Surface Facilities for Oil and Gas Handling

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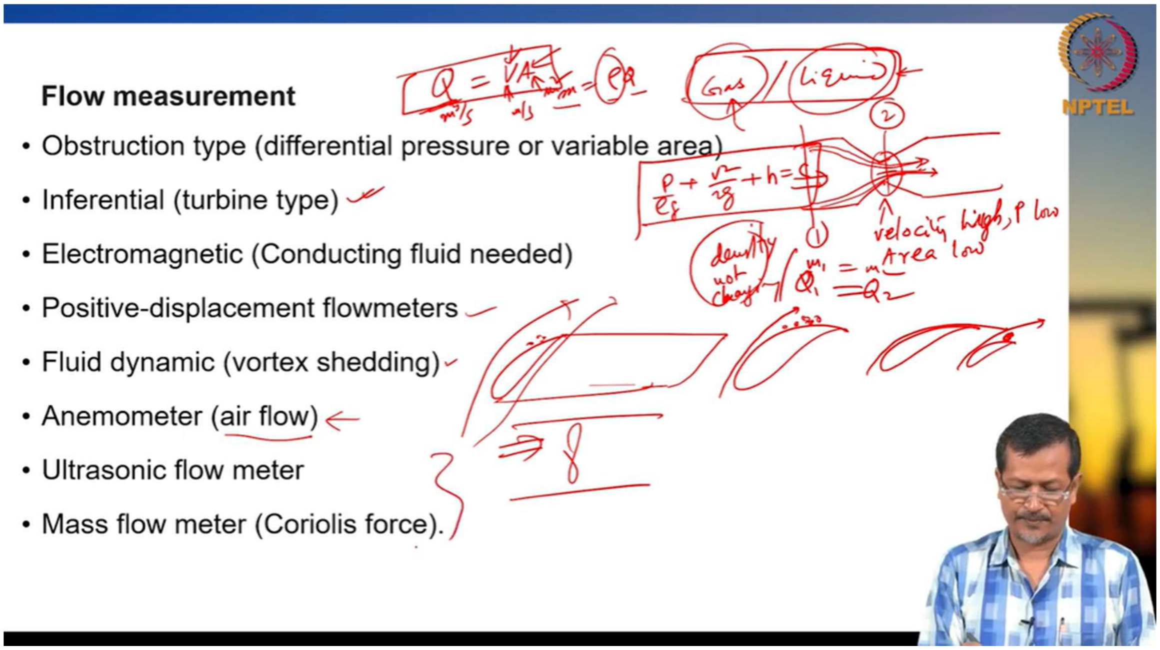
Flow Measurement Techniques-01

Good morning everybody, today I will start the topic Metering and Strategic Oil Storage ok. So, first let us start with Metering system. So, metering station allows operator to monitor and manage the oil as it flows through the pipeline crude oil metering skid can be installed permanently or be portable. Now metering means lots of instrumentation and your measuring parameters ok. So, some measuring parameter can be flow meter, can be pressure, temperature, measurement also and the electrical sensor also should be there like voltage transformer and those parameter also you have to measure because anything should not go uncontrolled ok. And normally these days everything will be connected to the SCADA system.

So, when you are controlling everything from using SCADA system that means, your metering system must be proper ok. So, you will have voltage sensor, pressure sensor and controlling equipment also at the same time valve automatic sensor, solenoid valve will be there. So, you check flow meter ok this much of flow rate is there and if it is within certain limit then ok if it is going beyond that limit maybe lower or upper then you have to take action. Again when you are delivering fluid to your customer so, that time also you need to measure flow and total volume measurement or flow measurement you need to require for in a pipeline you need to require to measure flow rate.

So, that you can calculate total volume how much you are delivering per month or per day or per year ok. And if you are transporting by train or cargo or truck then in that case you have to calculate volume total volume or how much you are putting into the system ok. So, there are different types of meters will be there. So, I will be focusing more on like volume flow meter and mass flow meter ok. One meter is there one parameter in storage tank specially called cat and mouse level indicator ok.



In case and mouse level indicator what happens like you have fluid here and you get give one float ok and you have one pulley maybe and one rope will be coming through pulley and you will have one mass here ok. And liquid level will be going up this mass will be going up going down ok. Now you put one scale here ok 1, 2, 3, 4, 5. So, as liquid level goes up your mass will be changing level. So, from outside actually is instead of accessing directly inside tank you can from outside you can see.

Even your water tanks also you can see similar system available actually ok that overhead tanks ah if you see IIT tanks those systems are there. Because from outside you can see you put big ah fonts of ah the digits 1, 2, 3, 4 you can see ok how much water level is there ok. These days electronic sensors are there. So, instead of mechanical this is purely mechanical right and easiest to use, but this is electronic sensor there using electronic sensor you can also measure ok. So, this is called cat and mouse indicator and normally it will be like polypropylene cord will be there polypropylene and there will be pulley ok.

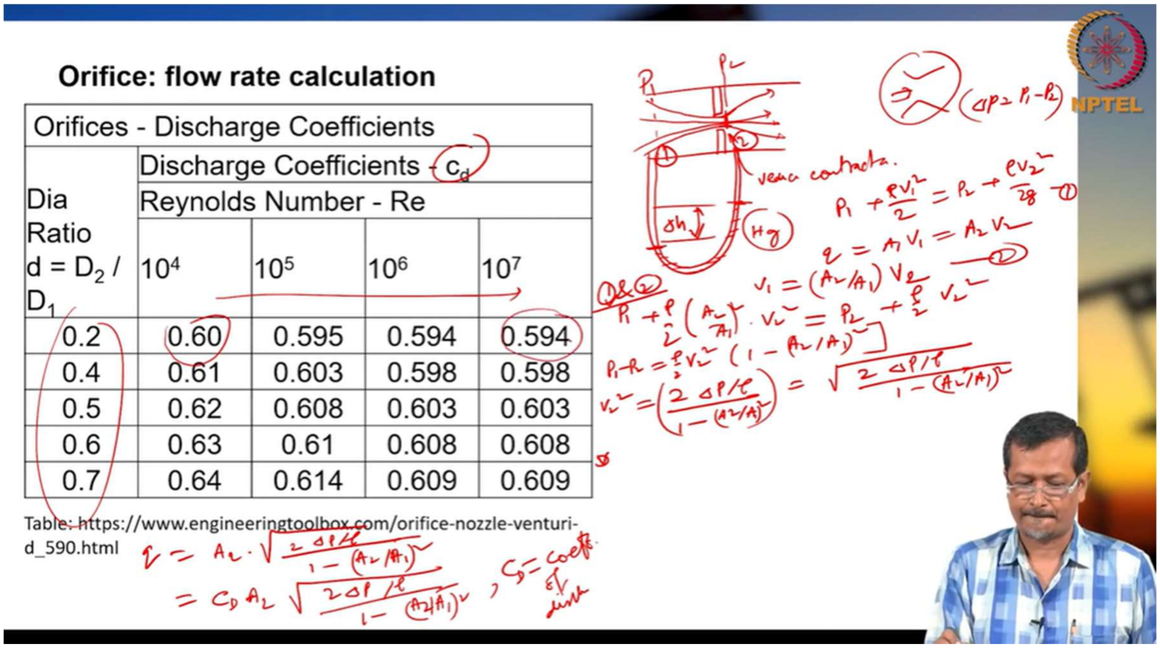
This will float will be there and one like this will be like clear PVC pipe. So, that from outside you can see this mass ok. So, clear pipe clear or transparent pipe ah pipe ok and these are level indicator will be there all marking will be there ok. This is called counterweight like this mass counterweight ok. So, when float is moving up this counterweight will be moving down.

So, this way you can see quickly is easily easy to install also easy to handle. So, this is oldest method of measuring ah the height level inside tank ok and if you are using electronic sensor then maybe you can take that data directly to your SCADA master computer system and you can control your level ok. It is like certain ah cases flow the level is going very down very low. So, maybe you have to fill that tank ok. In tank battery system you want to fill A B C D.

So, which I am going to fill. So, based on this one you can assess and there is a leakage and any other issue also you can check from this level indicator ok. So, ah you are talking about flow measurement. So, flow measurement like gas or liquid or liquid you are delivering to your customer. So, gas when you are delivering.

So, even actually you have to measure flow and you know you have to know temperature density right because temperature and pressure will be changing its volume flow rate volume rate ah, but when you are talking about liquid. So, normally liquid temperature the volume change will not be so high because of temperature change or pressure change ok because you are using dead oil. So, there is all volatile component already gone. So, that fluid you are delivering and normal temperature pressure you should not create any lots of vapor ok. Then liquid flow rate measurement is little bit easier you have lots of options, but when you are talking about gas flow rate measurement.

So, then you have to put some temperature sensor also pressure also you have to check, but flow ah liquid gas you may not have so much difficulty because there are lots of options available ok. And if you see flow meter type like obstruction type differential pressure or variable area. So, variable area means like venturimeter you may have seen your laboratory ok. So, you have one pipe fluid is entering and if we create restriction here. So, it will happen fluid same amount of fluid will be passing through the small gap ok.



When very high volume rate of volume flow rate is going through the small gap. So, velocity will be very higher this restricted or constricted location right. So, this variable velocity high where area is low velocity high ah high where area low ok and when velocity high actually pressure will be down p will be low. And ah other part for example, this is point 1 this is point 2. So, point 1 will be higher volume flow rate you are not changing actually same mass will be transferring because if you are assuming is liquid there is no density change then volume flow rate is not changing or mass flow rate not changing this is rho m equals rho q right.

So, q is not changing rho is not changing so mass will not change ok, but if you say gas rho will be changing. So, if you are changing rho then your store will be different ok, but the same philosophy will be holding, but direct calculation not possible you have to go through m z r t that formula ok compressivity formula also you have to included, but for liquid you are not including any compressivity formula ah. Larger diameter volume flow rate the smaller diameter volume flow rate same ok. So, like v q 1 and q 2 if I take actually same or mass flow rate if I want to take it will be same we are assuming density constant density not changing ok. And we are assuming other losses also not there if you have lots of losses then ah there will be certain discrepancy, but anyway mass you are not destroying because you are not giving any nuclear reaction here mass must be constant ok.

So, based on mass conservation equation energy conservation equation this formula will be holding ok. So, energy conservation equation will give this Bernoulli's equation Bernoulli's equation basically energy conservation equation ok. So, p plus v square by 2 g ah p by rho g v square by 2 v square by 2 g plus h equals constant am I correct correct ok. So, this p by rho g plus v square by 2 g equals equal constant. So, whenever you are changing the area.

So, velocity changing. So, when velocity changing your pressure must be changed ok then this equation will be holding constant value you are not changing ok. So, this obstruction type ah flow meter will be following this Bernoulli's equation or Benjamin meter theory or Bernoulli's equation you can say ah. Some turbine type flow meter also there ah, electromagnetic flow meter is there positive displacement type flow meter is there positive displacement type like you have ah reciprocating system or PCP progressive gravity pump system. So, they can deliver fixed amount of fluid.

So, if you give fixed amount using high pressure if you create ah reciprocity motion. So, because of certain pressure it will be creating certain motion ok. So, based on that you can calculate actually how much flow rate is going there ah. Fluid dynamic vortex shedding vortex shedding actually in my laboratory one ah flow meter is there like this. This is not vortex shedding, but this is another type flow meter this is called airfoil type flow meter ok.

Airfoil type flow meter like this ah. So, we have when fluid will flowing over the surface here pressure drop will be there you can remember the aerodynamic theories ok. When fluid is moving there at very high velocity pressure drop will be here ok. So, if fluid velocity very low this at low velocity fluid particle will be touching the surface at very high velocity fluid particle will not be touching the surface it will be going to straight path.

So, there will be gap. So, in gap is there pressure will be dropping ok. So, then you can correlate how much low pressure you are getting based on that you can back calculate and get the velocity actually fluid velocity. From fluid velocity if you know density. So, velocity and density and area then you can calculate your mass flow rate or flow rate ok. My turbine type flow meter in my laboratory we I measure air flow air flow velocity.

So, the same principle actually air flow ah not turbine there is a airfoil type flow meter. Another I have turbine type flow meter in turbine type flow what happens I want turbine ok I put it I will be putting inside in pipe. What will happen at low fluid velocity turbine rotation will be lower like wind turbine low velocity is there. So, turbine will be rotating very lower speed, but when air velocity very high turbine will be rotating very higher speed. Now, it is very much related air velocity more turbine rotation more turbine rotation more and now you produce electricity and check how much electricity you are getting.

So, higher amount of electricity you are getting means higher air velocity or fluid velocity. So, turbine flow meter ah I used in my laboratory actually. So, that based on this principle higher fluid velocity means higher rotation higher rotation means that in electromagnetism will be attached with this one that motor system not motor generator system. So, that will be producing electricity since the electricity now correlate with your velocity ok. First you calibrate then after that you pass certain amount certain fluid and it will give your flow rate ok.

You get fluid velocity and fluid velocity you get you know pipe area. So, velocity and area you correlate ok. So, flow rate equals V into A right am I correct V divided by A correct no. . Q meter cube per second meter meter cube meter cube per second ok yeah.

So, you can see this flow rate equals V into A. So, if I know velocity and pipe area I know then I can calculate flow rate Q ok meter cube per second is meter per second and this is meter square ok. So, every time you have to check dimensional balance ok ah and if you are using FPS unit or field unit accordingly your units will be changed. An animometer, animometer normally air flow meter will be used like weather department other department they will be using animometer. Normally you are not using for your high pressure application this will be low pressure application and this is also a flow meter actually.

Ultrasonic flow meter what what is ultrasonic flow meter I will explain later another is mass flow meter. So, both are very important actually I will explain ok. Ultrasonic flow meter what happens you give some ultrasound and you sense air ok. Based on fluid if flow velocity changing your sensing time will be changed ok.

So, based on that this is non-invasive. So, you do not put inside anything outside pipe you put this to this instrument ok. So, it will be put ultrasound again it will get reflect back. So, based on that it will calculate how much velocity is there ok. So, non-invasive type and differential pressure measurement like venturimeter we are creating I already explained. So, venturimeter what happens how to measure that pressure lower or higher ok.

So, what you do you create one pipe here small pipe another small pipe here ok. So, I said pressure is higher here ok P 1 P 2. So, pressure higher here means if I have any water level here water level will be very high ok, but here because of low pressure. So, water level will lower ok. Now if I can measure this two water level then I can get actually fluid velocity ok.

If I get different pressure then Bernoulli equation if you put because P plus V square by 2 g equals g rho g P by rho g and H ok constant. So, if you know the pressure or velocity if you know one then you can calculate other I am assuming let us say H is 0 at this moment horizontal complete horizontal, but if you have H value also you can calculate actually ok. So, this is called manometer. So, another way of placing that manometer is like this constriction is there is like this ok U tube manometer is same you call U tube manometer U tube ok. So, what happens you put on mercury H g and this pressure is high I told P 1 this is P 2.

So, high pressure means this will be pushing down this mercury column. If there is no pressure both column are having equal pressure let us say in atmospheric open to atmosphere then both column height will be equal ok, but if you are giving extra pressure here ok left arm is getting extra pressure. So, what will happen it will get depressed and this column will be moving up ok. So, one column will be lower another column will be higher height. So, find the difference between these two ok or del H you can say ok.

If you can get difference between two then you can calculate actually pressure velocity and flow rate and mass flow rate also ok, but then you have to calculate back calculation ok you get height then height H rho g you can get pressure. So, pressure difference you got based on that you calculate velocity or you got velocity you know pipe area is there then you calculate flow rate and if you want to get mass flow rate calculate with m dot ok. The Coriolis measurement Coriolis flow meter this is very important actually this is this will be calculated directly mass flow ok. So, it can be used for your air or anything because this is not related to volume this is related to mass ok. If your mass fluid is flowing through this if this pipe will be vibrating based on mass how much mass it is hitting this one.

So, that vibration sensor will be there. So, the sensor will tell this much of mass is coming inside ok. So, you should remember this is mass flow the normally it is called mass flow meter ok. Turbine type I already explained that based on fluid velocity turbine will change turbine speed changing this electrical signal will change and check the electric signal and correlate with your fluid flow ok. So, higher electricity you are getting this higher fluid velocity is there yeah. So, it can be gas flow or liquid flow does not matter ok gas or liquid.

When you are talking about gas then you have to include your z compressibility factor also ok, but if you are using only liquid then there is no compressibility ok. So, there also same thing gas or liquid maybe ok. So, floating element another type of flow meter is there floating element means like this is called conical tube like say I have one pipe here ok and fluid is flowing through this and I have one obstruction here ok. When fluid is moving at lower velocity the obstruction will be positioned at the lower position because it is not having so much energy to lift it up ok. But if I have very high fluid velocity the fluid will try to get more space.

So, what will what will it do? It will be lifting up this mass further up. So, it will get more space ok. So, then now you correlate with velocity. So, how much it is getting lifted? Ok lower lower lifting means velocity low higher lifting velocity now correlate ok then this is called floating element of flow meter ok. And electromagnetic again electromagnetic this is actually based on your ah conduct a conducting fluid.

So, if something non-conducting let us say oil, kerosene or something you are using. So, it will be very difficult to measure using electromagnetism. So, let us say dielectric fluid is there salty water is there those are the contactive fluid. So, contactive fluid can be measured in electromagnetic sensor this is also non-invasive. So, from outside electromagnetic pulses will be given and it will be captured ok.

Another type vortex, vortex type is like this you can see this picture ah let us say I have one bluff body ok and fluid is or may be circular body let us say circular body and lots of fluid will be touching this one and it will go like this ok. So, it will create vortex ok. So, vortex how if if you increase fluid velocity the vortex pressure pulsation will be very increasing very high rate ok. Very lower pressure lower velocity fluid is going this vortex will be it will create laminar flow and less vortex will be created. So, now, high velocity high vortex now you measure that parameter you capture that pressure pulses and measure the parameter then this also can be your one flow meter.

So, you first you have to know different types of flow meter then you have to see which one to use for your specific application because oil in the gas industry you have many application where you have to use a flow meter. So, not only one for only for tank right for many other purpose also you have to use flow meter. So, you have to know different options of flow meter and where to use which one. For example, you have you do not know which something is gas or liquid or gas liquid. So, in that case maybe corellias will be good because you are calculating mass based on mass you can calculate right because when you are delivering any fluid gas or oil actually you are delivering mass ok.

So, maybe one better suited flow meter, but if you think purely water is pipe flowing through one pipe and you want to measure how much water is going. So, simple turbine type flow meter will be very good. Some cases fluid flowing what you want we do not want to invade or you do not want to cut the pipe and put system then maybe electromagnetic or ultrasound type flow meter will be ok. So, you have different options now you have to see which one to use where ok.

The thermal dispersion another type flow meter. So, in that case what they do like I have one pipe I will generate one heat less I will be putting one coil here I will be generating heat. So, and fluid is flowing through this one what will happen this flowing fluid will get heated and heat will be transmitted ok. Now you put sensor one sensor here how much heat you are giving and how long this heat is going and what is the temperature if air velocity very high oh sorry if water velocity very high then what will happen heat will be transferred quickly ok. If water velocity very low or fluid velocity low then heat will be getting accumulated temperature very high. So, downstream temperature you can sense upstream temperature you can sense then you see the temperature difference if fully velocity very high the downstream sensor temperature sensor will be giving low temperature actually, but if fluid less if you stop fluid flow.

So, heat will be accumulated temperature much higher slowly fluid moving up then again temperature will be down very high velocity the hot particle will not be staying there. So, temperature rise will be lower ok. So, based on that theory actually they calculate heat transfer fluid flow rate. So, heat absorbs by fluid proportional to mass flow rate ok. So, mass flow rate increasing so, more heat will be absorbed and this temperature heating coil this area temperature will be lower ok.

So, one section generating heat very high flow rate you are giving. So, that heat will be carried quickly ok high mass flow rate means that heat will be carried quickly. So, that temperature will be dropping quickly, but downstream temperature may be different ok. So, based on this theory they will be calculating mass flow rate ok and orifice type flow meter you will do some calculation also based on flow meter ok. Orifice type flow meter is like this obstruction you are creating like venturi you created right this is also obstruction you created when fluid is going through this one you are creating narrow section you are obstructing the flow path. So, when you are obstructing actually there will be pressure drop pressure upstream pressure and downstream pressure will not be the same because there will be some losses and pressure drop will be there.

So, orifice type means you have pipe and you are obstructing with some bluff body maybe ok. So, what will happen fluid will be passing through this one ok they will feel very much difficulty to pass through the narrow section ok. And actually lower lowest that fluid stream lowest area will be here downstream of this just downstream of the orifice ok that is called vena contract ok. I think v n n a vena contract area. So, that area will be lowest area and pressure drop will be very high ok this is p 1 this is p 2.

So, p will be very lowest at that moment at that location may not be exactly at the orifice rather maybe little bit downstream ok based on the fluid velocity also fluid velocity very high that point also moving down further ok. And how to measure the parameter again if you I will putting one u tube parameter ok. I said p 2 is very low p 2 very low means if I put some mercury mercury means h g mercury will be like this ok. So, from here to here so, my mercury level difference will be here ok because p 1 is higher pressure p 2 is lower pressure.

So, mercury level will be going up ok ok. So, now, how to formulate this one how how much pressure drop how much flow rate is there using this one. So, p 1 plus rho v 1 square by 2 g z I am removing z we are assuming horizontal pipe ok so, p 2 plus rho v 2 square by 2 rho I am assuming same because it not change in liquid let us say constant rho or density. So, v 1 velocity p is the pressure upstream p 2 pressure at that narrow section ok. So, q equals A 1 v 1 A 1 v 1 ok flow rate at p 1 and what is the flow rate of v 2 p 2 or 2 section this is one section this is section 2 section 2 flow rate also will be same mass is not getting destroyed and density constant.

So, flow rate also same so, A 2 v 2 ok. So, then what is v 1 A 2 by A 1 v 2 is it ok. Now p 1 plus rho by 2 A 2 by A 1 square v 2 square I am putting this values here ok I can put number I can put equation number 1 maybe this is this is 2. So, 1 and 2 giving like this p 1 by rho equals p 2 plus rho by 2 v 2 square ok. Now p 1 minus p 2 if I do p 1 minus p 2 equals rho by 2 and v 2 also I will take out v 2 square 1 minus A 2 by A 1 square ok. Now v 2 square 2 del p by rho 1 minus A 2 by A 1 square and this is whole and del p equals p 1 minus p 2 v 1 minus p 2 del p ok.

So, v 2 equals root over 2 del p by rho 1 minus A 2 by A 1 square is it correct ok. Now flow rate I will write here flow rate equals A 2 into v 2. So, v 2 I have already got v 2 ah. So, 2 del p by rho 1 minus A 2 by A 1 square ah. If C d is the coefficient of discharge ah this is ideal case, but in actual case there will be certain losses.

So, we have to consider coefficient discharge. So, equals C d A 2 into same thing 2 del p by rho A by 1 minus A 2 by A 1 square. So, C d is coefficient of discharge coefficient of discharge ok. Ideally it will be 100 percent, but practically you cannot get 100 percent.

So, there will be certain losses. So, there goes C d. So, C d value can be 0.6, 0.7. So, here one table you can see based on Reynolds number C d value changing ok. This C d value changing diameter ratio if you know diameter ratio means like upstream and the orifice diameter, then based on different Reynolds number we can get C d value here 0.

6, 0.61, 0.64 ok. And you can see this Reynolds number changing your C d value also changing ok. Higher Reynolds number or higher fluid velocity. So, in that case you see point Reynolds number change ok. So, 0.6 to 0.59 become.