Surface Facilities for Oil and Gas Handling

Prof. Abdus Samad

Department of Ocean Engineering

IIT Madras

Pressure Vessel-03

In previous lecture, we have good morning everybody. Today, I will start Line Size and this topic is taken from Surface Production Operation book, Stuart Arnold book, GPP, Gull Publishing House, Volume 1. In previous lecture, we have seen that if we have any pressure vessel, so different end condition or head condition changes its weight. So head condition thickness will be changing your weight. So when weight is changing, your cost will be changing, your operation strategy also will be changing. So you have to optimize what will be the minimum weight possible and minimum cost possible.

Based on this actually you are buying or buying any separator system or high pressure system. But whenever you have lines, pipes, connecting two separator or transporting fluid from one point to another point with high pressure, so that design consideration also you have to consider. Because the pipe and pressure vessel two different thing actually because pressure vessel is having end, in pipe we are assuming there is no end. So design there will be certain changes.

So let us see what are the formula says. So when you are choosing line thickness, so you have to consider, so line size criteria. Both pressure drop del p and flow velocity v needed to be to choose line size. Normally del p or pressure drop is not main criteria for pipe in piping design. Most pressure drop occurs across a control valve because you have one pipe and you have one valve or any other mechanism fittings.

So their pressure drop will be more because whenever there will be laminar flow or laminar boundary layer and smooth the fluid is flowing through straight path, so pressure drop will be very low. But if there is any bend, so you can remember in previous I told in previous other lectures that whenever there is any bend or any fittings, fittings in nut, bolt or it is changing size of pipe directly expanding or directly in contracting, suddenly contracting, suddenly expanding fittings are there. So in that case your pressure drop will be higher. So normally del p not main criteria for piping. First you have to consider the most important part, for example any fittings, valves, notch or any change in flow direction, those things first you have to consider.

Then after that you can consider pipe friction total. So del pd is important for long pipe line equipment operating at same or nearly same pressure, flow between low pressure and atmospheric pressure vessel, equivalent length and elevation changes are there. So in that case del p should be considered. Line diameter, so velocity fluid velocity mean minimum, minimum fluid velocity and maximum, fluid velocity will be deciding your pi velocity. For example, you want to pass fluid through a pipe and you are creating very high pressure.

So in that case very high pressure drop also be possible because friction pressure drop f l v square by 2 g d formula is there. So if you are changing fluid velocity at very high level, so what will happen? Your pressure drop will be increasing. And how to change this fluid velocity? So if you enlarge piping diameter, so flow rate equals v into a. So you let us say you are getting very high fluid velocity and flow rate is not changing, flow rate will not be changing through the pipe because we are assuming you are not destroying mass and it is non-compressible flow. So in that case if you are changing flow area, then velocity must be changing.

Even in gas case also same thing will happen if you are changing flow area, then velocity will be changing. So velocity if you reduce, then your del p or pressure drop also will be reduced. So whenever you are designing any pipe, you have to consider fluid velocity. So that will be giving your pipe sizing, so minimum, maximum. And what will be the minimum pipe size? Minimum velocity will be decided based on your solid is there.

If solid there is a small small sand particle. If you are reducing fluid velocity, what will happen? Sand settlement you can remember. Sand particle will be settling in the pipe. That will be creating one layer. So slowly that layer will be increased, increased, increased, after certain time it will be getting blocked.

So if you are getting very low flow velocity, sand particle will be blocking your path actually after certain time. But if you are increasing flow velocity, there is very high rate, then your pressure drop will be there. Then you have to optimize what will be your optimal pressure drop or optimal size, so that you can use your pipe or high pressure pipeline safely and it will be giving long term efficient transportation. Erosion, noise, water hammer limit V max. So if we have very high velocity, then erosion also possible.

What happens at very high velocity, sand particle or solid particle will be hitting the metal continuously. When metal particle is constantly heated, so micro particle will be removed up, micro level. So that micro level particle 1, 2, 3, 4, 5, then after certain time you see lots of erosion happened in the pipe. So erosion happened means leakage and bursting possible. Again noise will be possible, very high velocity fluid passing through your system, your pipeline.

Then flow noise will be coming up, water hammering also will be possible, suddenly any flow blockage is there, water will be hammered, you see you have one vertical pipe. The high pressure fluid is moving. Now suddenly you close the valve, what will happen? All the momentum will be acting on the pipe, so pipe can burst actually. Fluid is moving and rushing at very high velocity, suddenly you close the flow path or because of certain reason flow path got abstracted. So because of that water hammering will happen.

Water hammering means the whole fluid column will be acting as hammer and it will be breaking the fluid pipeline. Surge, sand, other solid transport limits, minimum. So surging will be happening if you have very low fluid velocity, sand and other solid particle if there in the pipeline, so that will be getting deposited in the pipeline. So that will be one big problem. When fluid is flowing through a pipe, there will be erosion.

Erosion formula is like this, V e equals C by rho m power half. So what is C, what is rho? V is the erosion velocity, erosion velocity feet per second. C is a constant, empirical constant. Rho m is your density of fluid, density of fluid. Normally it will be used for two phase flow, that is why rho m is given.

So average density of fluid will be used. So L b per cubic feet. If velocity exceeds V e, erosion of the product will be happening and if corrosive fluid is there then it will be much more disastrous. In 1990s API gave some value of C. So they said C value should be 150 for continuous service, for, and for 200 for non-continuous service, for non-continuous service.

So erosive service solid present, erosive service. So this formula is given by A S W R I. So S W R I say like upper formula may not be applicable everywhere, so they have derived another formula called erosive service for solid if solid present, solid present in the flow without corrosion, in the flow without corrosion. So formula is that V e K S D root over Q S. For erosion, the erosional velocity can be determined by the above equation.

This is called erosional velocity V e. So K S is a, K S is a fitting factor. So it will be obtained from certain table. D is pipe inside diameter, pipe inside diameter in inch. Q S is solid or sand flow rate, sorry it may be sand.

And unit is F T Q per second, per day, not second, per day. And this formula is given to South West Research Institute, US, West Research Liquid Line. Say you are designing a pipeline, it is carrying liquid. So in that case, maximum velocity will be about 15 feet per second for a line searching to minimize noise, water hammer and erosion. Sand grain deposit on the bottom until equilibrium velocity is reached.

What happens? You have one pipe. So if a very low velocity, so sand will be deposited. Now you increase velocity. What will happen? This, this high fluid velocity, it will be trying to eroding this sand. Whatever deposit there, it will be trying to eroding.

And again after certain time, again one equilibrium condition will be coming. So x amount sand will be getting deposited. Same amount will be moving out. So in that case, there will be no extra deposition. And other certain amount depositors, amount is getting removed.

But again you reduce fluid velocity, again certain sand will be deposited and again equilibrium will be maintained. So that equilibrium maintenance will be working if you are changing fluid velocity. At very high velocity, erosion rate will be higher, so there will be no deposition, almost no deposition. So if V is increased, bed eroded to reach new equilibrium velocity.

V means velocity. Again it will be stabilizing. If V decreased, again some more accumulation will be there. Again established equilibrium will be coming up. Minimum V velocity, velocity of fluid can be 3 feet per second.

They are normally recommending. So fluid velocity, fluid velocity V equals 0.012 Q L divided by D square. So pi pi D I D and Q L is the liquid flow rate, flow rate. This is barrel per day or BPD I can write, BPD.

And this is in field unit, field unit. So erosion of metal, formula is the volume, volume equals K W V square beta g by p. So K erosion wear coefficient, K erosion wear coefficient, W is called total weight, total weight of impinging particle, of impinging sand particle, impinging particle. And V is the particle velocity, V is particle velocity, I am putting equal sign, particle velocity. P penetration hardness of the material. This is P is not pressure, penetration hardness.

So here hardness, hardness is how much hard the metal, how the test. So they will be taking one specimen, let us say one metal is taken and one small diamond shape or triangular shape, other solid strong metal they will try to push it down. So how much indentation happening here, so they will try to measure. So that way it will be showing how much hardness is there. Sometime this will be like diamond shape, sometime it will be like circular shaped, circular shaped on one tip you take and you try to push it down.

So how much penetration happening because of certain pressure, so that will give, that will be the measurement of hardness. So that is called penetration hardness. So there will be different methods, Charpy method is there, Brinell hardness testing method is there. So different methods are there using the material scientists, they will be measuring the penetration hardness or hardness values.

Beta, a value between 0.5 to 1.0 depending upon the impingement angle, depending upon the impingement angle of the particle. So pressure drop, there is one figure operating pressure and this is pressure drop, pressure drop per 100 feet psi. So curve will be looking like this. So if you are changing operating pressure, how the pressure is getting changed, you can get from this curve. So this is called figure acceptable pressure drop or I can write del P or del P, okay, acceptable pressure drop for short lines.

For long lines, the curve will be different. For gas line, the formula will be little bit changed. So if V or velocity is the major criteria, velocity is the major criteria, del P is not a much problem. Del P due to friction required by recompressing, so if there is any loss in del P, so again compression should be done. Minimum velocity 10 to 15 feet per second to minimize liquid settling out from the low spots or through pi fluid is going and if there is any liquid particle, it should not get settled out and should not get blocked. If there is lots of liquid settling out from the gas, so that will be blocking the flow path.

So maximum velocity can be 60 to 80 feet per second to minimize the effect of noise and corrosion, okay. So VE, erosion velocity, erosion velocity 0.6, C, C is a constant, erosional flow constant, and S is specific gravity of gas, specific gravity of gas at standard condition. Air equals 1, air specific gravity is 1, P is the pressure, Psi, T is Rankine temperature, okay.

So VE equals 0.6 C T by SP, okay. So here we assume Z equals 1, compressivity is 1, okay. Erosion velocity due to small amount of liquid in the gas can be calculated here, okay. So erosion velocity for small amount of liquid can be calculated using this formula. And another formula is there, D power 5, 1260 STF QG P by del P. So what is D? D is pipe ID, ID, S is your specific gravity, gravity of gas, T Rankine temperature degree R, QG your gas flow rate, P is your pressure, P sia, del P again pressure drop, P sia, and FTF Moody's friction factor, F is, F is Moody's friction factor, Moody's friction factor.

So from there we can calculate a diameter. And detail of the formula we will be using later. Two phase flow, most two phase lines operated high pressure and pressure drop is usually not used to calculate a diameter. Recommendation, minimum velocity will be 10 to 15 meter per second to keep liquid moving in the line to minimize slagging. If liquid is getting deposited then there will be a problem, okay.

Slagging of separator and other process equipment. Maximum velocity should be 60 feet per second for reduction of low noise, 50 feet per second for inhibiting COT corrosion and or other erosional velocities. So 50 to 60 maximum velocity can be kept. Erosional velocity expresses for two phase flow, erosional velocity, erosional velocity. C by pm, C is constant, rho m is your density and den, okay. The density of the mixture, the density of the can be expressed as rho m 12409 specific gravity into P 2.

7 SRP 198.7 P ZRT. So the terms are SG specific gravity, P is your pressure and S specific gravity. This is specific gravity of liquid, liquid relative to water, relative to water use the average gravity for hydrocarbon and water for mixture, okay. So SG use average, average gravity for hydrocarbon and water mixture, okay. R is gas liquid ratio, R gas liquid ratio and what is term is there? Z is compressibility factor, compressibility factor. S is specific gravity of air 1, a specific gravity of gas air equals 1, okay.

Okay, thank you very much for today's lecture. Next day we will try to solve some problem. Thank you very much.