Fundamentals of Industrial Oil Hydraulics and Pneumatics
By Professor R. Maiti
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur
Lecture 35
Air preparation - Compressor and Accessories

Welcome to today's lecture on industrial hydraulics and pneumatics. Now today's lecture will be on pneumatic system and components and this will be introduction to that and the particular topic will be air preparation-compressor and accessories.

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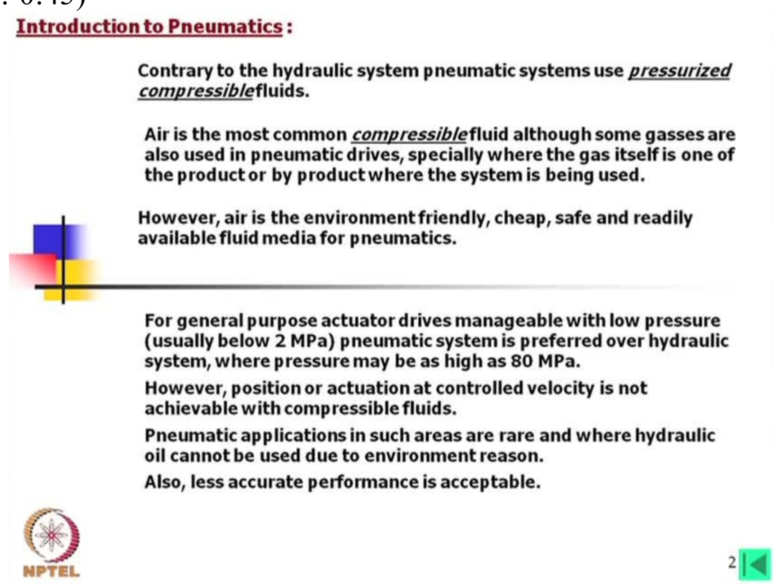

Now contrary to hydraulic system, pneumatic systems use pressurised compressible fluids. This means that in case of oil hydraulics, the fluid is incompressible and a pressurised fluid inside a conduit acts as a elastic body, maybe it is like an solid member. Therefore, in that case, particularly where with closed-circuit, there is no change in pressure once it is the fluid is trapped, of course that depends on the oad required we are moving.

But in case of this compressible fluids, air or gas, what happens? The fluid after utilisation, it is exhaust to the nature and in that way, pressure of the fluid reduces. So for the constant pressure system, it is not that much suitable. Also it is not suitable for very high-power. So but for the small applications, small power applications tools and others, you will find this pneumatic system is very useful and air is free of cost, you are getting at free of cost.

Only thing you have to prepare the air for utilising into a system. Now although other gases are used but air is the most common compressible fluid. Although some gases are also used in pneumatic drives, specially where the gas itself is one of the product or byproduct where the system is being used. However, air is the environment friendly, cheap, safe, readily available fluid media for pneumatic applications.

For general-purpose actuator drives, manageable with low-pressure is usually 2 mega Pascal. 2 mega Pascal means it is 20 kg per centimetre squares and you can see, just a little above absolute pressure. Pneumatic system is preferred over hydraulic system where pressure maybe as high as 80 mega Pascals. This means that in hydraulic system, we can go up to 80 mega Pascal but in normal case, as you know that in oil hydraulics, 20 to 25 mega Pascal is very common, 80 mega Pascal is very special applications but it is possible there.

However, position or actuation at controlled velocity is not achievable with compressible fluids. This is a drawbacks with compressible fluids. If you would like to control, the position control or the velocity control, then it is very difficult to achieve. For a small magnitude, small zone, it is possible. Relatively larger zone, larger range where the hydraulic fluid will be more useful. Pneumatic application in such areas are rare and where hydraulic oil cannot be used due to environmental reason.

Actually we had in some cases, it is compromised where the hydraulic oil cannot be used due to environmental reasons, so better to go for pneumatic applications. Say for example in case of food processing industry. Also less accurate performance is acceptable.

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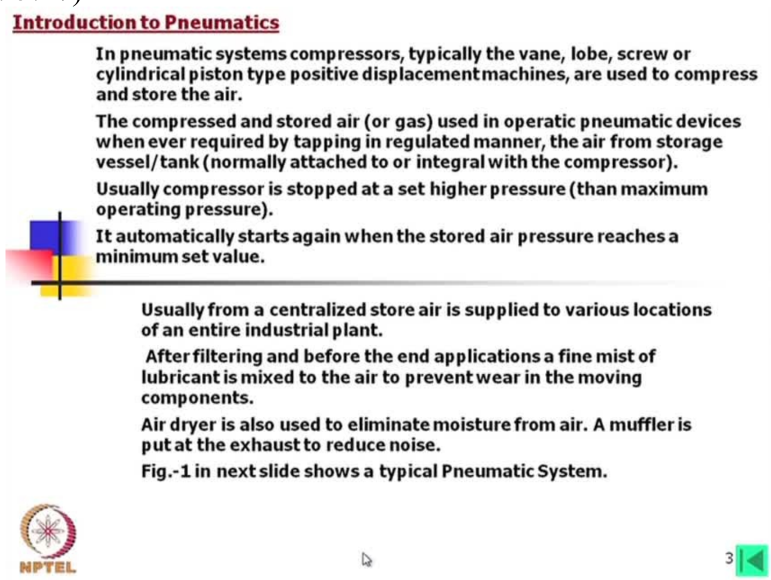

In pneumatic system compressors, typically the vane, lobe, screw or cylindrical piston type positive displacement machines, are used to compress and store the air. Now here again I would like to mention that in case of pneumatics or or the compressible fluid, the machines, the hydrostatic units are used, that is pump and motor. Those are in nature positive displacement. This means that their volume displacement ideally is will be equal to their geometry displacement.

It is not like hydro kinetic machines. For example, a blower. If you consider a blower, it is not a positive displacement machines unless it is a positive displacement machine is being used for for a blower. So I think you understand what is positive displacement, that if you calculate the geometric volume displacement, ideally that will displace the same amount of fluid. Now in case of compressible fluid, definitely, this volume is being compressed.

That means, when the pressure is increased, that volume is being compressed. So by the pump, that much amount is being pumped whereas it might be of higher pressure. And then it is going into the reserver, that means collector. And gradually, you will find that if you ask that how, what is the volume of air inside the reservoir, answer is that, what is the geometric volume of the reservoir, that is the volume at any point. Only thing, pressure is gradually being increased as you are running the compressor.

In case of oil hydraulics, it is not that. This means that in the conduit obviously, always you have to say volume is equal to the that amount of volume but you can say the your positive disposition machine also delivering the same amount of volume. In case of the air, it is not or gases. The compression stored air or gas used in operating pneumatic devices when whenever required by trapping in regulated manner, the air from storage vessel/tanker normally attached to or integral with the compressor.

This means that it is not that you are directly pumping this air to the system. In case of hydraulic system, most of the cases, you will find that there is no reserver in between. If you consider at all there is a reserver in between, that you may consider the accumulator, very small reserver. But in case of pneumatic system, there will be always a reserver. That means, 1st the air is stored in a reserver or receiver and then the air is used for the system.

You can simply tap the air with the help of a regulator and can use it. Usually, compressor is stopped at a set higher pressure than maximum putting pressure. Say for example, you are using a in your pneumatic systems in the in your workshop or I mean industry for machines, maximum is 1.5 mega Pascal. Maybe, you are storing that air inside the reserver at 2 mega Pascal. It automatically starts again when the stored air pressure reaches a minimum set value.

This means that say for the reserver, 2 mega Pascal is the upper limit. So when the pressure inside this reserver will reach 2 mega Pascal, it will be automatically stopped and probably it will start again. The minimum pressure what you need for the operation. Say for example, it might be 1 mega Pascals or might be 0.7 mega Pascal whereas maximum for some devices is 1.5. So when it will reach that 0.75 or 1 mega Pascal, it will start.

But one thing we should remember that if we had to use that instrument or device which is the which requires 1.5 mega Pascal, then we have to set the lower pressure as 1.5 mega Pascal. So then range will be 1.5 and 2 mega Pascal. And also usually there will be a time set. Otherwise, the compressor will run always. So that is a design criteria that you have to design. In a system suppose you are using this always it is 1.5 mega Pascal and very continuous consumption is there, probably you have to set the compressor reserver size in such a way, at least your compressor can be stopped for 5 minutes while it is running.

Otherwise question of heat generation and other problems are there. Usually from a centralised store air is supplied to various locations of an entire industrial plant. It might be single reserver, it might be multiple. Usually not more than two reserver are used to supply the plant. If the plant is very big, sometimes it is more than one reserver is used. After filtering and before the end applications, a fine mist of lubricant is mixed to the air to prevent wear in the moving components.

Now usually, if you find that air operated devices, say for example, air operated screwdriver so you just put say if you have observed in automobile industry, they had to tight the screw maybe in a line, in a assembly line they have to tight a screw, 100 screw per minute say just for an example. In that case, every screw driving by the screwdriver is not possible. You find the pneumatic screwdriver is there and it is set like that for this screwdriver device.

When the maximum torque is reached, it will automatically slip. So now in that case, that is connected with a pneumatic systems. Now usually, this moving components inside, definitely there is moving components. There is no separate lubricant inside. So with air, you have to mix that lubricant. Normally with the air, not with the other gas and other things. In case of gas also, you have to take care of that what type of lubricate you can mix.

In case of air, while lubricant can be mixed but before that, your air should be all dust free and it should be dry. That means, no moisture is allowed within this air. So after filtration or such preparations, again you have to mix with oil. That is important. This is required to lubricate the moving components. Air dryer is also used to eliminate moisture from air. So as I have told that you have to use an air dryer.

A muffler is put at the exhaust to reduce noise. Now muffler means the silencer is usually used at the exhaust point. Okay? Now when you are using a system, then the device you are driving. So it might be after that application, that should have muffler. That means, muffler in some cases you will find is an integral component of the pneumatic device which you are using. But there is also in-line muffler just to reduce the noise level.

When the air is flowing through these components, there will be noise. You can, you know it that when air blows through even if in nature also when air blows you can heard the sound. So to reduce such noise, there will be muffler or which is called silencer.

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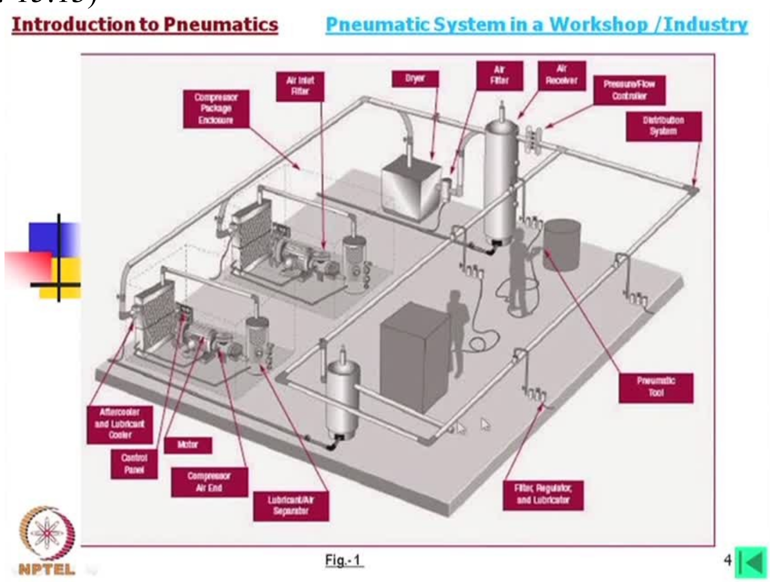

Now next slide, we will look into a pneumatic system. I think that that you cannot read this, not that clear but I would say that here, there is a this is the compressor unit. This compressor unit is having the this is the driving unit and then maybe filter, then cooler and after then this is the main reserver and here, there is a dryer. At that point, there is a dryer. And if you look into this, what we find? We have 2 parallel systems connected to the same line.

As I told, in case of if we find that air is being utilised in such a way, if we use single compressor, then it will run it has to run for I mean continuously. That is not permitted to look into the life of the compressor because during such process, huge air is generated. This is due to the molecular action within this air. Now you one can have one compressor and maybe two reservers or might be, there is a big reserver and two compressors.

This is usually safe system to use 2 compressors rather than manipulating something with the reserver. And then it is also shown here, say these are the 2 work points. But usually there will be huge I mean many work points. Now these tools are called pneumatic tools and here, this is the regulator. Filter and lubricator are used at different points. Say each and every, before each and every pneumatic tools, you will find a filter, regulator and lubricator is being used.

So this is a very schematic and very general system for a pneumatic. There will be a pipeline throughout the industry.

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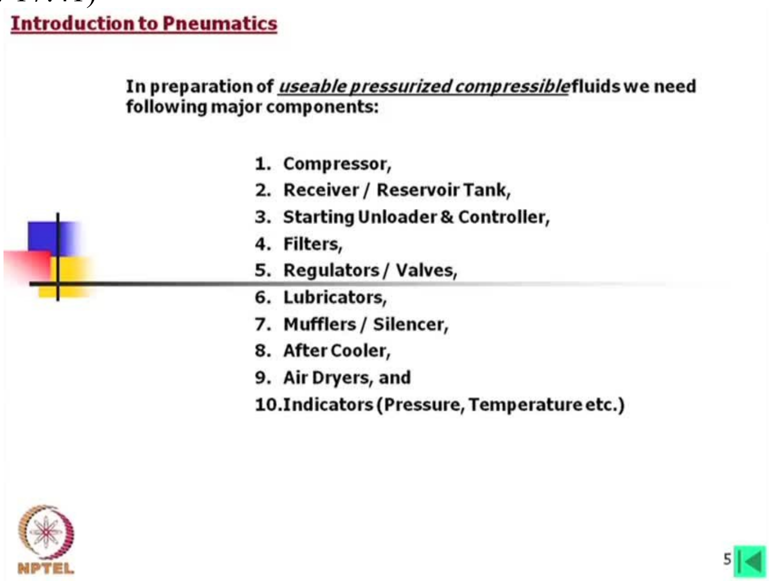

Now in preparation of usable pressurise compressible fluids we need following major components. One is that definitely a compressor. Compressor is nothing but a pump which is pumping the air or gas. A receiver or reserver bank, starting unloader and controller, this is very important. We will come to that what it is. Then we need filters. Now these filters is not again the suction strainer. The air will be there.

After the compression, we need a filter, online filter to make the air dust free. Then we need definitely a regulator and valves. We need a lubricator as mentioned. Mufflers and silencers, after cooler. We need a after cooler means, usually the air before entering into the machine, we need to cool it. Because the air we exhaust into nature. So we do not need after cooling means it is not after using this air.

In case of oil hydraulics, what is done? Usually after the application, we take back that oil to the reserver and before that, we use the cooler. In that case, before utilisation, a cooler is used but after cooler term is used after all process. That means drying, et cetera, then the cooling is done and finally it is used. Then air dryers and we need indicators, that is pressure, temperature, et cetera wherever required.

Also sometimes, a set of pressure and indicator is kept to inspect the pressure and temperature at different points. That is sometimes needed because there will be very big pipelines for the supply of the air pressure. Sometimes it is very difficult to find where the pressure drop, actual pressure drop is occurring. So for that purpose, we need a separate unit, pressure and temperature indicator.

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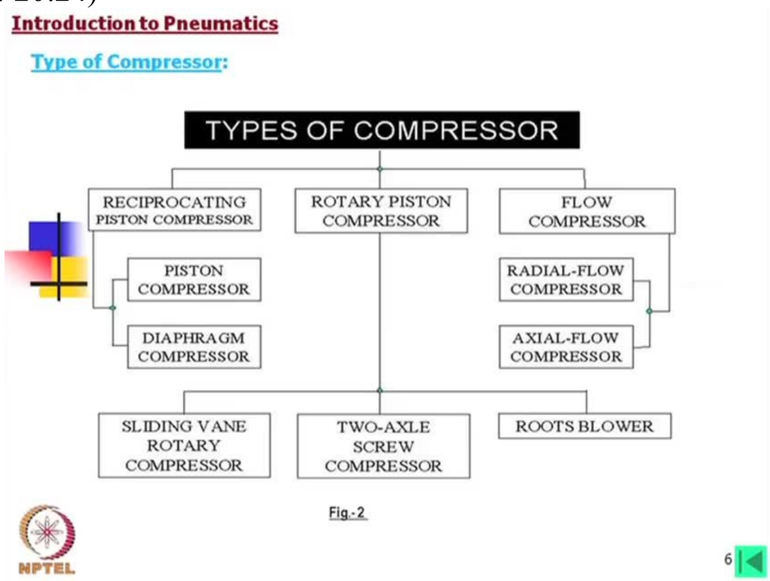

Now we will come to this components, what are the components and most important is the compressor. Now if you look in the type of compressor, then most common is the reciprocating piston compressor. And then again, the piston compressor and diaphragm compressor. Diaphragm compressor means in that case, a diaphragm is being moved by some means and that also compresses the air. And then, rotary piston compressor, this is sliding vane rotary compressor.

You see, one is that rotary piston and another is called rotating piston. Anyway, we rotary piston means usually a volume is trapped and then that is compressed by compressing the variable area. In case of reciprocating normally, the stroke length varies, area does not vary. Whereas in case of rotary pistons, you will find area is varying. Say gear pump, like that lobe pump, et cetera.

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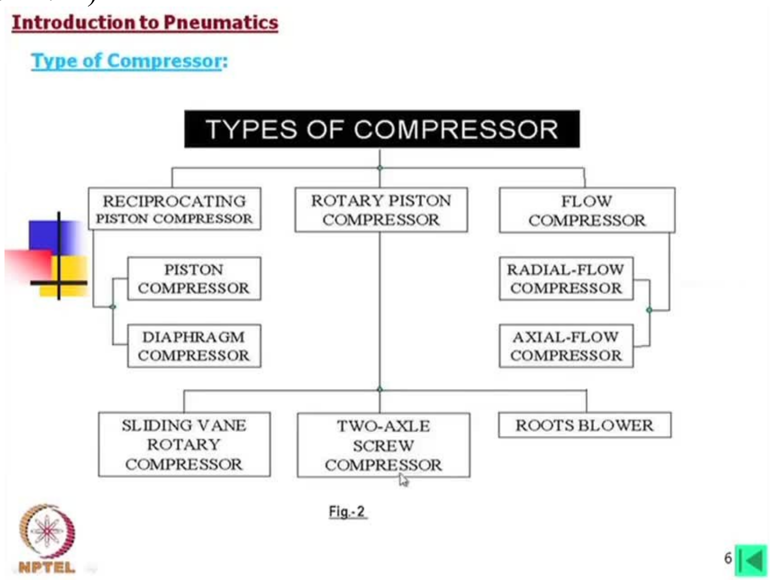

Then this rotary compressor against sliding vane rotary compressor, two axle screw compressor, say like gears and et cetera, that also fall in this category. And roots blower. And then another, it is a flow compressor, that radial flow compressor, axial flow compressor, these are 2 different type of separate flow compressor but we shall concentrate on these are the some special types, these are used for not normally such big system. Very small systems these are used but reciprocating piston compressor, this is very common particularly piston type.

And among the rotary pistons, both sliding vane and two axle screw or the gear type compressor are mostly used. So we shall concentrate on these items only.

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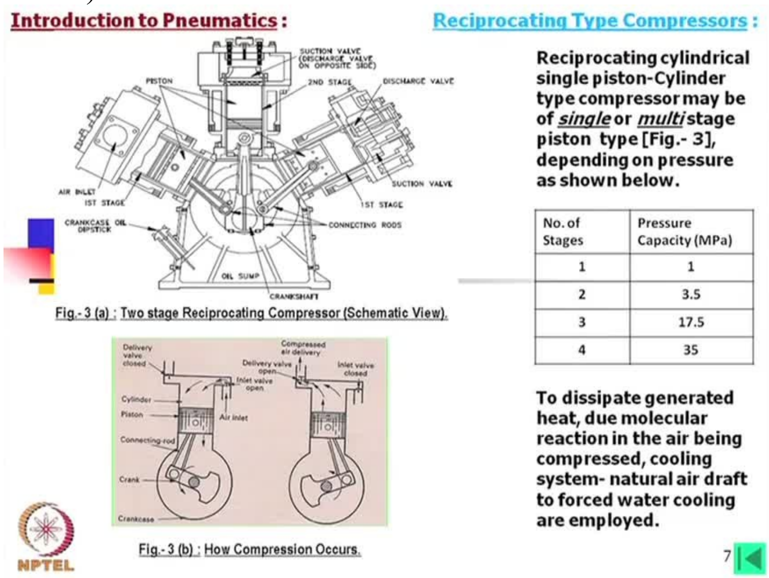

Now reciprocating type. Reciprocating cylindrical single piston cylinder type compressor may be of single or multiple. This means that it has a meaning that single means suppose there is a 2 pistons. That is not, that may not be two-stage. Only 2 pistons are being used. They are compressing the air at a same pressure. Whereas, you may find 2 pistons but that is two-stage. That means in 1st stage, one piston is compressing the air and in 2nd stage, other piston the compressing that air.

That means suppose you have to raise the pressure up to 2 mega Pascal, 1st piston may be raising the pressure not exactly half. It might be 0.75 mega Pascals and then 2nd piston, that compressed air is being further energised to make the pressure 2 mega Pascals. So that is called two-stage. Similarly there may have 3 stage also. So we use single or multiple stage. Now if I look into this figures, the left-hand side, this figure A, that shows a reciprocating two-stage compressor.

But before that, I would say that depending on pressure capacity, if the pressure capacity is 1 mega Pascal usually, in that case, we can go for single stage. Then it is, if it is 3.5, then two-stage. Then if it is 17.5 mega Pascal, in the higher side, and as well,we have to go for 3 stage and for 35 mega Pascal, this is 4 stage. Now 35 mega Pascals means it is very high. This is a definitely special applications. Normally in case of fluid power, we used normally 25.

Say 21 mega Pascal is equal to 3000 psi 21. So 35 means it is more than 4000 psi. Normally, there is no such applications but if it is required, then we have to go for 4 straight and normally, reciprocating type is not suitable for that. Usually screw compressor is used for such compressions. Anyway, if we come to these compressing machines, what we find? Here is one set of piston cylinder, here is another set of piston cylinder, and here, this is the 3rd.

If you look into these 2, these 2 are identical. Even they are having the same discharge valve, suction valve, these are same. Now these 2 cylinders together pumping the air for the 1st stage. That means, from the nature, the air is being taken and that is being pumped, that is being compressed to reach a certain amount of pressure. Say for example, two-stage means this is 3.5. Probably it is being raised upto 1.5 only.

Then this total compressed air, now that total compressed air, what the 2 piston has done, that volume has reduced, that for that only a single system can pressurise that amount of air further to 3.5. And that is the 2nd stage piston cylinder. Now the other details, you can study of your own from this figure okay? Now if we look into this principle, you know it but basic principle is that this while it is reciprocating then there will be, one is the inlet, and one is the delivery.

Say it is rotating in this direction, so only the inlet port is open and when it is rotating in the other half, then it is being delivered. This is the simplest form of this reciprocating system and the same thing is followed. Here, just only suction and compression. So in and out delivery. So if you look in this way, for one cycle only suction, so half the cycle suction and half the cycle the delivery. So you can put 2 cylinder, single stage but 2 cylinder in such a way that continuously it is supplying the air okay?

To dissipate generated heat due to molecular reaction in the air being compressed, if you compress the air, you will find that heat is being generated. Cooling system, natural air draft two forced water cooling are employed. That means for the small compressor, you can simply use a fan, just to cool. And this reserver as well as the compressor outside is made, body is made with additional heat dissipation area. That means panes are used even if the tank you will have you may find that additional panes may be used just to cool it okay?

But for higher pressure, maybe say in case of two-stage, 3 stage and 4 stage, you need to have forced cooling. And usually, cooling by water is done. Other fluid can be used. In case of say refrigerators systems, if some cooling is required, no water is used. But in case of general compressor, for big compressor which is used in industry, usually you will find the oil is being used and normally, if you look into these pistons outside, there are pockets.

These pockets are filled with water. That means water is always flowing through these pockets. That is called et. The piston is having the space through which the water is moving. That means while it is being compressed, then itself it is being cool to some extent. And after that also, there is a separate cooler is used to cool the air.

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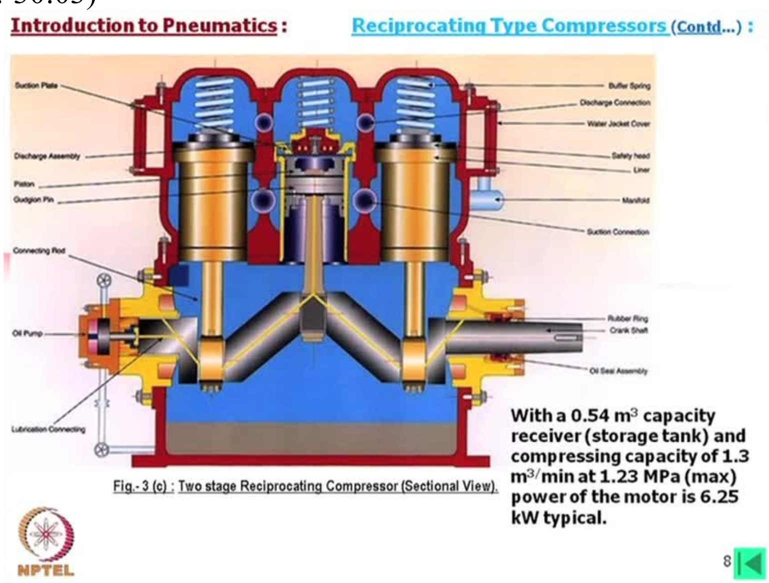

Now this is a photographic view. I am not describing the component. You can understand this. For the same machines, these 2 are for 1st stage and this is for the 2nd stage. Usually, a spring is provided just for the return stroke but if you look into the geometry of this crankshaft and other things, so you need to have some return. So the springs are buffer springs are usually used. And if you look into the capacity, with a 0.54 metre cube capacity receiver storage tank.

You can understand the 0.54 metre cube. So 1 metre cube is equal to how much? 1000 litre. And here, 0.54 means half of that, 500 litres around 540 litres around the volume and compressing capacity of 1.3 metre cube per minute. So this is called compressing capacity, not the flow capacity. We should call compressing capacity. At 1.23 mega Pascals power of the motor is 6.25 kilo watt typical. If you calculate this pressure into flow rate, it will not be 6.25 but usually efficiency of compressors is relative poor. That is why at least you need 6.25 kilo watt typical. We will calculate the sizing of certain compressors.

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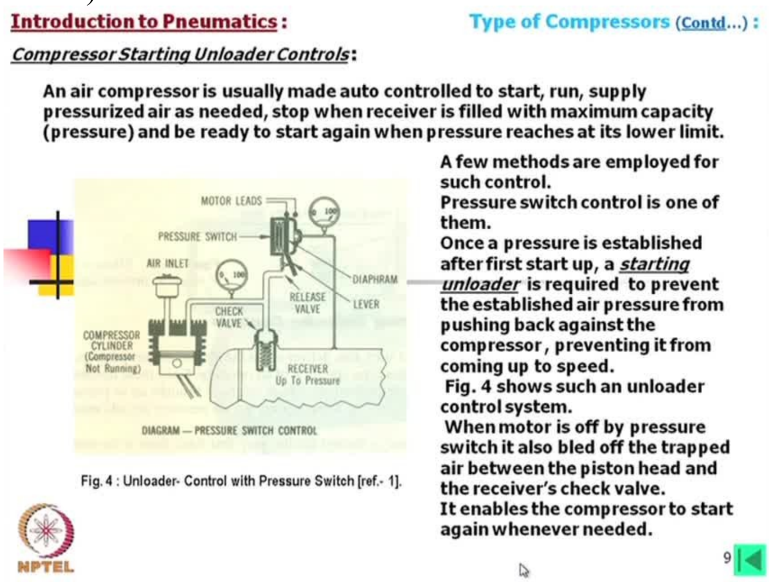

Now an air compressor is usually made auto controlled to start, run, supply pressurised air as needed and stop when receiver is filled with maximum capacity that is pressure and be ready to start again when the pressure reaches at its lower limit. A few methods are employed for such control. Pressure switch control is one of them. Once a pressure is established after 1st start up, a starting unloader. Look at this term. It is called starting a loader is required to prevent the established air pressure from pushing back against the compressor preventing it from coming up to speed.

The meaning of the sentence is that you have compressed the air and the compressor is stopped. Now if you look into this line, from the where the rotary piston, rotating piston is compressing the air, from that point to compressor, path is completely filled with pressurised pressure. Now it is cut off from the receiver. Receiver is supplying the air and that pressure when it is reduced then the compressor has to start. But when the compressor is going to be start, the trapped air to that, that will create a problem to start off the compressor.

So you need to release that pressure within that short path, that is from the compressor head to the receiver entry point. That is called starting unloader. Now we use here the pressure switch type. Now if we look into this figure 4, this is the pressure switch. What is if you look into this, this is the compressor head, so your inlet is here. Now this head is going and here is a nonreturn valve connected to the reserver receiver and then air is being compressed and forced with force it is being entered into the receiver.

Say it is 2 mega Pascal. Now when such pressure is this is receiver is being filled, then with a set pressure, this switch is there and that gradually disconnects the motor and your compressor will stop. But if you look into this path, then this path will remain filled with the pressurized air. Now to relieve that, what is there? With this pressure switch, there is a lever. That operates another valve. Actually, there is an another valve sort of things which are allowed or relieves the compressed air between this path.

Now here, apparently it is a open path. Maybe here, maybe some nonreturn sort of valve might be there which is not shown here but what happens? When this machine is stopped, the receiver is having its maximum pressure is set to 2 mega Pascal then this motor is stopped as well as this path is made free so that next time when the signal comes, it starts operating without any trouble. For that, we need a unloader. So this is you can say the starting unloader.

When motor is off, by pressure switch, it also bled off. It is, this operation is called bled off the trapped air between the piston head and the receiver's check valve. This is the receiver's check valve. It enables the compressor to start again whenever needed.

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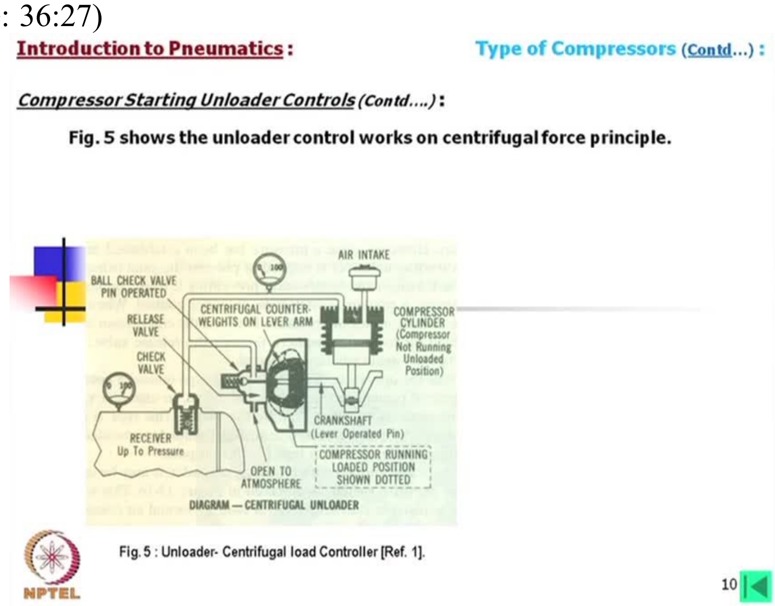

Now there is another type of unloader which is centrifugal type. The basic principle is that the a centrifugal mass is attached to rotating member. This is with the compressor crankshaft, then when it reaches, then it operates the switch the same way the pressure switch operates. Now in such system, greater production is ensured as the unloader valve is operated by the compressor itself rather than the pressure switch. Such normal controls described above are used where the compressor running time is 50 percent to 80 percent of total working time okay?

Now for the compressor starting frequently, say within every after 6 minutes or running time exceeds 80 percent of total time, more sophisticated constant speed control is adopted. That is usually nowadays with electronic controls, some controller is used to automatically cut off the compressor, start the compressor and in between, unload or the relieve the trapped air between the compressor head to the receiver inlet okay?

Now this 6 minutes figure what I understand, this is usually a figure. At least you should keep a 6 minutes time off between 2 running times. Otherwise, sufficient cooling will not be there.

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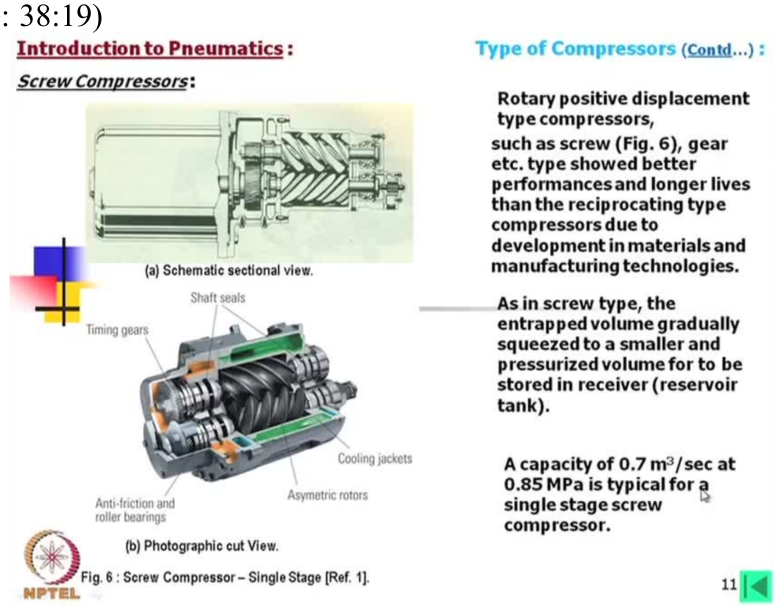

Now we shall consider another type of compressor which is called screw compressor. Now this is rotary positive displacement because if this is like an hydraulic the screw pump, here also the screw, 2 screws are rotating but if you look into this, this might be rotating at, these 2 screws are rotating at the different speed, not at the same speed. And this is the entrapped volume is being compressed. It is taking in and it is going out in the other side. That means, inlet and outlet is usually axial in case of the screw type compressor.

If we look into this figure, then it looks something like this. These 2 profiles are not same. I mean, this profile and this profile are not same. Here is also, it is not very clear from this figure but from the side view, you can look into this. And what we find then there is a timing gear, this is required to for inlet outlet control, the cooling ets is there and this is not symmetric, asymmetric rotors, antifriction and rolling bearings are used in between. Okay.

Now this is the what is found that this type of compressor is having much better life and it can perform better in high pressure. So you will find that of course, if you think in terms of volume, that will be less in comparison to the reciprocating type. So where the moderate volume is required with a very high pressure, maybe the screw compressor is the better than the cylindrical piston type.

As in screw type, the entrapped volume gradually squeezed to a smaller and pressurised volume for to be stored in receiver. Usually it is axial. Usually you will find the axial inlet and the outlet in the radial directions but at the other end. And these are the cooling ets. Now to assess an size of such a machine, 0.7 metre cube per second, that is the capacity of storing. 0.85 mega Pascal is typical for a single stage screw compressor.

So single stage screw compressor means it is not very high, 0.85 mega Pascal and 0.7 metre cube per second. So this volume not that small in that way. Maybe this this value may not be correct. I have to check it. 0.7 meter cube is a very big volume.

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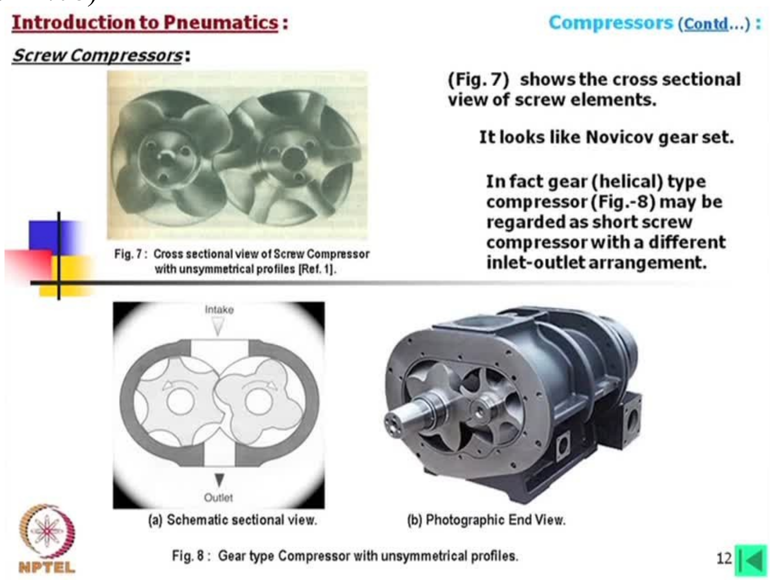

Okay, then if we look into the side view of this screws compressor as I told these are not symmetric profiles, it looks like something like this. One is that thinner and another is wider. And here what we find, this we have 4 lobes. That means, it might be 4 start screw. And here what we find? 1, 2, 3, 4, 5, 6. Here 4 and here 6. That is why, you will find that these 2 are getting at different speed and we need a separate gear of the same ratio at the end just to match that.

Now you may ask, why it is different. It is seen that this will give better performance as far the volume is concerned. And as this is being of different size, maybe to optimise the capacity it is better. Suppose if we use here 4 and here 4, you we may find that it is not the optimum design. Using 6 here and because this is the main pocket, as if this pocket is being compressed by this is the piston. You can consider, this is cylinder, this is piston. So 4 piston is compressing the air within 6 cylinder, roughly you can say like that.

But actual path is like that, it is a helical path through which the compressed air is being moved separated by the contact at these 2 profiles and by the casing. It looks like Novicov gear. If you look into this side review, it looks like a gear, not exactly Novicov gears, it is different. But as if it looks like a gear. In fact, gear type compressor maybe regarded as short screw compressor with different inlet outlet arrangement.

Now obviously if you look into this, if you would like to compare with this gear, sorry the screw compressor with a gear type compressor, definitely this is also helical. That means, Helix gear as if but this length of the screw conveyor, what is the length? In this case, length is very small. As well, you will find that inlet outlet is like that. But this is also of different profile as you can see, you can compare this. But remember, this one is the gear type or sometimes it is called lobe type and whereas this is the cross-section of the screw type compressor.

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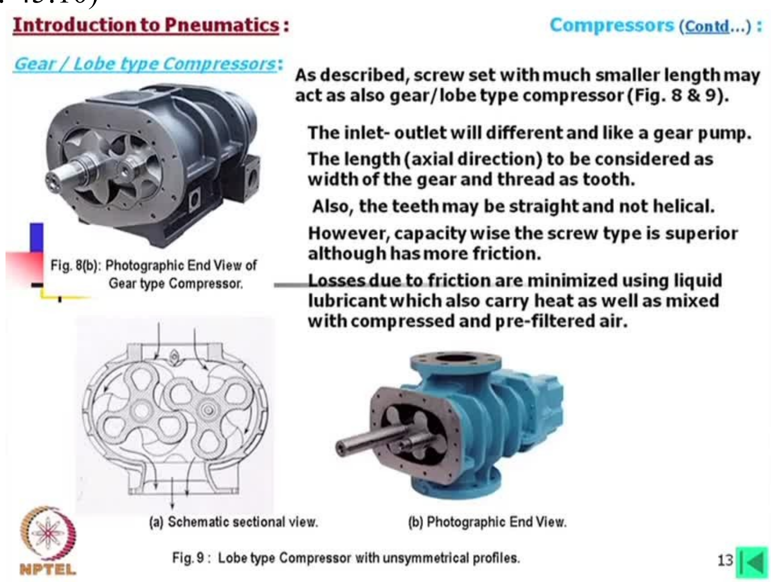

Now here again I have shown some, say this is gear type and similar is the lobe type. But in case of lobe type, usually these profiles are same, both the profiles are same and number of lobes will be same. But basic principle, these lobes and gear are the same principle. And you will find inlet outlet is like that but member, like the gear pump, this this is say suppose this is rotating in this directions then this will be inlet and this will be outlet.

Normal if it is rotating like in this the in this direction, then people confuses perhaps air is flowing like this in case of Al pump also but it is not like that. The air is coming in, then it is being trapped and it is going out. If we remember, recall that comparing with the gear pump, here, from this contact point and this 3 contact line or point on this plane, if we consider, with the rotation, this area will be gradually it will reduce.

That means, this volume will be compressed. So this compressed air will now go inside, it will be trapped and then it will be delivered in the other side. And this is the side view of this lobe type compressor. Inlet outlet is different. This is completely radial. In case of screw type, you will find, this is going like this and probably outlet will be like this. So the length to be considered as a width of the gear in this case. Also the teeth may be straight and not helical.

Say here, somewhat it is helical. One can use the straight teeth for the gear type compressor and lobes are always mostly you will find maybe straight also. Here of course, it is showing that as if it is helical. It might be straight also. In this lobe, there is no space within the lobe. But here this space is given. It might be this is all can be used for cooling purpose also. However, capacity wise, the screw type is superior although has more friction.

Losses due to friction are minimized using liquid lubricant which also carry heat as well as mixed with the compressed and pre-filtered air. Now in such compressor, you have to lubricate this so that lubricant is mixed with the air. So it might be we have to 1st de moisturise the air before entering into such compressor or else the the oil being mixed, that will not be separated.

We have to use the separator or filter in such a way, the oils are not being separated because the oil mixing is being to some extent, is being done while it is being compressed.

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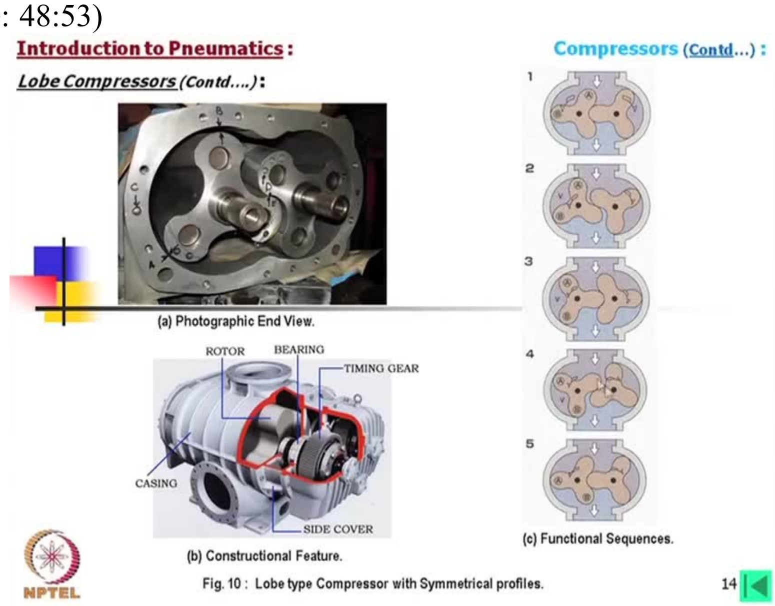

Now this is another view of the lobe type and this is the constructional feature, you can see in this case lobes are straight. Here as you can see. And you can see this operations, how this operations is being done gradually, 1, 2, 3, 4, 5. These are the 5 stage of operation. I think you can study yourself.

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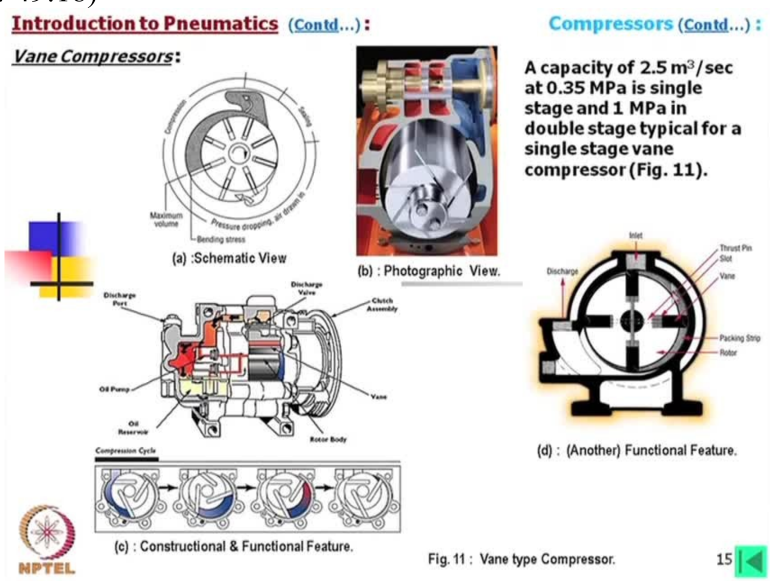

Now next one is the vane type compressor. In vane type compressor, this is the principle is exactly same as what is in hydraulic machines and oil hydraulic machines. Now the this is a typical capacity, 2.5 metre cube per second, this is very high and 0.35 mega Pascal in single stage. Now if you look into this, this vane are not placed exactly radial. You will find that is inclined. This inclination is given, is like that. For this compressor, you will find this is rotating in this directions, not in this directions so that this this is having the sealing effect, better sealing effect okay?

If we rotate in this direction, the pressurised oil will put the pressure and to allow it to go inside and so there will be leakage through this. Looking into this vane orientations, you can find that this is the direction of (())(50:43). That means from this side, it will rotate in the anticlockwise direction. This you can see how much this inclination is there and this is the constructional feature of the vane type compressor.

And also if we look into this, in this case of course the vanes are straight but this is on a what is that? There is a this is shown that how the thrust pin are provided and then this is the packing strip, this is the rotor and there is the slot, vanes, et cetera. This is a functional feature. Maybe this is also the straight type vanes are used. Here also, as we find, the vanes are straight.

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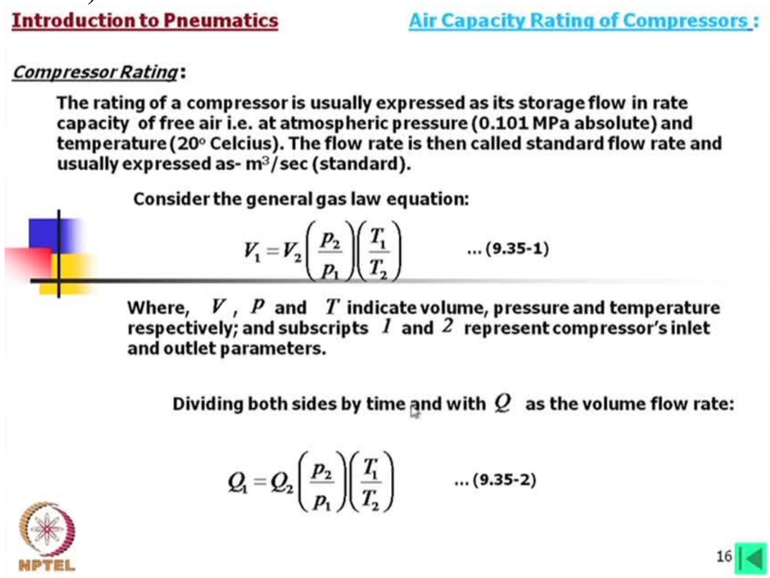

Now if we look into the compressor rating, the rating of compressor is usually expressed as its storage flow in rate capacity of free air that is at atmospheric pressure that is 0.101 mega Pascal absolute 14.7 psi and temperature is 20 degrees Celsius. Sorry. The flow rate is then called standard flow rate and usually expressed in metre cube per second. So this means that intake volume we call it metre cube per second. Okay.

That volume what we have mentioned in the capacity, that is the intake volume to the machine. So 2.5 metre cube per second is the intake volume per second. Now this gas law is known to you, so we can use this gas law to calculate the rating of the compressor. V, P and T indicate the volume, pressure and temperature respectively and subscript 1 and 2 represents compressor's inlet and outlet parameters. Dividing both sides by time Q, we get in terms of the flow rate.

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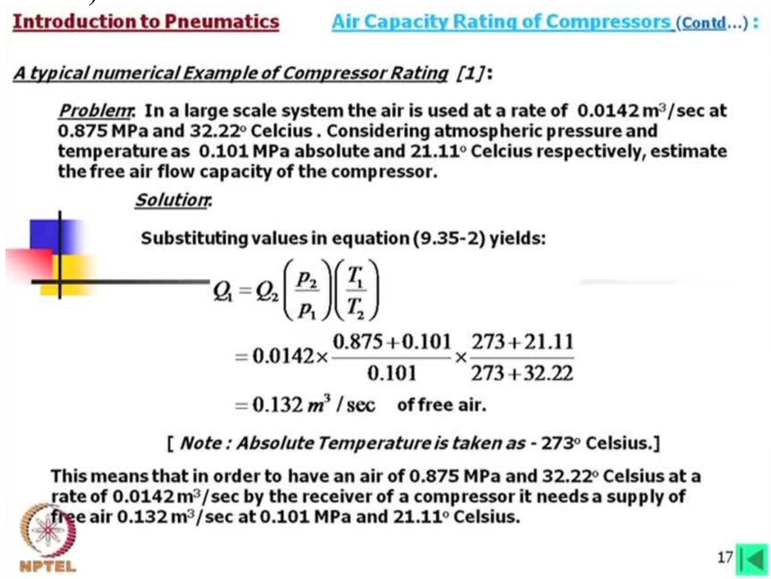

Now if we consider a problem, a typical a numerical example, in a large-scale system the air is used at a rate of 0.0142 metre cube per second at 0.875 mega Pascal and 32.22 degree Celsius. Celsius spelling will be S not C. Anyway, this is now this rate if you look into this rate is the delivery rate, utilisation rate, not the compressor's rate. Now we have to estimate the free air flow capacity of the compressor.

In that case, the solution is like that. In this equations, what we put? That is the Q2 is given. That is the utilisation side, that is the out outlet of the compressor. So Q2 is this much and pressure P2, now this pressure whatever pressure is given here, mind it we have to convert into the absolute. That means you add simply the normal absolute pressure and then the temperature is we have to add 273, that is the reference temperature. We have to add this and then the this to T1 and T2, temperature rise is from 21.11 to 32.22.

And what we find, that 0.132 metre cube per second of free air we need to compress. So note-absolute temperature is taken as 273 degrees Celsius and this this means that in order to have an air of 0.875 mega Pascals at 32.22 degrees Celsius at a rate of 0.0142 metre cube per second by the receiver of the compressor, it needs a supply of 0.132 metre cube per second at 0.101 mega Pascal and 21.11 degree Celsius.

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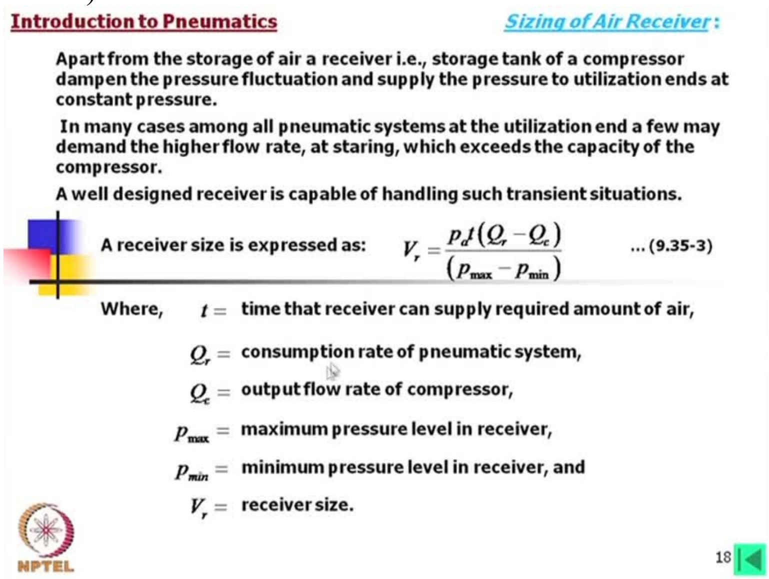

Apart from the storage of air receiver, that is storage tank of a compressor dampen the pressure fluctuation and supply the pressure to utilisation ends at constant pressure. In many cases, among all pneumatic systems at the utilisation end a few may demand the higher flow rate at starting which exceeds the capacity of the compressor. A well-designed receiver is capable of handling such transient situations. That means, time to time, we need more excess air to flow.

A receiver size is expressed, now we have to also depending on the plan we have to find out the receiver side. This is expressed by this formula where you will find T is the time that the receiver can supply required amount of air and then Qr is the consumption rate of the pneumatic system, Qc is the output flow rate of the compressor and P Max is the maximum pressure level in receiver and P Min minimum pressure level in receiver and Vr is the receiver size.

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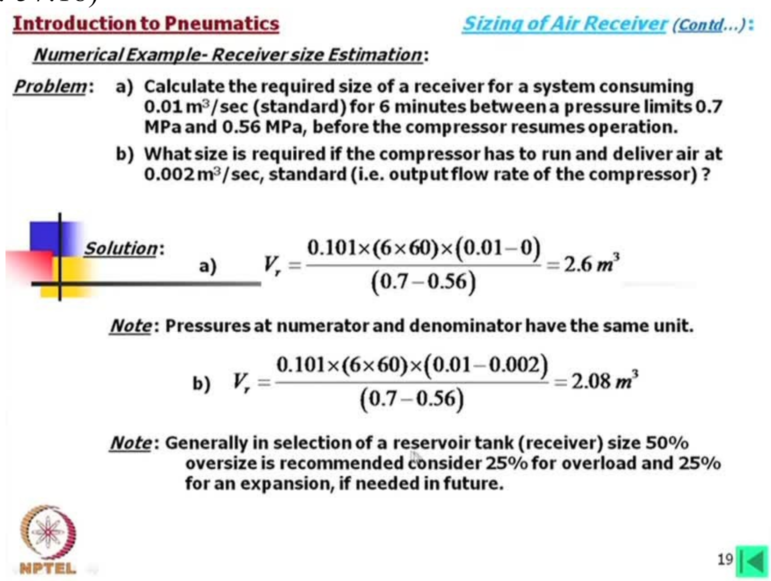

So again, we consider another problem. Calcutta required size of a receiver for a system consuming 0.1 metre cube per second standard for 6 minutes between a pressure limits 0.7 mega Pascal and 0.56 mega Pascal before the compressor resumes operation. That means, this is the maximum limit where the compressor will be stopped and this is the minimum limit when again the compressor will start. What size is required if the compressor has to run and deliver air at 0.002 metre cube per second standard?

Now simply in just to calculate the how they are, we consider this is the pressure and this is the 6 minutes time means this is in seconds and this is the difference of this pressure, pressure here and this is the difference in the capacity, flow capacity so what we find? That we need the receiver capacity of 2.6 metre cube at least but here we have simplified the problem. To arrive into this say formulation, the requirement is this.

You have to exercise, that really you have to make the average of total utilisation, compressor time, how much it should be stopped, et cetera. So that becomes a little complicated, not this simple but for as a numerical example, this is the way how to calculate the capacity of a compressor size of the receiver. Pressure at numerator and dominator have the same unit. That means in this case, you should take care that this should be same unit. Even if the pressure has expressed air in psi, that is not a problem, this and this.

And in case of B, as you can see that this is the metre cube per seconds, the standard supply. So for that, we need 0.208 metre cube. Suppose this amount of flow as intake is provided, then we can reduce the capacity of the receiver. Generally, in selection of a reservoir tank size 50 percent over size is recommended considering 25 percent for overload and 25 percent for an expansion if needed in future.

Say for you are designing a such an compressor and receiver for an industry, then in that case, 1st of all, you have to consider at least 25 percent overload maybe there is a so 75 percent directly coming over there. And usually what happens? After setting up, you may need to add 1 or 2 more equipments with that. So another 25 percent. That means whatever capacity is wanted for industry, usually if it is at the beginning stage, considering that is the 50 percent requirement, we usually consider 100 percent and then we design the compressor.

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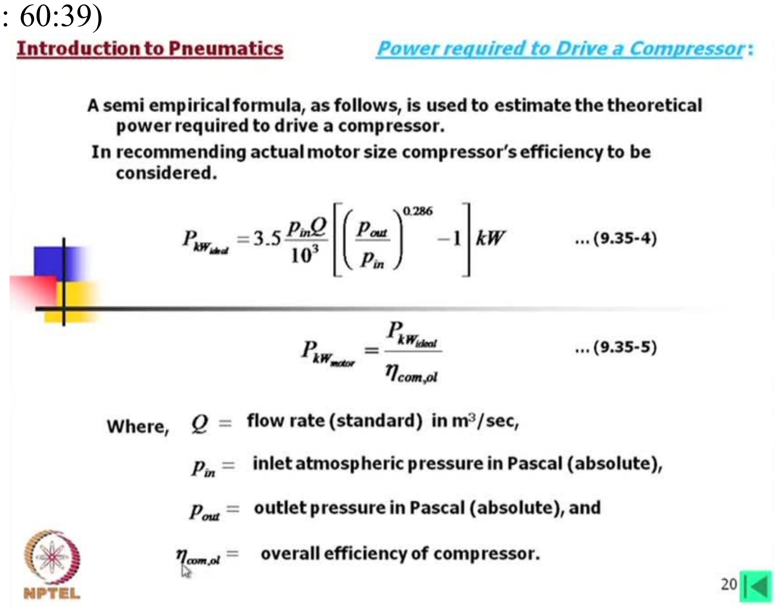

Now power required to drive the compressor, a semi-empirical formula is usually used. In recommending actual motor size, compressor's efficiency to be considered okay? Then this is the semi-empirical relation to calculate the power where P this is for the total of the motor and then this is ideal, so we are calculating the ideal one and then we divide it by the efficiency, overall efficiency to calculate the power.

And Q is the flow rate standard and P in is the inlet atmospheric pressure in Pascal and P out is the outlet pressure in Pascal in absolute and this is the overall efficiency.

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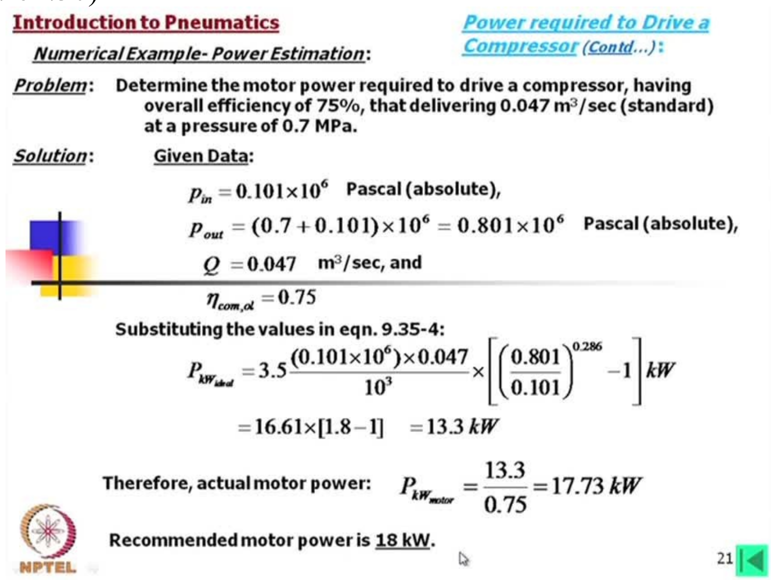

And again if we consider another problem, determine the motor power required to drive a compressor having overall efficiency is equal to 75 percent that delivering 0.047 metre cube per second at a pressure of 0.7 mega Pascals. So these are the given data, considering this, we can calculate this power ideal is coming 13.3 kilowatt and the efficiency is 0.75. So 17.73. So we recommend a motor of 18 kilowatt.

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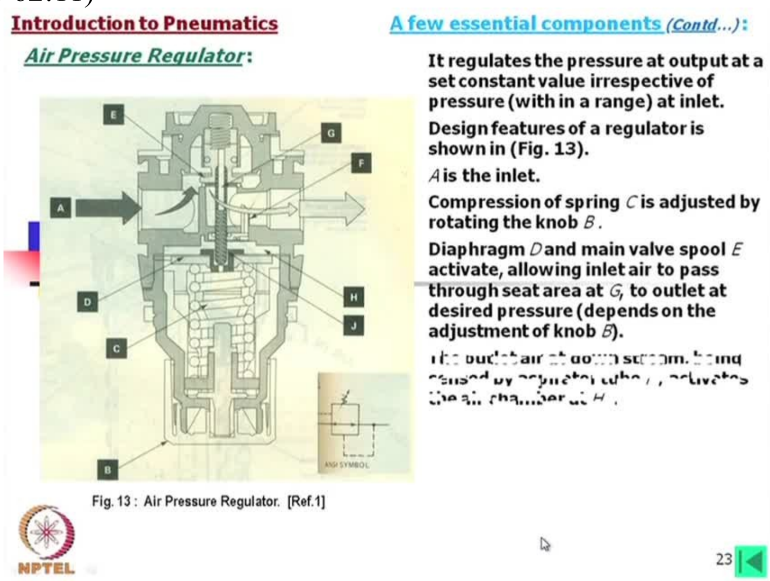

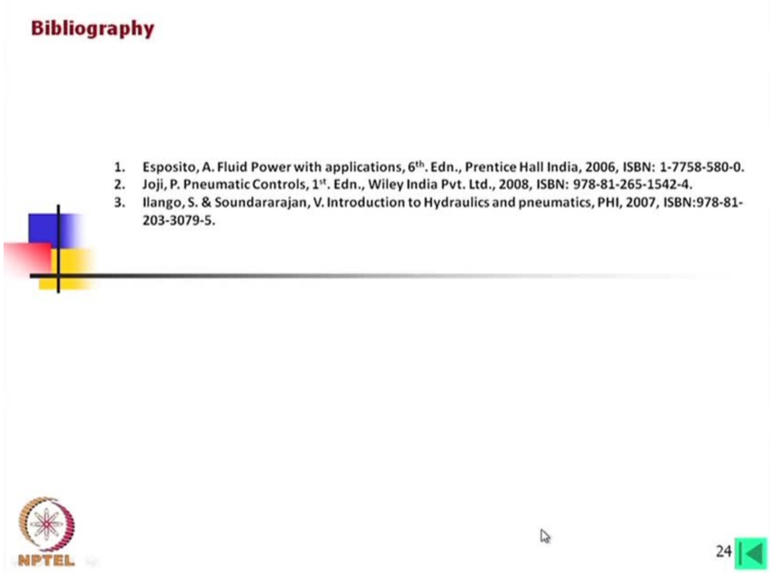

I think we can continue these components in the next lectures. So now this is main portion of this is a book and this is available in Prentice-Hall India Indian book. I do not know whether the print is still available or this is available in the market. But this is very good book to have some basic knowledge about the pneumatics also. There is another book, that is by Wiley India publications and also this is Prentice-Hall of India. But I some practical application, the 2nd book is good and for basic knowledge, the 1st one is very good. So thank you.

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