Ocean Structures and Materials
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Module - 4
Lecture - 1
Non-destructive testing

In this lecture we will discuss about details on Non-Destructive Testing as applied to ocean structures and marine structures.

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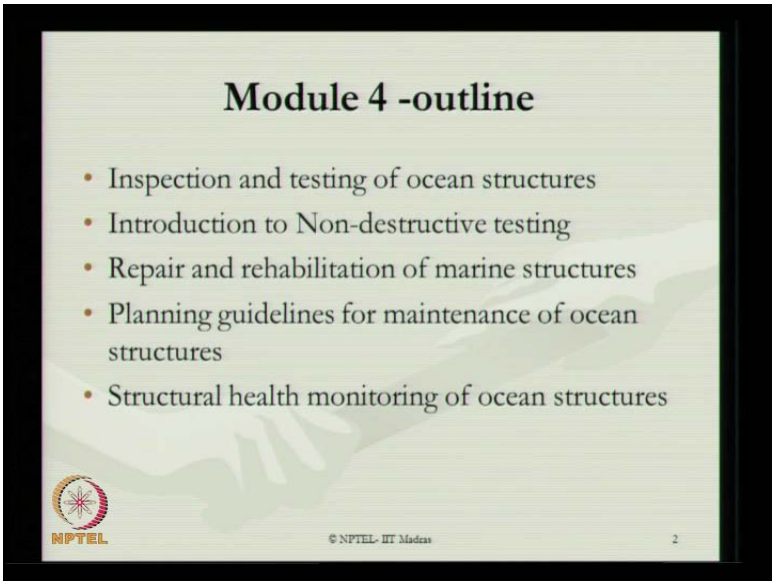

We will closely now look at the outline of module 4 of this course inspection and testing of ocean structures, we will cover introduction to non -destructive testing, we will talk about repair and rehabilitation of marine structures. We speak about planning guidelines for maintenance of ocean structures and we will also talk about structural health monitoring as applied to ocean structures in detail.

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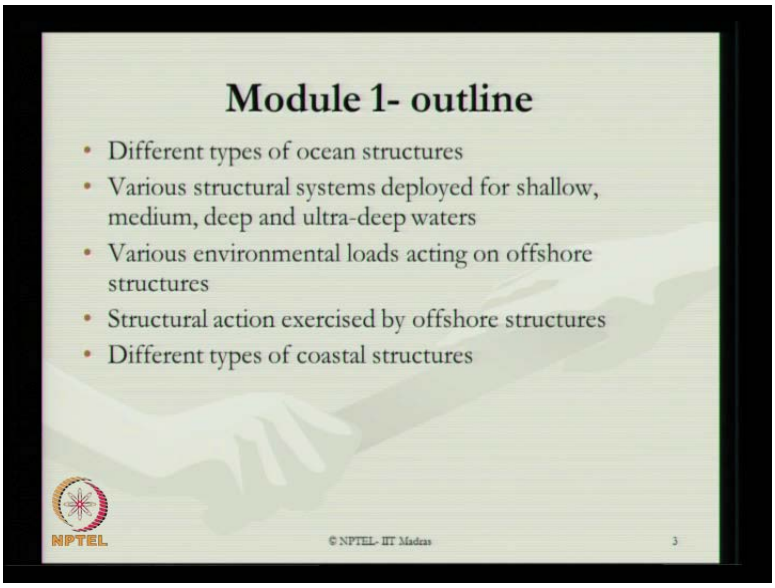

Just for the inference and benefit of the viewers, just review what we have done in the previous lectures. In module 1 we spoke about different types of offshore structures, we discussed various structural systems deployed for shallow, medium, deep and ultra- deep waters. We discussed various environmental loads acting on offshore structures, we also discussed about different structural action exercised by offshore structures, and we also discussed various types of coastal structures as applicable for the modern era.

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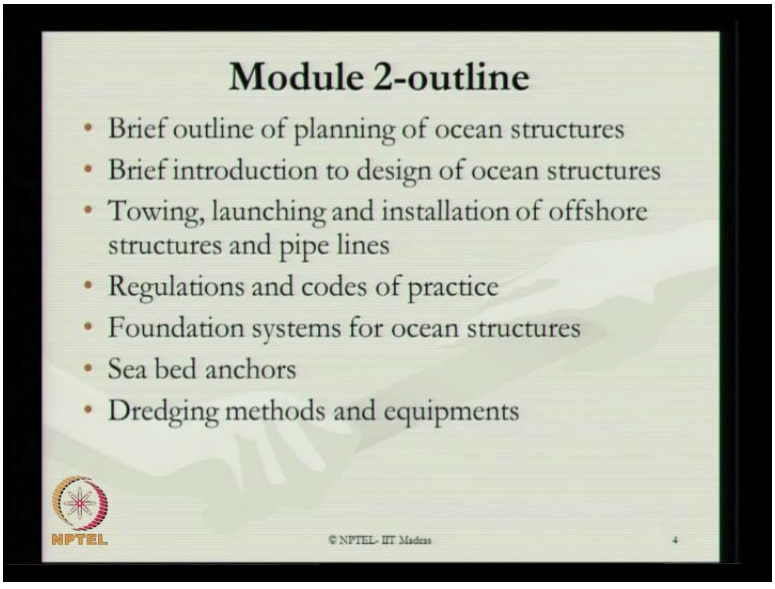

In module 2 we discussed and understood a brief outline about planning of ocean structure and a brief introduction to design of ocean structures. In this particular lecture we also discussed about levels of uncertainties involved and therefore, how to do the estimate and check the design adequacy for existing structural members. We discussed various construction methodologies involving, towing launching and installation of offshore structures and pipelines, with reference to these activities we discussed different regulations and codes of practice.

We also discussed in detail the foundation systems and seabed anchors for ocean structures, we had a very detail discussion on dredging methods and different equipments and various projects of dredging as applied in India.

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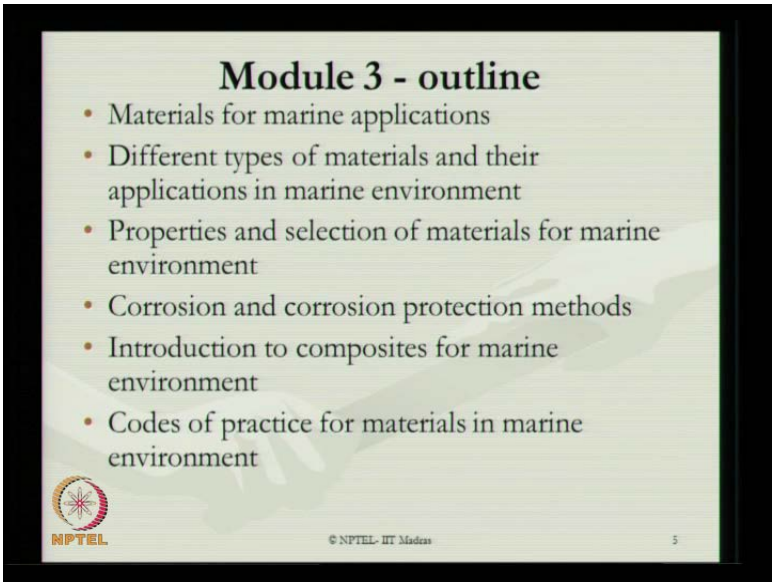

In module 3, we discussed about different materials for marine application, different types of material and their applications in marine environment, properties and how to select the material for marine applications. We discussed in detail about the corrosion as a process and corrosion protection methods, we also discussed about composites used for marine environment and in this practice of discussion, and we have also highlighted various codal provisions as available and applicable to design of marine structures especially in selection of material.

So, now ladies and gentlemen we are in the last module of this course ocean structures and materials in module 4 in lecture 1, we discussed about non- destructive testing. The moment I say non- destructive testing let us define NDT in a very conventional manner.

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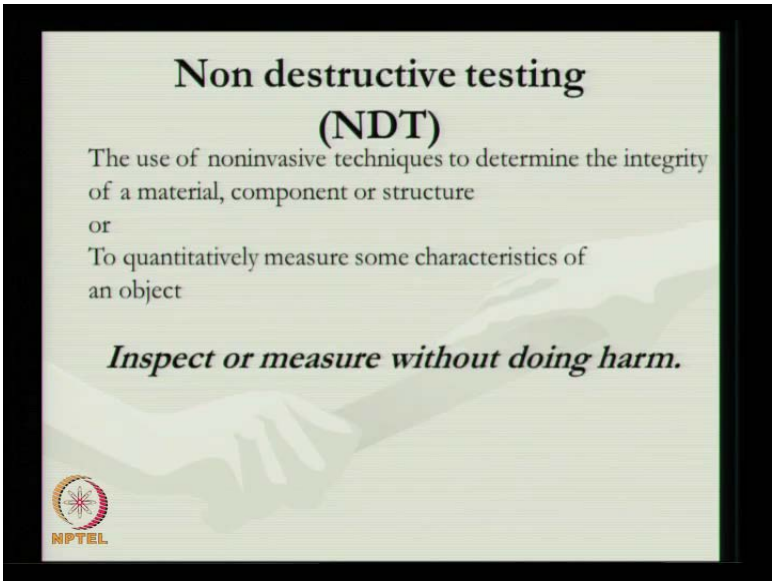

NDT is defined as the use of non- invasive techniques to determine the integrity of a material, component or a structure. Alternatively NDT can also be defined as a quantitative measure to measure certain characteristics of an object, the punch word as far as NDT is concerned is that inspect or measure without causing any harm to the structure.

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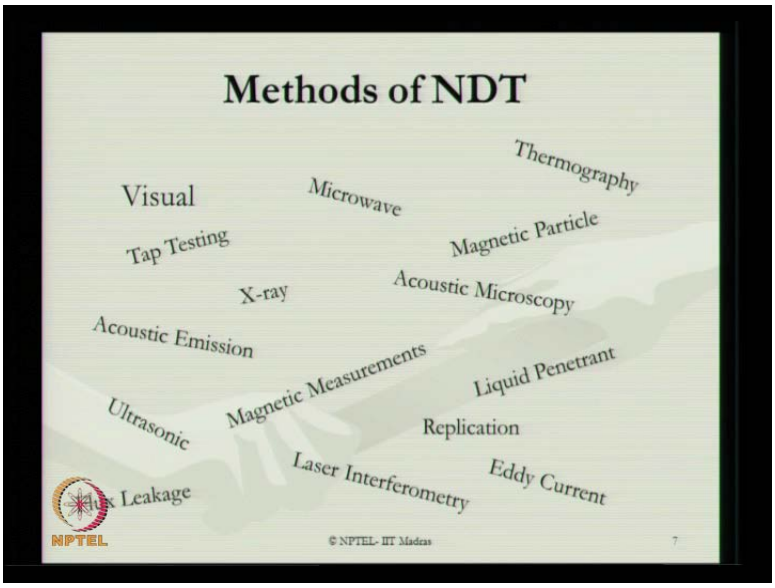

There are different methods of NDT as on today in the modern practice, varieties of methods are now discussed in the slide here. We have visual methods, we have microwave testing, thermography, tap testing, magnetic particle diffraction, acoustic microscopy, x-ray diffraction, acoustic emission, ultrasonic methods flux, leakage techniques, magnetic measurements, liquid penetrant methods, ray application methods, eddy current techniques and laser interferometry.

There are various varieties of methods available to inspect the offshore structures or any structural system without causing any physical harm neither to the material nor to the member.

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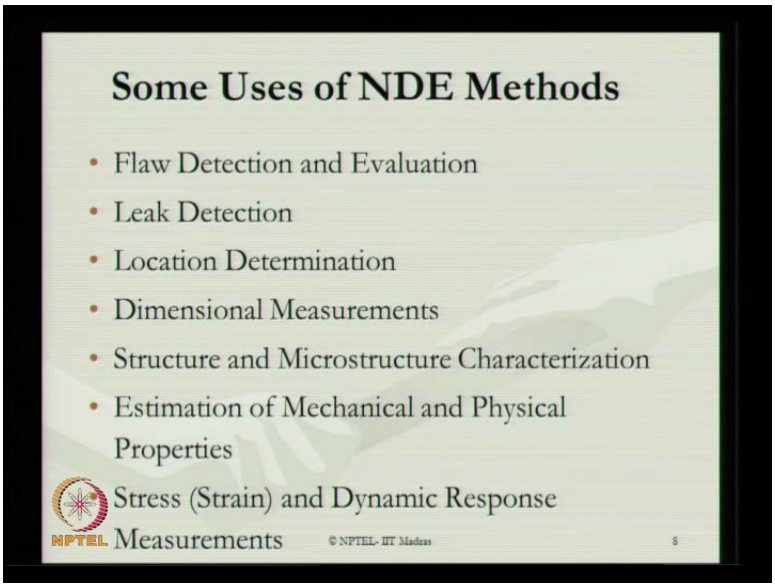

There are some classical uses of NDE methods, NDE stands for Non-Destructive Evaluation. For example, there are various uses namely, I can detect flaw and evaluate the flaw detection using NDE we can also detect leaks in any specific pipe lines we can also find the location determination. For example, where the cracks have been originated and where the leak exactly is happening in a given pipeline system, I can also do dimensional measurements, which are very important for estimating the corrosion resistance or the coating capabilities which are anti-corrosive agents applied in offshore members.

Structure and microstructure characterization of any given material can also be examined using NDE methods, estimation of mechanical and physical properties can be done well in advance and well reason methods in NDE. Stress strain measurements and dynamic response measurements can also be carried out using NDE evaluation.

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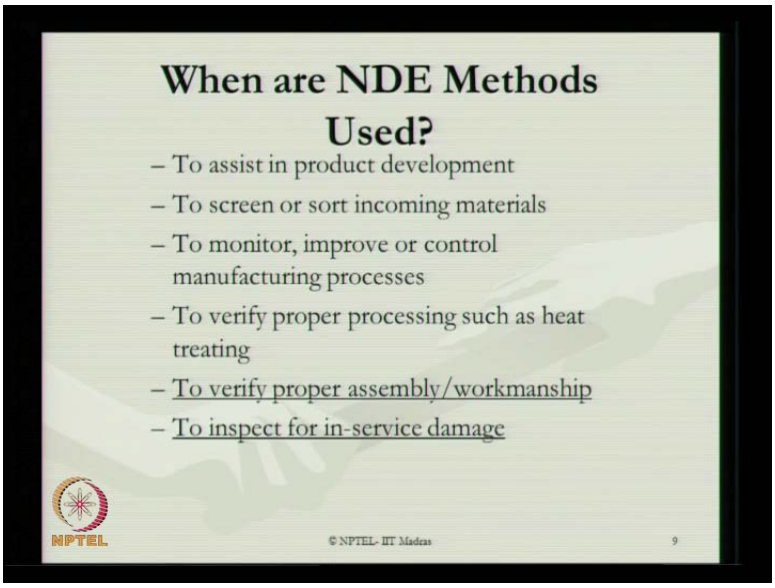

Now, the question comes when are NDE methods applicable to assist in product development to screen or sort incoming material in an inventory stage, to monitor improve or control, the manufacturing process. To verify proper processing such as heat treating as you understand ladies and gentlemen in offshore material, selection heat treating process is considered as an important stage based on which the properties and mechanical characteristics of the material used for marine application are listed in international codes.

For example, aprp2a NDE methods can also be used to verify proper assembly and workmanship, this is very important in the construction point of view for offshore structures. To inspect for in service damage where we talk about in service evaluation of structures for reliability estimates of marine structures, which is one of the recent demand as emphasized by international codes.

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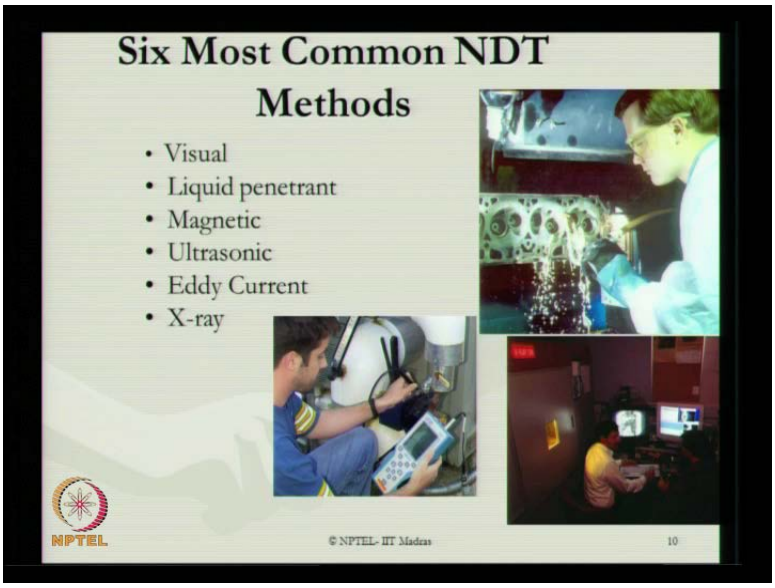

Let us quickly look at six most common NDT methods, which are commonly deployed visual method, liquid penetrant, magnetic method, ultrasonic, eddy current and x-ray diffraction are considered as six most common NDT methods valuable and applied in recent times.

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If you look at the visual inspection this is considered as one of the most basic and common inspection technique, tools used in this method are fibroscopes, boroscopes, magnifying glasses and mirrors. Robotic crawlers are also used, which can create or

measure observations in hazardous areas, such as air ducts, reactors and pipelines. So, I can use crawler, crawlers which are remote operated, which can be used for observations in hazardous areas, where human access is not possible.

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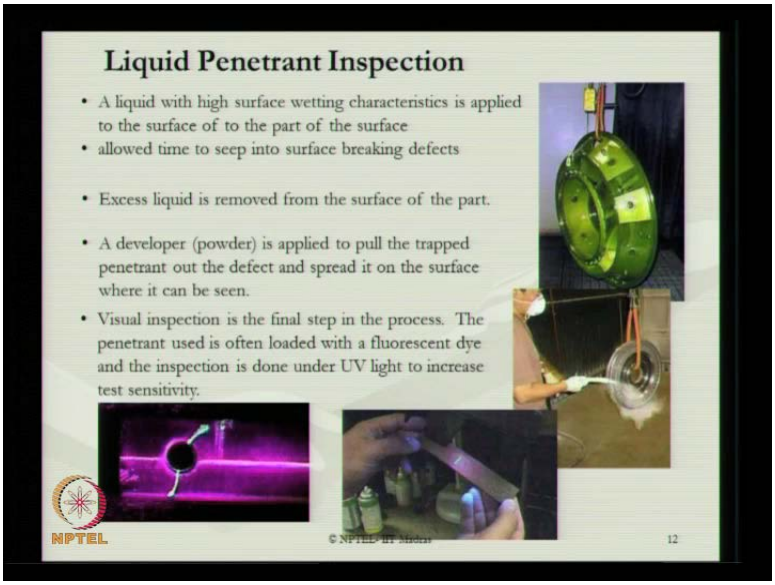

Liquid penetrant inspection is also one of the visual inspection methods which is also very advanced, a liquid with high surface wetting characteristics is generally applied to the surface or to the part of the surface. Time is allowed to seep into the surface which is showing to the breaking defects, and then successively excess liquid is removed and wiped off from the surface or from the part of the material. A developer which is nothing but the powder as you see in the image now is sprayed actually is applied to pull the trapped penetrant out the defect and sprayed on the surface, where it can be visually seen.

Visual inspection is the final step in the process, the penetrant used is often loaded with a fluorescent die, so that the color difference clearly shows the effect of leakage present or the detection present in the system; it is done under ultra violet light to increase the test sensitivity.

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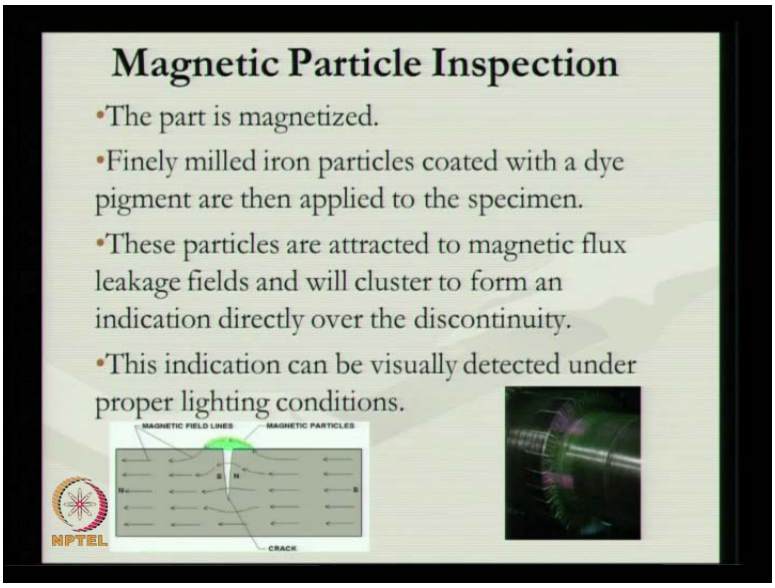

If we look at the magnetic particle inspection, the part is magnetized finely milled iron particles coated with the die pigment are then applied to the specimen. These particles are attracted to a magnetic flux leakage fields, I will cluster to form an indication directly over the discontinuity. This indication can be visually detected under proper lighting conditions as you see in the figure as well as the image which is being picturized.

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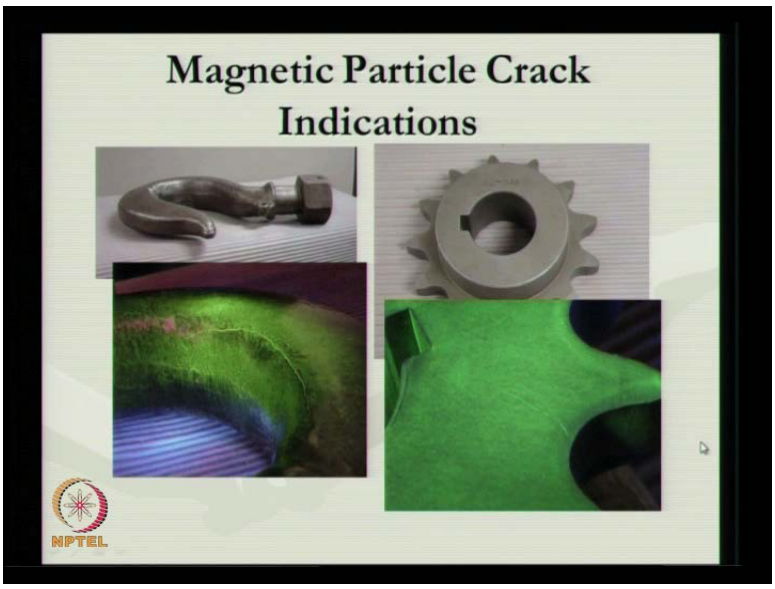

I can also do the crack indications using magnetic particle detection, we can see for example, look at the crane hook here, which is having crack detection is applied with the

fluorescent material. And the crack detection can be clearly and distinctly seen, because of this kind of inspection techniques.

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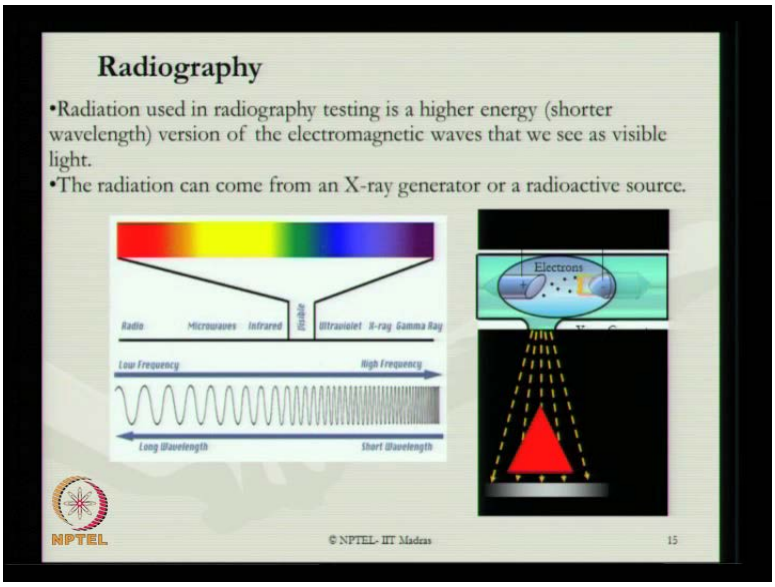

The other famous method which is used for NDE evaluation is radiography, radiation is used in the radiography testing, which nothing but a higher energy of a shorter wavelength of electromagnetic waves which we normally see as a visible light. The radiation can come from an x-ray generator or any radioactive source, as you see in this picture; this is a very common physical phenomenon which is applied to generate the radioactive waves which can be used for damage detection.

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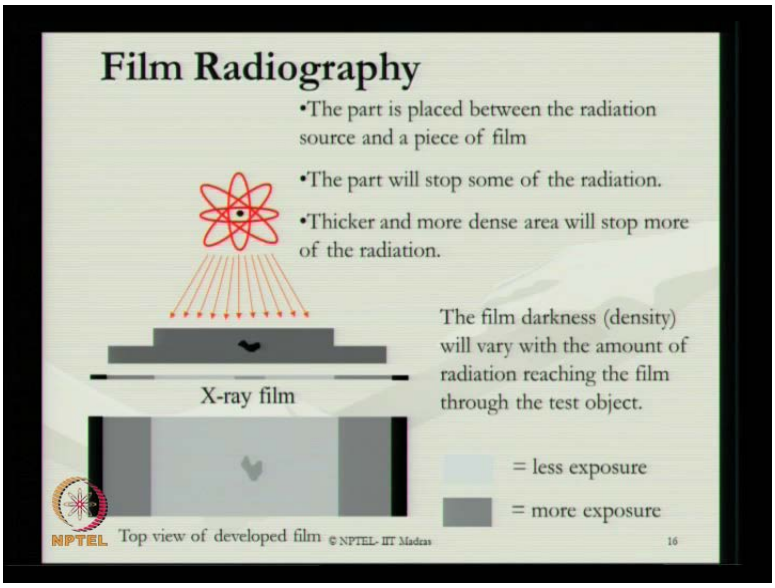

People also use what we call film radiography, the part is placed between the radiation source and piece of a film. We can see here this is my damaged part which I am interested in, this is my radiography source and this is my x-ray film, depending upon the part which is having some defect some sort of radiation will be trapped in the part. The thicker and more denser area will stop more of the radiation, depending upon the film darkness that is nothing but the density, which varies with the amount of radiation reaching the film through the test object, which depending upon; whether the test object is less exposed or more exposed I can easily detect the defect in a material.

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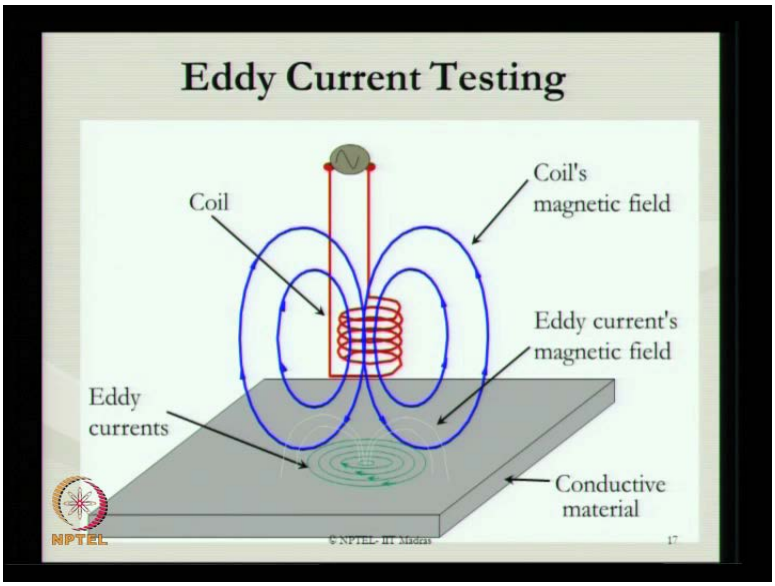

Eddy current testing is also another important method by which people use NDE evaluation, this is how the coil generates a magnetic field when the flux is created and the conductive material is placed in the part. And the eddy currents are developed which is shown in green color based on which the eddy current magnetic field is generated essentially used for NDE evaluation.

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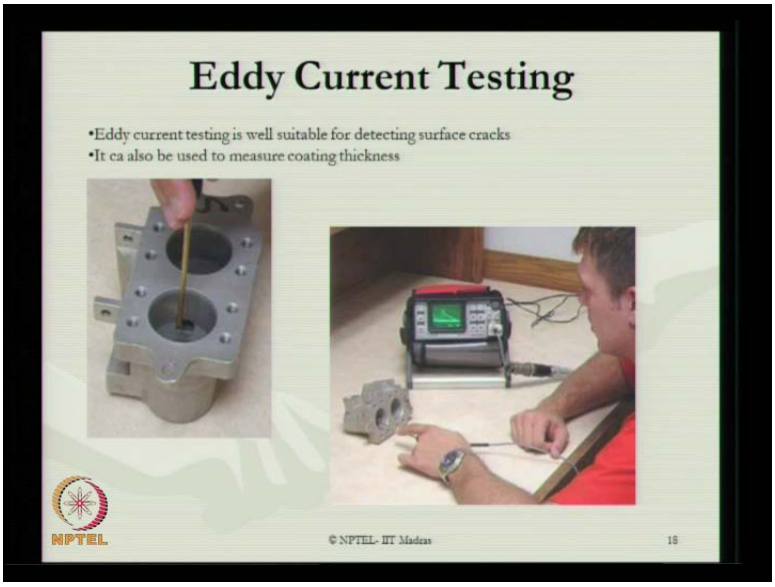

Eddy current testing is well suitable for detecting surface cracks, can also be used to measure coating thickness as you see in certain cases in the example shown in the slide.

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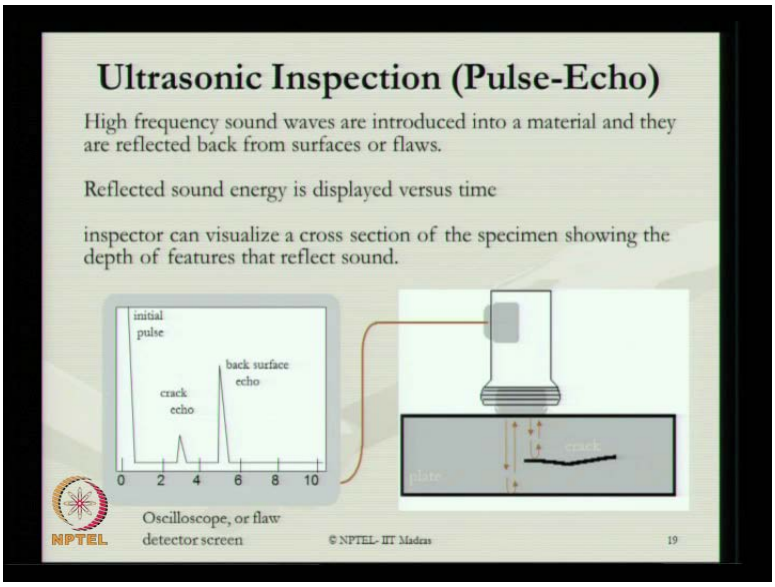

The other famous method used for NDE evaluation is ultrasonic inspection, which we also call as pulse eco. High frequency sound waves are introduced into the material and they are reflected back from the surface or the flaws. For example, let us have a plate material which is nothing but a thick plate is having a crack or a flaw, when the ultra sound waves are being inserted introduced in the material depending upon how they refract and reflect back and hit the time taken for the path of the light or the infra the ultra sound waves hitting the material.

One can easily plot and try to find out the crack eco location based on which depending upon the crack location, one can easily find out from the energy available on your plot, where is the crack located and how far or how deep is the crack from the surface using ultrasonic inspection. The reflected sound energy is displayed as a plot versus time and the inspector can visualize a cross section of the specimen showing the depth of the features that reflect the sound as you see in the figure.

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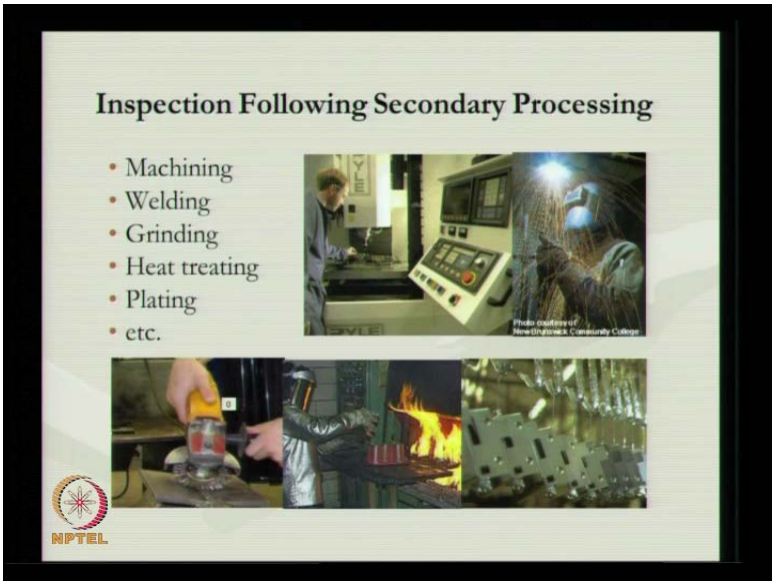

All these inspections are generally followed by secondary processing stages, like measuring, welding, grinding, heat treating and plating or electro plating etcetera.

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If you look at the inspection as one of the important objective for identifying in surface damage, inspection can easily identify in service damages related to cracking, as you see in the crane hook. Corrosion as you see in the plates and pipes and erosion and wear and tear of the material and heat damages, which is caused depending upon the flow temperature of the material inside the pipeline.

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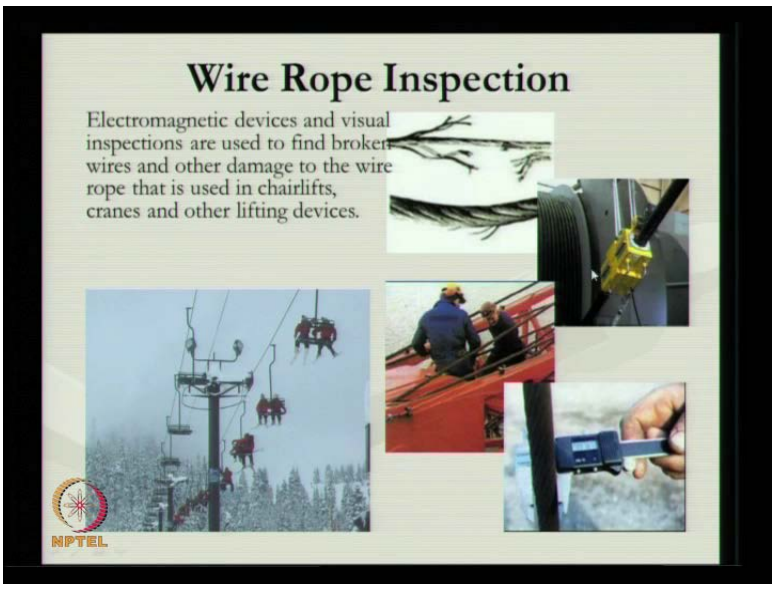

Interestingly, ladies and gentlemen, people have also used electromagnetic devices and visual inspections for identifying detection or fall in the wire rope by called wire rope

inspection. Electromagnetic devices in visual inspections are used to find the broken wires or other damages caused to the wire as you see in the picture here. Whenever there is a damage caused to the wire this can also be detected by an electromagnetic device this is very important, because in case of winches, in case of passenger travels, in case of moving teethers as far as offshore structures are concerned. Wire rope inspection plays a very important role for identifying the stability of the platform.

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In case of petroleum tankers, where we can also employ storage tank inspection. The robotic crawlers which you can see here are deployed on the surface of the tankers, which can use ultra sound techniques to inspect the walls of the large tankers for signs of corrosion or material loss and wear and tear. One can also place cameras on long articulated arms, which are used to inspect underground storage tanks for any specific damage.

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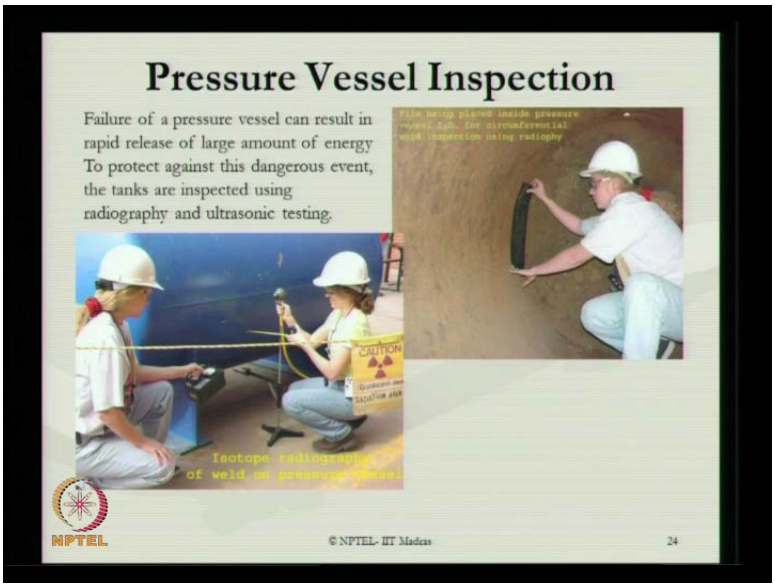

One can also use pressure vessel inspection; the failure of a pressure vessel can result in a rapid release or large amount of energy, which can cause catastrophic damage to the system. To protect against this kind of dangerous events the tanks are inspected using radiography and ultrasonic testing.

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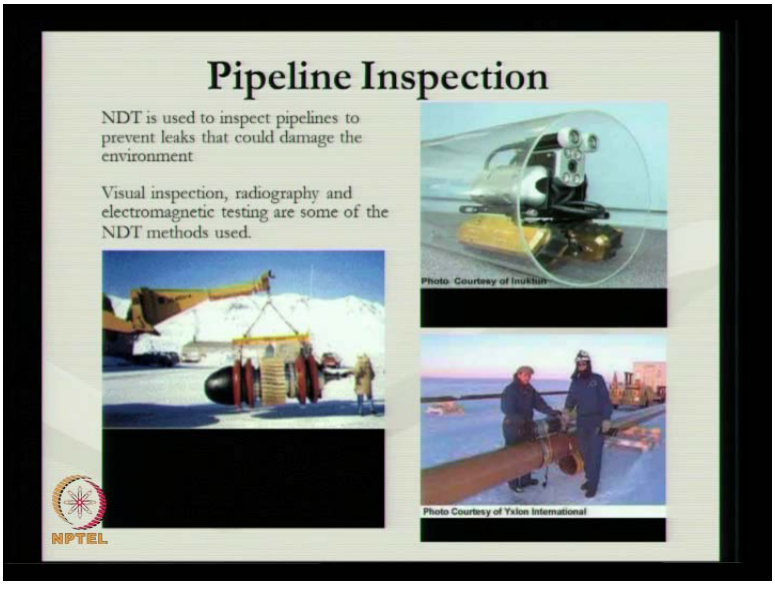

For pipeline inspection NDT has been used as a very common tool to inspect the pipelines to prevent the leakage that could damage the environment completely. Visual inspection radiography and electromagnetic testing are some of the NDT methods, which

are commonly used for inspecting pipelines, which carry fluid or oil at a high temperature and pressure.

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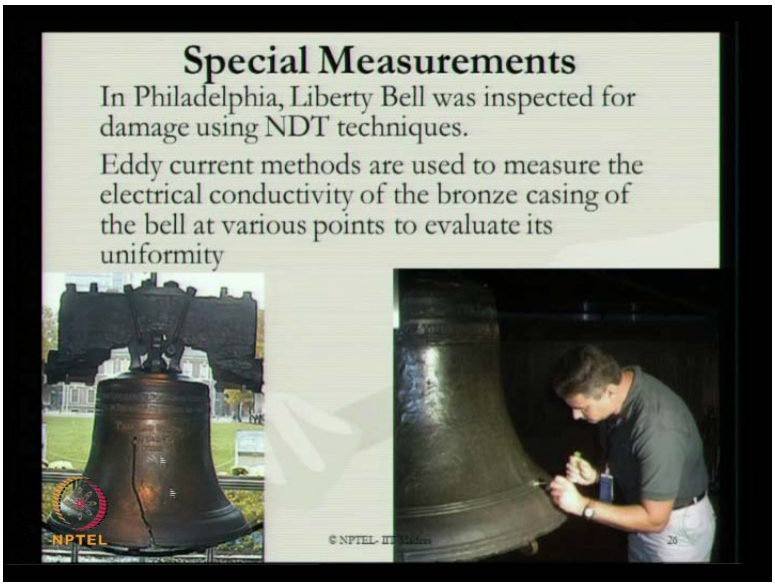

There are other special measurements, which are also deployed for example, in Philadelphia the liberty bell was inspected for a damage using NDT technique. Eddy current methods are used to measure the electric conductivity of the bronze casing of the bell at various points to evaluate it is uniformity of the casing. And ultimately they detected the ringing sound is affected because of crack formed them in the well and then they have done the repair to the specific kind of bell.

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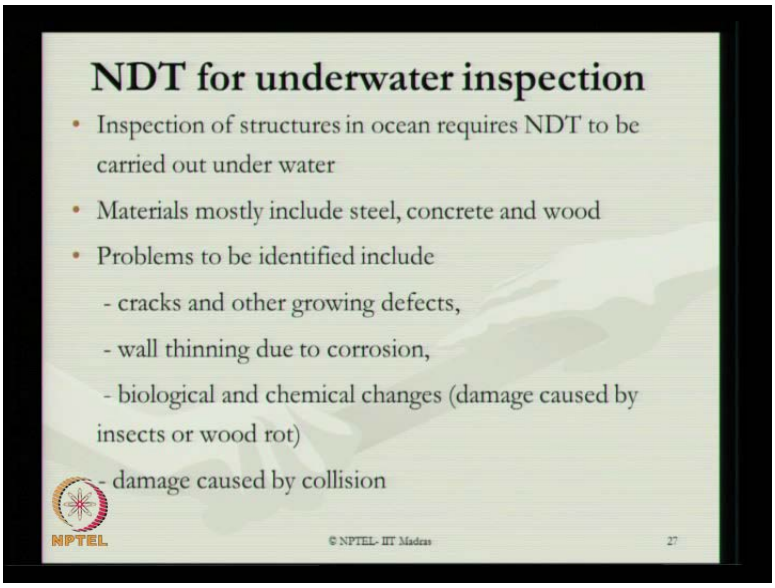

NDT, ladies and gentlemen, is also a very important technique which can be used for underwater inspection. Inspection of offshore structures in ocean require NDT to be carried out underwater, materials mostly include steel concrete and wood as far as ocean structures are concerned. Problems that are to be identified include crack and other growing defects which are formed on the material. Wall thinning which can occur due to the corrosion, biological and chemical changes which can result or cause a damage which is affecting wood or any rotten area or segment of the wood areas.

Damage caused by collision of ships and tugboats can also be identified, which generally happens at the water and n d t should be used for this kind of inspection.

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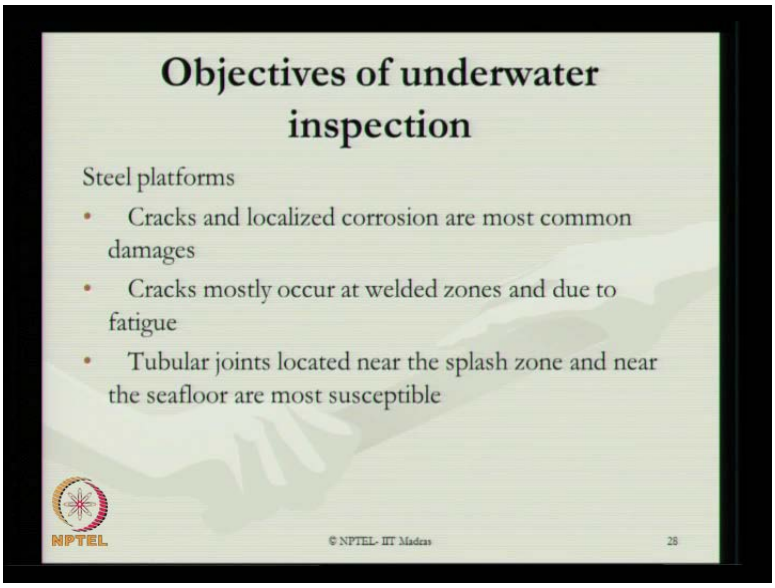

If you look at the primary objectives of underwater inspection, if you look at steel platforms when cracks or localized corrosions are most common damages, which are seen in steel platforms. Cracks mostly occur especially at welded zones or zones with high stress concentration factors, it can be essentially due to the fatigue, which can occur on the joints the tubular joints located near the splash zone and near the sea floor are more susceptible for this kind of faults.

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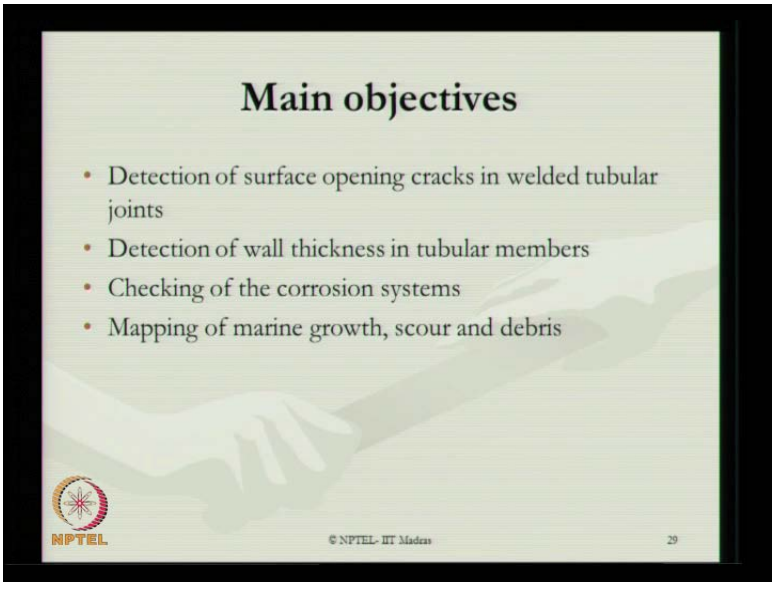

The main objectives of using NDT for underwater inspection could be detection of surface opening cracks in welded tubular joints, detection of wall thickness in tubular members, because thickness can always get compensated, because of corrosive environment present in sea water. Checking of the corrosion systems which has been deployed for example, cathodic protection systems, which has been used for corrosion protection measures which can also be checked using NDT.

The mapping of marine growth scour depth and debris can also be an additional advantage, which can be done using NDT evaluations for offshore structures underwater.

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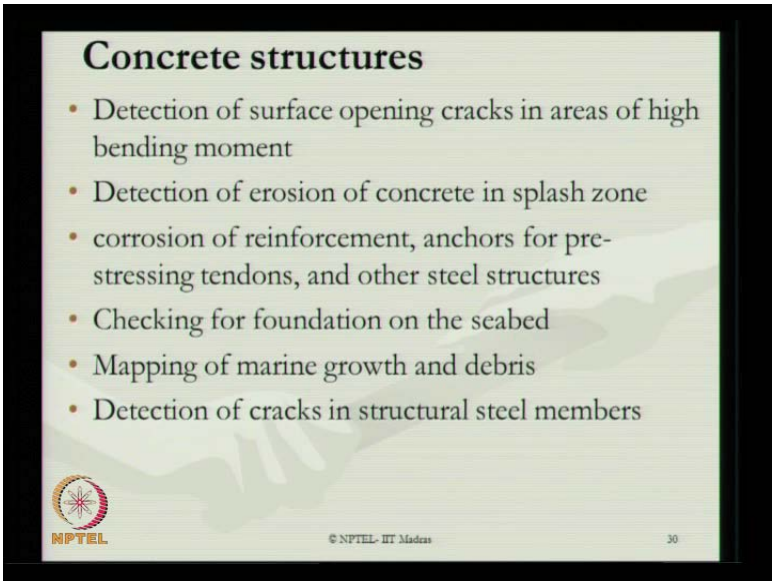

Ladies and gentlemen if you look at concrete structures or concrete as a material for offshore marine construction the detection of surface opening cracks in areas of high bending moment. Plays a very important role, because this gives way for corrosion to happen on the reinforcing bar of reinforcement concrete structures, especially when used in marine environment. So, detection of erosion of concrete in splash zone plays a very important role, because this gives the surface bleaching of concrete near this splash zone which will activate or initiate corrosion on the reebars.

Corrosion of reinforcement anchors for pre stressing tendons and other steel forms or elements or members of structures are also important to be identified in terms of their property or mechanical strength loss in due course of time, because of corrosive environment in marine structures.

Checking of the foundation on the sea bed plays a very important role, because the stability and position restrainment of the platform depends on how firmly they are hold to the seabed using different kinds of anchors, which you saw in the last module. The mapping of marine growth and debris plays a very important role if you really want to ascertain the strength loss or the corrosion thickness loss of any material, which is being used for marine application. Detection of cracks in steel tube members plays an important role to ascertain the (( )) strength of the members with respect to ageing of the material.

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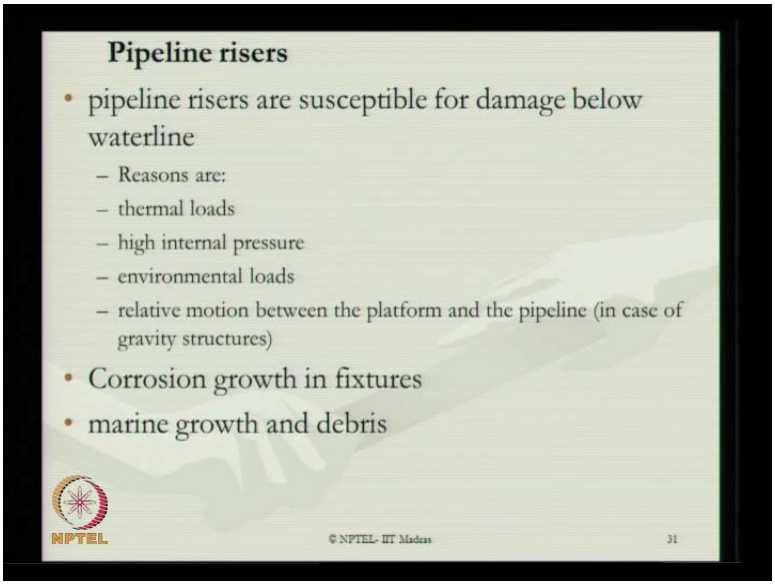

Now, NDT as applied to the pipeline risers also plays a very interesting area of domain of research. Pipeline risers are generally susceptible for damage below water line; the reasons are due to thermal loads, high internal pressure, environmental loads and relative motion between the platform and the pipeline in case of gravity structures. Corrosion growth in fixtures plays a very important criteria to be accessed for material, especially in case of joints. Marine growth and debris again becomes a very important area because they prevent access to inspection as well as NDT methods to be applied on buried pipelines in water.

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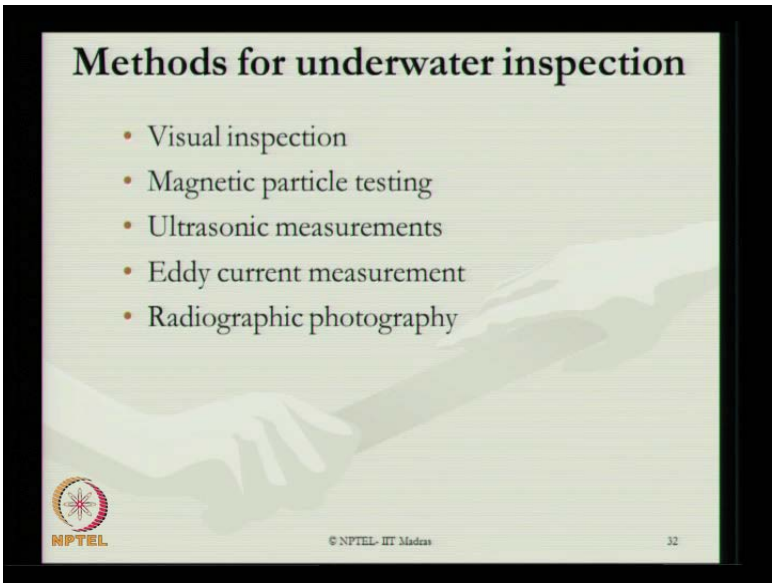

Look at the methods which are generally deployed for under water inspection, there are varieties of methods which are generally used for inspection of marine members under water. Visual inspection, magnetic particle testing, ultrasonic measurements, eddy current measurements, radiography photography are various methods which are commonly used for underwater inspection of marine structures.

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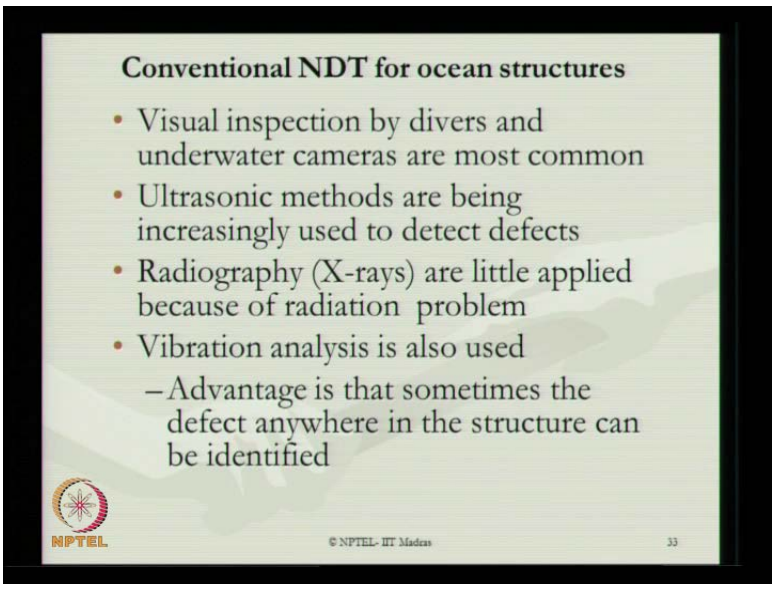

Now, one can also think of using conventional NDT for ocean structures visual inspection by divers and underwater cameras are most common methods employed for

creating visual inspection. And based upon that preliminary assessment of the members has been made, ultrasonic methods are been increasingly used to detect defects on the surface flaws of the members. Radiography what we call as x-ray diffraction are little applied because of the radiation problem, when they are used under water. Vibration analysis is becoming a very important technique which can also be used, because the advantage is sometimes they deduct they detect any defects in the structure in any location which can easy identified using this kind of analysis techniques.

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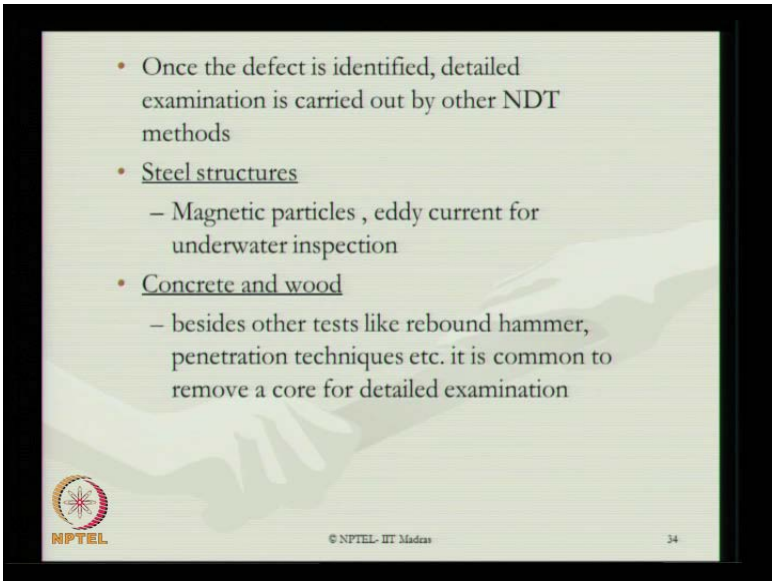

Once the defects are identified by visual inspection technique then detailed examination should be carried out by NDT methods. For example, in case of steel structures one can use magnetic particles, eddy currents for under water inspection and detection. For concrete wooden structures besides other stress like rebound, hammer, penetration techniques etcetera. It is also common to remove a core from the detailed examination then the core is examined for chloride diffusement etcetera to ascertain the (()) strength of concrete members underwater.

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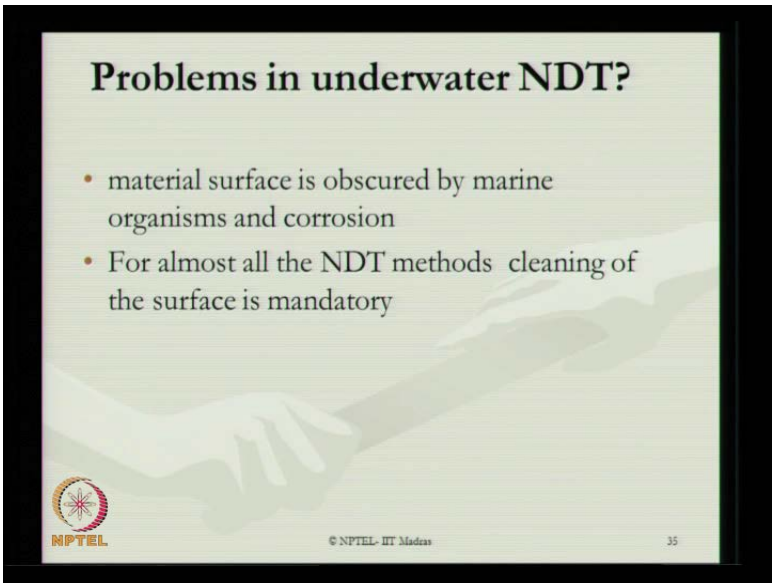

There are some problems associated with the NDT, when you carry out NDT underwater. Material surface is obscured by marine organisms and corrosion development products, which are formed on the surface of the member. So, these formations generally prevent and protect the members from accessing them for any inspection. For almost all NDT methods surface preparation is very important, cleaning of the surface becomes mandatory, if you want to successfully employ any of the NDT methods for members which are underwater.

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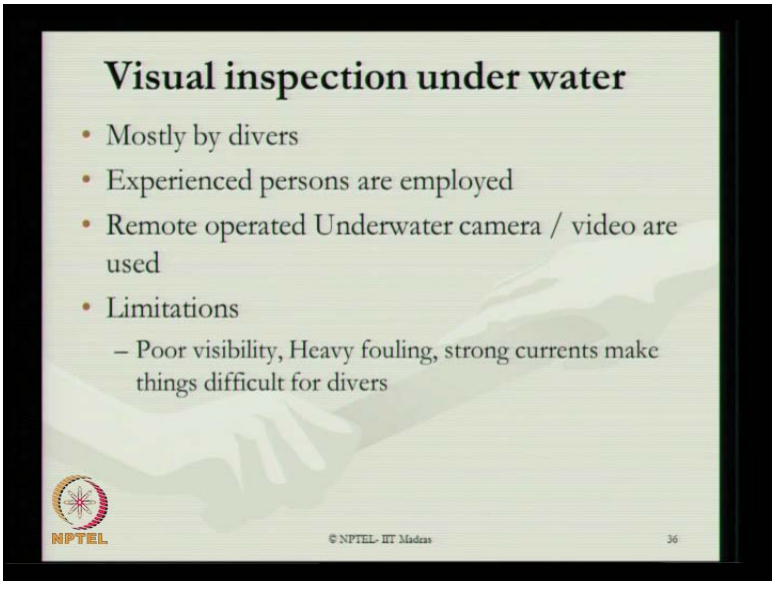

If we look at problems associated with visual inspection, which is done for members under water, mostly visual inspection is done by divers. Experienced persons are though employed remote operated underwater cameras and videos are also recently deployed for doing under water inspection of members. It has got of course, serious limitations because of poor visibility heavy bio fouling, strong currents makes the difficulty for divers to actually do inspection, the way in which the inspection should be carried out.

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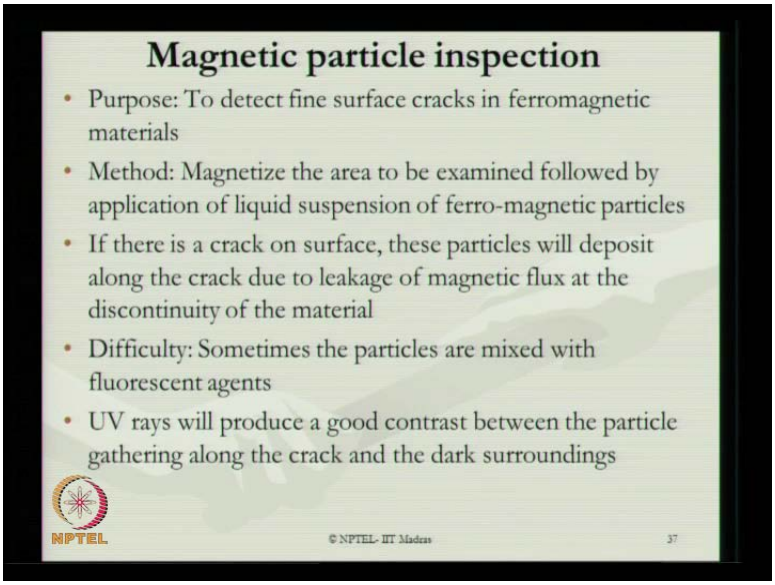

Therefore, people also do what we call magnetic particle inspection for members under water. The essential purpose of this kind of inspection is to detect the fine surface cracks in ferro magnetic materials. So, this can be applied only for steel structures, the method is very brief here magnetize the area to be examined followed by the application of liquid suspension of ferro magnetic particles. If there is a crack on the surface these particles will deposit along the crack due to leakage of magnetic flux at the discontinuity of the material where crack is formed.

Now, this method has specific difficulty sometimes the particles are mixed with fluorescent agents and you will not be able to identify the exact location of the physio of the crack on the surface of the material. Ultra violet rays will produce a good contrast between the particle gatherings, along the crack on the dark surroundings. And you can easily able to make out the difference between the areas which is cracked the area which

is having an external deposit, because of the fluorescent particle; however, the method has limitations as we discussed in this slide.

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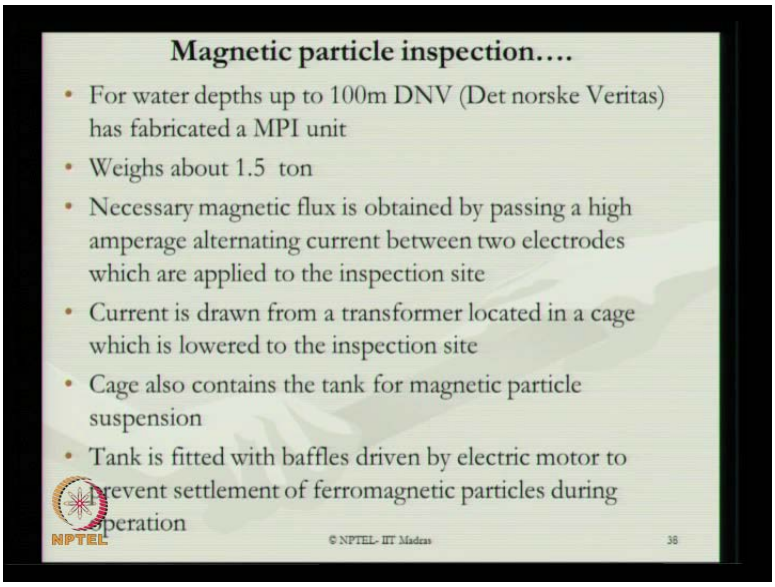

For water depth up to 100 meters DNV has fabricated as MPI unit, MPI stands for Magnetic Particle Inspection device. The device weighs about 1.5 tons the necessary magnetic flux is obtained by passing a high amperage alternating current between two electrodes, which are applied to the inspection site. Current is drawn from a transformer located in a cage which is lower to the inspection site; cage also contains a tank for magnetic particle suspension. The tank is fitted with baffles driven by electric motor to prevent settlement of ferro magnetic particles during the conduct of the experiment.

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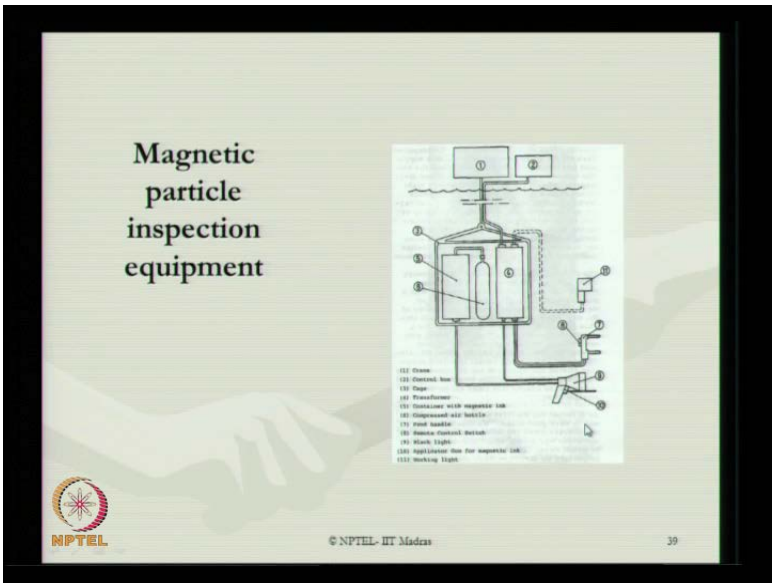

The model of the experiment or the device looks as you see here; the device has got different components. For example, the component number one is the crane which is located above water which is immersing the equipment under water. The part number two is a control box which is actually used to lower the equipment under water and also to control the measurements which are being made when the equipment is under operation.

The whole equipment is housed in a steel cage as you see part number 3, part number 4 is a transformer which supplies power for the execution of the experiment during conduct. Part number 5 as you see here is a container with a magnetic ink which is being used during detection, part number 6 is the compressed air bottle as you see here. And part number 7 is the prod handle which is actually used for detection, part number 8 the remote control switch which is controlled by a remote operated wiring done by the control station in component number two located above water.

Component number 9 is actually a black light which is being used to improve the visibility during inspection done by this kind of method and of course, part number ten is the applicator gun for magnetic ink. So, the magnetic ink which the fluorescent material is being sprayed using this particular gun on the material or on the member under water, which can then be easily able to locate the flaws or surface cracks on the member or on the material.

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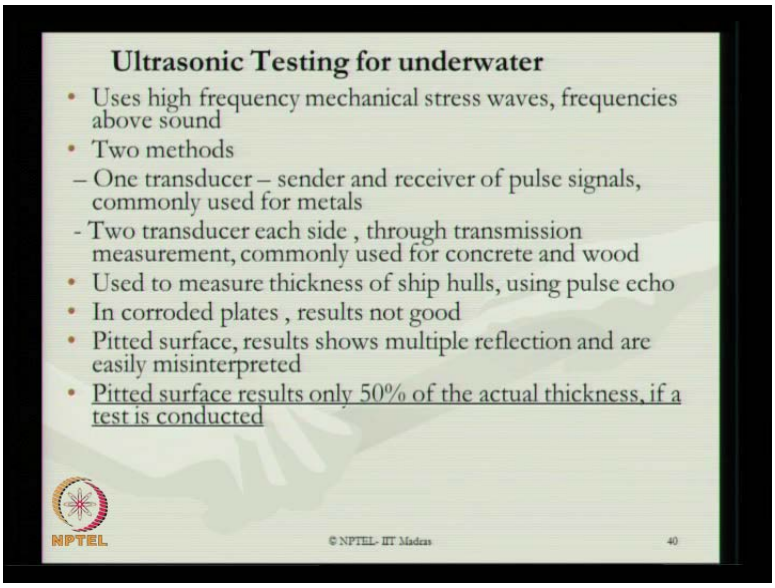

If you look at ultrasonic testing which is a method to be used for members under water. This uses high frequency mechanical stress waves, frequencies which are above sound frequencies. There are two methods by which this can be carried out the first method is a transducer based method where the sender and receiver of pulse signals, which are commonly used for metals being deployed for measuring the ultrasonic waves.

The second method is using two transducers side by side, through transmission measurements commonly this is being employed for concrete and wooden members or wooden structures. This technique is used to measure thickness of ship hulls using pulse echo method, in corroded plates when you apply this kind of method the results are not encouraging as you see from the literature. The pitted surface the results show multiple reflection therefore, they are wrongly interpreted with the help of the results produced by this kind of method.

The pitted surface results only 50 percent of the actual thickness and therefore, this method is not effective for pitted surface as you see from the literature.

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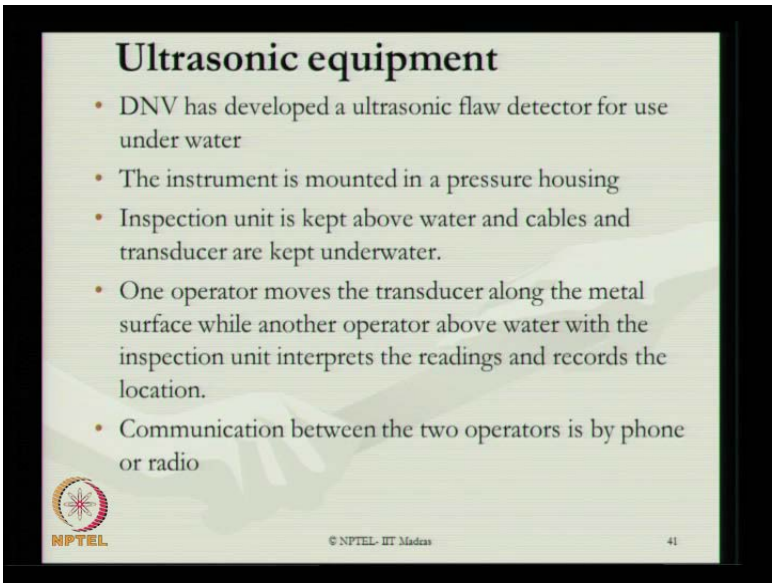

Look at the ultrasonic equipment DNV is again developed an ultrasonic flaw detector for using them under water. The instrument is usually mounted in pressure housing, the inspection unit is kept above water and the cables and transducers are kept under water. One operator moves the transducer along the metal surface while another operator above water with inspection unit interprets the reading.

So, there are two transducers, one transducer with the diver is moved along the surface of the member. And the corresponding next transducer is held by another person above water based upon the difference of the signals generated by these two transducers as the flaws are detected on the surface of the member; the communication between two operators is either by phone or by a radio.

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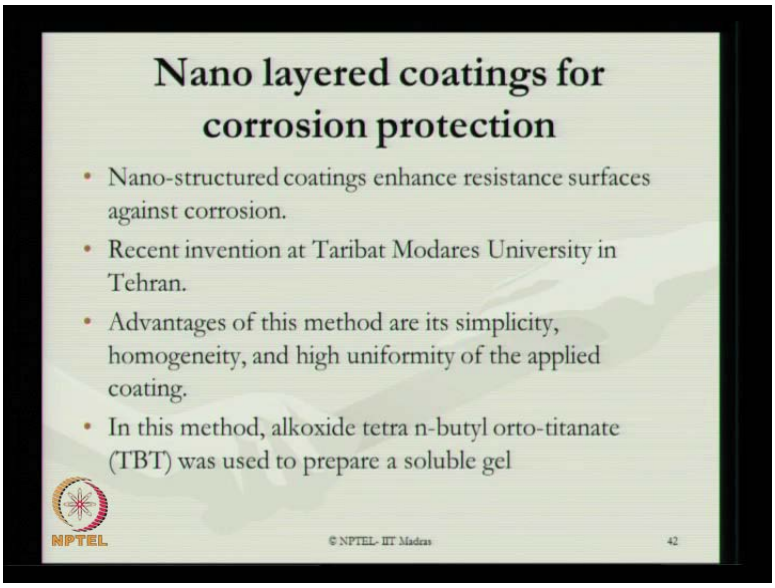

If you look at corrosion protection measures then we have got an interesting application which is one of the recent research being done using Nano layered coatings for corrosion protection. Nano structured coatings generally enhance resistance surface against corrosion, recent invention has been done in Taribat Moderas University in Tehran. The advantages as claimed by the researchers method are it is simplicity, homogeneity and high uniformity of the applied coating. In this method alkoxide, tetra butyl ortotitanate what they form as TBT was used to prepare a soluble gel.

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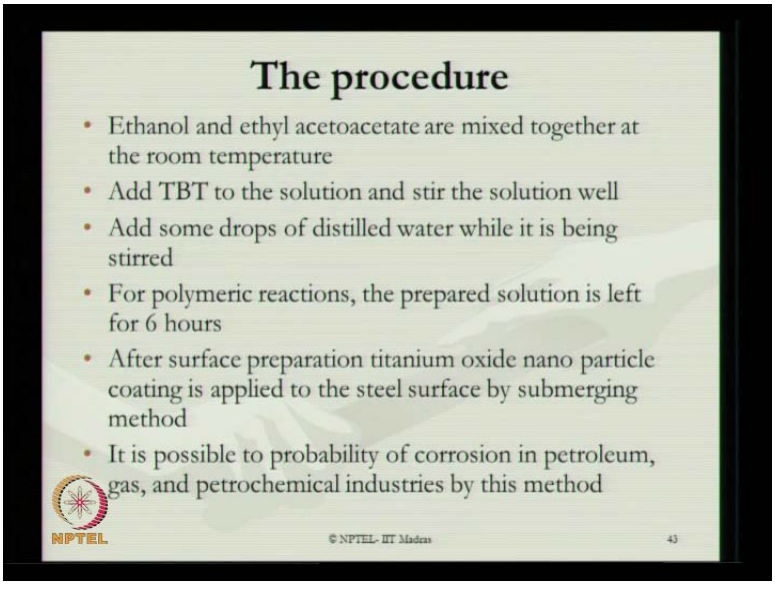

The procedure is explained in detail in this slide here, ethanol and ethyl acetoacetate are mixed together at the room temperature. Then add TBT to this solution and stir the solution well. Add few drops of distilled water when the stirring is being done for polymeric reactions to occur the prepared solution is left for 6 hours to settle after the surface preparation the surface as got to be cleaned. After is being prepared titanium oxide Nano particle coating is applied to the steel surface by submerging technique, it is possible to probably reduce the probability of corrosion by this method in petroleum and gas pipelines and of course, in petro chemical industries using this method.

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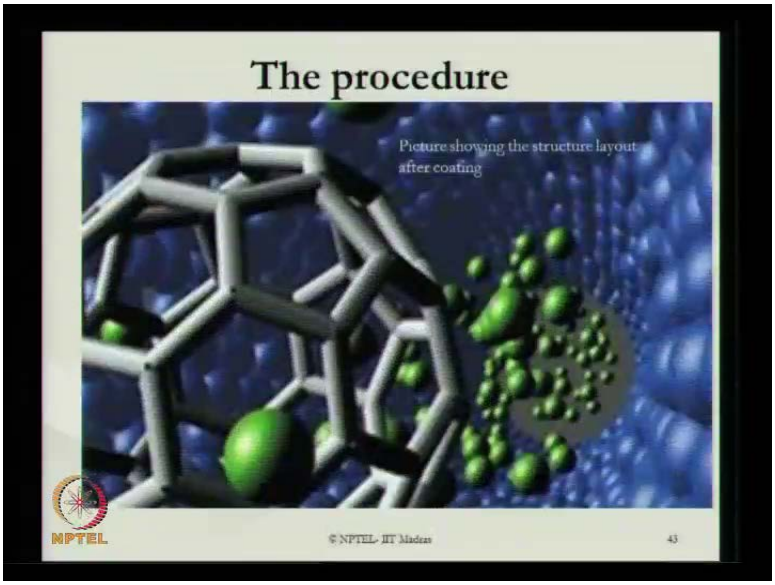

So, the picture shows here how the structured layout will be seen after the coating is applied on the member. So, ladies and gentlemen in this lecture we introduce you different kinds of non -destructive testing and non- destructive evaluation in general how they are applied and in particular how they are been applied for under water. What are the problems associated with the NDT methods as applied to members under water, we have also seen the recent invention of corrosion resistance as a Nano layered coating which can be applied on members.

Thank you very much.