Fundamentals of Industrial Oil Hydraulics and Pneumatics
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Lecture 32
Application and Selection of Accumulators - Part I

Welcome to today's lecture on application and selection of accumulators. This is part 1. Today we shall learn many fundamentals of accumulators.

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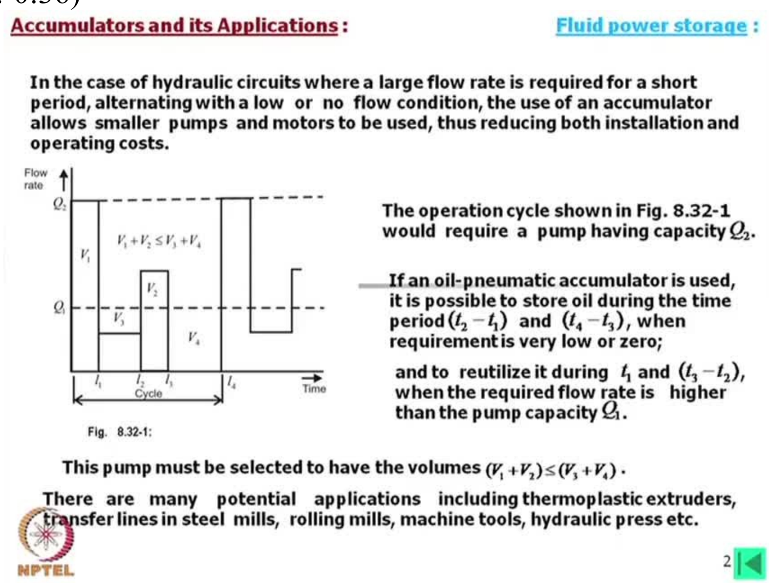

Now, in case of hydraulic circuits where a large flow rate is required for a short period, alternating with a low or no flow condition, the use of an accumulator allows smaller pumps and motors to be used. Thus reducing both installation and operating costs. So basically, we store the energy when the full energy is not required for the operations and it is kept in store and utilised when more power is required, more pressure is required and flow is required.

Now if we look into the cycle, operation cycle of any system which would require a pump having capacity of Q2 okay, then what we can do? Say initially it needs V1 and then V3, then volume V2 and then V4 and then so on, it goes on like this. This is one cycle, then next cycle is similar. In that case, also we considere V1 plus V2 is less than V3 and V4. Here V4 apparently it is 0 and this is the duration of such volume.

Then what we can do? We can use a pump of this capacity and an accumulator, obviously this period will not be very long, these 2 periods. Then the fluids which will be stored in the accumulator during this period and this period can be utilised to have V1 and V2 okay? If and while a pneumatic accumulator is used. Why this is while a pneumatic accumulator? Because this oil is stored in accumulator. Accumulator is nothing but a sort of a vessels, small vessel.

And within that, the oil, in this case oil, we are considering oil or liquid is stored. Where as some part of this accumulator or initially, accumulator is filled with say air and then air is compressed inside and oil is stored okay? This, there might have one separator. That means inside this accumulator, there might have another bladder in which the pneumatic or air may be there. Or it might be open, that means oil can have direct contact with air. Anyway, if we consider if an oil pneumatic accumulator is used, it is possible to store oil during the time T2 minus T1. Sorry this will be T1, T2 et cetera, not L1.

Say T2 to T1 and T4 to T3, these are not LT. Okay? As I already explained when the requirement is very low or 0. And to reutilise it during this period, T1 and T3 T2, when the required flow rate is higher than the pump capacity Q1. This pump must be selected to have the volumes V1 plus V2 which is again less than V3 plus V4. So average capacity is calculated in this way. There are many potential applications including thermoplastic extruders, transfer lines in steel mills, rolling mills, machine tools, hydraulic press, et cetera. These are only few to mention.

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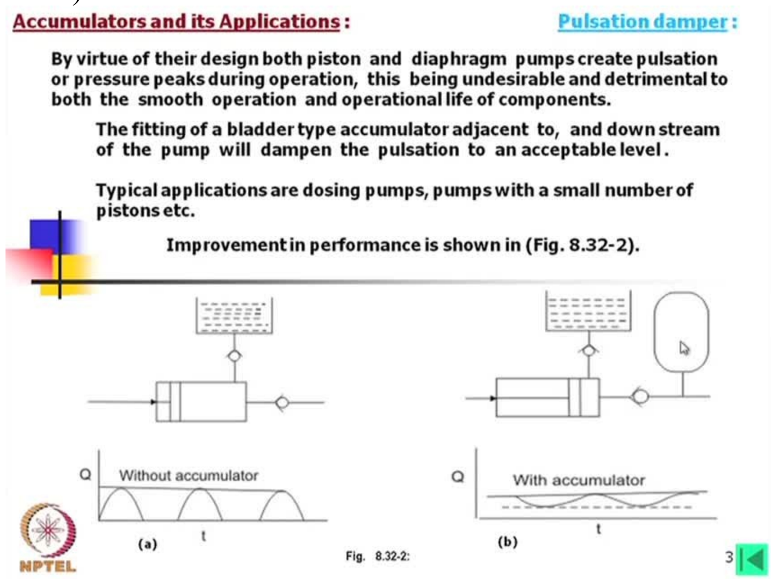

By virtue of their design, both piston and diaphragm pumps create pulsation or pressure peaks during operation, this being undesirable and detrimental to both the smooth operations and operational life of the components. This we have learned that if there is a pulsation, there is a ripple. Then that is performance wise, it is not desired as well as it will affect the life of the components also. The fitting of a bladder type accumulator adjacent to and downstream of the pump will dampen the pulsation to an acceptable level.

We have not yet seen what is a accumulator but as I told that there will be a vessel usually that is made of steel, metal body and inside, there will be bladder, say for example inside the bladder, there will be air or some gas and the rest portion will be occupied by the oil. In fact, bladder is initially will remain inflated and then gradually it will the size of its will reduce and the oil will be stored inside. However, there is also possible that gas and oil, they are in contact, the no bladder is used.

In any case, the fitting of bladder type accumulator adjacent to downstream of the pump, usually dampen, quite usually it will dampen the pulsation to an acceptable level. Typical applications are dosing pumps, pumps with small number of Pistons, et cetera. As you have learnt earlier, small pistons is having higher ripple, small number of Pistons and in most of the cases, particularly in cylindrical pistons, you will find that these numbers are odd to reduce the ripple and maybe, very common is 5, 7 and 9.

So 5 will have more ripple and if we use with that 5 pistons an accumulator in all applications then it is always better. And dosing pump, you understand it is some sort of feeding the oil, may not be the main system. Now improvement in performance can be realised from here. What we have done as if this oil is being pumped in from here, then without this accumulator, we may have ripple like this and if we use an accumulator, this ripple will reduce.

This is an accumulator, this one, very schematic diameter, this better sorry this very schematic diagram that how it look like that we would see later.

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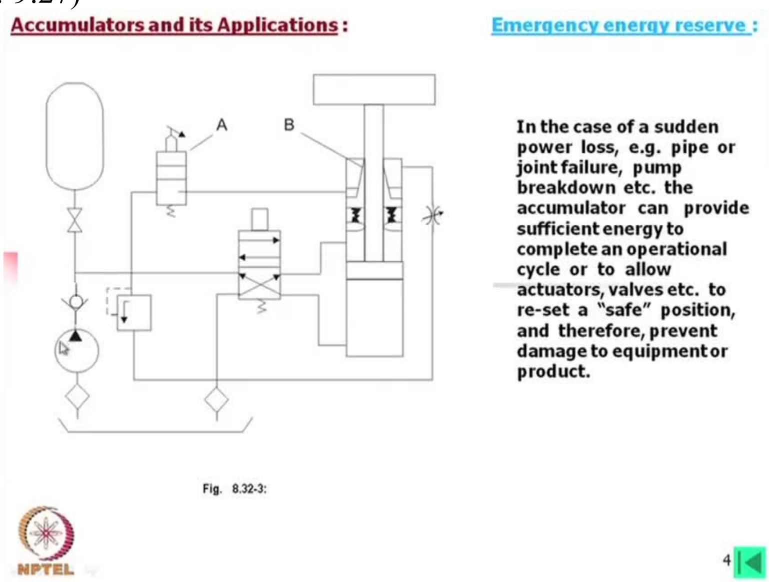

Now another applications, it is shown here. In the case of a sudden power loss, that is pipe or joint failure, pump breakdown, the accumulator can provide sufficient energy to complete an operational cycle or to allow actuators, valves et cetera to reset a safe position and therefore prevent damage to equipment or product. Now what is it in the circuit? What we find? That there is a pump, this is of course the filter and this is the reservoir from where the oil is being pumped through a nonreturn valves or check valve.

Okay? This is very schematic. It might be with spring, without spring. And then what we find? In that line an accumulator is fitted. In that accumulator, as we see that this is as if a vessel, inside there will be some gas. Actually, this is a gas precharge or sometimes you will find a bladder with a charged gas or air is there. Now this is a stopcork because sometimes we may not need to use the accumulator, we can separate it.

Now what we find from here? It is connected, this line, this is a joint, junction point, this is not crossing each other, this is a junction point. That means, this oil can 1st of all go through the relief valve okay? Then it can go to a 2 position valve. This is what you can say, some sort of switch, on and off. And then there is 4 by 2 valve, directional valve and through which it is going to a cylinder. And then from, in the return line what we find that, say this is head side return line, it can go to the tank again through this junction point or else the oil coming over here, this can flow through this flow control valve and it also can go to the tank.

Now what will be the operations? If we consider this connections, then oil is going to the rod inside of the piston and oil from this head side is going back to tank okay? Now in any case, if the pressure is increased, then oil will be relieved to the tank. However, when the full amount is not required, in that case this is being stored and it is not being operated. Now in case of any failure here, then this oil can go this side and through this, this is a passage, through this oil will flow to the tank in a controlled manner and this piston, although it will collapse to its position, but it will it will go very slowly okay?

So in that case, this accumulator is helping to prevent the sudden collapse of this cylinder. And if it is connected like this, in that case, what we find that this oil is going to the accumulator of course, within the pressure setting of the relief valve and this oil this side oil is going, perhaps this arrow could be in this directions is going back to the tank okay? So this is just to prevent a system in case it fails. So this is one application of such an accumulator.

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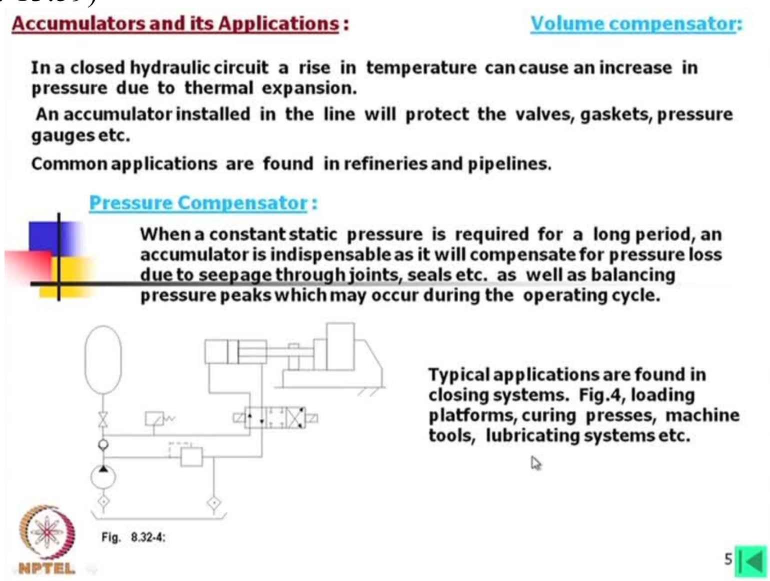

Now in a closed hydraulic circuit, a rise in temperature can cause an increase in pressure due to thermal expansion okay? In that case, how this accumulator can help? Then, title here it is written as volume compensatory but it will do an accumulator installed in the line will protect the valve, gaskets and pressure gauges et cetera. How? Common applications are found in refineries and pipelines where the temperature variations are there. So in that case, what actually happens?

This if there is a rise in temperature, there will be volume increase in the oil. So excess volume will generate a pressure. Due to this pressure, this oil can be stored in the accumulator and when the temperature comes down, again that will be filled. So very large pipelines and others where actually may not be hydrostatic transmissions but the oil is being transferred with full volume, is filled. In that case, such accumulators will be very helpful. So that is volume compensator.

Now we will think of the pressure compensator. When a constant static pressure is required for a long period, an accumulator is indispensable as it will compensate for pressure loss due to seepage through joints, seals, et cetera as well as balancing pressure peak which may occur during the operation cycle. So this means that we have to 1st keep in mind that oil is being when the pump is running, then excess oil is being accumulated in the accumulator.

Now, then if there is a loss, suppose the system is stopped, that means a weight is lifted and then it is stopped. Then what is happening? There will be leakage and et cetera. That leakage can be filled by the oil from such accumulator. Now this is an system. This is apparently, some sort of press sort of things where this is being pressed with a pressure for a, it is not very long time but this operation is being done for a substantial time and in that case, what is the system?

This is a pump with nonreturn valve and there is a direct relieve valve here, it is after the pump and then the nonreturn valve and this is the accumulator. And then with this there perhaps is another relief valve is there. And then oil is going like this and it is being used for pressing, this one. This is here written, typical applications are found in closing systems. Closing means, in that case is pressing something, closing something, loading platforms, curing presses, machine tools, lubrication system et cetera.

In that case, this accumulator whenever the excess flow and pressure will be required, that will help.

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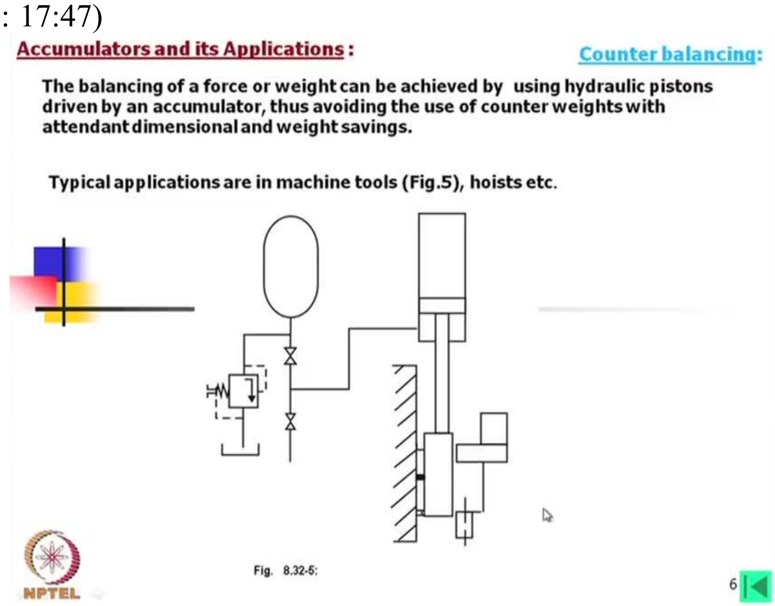

Now for counterbalancing, earlier we have learnt that counterbalancing can, systems can be designed using the pressure control valves. However to some extent if we use an accumulator, then the similar performance is also available. And this is not for very large load, small load and maybe for (())(18:15) it will be suitable. Now how it works? The balancing of a force or weight can be achieved by using hydraulic pistons driven by an accumulator, thus avoiding the use of counterweights with attendant dimensional and weight savings.

Now this system looks like this. Typical application is machine tools, hoists, I would say small hoist, not big hoist. Now in that case what we find? The pump is not shown but there is one stop cork. Not nonreturn valve, stop cork is there. This is just to show the schematic diagram, it can be replaced by nonreturn valve also. We find the relief valve is here from the accumulator side and then it is connected to this side.

Then how it operates? That either we can run the pump but when the pump is not running, then this oil will prevent a load for falling. Okay? So in many cases, you will find that machine tools, particularly say let us consider the drill hole, sorry grill head. It is coming down when you just leave it, that means when it the downward pressure is off, then gradually it goes off. So we would like to maintain that positions. In that case, we can call it counterbalancing and that can be done by an accumulator.

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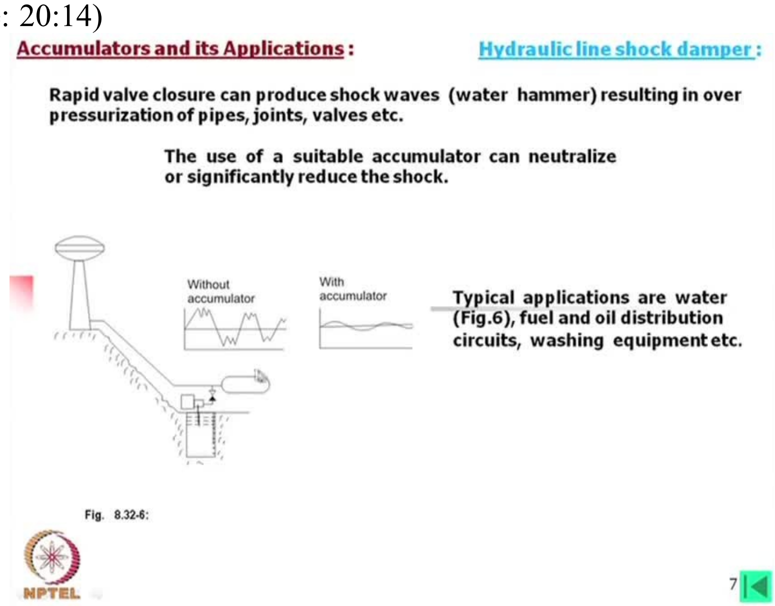

Now it can be used as a hydraulic line shock damper. Rapid valve closure can produce shock waves water hammer, resulting in over pressurisation of pipes, joints, valve et cetera. And even it can damage the system. You see this water hammer is it is name is water hammer because this is maybe 1st it observed with water flowing, water storage system but it can be it can happen in any liquid and if we close the valve suddenly, what happens?

The it is a pressurised flow but it is blocked. There will be very sharp rise of the pressure there. That will generate a wave inside the oil and that wave gets very rapidly and it oscillates, it generates a dynamic condition inside the storage and that may even cause the bursting of the system, pipelines et cetera. Now let us see what happens. The use of a suitable accumulator can neutralise or significantly reduce the shock.

Now this is an water storage system, this is the pump from the reservoir and water is being pumped here. Then let us consider, there is no accumulator, without accumulator. Then suddenly if we close this valve, then what will happen? This water this side will be disconnected and there will be an water hammer inside and this will be large pulsation of this liquid. Now if we use an accumulator, then when we close this one, then this shock will create waves and even if it is not 0, amplitude is not 0 but this will low amplitude.

So this can be controlled by using this one. Definitely there will be a vibration sort of things or you can see this is acting as a damper. In case of damper, of course there is a orificion of the system. In that case, it is, nothing is there, oil is going in and it is giving pressure on the bladder if it is inside or if the air is there, it is just knocking that air or gas and in that way, the shockwave here is reduced okay?

Now typical application are water, fuel, or oil distribution circuits, washing equipment et cetera.

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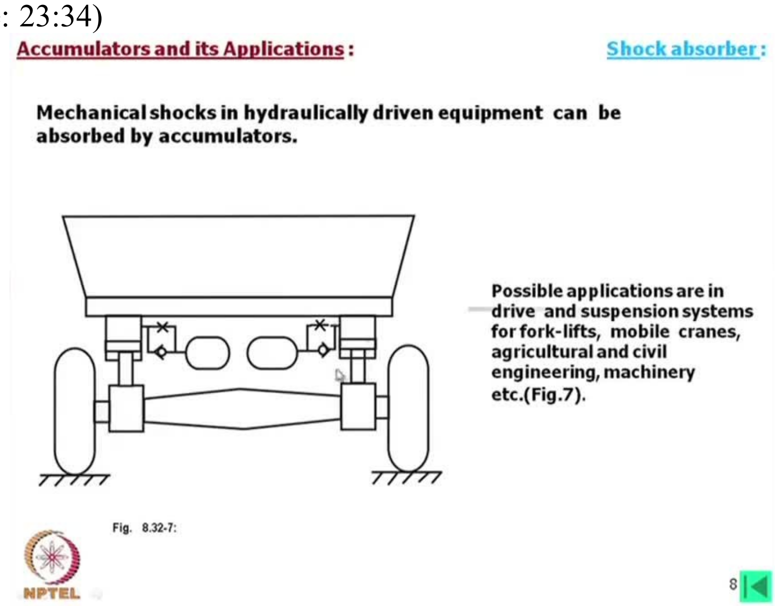

Now definitely as we have explained for reduce the water hammer or shock there, so definitely the such an accumulator can be used as a shock absorber also. Mechanical shocks in hydraulically driven equipment can be absorbed by accumulators. So in this case, what we have shown? A some sort of carriage or this may be to (())(24:10) some earthmoving equipment. In that case, what we find that this axle is on a damper. This is damper and in the damper, there is another accumulator is fitted.

But look into this, there is no pump. The oil is stored, so there will be, we have to precharge the system and then when any shock is coming over here, then the oil is going inside but this cannot be in here. So while it is going back to the cylinder, then it is going through this path. Okay? So it acts as a something you can say that hydraulic spring sort of things also. Okay? So instead of mechanical spring, one accumulator or along with mechanical spring, accumulator and a damper, will have a better vibration reduction than without accumulator.

So here the typical applications are forklift trucks, mobile cranes, agriculture, civil engineering, machinery, et cetera. But these are usually used for last system, not a very small system. However, you may find that similar accumulator, a very small accumulator also can be used for vibration isolations for small vehicles also.

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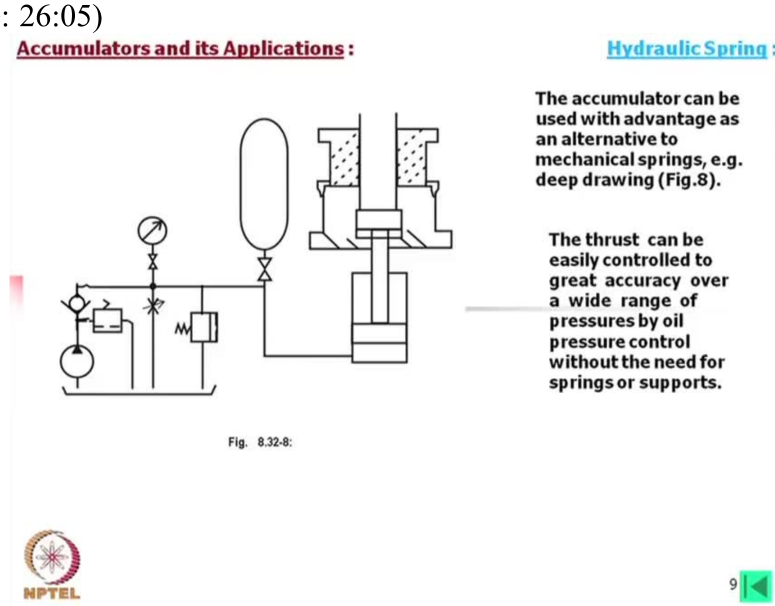

Now I have just mentioned the hydraulic spring. In that case again, we will find that this can be again used as a hydraulic spring. Now the accumulator can be used with a advantage as an alternative to mechanical spring okay? Instead of mechanical spring, we use some hydraulic spring. In that case if you look into these operations, there is an accumulator fitted over this system and in that case, this acts as a hydraulic spring. Probably this is an say hammering machines or forging machines.

In that case we can use such hydraulic spring instead of mechanical spring. The thrust can be easily controlled to great accuracy over a wide range of pressures by oil pressure control without the need for springs or supports. This means, in case of mechanical spring, you cannot change the spring constant. Okay? Only so it can take certain amount of load depending upon the how much compression is possible upto the failure of course. In this case you can change the stiffness of the spring, spring constant because you can increase the pressure of the system by regulating the pressure.

And your accumulator is selected accordingly.

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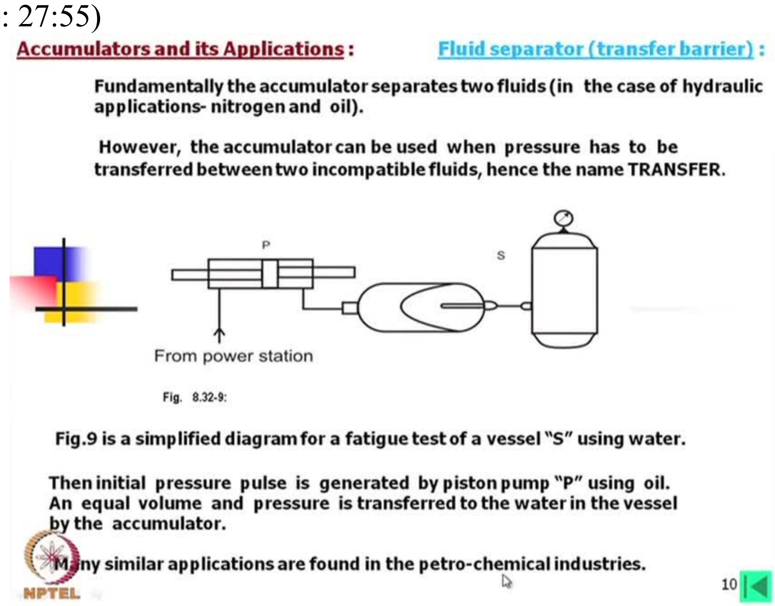

Now this is fluid separator and transfer barrier. This is another application of such an accumulator. In that case, what is there? And 2 sides of system, there are 2 different fluids. In between, there is an accumulator. Fundamentally, the accumulator separates two fluids in the case of hydraulic applications, say, we can say nitrogen and oil. However, the accumulator can be used when pressure has to be transferred between 2 incompatible fluids, hence the name is transfer.

Now this is a very simple system which is shown. Suppose what we consider that in figure 9, simplified diagram for a fatigue test of a vessel S using water. In that case, what we can do that we are testing, fatigue testing of this cylinder and here we are creating this pressure by the oil but inside, there is water and this is separated by an accumulator. So we are creating pressure here. Through this accumulator bladder, the water inside is being pressurised.

And by oscillating this one, we applying the fatigue load to this vessel. Okay? So this one application of this accumulator which is called transfer. Then initial pressure pulse is generated by piston pump P, this is the piston pump P using oil and equal volume and pressure is transferred to the water in the vessel by the accumulator okay? Many similar applications are found in petrochemical industries.

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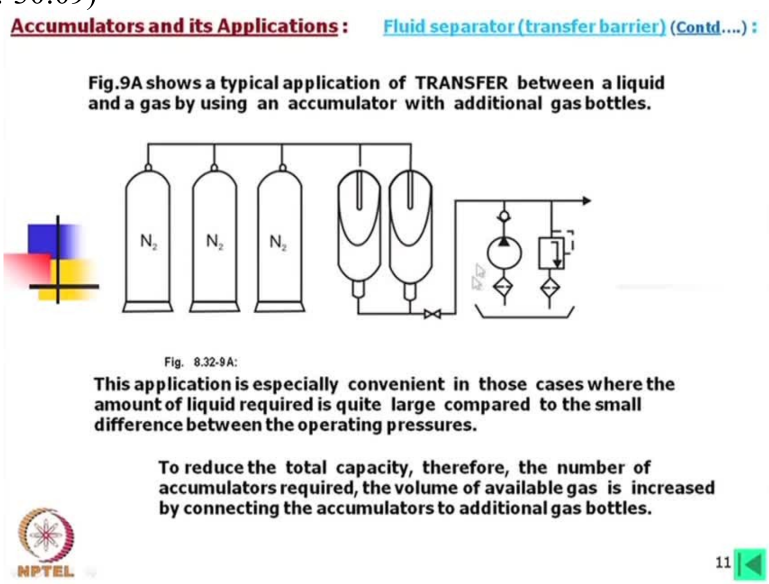

Now another example of the transfer barrier is that in that case, what we find that typical application of transfer between liquid and gas, this is nitrogen, by using an accumulator with additional gas bottles. See here as if two accumulators and oil is being pumped here, so this oil can go this way but when we open it, then this will be pressurised and then this nitrogen in this case nitrogen cylinder, that will be (())(31:03) equalised, something will be there. This is a very schematic applications of accumulator.

But this is the transfer process. These are usually used in industries, say chemical industries and similar big industries. This application is specially convenient in those cases where the amount of liquid required is quite large compared to the small difference between the operating pressure okay? This is in this systems, actually we need very large amount of oil with a very small pressure difference and then this accumulator helps in doing to meeting such requirements.

To reduce the total capacity therefore the number of accumulators required, the volume of available gas is increased by connecting the accumulators to additional gas bottles. So we can add more bottles and by this, we can reduce the number of accumulators.

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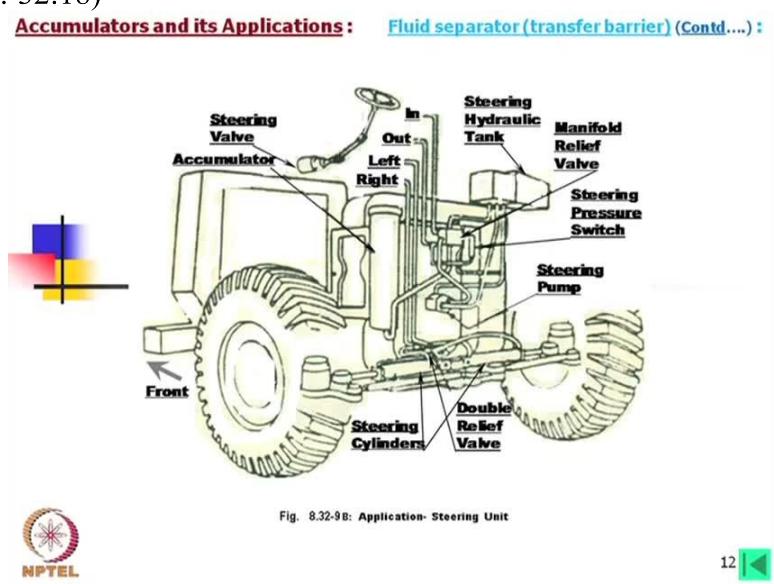

Now this is another applications where we can use the accumulator. This is fluid separator, this is same transfer barrier but this application is steering unit. What we find that this is the steering and this is the steering valve and this is accumulator okay. And we find that steering pump is here and steering pressures which is here, manifold relief valve is here, steering hydraulic tank is there. Now this is a circuit which is not very clear but in out, left and right, that means there are this is some separate operation, left, right motion and in and out motion okay?

Now these are 2 steering cylinders and double pressure relief valve is used here. Now this actually if we think of the steering, then in that case normally what we do? Suppose we are trying to turn the car or any vehicles, in that case, we move this one. Then there the steering system which is fitted to the wheel hub of the steering wheels, that is rotating the wheels to a position. Now actual force is required much more than what the force we are applying.

Then what happens? Sometimes we, suppose we are trying to negotiate these wheels but we are turning this wheel. We have to turn more and more to get the required action at these wheels. Now in that case, the accumulator is there, that will help in, help further to move these wheels. So this is not very, it will not be very clear from looking in the system. But this is just a system shown how it looks like.

So you will find usually, these are not the ordinary car, these are usually off-highway vehicles where in the steering wheel you will find the huge load is required much will find an accumulator is fitted to the system. Without this accumulator, this will also operate but you in that case you we find that you have to not only give more effort, more (())(35:18) as well as you have to give the more motion to get such action, get steering action. Accumulator will reduce such additional effort.

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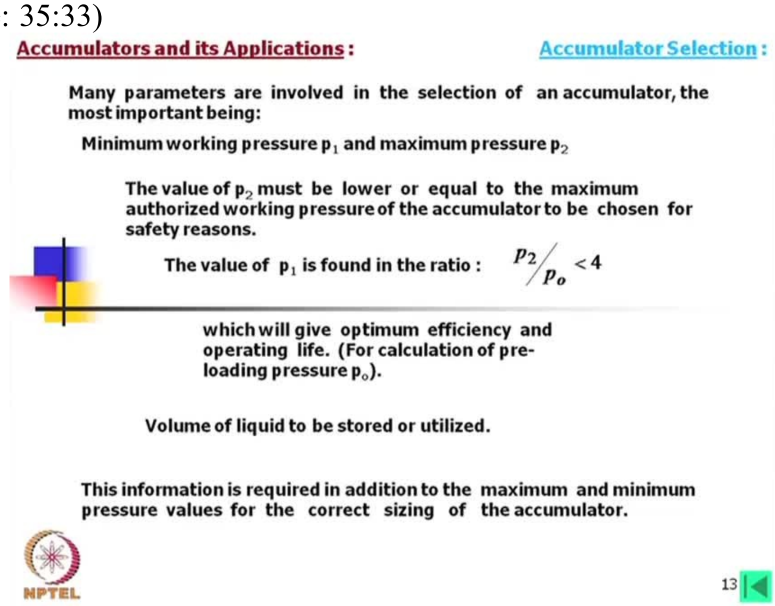

Many parameters are involved in selection of an accumulator. Now we will think of how this accumulator can be selected. We have seen just the very preliminary applications of accumulator. Now we will look into how it can be selected. Now the most important parts are, in the process of selection, 1st of all we have to think of what will be the minimum working pressure P1 and what is the maximum working pressure, P2.

The value of P2 must be lower or equal to the maximum authorised working pressure of the accumulator to be chosen for safety reasons. Now in an accumulator, whether it is with a bladder or simple the gas and oil accumulation, 1st of all we have to look into the capacity of such an accumulator. That accumulator can store say it is it can store at 10 mega Pascal, then maximum pressure of the system should be below 10 mega Pascal.

We cannot regulate that. That means, accumulator pressure, accumulator capacity is not regulated. It is always precharged okay? The value of P1 is found in the ratio P2 by P0 is less than 4 normally. That P0 is the charge pressure. P1, P2 is the working pressure of the system, minimum and maximum. P1 is the minimum, P2 is the maximum where P0 is the charge pressure and usually, P2 by P0 is less than 4. You see, look into this value.

Now as I told that it is less (())(37:40) one may think that P0 should be, that is charge pressure should be close to this one but actually what it means that if you measure the pressure of the bladder after charging, you may find that pressure is some P0 value. It will be less than the working pressure but when this pressure will work on that bladder or the gas or whatever is there, that pressure will rise okay?

And that pressure will rise, may rise a little above the P2. It is designed is in that way which will give optimum efficiency and operating life for life for calculation of preloading pressure P0. This is called preloading pressure P0. Volume of liquid to be stored or utilised, that you have to consider. We are looking into this accumulators selection. 1st of all we will look into the pressures in that way. Then volume of liquid to be stored or utilised.

That means in that case what may be the shortfall of the volume in the process, accordingly we have to select the accumulator size. Sometimes we may find that one accumulator may not be sufficient, we have to go for one more accumulator okay? This information is required in addition to the maximum minimum pressure values for correct sizing the accumulator.

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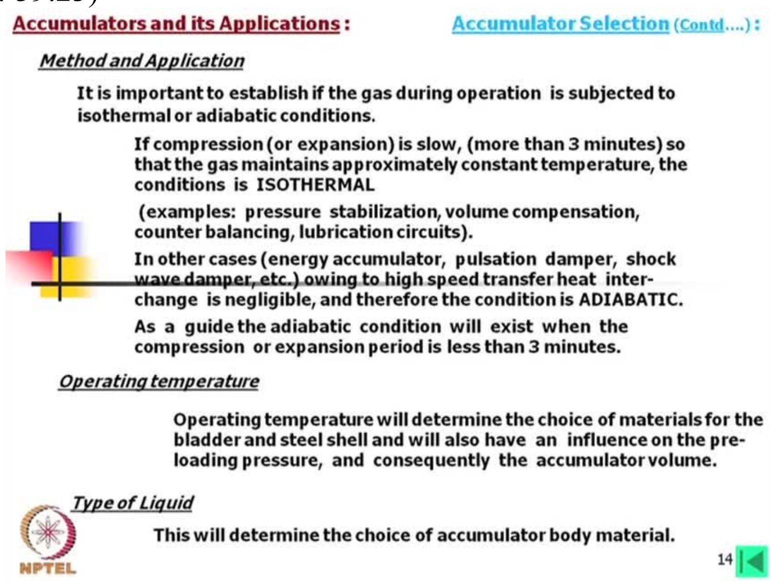

Now we have to look into the method and application. It is important to be established if the gas during operation is subjected to isothermal or adiabatic condition. Now this is some thermal consideration we must do for accumulator selections. If compression or expansion is slow, more than 3 minutes so that the gas maintains approximately constant temperature, the condition is isothermal. Okay? Examples-pressure stabilisation, volume compensation, counterbalancing, lubrication circuit. In that case, this is the isothermal condition.

In other cases, energy accumulator, pulsation damper, shock wave damper, et cetera owing to high speed transfer heat interchange is negligible and therefore the condition is adiabatic. Okay? As a guide, the adiabatic condition will exist when the compression or expansion period is less than 3 minutes. This guide means, just thumb rule. If it is less than 3 minutes then you may consider the condition is adiabatic. Okay?

So this adiabatic or isothermal is important for the what the gas we are using inside the accumulator. Operating temperature, the operating temperature will determine the choice of materials for the bladder and steel cell and will also have an influence on the preloading pressures and consequently the accumulator volume. Type of liquid. This will determine the choice of accumulator body material. Say what liquid we are using.

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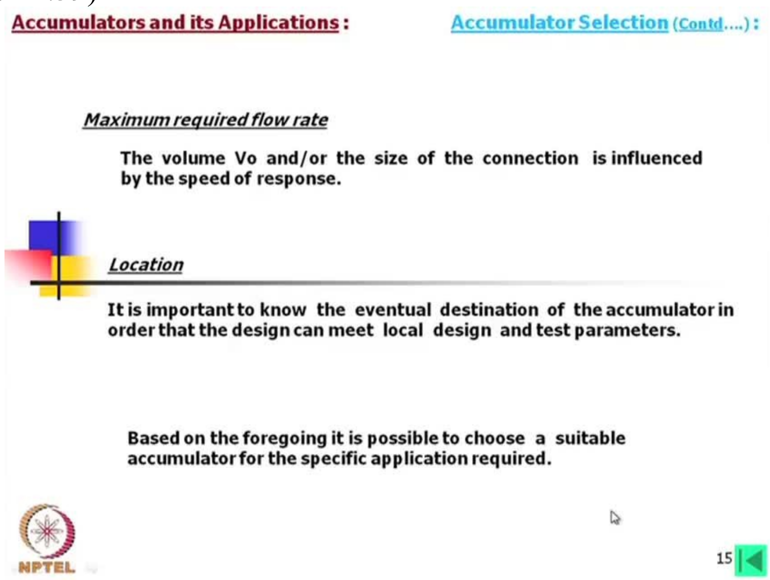

Now maximum required flow rate is another factor. The volume V0 and or the size of the connection is influenced by the speed of response okay? Location. It is important to know the eventual destination of the accumulator in order that the design can meet local design and test parameters. Okay. This is to I mean the position location selection of accumulator. Based on the foregoing it is possible to choose a suitable accumulator for the specific application required. There are other factors also which are not discussed but these are the main major factors we have to consider.

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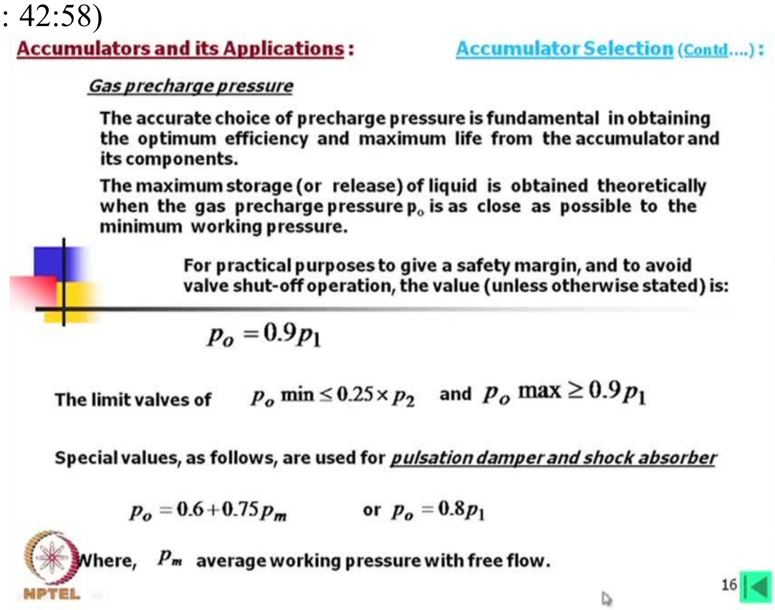

Now we will look into the gas precharge pressure. The accurate choice of precharge pressure is fundamental in obtaining the optimum efficiency and maximum life from the accumulator and its components. Okay? So we have to look into this precharge pressures which actually controls the accumulator performance as well as the life of the components. The maximum storage or release of liquid is obtained theoretically when the gas precharge pressure P0 is as close as possible to the minimum working pressure.

Now for practical purposes, to give a safety margin and to avoid valve shut-off operation, the value unless otherwise stated is P0 is equal to 0.9 P1. That means if we know the system working minimum system working pressure is P1, then we can as a thumb rule, we can select P0 will be 0.9 of that. That means if P1 is 1 mega Pascal, then you can have the charge gas pressure without loading I mean no fluid is coming in maybe 0.9 mega Pascal okay?

The limit values of P0 that is P0 min is equal to 0.25 into P2. P2 is the maximum pressure mind it or P0 Max 0.9 of P1. So P0 should be 0.25 into P2. At one point we have shown P2 P0 P2 by P0 is equal to 4. So from there this lesson and from this above lesson, we can have. So looking into these working pressures, we can have that what should be the P0 which will be in between this and this okay?

Then special values as follows are used for pulsation damper and shock absorber. The P0 is 0.6 plus 0.75 of PM. I think these relations we should look into again because this value is there without bracket. So if it is an additional part, this is definitely the unit sensitive. So we have to look into this this relation is whether this is correct or not. Or it is simply P0 is equal to 0.8 into P1, pulsation damper and shock absorber.

Where, PM average working pressure with free flow okay? Now this free flow means that the when there is no restriction over the flow from the accumulator.

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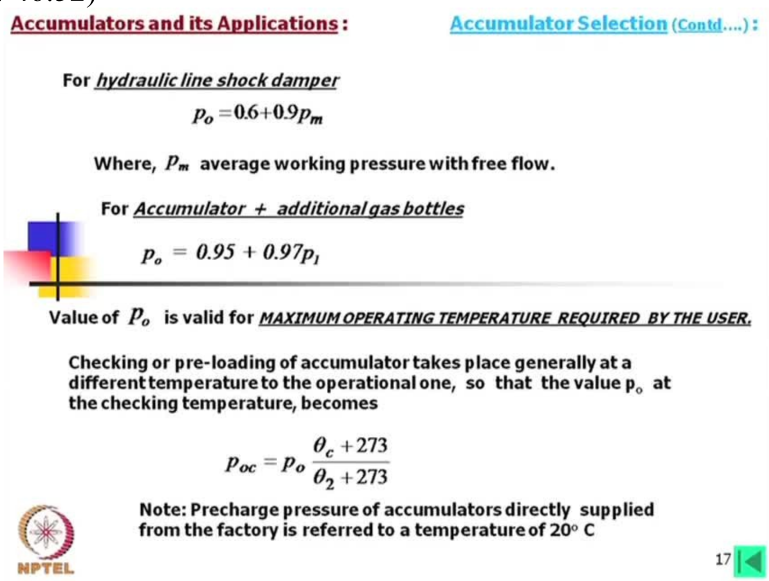

For hydraulic line shock damper, it is again taken P0 is equal to 0.6 plus 0.9 PM again it is the unit sensitive. So we have to look into this. Where, PM average working pressure with free flow, the same but these 2 relations are different for 2 applications. For accumulator plus additional gas bottles, it is 0.95 into 0.97 P1 where P0 is valid for maximum operating temperature required by the user. Checking of preloading of accumulator takes place generally at a different temperature to the operational one so that the value P0 at the checking temperature becomes P0 some critical value P0 into theta C plus 273 theta2 plus 273 okay?

This must be temperature in Celsius. Precharge pressure of accumulators directly supplied from the factory is referred to a temperature of 20 degrees centigrade. Okay? Now this lecture will be continued. Further we shall continue over the accumulator selections and then we will solve a problem also and we will learn more about the accumulator.

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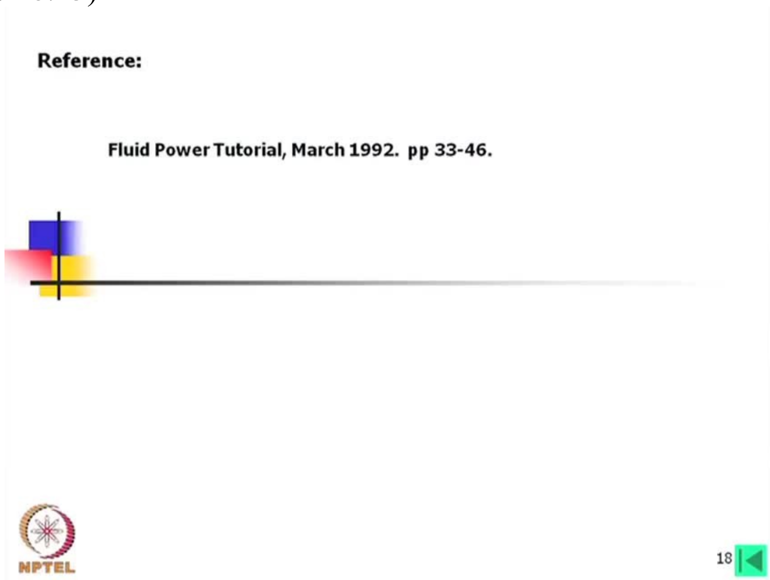

Now the reference for this one is very old, a tutorial note in a fluid for, it is not journal, you can say it is magazine. It was in 1992 when this accumulator was still in development stage or it was finding its application and then this topic was found very interesting. So this is from that topic. But next time, we will also consult some book. Okay, thank you for listening.