Ocean Structures and Materials
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Module - 3
Lecture - 7
Corrosion in concrete II

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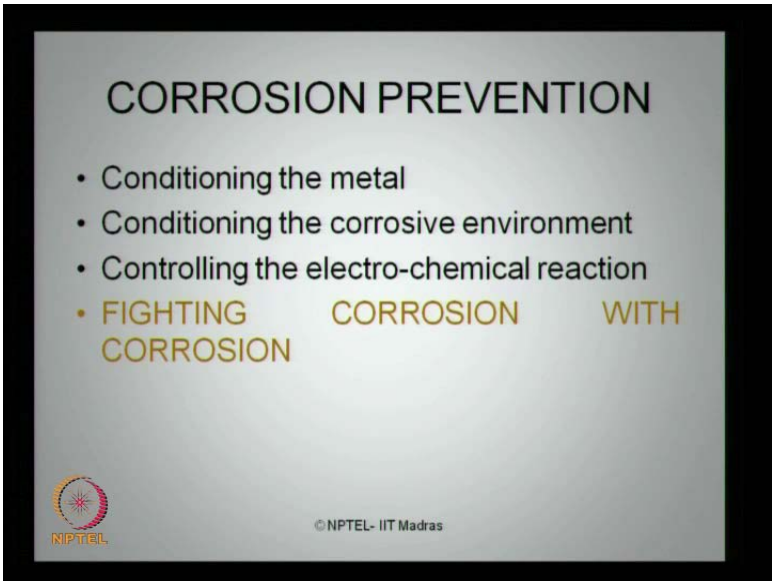

Under the braces of NPTEL, IIT Madras, in the last lecture, we discussed about corrosion protection methods as applicable to concrete .In this lecture also we will discuss further more methods of how to treat concrete or any metal surface, which is susceptible to corrosion. So, we will talk about corrosion protection in detail and corrosion prevention methods. There are different ways by which corrosion can be prevented. One - you can condition the metal surface; two - can condition the corrosive environment; three - can control the electro chemical reaction which is responsible for corrosion. Let see one by one in detail of all the three steps or three methods by which I can prevent corrosion.

The principle aim behind any corrosion prevention or protection method is that fight corrosion with corrosion. It means if you got to actually reduce corrosion, create a member or an element or a metal surface which you are sacrificing as a corroded member and then protect the member which you want protect in the offshore structure.

So, fight corrosion with corrosion is a very important underline theme as well as corrosion prevention methods are generally adapted for marine environment.

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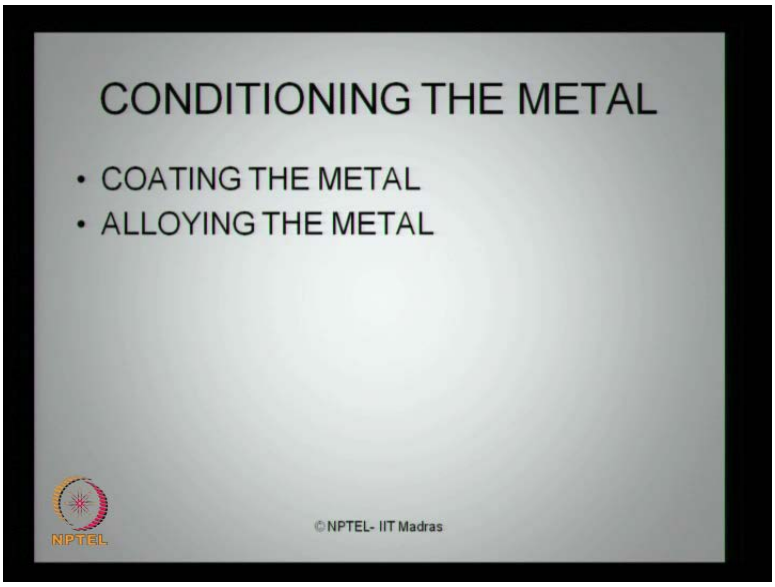

Let us quickly look out, the first component of how to prevent corrosion, how to condition the metal surface. I can coat the metal or I can make an alloy of the metal. In both cases, I will be able to retard the rate of corrosion or I can at least prevent corrosion to a large extent. When we talk about coating the metal, all chemicals, and composites and additives cannot be used to coat the metal, because they may have negative impact on the environmental assessment or environmental impact from the sea environment.

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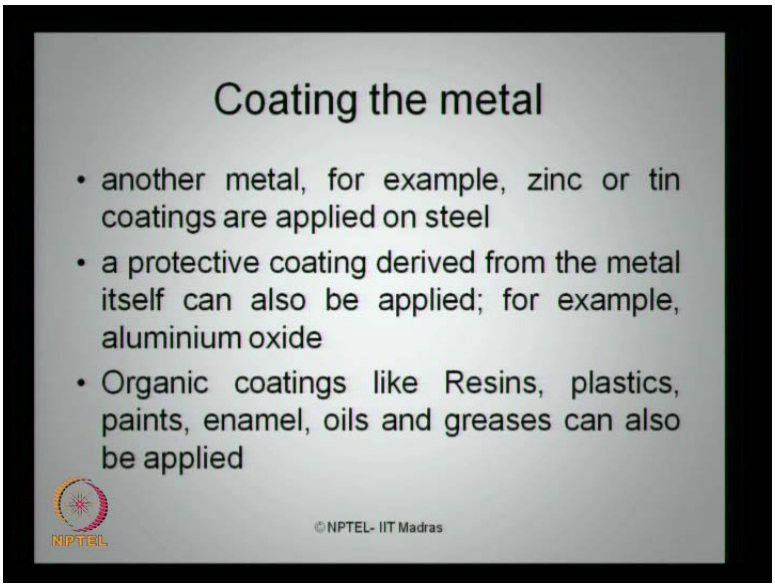

Let us quickly see how do we apply the coating on the metal and what are the different material which can be used for coating the metal surface. For example, we can use another metal to coat an existing metal surface in case commonly used are zinc or tin coating. They are generally applied on steel as an external coating surface. A protective coating therefore, derived from the metal surface itself can also be applied. For example, you can treat the metal surface of a member using aluminum, oxide coating; alternatively, can also do organic coatings like resins, plastics, paints, enamel, oil and greases.

So, ladies and gentleman, the first part, how do we protect metal to prevent corrosion is tocondition the metal. In that case, we have a first alternative as coat the metal. So, we can either use any other metal surface to coat it like zinc or tin, we can use a protective coating like aluminum- oxide or can simply apply resins, plastics, grease, paints, enamels etcetera on the member surface itself to apply as a coating which can protect the member from corrosive environment.

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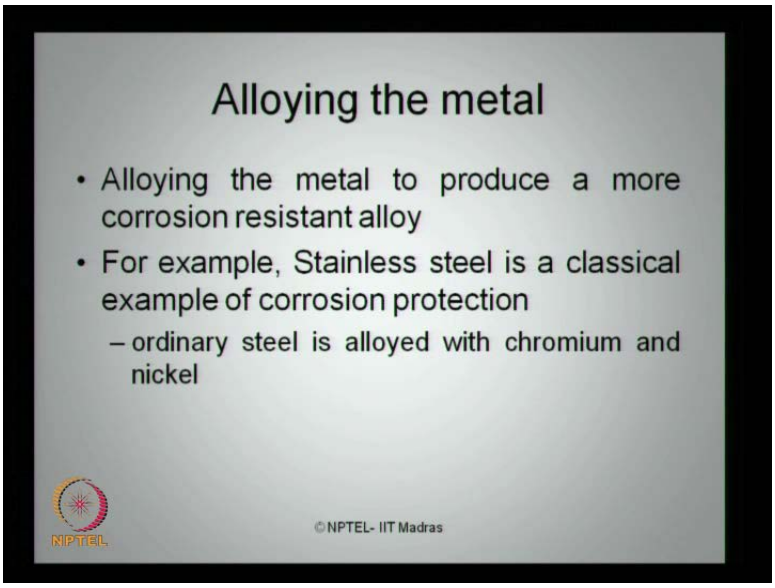

The second methodology by which we said is alloying the metal. So, you can alloy the metal to produce a more corrosion resistant alloy. There are significant examples available which we will be discussing now, for example, stainless steel is a very classical example of corrosion protection alloy which is an alloyed of ordinary steel with chromium and nickel. So, this alloy of chromium and nickel improves the conditioning of the original steel, and makes it corrosive resistant.

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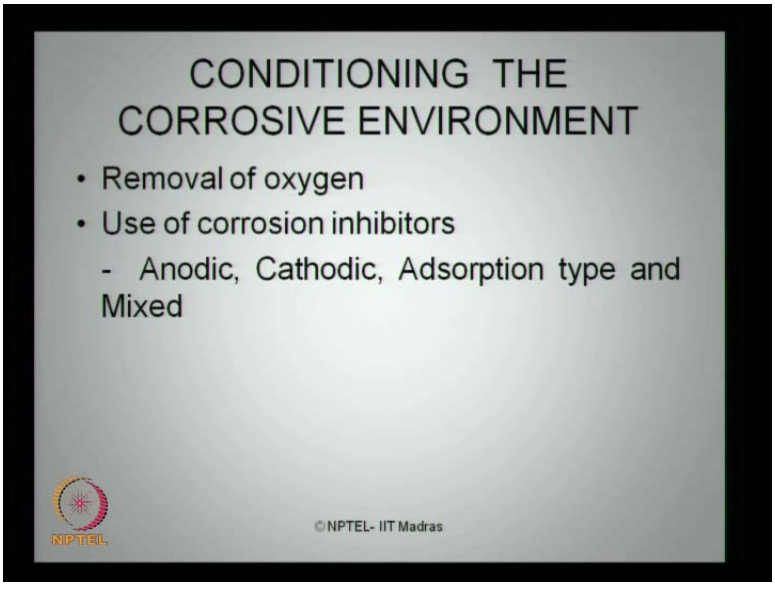

Let us quickly look at how to condition the corrosive environment. There are three components of corrosion prevention; one is condition the metal; two is conditioning the environment, which is responsible for corrosion. You can do by two ways; one is removal of oxygen or you can use what you call corrosion inhibitors, which can also help to condition the corrosive environment to a greater extent. Now when we talk about use of corrosion inhibitors then you can use anodic type, cathodic type, absorption type and mixed variety of this three.

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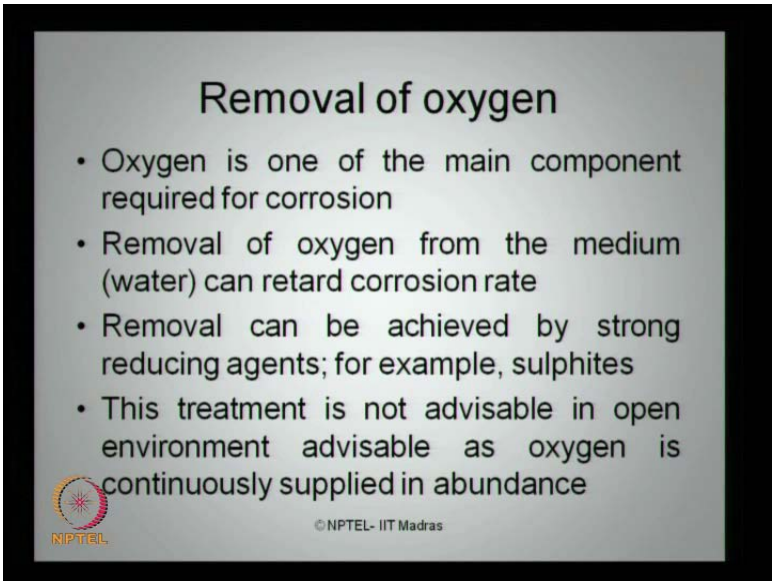

So, let us talk about how to work on depletion of dissolved oxygen content just removal of oxygen. As we all understand, ladies and gentleman, presence of oxygen is a very important component which is responsible for active corrosive environment. So, if you reduce the content of dissolved oxygen in the sea environment, it can help you to prevent or to protect the metal surface from actively getting corroded. Oxygen is one of the main components which is required to activate the process of corrosion. Removal of oxygen therefore, can help us to prevent or retard or to protect the metal surface from corrosion. Removal can be achieved by strong reducing agents, for example, you can use sulphites which can reduce the presence of oxygen content in the sea environment or in the environment which is responsible for corrosion. This treatment of course, is not advisable in open environment, because abundance of oxygen is available in the open environment. Therefore, it is only effective, if we use sulphites to reduce the oxygen content in the environment. In a close environment, this treatment can be effective which

can be used to achieve depletion of oxygen, dissolved oxygen content, however this cannot be used in open sea state.

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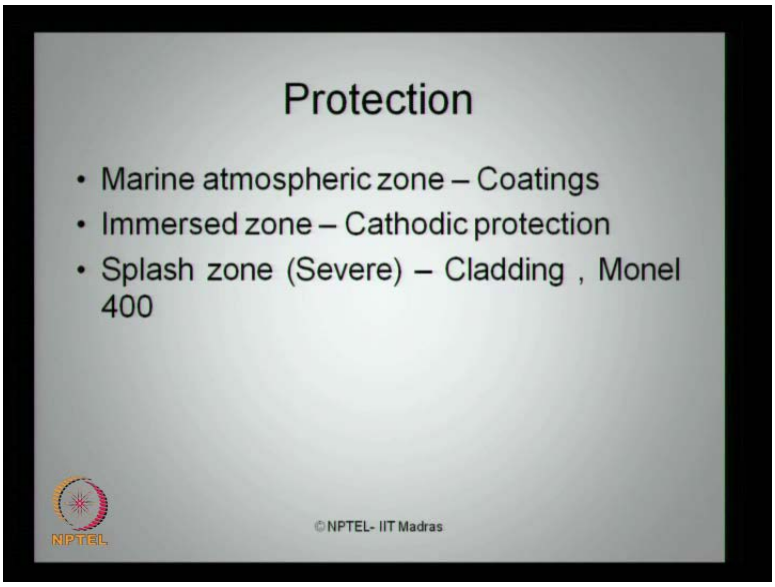

When we talk about protection, we have many varieties and options available to protect the material from corrosion. Let us say marine atmospheric zone is one zone where the corrosion is not very severe, but it is marginally high. So, we can use coatings as we saw in the last lecture as well. In the immersed zone, I can use what I call cathodic protection; we will see this type of protection in detail in this present lecture. When we talk about splash zone, where the corrosion rate is very severe, I can use monel 400 or cladding. I can use an external surface material as monel 400 to be covering the existing material or the member, and protect the member by this external cover, I call this protection layer as cladding.

So, let us talk about more in detail on protection applied to splash zones. You may wonder why, we are focusing on corrosion prevention and protection mode on the splash zones. The essential reason is that corrosion rate is extraordinarily high in the splash zone;, it is approximately double to three times at that of corrosion happening in the atmospheric, and the immersion zones.

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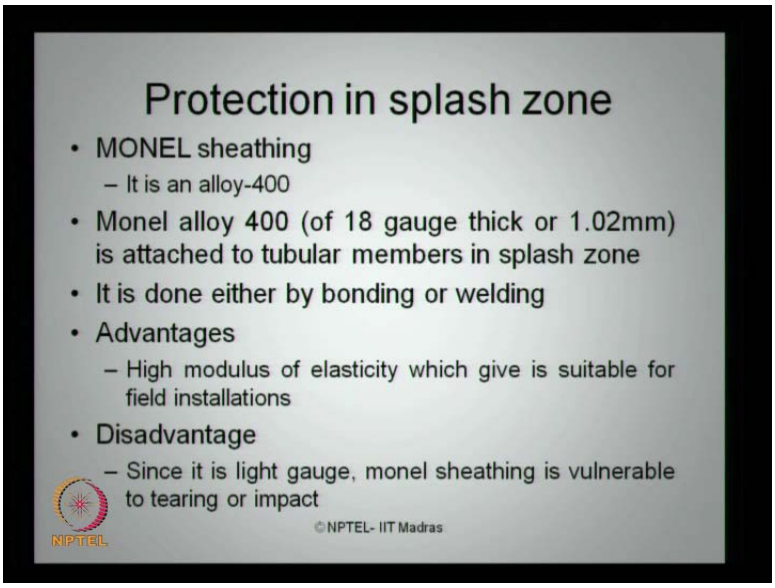

The foremost option what people generally used in protecting a member in the splash zone is monel sheathing. Monel is an alloy 400, Monel alloy 400 usually is available in 18 gauge thick, 18 gauge thick is approximately equal to 1.02 millimeter in metric units. It is attached to the tubular member in the splash zone. Remember ladies and gentleman, providing this kind of treatment of protection by putting an aluminum or monel sheathing will not be helpful for entire link of the member. It is effective only in the splash zone, where a corrosion rate is the maximum. So, monel alloy 400 is a common practice which is being use as a sheathing which is attached tubular member only in the regions of splash.

It is done either by bonding simply fixing the monel sheathing by addisive on the parent member or you can also weld this sheathing monel alloy 400 to the parent member. There are principle advantages of using this as a protection for the primary in splash zone. Monel alloy 400 has a very modulus of elasticity, and this gives me greater advantage, because the suitable for field applications. As we all understand when the offer platform are installed in-site for field installation, you will see that extra forces because of erection and commissioning of this platforms will play a critical role in designing this members.

So, monel sheathing 400 will not get damaged or under the stresses which are caused because of this installation process. However, it has got couple of disadvantages. Since it

is a light gauge material, the thickness of sheathing is approximately only one millimeter it is very light therefore, it is vulnerable to get damage because of tearing or impact forces. So, one has got to be very careful that the impact stresses should not be caused on the sheathed member especially in splash zone during erection or commissioning. And there is a tendency that this may even get teared off, because the thickness of the sheathing is very thin there is a tendency that the sheathing may even peel off or tear off from the parent's surface of the material.

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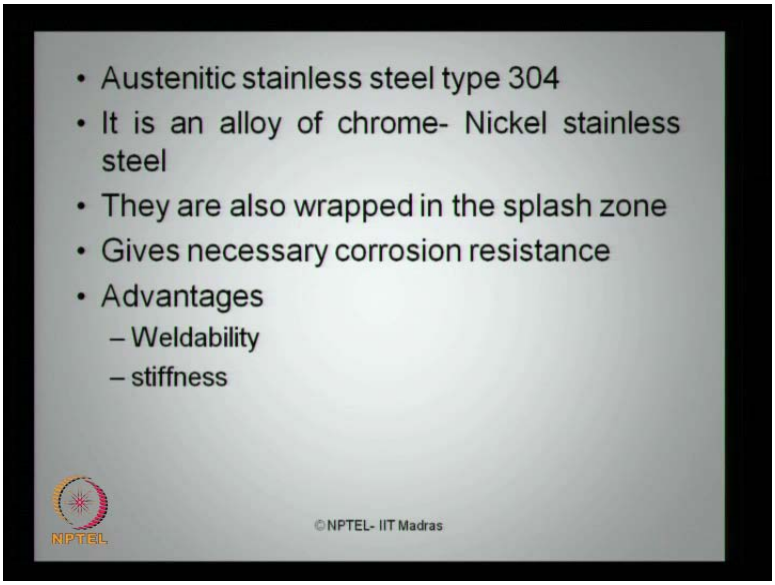

The other type of metal sheathing, which is generally done, is austenitic stainless steel type great 304. It is again an alloy of chromium-nickel stainless steel. They are also wrapped in the splash zone over the members kept in the splash zone. It gives necessary corrosion resistance to the parent member by wrapping this austenitic stainless steel type 304 on the parent member. There are specific advantages of using this kind of monel sheathing or this kind of sheathing on splash zone. They were advantages are this is having high degree of weldability and very high stiffness.

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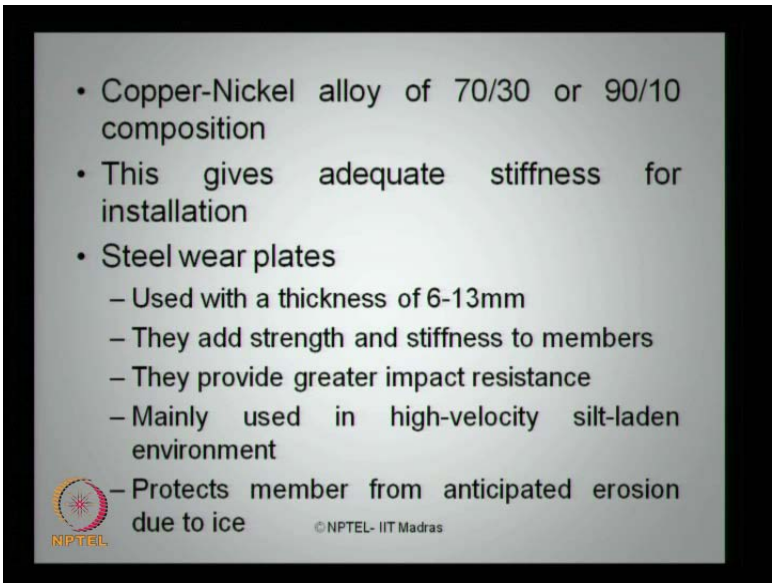

The other alternative material, which is also commonly deployed in this splash zone to protect members, is copper nickel alloy of either 70/30 percent distribution or even 90/10 composition. This gives an adequate stiffness for the material or the member during installation, which is required and demanded from the members during installation process. The alternative material, which is also used for corrosion protection of members in splash zone, is you can use steel wear plates. Steel wear plates are use with a thickness of about 6 to 13 millimeter. They actually add strength and stiffness to the members; they provide greater impact resistance on the members. They mainly used in high-velocity silt-laden environment in the sea. It protects members from anticipated erosion principally due to ice. Therefore, in arctic regions or in isolated regions, where the temperature variations can be very large and temperature can go to sub 0 or formation of ice, this kind of corrosion protection methods are generally advisable to members near the splash zone.

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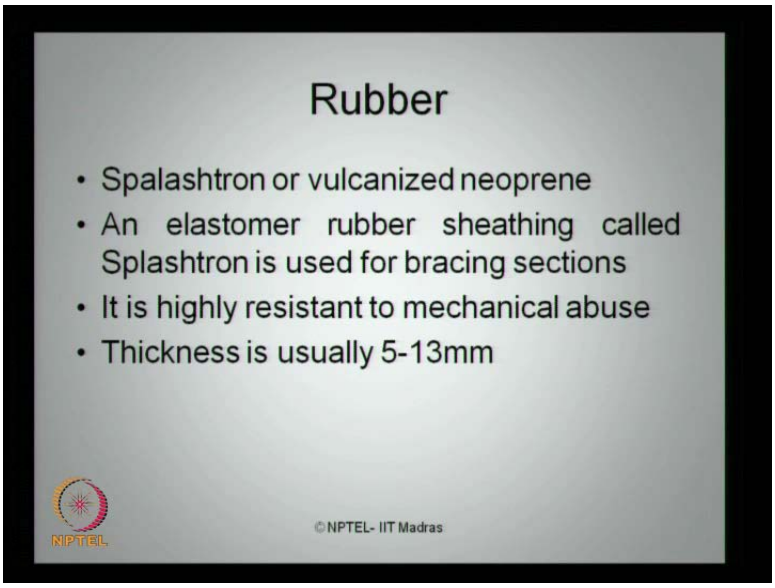

Ladies and gentleman, alternatively, another material which is also used to protect member in splash zones is rubber. Spalashtron or vulcanized neoprene are two varieties of rubber products, which can be used as a sheathing layer on the members or on the material surface near the splash zone. An elastomer rubber sheathing, which is called a Splashtron is a very common phenomena being try in bracing sections. It is highly resistant to corrosion and also to mechanical abuse. It is having a very high tearing strength and once the rubber coating or the rubber sheathing gets harden, you will not be able to tear it off so easily, it adheres to the parent material very strongly and tries to become or have a tendency to become an homogeneous material with that of the parent member. The thickness usually varies from 5 millimeter to 13 millimeter, which is substantially high compared to monel sheating, which is hardly only one millimeter.

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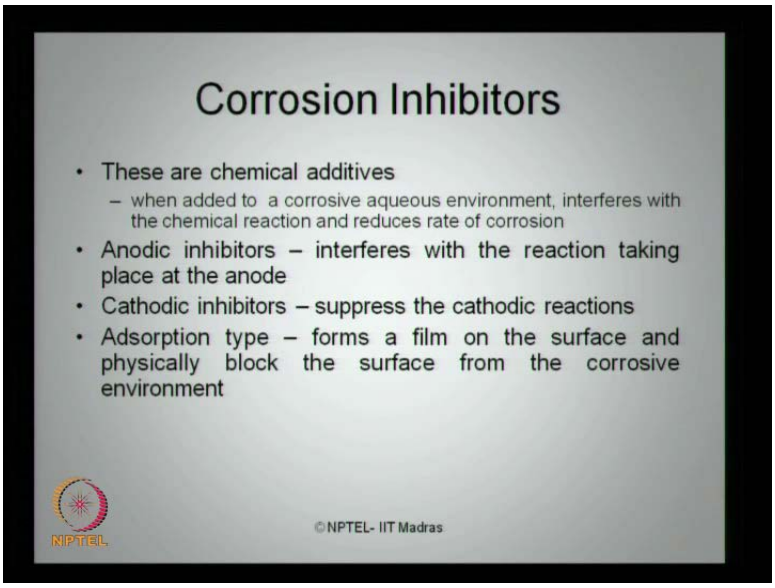

The other alternative which we saw in maintaining corrosion protection is that corrosion inhibitors. I can also use corrosion inhibitors to maintain corrosion preventive environment in sea states. These are nothing but chemical additives, when they are added to corrosive aqueous environment, it interferes with the chemical reaction and reduces the rate of corrosion are happening on the members. There are anodic inhibitors cathodic inhibitors and so on. Anodic inhibitors actually interfere with the reaction taking place at the anodes as the name suggest cathodic inhibitors - suppress the cathodic reactions happening on a bimetallic couple. Adsorption type corrosion inhibitors generally form a film on the surface of the member and physically blocks the surface from the corrosive environment. Ladies and gentleman, corrosion inhibitors are very commonly deployed these days and deep water platforms in particular in immersion zones and splash zones. Anodic inhibitors are more popular amongst all of these three type, of course, you got a mixed type variety as well is a combination of these.

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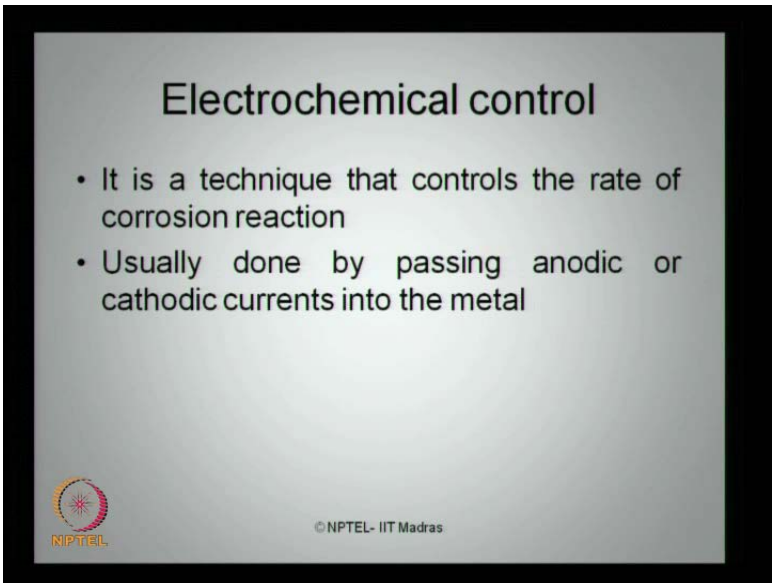

You can also control the electrochemical reaction happening which is also responsible equally for a corrosion process. Electrochemical reaction control is a technique, which control the rate of corrosion reaction. It is usually done by passing an anodic or cathodic current inside the metal.

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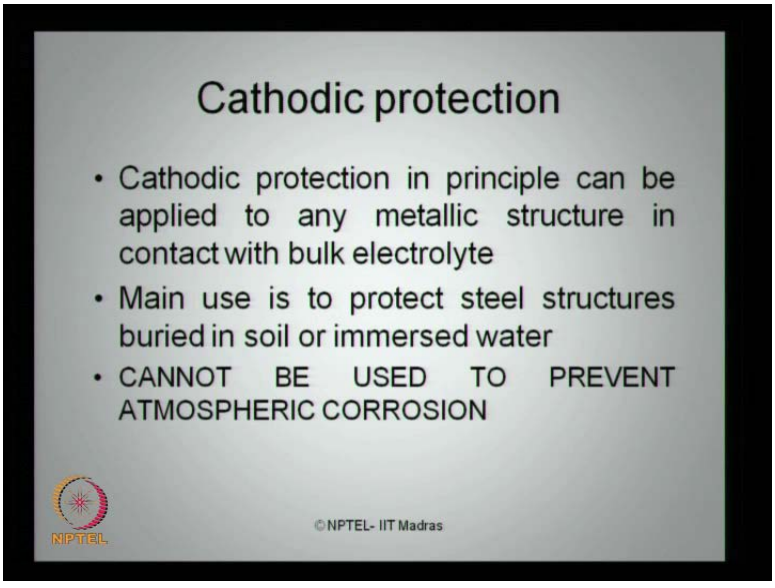

If you talk about cathodic protection, which is a very important and very common and very popular method of corrosion protection, which is happening in most of the members installed in offshore or sea environment. Cathodic protection in principle can be applied

to any metallic surface or any metallic structure, which is of course, in contact with bulk electrolyte. And this condition is automatically to fulfilled as for as offshore structure concern, because the electrolyte percent is nothing but sea water is also having lot of sulphites and chemicals inside, which access a massive volume of electrolyte which is present. Therefore, the members are in contact with a high bulk volume of electrolyte therefore, cathodic protection, ladies and gentlemen, is consider as the one of the very common method of corrosion protection technique on offshore steel members which are generally employed in sea environment.

Main use of corrosion protection method is to protect steel structures buried in soil or in immersed water. Remember the basic requirement of a cathodic protection to be apply to a member is that the member should have a bulk contact to electrolyte therefore, these techniques cannot be deployed in splash zone and tidal zone, where is an alternate wetting and drying taking place. So, it is successful for immersion zones alone. As we all understand, immersion zone rank second, in the rate of corrosion in the whole link of the member varying from the atmospheric to the mud line level. So, immersion zone, as comparatively good corrosion rate in compared that of the atmospheric level, but of course, it is lower than that is happening in the splash zone. Cathodic protection is one of the common methods deployed for members in the immersion zone. Remember, it is very important to understand that this technique cannot be used to prevent atmospheric corrosion.

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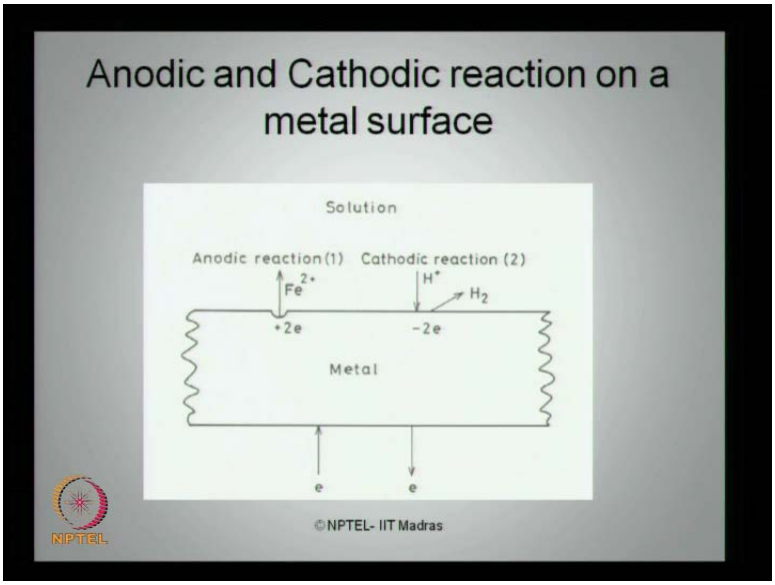

Let us quickly look at the anodic and cathodic reaction on a metal surface. If you understand this, it becomes easy for me to reply how we go about cathodic protection. Look at this figure; I got an aqueous solution which is electrolysis present in a bulk volume here. I have got a bimetallic couple form in the same member or a different material which I am using one is what we called anodic reaction, other is a cathodic reaction. Anodic is termed as anodic, because it releases electron and becomes the positive, whereas cathodic receives electron and becomes negative. Is what we have understood that the one which is releases gets anodic, therefore anodic part keeps on getting corroded that is why we call this as cathodic protection technique. It is very simple, ladies and gentlemen, the material which I want to protect has to be made as a cathode, the material which has got to be sacrifice should made as an anode, therefore we called this as cathodic protection technique.

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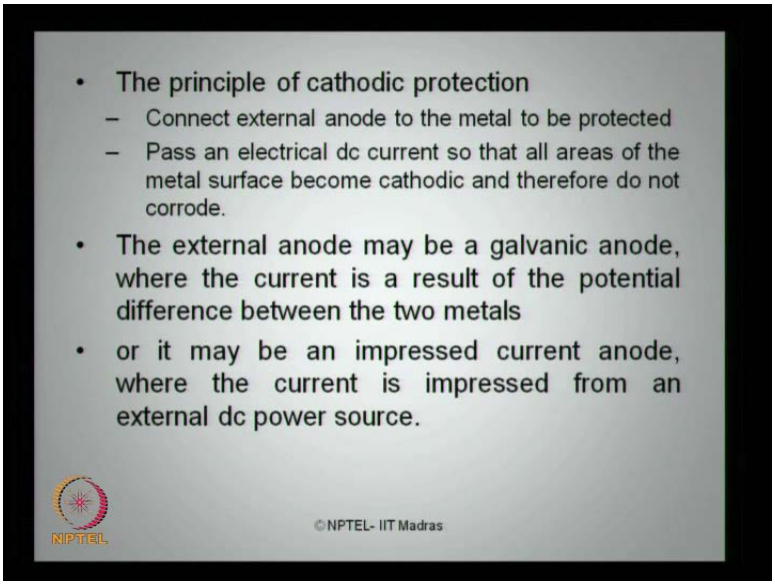

Let us quickly look at what is the principle behind the cathodic protection works. Now the steps are very simple. Connect the external anode to the metal to be protected; as I clearly said the metal which you want to protect should become a cathode, therefore you require an external metal which is going to become an anode, which is ready to release electrons in a chemical reaction, should be connected to an anode pass an electric DC current, so that all areas of the metal surface become cathodic completely, therefore do not corrode. So, the metal surface which we want to prevent from corrosion should be made voluntarily cathodic, by creating an artificial metal once again in the same

medium, which is made as anodic. Therefore, anode keeps corroding, which I am sacrificing to protect by cathode which is my principle member of an offshore structure. The external anode which is provided now may be a galvanic anode, where the current is a result of the potential difference between two metals. It can form what we call a galvanic couple as well. Or alternatively can use impressed current anode, where the current is impressed from an external DC power source on the metal.

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A Cathodic protection can be achieved in two methods. One - can use galvanic anodes, which we call as sacrificial anode technique. Or can use impressed current method, which we call as impressed current technique.

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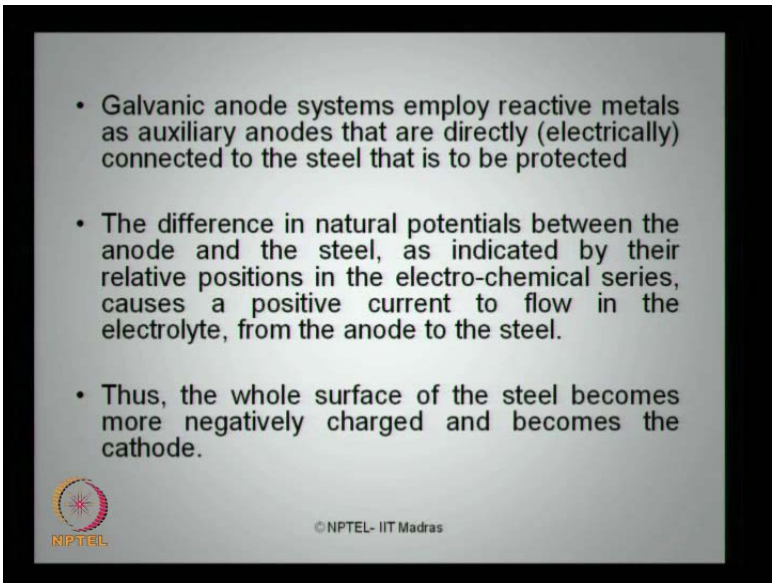

Let us look at the sacrificial anode or galvanic anode technique first. The galvanic anode systems employ reactive metals as auxiliary anodes that are directly connected to the steel, which is to be protected. So, the member or the steel surface which I am interested to protect should be made as a cathode, and I am introducing additional member which is galvanic anode system which is made as deliberately an anode. The difference in the natural potential between the anode and the steel as indicated by their relative positions in electro chemical series will make the material which is introduced now as anodic and therefore, corrosion start take place with this metal. It makes a positive current to flow in the electrolyte from anode to steel which results in corrosion of anode and that is how your principle member, which is cathodic, gets protected.

Thus, the whole surface of steel which is cathodic now because more negatively charged, and therefore they become a cathode automatically and they get protected that is why this method addressed as cathodic protection technique in the literature. However, in this method, I am using a sacrificial anode, therefore people use this as sacrificial anode technique of cathodic protection as well.

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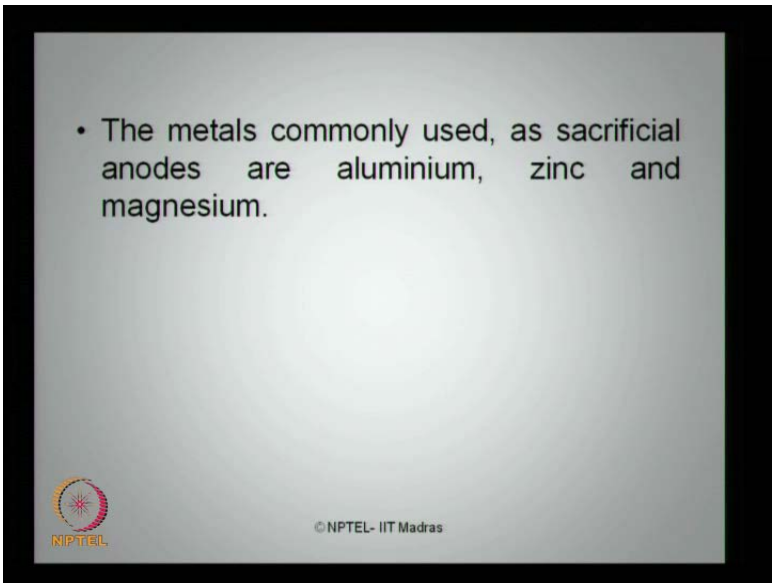

The metals commonly used, as sacrificial anodes are aluminum, zinc and magnesium.

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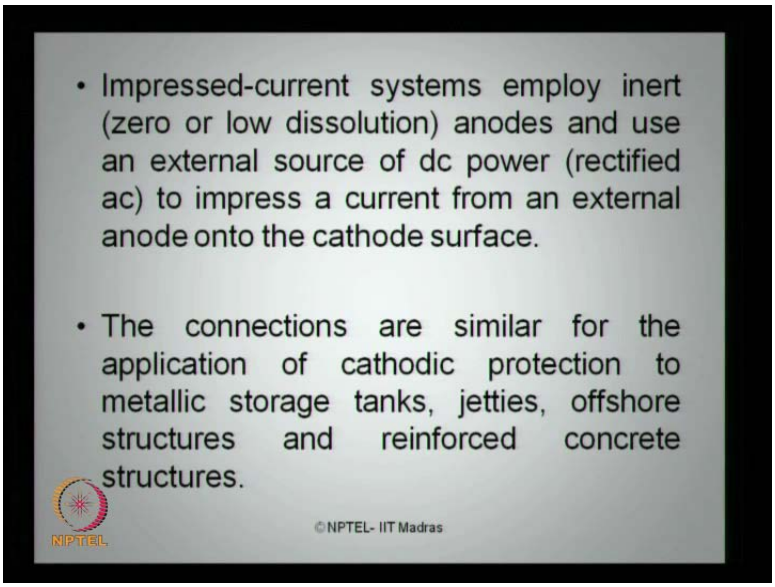

Now, the alternate method by which you can also use cathodic protection is that you can use impressed current to pass on the metal. The impressed current systems employ either zero or low dissolution anodes and use an external source of DC power to impress a current from an external anode onto the cathode surface. The connections are similar for application of cathodic protection to the metallic storage tanks, jetties, offshore structures

and reinforced concrete structures. So, cathodic protection method by impress current is also one of the popular methods which is being use on members in the immersion zone.

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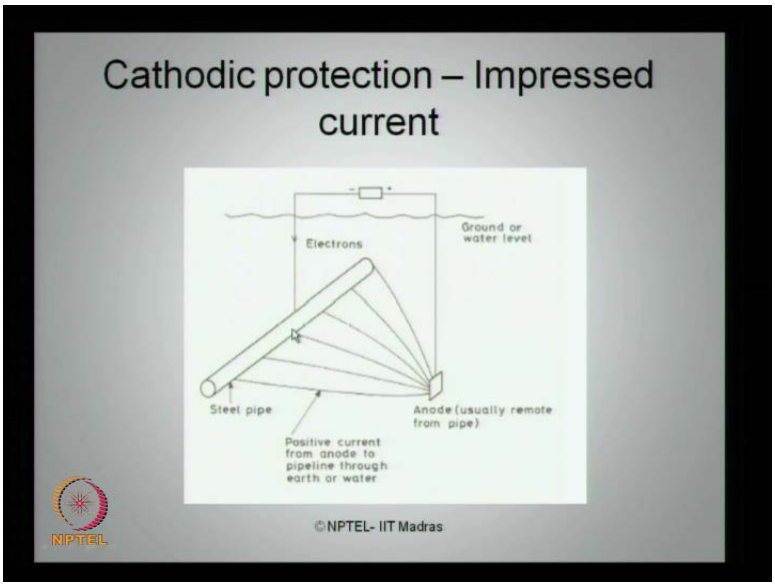

Here is the picture, which shows a cathodic protection technique using an impressed current method. It is a steel pipe which I want to protect and which I want to make as cathode. So, the anodes, which are I am going to introduce here, is a sacrificial anode technique which I am going to create which is usually from a remote pipe. So, the electrons are giving up and the electrons are received in the steel pipe which I am protecting. There is a positive current, which happens from the anode to the pipeline through the earth or water, which is actually my electrolyte or the medium. So, this is a very interesting schematic diagram which shows me, how I am passing impressed current in a location where I am protecting the original member to become cathodic and I am putting a sacrificial anode to make an anode, therefore the impressed currentis method is being used for cathodic protection.

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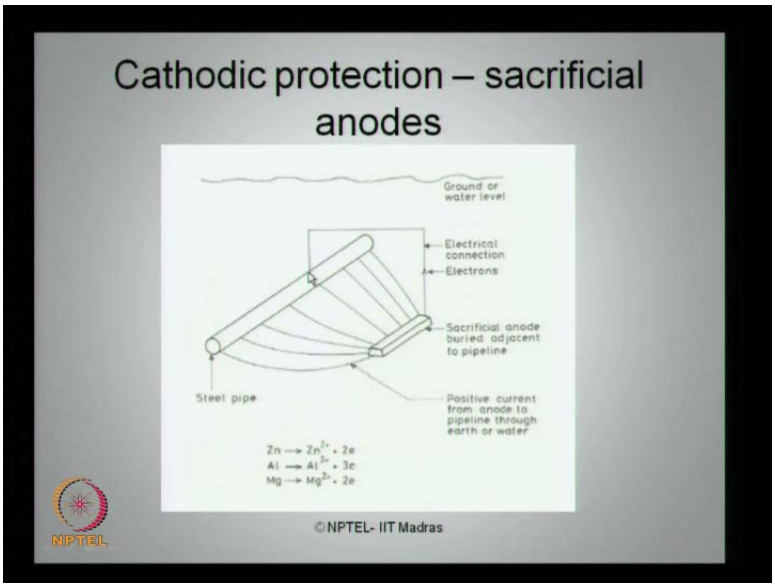

Alternatively can also use sacrificial anodes, where an external member or a material like aluminum, magnesium, zinc are connected externally to a pipe or a steel member or a surface which is to be protected. So, the steel member has to be got (( )) deliberately made as a cathode and the alternate member which you now introducing in the material is an anode. And the anode sacrifices, therefore it gets corroded and it is protecting alternatively the cathodic member, which is the original steel member of a material. Remember this method is effective only when we apply for these members, which is completely immersed, because this method requires a bulk contact of electrolyte for the process to activate very seriously.

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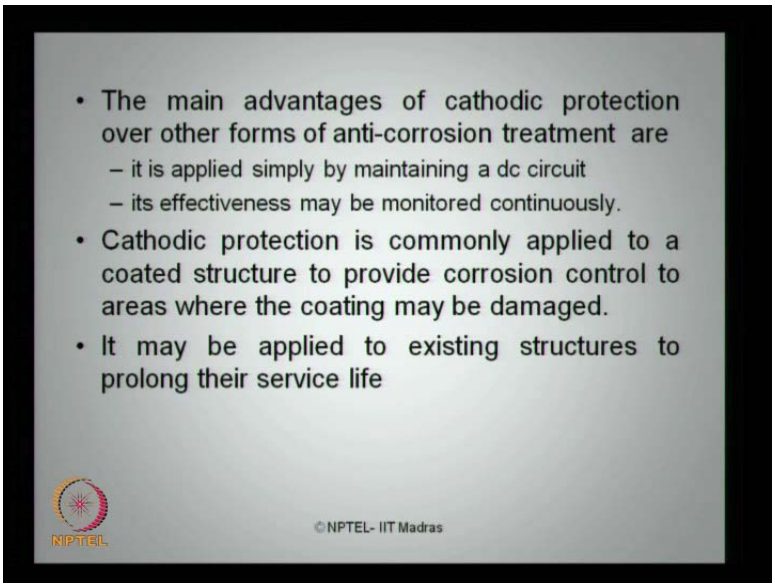

The main advantage of cathodic protection over other forms of anti-corrosion treatments is the following: It is applied simply by maintaining a DC circuit, its effectiveness may be monitored continuously. It is very important ladies and gentleman, all the cathodic protection treatments which we saw in the recent lecture are the slides is important that they should be monitored continuously; Because you have to record the amount of electronic flow or the electric flow happening between the terminals of anode and cathode which will tell you what is the rate of effectiveness of a protection treatment. So, constant monitoring of electric supply happening between the cathodic protection or the protected member and the sacrificial anode is very important in such control mechanisms. So, it is very important that the monitoring happens effectively and it is continuously happen.

The cathodic protection is commonly applied to any coated structure to provide corrosion control to the areas where the coating may be damaged. For example, you have a member which completely coated which lies in atmospheric in splash zone, there is always a tendency, that this coating may get washed off or leached off, because of the chemicals present in the sea environment. So, if you suspect that kind of let see erosion happening on the steel material surface then you can use this kind of protection in those zones which is possible that you can have corrosion very actively taking place. If the coating is likely to get damaged, you can use cathodic protection in those areas also. It may be applied to existing structures to prolong the service life; there is a common

phenomena what people use, nowadays cathodic protection techniques are also implemented in the design stage itself.

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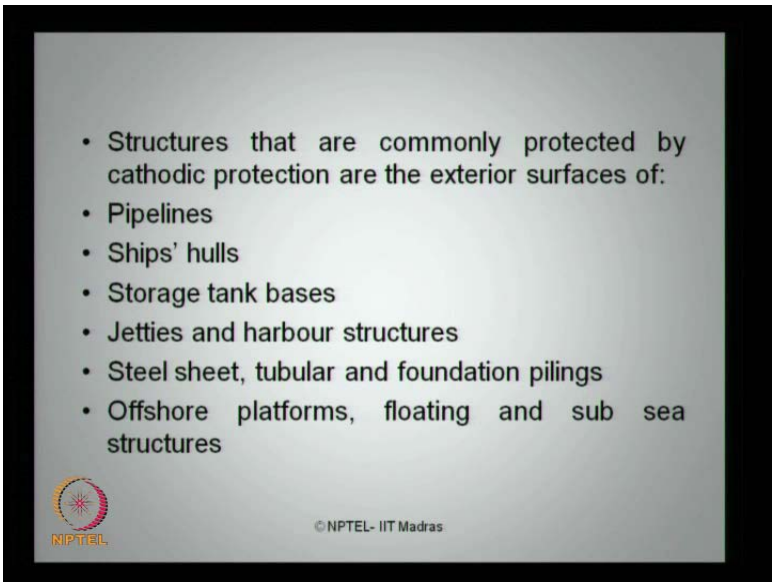

Structures that are commonly protected by cathodic protection are the exterior surfaces of course. The examples are the following, can use it for pipelines, can use it for ship's hulls, can use it for storage tank bases, can use it for jetties and harbor structures, can use it for steel sheets, tubular and foundation piles. Of course, offshore platforms, floating and subsea structure are common example where cathodic protection is very largely deployed in the recent pasts.

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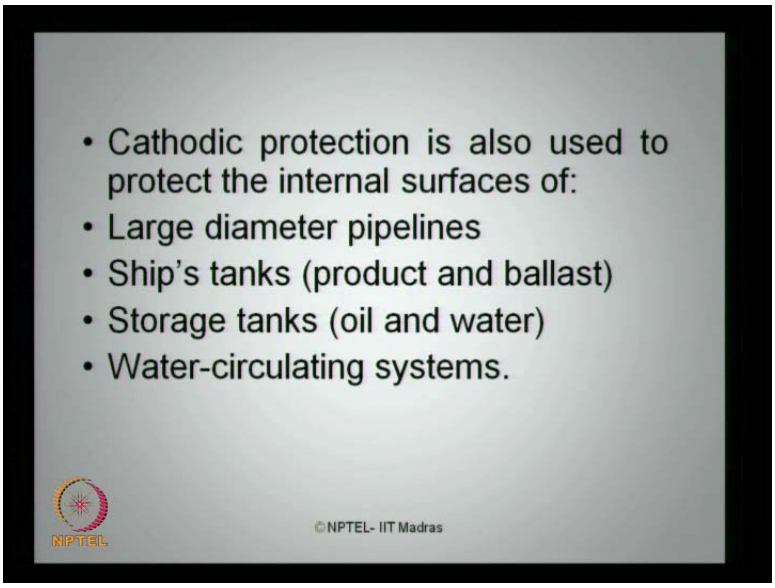

Cathodic protection is also used to protect the internal surface of certain members. Can use large diameter pipelines and you protect the internal surface from corrosion using this technique; Can also use the ballast tanks and products like this in ship tanks to protect it from corrosion; Can also use large storage tanks which are essential use for storing oils or water for corrosion protection, and of course water circulating system which are subjected to lot of differential heat or temperature variation can also be used, can also be deployed by this method to protect them from corrosion.

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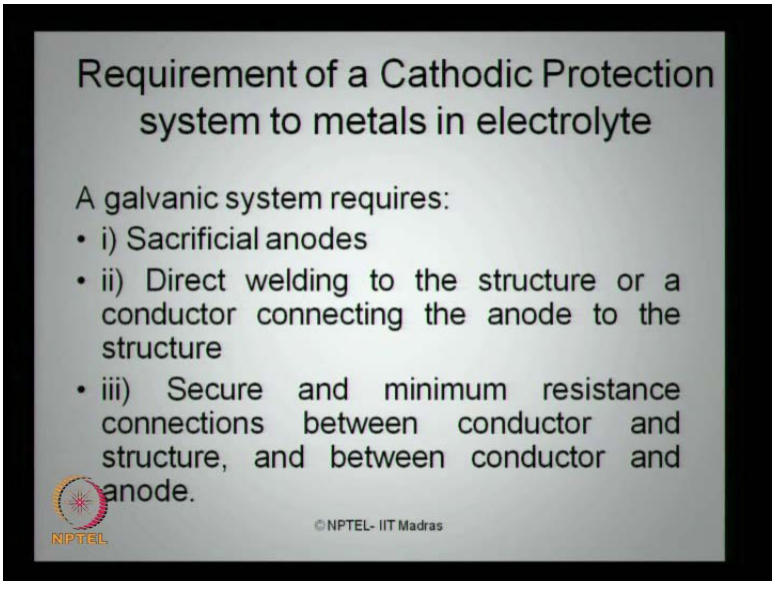

Now, let us look at the requirement of a cathodic protection system to metals in an electrolyte. A galvanic system, if you prefer to use, requires the following: It requires a sacrificial anode, it requires a direct welding to the structure or a conductor which connects the anode to the structure. And of course, a secure and a minimum resistance connection between the conductor and structure is to be ensured and between the conductor and the anode is also to be compulsory ensured to make this kind of protection more effective.

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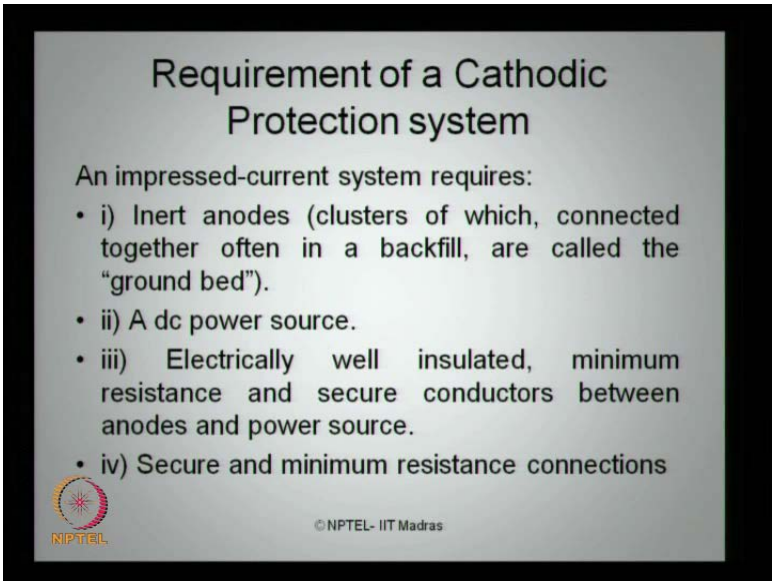

An impressed current system, of course alternatively requires the following. It requires inert anodes, which is nothing but cluster of anodes connected together often in a backfill which are called as ground bed. It of course requires an external DC power source and electrically well insulated system, the minimum resistance and it secures conductors between the anodes and the power source. Ladies and gentleman, in the present lecture, we discussed about different methods of corrosion protection, cathodic protection sacrificial anode etcetera, different combination of metals which can be used as coatings, sheathings etcetera to protect the metal surface from corrosion.

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We will discuss more in detail about the equipment types, which have been used for these treatments in the following slides. The equipment types, which are commonly used by galvanic anode or galvanic protection systems, are magnesium, aluminum and zinc. There are available in terms of rods, big blocks or wire forms, which can be wounded around the member. They are also cast around the steel inserts to enable their fixing. These inserts are then connected to the structure; they can be either bolted or welded.

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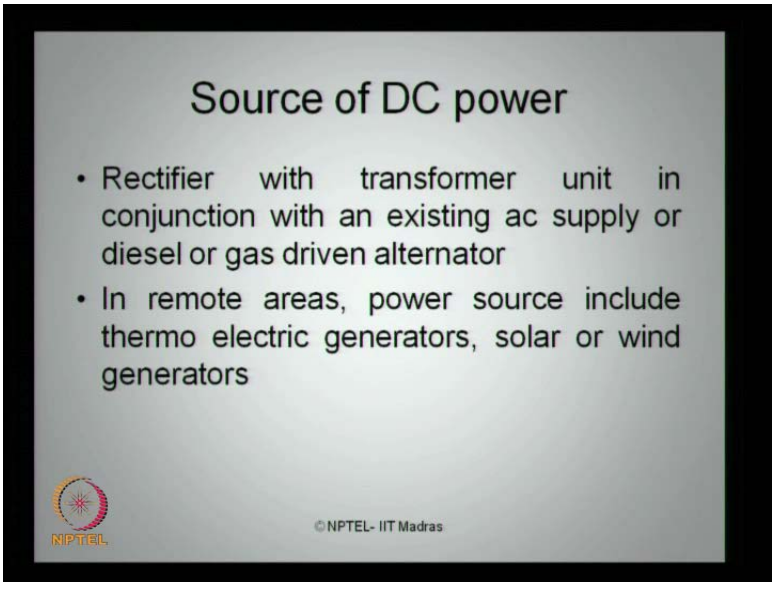

When we talk about source of DC power which is a vital path requirement in case of impressed current method. The rectifiers by transform units in conjunction with an existing AC supply can also be used, or alternatively can use either diesel or gas driven alternators. In remote areas power source include thermo electric generators solar or wind generators, which are commonly and widely deployed by generating the required DC power for impressed current methodology of cathodic protection treatments.

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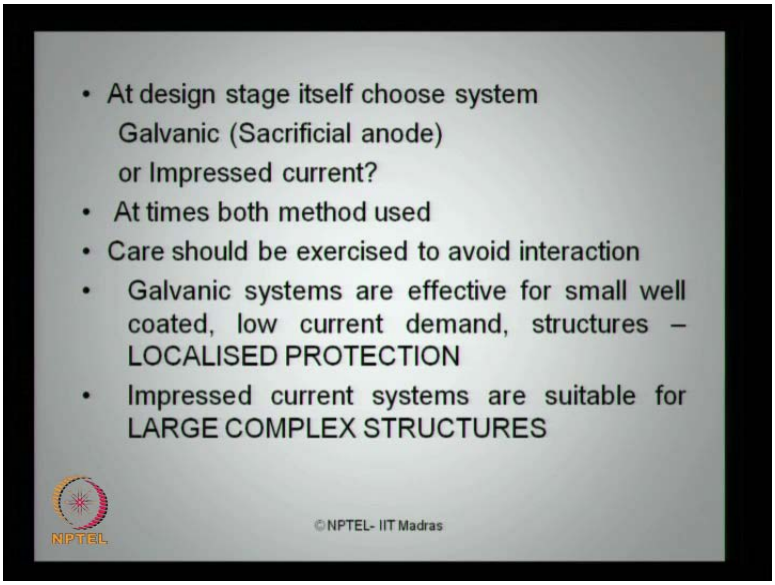

You can also do corrosion protection in a design stage itself. Can chose the system to be galvanic or can introduce a sacrificial anode in the system in the design itself, or you can plan the layout for an impressed current system. At times very commonly combination of both of them are used in the design, but most importantly care should be taken to avoid interaction between these two methods. Galvanic systems are effective for small well-coated, low current demand structures. On the other hand, they offer excellent localized protection, whereas, current system is recommended for large complex structures. Remember ladies and gentleman, the suitability of these two methods depends upon whether you were requiring an intensive localized protection or a requiring a generic large surface area protection. So, you can use either a galvanic system or an impressed current system for corrosion protection methods.

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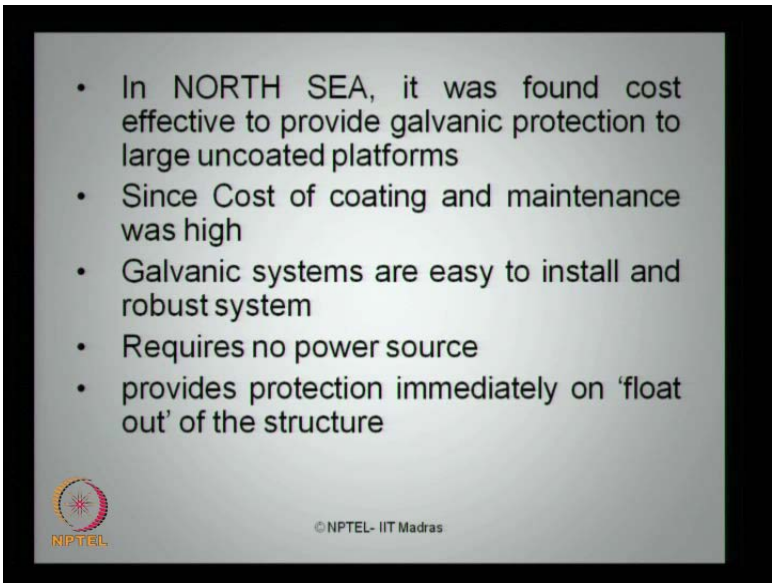

In North Sea, very commonly where maximum platforms are deployed, it was found that cost effective method proved to be galvanic protection against the large uncoated platforms. Since the cost of coating in maintenance was very high, people prefer to use galvanic protection techniques in Gulf of Mexico or in North Sea for majority of the platforms. Galvanic systems are easy to install and there is a robust system. It requires no external power source, so it is considered to be one of the main advantage of this kind of method. It provides protection immediately on float out of the structure. So, the corrosion protection by means of galvanic protection is very effective and more or less instantaneous for a structural system.

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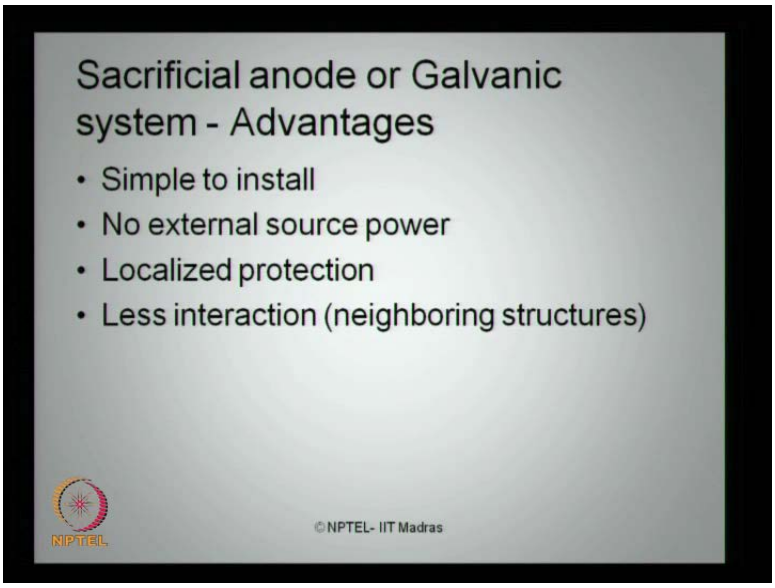

Whereas, as compared to the sacrificial anode or galvanic system, there are advantages, it is very simple to install, no external source power is required, localized protection is very highly effective and immediately available on float out, and less interaction with a neighboring structures.

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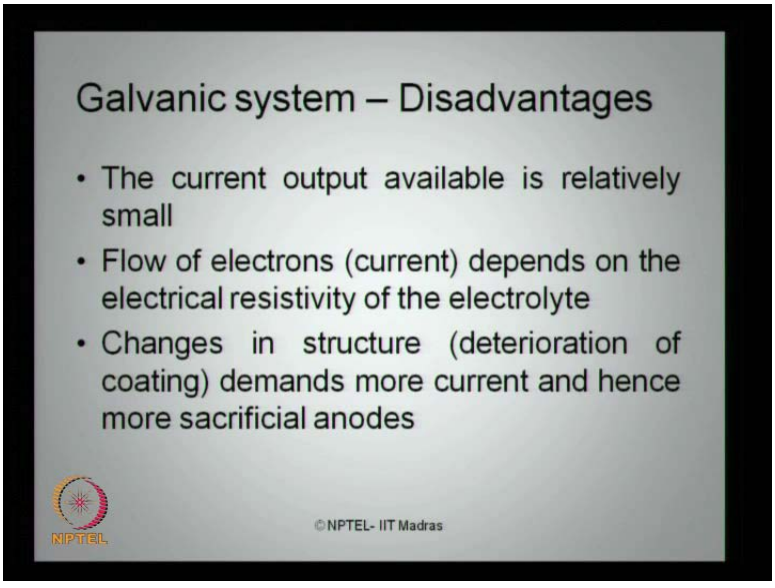

When we talk about disadvantages of the system the current output available is relatively small, therefore monitoring a galvanic system for effective corrosion protection is very difficult under surveys. A monitor system is highly sensitive to record small variation in

voltage. Flow of electrons depends on the electrical resistivity of the electrolyte. A change in the structure, that is, deterioration of coatings demands more and more current and hence more sacrificial anodes, therefore sometimes this method proves to be expensive.

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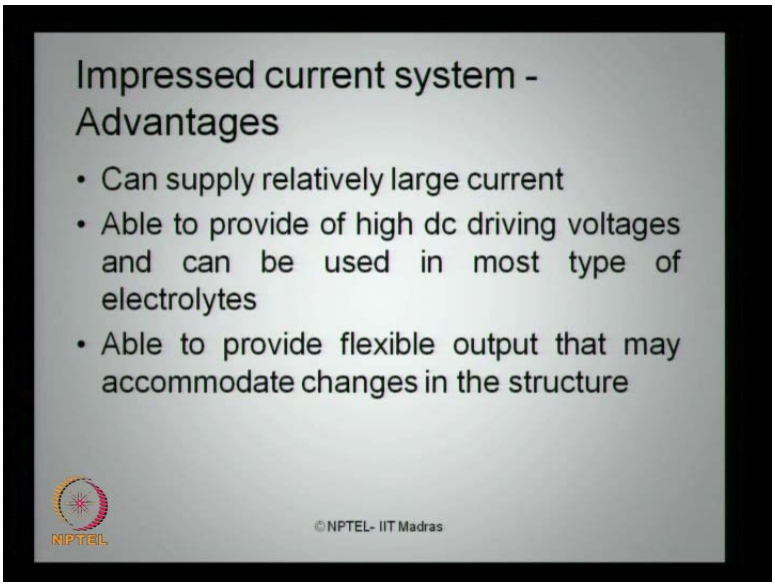

Alternatively, if we talk about impressed current system, it is having certain merits as listed below. Can supply relatively a larger current, therefore effective monitoring of control mechanism is highly feasible if you use impress current mechanism. It is able to provide high DC driving voltages and can be used in most type of electrolytes. It is able to provide flexible output; therefore it may accommodate respective changes in the structural members.

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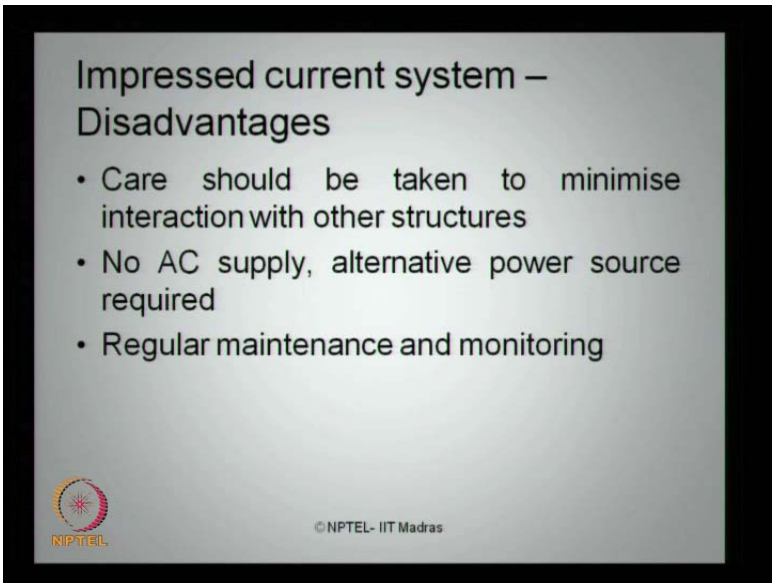

But, there are some demerits of the system, for example, intensive care should be taken to minimize the interaction with other structures, because it is uniformly available for larger protection surfaces, therefore interaction between the structural members in elements is also highly feasible in this kind of protection systems. No AC supply, only alternate power supply is required. Regular maintenance or monitoring is very important in this kind of protection system. Thank you very much; in the next lecture, we will discuss more about the corrosion protection techniques and the monitoring of them. We will also see this program in detail in the next module, where I will discuss about repair and rehabilitation of marine structures using advanced techniques.

Thank you.