Cathodic Protection Engineering
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Lecture – 06
Cathodic protection engineering: Assessment of pipeline condition through surveys: Part-II

Welcome to the Cathodic Protection Engineering lectures. As you have seen that, assessing the corrosion condition of buried structures is an important part of cathodic protection engineering.

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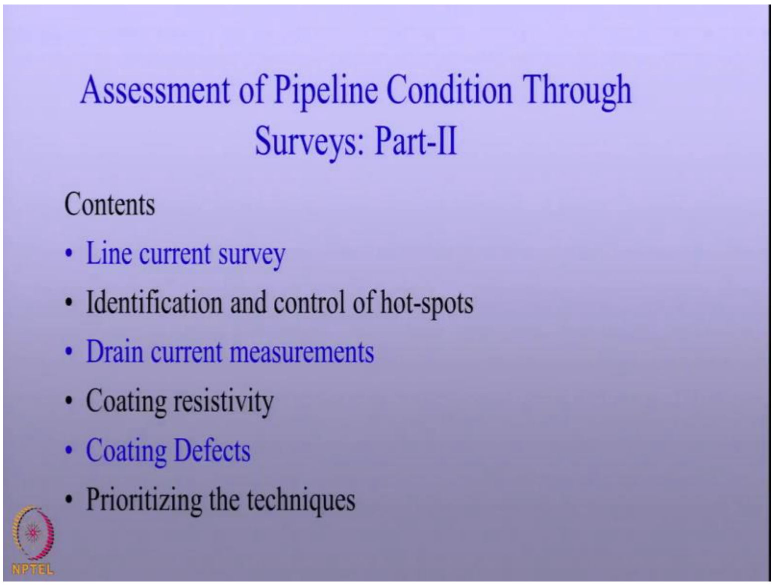

In the last lecture, we started the part I of how to assess the pipeline condition; today we will looking at the part II. In the last lecture, the two important techniques the pipeline pipe to soil potential. In the last lecture two important techniques we discussed; one the soil resistivity, the other pipe to soil potential. In this talk, we will look at the following; one is the line current survey followed by that we will look at how to identify hot spots in the pipelines.

Then we will go onto discuss drain current measurements, coating resistivity, coating defects and then we will end this lecture on how to; then we will end, then we will end this lecture on how to prioritize the techniques.

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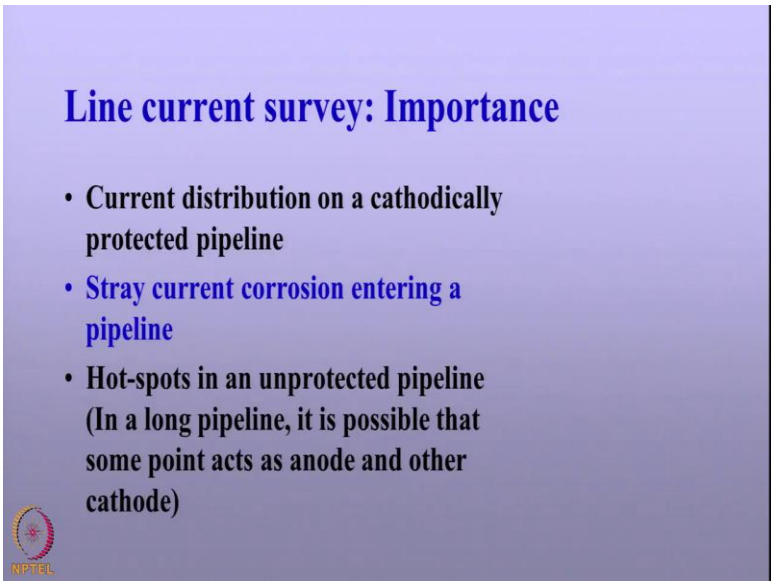

Let us start with discussing the line current. The line current is very important with respect to cathodically protected pipelines as well as unprotected pipelines. The current distribution in a cathodically protected pipeline decides how effectively the cathodic protection is done for a particular pipeline.

In addition to this, the stray current corrosion we have seen earlier is an important problem in pipelines. Line current measurement could enable us to identify the location, where the stray current corrosion occurs. In the unprotected pipelines there are specific areas where the pipeline suffers severe corrosion, they are called as hot spots.

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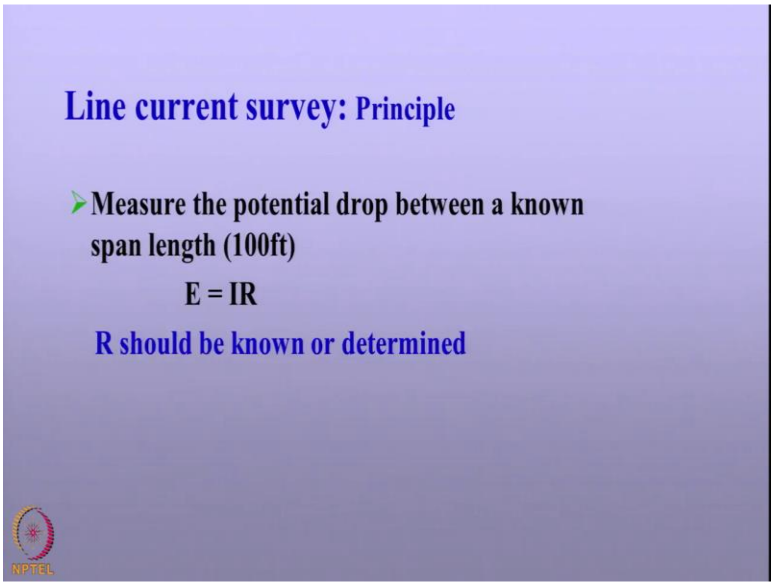

Line current measurements is based on a simple principle of Ohm's law. If one measures the potential across a known segment and if the resistance of the pipeline is known; then it is possible to measure the current flowing in that particular segment. Typically, about 100 feet length of the pipeline is selected for measuring the pipeline current. Line current survey there are two types of techniques; we shall look at the line current survey has two techniques, we shall look at these two techniques in detail.

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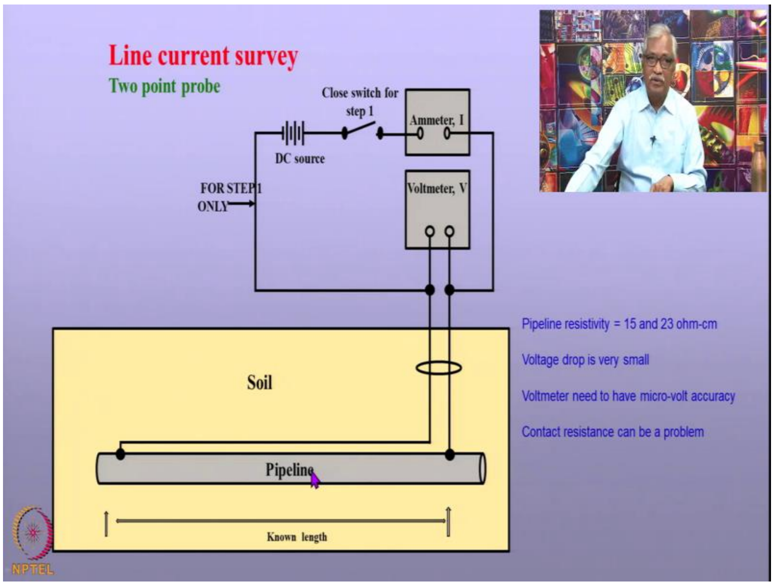

The first technique is two point probe, it is relatively simple. What is shown is the circuitry to measure the line current in a pipeline. It involves measuring the potential across a known segment of the pipeline length, you see here and normally one uses a milli voltmeter in order to measure the potential drop that occurs on the pipeline, because of the flow of current. If the resistivity is known, then it is possible to know what is the current flowing in the pipeline.

However, the resistivity of the pipeline is not known; then you add additional circuitry, wherein initially a known amount of current is passed through these two points using a DC source. And at the same time, one measures the voltage; when the voltage is measured and for a known current, it is possible to estimate the resistance offered by the pipeline in this segment.

Generally, the pipeline resistivity lies in the range of 15 to 23 Ohm's centimeter has a consequence; the voltage drop in the pipeline is considered to be significantly less. So, the voltmeter must have a resolution in terms of micro volt. In the two point probe technique, there is a problem; the problem is of contact resistance, these contacts can significantly add to resistance measured in the measurement. So, that is one of the disadvantage of the two probe technique.

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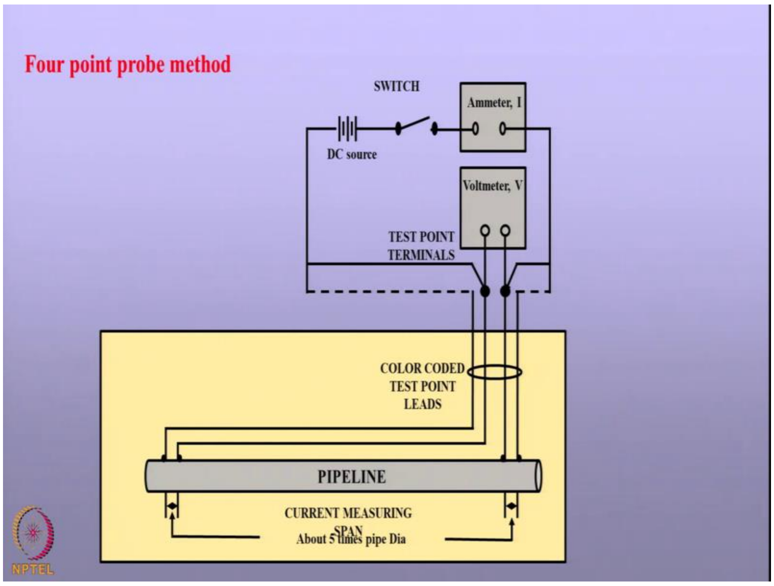

In order to overcome this, a four probe technique is used. The four probe technique, we have four probes you can see here right. And through the external probes, the current is passed, a known current is passed and the through the internal probes, the potential is measured. Since we know the current, since we know the voltage; a resistance of the pipeline is measured accurately. In this case, there is no need to have to know the resistivity of the pipeline. So, this technique is advantages as compared to the two point probe method.

So, far we looked at three important techniques involved in surveys; one is the pipe to soil resistivity, pipe to soil potentials, and the pipeline current. We shall see how these surveys can be utilized to assess the pipeline condition.

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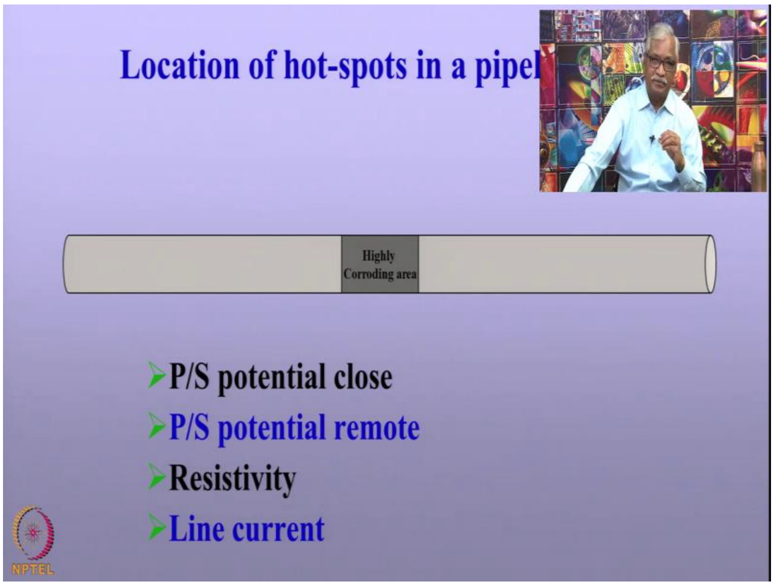

First let us take the example of how you apply this technique to hot spots in a pipeline? When you use this techniques to locate the hot spot in a pipeline? Before we talk about how we employ this techniques to detect the hot spots; let me first describe what is mean by hot spots. In a long pipelines over a small regions, the pipelines is expected to corrode at a higher rate as compared to remaining areas, as a consequence of say difference in side resistivity or some other reasons.

So, the highly corroding areas are rendered as the anodes, the other areas are rendered as a cathode. The current flows between the anode and the cathode; the current leaves this anode here and then goes to the cathode and then current flows through the pipelines. So, these are buried pipelines, they are not cathodical protected. So, let us see how you can locate this segment of the pipeline that is experiencing severe corrosion.

We can use three techniques; pipe to soil potential, resistivity, and the line current measurements. And we also know that the pipe to soil potential there are two types of pipe to soil potential measurements; one is the pipe to soil potential close, other is pipe to soil potential remote.

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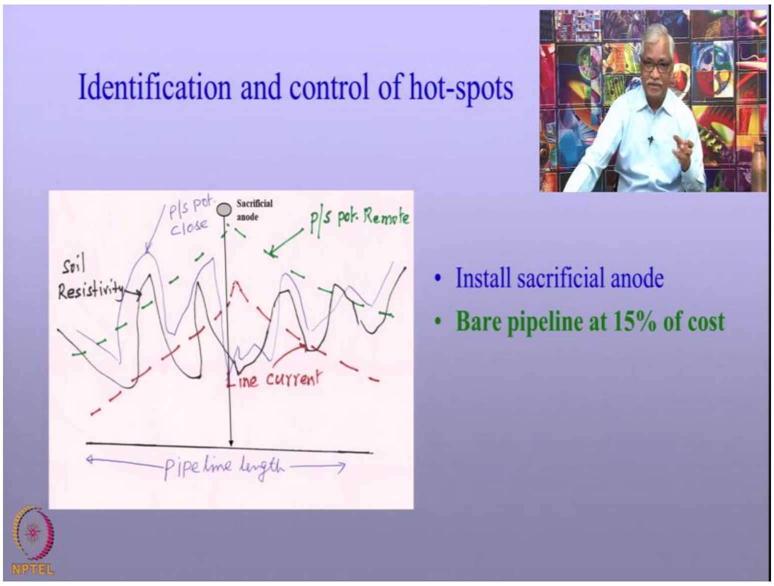

What I am going to show you is, a schematic of the measurements made over a pipeline segment. The data corresponding to pipe to soil potential remote. What you see here? How it is changing and the pipe to soil potential close? You can see how the pipe to soil potential close is varying in a very irregular manner, you can see this here.

And the line current, the line current varies in very systematic manner; you can see there is raise in the current over a distance and then that current really falls. As suppose to again line current, the resistivity where easily very irregular manner; it is expected, local soil may have different soil chemistry and as a consequence the soil resistivity really changes. But overall you notice that at these location, the pipe to soil potential is relatively positive; I mean the pipe to soil potential remote is positive.

And we also see that at this location, the current leaves the pipeline; the current is higher, it leaves the pipeline here. So, this location corresponds to the hot spots. So, the pipeline at this location will experience a more severe corrosion in relation to the remaining segment of the pipeline. So, it is possible to identify hot spots using the three parameters; pipe to soil potential remote, the pipe to soil potential close, soil resistivity and the line current measurements. All these parameters can be used to look at where the pipeline will undergo severe corrosion.

The advantage of this technique is these structures are buried. So, all these measurements are made above the ground. So, that is real advantage of using these techniques. So, how to control this? One way to control is install a sacrificial anode at the location of the hot spot and you may theoretically connection to the pipeline. With this it is possible to protect the pipeline from severe corrosion by just spending 15 percent of the overall cost of cathodic protection of the pipeline. So, that is a real advantage of using multiple surveys.

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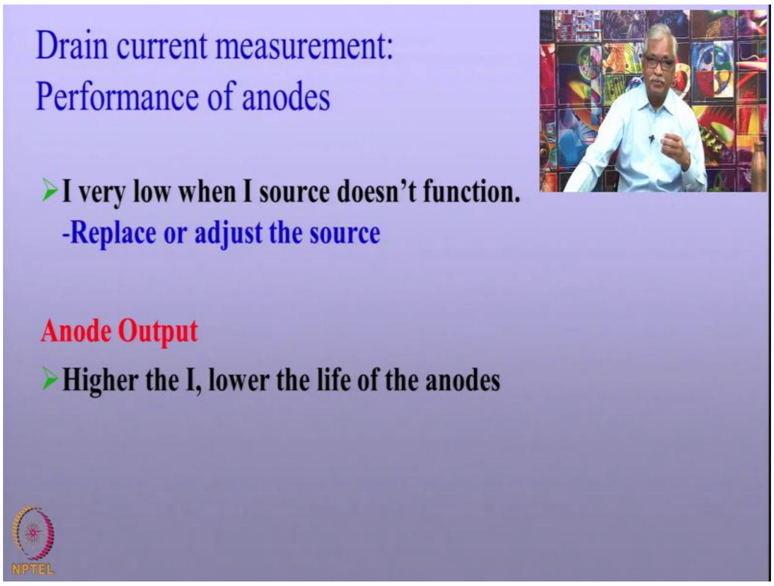

Then we move on to the next technique, the drain current measurement technique; this technique is primarily used to determine the performance of the anodes. We all know that the anodes are the source of current, the anodes they disperse the current in the soil; from the anode, the current goes into the soil and through the soil, the current enters the pipeline, the cathodic protection of the pipeline is happening.

Now, how do we know, how do you determine whether anodes are really functioning or not? Is to determine the current that is showing from the anode to the pipeline and this current is called as the drain current. Notably, if the anodes pass high current, especially their sacrificial anodes; lower the life of these anodes. So, it is necessary to periodically determine the drain current measurements.

The drain current measurements become very important, when one notices that the pipeline is not adequately protected cathodically in the potential drops below minus 0.85 volts. One of the reason could be that, the drain current in the anodes are not properly, are not adequate, the anodes may not properly functioned; either the resistance of the anodes are gone up or the anodes have broken, in either case that anodes low the capacity to dispense current in the soil.

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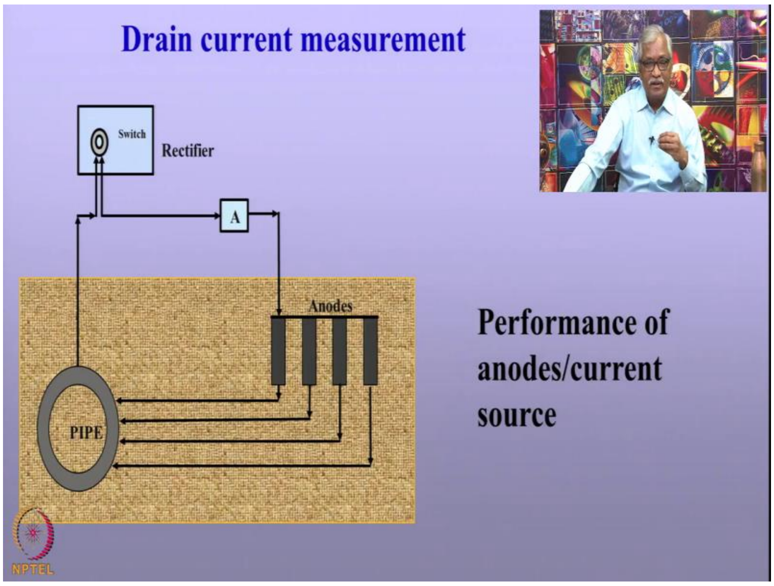

The technique used to measure the drain current is relatively simple; to insert an ammeter in series in the circuit as a note, here is a pipeline that is a stray station you can see.

It is rectifier in the case of impress current system; if it is a sacrificial anode systems, you do not have a rectifier, you need to connect the ammeter in series between the pipeline on the anodes and the current is so measured. So, the current so measured gives indication about the performance of the anodes or if the anodes have increase the resistivity.

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Let us move on to the next important topic of determining the quality of protected coatings in a buried pipelines or buried structures.

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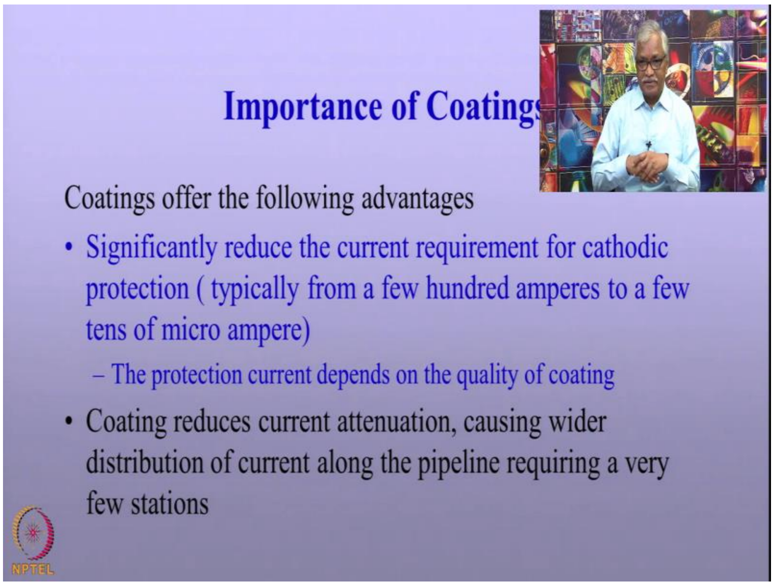

If you look at typically the cathodic protected; if you look at typically the cathodically protected structures, they are almost all of them are painted. Typical cathodic protection structures are coated with high performance paint coatings; because these coatings when they apply, can bring down the current required for cathodic protection from a few hundred amperes down to a few tens of micro amperes. However, the protection current depends upon the quality of the coatings.

In addition to reducing the current required for cathodic protection. Coating also reduces the current attenuation, causing a wider spread of current along the pipelines requiring a few stations.

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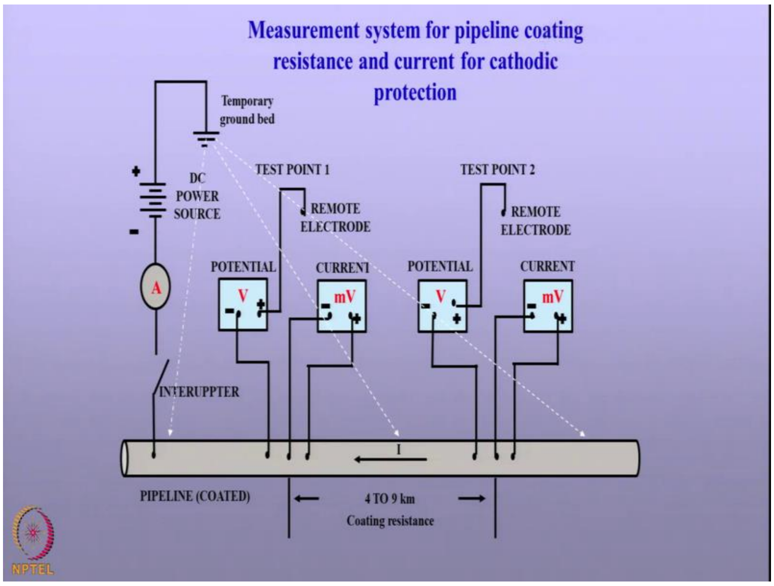

This is a typical set up that is used to determine the current; this is a typical set up used to determine coating resistance. If one has to measure the coating resistivity across a node segment of the pipeline, let us say about 4 to 9 kilometers; one requires a temporary ground bed to pass a current in a DC current source and they are connected to the pipeline through in an interuppter.

The current that is passing along the pipeline at these two locations are measured using potential drop, using a milli voltmeters. The pipe to soil potential at these locations are measured using a copper, copper sulphate electrode. This is the typical arrangement required to measure the resistivity of the coating in a buried structures.

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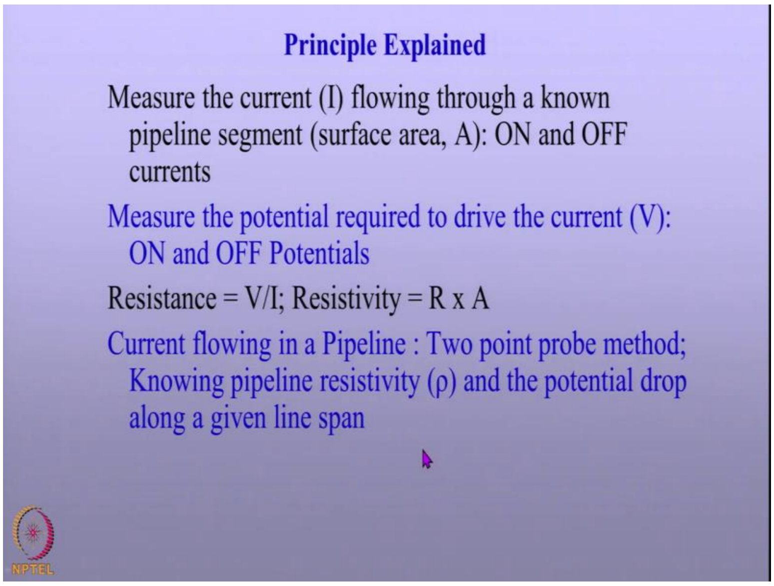

The principle involved in measuring the coating resistivity is very simple; one measures the current flowing in the node segment of the pipeline of say known area of A for example, the current is measured when the cathodic protection is turned ON and when is turned OFF. The difference gives is the current require, current that is passing due to cathodic protection. Similarly at these locations, the pipe to soil potential was measured in the ON condition and the OFF conditions.

So, once we know the driving voltage required pass this current, the resistance offered by the coating is obtained using the Ohm’s law. The resistivity of the coating is obtained by simply multiplying the resistance with the area of the pipeline. The current flowing in a pipeline is measured as you seen before using a two point probe method; wherein you need to know the pipeline resistivity and the potential drop occurs along the given line span.

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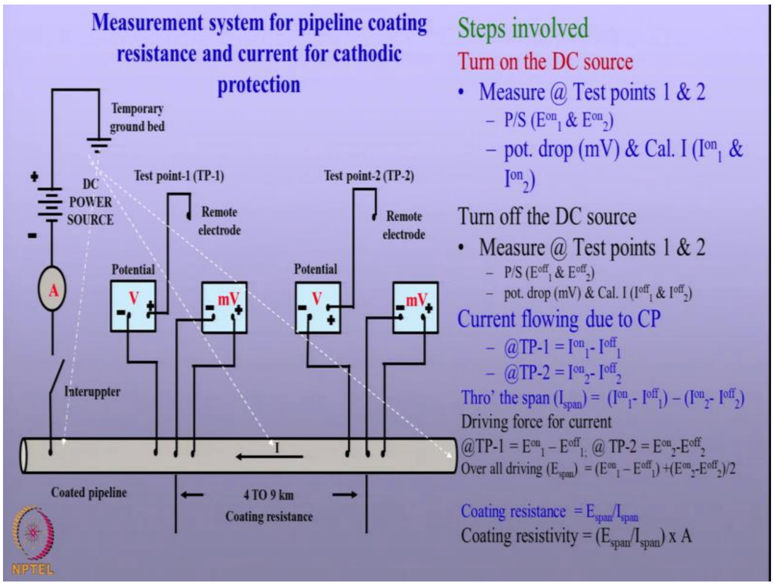

Let me now explain to you how one would arrive at the resistivity of the coating. The following steps are involved; one turns on the DC source, that is the power source here and then measures the pipe to soil potentials at the test point 1 and the test point 2. So, it is just given as E on 1 and E on 2; these two are the pipe to soil potential measured at these two test stations test points.

When it is turned on, the current that is flowing at the test point 2 and the test point 1 are measured; that is measured by knowing, the current flowing at the test point 1 and the test point 2 are calculated based on the potential drop that is measured at these two locations. Then you turn off the DC power source, we make a similar measurements of pipe to soil remote at the test point 1 and test point 2; we also calculate the current that is flowing at the test point 2 and test point 1.

Once it is done; then one can calculate the current that passes through the point 2 and point 1 by subtracting the current flowing in the on condition and the off conditions, that gives you the current that is entering the pipeline because of the cathodic protection or the pipeline.

Now, the current that is, the current that is entering this segment of the pipeline; how much current that is entered can be determined by subtracting the current that is flowing at the test point 1 and the current that is flowing at the test point 2. So, that gives you the actual current that is entering this segment of the pipeline. Now, the driving force for the current to enter the pipeline can be calculated again based on the pipe to soil remote potential measured and the on condition and the off conditions.

The difference gives you the driving voltage that is applied to get the desired current flowing at the pipelines. So, the overall driving force required to pass a current in this segment of the pipeline can be considered as the mean driving force that happened at the segment the test point 2 and the test point 1, so that you can able to calculate using this equation.

Now, the coating resistance can be obtained by using the ratio that is the potential that is average that we measure here upon the current that is entering the pipeline in this segment or the pipeline that gives the overall coating resistance and the coating resistivity is obtained by multiplying the coating resistance with the area of the pipeline.

So, by this method, it is possible to determine the resistivity of the coating. And once you know the resistivity of the coating, then we will be able to know the protective capacity of the coating.

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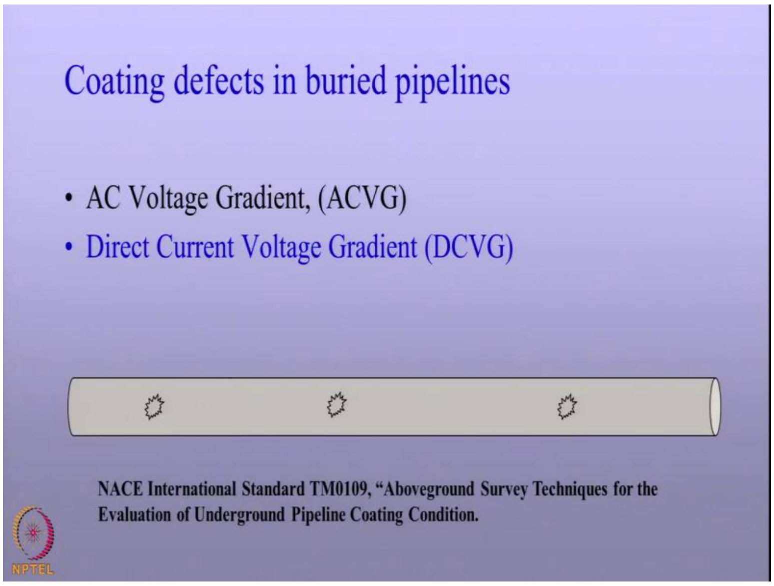

The paint coatings applied on the buried structures have a limited life, over a time period they disintegrate. The coating also get damaged whenever some maintenance work being carried out on the structures. When these coatings are damaged, the current required for cathodic protection significantly increases and in fact at these locations, the pipelines may not be adequately protected cathodically. So, it is very essential that these defects are identified and they are repaired with a fresh paint. And this is done using an above ground survey techniques.

The two techniques are used in order to detect these coating defects; one is AC voltage gradient, abbreviated as ACVG, the other case is direct current voltage gradient technique.

The principle employed in deterring these defects are as follows; when you have a defect in the coating and the pipeline which is defect free, there exist a potential gradient between these two locations. Because the resistance offered by the coating increases the voltage and also this voltage gradient is measured is an indication of the presence of the defect.

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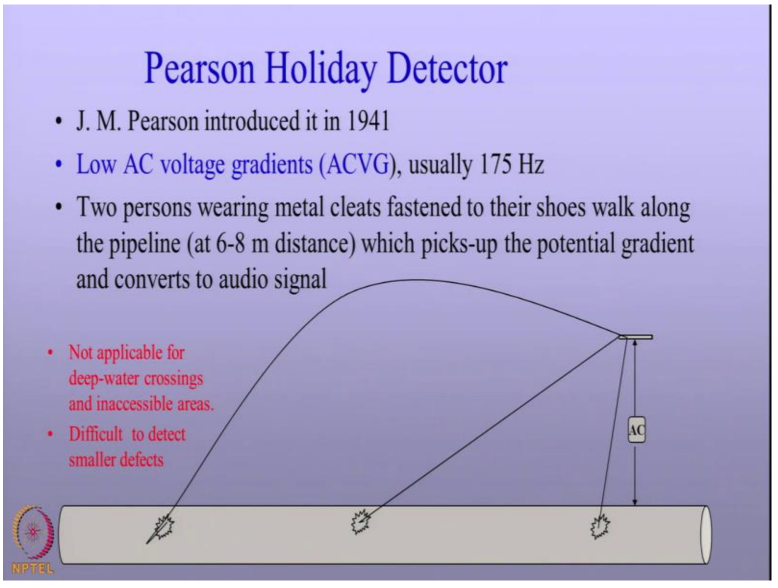

Let us look at the ACVG technique and ACVG technique is famously called as Pearson Holiday Detector named after the Pearson, who invented in 1941. In 1941, J M Pearson introduced this technique to determine the location where the coatings have failed in buried structures. In the ACVG technique, usually a low amplitude of AC signal is applied with the frequency ranging between 175 Hertz around this range.

The detection of these defects are done by two persons, who walker cause along the pipelines; these two persons they wear metal cleat fastened to their shoes and they walk with a distance of about 6 to 8 meter. Because they are wearing the metal cleats, they pick up the current. And so, if the person is very closely defect as compared to the other one, who is away from the defect; the voltage gradient is measured and this converted into audio signal and thereby the location is identified.

But this techniques suffers from the drawbacks; the drawbacks are it is not applicable for deep water crossings and also inaccessible areas or sometimes you may have a crowd or pipelines, it is very difficult to detect or apply. And when the defects are smaller size is very difficult to determine these defect areas.

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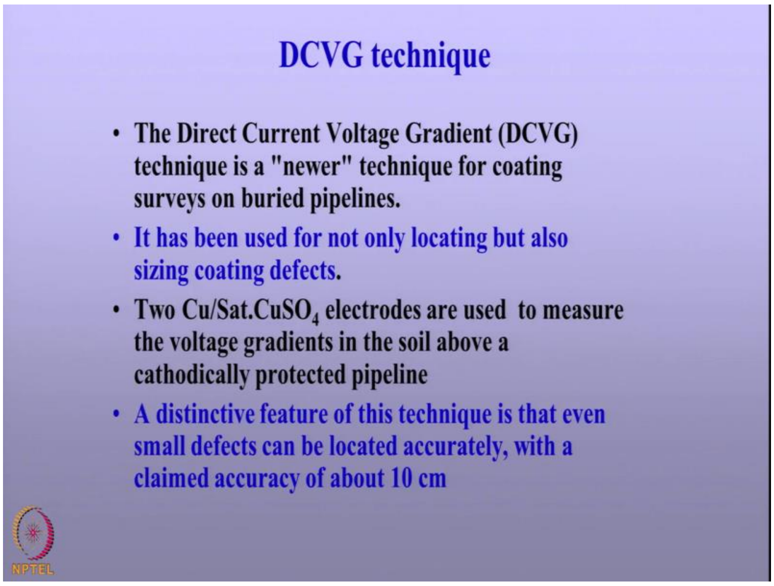

The DCVG technique is they are relatively a newer technique and these techniques we used not only to detect the coating defect location; but also the size of the coating defects. In this technique one uses two reference electrodes; same again a copper, copper sulphate electrodes to measure the voltage gradients in the soil above the cathodically protected pipelines.

The significant, this technique is very distinct; the distinctive feature of this technique is that, even a small defects can be located very accurately. This technique has a ability to detect even the smaller defects of the order of 10 centimeters.

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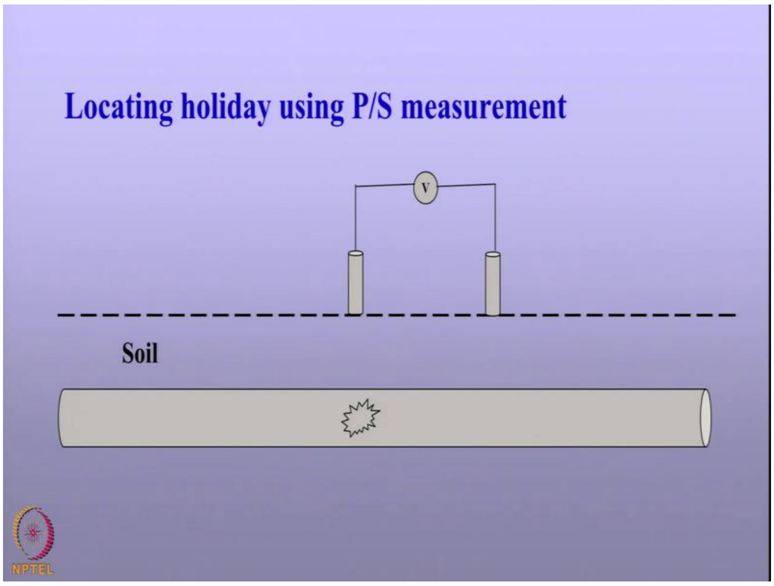

What I shown here is, how one measures the pipe to soil potential measurements to locate the defect, ok. This is a pipeline what is this represented here and you have defect and this buried in the soil; the two reference electrodes are kept over the soil actually and they are connected through a voltmeter.

And voltmeter measures the potential gradient between the two reference electrodes, when the these two electrodes are moved along pipeline with the fix distance of about a couple of meters; whenever one of the electrodes encounter the defect, a potential gradient establishes between the two electrodes and thus identify the defect present in the coating.

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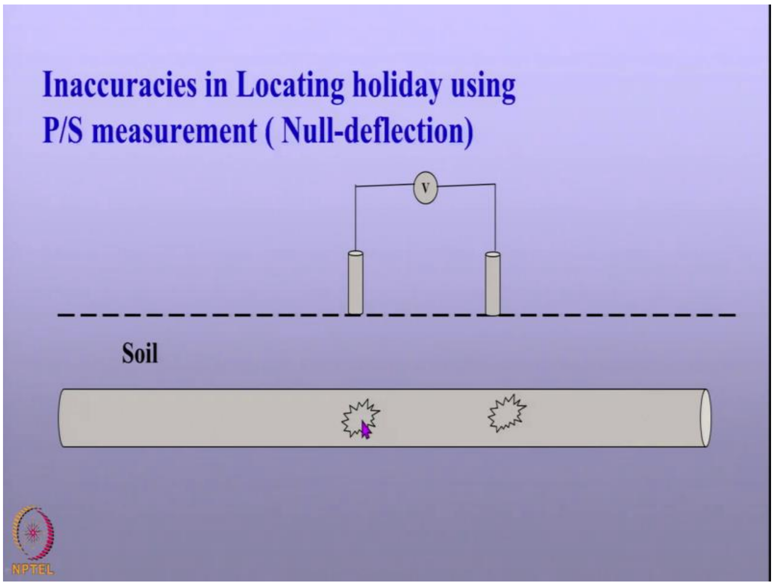

There are situations where this problem can arise; this technique cannot detect the defects. It so happens that, the two reference electrodes are kept exactly over two defects of similar nature; then the voltmeter cannot detect the potential between these two, because there does not exist any potential difference between these two defects. So, which case, it is not possible for this technique to detect.

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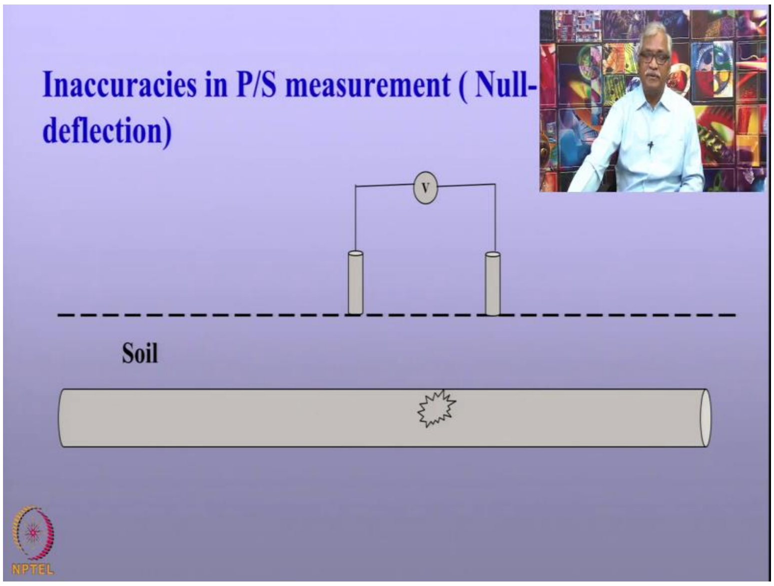

It is also possible that the spacing between the two electrodes are very symmetrical across the defect; which means the electrodes cannot detect the defect at all, because the voltage gradient does not exist between these two locations. So, there are some disadvantages in using this technique.

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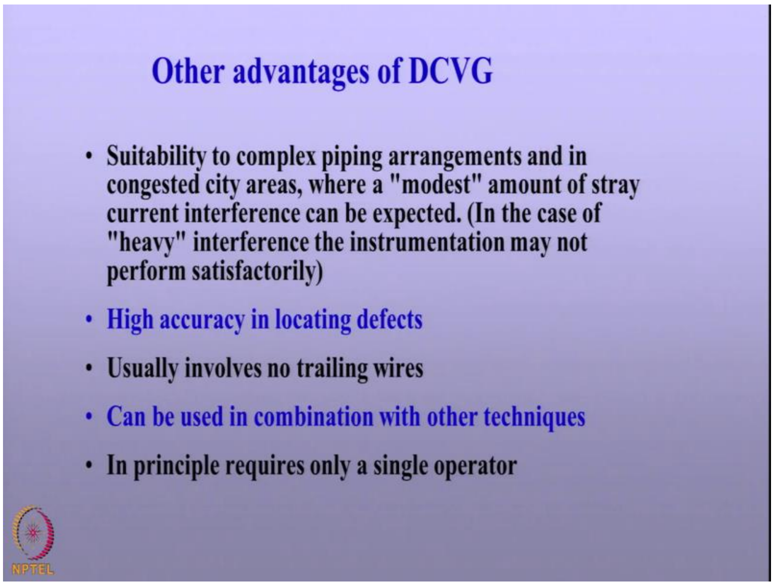

There are other advantages in using a DCVG technique; in fact this technique can be used in a complex network of pipelines. The person already detected technique cannot be used in a very highly congested areas or pipelines in a plant, in a chemical plants. The other advantage is high accuracy in locating the defects, no trailing wires are involved; this is very small segment, small wire that is connecting the two reference electrodes.

It can be used in combination with other techniques and unlike your person take detected technique, in this technique requires only one single operator.

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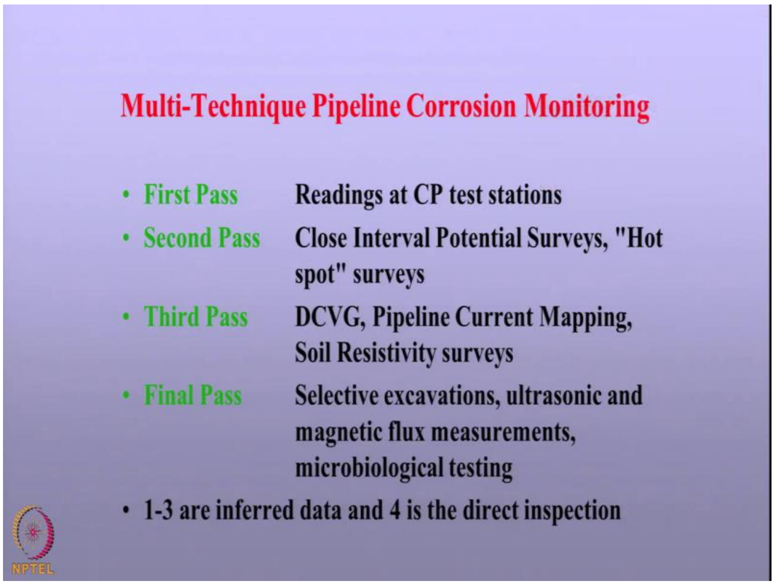

We have seen several different techniques for assessing the corrosion condition of the pipelines; is very important that we use them very judiciously, so that the cost of survey becomes very less. So, what I have listed here is four levels in which you can use this techniques; the first level is the most simple one, if the cathodic protection that. So, whenever you see that the pipeline is under protected, you will use the first pass that is checking the CP stations, ok.

And see that the CP station is properly functioning in terms of cables or the fuses in the rectifier; these are fairly simple procedures, it can be adopted, if anything is a problem, it can be easily set out, it can be easily set right. If we do not find any problem over here in the CP station, we go to the next level of surveys, which is close interval potential survey; this also we called hot spot surveys.

Potential measurements is still relatively simpler technique as compared to the other technique. If this the close interval potential survey does not indicate the problem; then one move moves on to DCVG to be identify any coating damages in the pipelines. We can also use pipeline current mapping and soil resistivity surveys. And with this, it is possible to identify a location where there is a problem; then we go for excavation, that is called Vellore examination.

We can also use ultrasonic and magnetic flux measurements and microbiological testing, so that you confirm the problems experienced by the pipelines.

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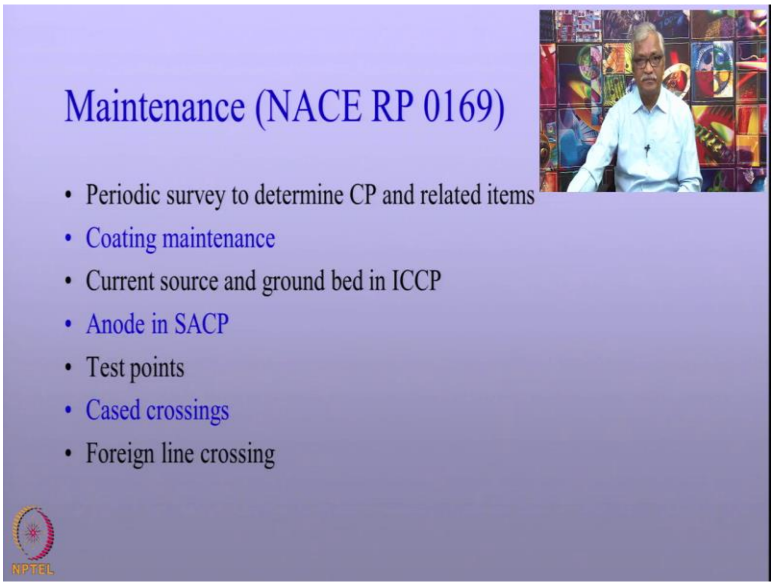

NACE RP 0169 provides various information about the surveys in terms of determining the CP and related issues; a coating maintenance, current source, anode when we use sacrificial cathodic protections, test point surveys, there are case crossings and foreign line crossings. The more practical a problems can be seen using this particular standard.

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Before I close, I would like to give a glimpse of how to address the troubleshooting in a typical cathodic protection problems. If there is no power to rectifier ok, you can see that AC look at the causes; circuit breakers off, input fuse blown, insulation breakdown.

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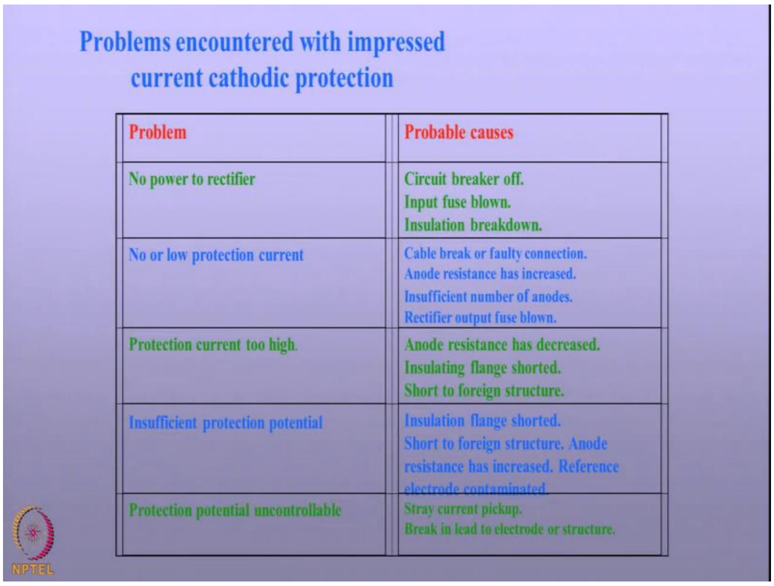

If there is low current, low protection current, then it can be any of these reasons cable snapped, the anode resistance has increased; you have seen that earlier the anode resistance is increased, the drain current measurement is made in order to identify the anodes of the problems, insufficient number of anodes, rectifier output fuse blown. Protection current is too high; then anode resistance decreased, insulating flange shorted, short to foreign structures.

Insufficient protection potentials; the flanges insulation is been shorted, they shorted to foreign structures, the anode resistance again is increased, the resistance of the electrode, reference electrode is got contaminated, the reference electrode got contaminated. Protection potentials uncontrollable; there is very likelihood of stray current pickup and break in lead to electrode or the structures.

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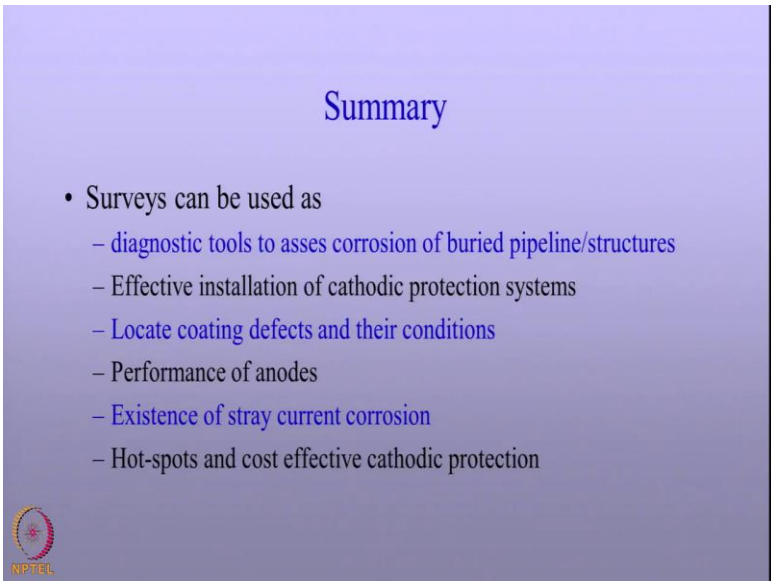

To summarize what you have seen so far, the surveys are can be used as a diagnostic tools to assess corrosion of buried pipeline structures. It is used for effective installation of cathodic protection systems; for example, side resistivity surveys ok, it talks about how severe the corrosion of the pipeline will be, you can use the surveys to locate the coating defects and their conditions.

The performance of the anodes be it sacrificial or impressed current anodes; the existence of stray current corrosion hot spots and cost effective cathodic protection.

I hope these two lectures will give you a brief overview about how to assess the corrosion of the buried structures.

Thank you.