INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-33
Air Distribution System-2

with
Prof. Ravi Kumar
Department of Mechanical and Industrial Engineering
Indian Initiation of technology, Rookee

Hello I welcome you all in this course on refrigeration and air conditioning. Today we will continue our discussions on air distribution system.

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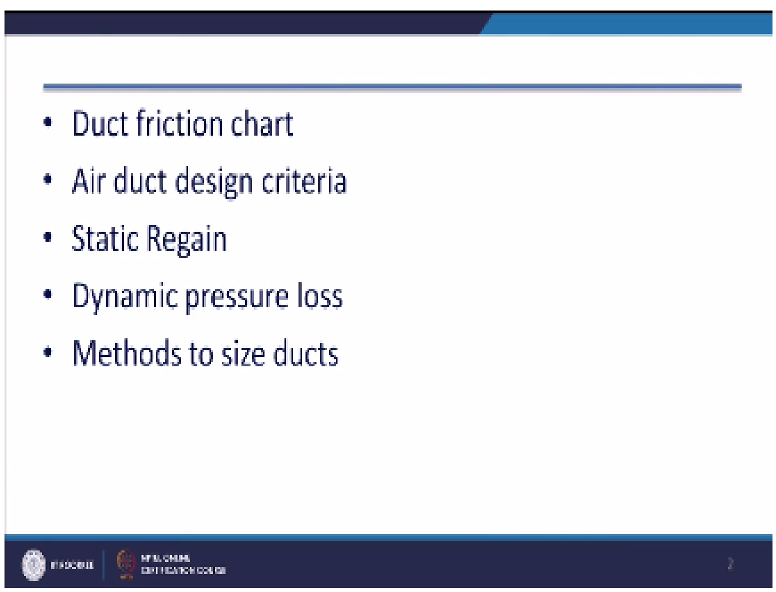

In today's lecture we will be covering duct friction chart will discuss on the duct friction chart, air duct design criteria, static regain phenomena, dynamic pressure loss in the ducts, and method of method to sized ducts.

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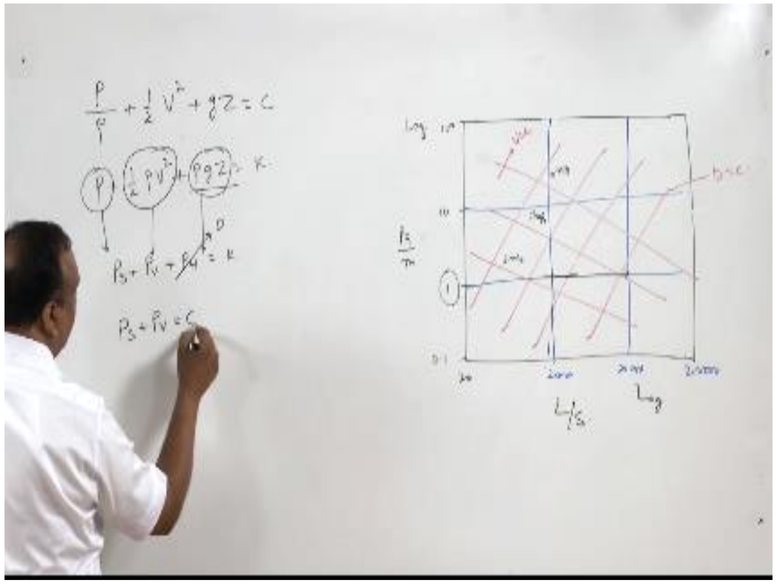

In connection with the air distribution system last time we discuss the duct design charts these charts in these charts on x-axis is a log-log scale chart it is known as duct friction chart for on a log-log scale so starting from 20 then it is going to be 2000 this is 2000 then 20,000 and then to 2,00,000. Similarly starting from here 0.1 Pascal then it is going to be 1 Pascal, 10 Pascal and 100 Pascal this is Pascal per meter right and on x axis it is liters per second.

So definitely the horizontal lines they show the constant duct friction now this is 10 Pascal not 100 Pascal. So 110, 100 okay, now these horizontal lines are constant duct friction lines and vertical lines are constant discharge lines. Now these charts duct friction charts they have some inclined lines also they are known as constant diameter lines here diameter is equal to constant perpendicular to these lines are constant velocity lines.

So towards this the velocity is equal to constant so in these charts now we have all characteristic lines. Now horizontal lines for friction pressure drop Pascal/m vertical lines for discharge is given in l/s there are inclined lines right, they are constant velocity lines velocity is increasing in this direction and there are other set of inclined lines which are constant diameter line when diameter is increasing in this direction.

Suppose I want to maintain constant discharge 200 m/s right at 200 m/s if I am reducing the duct diameter because done in this direction the duct diameter is reducing. So when the duct diameter for example, for a particular discharge this is the duct diameter if I reduce the duct diameter for the same discharge velocity will increase and because velocity is increasing in this direction so these are constant velocity lines.

So for example, for this the velocity is 2 m/s for this it may be 5 m/s for another line it may be 10 m/s they are all assumed values. So velocity is increasing this direction so the moment we are reducing the duct diameter the velocity is increasing, but we should bear in mind the moment the velocity in the duct is increased the noise level in the duct will also increase.

So that has to be taken care of while designing a duct. Now if I am moving in a horizontal direction suppose I am moving in a horizontal direction in that case starting from 2000 LPM towards 20,000 LPM in that case duct friction is remaining constant, but at the same time duct diameter is increasing that is obvious for same friction loss if I want to have more discharge definitely the duct diameter will increase.

And at the same time it is going to affect the velocity also, so the well of both if I want to maintain constant pressure drop friction pressure drop then the diameter of the depth and velocity as well will increase. So this is how we can move on this duct friction chart if two properties are known suppose I know the discharge and I know the velocity in that case other things like friction pressure drop and diameter of duct can be easily calculated like any other chart.

Now before we move on this chart we should understand the flow in a duct. Now in order to understand the flow in a duct it will start with Bernoulli's equation, Bernoulli equations say that P/rho + ½ V^2 + Gz = 0 so that is 0 it is constant some constant or P + ½ Rho V^2+rho Gz is some constant let us say k, this P is taken as static head.

This ½ rho V^2 is the kinetic energy of the air it is known as dynamic head or PS + PV and this is potential head and some of these all pressures is constant. Normally in the duct design if you, if the duct is horizontal then there is no change in potential energy even if there is a change in potential energy it is not very significant.

So it is often neglected, normally it flow for the flow through a duct static pressure plus dynamic pressure they are assumed to be constant. This is an ideal condition this is an ideal condition where suppose there is a diverging section, there is a diverging section.

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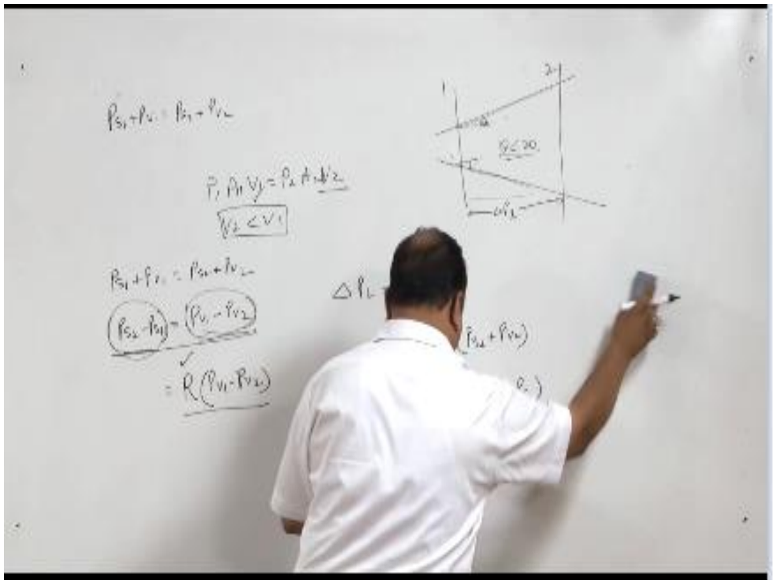

Now state 1 and state 2, so in diverging section PS1 + PV1 = PS2+PV2 provided there is no friction pressure drop right, but in actual earth there is a fan also which circulates air in the, that which is known as air handling unit. And due to this fan, fan total pressure STP shall also be added here. So PS1 + PV1 + fan total pressure is equal to PS2 + PV2 + this frictional pressure drop that is PD pressure drop in friction PDF right.

So this is the equation for the flow in a duct having a fan arrangement. Now there is any air movement there is no fan and there is a movement of air in the section, in a movement of air in a section then we can always say that P1 sorry P1S+PS1 sorry PS1 + PV1 = PS2 + PV2. Now static head at one dynamic head at 1 is equal to static head at 2 and dynamic head at 2.

If this diverting section angle of this diverging section theta, theta is less than 20 it is assumed that because in this case you can easily find if you use the continuity equation Rho1 A1 V1 = Rho2 A2 V2, so you can find that V2 is less than V 1 or the velocity of air has reduced and this is known as loss in dynamic head.

Now in this case this loss of dynamic head will be converted into gain in the static head that is why it is known as static gain during the flow through the duct. So PS1+ PV1 this is the equation PS2 + PV2 so

PS2 - PS1 = PV1-PV2 right, and this is totally converted into this static head and the situation is there when it is not totally converted into a static head.

Now change in the static head is equal to change in dynamic head or we can say that yeah, so the whatever drop is there in dynamic head is coming into the gain in static head, but that is the case when theta is less than 20 or diverging this section is where is the semi vertex angle of diverging section is less than 20°.

If it is more than 20° then this will hold, will not hold true and static regain is going to be this is has to be multiplied by a factor R which is known has a static regain factor which is known as static regain factor, it means some losses will be there so this R is less than 1, so change in the static head due to this change in dynamic head has to be this change in dynamic head has to be multiplied by the static regain factor and only then we will get the static regain.

Now further it duct flow with friction loss during this flow there is a friction loss right and friction loss if you take friction losses into the account then ΔP along the length so L so ΔPL is equal to total pressure at 1 minus total pressure at 2, the total pressure at state 1 minus total pressure at state 2 will give you the pressure loss during flow in the duct.

The PT1 is PS1 + PV1 and PT2 is PS2 + PV2. Now if we rearrange these values then we get PV1 – PV2- PS2-PS1. Now PS2-PS1 it means static pressure at state 2 minus the static pressure at a state 1. It can always be expressed in terms of V1 and V2 and that is equal to PV1 – PV2 this multiplied by static regain factor are from here and we get PV1 – PV2.

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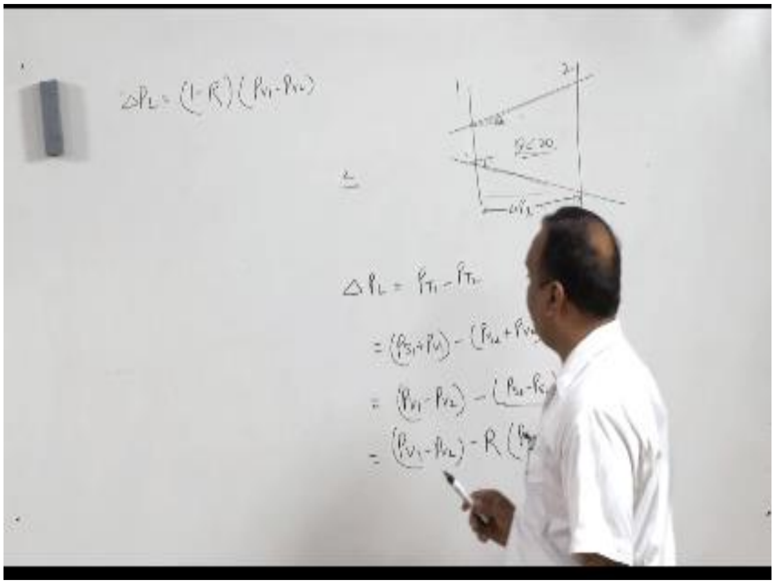

So friction pressure loss ΔPL can be written as 1 - RPV1 – PV2 it means if I know the velocity at state 1 and velocity at state 2 static regain factor is with me I will get the pressure loss.

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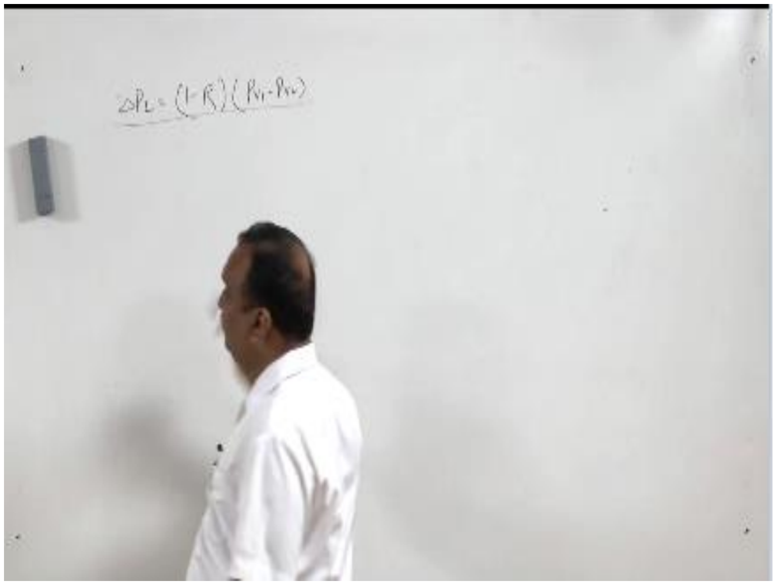

Now this value of R is different for different geometries and this method this this property is used while designing a duct system when we will use the static regains. Now I will go back to the duct friction chart actual duct friction chart in this duct friction chart the actual duct friction chart prepare for a round duct circular round duct air density 1.2 kg/m^3 and the friction, the reference of the duct is 0.09 mm. Now this duct friction chart no correction is needed in this the values getting out of this duct friction chart.

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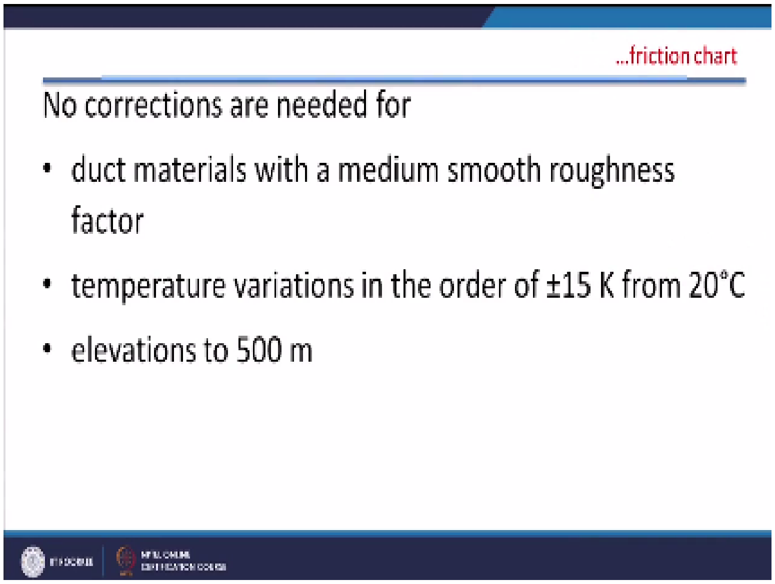

When the duck material with a medium or a smooth roughness factor is used and temperature variation is plus minus 15 Kelvin from 20°C or elevation up to 500m. So corrections are not required even if we use this chart to a elevation of 500m. Now here in this duct chart now they are real values I explained you earlier with a sketch now this is the actual just duct to friction.

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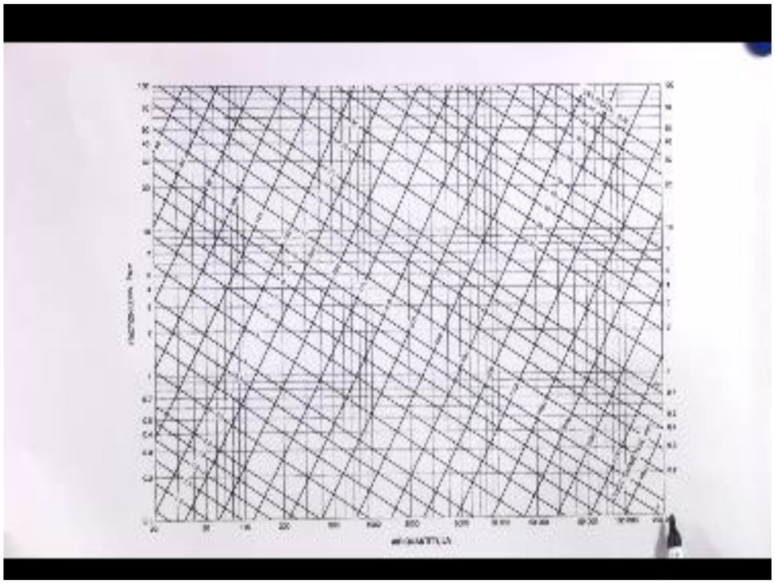

Chart taken from extra handbook of fundamental 2013, on x-axis the flow rate is varying from 20 to 2, Let the same value I mean in on a log-log, scale y axis the pressure is wailing pressure loss per meter varying from 0.1 to 100 Pascal's per meter, there are inclined lines which are showing the change in duct diameter, from 15 millimetres to 3150 millimetres, and there are lines which are showing the duck air velocity, starting from 1.2 meters per second to 30 meter per second.

Suppose I want to design a rectangular duct, what should I do? Here diameter of the duct is given as D, I want to design a rectangular duct and you must have seen.

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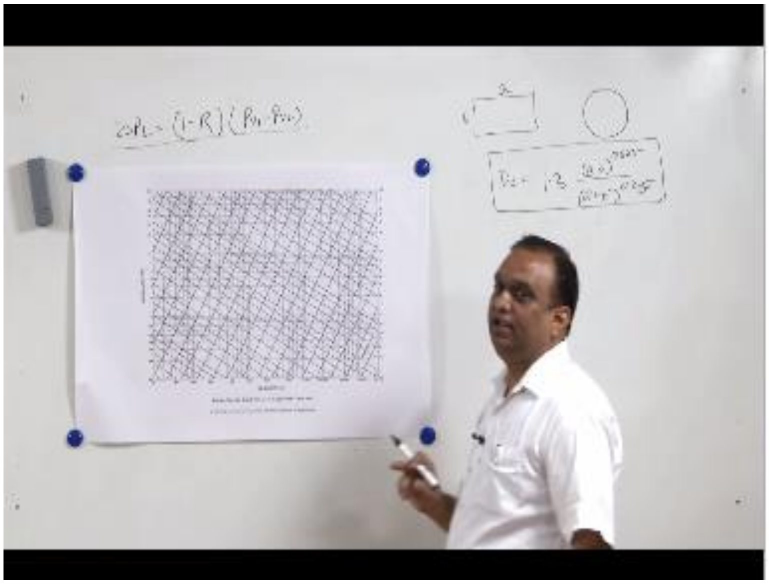

A number of rectangular duct and diameter of equal I'd circular duct, is expressed in terms of zero point what is it? sorry! 1.3 $AB^{0.625}$/ a + $B^{0.25,}$ this is A and this is B, now in order to find this because friction loss we assume in both the cases are same, whether it is a rectangular duct or a circular duct, friction loss per meter length is saying because friction loss per meter length is directly reflected in power consumed by the fence.

We will use different methods there are different methods for duct design, so first of all guidelines for air duct design, air should be conveyed as directly as possible.

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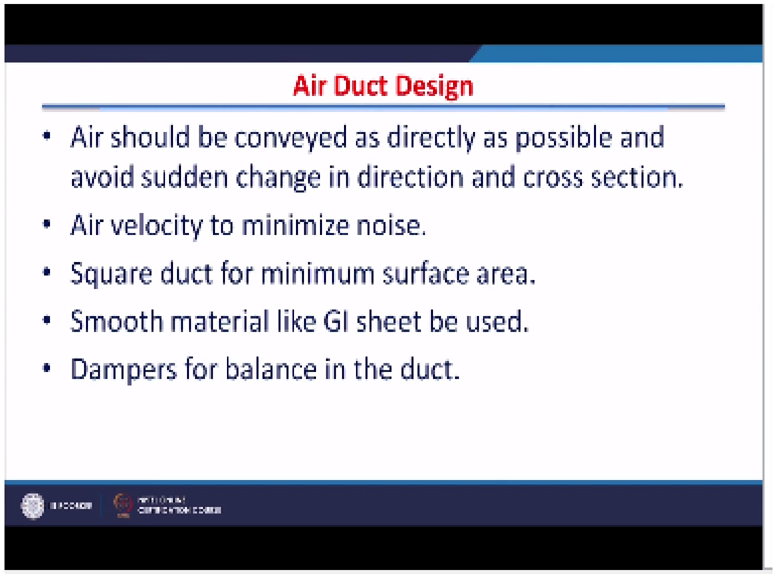

Avoid sudden change in direction in cross section; it is obvious if there is change in inertia, if there is change in inertia, pressure there is it going to be loss of velocity.

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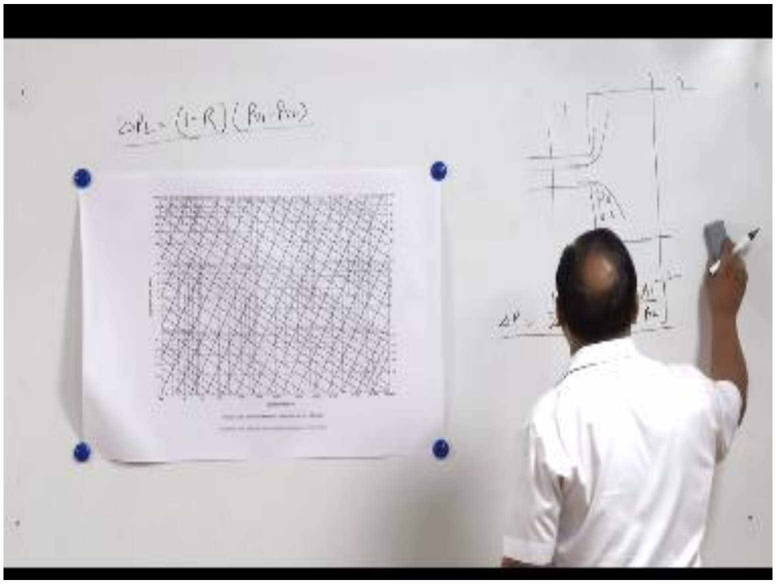

Head dynamic head and this has to be avoided, if there is a sudden change the loss will be more the loss will be more, suppose there is a sudden enlargement in the area suppose there is the sudden enlargement in the area, the flow in this direction, and there is sudden enlargement right, this is section 1, this is section 2, definitely when air will enter from this side, it will not immediately move in this direction okay.

It will take certain curvature and EDS will be formed in this zone, and losses will take place, now dynamic pressure loss in such a scenario, is going to behalf P v 1 ^{2} 1 - a 1 / a 2^{2}, this is going to be the dynamic pressure loss in this case, remember if it is diverging with a vertex angle of less than 20^{0}, the loss is those lost all dynamic head will be converted into the static head.

But here the dynamic head loss is going to be the switch, if there is a sudden contraction it means there is in large duct and there is sudden contraction in this case also this is state one this state 2, in this case also there is a border card or discipline is boarder card around equation so in this case also there is a border current equation, and that equation say then the pressure loss is P V 1 ^{2} a 2 / a 1 -1 ^{2} , so these are two border chord equation which are used for pressure drop in such an enlargement, and sudden contraction in the duct.

So these types of things are helpful in duct design, now there are three methods for duct design, where variable flow method is, and other is equal friction methods. And third one is static regain method, now in variable flow method, variable flow method is not a optimal method, of duct design it is more towards the experience, of duct designer, in this method some velocity is assumed some velocity in the duct is assumed, five meter per second six meter per second, that comes from the experience of the designer, and this velocity is known discharge is known to us, with the help of these two values we can find the cross section area.

Of the duct and cross section area in different section of the ducts, so the variable flow method is very popular among the design engineers because it requires minimum number of minimum length, of calculations and but this is not an optimal method of duct design, another method is equal friction method, in equal fiction method it is assumed that throughout the duct work then the pressure drop. There is a constant pressure drop per meter length, Pascal per meter it means, suppose I assume one Pascal per meter.

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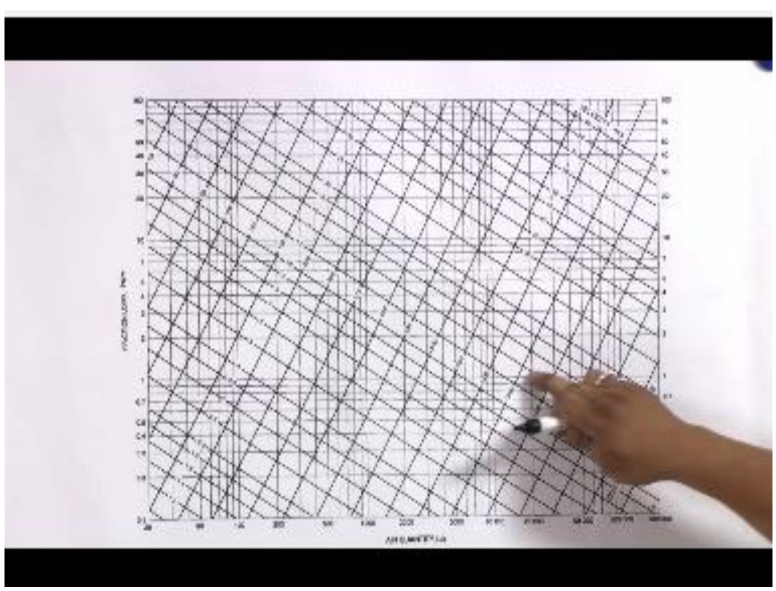

So I will be falling this line throughout the design of the duct and throw the design order for any discharge I can immediately find the diameter suppose discharge is 2,000 litres per second, I will draw into the constant pressure drop immediately, I can locate the diameter if the discharge is 10, 000 immediately, I can look at the diameter it is approximately 1050 if the discharge is 500 I can immediately locate the diameter, it is approximately 350 millimetres 3 50 millimetres.

So in equal friction method in all branches of duct, well suppose there is a duck network with a friend and one outlet is here A, another outlet is B is here third outlet C, is here we can have further we can have out lets like this, be and then we can have E, and throughout the system throughout the system there is a constant friction pressure loss, and then we calculate how many much air has been and then we decide the diameter of the different section of the ducts.

Now here what happens suppose if you take this discharge from here, so pressure drop from between these two point absolute pressure drop in Pascal will be less than the pressure Rob between this and the farthest point, so in that case what happens there is an imbalance of airflow, and it is possible that air flow from B is much higher than the required value, and we don't get any air flow outlet at D, the air flow at the S outlet.

So in order to control this tempers are provided at all the openings, now dampers in duct dampers are nothing but they are like a window, if damper is open damper is open then there is a if it is 100 %, open then it is all right but if it is partially open then there is a pressure drop across the damper, and this pressure drop initial pressure drop consider compensate the pressure difference between this point at this point.

So dampers are provided it or, this is not a very, I mean we cannot say it is very energy efficient system because, on the one hand we are increasing the pressure, with the help of a friend on the other side we are defusing the pressure using dampers, but we have no other choice, if we want to balance the system C is the case with the variable flow method also, in variable flow method also because it in different part of the duct network, the velocity is chosen by the designer, and in this case also in order to balance the system ultimately, tempers are provided so that there is no imbalance in the system.

Now static regain method I have already explained you, and in static regain method the depth where network is designed in such a way, that static regain in a particular section is sufficient to overcome the friction loss in subsequent section, so this static regain method is used for large networks where optimum design is major concern of the designers, and normally for normal small scale duct designs variable flow method and equal friction methods are used, in the next class we will solve a numerical on this duct design methods then you will have more or clear inside of the duct designing, this is all for today thank you very much.

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For Further Details Contact

Coordinator, Educational Technology Cell
Indian Institute of Technology Roorkee
Roorkee – 247667
E Mail: etcell@iitr.ernet.in, etcell.iitrke@gmail.com
Website: www.nptel.ac.in

Acknowledgement
Prof.Pradipt Banerji
Director, IIT Roorkee

Subject Expert & Script
Prof.Ravi Kumar
Dept of Mechanical and

Industrial Engineering

IIT Roorkee

Production Team

Neetesh Kumar

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