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Lecture-48
Water Loss Detection and Control

Hi friends and welcome back, so we have been talking about water losses in last couple of classes. We did talk about the basics of water losses and how we use the concept of water auditing or water balance for estimation of the water losses. Now this class we are going to talk about the detection and control measures for the water losses.

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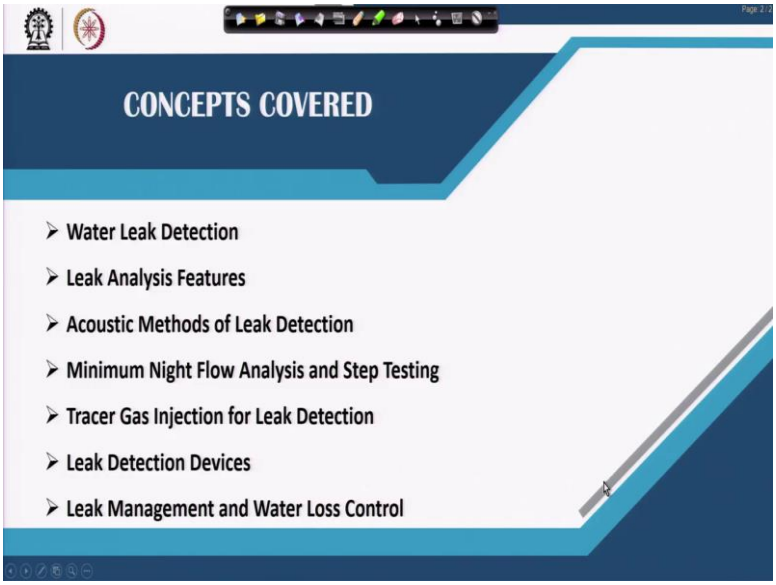

So, what practically we will be discussing is the leak detection because as we discussed that losses are of two types the real losses and apparent losses. So, apparent losses detection is depends on the management of the utilities how they are managing because that is more related to the kind of various errors in the data handling the metering inaccuracies or the theft or stealing of water. So, they are more of the management related issues but physical losses are actually the network issues.

So, how we detect these physical leaks that will be discussing we will talk about the leak analysis features and then there are various methods for leak detection. So, we will see some of those major methods of course will not be able to cover all the methods. But like a caustic methods or the treasure gas injection methods. We will talk about we will talk about the leak detection devices as well some of the analysis like minimum night flow analysis.

The step testing those things we are going to discuss and we will conclude with the leak management and water loss control measures.

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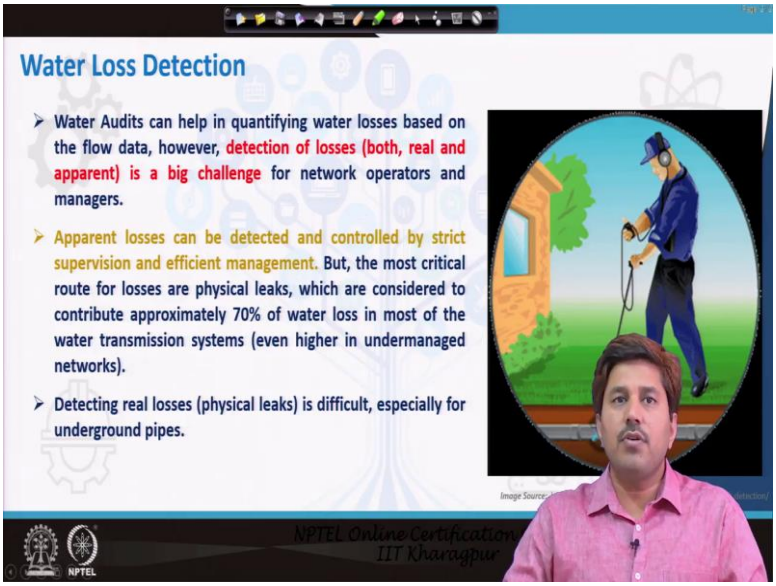

So, when we talk about the detection of water losses what our audit as we discussed in the previous class can help us giving us an idea of the quantity of the overall water losses that is happening in the network based on the flow data. So, you know the input volume you know from the consumer ends how much is actually getting consumed and you subtract and you get an idea of the losses. But detection of losses means say you estimated that this utility is having say 25% physical losses or real losses.

Now where are those real losses in the utility that 25% is coming from which section of the network which pipe which area which reason that is a big challenge. So, the detection part of the losses many times even apparent losses because apparent loss is also stealing and those kind of things or metering inaccuracies, so you do not know that whether error meters are correct or not correct.

So the detection part of these real and apparent losses is actually a very big challenge. Now the apparent losses can still be detected and controlled by the strict supervision. So, for say as we discuss there are the major components of the apparent losses. So, let us say you are talking about the inaccuracies in the monitoring devices inaccuracies in the meter. So, you keep on calibrating the meters on regular basis.

Then if there are say stealing or theft so you keep your system kind of protected from those things again a regular monitoring supervision or the vigilant staff would be helpful in those kind of thing if there are like yeah there might be one source is the data handling errors so you make sure that the data is entered into the system is correct and proper. So, that way like just by the supervision and efficient manage some of these apparent losses can easily be detected and controlled.

But the major routes for these losses are actually the physical leaks which kind of accounts for approximately 70% of the total water losses. So, if a utility is say supplying hundred unit of water is facing say 40% losses, so of the 40% losses I guess like around 30% is going to be the like of this 40%, 10% might be and 30% might be real so that is kind of a wider average for the systems which are not very good this could actually be even higher.

Now detecting these real losses or physical leaks is very difficult and especially in the underground pipes. If the pipe is going on the surface it is easier because just by the visual inspection it can be identified if there are say of mains going on the surface and if there is any crack or any place water is leaking somebody can see that inform the utility or the utility like operators during their visit can easily see that.

But in most cases or in several places these pipes are laid underground and if they are underground so these leakages that are happening below the surface is very, very difficult to detect.

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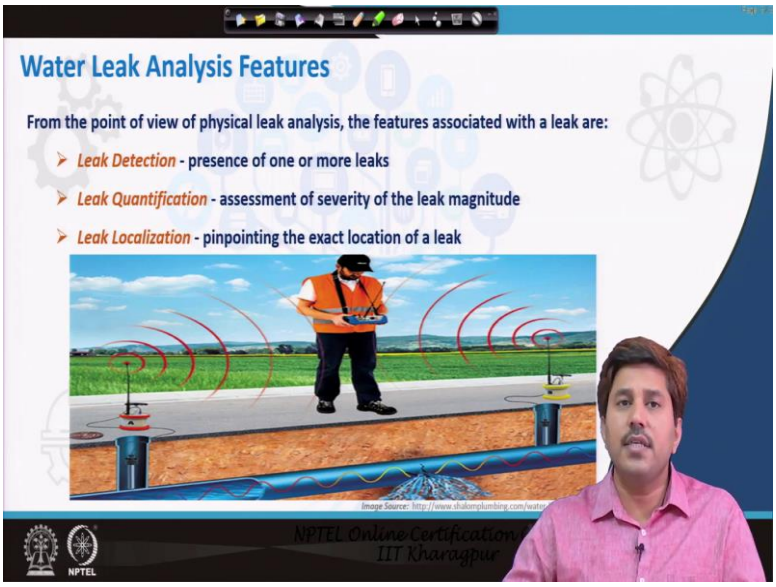

Now the for the purpose of leak detection there are basically different features that are associated with the leaks now there is one component is leak detection. So, leak detection is the presence of one or more leaks if in a pipe system you are having say where you are having leak in a pipe let us say we have a pipe here now the leak may be here the leak may be here or the leak may be actually at many places.

So leak detection is just knowing that in this section of pipe you have leakage or you have water leaking through or water loss in this section of pipe that is the detection part. Now the next is the quantification part if there is a leakage what is the quantity of liquid whether this is say a 10 liter per second whether this is 100 liter per second or it is higher or it is lower so what is the quantity of the leakage which is happening in a particular section of pipe or at a place where the leak is occurring.

And the next part is the leak localization means basically pinpointing the leak, locating the leak where it is because a section of pipe may be very long if here section is pipe say of 500 meters. So, in these 500 meters whether the leak is here or the leak is here or the leak is at both places. How do we know? So, for that purpose we need to localize the leaks so that is known as the leak localization are the pinpointing the exact location of the leak.

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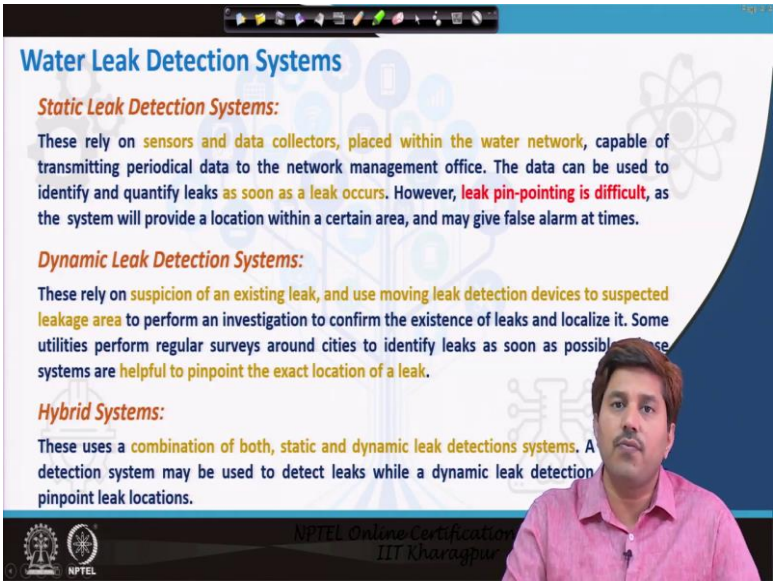

So, these are the major features when we that we kind of try to see when we go for the leak detection. Now the leak detection systems are generally means can be categorized broadly in two major categories static leak detection systems are dynamic leak detection systems. So, a

static leak detection system relies on the sensor and data collectors which are placed within the network they are static in a way.

So if we have say like a pipe system we are having a hydrant or pipe main or whatever and we have installed some sort of leak detecting device or some sort of sensor it could be anything at both the places. And we are regularly using and monitoring this data to kind of see if there is any anomaly taking place in this pipe. So, it is a static system these devices are fixed they are capable of kind of transmitting periodical data to the network management office and then that data can be analyzed and I like can be seen if there is any leak present is not.

As soon as there is a leak occurs of course there is going to be variation in the data that is being transmitted from the regular, so the operator or the utility manager will know that yes there is something wrong in this pipe. So, as soon as the leak occurs this kind of system can guide us about this. But the pinpointing is very difficult because we cannot have sensor at each and every place we can have sensor let us say a joint at walls at hydrants.

So if you are having sensor at say those locations in between that section it will say that there is leak happen but pinpointing the leak where exactly leak is that is difficult for these systems to tell usually. And many times they may give you an in fact the false alarm as well. Then there are a dynamic leak detection systems which rely on the suspicion of an existing leak. So, if a utility suspect that ok there is a leak somewhere in between this section of the pipe then a dynamic system may be adopted like a leak detection device may be taken and a survey of this reason may be carried out.

A survey of the reason may be carried out and that way we can basically pinpoint the leak where the leak is and may like even able to quantify the leak. So, the quantification and pinpointing can be done more sewers the pinpointing is easier in that dynamic leak detection method. Many times the combination of these two is used which is basically a hybrid systems. So, we have basically both static and dynamic leak detection systems.

We have a few static systems to guide us about if there is a leak prevailing in the line or not and once we know that if there is a leak so we can take our dynamics detection devices or detection tools there in that particular section survey that section and pinpoint the location.

So, the detection usually is done through static systems and pinpointing may be done using the hybrid systems.

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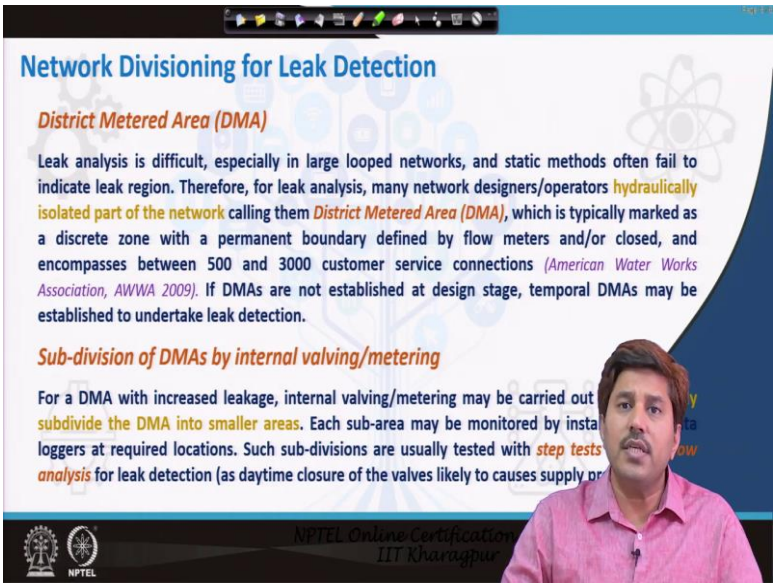

Now for the purpose of leak estimation one thing which is usually a top place did is basically the we do we kind of divide the network. Because usually for very large network and particularly if they are large loop network. So, these static methods will often fail to indicate the leak reason, if you are say having a method where basically you are say a gridded network or a looped network.

Now if this place there is a leak occurring and you are having a said here a censored here and maybe a censor here and censored here. So, all censors might actually saw some variation even because of the value of fluctuating here this because this is an interconnected system so a leak here will is actually going to affect the discharge and other things in this pipe in this pipe in this pipe in this pipe and many other pipe.

So, all sensors might see some variation some anomaly from their standard from their kind of standard values which they are transmitting otherwise. So, in that case it becomes difficult to kind of identify where the leak is whether leak is in this pipe leak is in this pipe leak is in this pipe or means which particular pipe the leak is. So, in that case and like even if you want to adopt the dynamic systems if you do not have an idea actually your survey field becomes too large.

Your survey field becomes too large to kind of identify the leak location and that is why it becomes difficult for this these kind of large loop networks to adopt any specific any particular static or dynamic method for leak detection. So, for purpose of leak analysis what many operators do or in fact that the design is scale these days are done is the part of the networks are isolated and they are known as the district metered areas or DMA.

So DMA's are essentially the hydraulically isolated part of the network, so we can mark typically a discreet zone with kind of a permanent boundary. Boundary as in like pipe network boundary it is not that the physical boundary it is a basically pipe network boundary and we can place the flow meters at appropriate positions. These boundaries may be like kind of it can contain typically between 500 to 3,000 customer service connections as per the standards given by the American Water Works Association.

So that is the typical size of DMA but DMA's are smaller as well as larger light times that DMA is containing in fact more than 5000 consumer service connections. So, if these DNA's are established at a design scale it is very good if they are not then temporarily amazed may be established to undertake the leak detection exercise and this can be done by kind of putting the appropriate walls. So, walls might be put and then we can close the walls so that we can hydraulically isolate certain section.

Many times these DMA's also subdivided by the valving or metering purpose. So, for a DMA with increased leakage we can again use internal valving or metering for carrying out the temporarily subdivision of the DMA's into further smaller areas. So, each sub areas may be monitored by installing again flow loggers at the required location and these subdivisions will be usually test with either step test or night flow analysis kind of methods for leak detection.

Why we use this kind like night flow analysis and these methods because day time closure of these walls will cause the supply problem.

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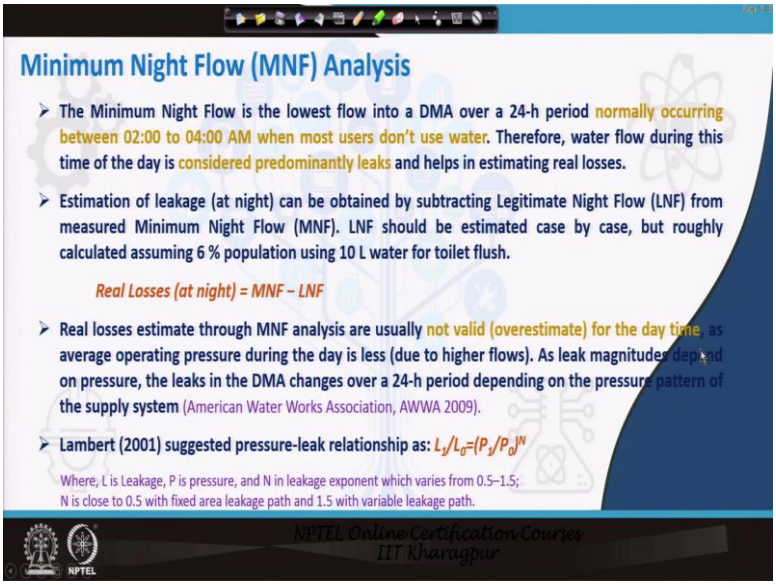

So, if we are isolating some part in the DMA so that can be done usually by like closing the walls or interrupting the supply for some area if you do that in a day period it becomes difficult so that is why the many times this leak detection exercises or particularly this kind of leak detection exercises are done in the night time. And one of the methods for this the popular method for this is the minimum night flow analysis which is known as MNF analysis minimum night flow.

So minimum night flow is the lowest flow in a DMA which occurs over a kind of 24 period and normally this occurs between 2 in the night to 4 a.m. in the morning. Why this period because this is the time when most users do not use water. So, most users are kind of sleeping it is a very it is a kind of time when almost very little population is there at work. So, in these cases this is the typical time it is not it is not again a hardbound many times like people start at around 1:00 and then go at around 4:00 or 5:00.

So whatever time window you are taking in that time window you try to monitor the discharge you try to monitor the flow and let us say if this is your flowed in that period. So, whatever is the minimum flow in this period is considered as the minimum night flow now this minimum night flow means your system is still having this much amount of flow in the leanest period of the demand.

Because that time the demand is minimum and whatever flow is there is considered to be predominantly because of the leaks. So, that means whatever flow is causing is predominantly because of the leaks. Now there could still be some demand so like that is

known as the legitimate night flow which is the kind of legitimate demand even in the night. So, this legion legitimate night flow is estimated case-by-case roughly it is like estimated assuming 6% population is using 10 liter of water for toilet flushing in the night.

So let us say if you are having 1 lakh population if you are having say 1 lakh population then 6% of this that means 6,000 people might be using 10 liter water that means 60,000 liters of water becomes your legitimate demand. And if say you have you have recorded say 5 lakhs liter of minimum night flow that means you know that of 5 lakh litres 60,000 is your legitimate demand so that means 440,000 liters is going through the leakages.

So this way we can estimate the real losses at night which is equal minimum night flow minus legitimate night flow. So, legitimate night flow we can have an idea based on again like it should be submitted though case to case basis but as a roughly 6% population using 10 liter of water we can consider as legitimate night flow demand. And we subtract this demand legitimate demand from the observed night flow demand minimum night flow demand and then we get the idea of real losses at night.

Now this real losses that we estimate at night may not be valid for the day period as well because in the water pipeline when day period the demand is high the pressure that runs through the pipeline is low where is in the night when demand is very low or the minimum demand is there. So, pressure is higher so when the pressure is higher the losses is going to be higher. So, the real losses that estimate in the night is actually more than that in the day period.

Because in day period the network often runs with us smaller pressure as opposed to the pressure that is observed in the nights, so, that is why this MNF analysis will not be valid for the day time as it will actually provide you overestimate. Because the losses is higher in the night as opposed to the day. So, if you round it off for 24 hours you will actually get our estimate of the losses.

Losses are lesser or smaller than the value that you are going to estimate that way. So, for that purpose basically we can see the effect of pressure how it is varying and Lambert has suggested a pressure leak relationship as the L 1 by L 0 is equal to P 1 by P 0 to the power N where L is the leakage and P is the pressure. So, for any standard leak or no leak condition

you know the pressure L 0 and for any like then any leak value if you want to estimate the leak at particular another pressure.

So far say in the night you estimated you know the your L 0 is safe for leak in the night and p 0 is the pressure in the night P 1 is the pressure in the day so L 1 that you want to estimate what is going to be the leak in the day time is actually going to be the Nth power of this. And the N value is basically which is X leakage exponent it varies from 0.5 to 1.5 it is taken as 0.5 with fixed area leakage path and 1.5 for variable area leakage path so that way we can have we can estimate the leak at the different pressure pressures and based on the operating pressure we can accumulate for over a period of 24 hours to get a daily idea of the leak volume.

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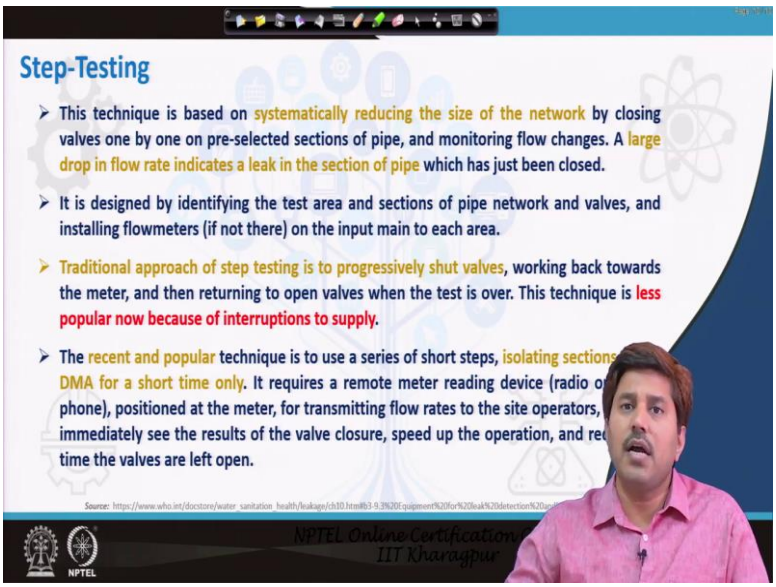

So, that is how we estimate the leak it is through the night flow analysis we do use some time step testing for leak analysis. Now step testing is a technique which is basically based on the systematically reducing the size of the network. So, we have say a big size of network and we want to estimate the say leak so what we do we like from tail in one by one start closing the walls so far say we will close the valves one by one will close this valve.

So our network becomes this valve then might be closing this valve we might close this valve we might close this valve so one by one will start closing valve and that way we keep on reducing the size of the network. So, we do that by pre selecting the closer of the walls and then we monitor the flow changes a large drop in the flow rate will indicate the leak in a section of pipe which has just been closed.

Now this is designed to identify the test area and section of the pipes networks and valves and then we need to install the flow meters if it is not there. And basically see that how much flow is going to the each section the traditional approach is to basically progressively shut walls working back towards the meter. So, we will basically start from we generally start from here and work back towards the meter and then when we return we keep on opening the walls once the test is over.

But this traditional approach is less popular now because what happens if you are testing this kind of thing you are closing the walls so you close this particular wall a section of the see utility will get no water. So, it can cause interruptions to the supply many times there are quality issues as well because you are there are walls and you are closing and reopening. So, there that is like at times the quality issues are also considered but mostly it is because of the interruption of supply and that is why either like people do step testing also in the night period if they are going to use this approach.

Or there is a recent and popular technique is used to basically series of short steps instead of just closing wall one by one so you use sort stuff for isolating sections of the DMA for a very short time only. It requires basically a remote meter reading device so radio or mobile phone kind of systems which we position at the meter and these will basically record the flow rate and transmit it to the site operator who is operating the valves.

So, based on these inputs the operator can immediately see the results of wall closer and then speed up the operation and reduce the time of the like when the wall is left closed or left open. So, that kind of monitoring can be easier with automated recording and transmitting devices.

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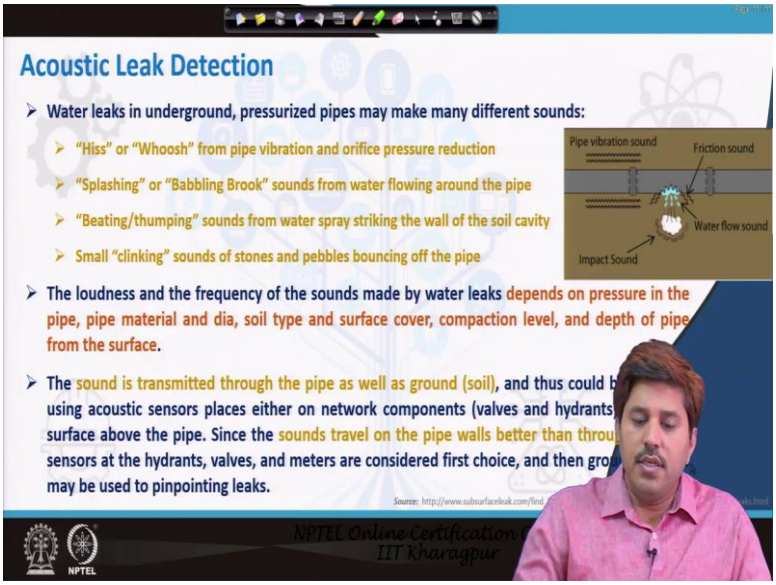

These are the just gross approaches the step testing or the night flow analysis for detecting the leakage. Now again for specific like even the night flow analysis will give you an idea of there is a leakage in this particular section but it does not pinpoint the leak so for leak location or locating the league generally various other methods are used one of the most traditional and popular methods are the caustic leak detection where we use the sound of leak as a tool for detecting the leak.

So there is like in the pressurized pipes and particularly underground pressurized pipes there would be different kind of sounds coming in either hitch or whoosh kind of sounds when basically the pipe vibration and orifice pressures are reduced. There good base flashing or bubbling rock sounds when the water is flowing around the pipe. There could be beating or thumping. So, if basically there is a leak and water is heating to the kind of surface so it can actually either strike the wall or the soil cavity.

So because of the impact it can basically have a beating or thumping sound it can have a small clicking sounds if stones and pebbles are bouncing so if water is released here and some stones and pebbles are basically bouncing so that kind they can also create certain sounds. So, these these are variety of sounds now the most these generally are much smaller and the most prominent sound of a leak is this which is basically coming out of the pipe vibrations and the orifice pressure reduction.

So as soon as the water basically releases here so the kind of pressure that reduce or the pipe that vibrates, so this kind of sounds the hiss Shorewood sound that will be basically coming

out. So, these are the more prominent and the caustic detection devices mainly focus detecting this particular sound. Now the loudness and frequency of this sound made by the water leaks will depend on the pressure in the pipe, pipe material and dia while type and surface cover it will depend on the compaction level it will depend on the depth of the pipe from the surface.

So it depends on all like so many factors the pipe is deeper the sound at the top is going to be obviously much smaller. If the compaction level of soil is good the like the pore spaces or capillaries through which sound can move are the air ways through which sound and transmit is lesser. So, sound will be smaller it depends on the soil type and surface cover if you have a paved cover unpaved soil and what is the basically composition of the soil.

It depends on the pipe material and dia the pipe is bigger pipe is smaller it depends on the pressure in the pipe and the opening like what is the leak opening what is what kind of like fracture is there, so it depends on all these factors. The sound is transmitted through the pipe as well as ground. So, like we the sound that is generated it is basically transmitted through the pipe and through the ground as well.

So, it can be detected either at the top level of the surface or it can detect somewhere at the pipe ends. So, it could be that way detected using acoustic sensors placed either at the network components so we can place the sensor set valves or hydrants and when the sound travels through the pipe so they can detect that particular sound or basically since the sound travels through the surface also so we can put on the surface above the pipe.

Now because sound travels faster in the pipe walls then that in the soil so sensors at hydrant walls and meters are considered as first twice and then ground sensors may be used for pinpointing the location.

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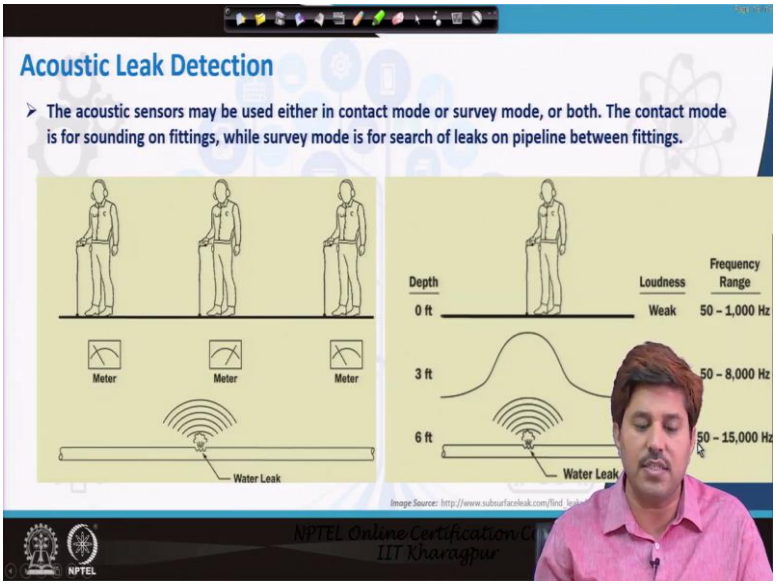

So, first basically we go for the fixed sensors so the approach is simple if you have a water leak here let us say you have one sensor here one sensor here. So, you can actually like sense it through the sensor. And if you are sensing just at the ground so you would not find it here you like here you it would not say very low sound or no sound and when you reach that particular location your meter will so higher sound.

Or if you are actually placing sensors on the side you have fire hydrants or walls or meters here and you are placing sensors here. So, sound is travelling through this way will be detected here and here as well and then you know that in this particular section there is a leak and then you a manual survey can be done in order to identify the location or pinpointing the leak. Of course like the sound will be highest at the pipe level itself then as you move up it is going to go weaker as the frequency will be actually reduced. So that is the basic concept of the acoustic leak detection systems.

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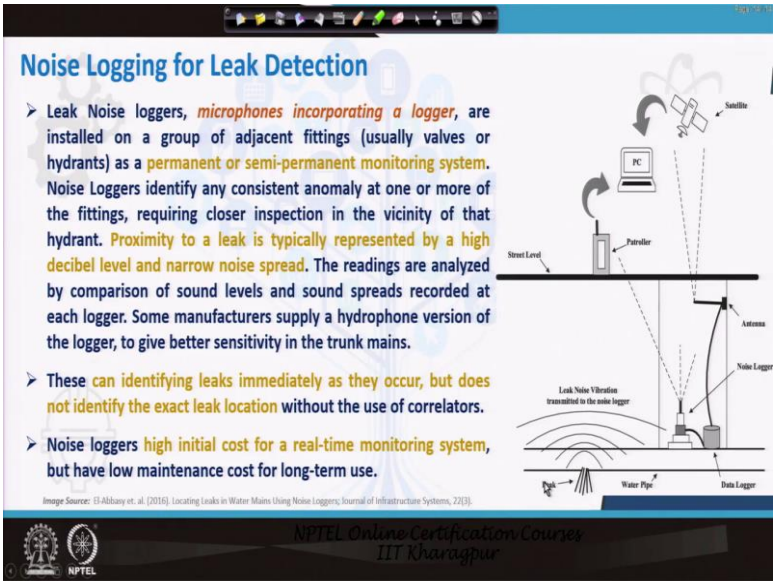

Now in the caustic leak detection there are nice loggers for leak detection purpose so these noise loggers use microphone incorporating as logger. So, you just have a simple microphone it you install it generally in the adjacent fittings which could be usually valves or hydrants as a permanent or semi-permanent monitoring systems and then it will be basically given an idea of proximity of leak typically depending on the high decibel level and narrow sound that is coming from there.

So this readings are analyzed and then compared and this can give you an idea this can also help in localization of the leak but not as effective as the specific site surveys can. So, it can identify the leak immediately as they occur but like exactly leak location is difficult but it can use the noise correlators for identifying the leak location as well. They have generally high initial cost for real-time monitoring but have low maintenance cost if you are using for long term but because of high maintenance cost these are not that popular like to install everywhere in the network.

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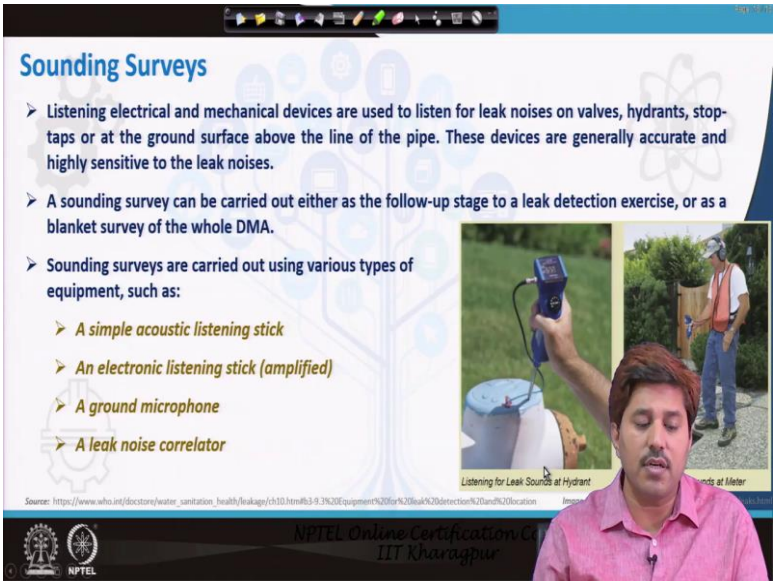

Then there are sounding service the sounding service used listening electrical or mechanical devices which are used to listen the noise. So, you like you can have a device which you try to put listen the noise and based on the like recording the noise level over here you can identify if there is a like let us say if this is a hydrant and you record noise level here without a leak condition and with a leak condition so you will be the difference you can identify that this hydrant no the sound at this hydrants is not normal and it is affected by a leak nearby.

So these devices are basically generally accurate and have high sensitive to the leak noises. It can be carried out either as a follow-up stage of the leak detection exercise or a blanket survey of the entire DMA. But blanket survey because DMA's might be very large. So, blanket service might be difficult. There are various type of equipments which can be used for listening so a simple acoustic listening stick can be used or electronic listening stick can be used this electronic string listening stick has generally amplifiers.

So the level of sound will be higher in there. A ground microphone can also be used and a legalised correlator can also be helpful in this kind of cases.

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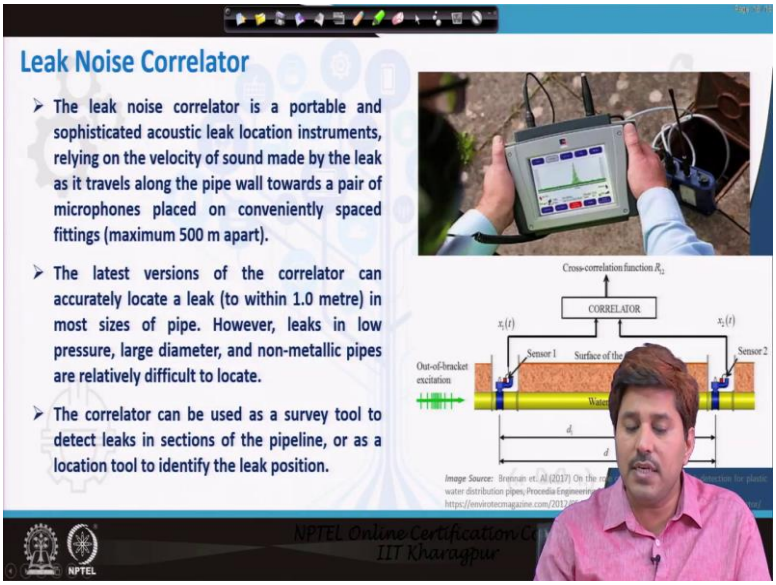

Now this leak noise correlator is basically device portable and sophisticated kind of a caustic leak location instrument which relies on the velocity of sound that travels through the pipe material and originates from a leak. So, generally like we place sensors at a size of pipe if pipe sizes are maximum 500 meter apart from where we are placing sensors and then we are actually getting a sound here and a sound here leak sound here and leak sound here.

And then we try to use correlator for kind of pinpointing the leak location. So, it will be actually give you a peak over here that where the where this like it will record here and here but it can give you a peak in that reason giving this where is the leak. So, the latest version of correlators can kind of accurately locate leak within one meter distance for the most pipe sizes however if there is low pressure and large diameter nonmetallic pipe then it is difficult to locate.

Because the sound travels better through metallic pipes so it is good in a metallic pipe but nonmetallic pipe it could be relatively difficult. And these correlators can be used as a survey tool to detect leak in a section of pipeline or as a location tool to identify the leak location as well.

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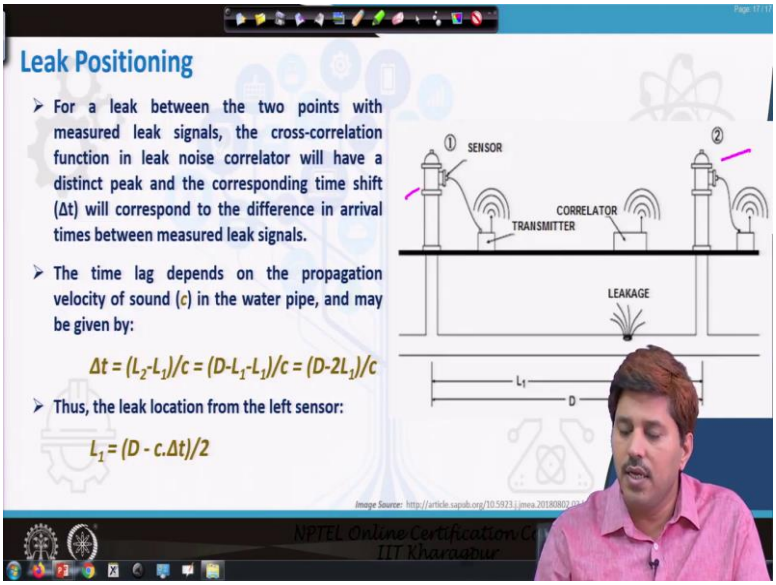

Now how these leaks are positioned using these survey tools so let us say you have one sensor here one sensor here and you have a leakage which is say L1 distance from this side and L2 distance from this side see is considered as the propagation velocity of the sound. So, if C is the propagation velocity of the sound. Now the sound will propagate towards this side and sound will propagate towards this side and what this correlator will do it will identify the time gap between the sound reaching here.

And sound reaching here so that is the time gap that it will actually give the correlator will give and if you know the time gap the time gap is essentially the difference between the distance L1 and L2 so L1 and L2 distance there is the extra like that is the distance and C is the velocity of sound. So, this additional distance covered at the C velocity is actually responsible for this time gap. Now L1 is can also be read the L2 can be written as D - L1.

So, that way it will be D – 2 L1 divided by C and then we can get a leak location from the left sensor as L1 is D - C into delta T by 2 by solving this. So, this is the basically distance of the leak location from your left sensor, so, from the left sensor you can pinpoint the leak location and that is how the leak is positioned in this system.

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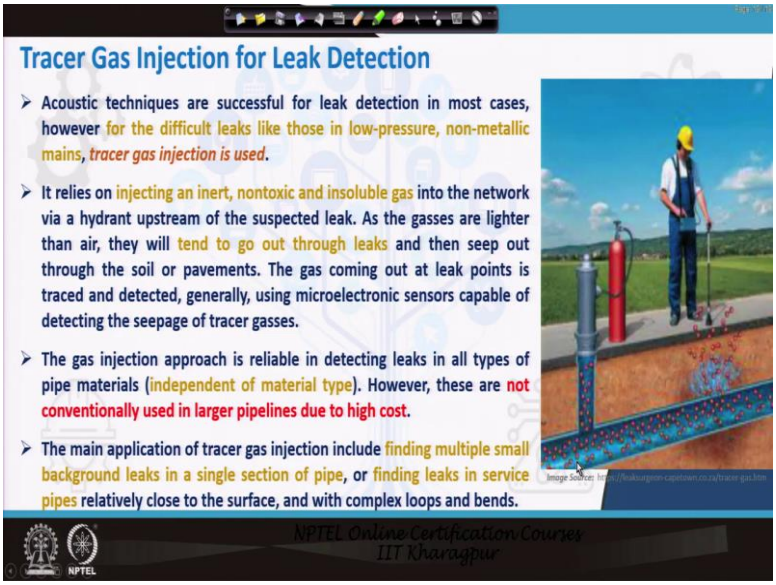

Then there are gas injection systems for leak detection purpose these are basically like the bigger size leak or moderate-sized leak can easily be detected using the caustic methods but very small size leak are very difficult to detect. The leaks which are in low pressure reason or non metallic means so the that can be difficult to detect using the caustic system. So, tracer gas injection method can be used now this treasure gas injection is a system where a gas is injected in the system this gas has to be inert non-toxic and insoluble of course inflammable.

And this will be injected through a hydrant and then these travels and where there is a leak so because the nature of the gas and it is basically injected under pressure. So, it will come out of that leak location and then we use a sensor to detect where that gas is coming so gas coming out at leak points will be traced and detected generally using micro electronic sensors which is capable of detecting the seepage of these racial gases.

This approach is very reliable in detecting leaks in all type of pipe material because it is a travelling of gas or it is independent of the pipe material it does not depend on what kind of pipe we are using. However these are not conventionally used because the cost is too much. Injecting a gas realized gas in a water pipeline and particularly the larger pipeline the cost is going to be too high. So, they are generally not used in those larger pipeline the main application of these systems is finding multiple small background leaks in a single section of pipe or finding leaks in the basically service pipe which is close to surface.

And with complex loops and bends because a caustic methods might fail there so this gas injection systems may be helpful there.

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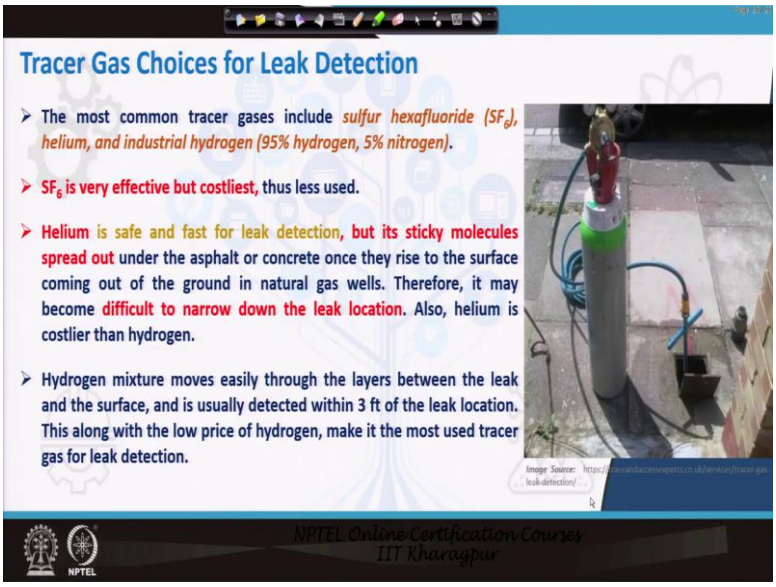

There are variety of gases which are used the most common ones are the sulphur hexafluoride which is known as SF6 helium or industrial hydrogen this SF6 is very Factory but very costly so very little used, helium is safe and fast for leak detection but the problem is that its molecules are sticky and when it basically comes at the surface through the basically ground natural gas wells. So, then it gets spread out under the asphalt and concrete and that time like the narrow down the exact leak location or leak pinpointing becomes difficult.

Also helium is costlier than the hydrogen so hydrogen comes as a very good choice and is kind of one of the most popular treasure gas. This hydrogen is essentially 95% hydrogen and 5% nitrogen this industrial hydrogen so this moves easily through the layer between the leak and surface and is usually detected within 3 feet from the leak location. So, we do know like the season of 1 meter it can give us the leak location and the price is also lower as opposed to the helium or SF6. So that is why it is considered as most convenient for the treasure gas based leak detection systems.

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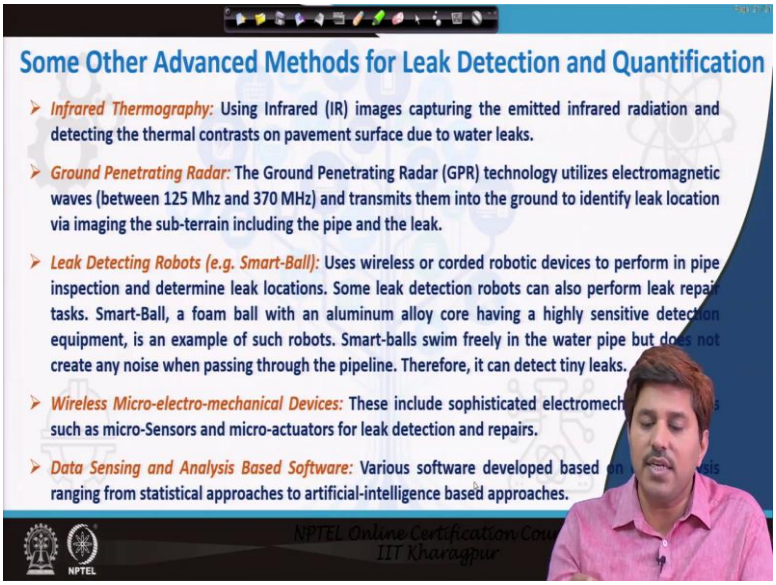

There are various other advanced methods for leak detection and quantification like there is an infrared thermography which depends on the like which captures the infrared images. And the infrared images infrared radiations that are emitted will depend on the wetness of the surface. So, if there is any sort of leak so that can be detected then there are a ground-penetrating radar. So, these are the like electromagnetic waves between 125 megahertz to 370 megahertz.

And these are transmitted into the ground to identify the leak location why are imaging the sub terrain so sub terrain can be images and then we can get the pipe Network as well as the leak. There are leak detection robots like for example smart balls. So, these are basically wired or wireless robotic devices which perform leak inspection and determine the leak location these many times like are in pipe system.

So for example this smart ball so they are made of the and they are generally a foam ball so form is lighter so they can float easily in the water and they have aluminium alloy in the core and that aluminium alloy have a highly sensitive detection equipment. Generally this also detects sound only so what happens when these are released in the in the water pipeline so they will swim freely in the water and where there is basically a sound of leak.

Because they are in the pipeline so they can easily detect and transmit that sound of the leak from that particular location. So, that way we can know the leak location some of these robotic devices have capability of like managing the leak also so they can actually do the leak repair as well within the tanks or within the pipe systems. There are various wireless micro

electromechanical devices. So, these are just sophisticated electromechanical devices such as micro sensors or micro actuators for leak detection and leak repair.

Then there are software based methods which is based on the data sensing and analysis like pressure data or flow data are sensed and these software methods based on the pressure and flow variations they can; kind of analyze the data and guide about the quantification about the quantity and location of the leak. So, various such methods are being developed which works in a steady state and transient basis.

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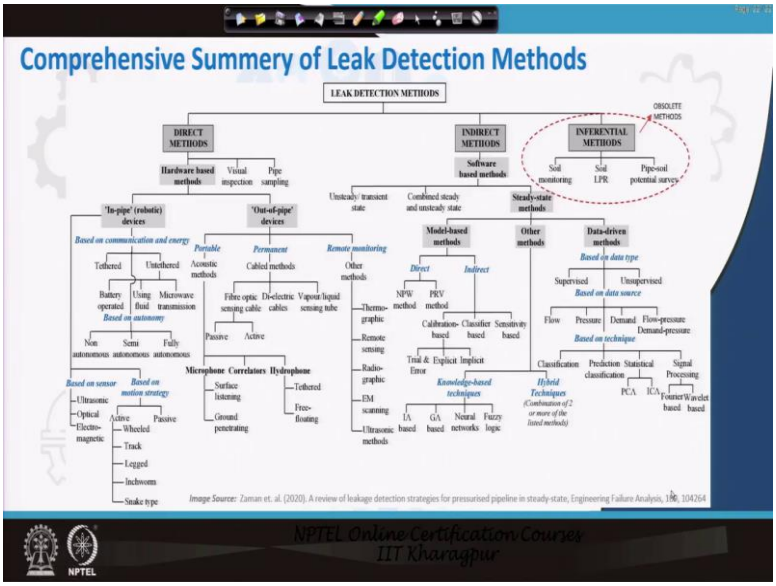

Now these are like the summary of kind of various leak detection methods so as we discussed some but like there are many other approaches which are adopted so direct methods are generally Hardware based methods which can be visual inspection or pipe sampling then there is a in pipe or robotic devices there are outer pipe which is like a caustic methods or cabled method or various other methods as just like remote sensing and those methods who you are discussing.

There are indirect which are primarily software based methods and these may be unsteady or transient state or basically combined or steady state methods. Then again they are model based or data driven methods which are based mostly like statistical type of this may be supervised or unsupervised and various software based methods are also used. There are inferential methods which are now obsolete and very rarely used.

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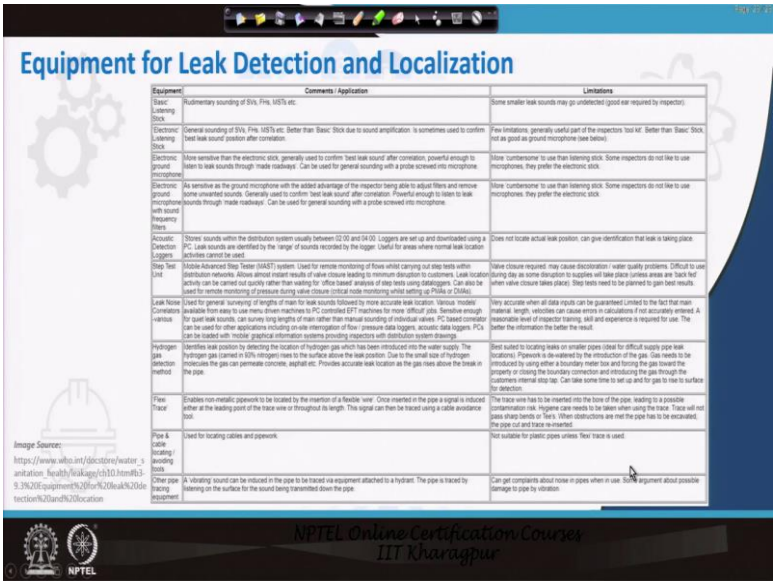

These are some of the equipments for like basic listening snake electronic listening snake the electronic ground microphone, acoustic detection loggers, step test units leak noise correlator, hydrogen gas detection then flexi traces so these are some of the equipments and their various applications and limitations. So, we are not going to like go into the detail.

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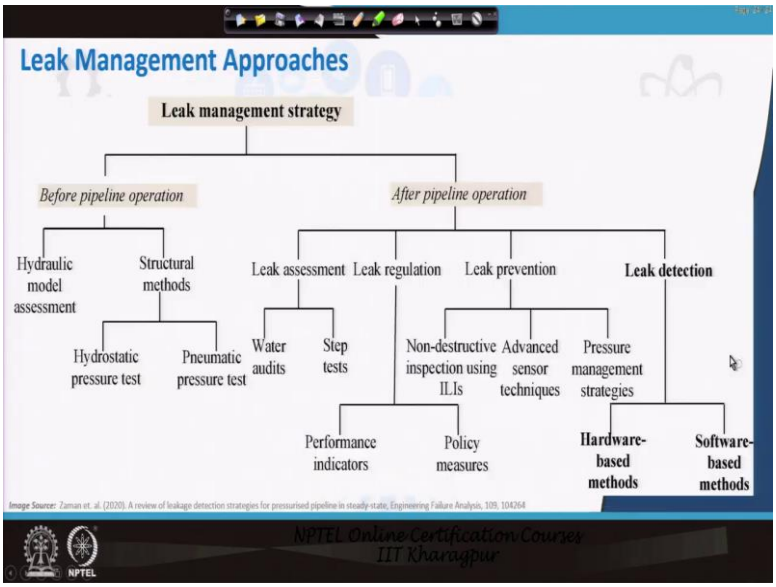

Now after we are able to detect leak or say even before if for management purpose of leak this leak management is usually can be taken before pipeline operation or after pipeline operation. So, there are two major approaches before pipeline operation means during the time of installation we can do the hydraulic model assessments we can go for structural methods. So, hydrostatic pressure test pneumatic pressure test kind of things and after pipeline we can do leak assessment through water audits or step tests.

Then we can leak regulation by like policy measures or setting of the performance indicators which needs to be followed. We can do leak prevention by non-destructive inspections using infrastructure leakage index or other things we can use the advanced sensor techniques. We can use the pressure management strategies for leak prevention and the leak detection we can use software or hardware based methods, so like these are some of the basic approaches.

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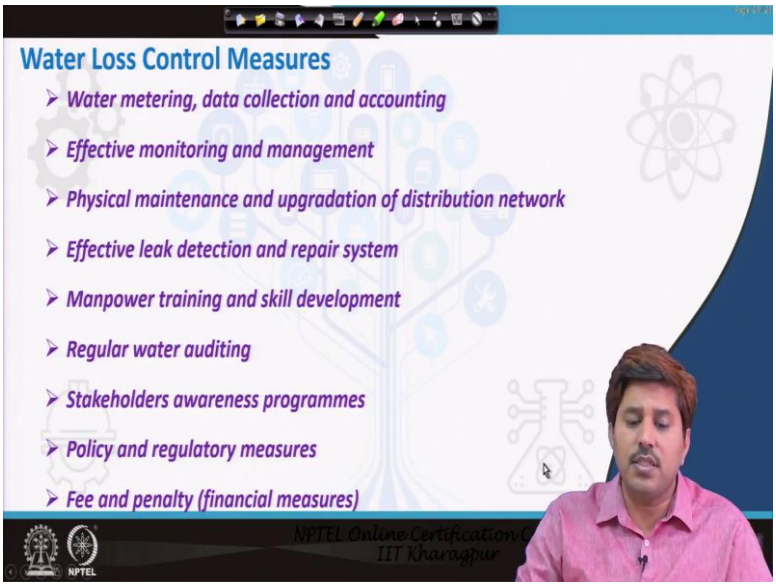

Now the control methods water loss control methods so there are various approaches which must be kind of considered important here. So, there is water metering and data collection and accounting. So, that is first if you want to control the losses you first have to record them you first have to know them and for that purpose the metering and data collection is essential. So, one must you like setup must be metered the data must be collected and accounted so that we can get an idea of the leakage that that is one of the measures which will eventually help for the controlling purpose.

Because this will give us an idea of the leak and then we need effective monitoring and management of the system this is very helpful in the apparent loss management. The; like if you are monitoring the network looking at the like preventing the theft cases looking at the accuracies of meter setup system. So, these are that way quite helpful. There is a physical maintenance and application of distribution network.

So for aged networks there are a lot of leaks and those kind of things happen so we must go for upgradation of those places where there is a faulty and physically maintain the network that is one of the important steps for the leak or water loss control. Then we have to have

effective leak detection and repair system as we were just discussing if there is any leak occurring in the system it should be effectively or quickly detected.

And we must have a repair system for that so that it can be repaired. Manpower training and skill development is needed then the regular water auditing has to be there in order to like set up the performance indicators. The stakeholder awareness program then policy and regulatory measures are to be adopted for control of the leakage. The fee and penalty or financial measures particularly like for apparent losses or if somebody's found stealing or say bypassing the meter or those kind of things so there has to be apparent fee and penalty for controlling these.

May be a penalty might be kept on the utility as well for not being able to control the real losses. A few other control measures are also there. Like pressure management so like pressure management as we were discussing that quantity of leak depends on the pressure so if it is a highly pressurized network their leakage chances are going to be more. So, we must ensure that pressure is adequate and not more than the desired in the pipeline. So, these are the major approaches through which we can go for the water loss control.

So, we will conclude this class here and in next class we will take some practice problem on the water auditing and leak assessment and there will and the discussions for this particular week. So, thank you for joining see you in the next class.