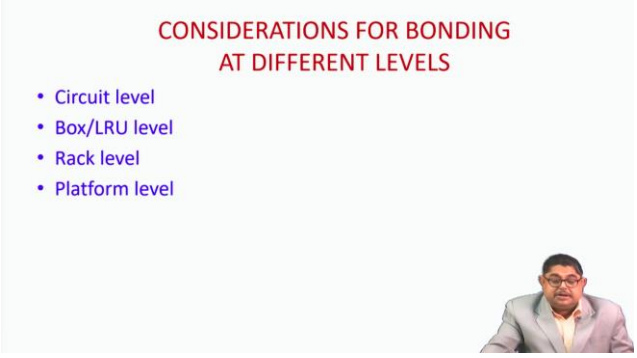
Good bonding practices you will have to have bond strap, then you will have to have tooth lock washers. So, washer etcetera you will have to properly give. So, it is a bolted connection.



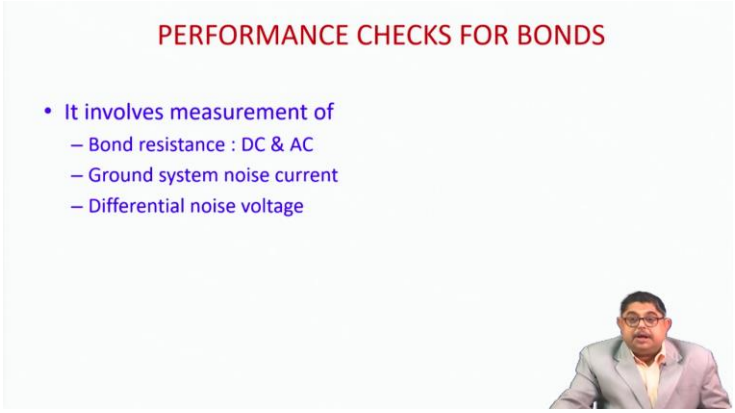
good bonding practices bond immediately after cleaning the mat surfaces do not give time for the surface to again invite unwanted material use of agilitator clips and other spring loaded clamps. Even after your bond if you use this clips then they will be properly bonded.



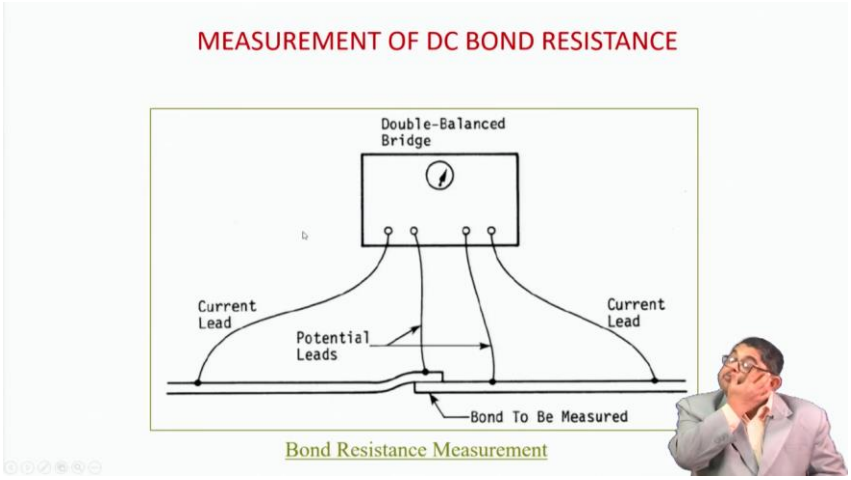
Now, you will have to see bonding at different levels circuit level, box level, rack level, platform level etcetera.



Also you will have to do periodically performance checks for the bond also at the time of installation you will have to check and frequently depending on your application after how many times how many how many times you will check. So, it involves measurement of bond resistance that means whether the bond resistance is within the limit. So, you will have to make both DC and AC measurement then you will have to make that ground system noise current how much it is coming differential noise voltage how much it is coming.

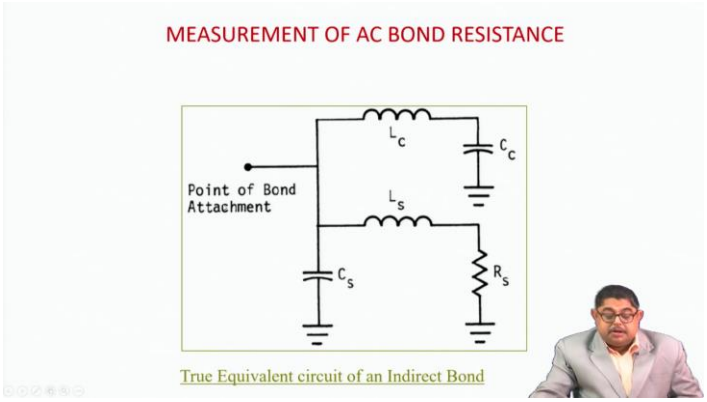


So, you see this is the measurement set up for DC bond resistance you have a double balance bridge from that you are getting current lead you are getting potential lead they are coming to this is the bond to be measured you are then putting on the this power supply and then you are seeing whether there is any deflection in the bridge this is simple DC measurement. So, DC supply you are giving.

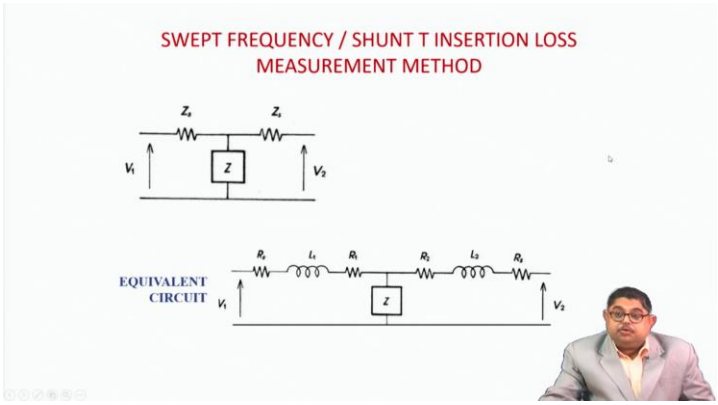


now this is AC bond resistance measurement there you will have to have a LC circuit this circuit with that C S. So, that should be attached to the bond. So, this is the equivalent circuit of an indirect bond. So, you see the L S C C C C S they make it

evident that the it is an AC measurement. So, you connect the bond attachment point here with the an AC source and you measure.

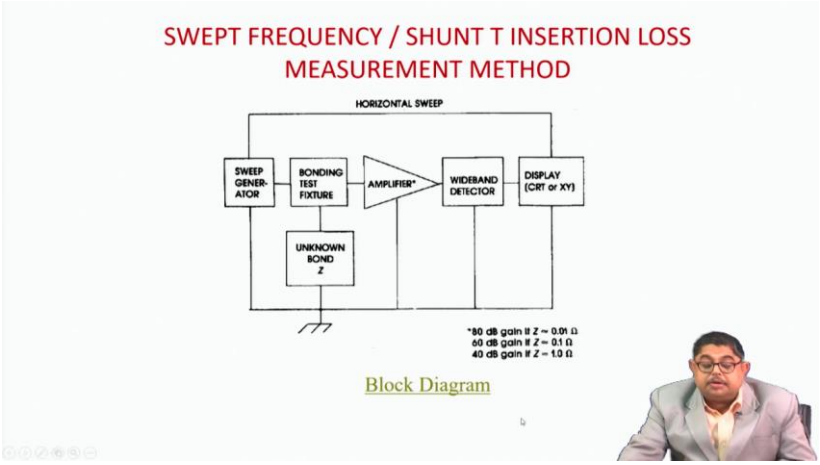


Then you can you also want to know at various frequencies what are the insertion loss of the bond. So, insertion loss you can measure between two ports you put the thing. So, without putting just putting it through how much was the S 2 1 and after putting it how much is the S 2 1. So, from that you can find the return loss this is the equivalent circuit of a bond. So, this is a T shunt T circuit. So, the shunt elements are this thing R S L S L 1 R 1 and R 2 L 2 R S. So, then you can make the connection and find sweep frequency.

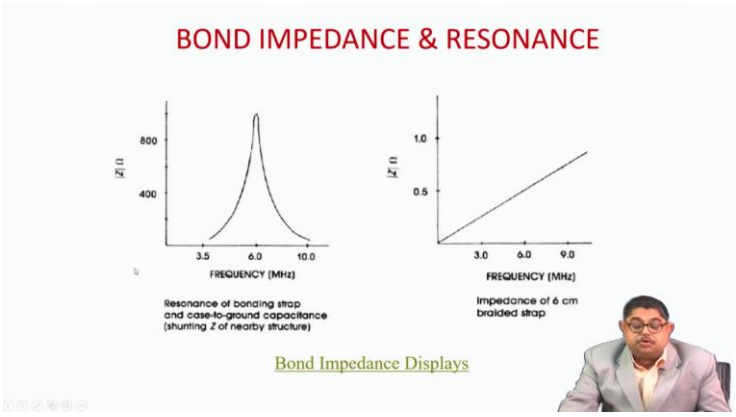


Now, to have sweep frequency insertion loss measurement your block diagram of the setup will be you sweep frequency means you will have to have a sweep generator then then the bonding test fixture is there. So, you put all that previous diagram that bonding thing you put it then amplifier you put because the bond test fixture that will give you quite small amount of signal. So, you need to amplify and then with a wide band detector you connect it to display etcetera. Now, if you get Z that means, this unknown bond resistance bond impedance Z is of the order of 0.0 ohm then to this amplifier you give 80

dB gain if it is 0.1 ohm you give this amplifier 6 dB gain if it is unknown impedance is 1 ohm then 40 dB will be sufficient for you.

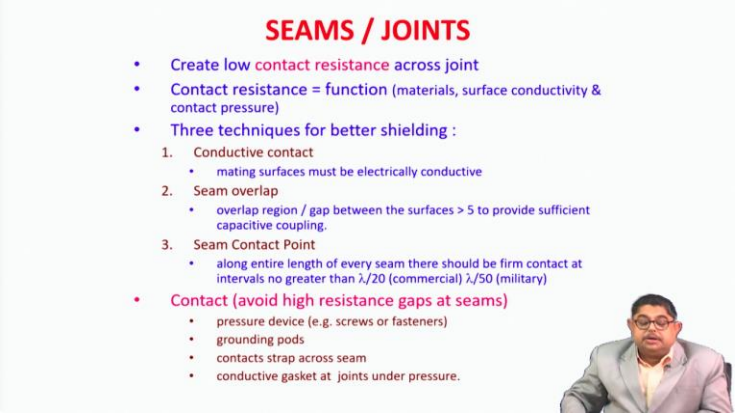


So, it is the how bond impedance varies magnitude part of the bond impedance varies with frequency it has a resonance type of curve. And, this is the again impedance of 6 centimeter braided strap. So, it is input impedance that is a linear variation, but this one bonding strap that has a tuned amplifier type of or a resonance type of behavior.

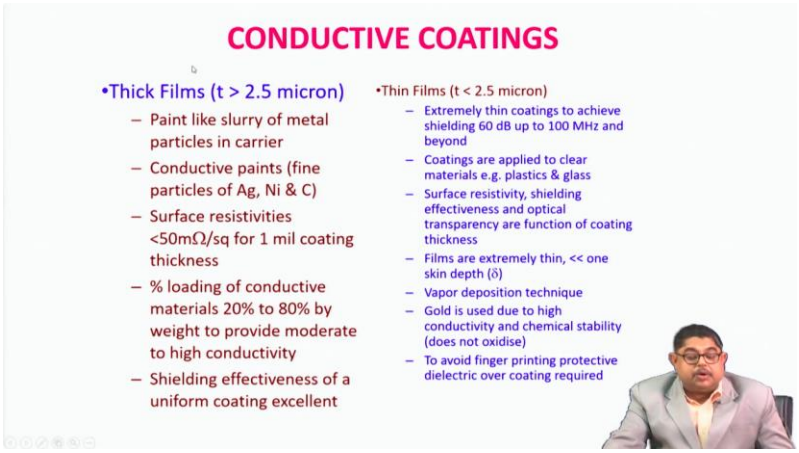


Then so, that was our discussion about bonds now there will be also joints necessary because 2 metals etcetera when you connect. So, there are joints so they also provide low contact resistance across joint. Now, this contact resistance is a function of materials surface conductivity and contact pressure 3 techniques are there conductive contact, seam overlap, seam contact point. Now, in while you may making contact avoid high resistance gaps at seam. So, that is why you will have to use some pressure device like screws or fasteners, grounding pods, strap across seam or conductive gasket and adjoins

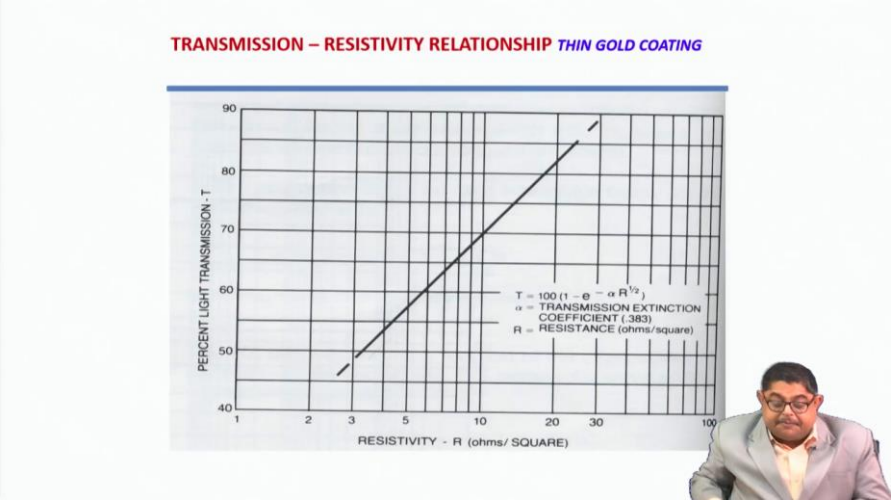
under pressure. Whenever you are giving pressure and making gasket is necessary that we will see in the end of the this talk.



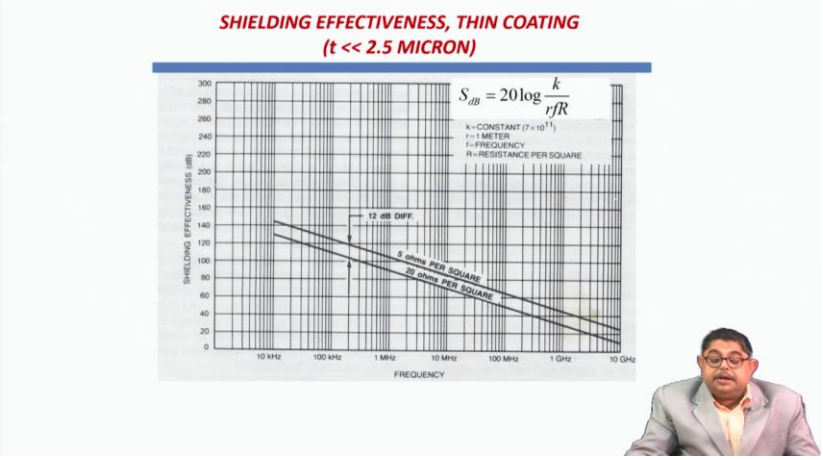
Now, conductive coatings you can have a thick films or you can have a thin films their boundary is 2.5 micron whether it is greater or less. So, you see that conductive pens basically they consist of fine particles of silver, nickel and carbon. So, remember carbon is conductive that is why in grounding also we have seen that they were used. So, here also and you will have to have surface resistivities for 1 mil coating thickness that should be less than 50 milliohm per square per square meter you will have to have percentage. So, it will be per square meter percentage loading of conductive materials 20 percent to 80 percent by weight, shielding effectiveness of a uniform coating is excellent. Now, for coating also that is required to give you an uniform coating otherwise in that whenever there is a discontinuity the resistance will go up. Now, thin films so they can give you shielding 60 d B up to 100 megahertz and beyond. Coatings are applied to clear materials surface resistivity shielding effectiveness and optical transparency are function of coating thickness etcetera. Now, they this type of less than 2.5 micron you cannot do by simple hand. So, there are various technique vapour deposition is one and in all these cases gold is used due to high conductivity and chemical stability. That means, it does not corrode or oxidize to avoid finger printing even after giving the conductive coating protective dielectric over conductive coating is given.



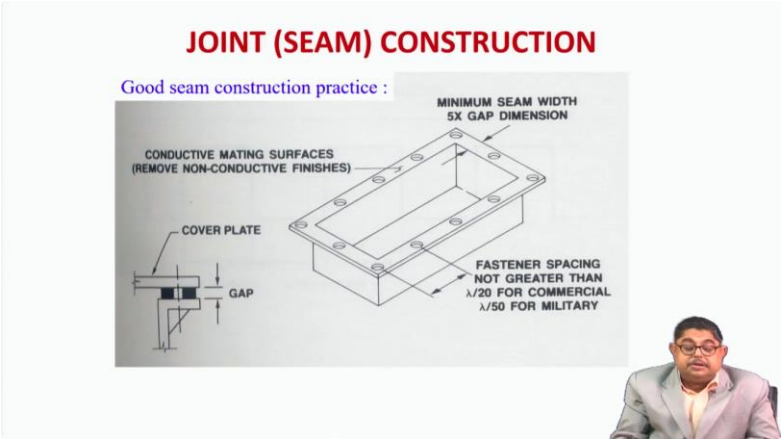
Now, this is the trans resistivity versus transmission coefficient of percent of transmission. Now, you see that if resistivity increases the transmission will increase. So, you will get lot of problem EMI problems that is why resistivity you should be low as we have say seen that in this case surface resistivity should be less than 50 milliohm per square meter.



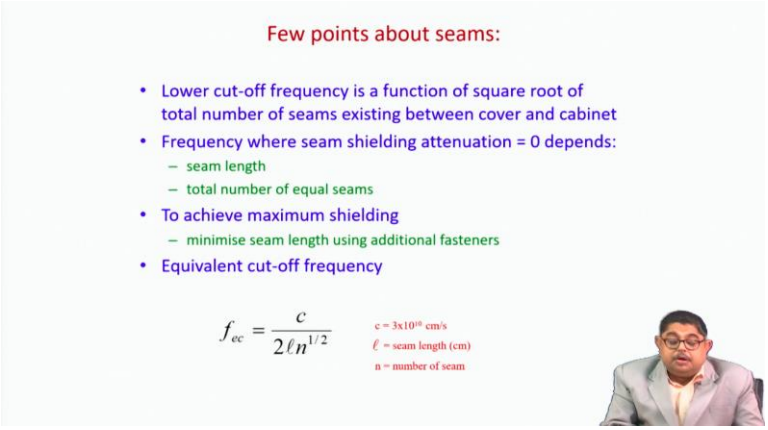
So, this is one important chart similarly shielding effectiveness d B is directly calculated for this thin film there you see that if 5 ohms per square if you have the resistance per length that 5 ohms per square you have this linear graph 20 ohm per square you have this graph you see 5 ohm to 20 ohm if the resistance changes per square then you are getting 12 d B difference which is a 12 d B means almost it is a more than one decade almost you can say that it is 10 d B difference 10 into the 20 times roughly. So, that so this is very important that you maintain the low resistance contact.



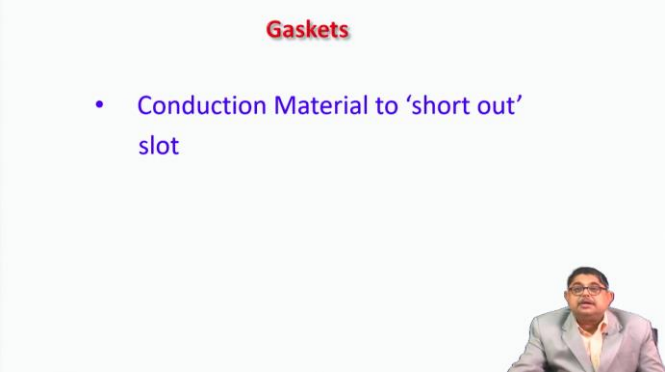
Now, this is the good film construction practice conductive mating surfaces then you have a cover plate then a gap and minimum sim width is 5 into gap dimension. Seam and joint are same thing sometimes we call it seam sometimes it is referred as joint in industry generally people call it seam.



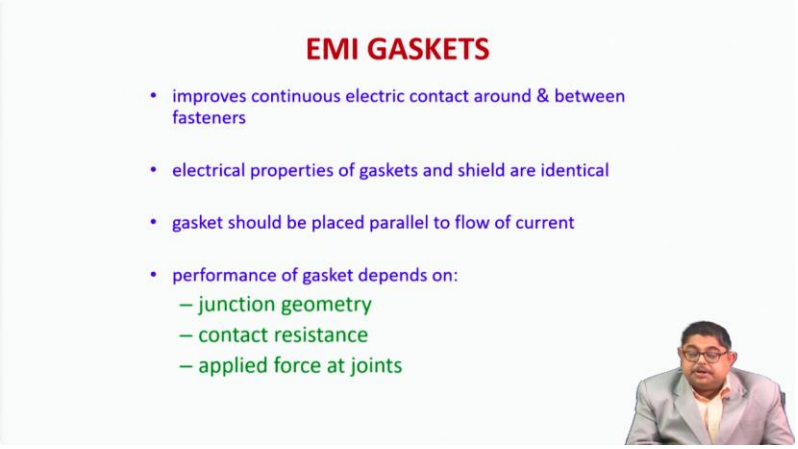
lower cut off frequency of the seam is a function of square root of this expression you can see at the bottom of the slide. So, lower cut off frequency is inversely proportional to square root of n square root of n means the total number of sims existing between the cover and the cabinet. Now, frequency where sim shielding attenuation goes to 0 that depends on seam length and total number of equal seams. So, to achieve maximum shielding minimize sim length using additional fasteners. So, you give more fasteners so that with less length you can make the seam.



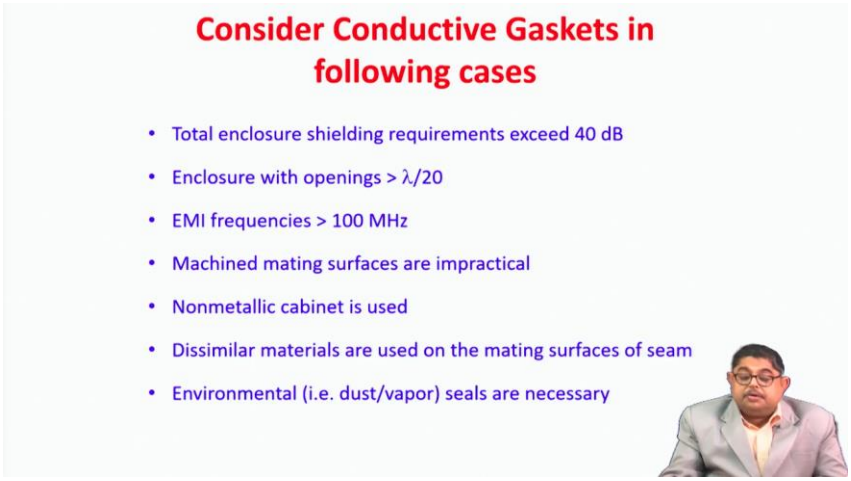
Now, whenever there are the seams are made with pressure then you need to have gaskets these are conduction material to sort out slot or if there are any slots created while pressuring that to sort out gaskets are used.



That improves continuous electric contact around and between fasteners electrical properties of gaskets and shields are identical gaskets should be placed parallel to the flow of current performance of gasket depends on junction geometry contact resistance applied force at joints.



Conductive gaskets in following cases as I was saying how you understand when to use total enclosure shielding requirement exceed 40 dB. Now, which is 40 dB is a very moderate rate. So, gaskets are often used then enclosure with openings greater than lambda by 20, EMI frequency greater than 100 megahertz machined mating surfaces are impractical you will have to have the indirect type of things nonmetallic cabinet is used dissimilar materials are used on the mating surfaces of sim environmental seals are necessary. So, in all these cases you can consider having a gasket with the joints.



EMI gasket installation you see that this is the cover plate this is the enclosure this is the gasket, but this is correctly done because it is near the pressure is coming here cover plate. So, gasket is holding that, but here you see the pressure is in this side, but gasket is in that side. So, this is an incorrect way of doing now this is the cover plate this is the proper way of gasket. So, various cases have been noticed done here that what are the various joints type. So, even this is gasket fixed with conductive adhesives. So, this is gasket this is the panel. So, feed through filters there. So, there is a need for a joint because this thing the feed through filters they need to be connected to the panel. So, that time you see with conductive paint the gaskets are used I think I have come to the end of this discussion. So, we have seen in this class the bonding bonds and joints, joints are required to have two dissimilar material metals and bonding is required to connect one part of grounding network to another part of grounding network all this basically comes under shielding. So, to improve shielding effectiveness you do the thing shielding effectiveness and grounding to help this these components are necessary, but there also proper engineering is required. So, that is why we discuss this that these considerations are required to have the design of engineering design of seams then gaskets then bonds etcetera.