Fundamentals of Industrial Oil Hydraulics and Pneumatics
By Professor R. Maiti
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur
Lecture 33
Application and Selection of Accumulators - Part II

Welcome to today's lecture. This is continuation of application and selection of accumulators.

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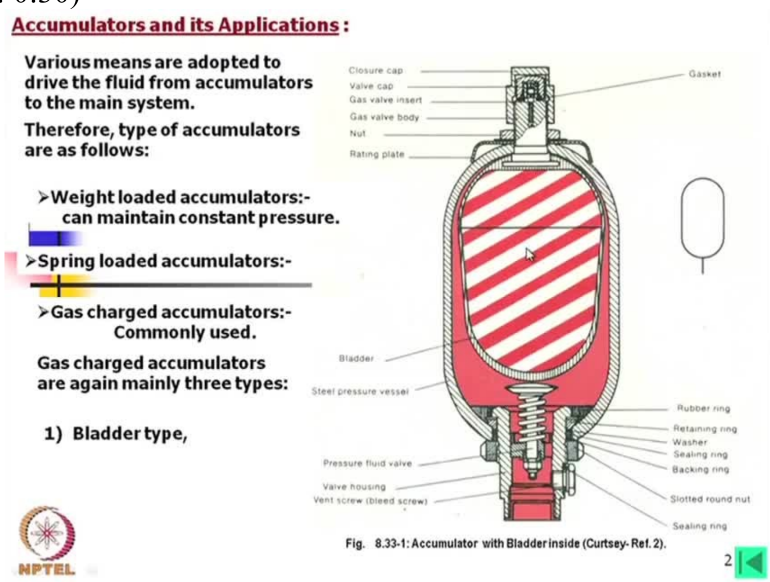

Now various means are adopted to drive the fluid from accumulators to the main system. Therefore type of accumulators, we can put according to the how the, they are driven to the main system. These are as follows- weight loaded accumulators. This has unique advantage that it can maintain the constant pressure. Spring loaded accumulators, that obviously the force reduces when the compressive spring expands. So therefore, there will be change in pressure, variation of pressure.

Gas charged accumulators which are commonly used. In fact, weight loaded accumulators may be the best in that point but for high-pressure, you have to use huge amount of load and the construction of such an accumulator is difficult. And it is found that spring-loaded, although this can be used but gas loaded is best because of the reason in some cases, you can regulate the gas pressure from the outside although it is not normally done. Gas charged accumulators are again mainly 3 types.

The most common you will find the bladder type. What it is? If we study this figure, then we will find that outside this is the main casing of the accumulator. So this you can consider that this is a steel pressure vessel. And inside that, there will be a bladder which is usually charged by gases. Nitrogen is very common. However one can use the ordinary air also. Now if we look into the other details, then what we find that this is a closure cap, this is just to protect the main cap which is you can say valve cap or the total valve system.

If we remove the closure cap, then we will have a valve cap and if we remove that one, then that is a valve. It is basically non return valve and we can insert the gas and then this is you can say this is the valve body, this is fittings of the valve on the steel vessel, then there is a rating plate which is by tightening which, we can make it leakproof with gasket, of course gasket is there. Here is also a gasket.

And then, so this is for charging the gas inside. Now if you look into the bottom side, then there you will find pressure fluid valve. So there is another valve which the oil is allowed to the main system and then this is a vent screw. It is if there is some bleeding is necessary, then it is done through this. Then this is a slotted round nut to fix this one and there are many other small components to make these fittings leakproof to from the accumulator.

And this symbol of this accumulator whether it is bladder or other type, is usually given by a symbol like this.

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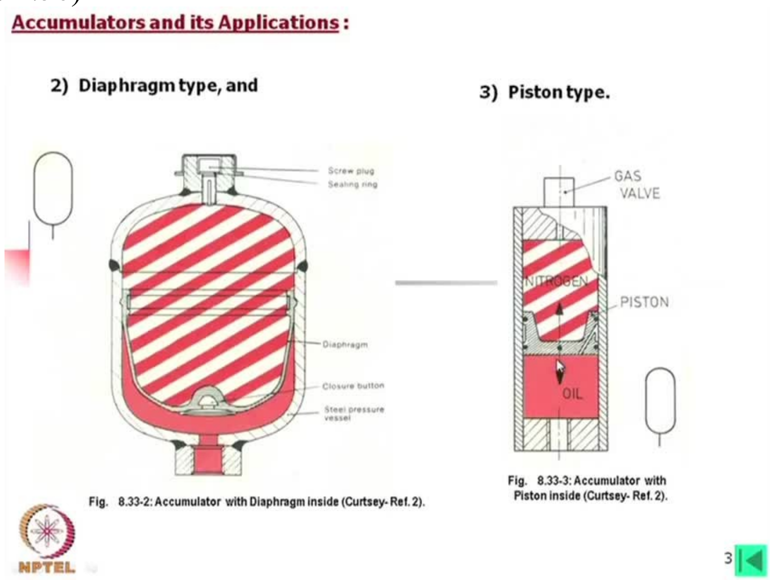

Now next one is the diaphragm type. In case of earlier one, the bladder is filled with gases with a pressure. So when the oil is required from this accumulator, then bladder expands gradually which is having the oil was having the same pressure as the pressure inside the bladder. In this case, instead of that bladder, we have a diaphragm. This diaphragm is fitted to this body okay? Now the gas, pressurised gas is put or inserted in the upper portion and lower portion is filled with oil.

Now this diaphragm is commonly will be harder than this bladder. So this is usually for volume displacement but higher pressure. Now this is again some this closure button and this there is a plug screw, et cetera. So what will happen? When this oil, excess oil is being pumped in to this accumulator, then this will contract a little bit and this volume will also contract and then when again this oil is required by the main system, this will expand and this oil will be pushed in to the main piston.

Definitely, pressure will vary. That means, here inside the gradually the pressure of this oil will reduce, pressure of this gas as well as this pressure of this oil will reduce when it is being injected to the systems but it is obviously the lowest pressure here will be equal to or higher than the pressure required by the system. And the 3rd one is the piston type. In this case we can imagine a cylinder finished inside, bore is finished to accommodate a piston.

This piston is having no rod, then oil is being injected from this side and the gas is being gas is charged from the other side. So this works in the same fashion but here also, this work for very high-pressure but the displacement of the oil may not be very high or can be made high if we make this piston longer. But we have to keep in mind this gas when it is expanding, then gradually the pressure is decreasing.

So it is not may not be very worthy to make it very large one. But this as well can be made very small and it can be fitted wherever required in the system.

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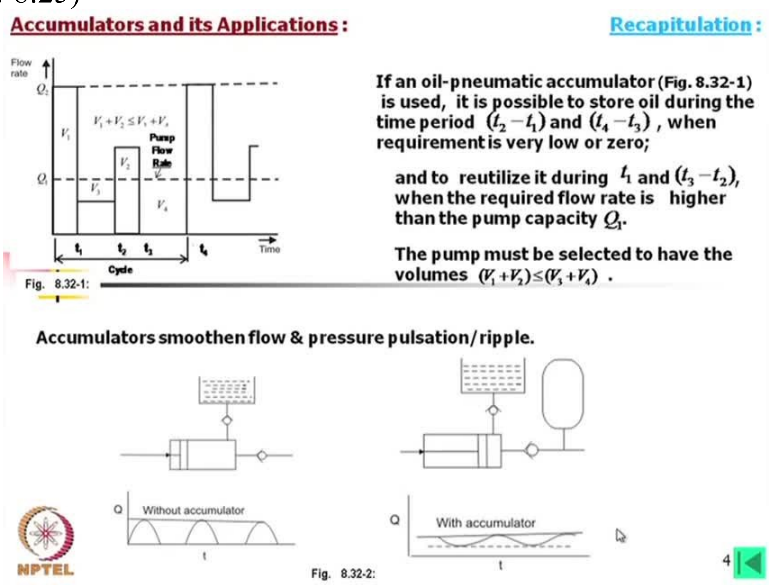

Next if you recapitulate our knowledge that the accumulator is used usually there will be a pump of low-pressure, sorry low flow, Q1 low flow and the excess volume if it is required for the short period it is supplied by the accumulator. So if you look into this figure, the Q1 is the pump flow, maximum pump flow rate wherever the system may require the flow up to Q2 for a time period T1, then T1 to T2 is the volume required is V3. And then T2 T3 is volume required is V2 and then T3 to T4, this volume requirement is 0, this is the cycle.

Now in that case, pump, when this pump is running then for this period, oil is being injected from the accumulator to the system in this point. If this is a fixed displacement pump then this oil, excess oil is going to the accumulator and here again, from accumulator to system and in this case, full volume is going into the accumulator and after the accumulator has completely filled in, the oil in case of fixed displacement pump system, oil goes to tank via the pressure relief valve.

Now here is one relation we must remember that V1 plus V2 must be less than equal to V3 plus V4. That is, otherwise if the excess oil is required by the systems, we cannot supply it. Accumulators smoothen flow and pressure pulsation or ripple. So this also we have already studied. A system without an accumulator having the pulse like this and if you put an accumulator, then this pulse is reduced. It is, may not be possible to eliminate the pulsation completely.

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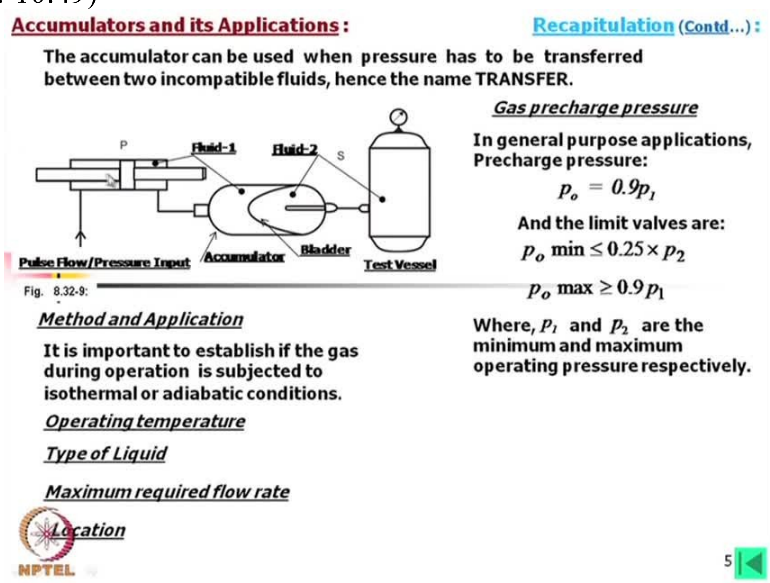

Now again, if we look into the applications, then this also used for the transfer. Transfer means, say for example this is a test vessel, this is being tested by water. So what we can do? Inside bladder, we can put the water and this also, we can filled into water. This side, it is usually oil, hydraulic oil and then by a reciprocating pump or actuator you can say, it is of equal rod both the side. What we can do? We can generate a pulsating load here which is transferred through this accumulator to this vessel and then this vessel is tested for fatigue load.

Now if we look into the gas precharge pressure, in general purpose applications, precharge pressure is usually equal to precharge pressure is P0 is equal to usually 0.9 into P1. Also the volume of the vessel if we can estimate what is the maximum requirement from the accumulator, then the accumulator inside volume is usually point sorry, the gas charge we do 0.9 percent of the total volume and that means 0.9 percent, sorry 90 percent will be the volume required. We make it and if the volume of the accumulator is 100 percent, in that way.

And the limit values are V0 is minimum is 0.25, that is 25 percent of the maximum pressure whereas P0 maximum is equal to greater than equal to 0.9 of minimum system pressure. Now method and application, it is important to establish if the gas during operation is subjected to isothermal or adiabatic condition. So that we have to look into this. Isothermal process as you know that if the process is occurring very quickly, then we can go for isothermal.

Or otherwise, it will be the adiabatic isentropic conditions. And then we have to calculate accordingly. Now as well the operating temperature is important, type of liquid is also important, maximum required flow rate that we have to look into the location where we should put that accumulator. This type of, depending on the type of liquid, we can select what should be the bladder material.

Usually, the outside body is steel, if it is not corrupted with the steel, this main oil, if this main oil is cannot be used with the steel, then we can think of other material. But inside gas and oil or whatever is flowing, the main medium of the system, looking into that, we select these materials okay?

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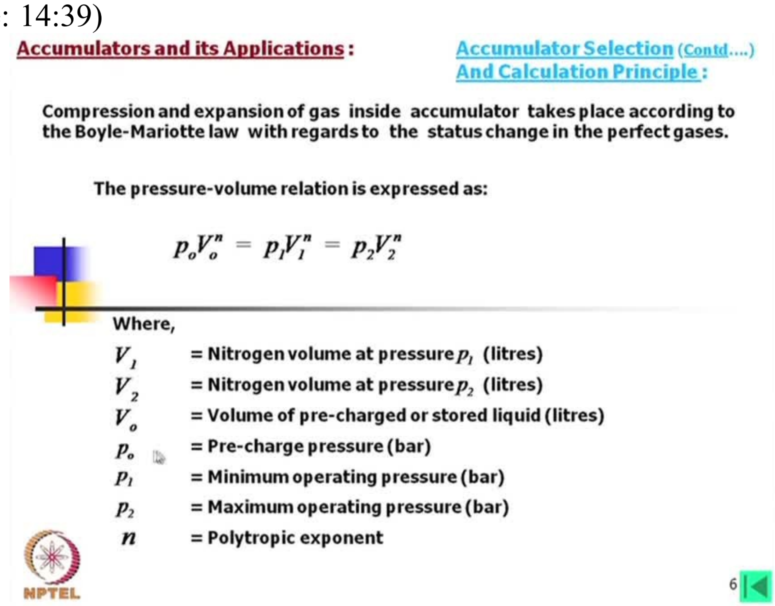

Then compression and expansion of gas inside accumulator takes place according to the Boyle-Marriot Law. With regards to the status change in the perfect gas. This means, we considering the isentropic change, the pressure volume relation is expressed as P0V0 equal to P1V1 IS equal to P2V2. That V0, V1 and V2, these are the volumes of the bladder okay? Now N is the this power, N power, is equal to 1 in case of isothermal. In case of adiabatic, usually it is 1.4 or something like that.

In between that, we can select according to the time taken, we can select this. I am coming to that later. Now here, this I have already explained but still V1 is the nitrogen volume at pressure, we have assumed this gas is nitrogen. So P1 is the pressure, minimum system pressure, V2 is the nitrogen volume at pressure P2 is the maximum pressure, system pressure, V0 is the volume at precharge or stored liquid, P0 is the pressure at precharge, P1 is the minimum operating pressure, P2 is the maximum operating pressure, et cetera. And this is the polytropic exponent, N is the polytropic exponent.

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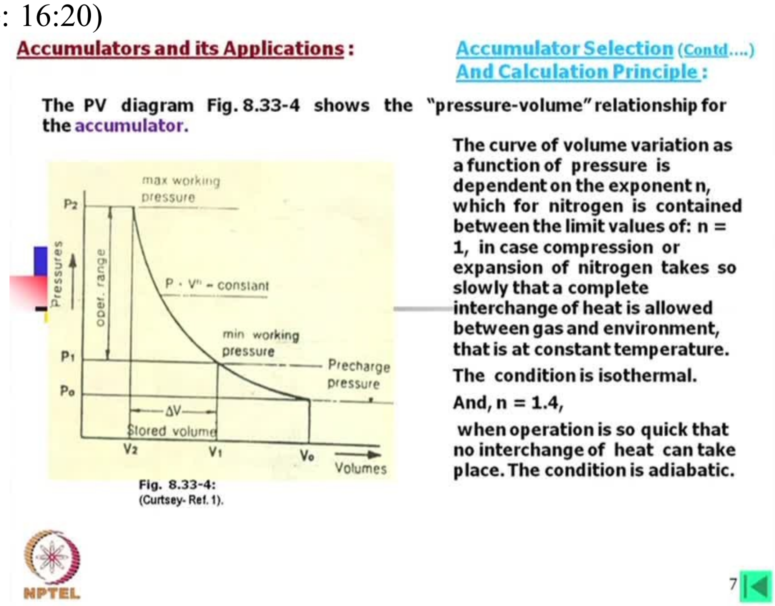

Now if we look into this normal, this very ideal, then PV diagram is usually as follows for a gas. And you can see this is the maximum pressure, it is like that over the range and P1 is the working pressure and P0 is the minimum gas charge pressure. And this is the volume, store volume being used for the system. This is the used volume for the system. That means when the pressure P2, then volume, minimum volume and then V1 is the minimum pressure, that is the maximum volume and this is the charged volume, right?

Now obviously if this is 1, N is equal to 1, this is a straight line. But this is ideally it will follow this curve. Whatever maybe this value, we can have the curvage of this nature. The curve of volume variation as a function of pressure is dependent on exponent N which I have explained which for nitrogen is counting between the limit limiting values of N is equal to 1. In case of compression or expansion or nitrogen takes so slowly that a complete interchange of heat is allowed between the gas and environment that is at constant temperature.

So this is for the slow process. Now this condition is, we call it isothermal. Sorry, this perhaps I told that very quick process is isothermal. It is not that. We have to this interchange time is required. And N maximum is equal to 1.4. When operation is so quick that no interchange of heat can take place, the condition is adiabatic okay? So if there is a very quick change, then this condition is adiabatic but when it is a relatively slow process, then we can call it is isothermal.

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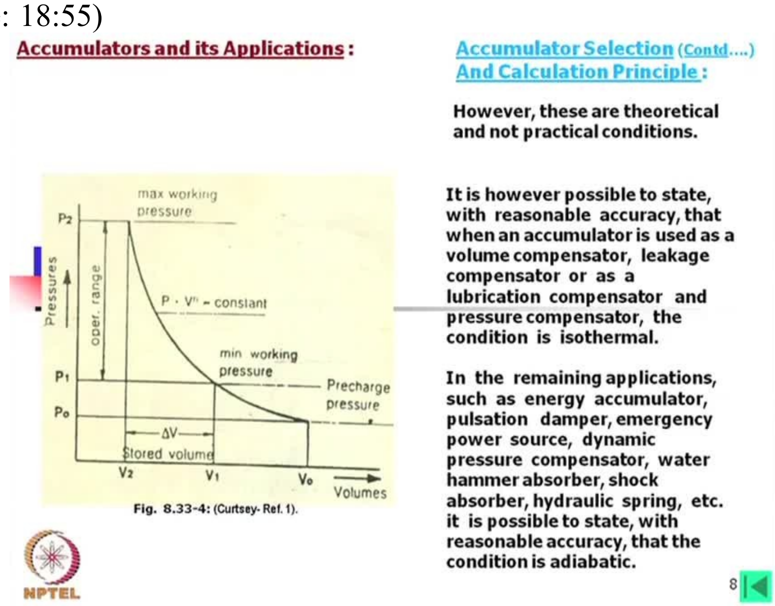

However, these are theoretical and not practical conditions. Then it is possible to state with reasonable accuracy that when an accumulator is used as a volume compensator, leakage compensator or as a lubrication compensator and the pressure compensator, the condition is isothermal. Whereas if in the remaining application, such as energy accumulator, pulsating damper, emergency power source, dynamic pressure compensator, water hammer absorber, shock absorber, hydraulic spring, et cetera.

It is possible to state that with reasonable accuracy, with reasonable accuracy that the condition is adiabatic. That means there is the very quick process is going on.

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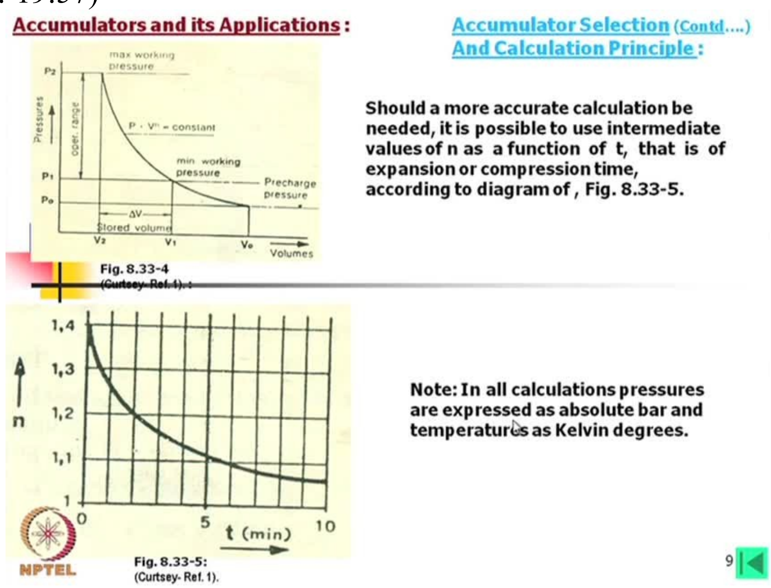

Now should a more accurate calculation be needed, it is possible to use intermediate values of N, that is exponent as a function of t, that is a expansion or compression time according to diagram in figure 5. Say for example, if time taken more than 10 minutes, this is again I think with respect to nitrogen and hydraulic oil. Then if more than 10 minutes then we can call this is isothermal and we can take this value is 1. And if this time is 0 to 10 minutes, then depending on the time required for the process, we can select that N. Obviously, that may this curve may be different for different gases we are using in the system.

And if it is very quick process, only then we call it adiabatic and we take this value is 1.4. This means, if usually, the classroom type problem or examination problem, we mean it is adiabatic. Then we have to take 1.4. Otherwise, sometimes it is given, this curve will be given to you and this time will be mentioned and from there, you can select what will be the power of N. In all calculation, pressures expressed as absolute bar and temperature as Kelvin degrees. That we have to remember.

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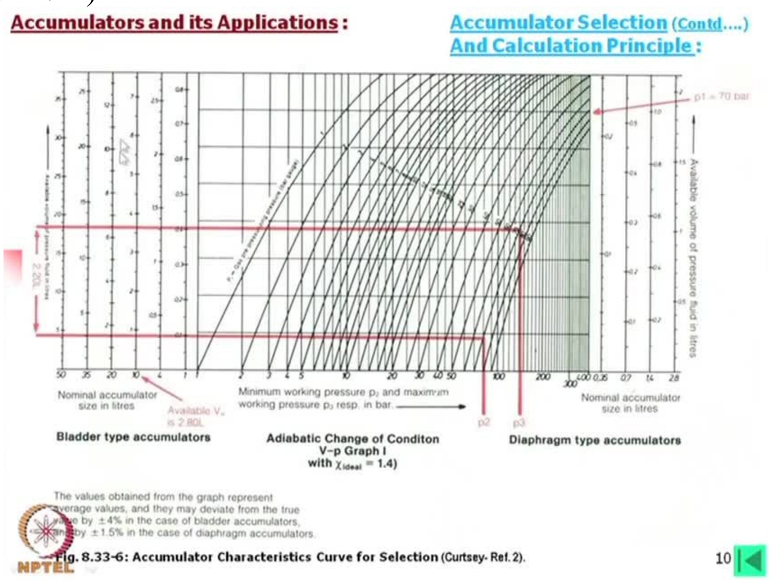

Fig. 8.33-6: Accumulator Characteristics Curve for Selection (Curtsey- Ref. 2).

Now this is for the selection while we are selecting a accumulator. So this curve is usually supplied by the accumulator manufacturer. Say for example if we consider that V volume 1 by volume 2 is 2.20 litre then we can have this curve and then this is the actual volume of the accumulator. That means, if we measure the vessel volume, it is 10 litre capacity but actual available is 2.20 litre. We are working within this range. Obviously, it may be slightly more maybe available from this system.

And then for different, this is the for different pressure curve okay? And this is 1, 2, 3. So this is 50. And pressure is P1 to P3, that means we are working maybe from 70 to this is 140 say. Let us assume this is 150 say 140, 70 to 140 we are working. That means within this pressure range and within this flow range, these are the applicable area. With our calculation, all estimation will be within this region.

And here, average volume of pressure or fluid in litre, so we can estimate how much volume will be available for working. We will just consider a pressure range and from there, we will get it. And here, this is also available volume on the same scale on both the sides it is written. Okay? So in that way, we can use this graph. Now this is again, this is for bladder type accumulator and this is for diaphragm type accumulator okay?

These lines are from diaphragm type accumulator and these lines are for bladder type accumulator okay? And here, it is on the, curves are on N is equal to 1.4 okay? And there are some other, say tolerances are given. So if you would like to select what should be the say suppose our using volume is 2.2 litre we can maybe we are tempted to go for a 4 litre accumulator but in that case, we may not have that good pressure range. That you can study this graph separately to understand this.

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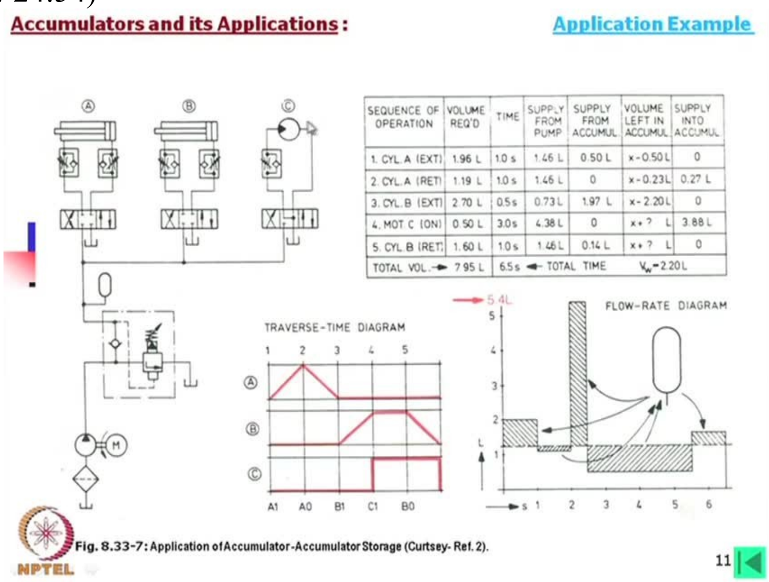

Now these are a few systems are shown. So application of accumulator and accumulator storage, that means how the volume is being stored in accumulator for different process, that is given over a chart here. Let us consider a system. This system is like this. That there is 3 we can consider 2 linear pistons and one rotary pump is there and this is being run by the same system okay?

So we put the accumulator over here. So it is like that. This nonreturn line is there because from the accumulator, oil should never come to the pump side. That is why it is there. And then, oil from here can directly go to the system. It is, we do not need any other valve there because whenever the excess oil is there, 1st this will be filled, then when it is completely filled, then this oil go through this relief valve okay?

Now what we find this operations? This is cylinder A, this is cylinder B and this is pump C and both are having a flow control valve. This means that maybe this system is required we need motion of this forward and backward return motion. Both are with controlled speed. That is why control flow control valves are there and this is operated by a this is completely close centre, 4 by 3 directional valve.

And in this case, what we find it? This is this is also 4 by 3 but it is not closed centre, it is only partially open centre. Partially open centre means in normal conditions, neutral conditions, oil goes back to tank. And in neutral position, the pump is closed centre. That means, this pump is always ready with pressure if it is in all are in neutral.Now what we do? Cylinder A, we are extending. Extending means, this is going out. Then definitely, valve we will put accordingly.

That means, this side will come here to operate this one okay? Then volume required is 1.96 litre. This, wish you have used this flow control valve and this is the requirement. And it is required is in 1 second. So 1 second means this process is 1.4 polynomial adiabatic process almost okay? So we will consider that. And then, say this is this guideline is given to how how to select this accumulator looking into this that chart.

Then supply from pump is 1.46, that is Q1 if you remember that. This is 1.46 litre only at that conditions, supply from accumulator is 0.5 . So volume left in accumulator is 0.50 litre and then supply into the accumulator is 0 at that conditions. That means to have 1.96, 1.46 from the pump and 0.5 from the accumulator at that condition and we should find this this is the curve. Next, we come to the cylinder A, it is retarding.

Then we need 1.19 litre for the same type 1.0 because why we need the less oil? Because there is a rod is there. So for the same period, definitely oil requirement would be less. In that case, 1.46 is from the pump. So volume left in accumulator is it was this much but this this is definitely higher than this one. So excess oil is going to the accumulator. Next, we are extending B. It requirements, 2.70 and within 0.5 time again, this is adiabatic and 0.73 litre is supplied from the pump and 1.97 litre from the accumulator.

This might be due to the pressure requirement, this is it is taken like this. So 0 is accumulated in the accumulator. In case of C, the motor is running. 0.50 volume requirement see and within 3 seconds, so supply from pump, 4.38 litre, supply from, this is from 0 and then this is of course volume left in accumulator, it is unknown because 4.38 litre is being pumped. So 3.88 litre will try to go into the accumulator.

And then, cycle B again, return of V, 1.06. And this is the chart, you can follow this chart. And then, what is there? So total volume requirement will be there, and time etc, all and it is found that 2.20 litre is the working volume, keeping that as working volume and 10 litres, that what we have seen, 10 litre accumulator size is suitable. And from this graph again, this graph is generated and then when the oil is going from the accumulator when oil is being stored in the accumulator, this is shown in this graph.

So this means that when we are going to design a system with accumulator, we have to make such pressure and volume history of the total cycle of the projections and then from there, we can select a an accumulator of suitable size and to make the system more efficient, suppose if we use a bigger accumulator here, this will be no use and performance may not be that efficient and if we use a smaller one, definitely purpose will not be served okay?

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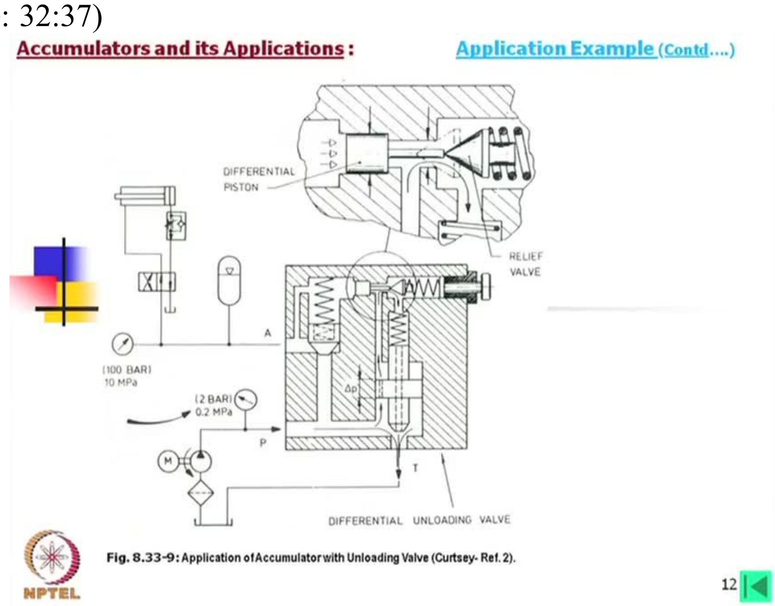

Now this is another application is shown here. In that, this is unloading valve. We have earlier learned what is unloading. Unloading means while the system is not working, in that case we have to unload this pump, okay? 1st of all, it can go through the relief valve but going through this relief valve means there is a huge pressure loss. Now we can go for an open centre valve but open centre valve is the problem is that the oil does not remain ready with working pressure.

So another option is that we can use 4 by 2 valve, that is on of on-off type valve. The changing the directions and on-off, there is no intermediate positions. If we use this valve as well there is a flow control valve depending on the requirements, then what we can do, we can put an accumulator here and this is the our unloading valve. Unloading valve, how it works? Say it is working at say let us consider the pressure is 0.2, very low pressure.

In that case, oil is flowing through this tank and also how it is flowing through the tank? Oil is coming over here, it is coming over here but this cannot move this one because the pressure requirement pressure is low pressure or ideal, it is not working. In that case, the oil is going through this place and there is a differential pistons, that means, this side is very small pressure and this side we can assume there is no pressure.

So this will move in that way and this oil is going to the tank completely. Now suppose here we have a requirement with a pressure. In that case, what will happen? This will move, this is being a setting pressure, of course by adjusting this one. Then piston this side will have a pressure, the same pressure or may not be same pressure, a little lower pressure will be this way and then this will be in a controlled position because earlier, there was a pressure, whatever may be the low pressure, but still it was there.

In that case, we have a differential pressure with a controlled load. So this flow will reduce and this flow will be there and when this is completely filled or maybe the excess flow is there, then this requirement here, then this will be accumulated in the accumulator. So this is some unloading system applications without this accumulator. Only thing this operation will be definitely that will be done but this will not be that smooth what is available with this accumulator.

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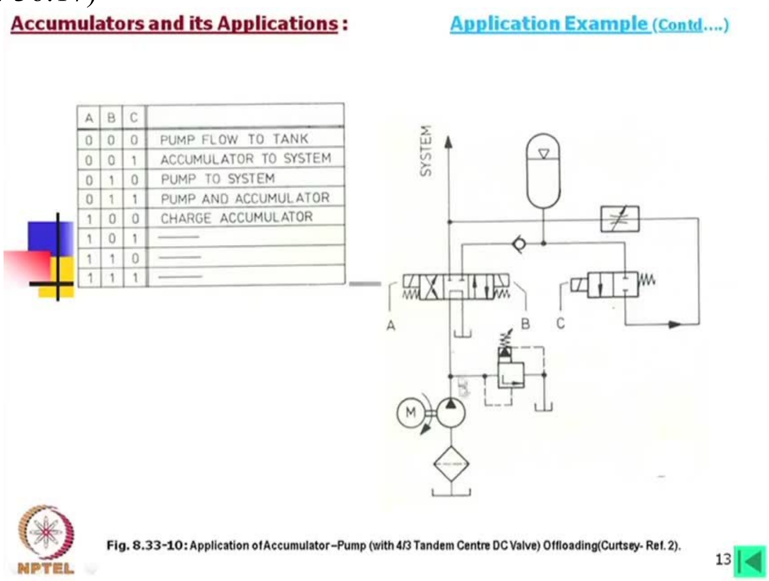

Fig. 8.33-10: Application of Accumulator–Pump (with 4/3 Tandem Centre DC Valve) Offloading(Curtsey- Ref. 2).

Now another application is that we have pump with 4 by 3 tandem centre DC valve. This is a tandem Centre means in normal conditions the oil is going to the tank. So this operation, it is written here in a chart. Say A, B, C are the 3 positions of this valve. What we have in this system? We have one tandem valve, A. No, sorry, this has 2 positions. A is the cross connection, B is the straight connection and this is an intermediate positions.

And for this one, this is simply on-off types which. Now what is the written here? A is closed, B is closed, C is closed. That means, this is in that condition, pump flow to the tank. Okay? Now then A is closed, B is also closed but C is connected. In that case, accumulator to system, oil is going to accumulator to the system okay? Right. From here too, it is going to the system. Then A is closed, B is open, and C is closed.

That means we are having these connections. Then pump and accumulator pump is supplying oil to the system as well as to the accumulator, of course depending on the requirements of the main system. Then A is on, B is off and C is off, then only this accumulator is being charged because this oil from the main system is going to the tank and this is oil is being charged through this accumulator okay? So this is another the application of accumulator with a hydraulic system is shown here how it can be arranged.

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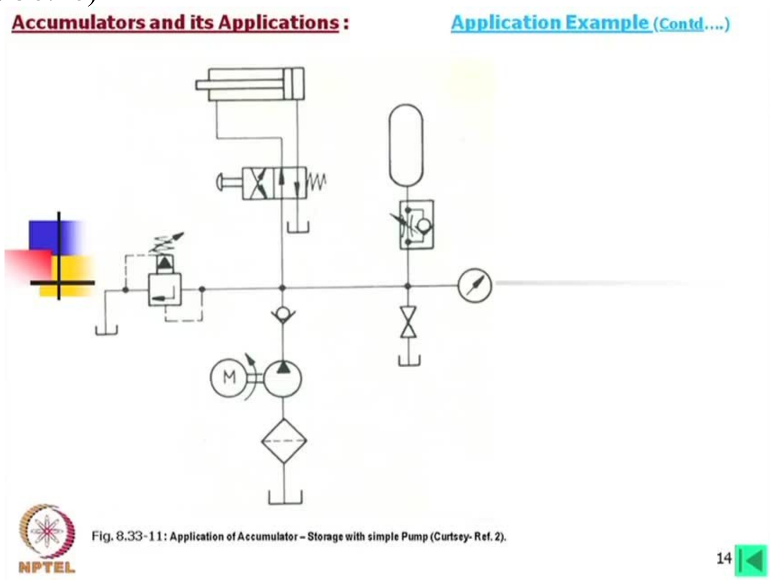

Now next to that application of accumulator, storage with simple pump. Now in that case, this is a very simple system but we are having again on-off type valve, 4 by 3 on-off type valve. This means that either this position or this position, it will be there. So let us consider the normal position which is shown, in that case oil is going to the accumulator as well as to the system. Depending on the pressure and flow requirement, accumulator will be charged or from the accumulator, oil will flow to the system.

Now next when this is being charged like this, this is coming to this position, then oil will go to this side okay? And oil from here, it will come back to the system. Again, in that condition also, the accumulator may be charged according to the requirements set.

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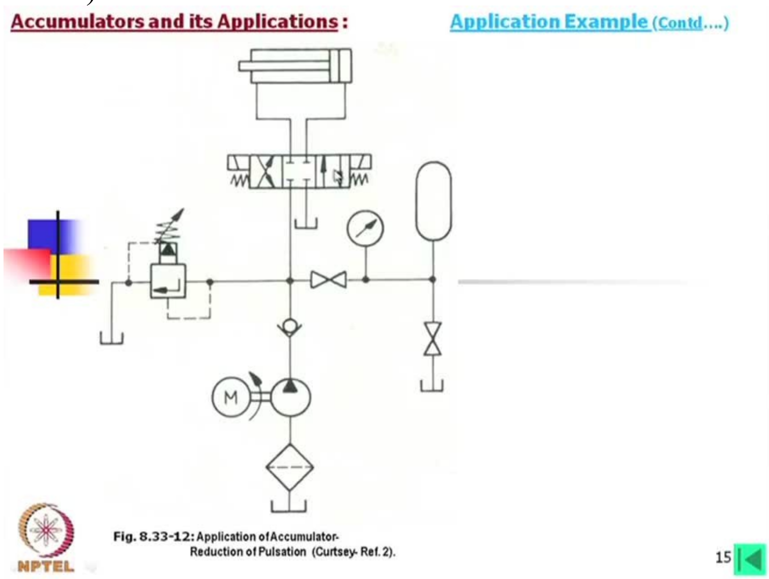

Now another system, this is for pulsation reduction. In that case, we have used 4 by 3 closed centre valve. And this is as I told that if there is pulsating load, to tackle such pulsating load with less reduction of ripple or pulsation, we can simply use an accumulator in the line.

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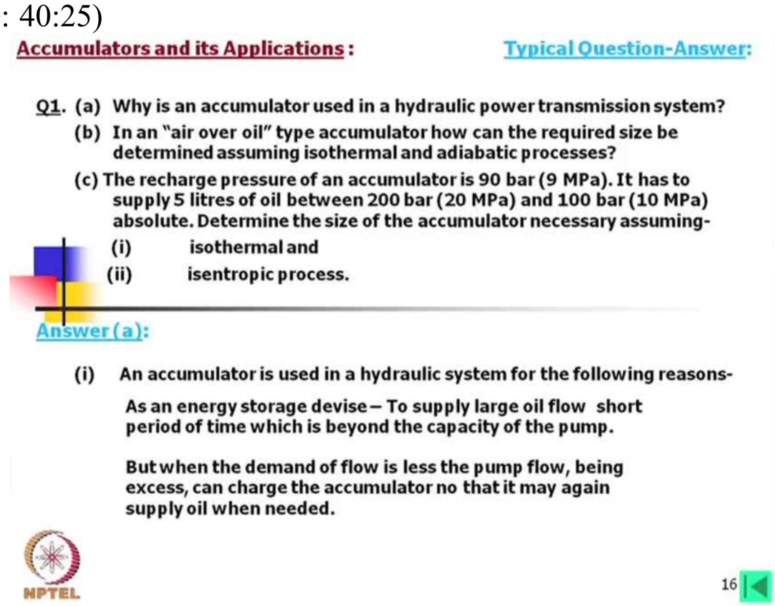

Now we should look into a typical question answering. Why is an accumulator the question, typical question, say this is usually 4 to 5 such questions or 5 to 6 such questions to be answered in 3 hours. We will consider let us consider that this is about we have to answer 5 questions and this is one full question. The part A is that why is an accumulator used in a hydraulic power transmission system? 2nd part is that, part B, in an air over oil, that means in this accumulator, maybe we can think of a piston type.

Gas is air and bottom is oil. Type of accumulator, how can the required size be determined assuming isothermal and adiabatic process? Then the recharge pressure of an accumulator is 90 bar, 9 meg Pascal. It has to supply 5 litres of oil between 200 bar, that is 20 mega Pascal and 100 bar is 10 mega Pascal absolute. Determine the size of the accumulator necessary assuming, one is the isothermal and two is isentropic process.

Means in this case, we may consider adiabatic or something we can we will consider. Now answer part A, why is an accumulator used in hydraulic power transmission system? Then, an accumulator used in hydraulic system for the following reasons. One, is an energy storage device- to supply large oil flow short period of time which is beyond the capacity of the pump okay? But when the demand of flow is less the pump loading excess, can charge the accumulator so that it may again supply oil when needed.

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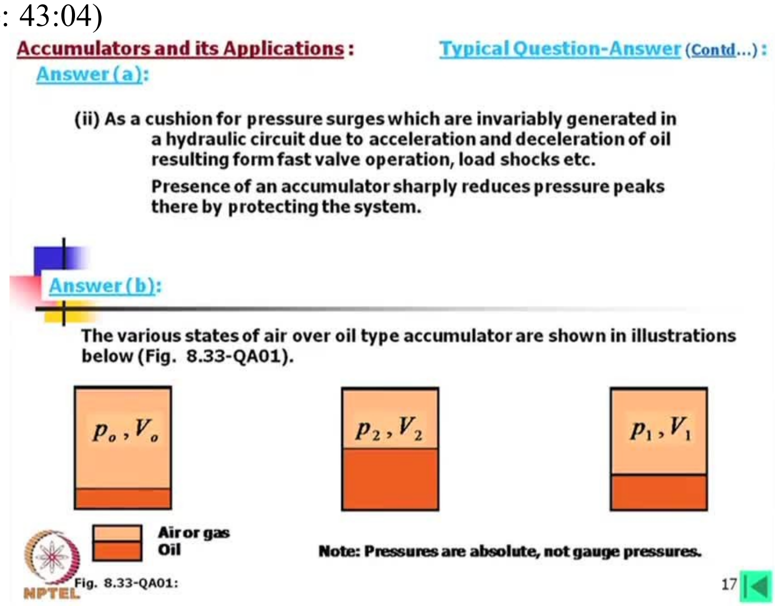

Then another if we think an application of that, as a cushion for pressure surge which are invariably generated in a hydraulic circuit due to acceleration and deceleration of oil resulting from fast valve operations, load shocks et cetera. That means, this is the reduction of pulsation, this accumulator is used. Presence of an accumulator sharply reduces pressure peaks thereby protecting the systems. So this is the, how briefly you can answer the application of the accumulator.

Next comes the part B where that air over oil accumulator and we have to express that how they function. Now in this case, this is a simple diagram. You can you such colour to mention. So 1st when we are charging this volume, this you can say that 90 percent of the total volume of the accumulator okay? That is shown. This is a precharge pressure and then this is air and this is oil. And P2V2 is the say maximum pressure and this is at that condition, the volume of the say bladder or the top side of the diaphragm.

But that is nitrogen gas let us consider. And then the oil can be used up to this, that means the total oil will be pumped from the accumulator to the system can be calculated, V1 by V2 and by that time, pressure reduces from P2 to P1.

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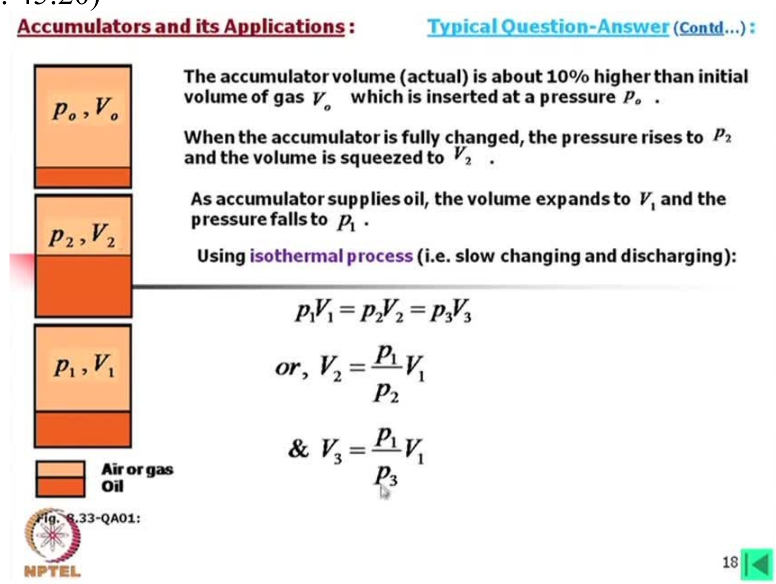

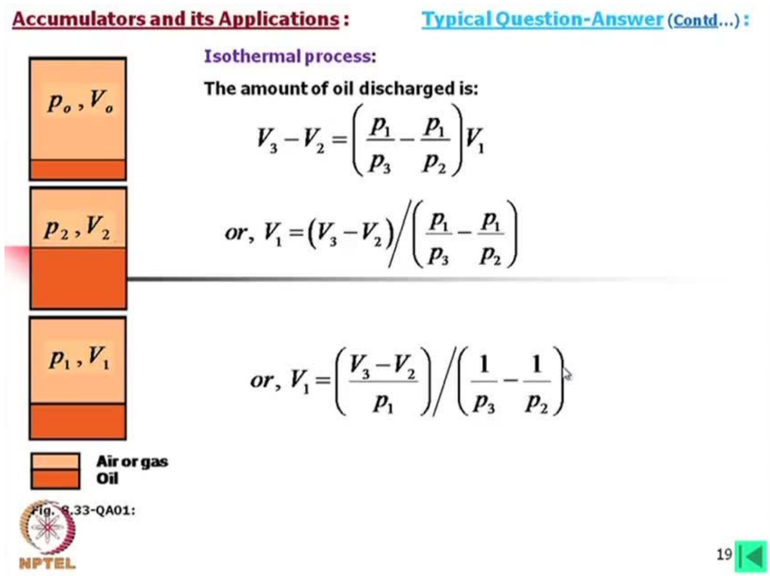

Now the accumulator volume actually is about 10 percent higher than this which I have explained already. So you can mention that thing. That is why the figure is like that and when the accumulator is fully charged, the pressure rises to P2 and the volume is squeezed to V2 okay? An accumulator supplies oil, the volume expands to V1 and the pressure falls to P1. Now we consider the isothermal process, that is slow charging and discharging.

Then we will consider that the power N is 1. So P1V1 is equal to P2V2 is equal to P3V3 okay? Now the V2 is equal to P1 by V2 is equal to V1 and V3 P1 by P3 into V1. And then for the isothermal process, the maximum volume, the amount of oil discharged, that means maximum volume of oil, we can use is V3 by V3 minus V sorry, this will be actually V2 minus V1. Sorry this is we have used P1, P2, so this will be V2 minus V1 is here will be P2 and this will be P0. Sorry, equation is not written correctly.

And anyway, we are dealing with this volume, so V1 is the charged volume in this case and this can be expressed in this way. And finally we can find out the relations what will be the relations of this volume.

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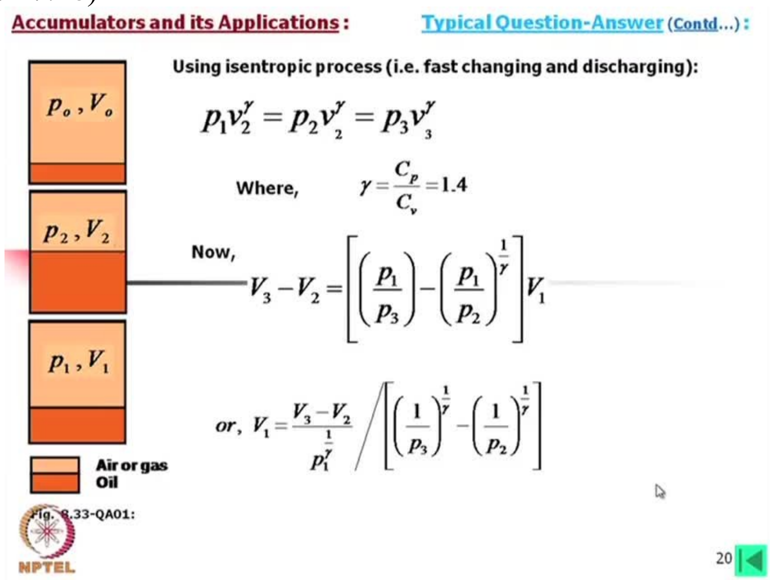

Now in this case, the instead of using N as the power for isentropic process, we have considered isentropic, we have not mentioning this adiabatic process, we consider this gamma. And then, with this we can say that gamma is equal to CP by CV is equal to 1.4, that is the for the adiabatic change, we take that 1.4 and then these equations come in this form and finally, V1 is calculated within this form.

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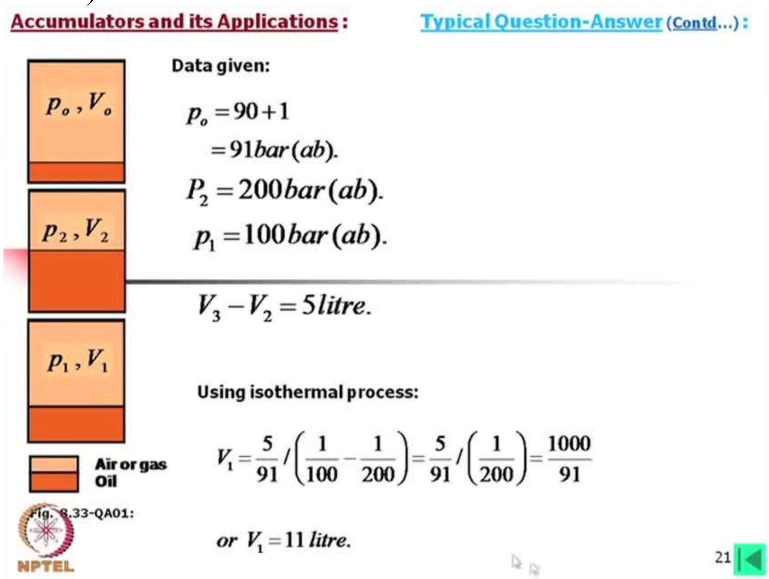

Now we are coming to this part C where the pressure is now this is, you see this charge pressure was set 90 bar, charge was done at 90 bar. So now that 90 bar is the gauge pressure there. So we add plus 1 to make it absolute pressure 91 bar whereas the system working in 100 to 200, that we consider as a absolute pressure. Now volume is this, again this is a mistake, this will be V1 minus V2 is 5 litres okay? And then using this calculation, we can have V1 is equal to 11 litre. That means in this case, V0 will be 11 litre.

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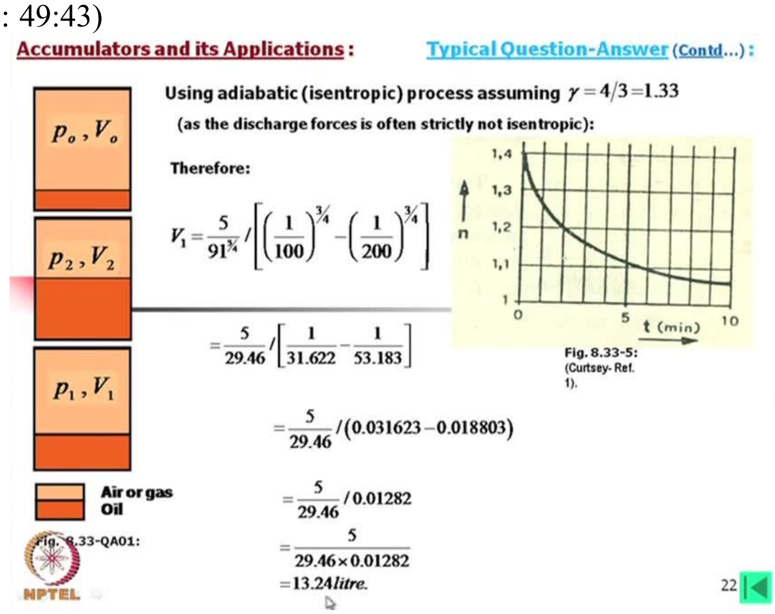

Now if we consider this this calculation, we have shown for isothermal. Now we are considering, this is not exactly adiabatic but we are someisentropic and we have assumed this value is 4 by 3, that is 1.33. Now in that case, you see, this according to the times, that means, that is probably this time of change is this much of that looking into the graph. Say it is about taking half a second okay. In that case, we consider it is 1.33 and according to that, we calculate this, what is the volume.

So volume comes is 13.4 litres. Earlier, in case of isothermal, we found it was 11 litre and in this case, we need 13.24 litre.

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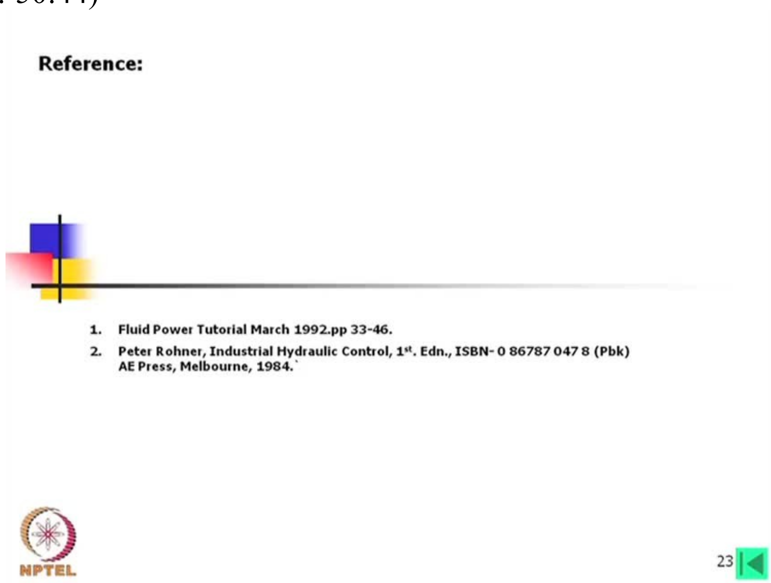

And then this is the reference we have followed that one is that some tutorial note in a journal that is in 1992 but as well, this is a good book. I do not know whether it will be available here but this is on the industrial hydraulic control by P Rohner that is published in 1984. Thank you.