Oil Hydraulics and Pneumatics
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Part 03: Pressure drop Predictions using Various Empirical Formulae and Nomogram, Best Practices for Compressed Air Piping System and Installation Tips
Lecture – 29
Pneumatic Pressure Drop

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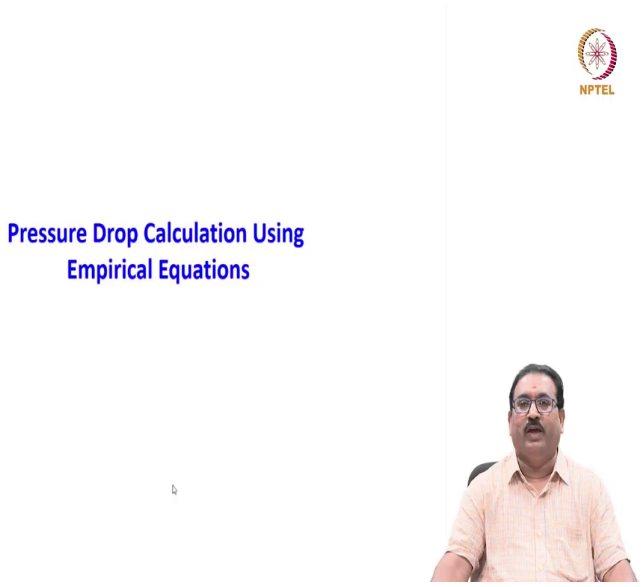

My name is Somashekhar, course faculty for this course. Knowing all these parameters, now we will predict the Pressure Drop Using the Empirical Relations. The people have derived the empirical relations to correlate these parameter in predicting the pressure drop very quickly. What are those, we will see now.

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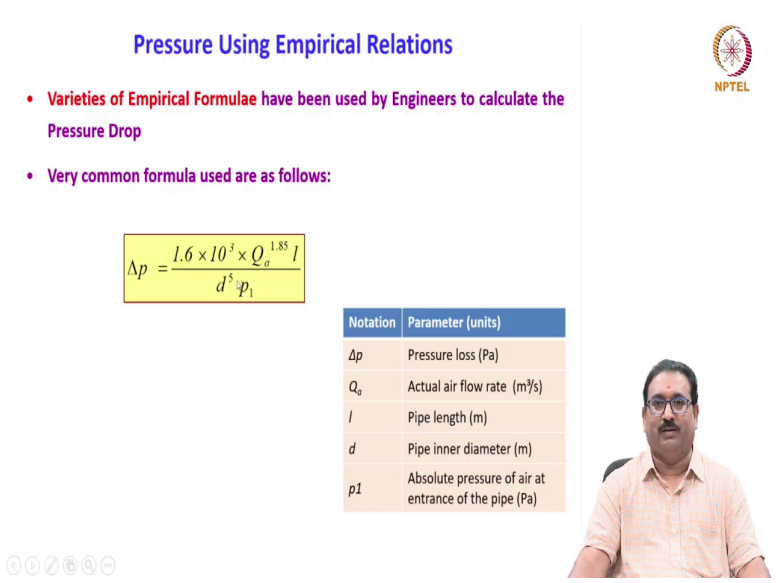

Varieties of empirical formulae have been used by engineers to calculate the pressure. Very common formula is delta p equal to 1.6 into 10 to the power of 3 into Q a raised to 1.85 into l divided by d to the power of 5 into p 1.

This is empirical relations friends, which specifies the delta p pressure loss or a pressure drop in Pascal provided you will put all Q a, l, d, p 1 in the same unit as I have mentioned here. Q a is actual air flow rate is m cube per second, pipe length in meter, pipe inner diameter in meter, absolute pressure of air at the entrance of the pipe Pa Pascal.

All you will see all SI units you have to put then only you will get delta p in the Pascal; meaning whatever the units you are using inch so many things you have to convert into the same units you will put it here. Otherwise you will modify this empirical relations.

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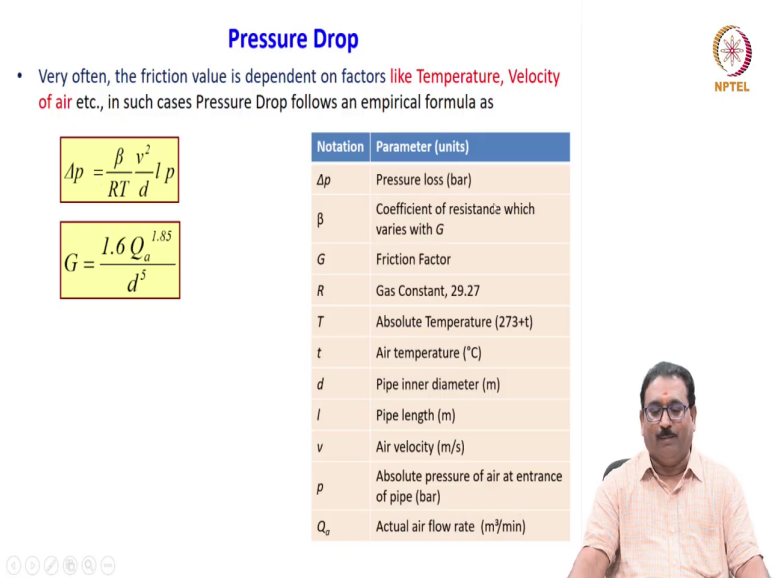

Very often the friction value is dependent on factors like temperature, velocity of air etcetera. In such cases the pressure drop follows the empirical relation is delta p equal to beta by RT v square by d l p. Again, here you will see friends delta p you will get it in bar provided the beta is the coefficient of resistance which varies with G. What is a G? G is a friction factor is determined using 1.6 Q a raised to 1.85 divided by d to the power of 5.

Here you will see the R is a gas constant 29.27, T is a absolute temperature 273 plus t, t is a air temperature, d is a pipe inner diameter, pipe length, v is a air velocity in meters per second and p here p absolute pleasure of air at the entrance of pipe in bar, Q a is a actual air flow rate. If you substitute all these values in this unit you will get delta p in the bar, all are empirical relations.

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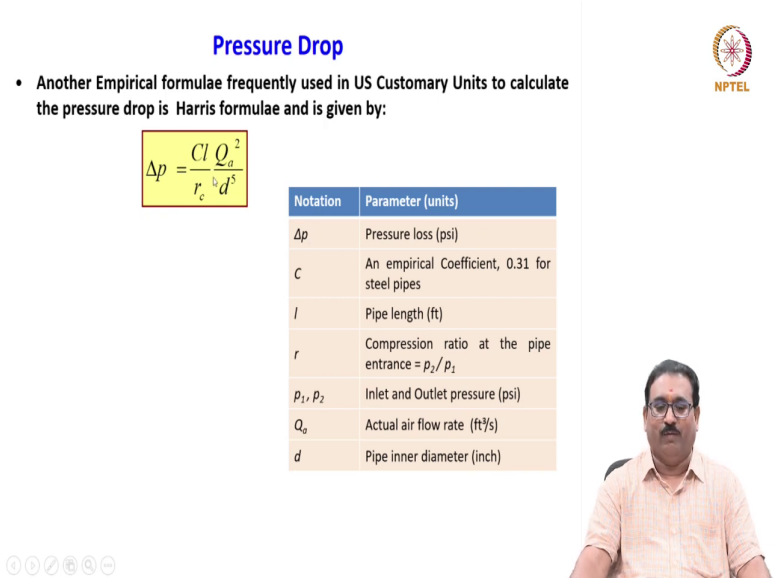

Another empirical formulae frequently used in US Customary Units to calculate the pressure drop is a Harris formulae more frequently used in US and is given by delta p equal to Cl by r c Q a by d here 2 and here 5. You will see what is delta p; you will get it in the psi pounds per square inch US Customary Unit.

C is an empirical coefficient 0.31 for the steel pipes like this you will get for the different materials, l is a pipe length in feet. r is a compression ratio at the pipe entrance which is a ratio of p 2 by p 1; p 1 and p 2 are the inlet and outlet pressure again you will mentioned in the psi. Q a is a actual air flow rate cubic feet by second and d is a pipe inner diameter in inch. All are US Customary Unit you will get delta p in pounds per square inch using this empirical formulae.

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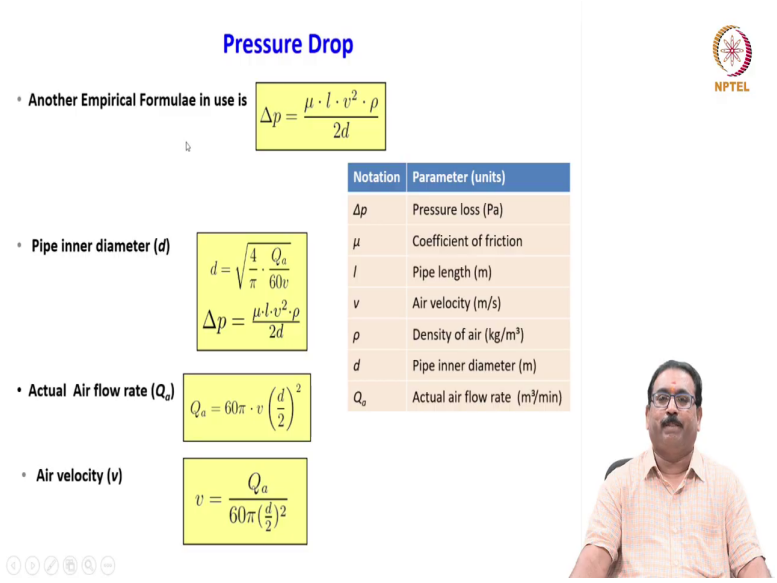

Also another empirical formulae delta p equal to mu l v square into rho 2d. Here they are considering the density of air again one more empirical relation. Here also we will see friends delta p we will get in Pascal. You will put the coefficient of friction, l is a pipe length, v is a air velocity, rho is a density of air, d is a pipe inner diameter, Q a is actual air flow rate m cube per minute.

The pipe d here is you know you will calculate to relate the Q a, this d you will get it from the root square root of 4 by pi into Q a by 60 v, correct? Again, here you will see this Q a you will get it from the 60 pi into v d by 2 whole square. Here again you will see this this v you are getting from Q a by 60 pi d by 2 whole square.

All are the empirical relations used to calculate the pressure you will see understand friends. All this pressure drop calculation is related to the all the piping and tubing parameters and

frictional parameters, correct? In all these you will see if you know all these parameter very easy to calculate the delta p.

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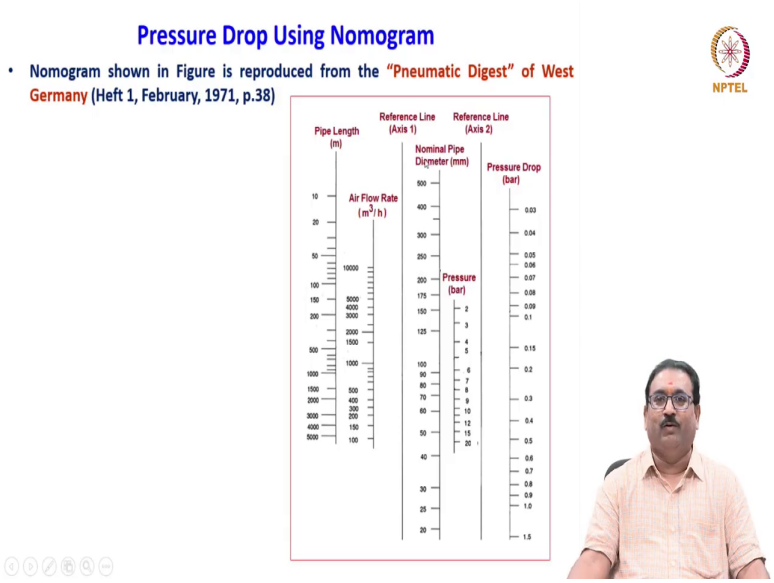

Now, currently people are using the nomograms where is the graphical method it is to predict the pressure drop. What is this nomogram? Nomogram shown in figure here is reproduced from the Pneumatic Digest of West Germany. What it is? This nomogram is having the parameter pipe length, air flow rate, nominal pipe diameter, pressure absolute pressure and a pressure drop.

You will see here again friends the first vertical line is a pipe length. You have to calculate the effective pipe lengths; meaning you will consider all the pipe fitting and align fitting and then you will include in the calculation of pipe length total pipe length in meter you have to put.

Then air flow rate based on the requirement m cube per hour you have to put, then one more you will see here reference line is there which is axis one. What is the duty of this I will tell you. Then next line is the nominal pipe diameter in mm you have to put, then pressure absolute pressure in the bar, then the reference line axis 2 is there, next vertical line is a pressure drop.

What I am using here now friends if you know the some of the parameters here and other parameters you have to calculate and finally, I want to know the pressure drop. If you are restricting if you know the pressure drop and some other parameter you will be able to calculate the other unknown parameters. You will do vice versa.

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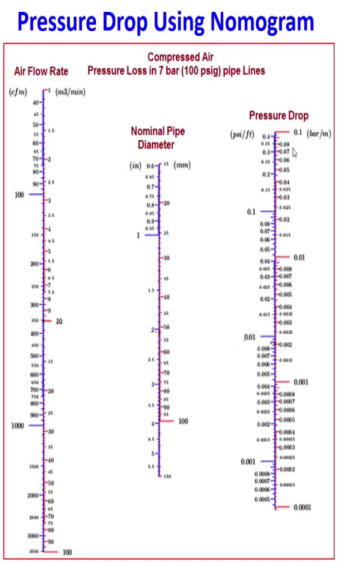

Now, I will show you very quickly some of the things. Now, let us we will see one more nomogram in which the three vertical lines are there here. The air flow are mentioned here the

two units nominal pipe diameter again inch and mm pressure drop again psi per feet or bar per meter, correct.

Now, we will see friends here if you know the air flow rate and a nominal pipe diameter, mark it and join by these two points and extended to the pressure drop to predict the pressure drop or you want to fix the pressure drop and a nominal pipe diameter to know the air flow fix the two points and extend this line to the third vertical axis. This is also another way of used in the nomograms.

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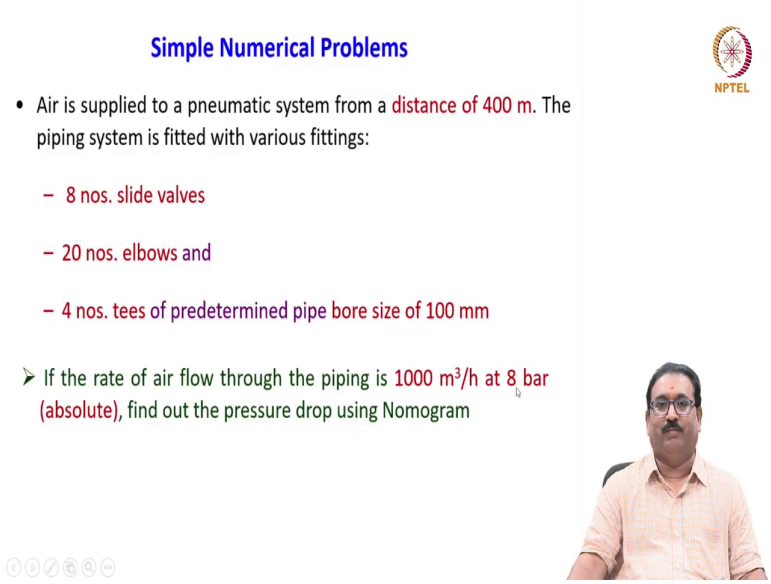

Now, I will show you one simple numerical problems how to use the nomograms in predicting the pressure drop. Air is supplied to a pneumatic system from a distance of 400 meter; the piping system is fitted with various fittings. 8 numbers of slide valves, 20 numbers of elbows, 4 numbers of tees of predetermined pipe bore size of 100 mm.

If the rate of air flow through the piping is 1000 m cube per hour at 8 bar absolute pressure find out the pressure drop using the nomogram. Now, you know already the total distance of the piping is 400 meter, but to make the complete the piping layout, it uses the various types of tube fittings or a what I will call accessories like a 8 number slide valve, 20 number elbows, 4 number of tees, also we know the air flow rate required here at what pressure. Now, how to do this?

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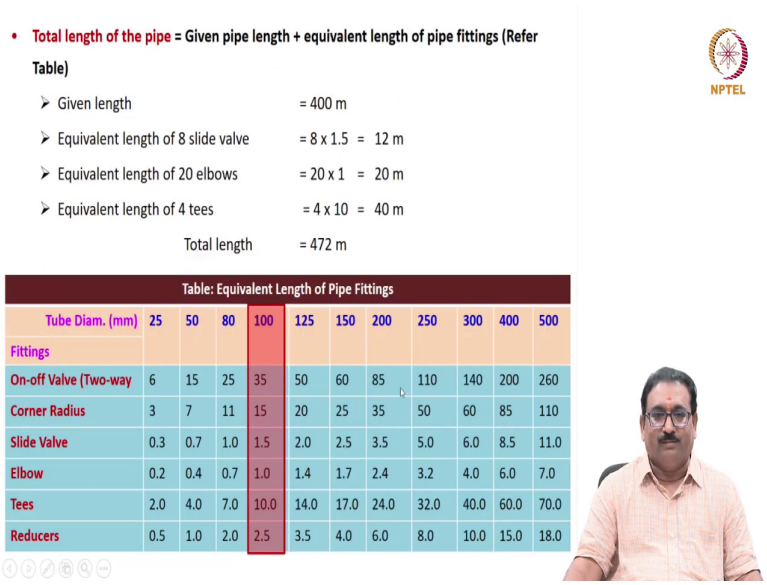

Now, we have to calculate as I have told you the effective length is very important total length of the pipe. What is that given pipe length? What it is? 400 meter they told, then equivalent length of the pipe fittings, how we will get equivalent length of the pipe fittings?

For the various types of fittings here I have shown you the various types of tube fittings are there and their corresponding length I am given in this table for the different types of tube

diameters you will see 25, 50, 80, 100, 125. Now, our pipe diameter tube diameter is 100. Corresponding to this, what are the valves I am using? Equivalent length 8 number of slide valve; slide valve is 1.6, then what we will do 8 into 1.5, correct? Equivalent length of the 20 elbows; elbows you will see, what is the equivalent length? 1. 20 into 1.

Tees tee you will what is the tees? Equivalent length is 10, 4 into 10. Now, the total effective length is 472. You do not use directly as a pipe length alone. You will convert the fittings whatever the they are given into the equivalent length using this table. Then, now we are getting 472.

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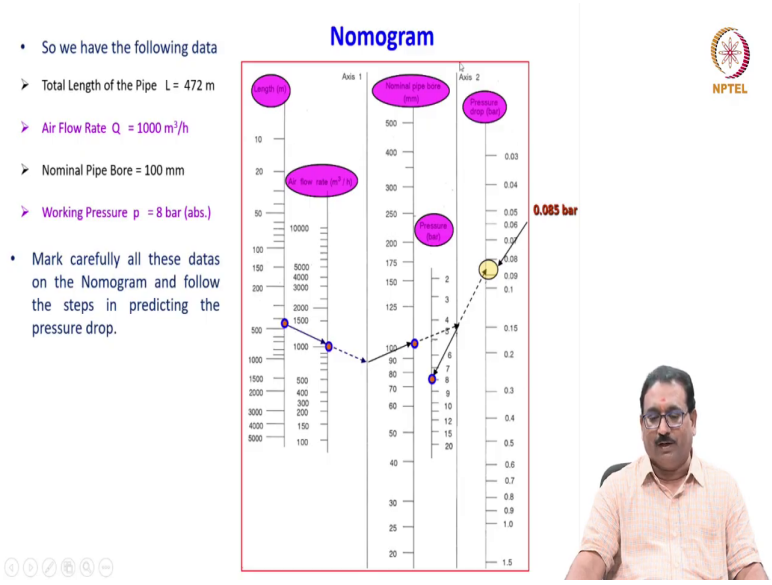

Then we will go to the nomogram what I have shown you. Here now we have the total length of the pipe is 472 meter, air flow rate is thousand m cube per hour same thing what we are

having required here; the nominal pipe bore is 100 mm, nominal pipe bore we have to put it in 100 mm only. Now, it is in the same unit.

Then working pressure in bar, then what to do friends now? Now, mark all these data on the nomogram and follow the steps in predicting. Length of the pipe, air flow, nominal pipe, pressure, mark it all these four important points on the axis.

Then how to predict the pressure drop? You will join these two, then extend the same line to the axis 1. Please understand, then join from this intersection to nominal pipe bore. Then what we will do? Extend this line to the axis 2. Then you will backward propagates to this pressure.

Then same line you will extend it to the pressure drop line which is nothing, but 0.085 bar is a pressure drop for the given pipe fittings and a pipe length, air flow rate and a pressure. This is a very quick way to predict the pressure drop by knowing these parameters.

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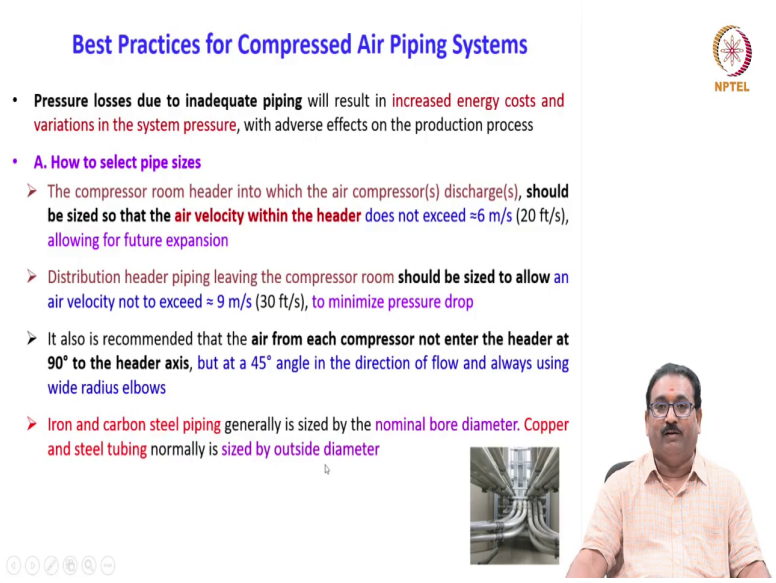

Now, quickly we will move on to the best practices for compressed air piping system. Pressure losses due to the inadequate piping will result in increased energy cost and variation in the system pressure with adverse effect on the production process. So, how to select the pipe sizes? The compressor room header here this is compressor room header full into which the air compressor discharges should be sized, so that air velocity within the header does not exceed 6 meters per second allowing for future expansion.

Distribution header piping leaving the compressor room should be sized to allow an air velocity not to exceed 9 meters per second to minimize the pressure drop. It also is recommended that the air from each compressor not enter the header at 90 degrees to the header axis, but at a 45 degree angle in the direction of flow and always using a wide radius

elbows. Iron and carbon steel piping generally sized by the nominal bore diameter. Copper and steel tubing normally sized by outside diameter keep in mind friends.

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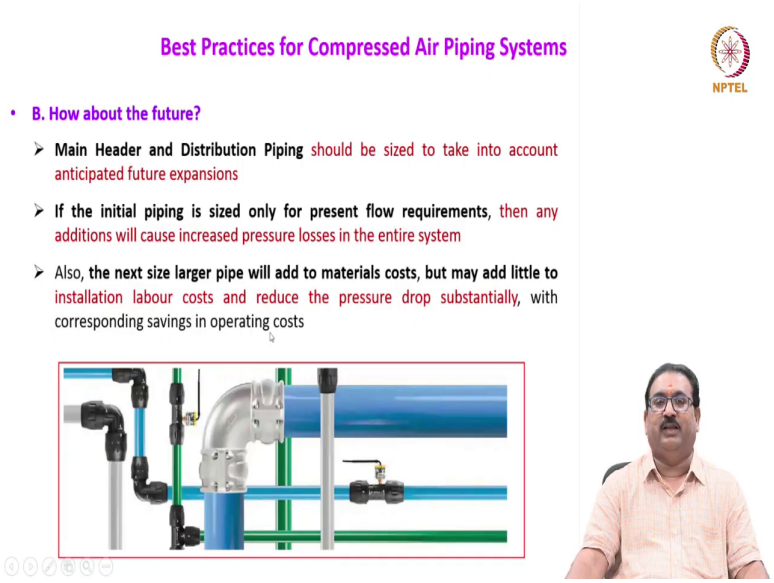

Then how about the future? Main header and distribution piping should be sized to take into account anticipated future expansions. If the initial piping is sized only for present flow requirements, then any additions will cause increased pressure losses in the entire system. Also, the next size larger pipe will add to material costs, but may add little to installation labour costs and reduce the pressure drop substantially, with corresponding saving in the operating cost.

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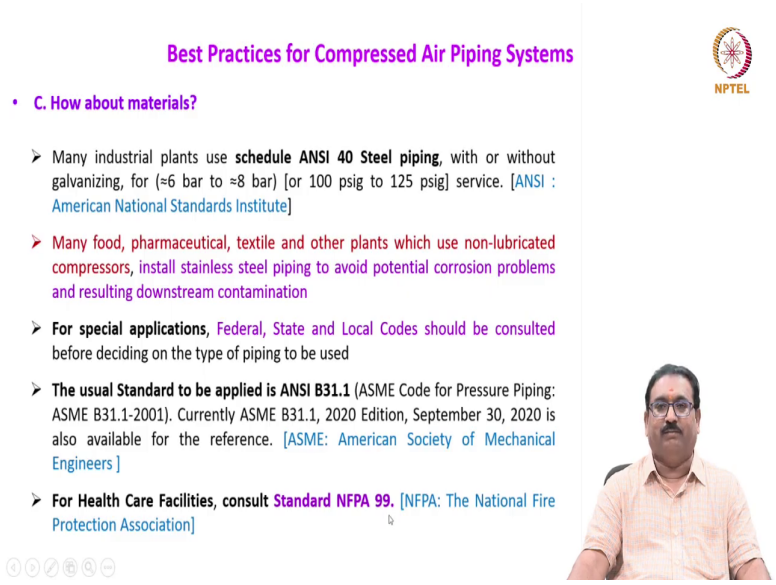

Now, how about the materials? Many industrial plants use scheduled ANSI 40 Steel piping, with or without galvanizing for 6 bar to 8 bar service. Many food and pharmaceutical, textile and other plants which use a non lubricated compressors install a stainless steel piping to avoid a potential corrosion problems and resulting downstream contamination.

For special application federal state and local codes should be consulted before deciding on the type of piping to be used. The usual standard to be applied is ANSI B31.1. Currently ANSI B31.1 2020 edition in September 30, 2020 is also available for the reference. For health and care facilities consult Standard NFPA 99.

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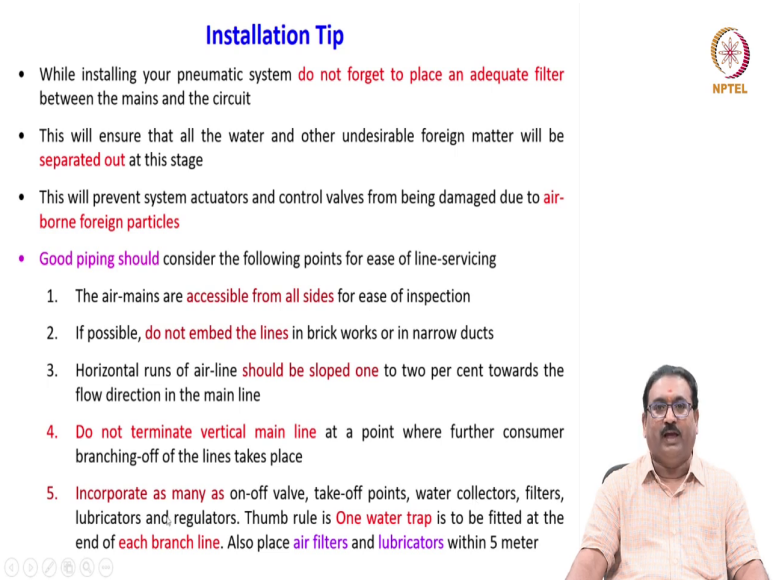

Quickly I will tell you some of the installation tips while laying the pneumatic lines in the industries. While installing your pneumatic system do not forget to place an adequate filters between the mains and the circuit. This will ensures that all the water and other undesirable foreign matters will be separated out at this stage itself. This will prevent system actuator and a control valves from being damaged due to the air borne foreign particles.

Good piping should consider the following points for ease of line servicing. The air-mains are accessible from all sides of for easy inspection. If possible, do not embed the lines in brick works or in narrow ducts. Horizontal runs of air-line should be sloped one to 2 percent towards the flow direction in the main line.

Do not terminate vertical main line at the point where further consumer branching-off the lines takes place. Incorporate as many as on-off valves, take-off points, water collectors,

filters, lubricators and regulators. The thumb rule is one water trap is to be fitted at each end of the branch line. Also place air filters and lubricators within a 5 meter in the air distribution system.

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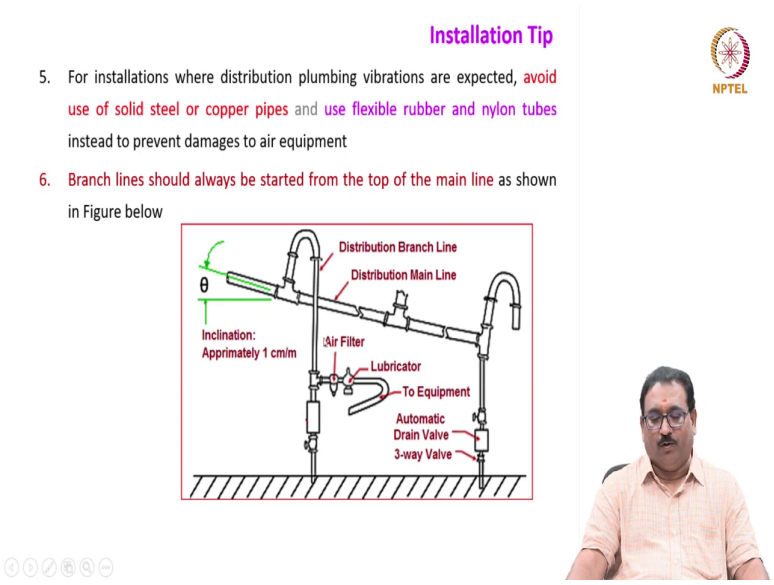

For installations where distribution plumbing vibrations are expected, avoid use of solid steel or a copper pipes and use flexible rubber and nylon tubes instead to prevent the damage to air equipment's. Branch lines should always be started from top of the main line as shown in the figure. Always the tapping lines should be from the main line you will take it from the top side, not from the bottom side. Horizontal pipes always you will put the inclination approximately 1 centimeter per meters.

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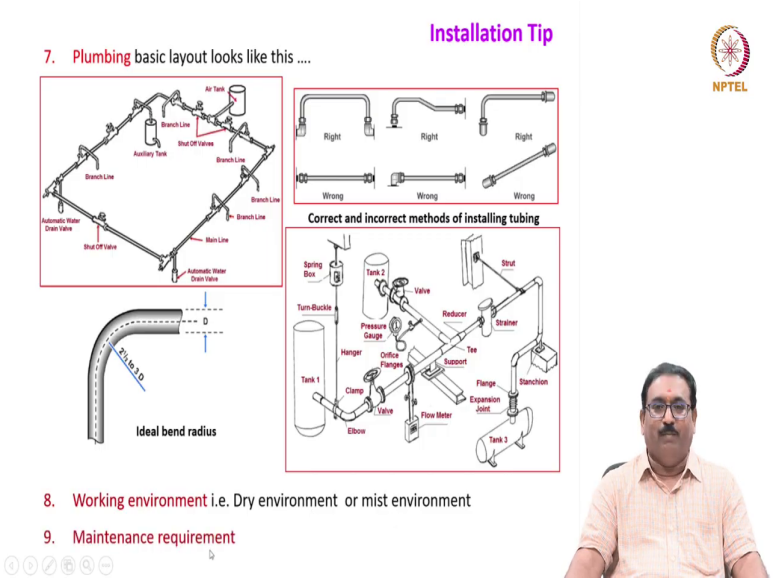

The plumbing basic layout looks like this. You will see there are so many plumping layouts. You already seen. This is a you will see now the pipe you should not put straight like this is allowed. Similarly, it is a wrong, you will put like this always inclined. Here you do not put like this, you will put like this.

These are the correct and incorrect methods of installing the tubing and pipings. You will see here the bend radius is also very important which should be 2 and half to 3 d, d is diameter of the pipe. You will see here friends there are so many on-off valves and so many valves connectors are used in the distribution systems. Working environment which would be the dry environment or a mist environment you have to consider this and maintenance requirement.

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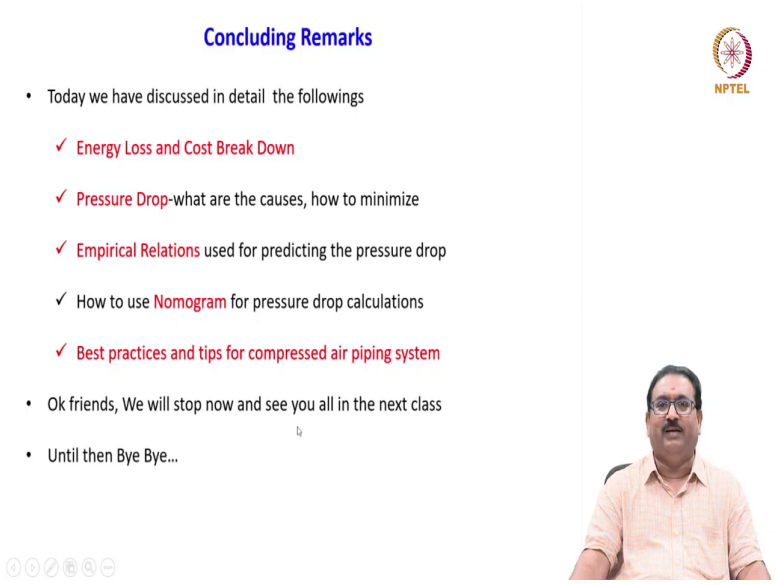

After knowing this, we will concludes the today's lecture. Today we have discussed in detail the followings: energy loss and a cost break down; pressure drop – what are the causes, how to minimize; empirical relations used for predicting the pressure drops; similarly we studied the nomograms in predicting the pressure drop pressure drops; best practices and tips for compressed air piping system.

Ok friends, we will stop now and see you all in the next class. Until then bye bye. Thank you one and all for your kind attention [FL].

Thank you. See you in the next class.