Fundamentals of Industrial Oil Hydraulics and Pneumatics
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Lecture no 25
Module no 06
Regenerative Circuits

Welcome to a lecture 25 Regenerative circuits, this is under module 6 Hydrostatic transmission system, but I would say hydrostatic transmission system are described in the last lecture is comprised of pump and motor together, there will be pump unit, there will be motor unit, they will operate 1 to each other and the it might be open circuit, maybe closed-circuit. In comparison to that or if we in terms of that say the regenerative circuit is mostly that piston cylinder and valves operated definitely by a fluid power system felt the pump and other components are there. And this may be put into the other module where we discussed about the hydraulic sockets.

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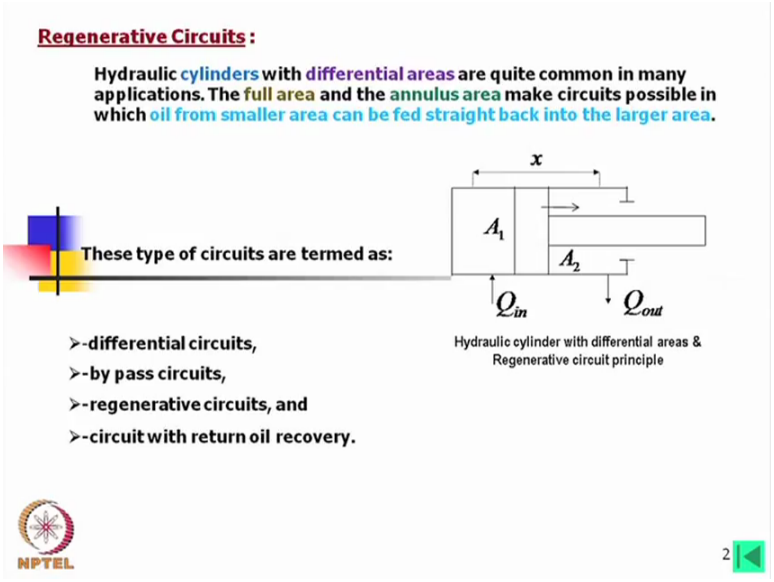

Anyway for the distribution of lectures under different modules, I have put in this module and this you will find very interesting. Now what it is if we consider any hydraulic cylinders with special areas, mostly you will find that one side there is rod and other side there is not, the piston rod is not there and these are quite common in many applications. The full area and the annulus area makes circuits possible in which oil from smaller area can be fed straight back into the larger area. This means that we can mix up this oil with the oil in, you will find that mixing in the

other way is not possible, we can mix only in this way and that obviously increases the speed of the piston.

These types of circuits are termed as; differential circuits, bypass circuits, regenerative circuits and circuit with return oil recovery, various names are there but maybe regenerative circuit is more lucrative so I have given the title regenerative circuits and I shall discuss how it works and what are the possibilities of using this circuit and system for variety of output.

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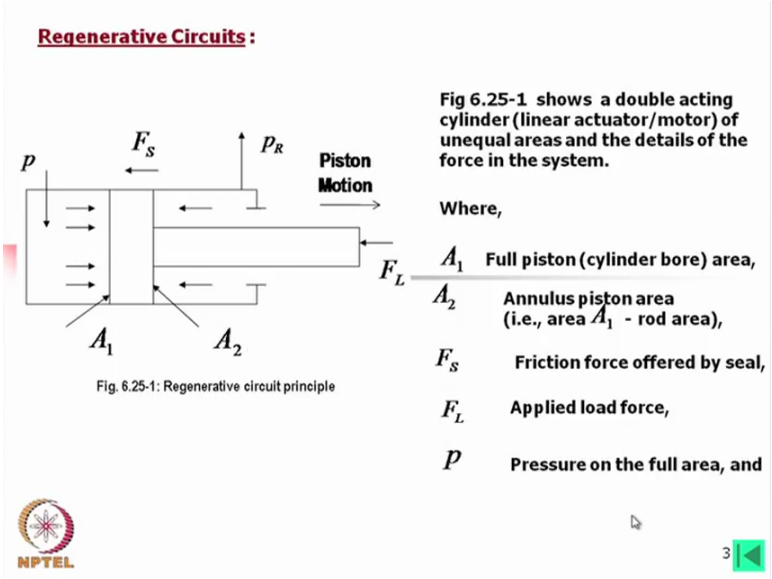

Now in this figure we find a double acting cylinder linear actuator motor we can say linear actuator motor of unequal area and the details of the force in the system. Now I would say that if you remember this term double acting, double acting means its acting in both way, it can do work while it is moving in former direction, also it can do work while it is in the written motion. However, in most of the cases you will find the return load is usually less it is mostly less.

Now I have shown the forces acting here, now what is there say we are supplying say let us consider it is moving in this direction okay and it is also moving to load due to which F L is the force acting in this section so there must have some pressure which ideally we can get this force divided by this area P that pressure is there. This side if we connect directly to the tank then only pressure will be some resistance to flow oil, otherwise there should not have any pressure. So to so to say we can say this pressure to find out this pressure we should calculate this force then is

must be equal to this force – this force, where this force is the annular area A 2 into the pressure P R.

Let us consider it is going back to tank and there is no resistance, so this pressure is 0 okay. Now what we can consider that there will be some friction force, this friction always will act in the direction of opposite to the direction of motion so this will be added to the load it is handling. So that this means that to calculate the P, we have to add this load with this load and then divide by this area okay. Now where that A 1 I have already discussed, it is the full piston area, you can simply if you know the cylinder bore diameter then from there you can find out the area A1. Now A2 is the annulus piston area, remember this full area – this rod area okay.

F s is the friction force offered by seal here, also there will be some friction but this friction will be similar than the friction here because as it is a double acting there is also seal. So we while we are considering the friction, we will consider this = this friction, it is apparently written here only, but this is the component of this friction force and friction force at this gap also. F L is the applied load and P is the pressure on whole area and P R pressure in the return line.

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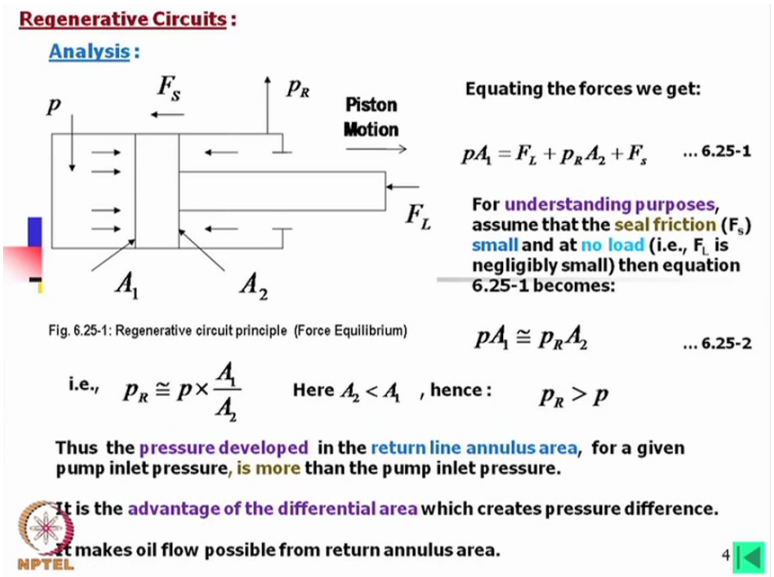

Now we can use this force, P into A 1 that is full area must be equal to FL = PR into a 2, whatever may be this pressure = F s the friction force okay. For understanding the purposes of the regenerative circuits circuit how it works, let us assume that friction force is negligibly small and we shall also equate this at no load, then equation 625-1 becomes P A is equal to P R into A

2, or in other words that just to understand that if we would like to generate a pressure here, what we can do we can put a restrictor here.

Say we can connect this path to a pressure relief valve, which is set some pressure may be up to this pressure, in that case what we can do, what we will find that this will generate a pressure, say any pressure, this pressure relief valve that at any pressure say 5 Mega pascal, then here must be 5 Mega pascal to be generated for the leakage, then whatever P is required here that also can be calculated that means at that the condition we can write down this equation. Or in other words if some resistance is put here then we can generate the pressure by creating the pressure here. Now, that pressure again we can calculate directly from this equation, this equivalent sign is given to estimate this pressure okay.

Now here A 2 is less than A 1 hence P R must be greater than P that means this pressure will be higher than this pressure, this means that we can directly allow this flow to mix with flow in here because it is less pressure than the flow will try to go in this direction. Of course, there is a question of displacement, if there is no space to flow then there will be no flow but once the pressure is higher than this side, we can measure the flow so that much is sure but still we do not know how to engineer it.

Thus the pressure developed in the return line annulus area for a given pump inlet pressure is more than the pump inlet pressure. It is the advantage of differential area, if the same rod to be also in this direction, in some arrangement it is like that, in both side there are piston rod of equal diameter, in that case we will not have such facilities. It makes oil so possible from written and less area, which I have already described.

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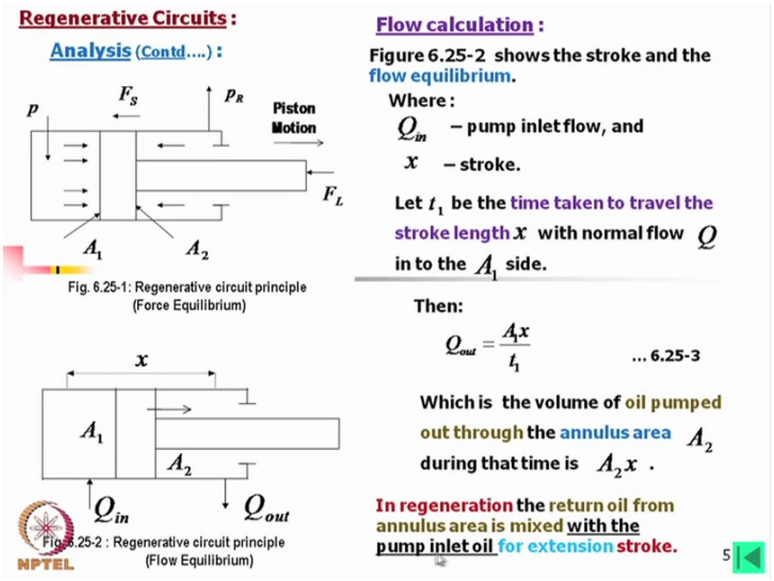

Now let us calculate the flow, now figure this figure 6.25-2 shows the stroke and and the flow equilibrium. This means so stroke length is this much, for that we will estimate what is the flow here and what is the flow here and that we say that the equilibrium inflow and if we write in the form of equations, this will be calculated 1st considering the time, we shall consider that t 1 be the time taken to travel stroke length x for this motion in the outward direction okay and Q is the flow, then we will estimate what is the Q out. The Q out definitely is A 1 x, A 1 x is the total volume right for the x stroke in this side and that divided by t 1 is the Q out okay.

Q 1 is the by this time which is the volume of oil pumped out through the annulus area A2 during the time okay, the volume of oil pumped out through the annulus area A 2 during the time A 2 x, I think this equation I have written wrong, this will be Q in is A 1 x by t 1 okay. Now A 2 x we will estimate, in regeneration the return oil from annulus area is mixed with the pump inlet oil for extension stroke okay, now we will see that.

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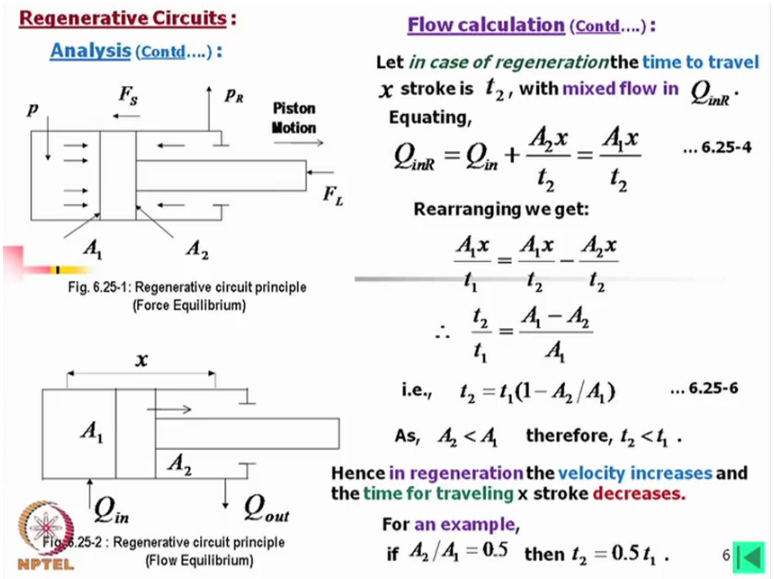

Let in case of regeneration the time to travel x stroke is t 2 that means if we now mix the oil, definitely this time to travel will be different because the original flow Q in is there as well as Q out is there. Now this flow we can calculate, now the new flow when this Q out is mixed with this then the Q in whatever it was there it is there and = A 2 x is the flow out from this side the annulus side. Time taken is t 2, so this must be flow out and that is mixing with Q in x and that must be equal to A 1 x by t 2, so in earlier equation and definitely this equation I have written wrong that will be Q in.

This is very simple equation but if we now equate for this area and time what we find that A 1 x by t 2 is equal to A 1 x = t 1, this is equal to A 1 x by t 2 – A 2 x by t 1, so this is coming from the equation 6.25-3 so this must be Q in there, okay. Now further equating we get t 2 t 1 definitely t 2 will be less is A 1 – A 2 by A 1 and that is t 2 = t 1 1 – A 2 by A 1 and as A 2 is less than A 1 therefore t 2 will be less than t 1 that means we are getting additional speed by mixing the oil okay. Hence in regeneration the velocity increases, the time of travelling into stroke decreases x stroke this is the x length x stroke decreases okay.

For an example, if we take this A 2 by A 1 = 0.5, now remember here the A 2 is the annulus area, this means that when A 2 by A 1 is equal to definitely the diameter of the rod is half of the total area of the piston, but that does not mean diameter is half of that. I have seen that while, calculating many students many engineers they make a mistake, they consider the diameter is

half and they arrive into wrong result so just remember this area is half, not the diameter. So what we get, t 2 is half of t 1 so in simple circuit whatever the time taken in case of regenerative circuit, we have half the time to solve, now we will look into the applications.

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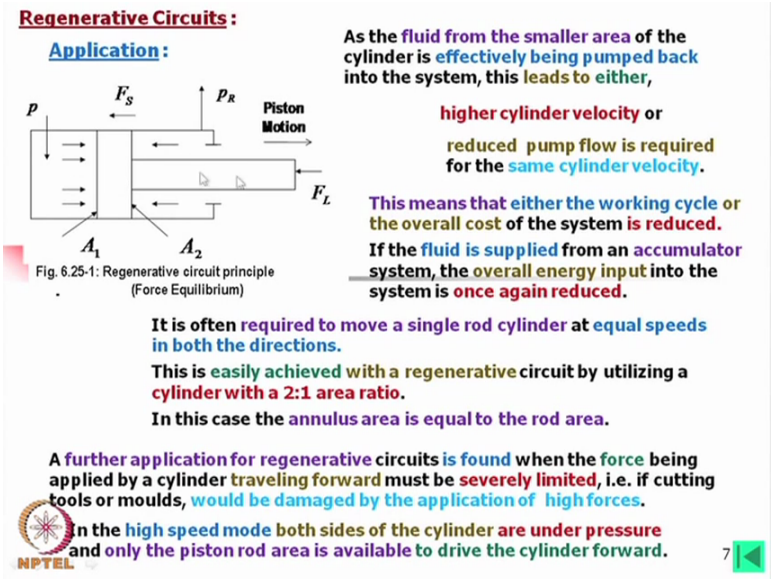

As the fluid from the smaller area of the cylinder is effectively being pumped back into the system, this leads to either higher cylinder velocity or reduced pump flow is required for the same cylinder velocity. Now here I would say that instead of cylinder velocity we can write the piston velocity. Anyway, this means that either the working cycle or the overall cost of the system is reduced, definitely we are recycling the oil. Now this cylinder velocity maybe in the specific difference so where this piston is fixed and this is being moved, in some cases it is like that, when this is carrying a particularly table or other thing, the cylinder moves perhaps that is why it is written the cylinder velocity.

Now, the fluid is supplied from an accumulator system, the overall energy input into the system is once again reduced. Along with these regeneratives sometimes an accumulator is also used and there you will find that we are getting much faster speed. You can think of one application directly here itself say for example, the shaping machines or crane machines, where the return stroke is much higher. This has another application this control velocity because we are now moving something say for example, if you move a pen like this just pushing like this then you will have less control facility then if we move like this, you are putting pressure here, pressure

here then you are moving like this, so control point of view also regenerative circuit will be better.

It is often required to move single rod cylinder at equal speed in both the directions, so if you find that for half area if you allow to the oil the same flow rate whatever the speed will be in return stroke, the same speed will be in the forward stroke if the oil is mix, so with this also we will get equal speed in both the directions that is another advantage. This is easily achieved with a regenerative circuit by utilizing a cylinder with a 2 is to 1 area ratio what I have mentioned now. In this case the annulus area is equal to the rod area okay. A further application for regenerative circuit is found when the force being applied by a cylinder travelling forward must be severely limited that is if cutting tools or molds would be damaged by the application of high forces.

That what I mentioned, so if you move this piston in this direction with force in both the directions, it will have much better control. Another point to be mentioned, in the high-speed mode both sides of the cylinder are under pressure and only the piston rod area is available to drive the cylinder forward. This means that you see if the pressure is acting over here, now when this is mixed definitely pressure both the side has to be equal, now in that case real area available to tackle this load is only this much area okay so that means you will find that in that case pressure is equal to force divided by simply this rod area okay.

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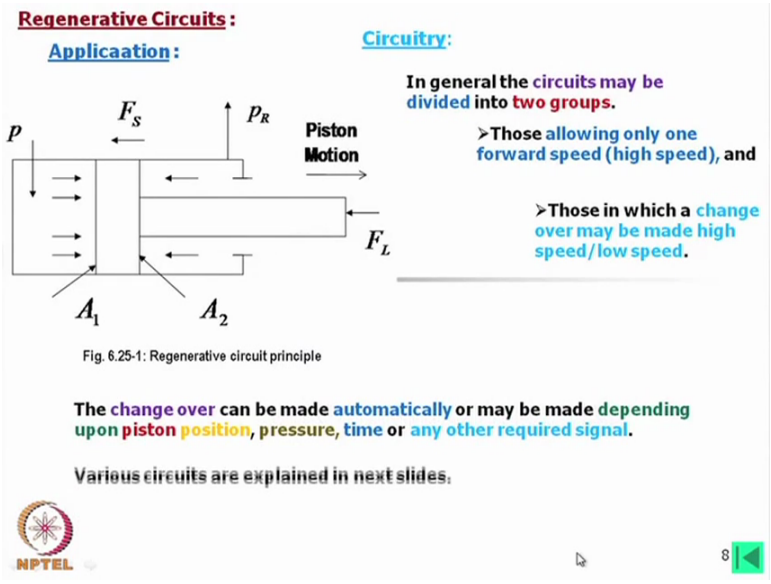

So this means that you are handling a smaller load holding the piston with higher load, this is another I would say this in another form of presentation the facilities and control. Now we will think of the circuit, how we can make the difference circuit in regenerative process. In general the circuit may be divided into 2 groups, those allowing only one forward speed high-speed and those in which a changeover may be made high-speed, low speed, et cetera. So in one application for regenerative simply we are mixing the oil for forward motion, simple and oil it is written only then it is a simple circuit okay.

But with different types of valve and the circuit what we can do, we can make this system this one cylinder to move it in normal speed then regenerative speed, et cetera, we will discuss about those circuits. The changeover can be made automatically or maybe depending upon the piston position, pressure, time or any other required signal or it might be manual simply manual or it might be automatic or semiautomatic, many things are possible with the application of other controls, maybe hydraulic, may be pneumatic maybe even be electronic, various circuits are explained in the next slide.

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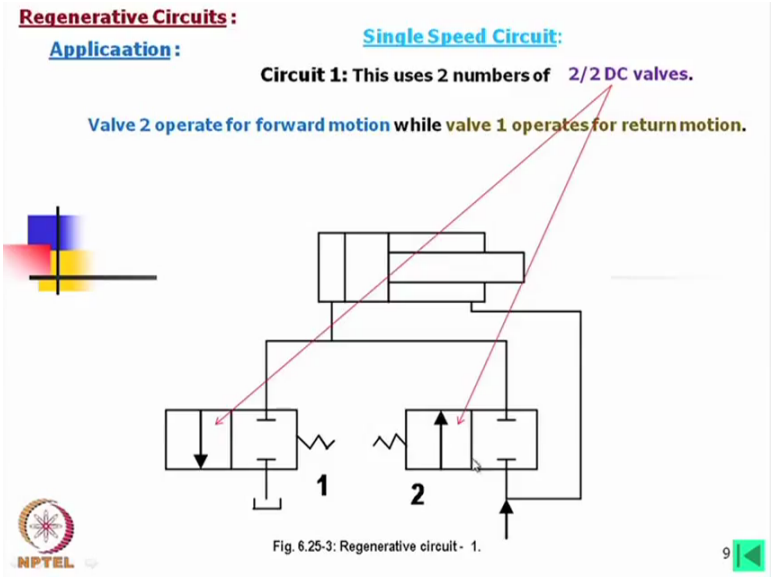

Now this circuit, we will discuss few circuits, in this circuit we have used this we have used 2 DC valves 2 by 2 DC valves, definitely you understand as you know the symbols that 2 by 2 DC valve. Then how it operates, valve 2 operates for forward motion that means and valve 1 operates for return motion, let us say valve 2 is engaged that means the flow is going like this okay, this is

closed so this means that oil is being mixed, the only regenerative. Now, when valve 1 is engaged that means this line is connected and valve 2 is closed that means it is in this position, then oil is coming back to the tank from the full area side and oil is going to the return side that means normal return and regenerative forward motion, so this is the simple circuit but we have used 2 by 2 two DC valves.

Now let us consider another case that both the valves are open that means connected, in that case what happen? Tell me, in that case cylinder will move in which direction? The answer is, it will not move because oil will always flow to the less resistive path and that is definitely the return path. Oil if this is connected and this is connected oil will simply go like this and it will go back to the tank, it is not operate this one because there is some resistance and some load is there so in no case of this will move, so that means this is not a hydraulic operation, this is a simple case of oil is flowing.

In fact that can be done because if you do not want any operation here and the pump is still ON then oil will go back to the tank, not through this so that will act as an open circuit sorry open center valve so you can design the circuit in this way okay. Valve 2 mixes pump input flow and flow from annulus side as being high forward motion.

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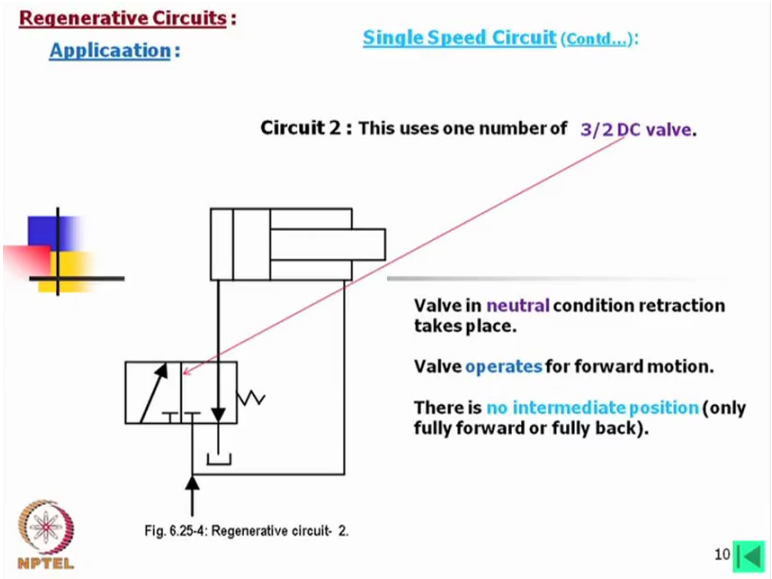

Now if we go to the circuit 2, in that case what we have used? A DC valve again and that is 3 by 2, why 3 by 2? This is 3 port, there are 3 ports 2 way 2 position or you can say, 3 way 2 position;

1, 2, 3 so 3 by 2 means 3 way 2 position valves, always the number of (())(28:39) is at the beginning so 3 by 2 DC valve. Now let us see what happens, valve is in neutral condition retraction takes place that means if we put the valve in this direction this is the neutral position, it has been say position 1, instead of neutral we can say this is the position 1, this is the normal position and as the spring is there means if you do not operate the valve it will be here by the with the help of this spring.

Now in that case oil is going in this direction and oil from this side it is coming back to the tank okay. Now what we do, we operate this to the other position then there is no intermediate position, only full forward or full back and in that case that means if it is in this position then oil will go here and this oil will also be mixed that means this is having when regenerative and 1 return position.

What will happen, we do not have any other position, in comparison to the 1st circuit there only we get 2 possibilities, there is no 3 possibilities 3rd possibility and in that case what will happen, when it is fully retracted, oil has to go back via the pressure relief valve so that means it is you see that close centre, it will act like a close centre valve in normal conditions. Normal condition means again I would say while you have your valve in this position, if it was fully forwarded then it will come back to its retract position and then this will the flow will bypass via the pressure relief valve.

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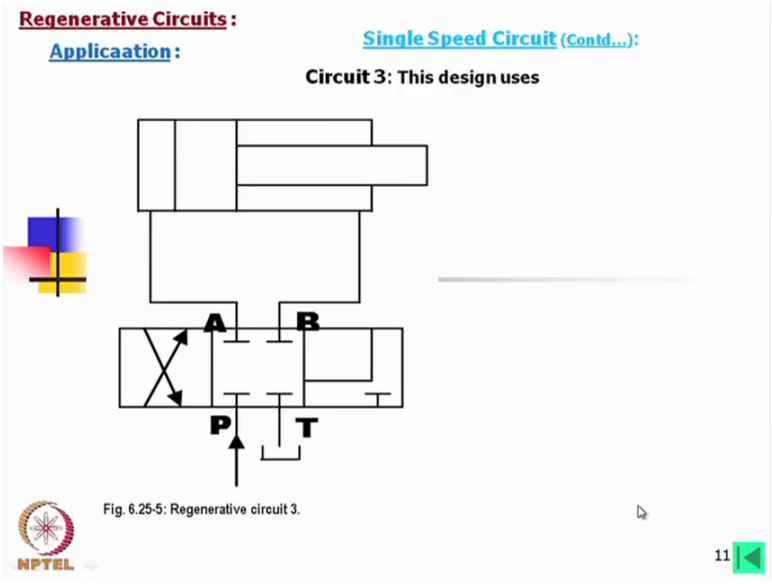

Now circuit 3; in this case before writing this what is this valve? 4 by 3 valve, this is 4 by 3 DC valve okay. Now when the spool is in neutral condition, all the ports are blocked so there is no motion. During the right solenoid operation, regeneration takes place that means here the in the valve itself the regenerative circuit is made, it allows the mix this oil with this one, but when it is sorry this in the other position which I have not shown that is that will give the normal return okay.

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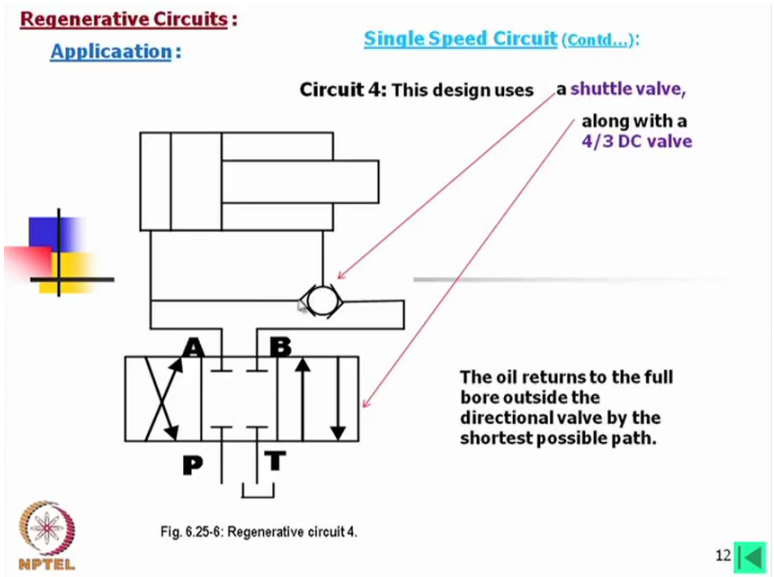

Now if we come to the circuit 4; in that case again this is a normal valve, 4 by 3 DC valve this close center valve okay. Along with that we have added something such to make it regenerative circuit, what we have added a subtle valve and along with this 4 by 3 DC valve, the oil returns to the full bore outside the directional valve by the shortest possible path. This means, when in the right-hand side of this valve then definitely this oil flow is going in this direction and oil coming back from this side as there is a subtle valve, the subtle valve will automatically mix with this one, it will not allow the oil to go in this direction so this valve is such that it will come and it will flow like this, it will not come in this direction.

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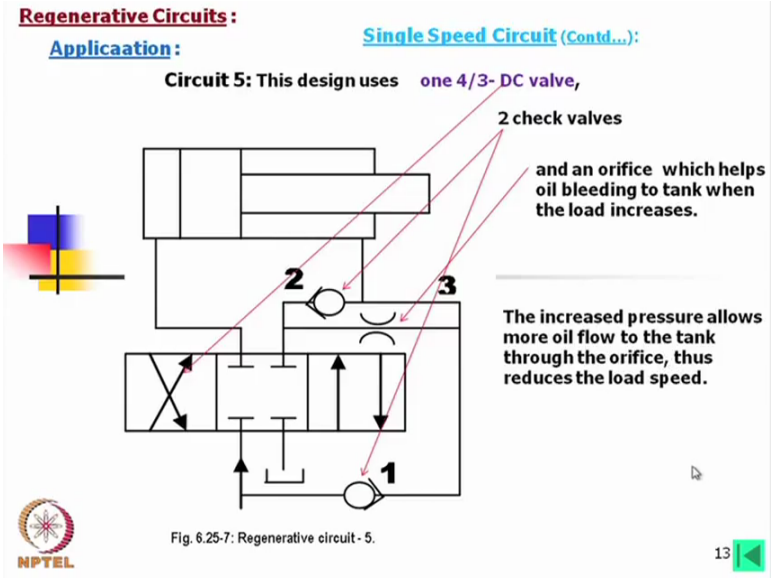

Sorry, this is but you see this in the other position, left-hand position, you will find this oil being the forward sorry the return stroke is in normal using this sign this symbol. Now in this case again what we find the same valve, but instead of subtle valve we have used 2 check valves 1 and 2 and also there is a flow restrictor. So definitely this is having say regenerative = something maybe we can expect from that, we can analyze this one but let us see what are the valves are there. So for 4 by 3 DC valves are there, 2 check valves and orifice which helps oil bleeding to tank when the load increases, what happens let us see.

Now let us connect the right-hand side, in that case then oil is going like this and oil is coming from here this will now being mixed because here the pressure will be more so it will be mixed here but when it it will be mixed then pressure is equal, it by no means it can go in this direction. Now what it said, if there is more load suppose the load is increases, how it can happen we are using for say metal cutting process in a machine tools, due to some reason the load is increased.

When the load is increased, in that case automatically that will be increasing pressure because this pressure this area – this area and only we are getting this rod area for generating the force and obviously there will be more pressure and due to that you will find that this flow also taking place through this path and automatically this speed is reduced okay. Now if we bring the valve in this position then the oil is going to only this side, it also can flow in this way provided the load is more, in case the load is more then it will flow through this otherwise, it will not flow.

If even if it flows through this, it is again will be mixed with this, it cannot go to the tank, whereas this side oil is directly go back to the tank. So in that way using this we can have an additional advantage that with the increase in load, there will be the bypass flow and the bleeding flow you can say and the speed will be automatically reduced, so this is regenerative and bleeding mix together. The increased pressure allows more oil flow to the tank through the orifice thus reduce the load speed.

Now we shall have discussed only 5 circuits, now there what we will find there are another 6 circuits which is from 6 to 11, this will be shown now and this is mainly for your exercise. So there is no not much explanation is given, from there you have to understand how these circuits are being operated. Now in some of those circuits, combination of valves are used, this is not a single valve you will find the few valves are being used to have particular function, we shall explain.

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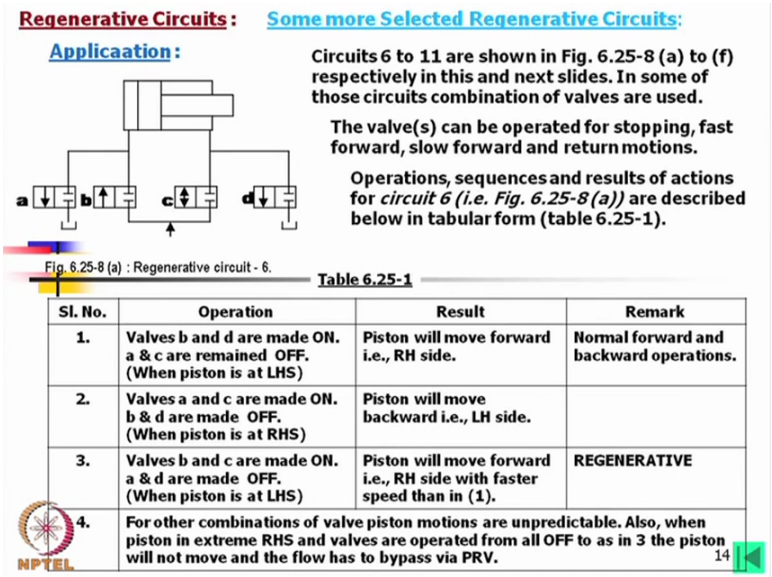

Now let us consider the circuit 6; the valves can be operated for stopping, fast forward, slow forward and return motion. What we find, we have these are which which third types of valves, 2 by 2 DC valves, what we find that there are identical 2 by 2 valves so this is a, b and d, these are same, basically same, only if you have just put in the opposite direction considering that oil is only allowed to flow in one direction so you can put the valve in other way then it will go in this direction and this and this identically same, this is also same but put in the other way okay. But

there is one valve at least which allow flow in both directions and the pump is connected to these 2 valves, whereas return lines are connected to valve a and d okay.

Now operation and sequential and its results of actions for circuit 6 are described below in the tabular form. Let us consider the operation is that valves b and d b and d are made ON, ON means these are connected okay, a and c are remain OFF okay. When piston is at left-hand side then what will happen, piston will move forward that is right-hand side, we have connected this path, we have connected this path okay, so oil is so d are made ON that means oil is going through this and oil is going back to the tank through valve d, so normal forward and backward operation in that case okay.

Now next, the valve a and c are made ON and b and d are OFF, then piston will move backward that is left-hand side, so what we have made? We have made a and c ON, this is ON as well as a, so oil is going in this direction, this is closed so oil cannot flow in this direction and oil has to go back to the tank so we can normal return operation. Now valves b and c are made ON, b and c both these valves are made ON and a and d OFF; the piston will move forward that is right-hand side with faster speed than in 1 so this must be regenerative okay.

For other combinations of valves, piston motions are unpredictable that means if we now other than this is we connect in other maybe c, d or any at random, you will find that this is not moving or it may move in one direction depending on the resistance here less than the resistance for the flow through any valve return to the tank so basically we should say this unpredictable. This means that while you are given a circuit like this for yourself understanding or maybe you have any question you have to answer, you have to make a table like this, you have to look into all possibilities and you have to write down what are the operations, what are the motions possible with that combination of the valve.

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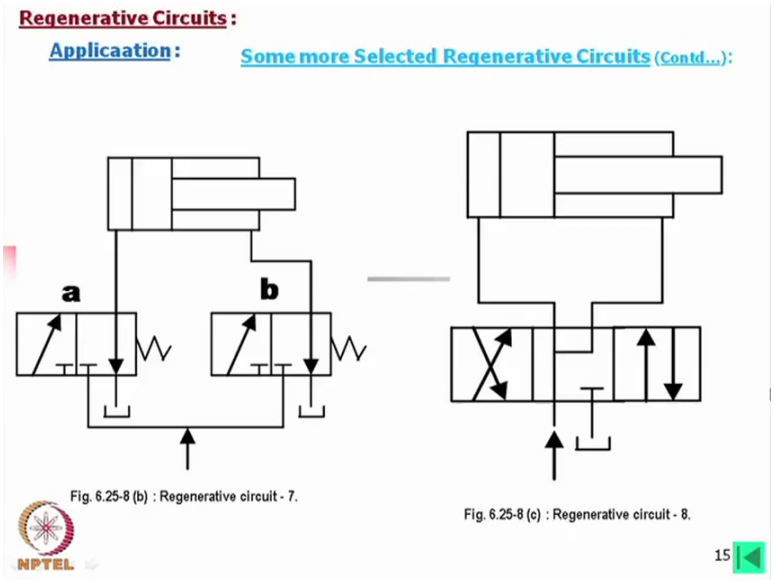

Now if I consider the other circuit that is for self exercise and let us consider this circuit so regenerative circuit 7. Here we have used two 3 by 2 DC valves and both are connected like this. This now let us consider that this side this when this connection is shown, right-hand side is the neutral condition and the other connection is the operational condition. Now, both the valves looks same and they are same, now if we let consider b is in this position this and a is connected that means we have connected this way then what will happen?

Oil will go to this side and it will be backed through this valve b, this means this normal forward operation so you make a table and you write this for a is ON, b is neutral position, it is not actually OFF because this is connected, you can say this is OFF. It has 2 positions, this is automatically it will in this position due to the spring okay, so this is not operated and a is operated, in that case normal for motion. Now let us consider a is closed or its neutral position and b is open, so this is normal return.

Now what other combination may be, so both are closed that means what is shown there, in that case the flow is going to the tank, no operation is there, it is going back to the tank through the pressure relief valve, there must have a pressure relief valve okay. Now if I connect both, a ON and b ON, in that case flow will be mixed so there will be 1st forward motion and regenerative circuit, so make a table and write in this form right. Not taking another circuit, in that case what we have taken? This is a 4 by 3 valve but center is specially connected, this is neither close

Centre nor open Centre, only thing the tank side is close and other is as if this is showing the regenerative path.

In that case a neutral, this is definitely a neutral position, in neutral condition regenerative forward motion portion is there, but for the other 2 connections there will be normal, one is return motion and another is forward motion. Now let us consider by due to some reason, it is here in this position, the rightmost position and then this regenerative circuit is ON the neutral position, when you have bought it in the neutral position after this operation then what will happen? Only then there will be the flow through the pressure relief valve, you can write this note say while you are trying to answer this what will happen to the system, you can write in that case it will be there will be flow to the tank through the pressure relief valve.

We are distinctly getting one normal forward motion, one regenerative motion and one return motion for the 3 valve positions, but it might be while it is say supposed it was in this side and then we have bought this we have given this connection, it was here and again we have given this connection, in that case also what will happen, this oil is trying to go here and oil is just trying to come back here but this will go back to the tank.

So this you have to mention but in this case there is no such position that unpredictable position is not there. Suppose this piston was at the middle position and then one of them you have connected so at least one operation will be there, it is not unpredictable in case where the flow was directly being connected to the tank in comparison to other cases.

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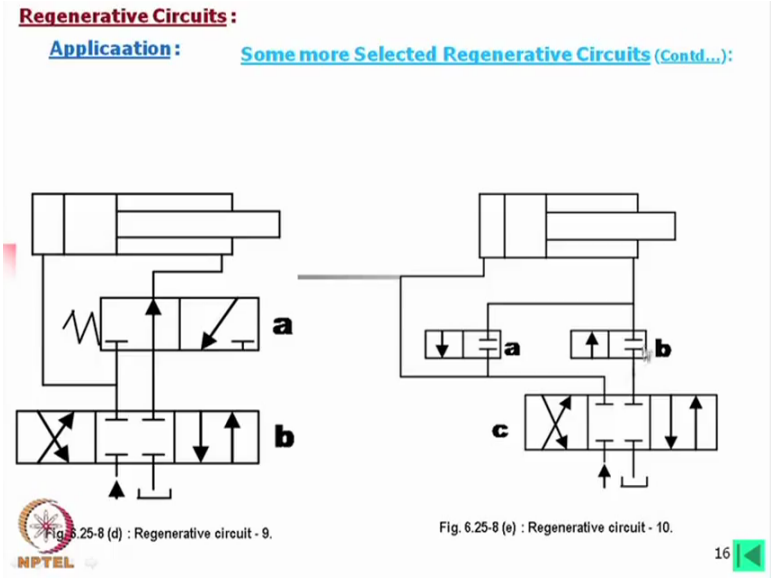

Now we shall consider the circuit 9; in that case this is 4 by 3 close Centre DC valve normal valve and what it is, this is 3 by 2 and neutral position it is connected in this way. So what will happen, if this is in neutral position and this is connected then there is no operation because oil is going back to the tank no operation but definitely not unpredictable right. Now if it is connected in this side the right-hand side then oil is so then this path is connected and this path is connected. Now what will happen, this oil will go to this side but this oil also go to this side or you can say then only this regenerative that means it is connected like this regenerative.

No, it is like that think twice, say this is connected and this is connected then oil is going to this, this is moving and also this connection is there so this cannot go back to the tank, oil is going there and oil is going here, so what will happen in that case tell me in both sides are connected? So oil can go both side, so possibly this will act as an but there is no connection in between, so there is no chance of regenerative circuits okay. Now let us consider that this is undecided, now what happens we have connected this and we have made this connection, in that case oil will return to this tank so this is normal forward operation.

Now let us connect this one, in that case oil is going to this and oil is coming back through this and this is in neutral position, so in that case with this connection and this neutral position, this normal return. Now with this connection and this connection, then oil is coming through this path and this is closed so oil is coming through this path that means oil is not going here and then

it is being mixed with this one so regenerative. So one of that is unpredictable and with this connection we can have with this connection and this connection we can have regenerative.

So please you should make a table and say I would suggest, so usually the pattern of questions are like that, the circuit will be given, you have to say what will be the operations, so please make a table and you analyse your, self-analyses is required for this. Now we shall consider another circuit that is in that case what we have used, this is 4 by 3 DC valve close Centre and this is 2 by 2 valve. In that case let us consider this is a neutral position, obviously as it is a close Centre there is no flow no operation. Now if we connect into the right side, this then this will be connected and this path will be connected.

Now once this is connected but this is closed and this is closed, so no operation again no operation, but with this connection you can operate this, suppose you have operate this operated this one, then oil will go here and oil will try to go this side. In that case, oil will go this side and oil from here will return to will return through this path oh sorry, oil is coming back from this path because this is connected okay, and oil is going through this path so this is normal operation, no mixing, it is not being mixed. Now with this connection we connect a, and b is closed, in that case what will happen, this oil will go to this side and also it is coming like this and oil will be mixed so a is operated means then only it is regenerative right.

Now let us consider this is connected and both a and b are also connected, in that case oil will go like this, it will try to go in this way and it will try it will go in this way also and as it is connected, this oil will come back to the tank, no regeneration, it is a oil will directly go back to the tank. Now let us consider this connection c, if the c is connected and then let us consider b is closed, a is closed, so no operations obviously. Now this is I would say this is going like this and this connection is there so no operation. Now if b is open then oil is going like this and going trying to go this side as well as this side, but this it cannot go so it is normal backward operation because this connection is there so normal backward operation.

So this means that by combining these 2 valves we can get normal forward, regenerative and normal backward but only for the cases when a and b are open then there will be no operation, unpredictable. So this you have to clearly mention for which operation valve combination that there is unpredictable that you have to mention. In some circuits you will find that there is

unpredictable cases, in some circuits there is no unpredictable cases, there will be some operation.

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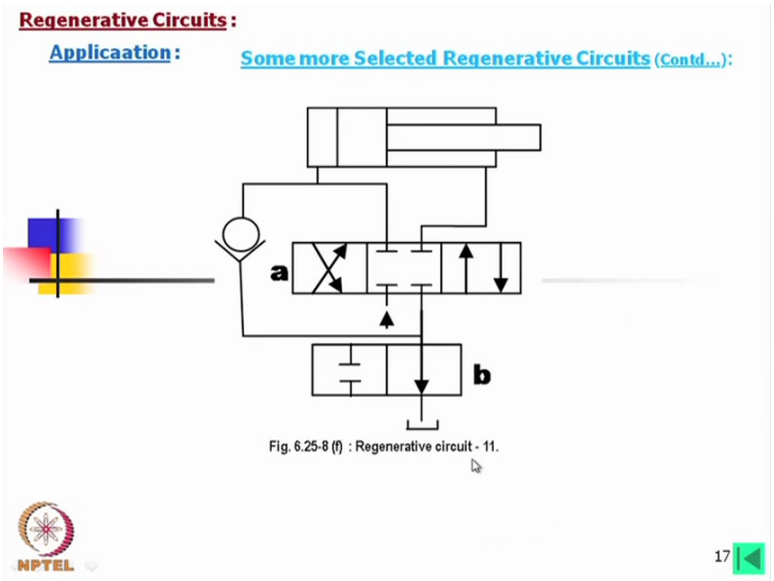

Now in case of 11 what we find that the pump is connected to again this is by 4 by 3 valve, only on the return side there is one 2 by 2 valve and in that case if it is in the neutral position, no operation, if it is in the right-hand position then oil is going to this and as there is a check valve, oil is going like this and oil is coming back to the tank, no regeneration okay, we have connected this and no regeneration. Now we have connected this and we have operated also this valve, in that case the oil is going like this, oil cannot come back to the tank and it is being mixed so regenerative. So right-hand side and this operation putting into this position, there will be regenerative.

Now we have connected this one, so oil is trying to go in this direction okay and oil from here it cannot go this way, it is going to this path okay. Now what we have done, we have operated this one, then this oil is trying to mix with this side but there is no way so it can only circulate, it is trying to circulate within this path, this means that it will normal return, there will be normal return because this oil can circulate there. No, if it is circulate means full path is closed, say this path it is closed, no return so it will not be able to return, it will not be able to return also, do you understand?

Not unpredictable, you have you see this you have operated this one, so oil can go this way it can return and oil can come from this way and it can go back to tank if it is in the neutral position. But if you immediately put in this position, this oil is connected to here but this oil cannot go back to the tank rather it will try to circulate means here is there is no volume displacement, there is no scope, the full path is full with oil and it is locked so it is a breaking condition, but we should not say no operation. It has returned up to some length and then suddenly you have to stop, so it will be in lock position break position okay.

So I think this is the end of the circuit and this there is no reference, I have not seen this article in any book, one or 2 circuits only. These circuits I have collected from an article, even if there is no clue it is from which journal and it is from that article, this is I have written what was written there and this analyses I have done of my own obviously but I think it is correct but still I request you to please try to understand go through the exercise and find out what are the real possibilities, before writing unpredictable you should think twice category, okay thank you.