Aqueous Corrosion and its Control
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Lecture - 12
Forms of corrosion: Preventive measures for uniform corrosion (Part-I)

Today, we will continue our discussion on corrosion protection methods as applicable to uniform corrosion. We listed in the last class that the following methods can be applied to prevent uniform corrosion involves uniform corrosion.

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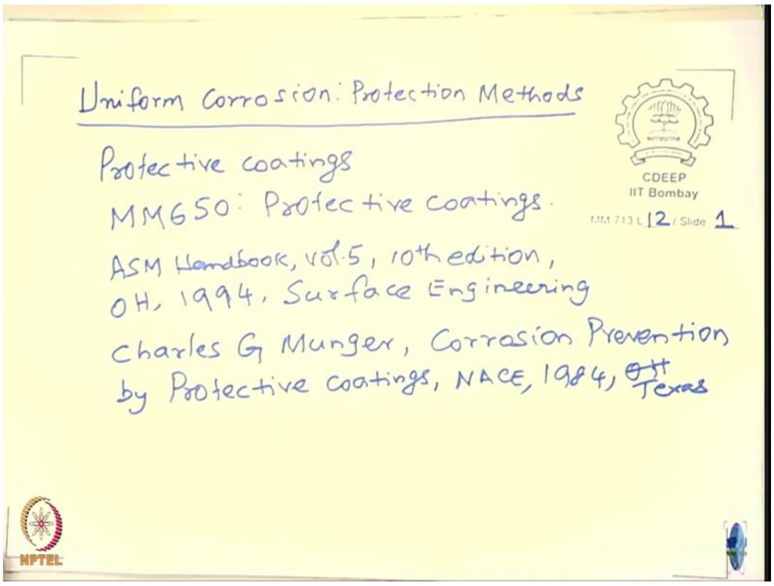

Uniform Corrosion: Protection Methods

Protective coatings

MM650: Protective coatings.

ASM Handbook, vol.5, 10th edition, OH, 1994, Surface Engineering

Charles G Munger, Corrosion Prevention by Protective coatings, NACE, 1984, ~~OH~~ Texas

Uniform Corrosion Prevention methods involve, material selection and the Protective coatings, inhibitors and we said that there are two electrochemical techniques. The electrochemical techniques you have two methods one is cathodic protection other one is the anodic protection. In the last class we discussed in detail about the methods of selecting materials, depending upon the requirements.

Like how critical a component is depending upon that you choose a corrosion resistant material actually. Because you know if you are going to increase the corrosion resistance of a material then the cost of the material also goes up. So, the application of the corrosion resistant material also depends upon, what depends upon how critical the component is. And we also looked at the two types of metals and alloys.

One based on the noble character the other one is based on whether the metal can offer a passivity, both cases the criteria of the material corrosion resistance we have seen in the last class we will continue this. And the next important aspect of uniform corrosion control is the application of protective coatings.

See if you look at from the point of view of wider application of a single technique for corrosion protection, protective coating stands first. It is applied at ease, it is applied you know very versatile and most applications it is possible that you can use a protective coatings.

And here we are not going to go in detail, we are going to give very broad outline we will be having a course in the 2nd semester, which is called as MM650 it is devoted to protective coatings. So, a detailed course will be offered on that, those who are interested will attend that course and you get a much deeper understanding of protective coatings.

We just give an outline here again for those of you want to read more on this you can refer these books one is ASM Handbook volume 5, 10th edition and this is OH 1994. This covers almost all kinds of coatings metallic, non metallic, polymer coatings and various types of things.

It is on surface engineering, the other book you want more towards the paint coatings polymer coatings you can read Charles G Munger, Corrosion Prevention by Protective coatings. It is a NACE publication 1984 and the it is Texas and this is more on paint coatings organic coatings.

Whereas the first book covers in detail various aspects of surface engineering that includes coating itself ok.

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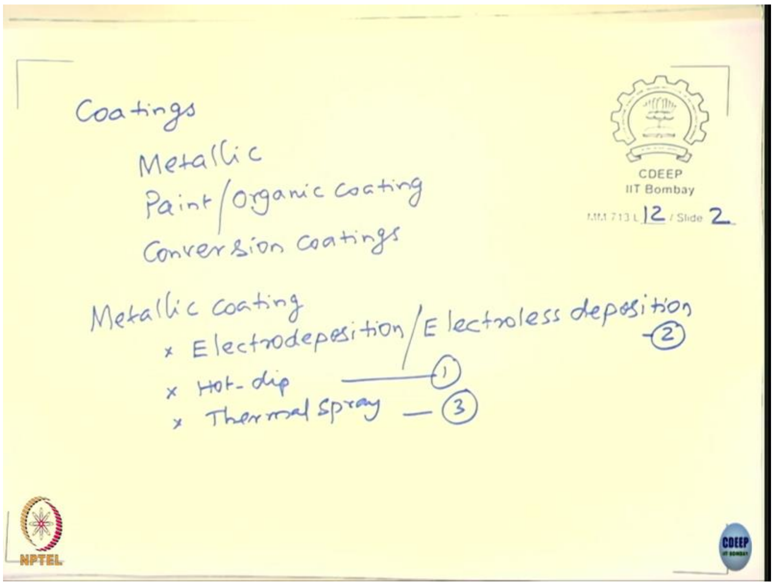

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Coatings
- Metallic
- Paint/Organic coating
- Conversion coatings

Metallic coating
- × Electrodeposition/Electroless deposition — ②
- × Hot-dip — ①
- × Thermal spray — ③

So, those who are really interested to go more detail I would suggest you refer this these two books actually. Let us go to the coatings broadly, you can classify the coatings as metallic a paint or also called as organic coating.

You can like to add this along with that as the conversion coatings. The conversion coating is not really a full fledged you know standalone coatings, many times the conversion coating helps probably other coatings in few cases the conversion coating can be a standalone coating.

Let us look at briefly what are these types of coatings. If you go to metallic coating, you can classify them based on the way you apply the coatings. You can have electro deposition, you can have hot dip, you can have thermal spray. In fact, I want to add along with the electro deposition which is also a variant of it is called Electro less deposition.

So, these are the broad classification based on the way you apply. You also have you know you have some physical vapour deposition and you know there are several other magnetron sputtering, widely used relatively in large quantities these are the type of coatings used for corrosion resistance application.

Otherwise you have a variant of several types of applications. We are not going to be focusing on that ok, but these are all generally used in large numbers. If you ask me the most widely used of course, is a hot dip coating this thing the 2nd one is your electro deposition the 3rd is thermal spray.

In fact thermal spray is becoming more and more popular now actually the time the extent of application of thermal spray coating increases.

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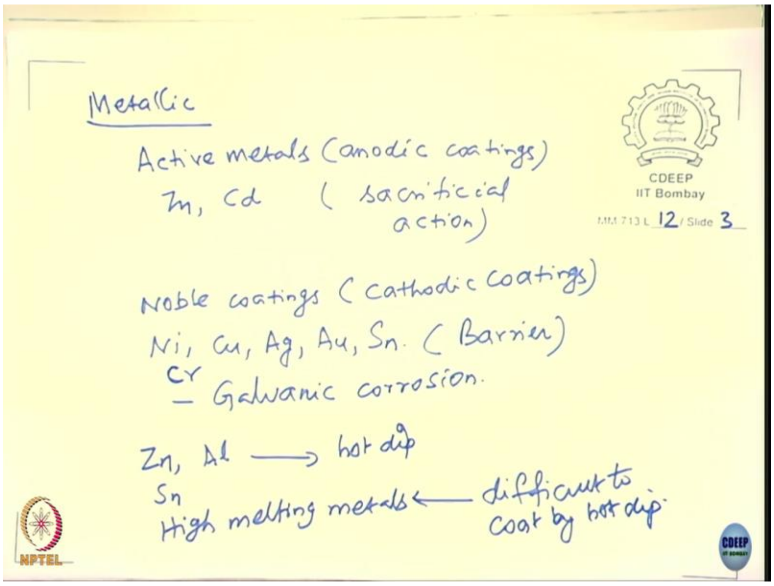

Metallic

Active metals (anodic coatings)
Zn, Cd (sacrificial action)

Noble coatings (cathodic coatings)
Ni, Cu, Ag, Au, Sn. (Barrier)
Cr
– Galvanic corrosion.

Zn, Al ⟶ hot dip
Sn
High melting metals ⟵ difficult to coat by hot dip.

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Now if you look at you go a little more into details about these coatings, you would say you can have relatively active metals or you can call as anodic coatings.

And you can also have relatively a noble coatings, this is we can call as a cathodic coatings. Most of these classifications are in relation to the steel you know not necessarily to steel, but steel is very widely used and requires protection. So, when we normally talk about anodic and you know cathodic coatings we refer only with respect to the substrate the substrate here is steel.

If you change the substrate it is possible that what was anodic to steel may not be anodic to some other metal ok. Now suppose you take steel as the substrate which is widely used you have zinc coatings, cadmium coatings these are all relatively the anodic coatings. Nickel, copper, silver, gold, tin these are all relatively noble coatings.

The active coatings they go by sacrificial action. We will see this later, what is into a sacrificial. The noble coatings mostly is as sort of barrier you can say, you do not allow the corrosion to occur because the relatively noble the rate of corrosion of this metal or relatively less compared to the substrate. Each of these coatings have their advantages and disadvantages.

Noble coatings sometimes can cause it can cause a galvanic corrosion, we will see this later. But the surface can look very bright you give a nickel coating surface looks very bright, to this you can also add chromium can also add chromium to this chromium is also is widely used ok.

In these metallic coatings you see zinc and aluminium are used as hot dip. Even tin can be used as hot dip coatings. And the metals high melting metals difficult to hot dip difficult to coat by hot dip process technique because the melting point is so high, the substrate might warp substrate may be melt all this can happen.

Zinc and tin and aluminium are widely coated by hot dip process. Now the high melting metals.

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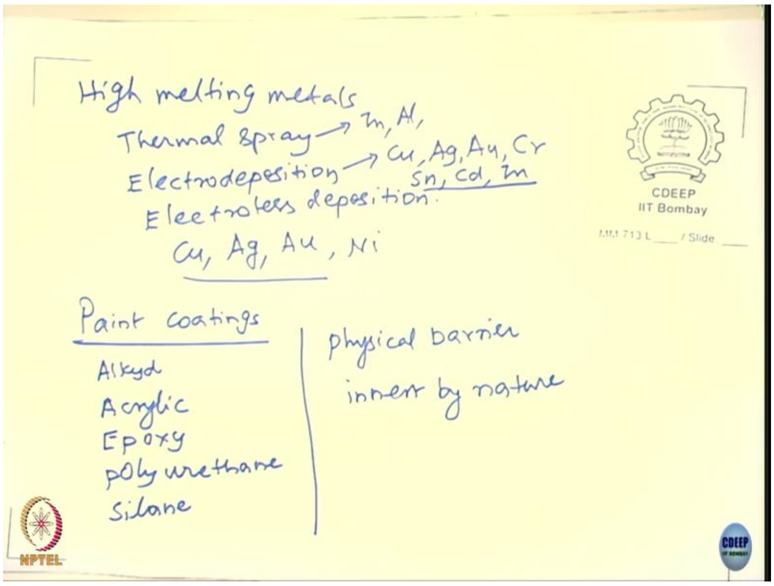

High melting metals

Thermal spray → Zn, Al,

Electrodepesition → Cu, Ag, Au, Cr, Sn, Cd, Zn

Electroless deposition.

Cu, Ag, Au, Ni

Paint coatings

Alkyd

Acrylic

Epoxy

polyurethane

Silane

physical barrier

innert by nature

Now, this metals. So, high melting metals how can you coat how do you coat?

Student: Process.

Yeah.

Student: (Refer Time: 15:07).

Either do thermal spray yes or you can do electro deposition you can also use electro less deposition, but again there are some restriction in all cases is not that you can do it, but I just give a broad picture about this if you talk about electro deposition you all have an example of this.

You can do copper you can have silver, gold, chromium you can do that, that way you can even coat tin, you can coat cadmium, you can coat zinc also they may not be high melting metals, but you can coat them by they call as electro galvanizing right electro galvanizing is quite common.

So, that way zinc is little unique you can coat by thermal spray, you can coat people do by thermal spray people coat by electro deposition people coat by a hot dip process all are possible with zinc actually.

Electro less deposition here you coat you can coat generally copper you coat you can coat silver you can coat let us say gold you can also coat nickel. Thermal spray widely you can do you can use again zinc, you can have aluminium that way most metal that you can do actually you know zinc and aluminium is very widely used coatings ok.

A complex alloys are done by the thermal spray nicraly and cocraly all this kind of high temperature coatings are done stellite coatings are done. So, there is other coatings people use thermal spray as a technique to do that ok. So, there are high temperature hard coatings it also give you high corrosion resistance.

So, that is also possible. I do not think we should get into discussion about, too much discussion about what these techniques are you know electro deposition means what you make the substrate as a cathode you pass a DC current, you get the coating on the substrate. The thermal spray you melt it and throw it at high velocity and they go and get deposited on the surface.

The electro less deposition you do not pass current, but what you do normally you add a reducing agent in the bath ok. So, that reducing agent reduces copper, silver or gold or nickel on the surface and forms the coating, is very important. If reduction takes place in the bulk and no use everything becomes a powder.

So, they are very catalytic surface catalysts. So, most of the coating occur on the surface by electro less deposition. So, these details you will not go into you know in this course now, the other course you will read them a lot. Now that is about the metallic coatings is get into the paint coatings.

Mostly organic coatings there are several coatings lots of coatings, but the important are Alkyd, Acrylic coatings you have Epoxy, Polyurethane, nowadays you have silane coatings and each of these coatings they have their uniqueness ok, but these coatings they act as a physical barrier.

See they are inert mostly they are inert by nature. They are supposed to not to allow water in the system, but you know organic coatings are not impervious to water it slowly permeates and so, it limits the life of these coatings ok. However, it is to say that these paint coatings are termed as the barrier type of coatings.

They do not allow the water to permeate and reach the substrate and so, it is isolates the environment it isolates the water it can happen. Now in the coat, in the paint coatings how it is done if you look at a painting generally it consists of minimum of 2 layers, 1 you must have a primer, you have a top coat.

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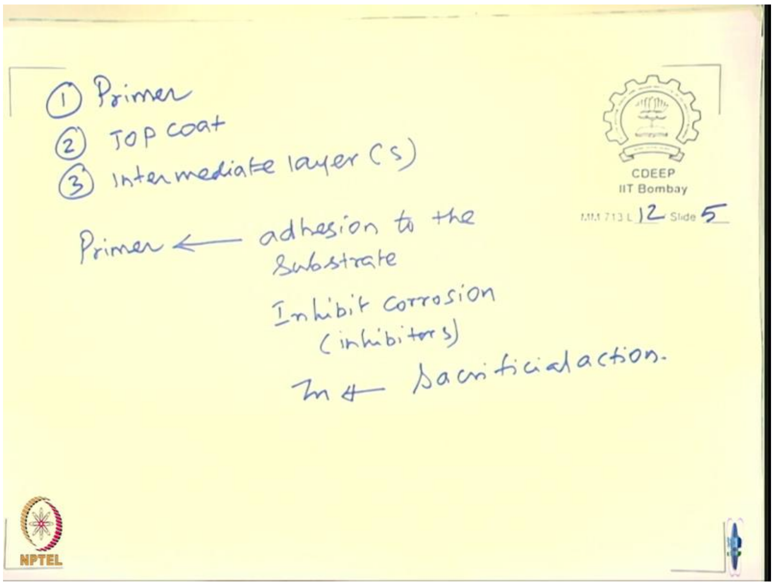

① Primer
② TOP coat
③ Intermediate layer (s)

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Primer ← adhesion to the substrate

Inhibit corrosion
(inhibitors)

Zn ← Sacrificial action.

NPTEL

Sometime you may have more layers you can also have intermediate layer, intermediate layers you can have intermediate layer or it can be layers, it can be have many many thing you can have ok. The purpose of the primer, the primer the purpose is to provide adhesion. First and foremost is it provides adhesion to the substrate; the primer may also has some additives into this there are some additives.

But a few of them I can say they can inhibit corrosion; you may have some inhibitors. They may have some kind of you know additives like zinc and all like that they may have, they can have sacrificial action, primer is in fact is a key in the painting process the topcoat gives you maybe other properties.

It might give you like sometimes you know chipping resistance it may give UV resistance there are other properties. In fact, the paints if you take it is very versatile because you could have n number of properties at your disposal, you can have different colour for example, can be anti graffiti you know write something it would not stick on to surfaces or you could have water repellent properties.

Several properties are tailored on the top coatings the intermediate layer also can have different properties because it would augment the corrosion the intermediate layers are given ok. So, the primers when we talk about these primers can be based on alkyd primer, acrylic primer, epoxy primers, polyurethane primer and all this kind of primers.

So, these primers you know are the key without applying primers I do not think we are going to apply a coating at all. So, this is the key in the paint coating of any metal substrates.

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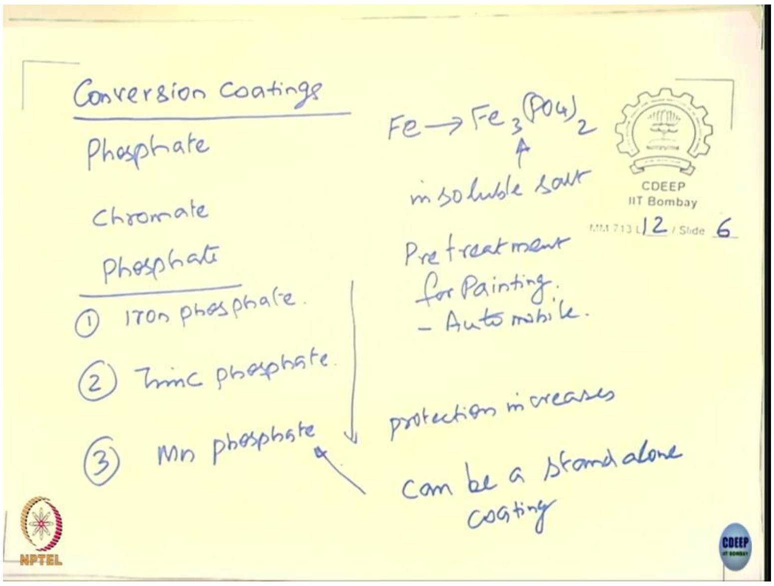

Conversion Coatings

Phosphate

Chromate

Phosphate

① Iron phosphate.

② Zinc phosphate.

③ Mn phosphate

$Fe \rightarrow Fe_3(PO_4)_2$

insoluble salt

Pretreatment for Painting.

- Automobile.

protection increases

Can be a stand alone coating

In the conversion coatings we have like phosphates ok, in the phosphate and you also have chromate conversion coating right. The phosphate has several classifications take a phosphate for example. In this you have simply a iron phosphate coating, you can have zinc phosphate 3rd is the manganese phosphate. You can say overall the protection ability of the phosphate coating increases from iron phosphate to zinc phosphate to manganese phosphate ok.

The protection ability protection increases from iron phosphate to zinc phosphate to manganese phosphate. What do they lead to, what do you mean by conversion coating what do what is happening here? You are converting the substrate into a phosphate for example, if I have iron.

The iron is converted to iron phosphate this is an insoluble salt. So, the insoluble salt it provides resistance against corrosion and sometimes the phosphate also can act as a inhibitor. These phosphates are also given as a pre treatments before you coat you apply a paint coating ok.

It can be pre treatment can be a pre treatment for painting you do in the automobile for example, in automobile the automobile industry they apply a phosphating treatment. Even in the case of aluminium alloys zinc alloys zinc they give a like a chromating they do that and then they apply a painting.

So, they also enhance the adhesion strength of the paint coatings. In the case of manganese sulphate it can be a standalone coating, it can be a standalone can be standalone alone coating whereas, iron phosphate and zinc phosphate they are not standalone you again over that you apply a paint coating chromating is the issue here chromating.

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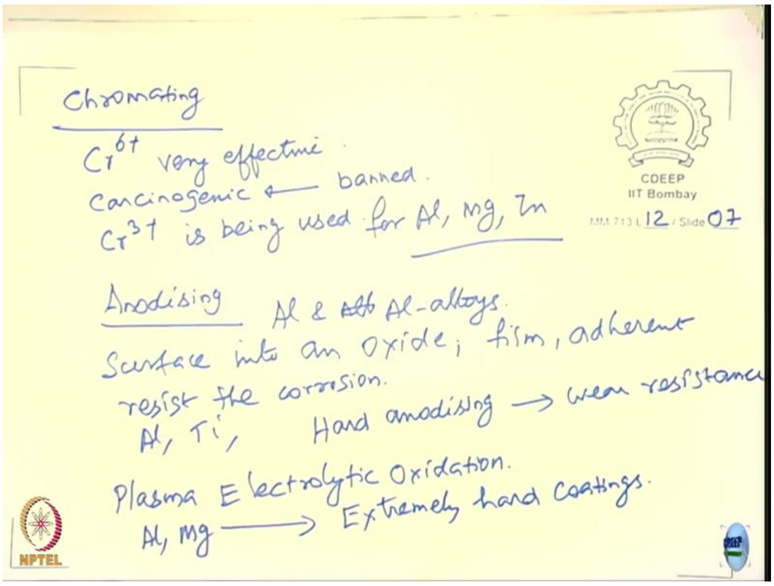

Chromating

Cr^{6+} very effective.

carcinogenic ← banned.

Cr^{3+} is being used for Al, Mg, Zn

Anodising Al & ~~Alb~~ Al-alloys.

Surface into an oxide; film, adherent

resist the corrosion.

Al, Ti, Hard anodising → wear resistance

Plasma Electrolytic Oxidation.

Al, Mg → Extremely hard coatings.

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We people use a chromium 6 plus people use it very effective what is the problem it is carcinogenic it is almost now banned many cases. So, people start using Cr^{3+} or is being used and even this is now not allowed in the case of steel, but it is allow in the case of used for like aluminium magnesium zinc for these cases.

They use otherwise a chromate is one of the most efficient least expensive type of conversion coating for most of the metals. In the same line you have one more type of you may call it as conversion coating if you wish, you call them as anodising. What is anodising? It is done for aluminium alloys, aluminium and its alloys use that. So, they convert the surface what do they do into.

Student: Oxide.

An oxide now oxide is already corroded right is a corroded product it is if it is forms a forms a film, which is adherent resist the corrosion. Again it is not very simple and you know you need to anodise it there are pores you need to seal them.

Its a technology of anodising it should be understood properly. I am just giving you various options available for us to for use for corrosion prevention of alloys, but again anodising cannot be applied widely right is used for it is used for aluminium alloys it can be used for titanium alloys for example, but the most widely used is aluminium.

In this also there are two cases you know one is called also called as hard anodising it is used for the wear resistance, it is quite hard aluminium is alumina is very hard. So, in order to get a similar thing people also go for we call as plasma electrolytic oxidation, it is done for aluminium very nicely.

And now people have also developed it for magnesium, it gives you extremely hard coating. The main purpose here is to provide hardness wear resistance, corrosion is secondary in this case ok. Now we have seen you know a sketch of different type of coatings that they are available for us.

What I like to now discuss with you is, what are the requirements of the coating? When do you get a good coating?.

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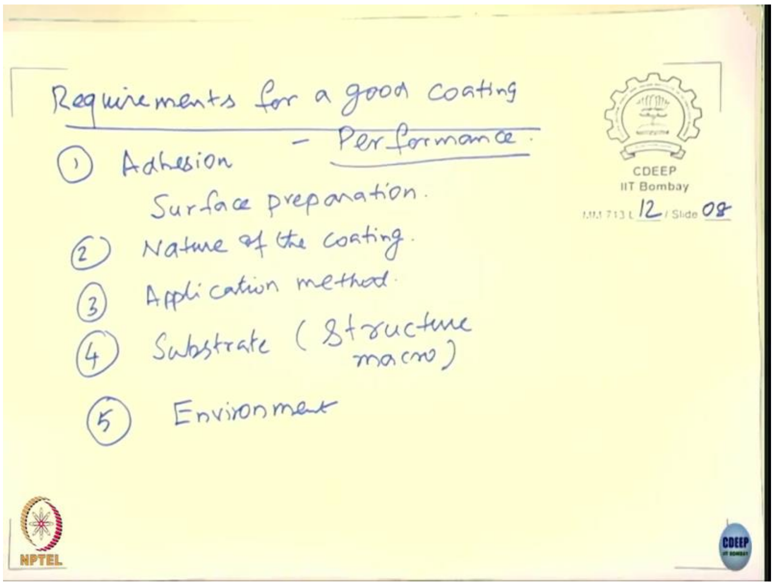

Requirements for a good coating

– Performance.

① Adhesion

Surface preparation.

② Nature of the coating.

③ Application method.

④ Substrate (Structure macro)

⑤ Environment

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The 1st and foremost is adhesion, it is a big subject actually the way the adhesion is developed it varies from the coating to coating.

If you talk about electro deposition I will talk about hot dip coating the bond between the coating and the substrate is metallic, but in the case of a paint coating the bond more often comes by a mechanical interlocking the surface is rough the paint goes and then locks by itself.

So, in all these cases surface preparation becomes very important because, it is surface that connects the substrate and the coating. The surface is not clean the surface is not properly prepared I do not think you can ever get a good coating at all.

So, surface preparation is an important aspect of this a lot of standards are there for that to do to understand to follow. The second aspect of that is the nature of the coating. You see each coating they have their own properties inherent properties right, if you say zinc coating it is sacrificial take a copper coating is noble coating.

You take a paint coating for example, epoxy coating if you take it is resistance to chemical resistance it had got very high adhesions, but it is not good from UV resistance point of view, but if you take acrylic it is good from UV resistance point of view polyurethane is a tough. So, nature of coating also plays important role in terms of it is performance of that actually.

The third the application method, the same coating can be applied by different means it can be hot dip coating or it can be electro deposition coating zinc. For example, a hot dip coating hot dip galvanized coating and electro deposition coating the formability suppose you take the metal and then sheet and bend it the formability of electro carbonized coatings are far superior compared to the formability of hot dip coatings.

Similarly, if we take a paint coating you can apply through brush, you can apply through spray. I mean you can do electrophoretic coatings several ways that you can apply the coating the performance of these coatings are going to be different. And the substrate is going to decide about it. And I call a structure I say macro structure macro.

If you are going to have a electro deposition of sharp edges different, intricate components are different you cannot put them say substrate nature the way substrate is there. Of course, the performance of the coating also depends upon what it depends upon the environment coating and you can also add here is a performance.

All this will be discussed much in more in detail in the MM 650 course when you take it in the next semester these are about coatings, you have any anybody has any questions it is more affirmative rather than going much into details.

Student: You said that we do not use Cr^{3+} for steals why is it so?

See what happens is now all said and done. We do not want chromium per say for use in any structures why we do not use, why we do not use chromium 3 plus chromium 6 plus steel is that we have other alternatives, can we have phosphates right? In fact, the European Union now even banning the phosphate also now they are going to non phosphate based coating based you know which consists of titanium containing silicon containing all these kind of things.

So, most of this you know regulations come from the environmental issues now until you find a solution people still start using that they found alternative for iron steel. So, use and aluminium is still is a problem I think there are certain deadlines even for that they have to replace chromium totally with respect to aluminium and magnesium and all actually. So, it is a matter of developing technology to find alternatives ok.

Chromium is bad either way we can we can we do that it is a good question thank you ok. So, let us move to the next topic which is.

Student: But in.

Please.

Student: We are using chromium in making steel also that time stainless steel that is also forming a layer of chromium oxide on the top of stainless steel?

It is a good question actually. I mean chromium nickel these are all not very good. In fact, nickel is even more dangerous actually if you wear a ring of nickel you know you see skin will be very allergic to that actually. The difference between the stainless steel and the coating is it forms a very very thin oxide in the surface. You know already that you know by the amount the thickness of the passive layer they are less than 100 angstroms.

And then they do not very easily dissolve and they just remain on the on the surface quite long actually. And if you calculate the rate of dissolution corrosion of steel, they are somewhat in microns per year something like that. So, the extent of corrosion that it can happen is very very less ok, but nevertheless it can cause the problem. Especially, there are cases where people do not want to use the body implant for example, we discussed other day ok.

There you are extremely careful about all these actually nickel we do not want to have nickel. And some of your stainless steel people replace nickel with manganese and nitrogen and high chromium content. So, they are of course, issues and then we only have to see how best that you can tackle them into that actually. Any other questions?. So, let us go to the next topic thank you is a inhibitors.

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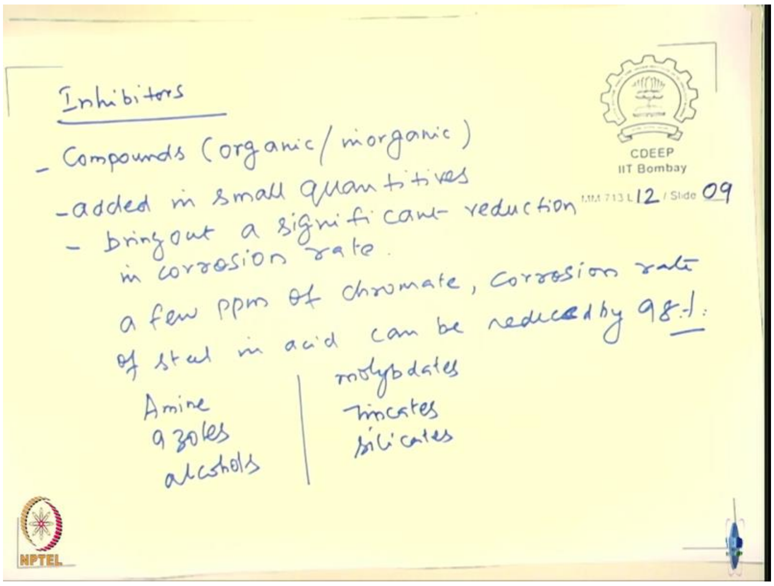

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Inhibitors

- Compounds (organic/inorganic)
- added in small quantitives
- bring out a significant reduction in corrosion rate.

a few ppm of chromate, corrosion rate of steel in acid can be reduced by 98%.

Amine	molybdates
azoles	zincates
alcohols	silicates

Now, inhibitors are added are compounds. They can be organic compounds or it can be inorganic compound compounds added in a small quantities. Now what happens, but bring out a significant reduction in the corrosion rate. For example, if we really want to not worry too much about environmental issues; if we add a few ppm of chromate, like potassium dichromate and all like that you add ok. The corrosion rate of steel in acid can be reduced by even 98 percent. There are several inhibitors like you have amines, azoles then even you know alcohols ok.

In amine there are can be aliphatic, aromatic ring all so many kind of amines are there. A secondary amine, tertiary amine so many kinds of compounds are available to that. You can also have molybdates, you can have zincates also ok, you can have silicates; these are inorganic kind of compounds there are organic compounds. In fact, if you look at it some of the publications I know there are 1000 of publications where people develop lot of inhibitors.

Nowadays people talk about green inhibitors; they extract them from the plant and start using them. And so they are in fact used in specific applications. When I say specific application where the environment is confined; obviously, you know what do you mean by confined?

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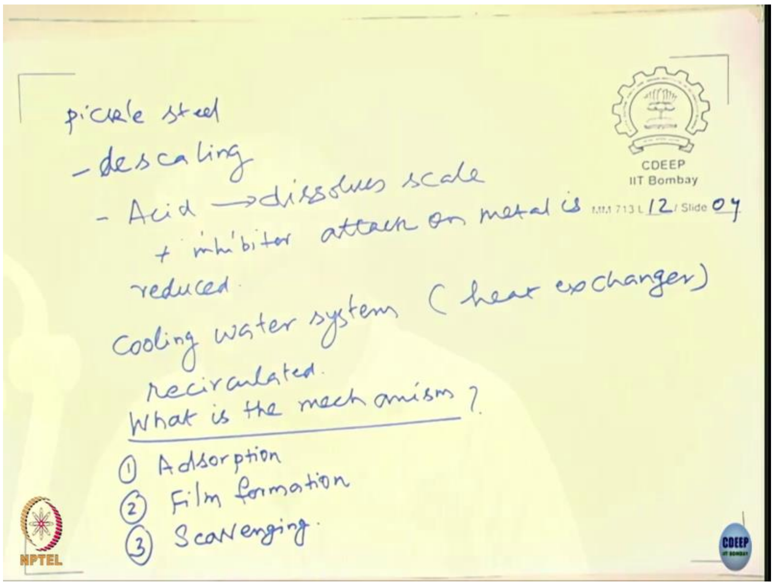

pickle steel
- descaling
  - Acid → dissolves scale
    + inhibitor attack on metal is reduced.

Cooling water system (heat exchanger)
recirculated.

What is the mechanism?

① Adsorption
② Film formation
③ Scavenging.

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For example, I want to pickle steel right. What is called this called de scaling right you want to de scaling is one of the very widely used operation ok.

You have an oxide, you know magnetic oxide or wurtzite you know or maybe hematite formed on the steel I want to remove this scale. You can do a mechanical removal you can do or you can do a chemical removal you can do that. And chemical removal is called pickling you normally people use acids right. They use acid, the acid dissolved what are it dissolves what dissolves the scale right.

But you can start attacking the steel you do not want the steel to be attacked. So, when add an acid, sorry to acid we add a inhibitor, attack on metal is reduced. The other example is cooling water systems in industry; that is your heat exchangers, your refrigerator is heat exchanger right. So, they add they add inhibitors to it to reduce the corrosion of metals by water ok, they are lots of inhibitors in that they use it ok.

And the cooling water this cooling water here is it is a re-circulated. Sometimes inhibitors are added to coatings also a paint coating you can add strontium chromate you add to it.

Student: (Refer Time: 47:47).

I will come to that it is a good question I will come to that. You add very small quantity, how does it you know lower the corrosion rate of a metal ok. So, it has a limited application of course, it is not very wide application but they are critical applications.

If you do not use you know inhibitors in cooling water system. You cannot use stainless steels use stainless steels, you cannot use copper based alloys, you cannot use in some cases people use even carbon steel they use.

So, it is not possible to use them, but mind you that this water is re-circulated similarly the boiler you know complications ok. Now water is being re-circulated you cannot use corrosion of structures in sea water can you do that you going to add it because it is simply not possible to change the environment at all actually.

So, in a limited you know applications inhibitors are very successfully employed and to prevent the corrosion of metals. And the question is what is the mechanism or what are the mechanisms? It is not only one mechanism, 1; they do by adsorption do, 2; is film formation, 3rd; it could be scavenging action, scavenging you can remove the species responsible for corrosion ok. I will give you some example here to understand how this mechanism in practice really function.

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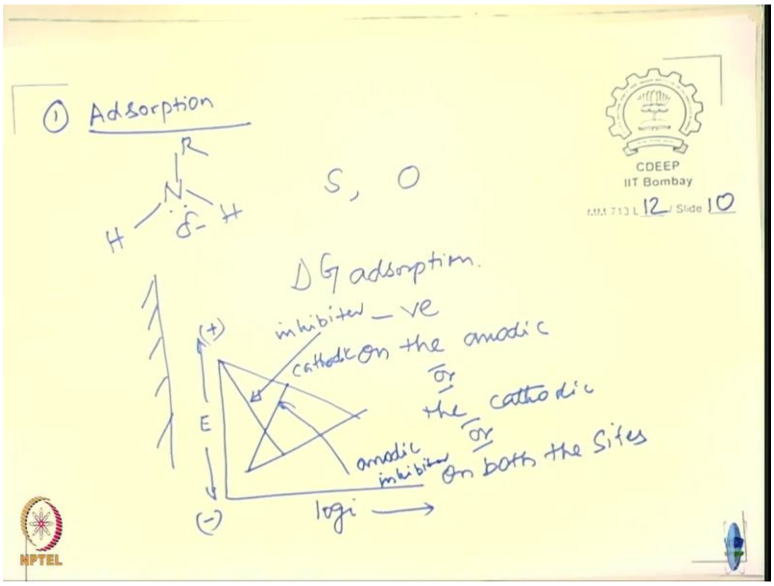

So, let us look at the Adsorption. Let us take an amine, how many of you know amine? It has got N H group this may be some R alkyl group something like that it is a primary amine right. You take amine, what is special about this nitrogen molecule? What is special about this molecule? I am sorry what is special about this nitrogen atom?

Student: (Refer Time: 51:03).

Yeah.

Student: Polar.

It is polar a lone pair of electrons are there are lone pair of electrons available. So, it is a relatively negatively charged. So, it can adsorb onto the metal surface. You can have similarly a sulphur kind of things ok, you have oxygen example there are several kinds of the functional groups.

Student: Yes sir.

Most of them are polar in nature they can get adsorbed on the metal surfaces. When they get adsorbed on the metal surfaces on the metal surfaces there are several thing you know now what happens that depends upon the.

Student: (Refer Time: 51:56).

Free energy change for adsorption or absorption both you can call about it. If it is more negative it is going to adsorb much more effectively and why it happens. So, that is why a lot of chemistry people develop so many molecules you know bigger size molecules means it is easier to adsorb on the metal surfaces is talk about stearic, is talks about polarization several factors not worry about it they get adsorbed when they adsorbed you can adsorbed on the anodic site or on the cathodic site or you can adsorb on both.

Now, assume that it is now adsorbing on the anodic site can I find out by some test if it is getting adsorbed on the anodic site. You are now you expert now, you electro chemistry, you know how to carry out test you know all these right. You know polarization. How do I know the molecule is adsorbing on the anodic side?

Student: (Refer Time: 53:27).

It is activation polarization. So, what happen in activation polarization?

Student: (Refer Time: 53:36) for a relative charge foundation (Refer Time: 53:39).

You are there, but you I want to be repeat more specific. It control for example, it adsorb from the anodic site what happen to anodic reaction?

Student: (Refer Time: 53:52).

Well what will happen to anodic kinetics? What will happen?

Student: (Refer Time: 53:58).

Increase or decrease?

Student: Decrease.

It decrease right. So, if the anodic kinetics are decreasing. So, how will be revealing it electrochemically you know all this right you have seen the lot of diagrams and all you are drawn something right what happens? You know it.

Student: (Refer Time: 54:21).

Cannot oppose will decrease corrosion rate will decrease right. But how do you know it is an anodic inhibitor? And how you know it is a cathodic inhibitor? How do I find out?

Come you guys know quick. You do a test in the lab and then come out with the results, this is anodic inhibitor. What is the parameter that will tell you that it is anode it is a anodic inhibitor?

Student: (Refer Time: 54:49).

Tafel slope.

Student: Yes.

You agree with him which tafel slope you think will happen.

Student: (Refer Time: 54:54).

Which one there are two tafel slopes right?

Student: (Refer Time: 54:57) sir.

Beta?

Student: A beta a.

Beta a right? So, it is the anodic tafel slope that is going to be changing that will that will increase or decrease you think? It will.

Student: Increase.

It will increase right it will increase because the current will not be the current is not going to be more the current will be decreasing right. So, the slope will be going. So, if I plot; if I plot if I look at a Evans diagram and if I get a I this is without inhibitor ok. I added an inhibitor and I get this like this. What is this inhibitor called? What is this inhibitor called? What is this inhibitor called?

Student: Cathodic.

Are you sure?

Student: I do not know sir.

See he has got the answer, is he right? It cathodic it is cathodic reaction right. So, it is a cathodic inhibitor it inhibits a cathodic reaction right. So, it is a cathodic inhibitor right. On the other hand if the slope goes like this what happens this? What is this inhibitor called? An anodic inhibitor, if I add an inhibitor I get both anodic and cathodic both are getting rid slopes are increasing what will happen? You call that as a mixed type inhibitor.

So, it is possible for us to quantify and the extent of inhibition. It is also possible for us to know the mechanism through which the inhibition is really occurring on the surfaces. Agreed or not agreed? I hope you will able to recollect your Evans diagrams right. So, please understand this. Now what is the consequence of that look at this if the cathodic inhibitor what happens to E_{corr}, E_{corr} goes up or goes down?

Student: Goes down.

Goes down. Anodic inhibitor the.

Student: Goes (Refer Time: 57:40).

Goes up, but at same time i_{corr} also.

Student: Decreasing.

Decreasing right. So, this is how you try to understand the role of inhibitors and how the inhibitors, you know function for different types of metals. Understood or not understood ok?

(Refer Slide Time: 58:08)

Film forming

Benzotriazole, Cu in HCl

Sulfur containing aromatic compound.

thin film of benzotriazole.

Now it is a film forming is one more type, an example of this is benzotriazole and it is copper inlets some acid may be in copper in hydrochloric acid. The benzotriazole is a compound it is organic compound you dissolve it. In fact, it is very difficult to dissolve in aqueous solvent, you dissolve it in some alcohol or something and add small quantities in hydrochloric acid.

What can happen is they form a very very thin film, very thin film is formed, very thin film of benzotriazole. There are several types of azoles polytriazole, macabre, benzotriazole kind of compounds, and these are all sulphur compounds, sulphur containing aromatic compound. So, they form a barrier for corrosions. Of course, sulphur also absorbs it does both ok, but it forms a nice film on the surface.

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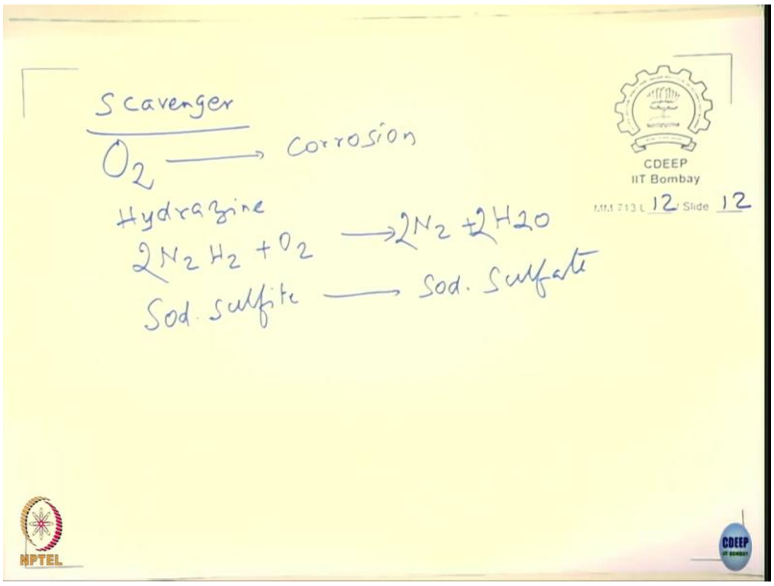


Scavenger

$O_2 \longrightarrow$ Corrosion

Hydrazine

$2N_2H_2 + O_2 \longrightarrow 2N_2 + 2H_2O$

Sod. sulfite ⟶ Sod. Sulfate

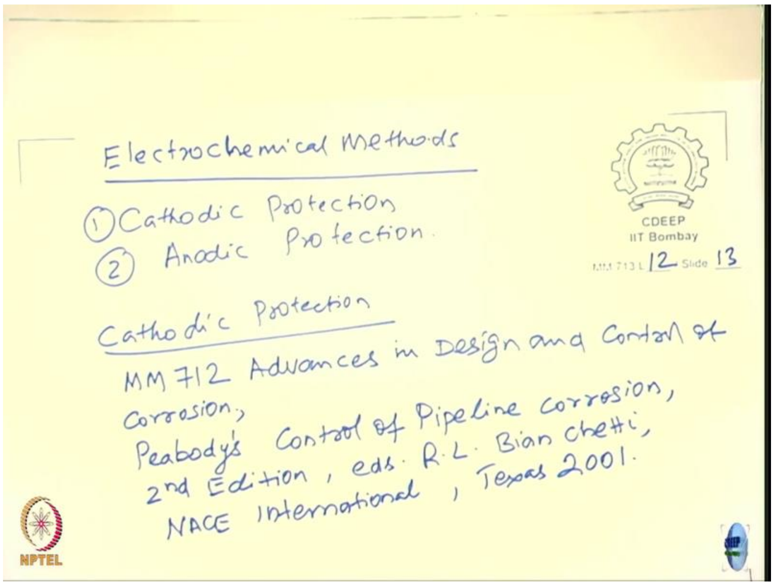
The next one is scavenging I would say, scavenger you want to call it and it is done in the case of boilers. For example, oxygen is a molecule which is going to be involved in the corrosion process, you all know. What it can be done you can add compounds like hydrazine and this is I think N_2H_2 it combined with oxygen and forms nitrogen and plus water; like this can happen sodium sulphite.

$$2N_2H_2 + O_2 \rightarrow 2N_2 + 2H_2O$$

What does it happens? It becomes sodium sulphate. So, there are several other efficient compounds which are added to water to remove the oxygen content they are called as scavengers.

Well I have one more topic to be covered which is anodic protection and cathodic protection. I am not sure whether we can finish it, but let us start with the principle ok. Let us start with the principle of just one second.

(Refer Slide Time: 61:55)



Electrochemical Methods

① Cathodic Protection

② Anodic Protection.

CDEEP
IIT Bombay
MM 713 L 12 Slide 13

Cathodic Protection

MM 712 Advances in Design and Control of Corrosion,

Peabody's Control of Pipeline corrosion, 2nd Edition, eds. R.L. Bian chetti, NACE International, Texas 2001.

Let us take this it is electrochemical technique electrochemical methods we call it the two methods; 1 is cathodic protection, 2 is the anodic protection. They work diametrically opposite way in preventing the corrosion of the metal. We have seen how the electrochemical reaction occurs for corrosion right let us take the; let us take the case of cathodic protection.

If you I think we will be also having a having a course wherein we are going to discuss in detail, but very brief other is MM 712 Advances in Design and Control of. So, there we will be discussing in detail I think you know about 12, 13 lectures we will be talking in detail about the cathodic protection. What we will be talking about here is a very brief discussion on the cathodic protection; principles only you can do that.

And again you want to read more in detail if you do not attend the course. Suppose you want to read you can read this book Peabody's control of pipeline corrosion 2nd edition this was edited by so edited by R L Bian Chetti. And it is again NACE publication, Texas 2001. It is a nice book mostly focused on pipeline related cathodic protection.

And it also deals with the coatings as applicable to pipelines and you do not of course, talk about cathodic protection of the tanks and all these stuffs are not there. But it is a very nice book you can look at the basics; you can get a better picture about what the cathodic protection is.

Let us start understanding an electrochemical corrosion ok.

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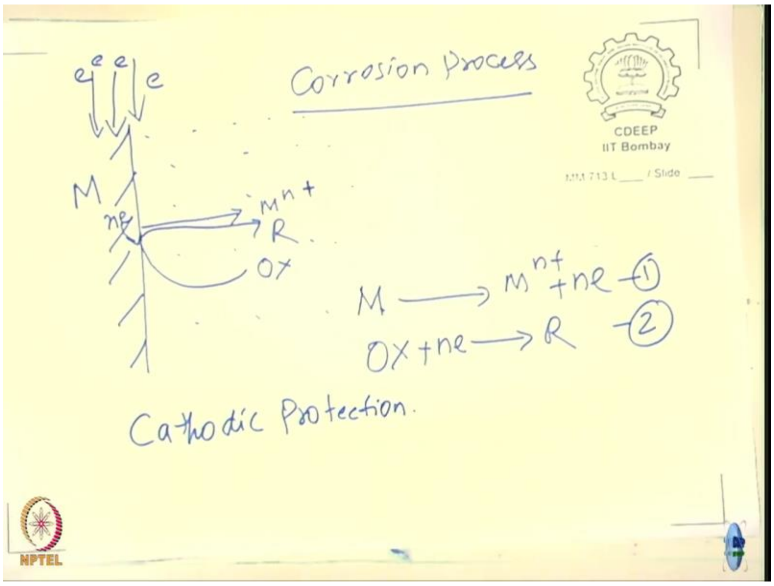

Let us recollect that what you have said. We said that in the electrochemical corrosion a metal is involved exposed to the environment. The metal is getting oxidized in environment maybe some M n electrons are released.

$$M \rightarrow M^{n+} + ne$$

So, you have n electrons are released on the substrate some species from the environment ok, some species from the environment they will take this electron and they get reduced some oxidized species they take this electron and get reduced into reduced pieces. And this is a metal, this is the corrosion process right.

$$Ox + ne \rightarrow R$$

The when it is corroded the metal exhibits a potential which is equal to what is the potential called? What is that potential? When metal is corroding if you measure that potential using a reference electrode; what is that potential called?

Student: (Refer Time: 67:23).

It is a.

Student: (Refer Time: 67:25).

It is a corrosion potential right. So, it is a corrosion potential at that potential the rate of oxidation of the metal equals to the rate of production of the species involved in the corrosion process.

The metal is quite neutral right am I right, metal is metal surface is quite neutral because the number of electron released or consumed by the species from the environment. Now what we are going to do is suppose I am going to now I am going to pump electrons here, I am going to pump electrons on the surface I am going to put more electron. I am going to flood the surface with the electrons.

So, what happens? Look at this diagram if the surface is flooded with electrons what would happen to this corrosion process? There are two; there are two reactions here right. One reaction is metal going as M n plus plus n electrons right.

The other reaction involved is some species take away this electrons like this. When I am flooding this surface with electrons; what do we think will happen? I want you to spell out clearly tell me.

Student: (Refer Time: 69:01).

Yeah.

Student: Polarization.

It does polarize, the reaction this is reaction 1, reaction 2 it polarizes right. So, what will happen to the corrosion what happened to these reactions? What will happen to reaction 1 what will happen to reaction 2 the reaction 1 will?

Student: Slow.

It get slow down when you have more electron; that means, as well forget about electrochemistry as per Le Chatelier principle the reaction will revert back because you are supplying more electrons here.

So, the reaction will turn towards like this what will happen to 2nd reaction will increase actually. So, you find the metal surface the rate of corrosion decreases whereas, the other reduction reaction rate increases.

So, when you put this more and more electrons on the surface and that is what really happens. And that process is called as cathodic protection.

Now the there are this is simple concept is very simple I have more electrons on the surface and so automatically the oxidation of the metal is getting reduced. But of course, the cathodic reaction which is you know is now it takes electrons the rate of that reaction will increase. And this is the essence of cathodic protection of metals.

So, I stop here.