Control Engineering
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Lecture - 2
Basic Feedback Structure

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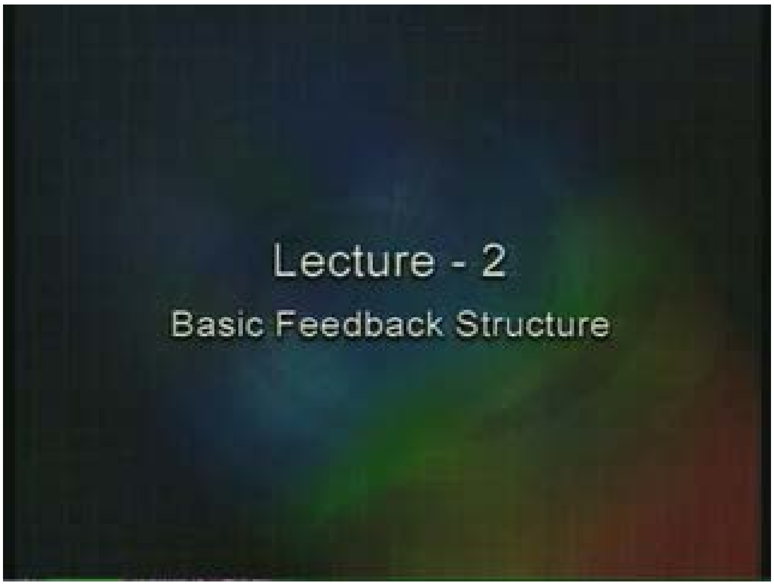

I am going to talk about the basic feedback structure. The strategy will be to give you simple feedback control examples first; many of them known to you and many of them from the industrial sector; and through those examples I am going to give you the feedback structure that the basic link which connects all those examples. This point may please be noted at the outset that the discussion of these examples will not be in depth discussion because either in the lecture class or in the tutorial classes these examples, that is their complete discussion analysis and design will reappear. The purpose of these examples today is only to give you the link between the link among various ((00:01:50 min)) systems and the basic structure can evolve out of them.

My first example is a bathroom toilet tank. Well, well-known to all of us. And as you will see this particular simple system has got all the ingredients of a feedback control system.

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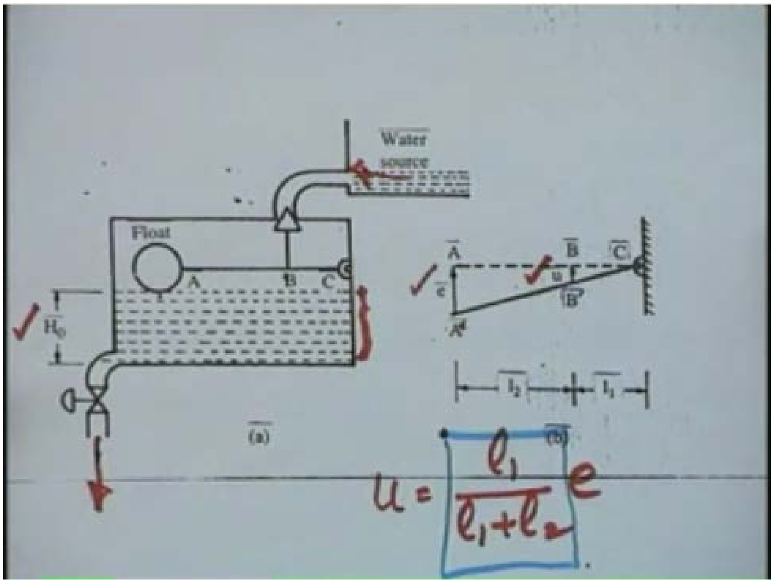

Let me take up this particular system; the schematic of a bathroom toilet tank is in front of you. Here what is your objective of this system? The objective is to control the height of the water level in the tank. So naturally the water level in the tank becomes the controlled variable in terms of control system terminology. What is the command signal? The preset height H bar becomes the command signal for this particular system and the disturbance flow in this particular system or disturbance variable in this particular system is the outflow, and the manipulated variable is obviously the inflow from this particular tank.

Now let us look at the objective of the system. The objective of the system is to control the water level in the tank to the preset level in spite of disturbances acting one this system. I hope this is alright. And now let us see where is the controller in this system. As I said, that this particular system has got all the ingredients of a feedback control system so naturally there is a controller in this system as well. I will say that this flow (Refer Slide Time: 3:40) and the lever mechanism is acting as a controller. Let us see how.

Assume that there is a disturbance. If there is a disturbance naturally an error will come between the desired water level and the actual water level and this error I have represented by the variable e. now this error variable is going to activate the controller. What is the controller? The feedback linkage. Because as soon as this error comes this variable u appears. This variable u (Refer Slide Time: 4:14) you can see is nothing but the opening of the valve. And you can very easily see from this particular triangle that a simple relation exists between u and e it can easily be established that u equal to l 1 over l 1 plus l 2 where l 1 and l 2 are the corresponding lengths given here. So you see that it is this into e of course. So you see that it is a proportional logic that is the controller controls the position of the valve proportional to the error signal and this proportional constant you can see l 1 over l 1 divided by divided by l 1 plus l 2 can easily be adjusted by adjusting the position of this particular point B.

Now, as soon as the valve opens this water level rush this particular tank rushes water into it and slowly the error reduces and when the error becomes 0 u becomes is equal to 0 and the system comes to its steady state. So it means the purpose of this control system is self-nulling, as soon as the error comes it will automatically reduce the error to 0. Let me look at the block diagram of this particular system. How do I draw the block diagram of this system? I will put it this way.

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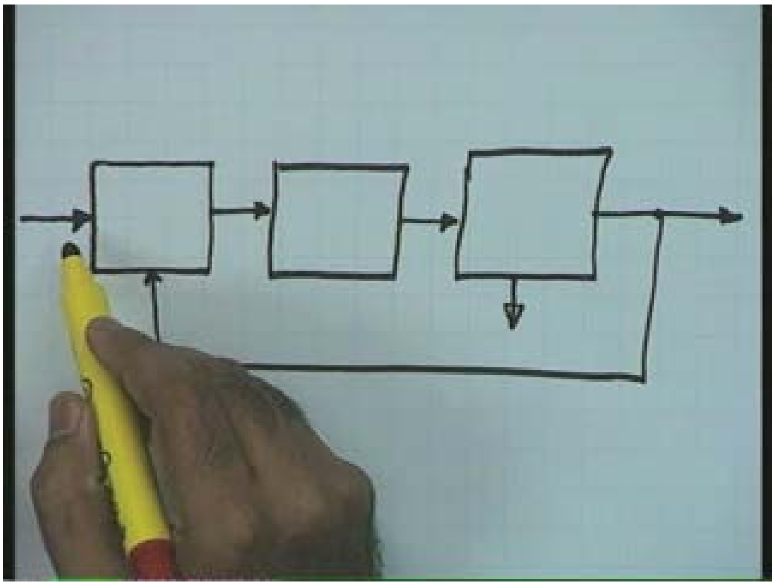

This variable let me say is the command signal. In this particular case the command signal is preset height H bar. This is your command signal. And what is the controlled variable? Actual height H is the controlled variable. And here is the sensor and the controller. What is the sensor and the controller? Let me put it this way; the float plus the linkage is the sensor and the controller. It senses H bar and H, generates an error signal and that error signal is given to the plant. And what is the plant in this particular case? The water tank is the plant. And here (Refer Slide Time: 6:37) is your disturbance flow or disturbance signal which is the flow out of the water tank.

What is the block in between? The block in between you can say, it is source of water plus valve. This I can say, this variable in the control system terminology may be referred to as the control variable; the u signal given earlier. And this particular variable (Refer Slide Time: 7:10) is nothing but your manipulated variable which is the flow of water into the tank. So you can see that this particular system represents a feedback system wherein the controlled variable, wherein the command variable, the control variable generated by the controller, the manipulated variable going into the plant are all visible.

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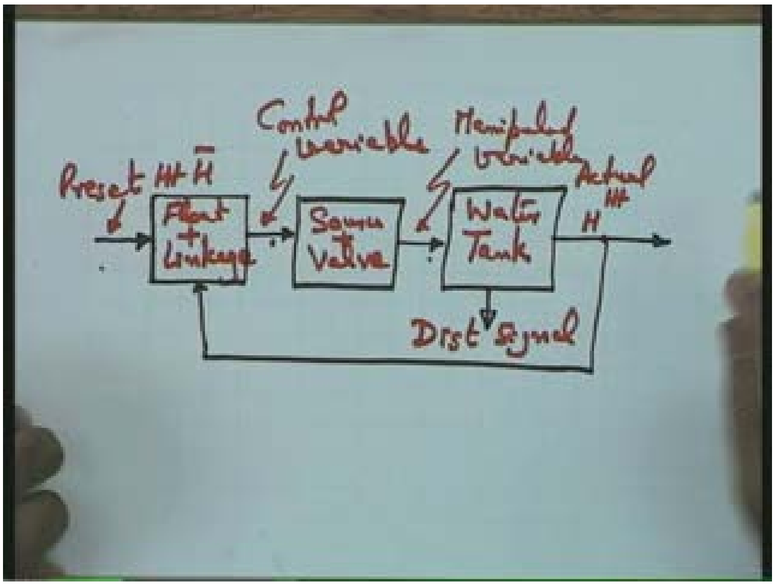

What will happen if this diagram is redrawn into a general format? The format will look like this. So in this particular format I have shown the error detector by this symbolic diagram.

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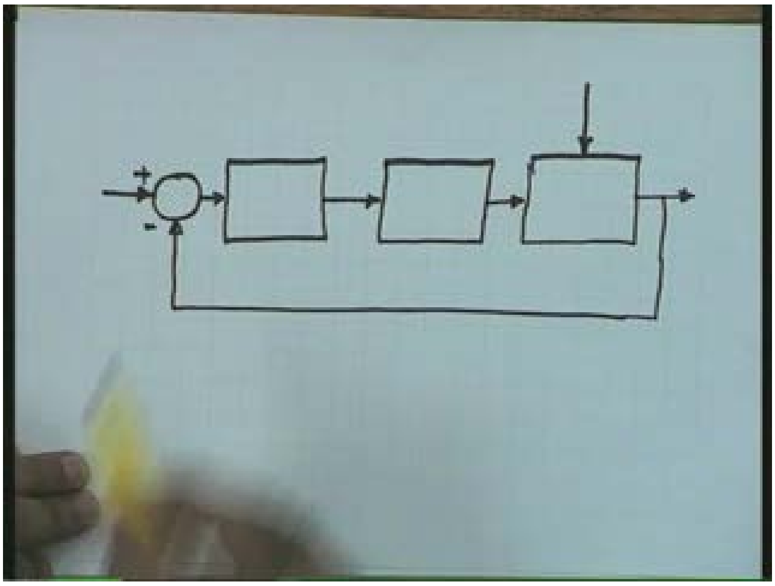

So in this particular case I can say that H bar is the preset height and H is the controlled variable. So this error detector is a comparator of the controlled variable with the preset height. Though this is not a separate physical system available over here the error detection is going on within the controller block that is the float and the feedback linkage. But in the block diagram structure it is more convenient to represent it this way. So this particular error signal which is the difference between H bar and H is given to this controller or let me put it as a control logic block. The control logic block is nothing but the float plus the lever.

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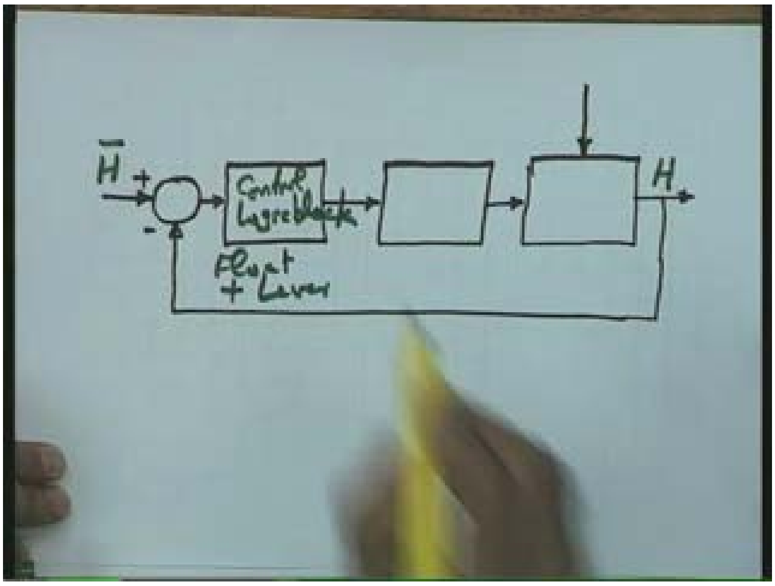

Now, out of this control logic block, now this is a general block diagram I am drawing. The signal which is nothing but the control variable u is given. u is ((00:09:04 min)) reserved for control variable. And this particular block let me name as actuator. What is the actuator in our case? The actuator in our case is source of water plus the valve. And from the actuator I get the manipulated variable and this manipulated variable acts on the water tank which now let me call this as the plant. And on this particular plant is the disturbance signal which is the water out flow and therefore this is the feedback structure. We will see that all the control systems can be cast in this particular structure.

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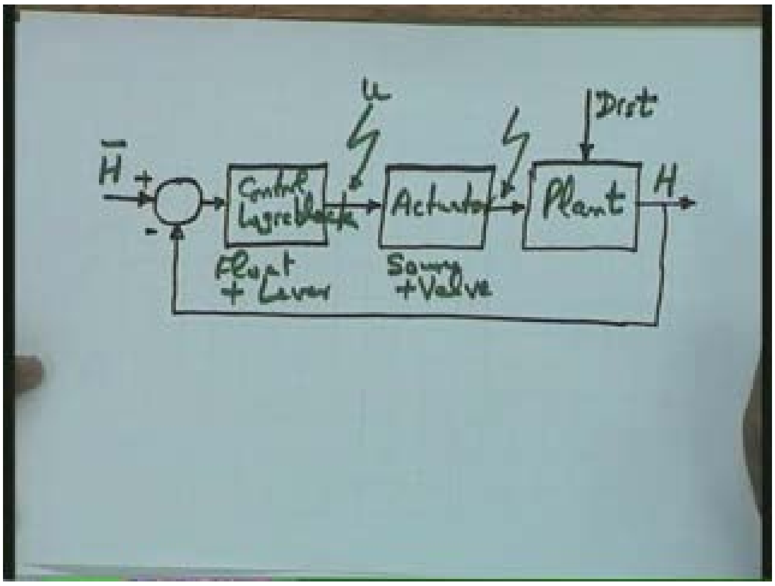

One point I like to mention here; rather one terminology I like to give over here that in this particular case the command signal is a fixed signal, is a constant signal, is not changing with time such a command signal we will refer to this as a set point. This is as per the control system terminology. A set point is a constant command signal. And what is the requirement of its system now? it is required that the controlled variable always maintain is maintained at the set point such a control system is referred to as, in the literature as regulator system. Please note that these terms will be coming quite often.

And the specific objective of today's lecture is to make these terms clear which will come in our discussion during the later lectures on this subject. Let me take another example again very well-known to you, this is the block diagram which I am going to complete of an automobile driving system.

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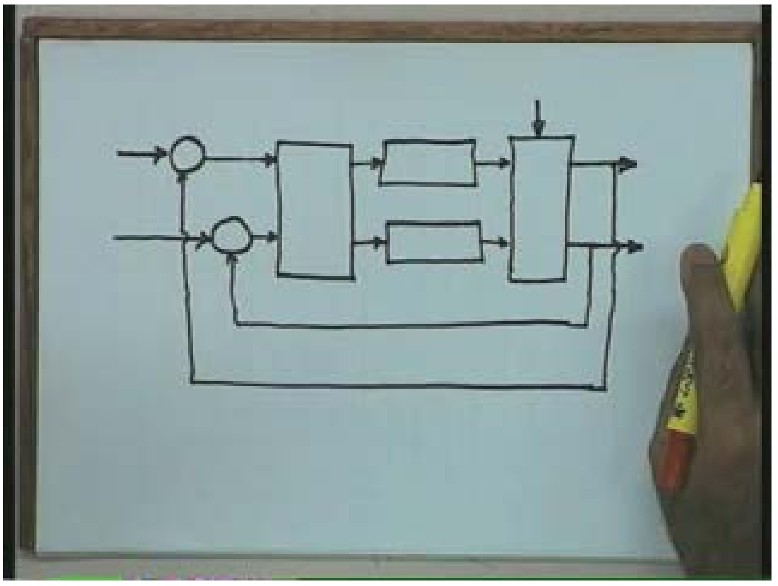

Again many important terms will evolve out of this example. Please note this very carefully. In this system you will note a departure from the previous example. There are two output variables. In the previous example, recall, there was only one output variable one controlled variable. The two output variables in this system are; let us say as the heading and the speed. Now the plant in this particular system is the vehicle. What is the disturbance acting on the system? It is the wind force plus, plus what else please? May be road traffic conditions; fine. Look at the input variables. naturally if these are the controlled variables there will be corresponding command signals and higher I say that the direction of the highway is one of the command signals and the speed limits as given by traffic signals is the another command variables. So, fine.

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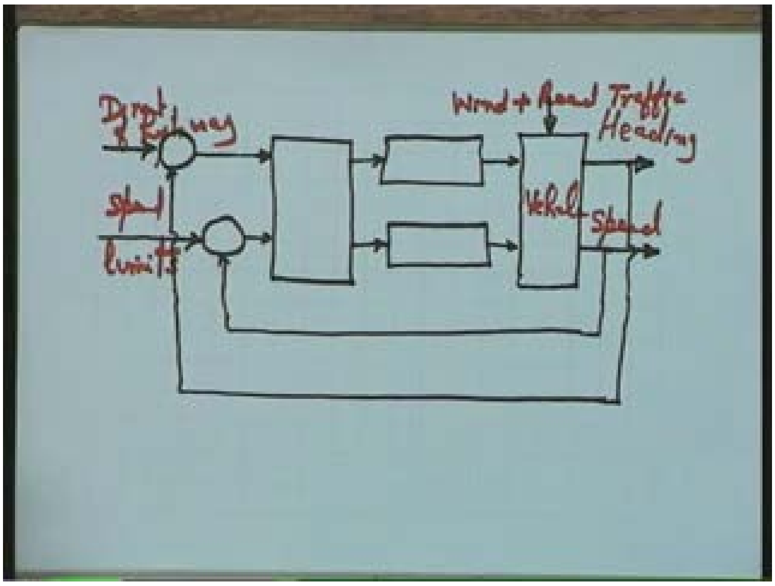

Now, in this case the manipulated variables you know it very well. For this heading the manipulated variable should be here (Refer Slide Time: 12:52) this steering position, this steering control and the manipulated variable here will be the accelerator or the brake position to control the speed. I said that there is going to be a difference between these systems: the automobile driving system and the earlier system the bathroom toilet tank. The difference lies in the number of input and output variables. In this case there are two command variables and two controlled variables.

A system with multiple input and multiple output variables in the literature is referred to as an MIMO very standard name we will be using Multi-Input Multi-Output system or a multivariable system. In contrast to this system, the earlier example was an example of an SISO Single Input Single Output system. These terms are quite frequently used in the literature or let me call it a scalar system.

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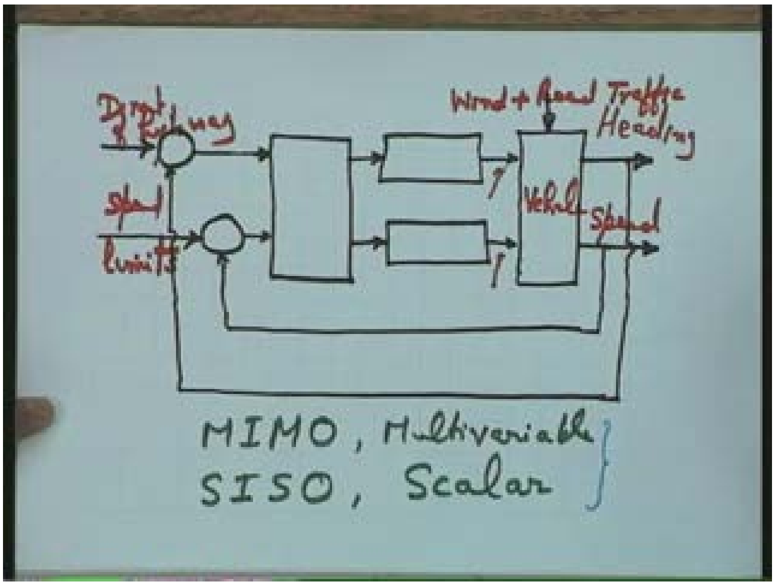

Well, the basic difference, as far as the control design is concerned in these two classes of systems it lies in the interaction. You will please note very carefully that in this particular case one manipulated variable here may affect both the controlled variables as far as this plant is concerned. This is called the coupling between the input variables and the output variables or the interaction between the input and the output variables. This interaction, as you will see later, makes the control decide the task, a very difficult task, really very difficult. That is why the design of multivariable systems is quite difficult in nature because of the interaction as you will see later.

Let us look at the interaction in this very example. You will please note that this steering command over here is really not going to affect the speed as you know; it is going to affect the heading only. However, the brake position may lock up the wheels and hence may have an effect on the heading. So it means in this particular case if we model our system taking this interaction (Refer Slide Time: 15:41) into account then this becomes a multivariable system. However, if I neglect this interaction, if I assume the effect of braking on the steering or on the heading is going to be negligibly small. In this particular case please note that I can treat this system as a set of two single input single output systems. That is, a plant wherein the input is a steering command and the output is the heading; a plant where the input is acceleration or brake position and the output is the speed. If I am able to do it, please see I have simplified my design job considerably. And this point is to be very carefully noted that in most in many industrial situations it is possible to make this assumption that is why the design methods centered around the scalar systems are single input single output systems that are quite important.

In fact our total course the control engineering course is centered around the design of single input single output systems only. So really as you will feel, this is very important point. When I am going to design always throughout the course a single input single output system it does not mean that in the actual industrial scene I always come across single input single output systems, it simply means that I am handling those situations wherein the interaction can be neglected and a multi-input multi-output system can be considered as a set of single input single output systems for the design and implementation purposes.

Now with this now let me come to the other blocks. What could be this block? Well, this is an actuator. In this particular case help me please this naturally hence in this particular case; another actuator you can say foot here (Refer Slide Time: 18:01). So in this case the error detector we have to identify. The error detector is here because this circle has a schematic has been taken as an error detector. Well, we don't have a hardware error detector in this example; the eyes of the driver are going to act as an error detector in this particular case. So depending upon the error in this case I put this block as control logic.

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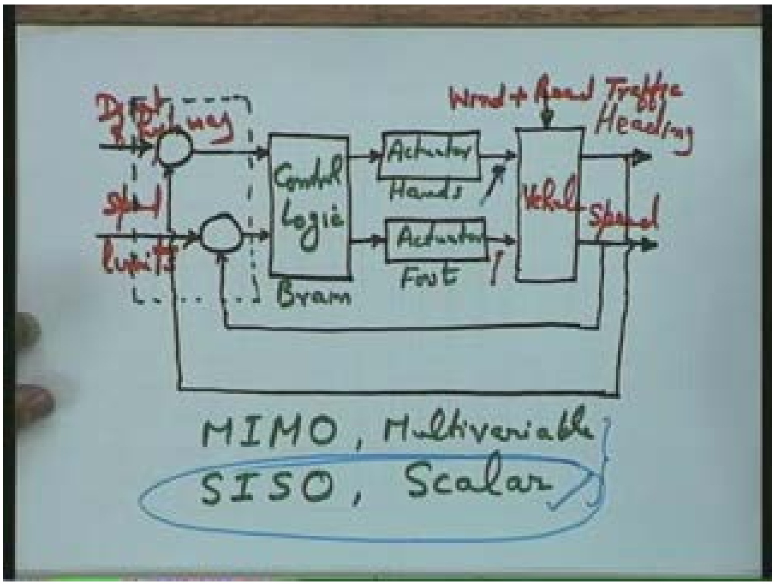

The control logic is in the brain of the driver and a suitable action is taken by the driver depending upon the control logic he has set in his brain so that the manipulated variable through the actuators are suitably controlled so as to make the controlled variables follow the command. In this particular case the commands are not fixed in time. The commands are function of time and that too depend upon the speed limits as given by the traffic signals and the direction of the highway. So here also I like to give one important terminology. When the command signals are changing with time and the purpose of the controller is to make the controlled variable follow the time varying commands then this control system is referred to as a tracking system. So, in contrast to a regulator system given over earlier I have here a tracking system. Or equivalent term, a command following system.

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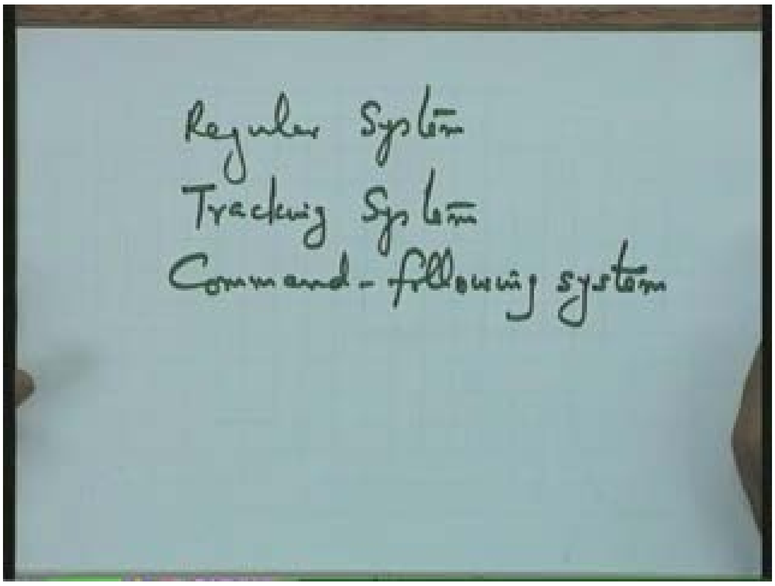

One more difference, these two examples bring out one more point. In the example on automobile driving, as you have noted, the driver is in the feedback loop, it is not complete hardware system. Well, consider the earlier case, the case of a bathroom toilet tank, there is no human operator in the loop. So, in these systems wherein there is no human operator in the loop, well, we may call those systems as automatic control systems and the systems the feedback systems wherein the human operator in the loop, well, may be referred to as man-machine control systems.

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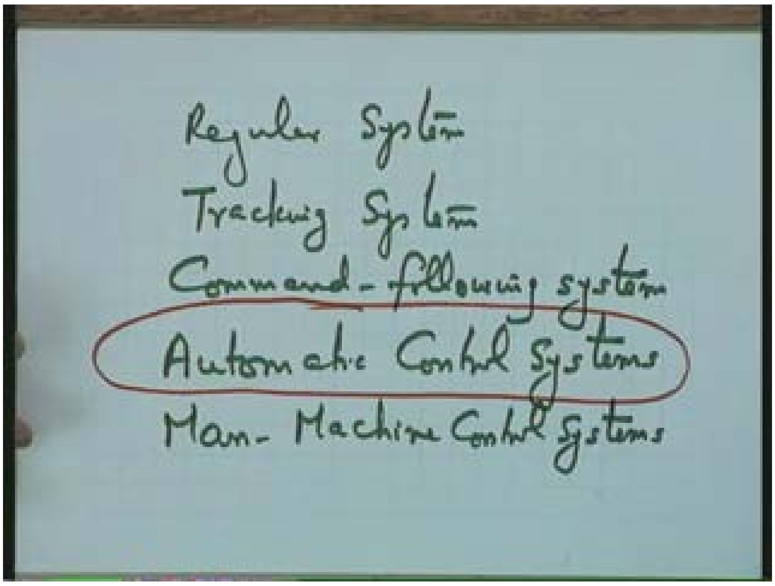

Our emphasis throughout the course is going to be on automatic control systems. The complete hardware will be described which is to be used inside the loop to realize the objective of control. No operator will be required to realize the objective.

Well, another example. I give here an example, again a known example to you, a hydraulic power steering mechanism. As I told you, the detailed study of these systems will come later. Here the objective is only to look at the feedback structure through all these examples.

In this particular case, again very simple, see the feedback link here, the cross bar, let us say this is the cross bar, when this is horizontal what will happen in this particular position; in this particular position this spool I will say it is in the neutral position. I hope you are getting my point. This is in the neutral position and this spool in the neutral position means thereby this oil supply port is cut off. There is no high pressure oil flowing in. this feedback linkage is in the steady state position and the wheels are along the longitudinal axis of the vehicle. I want you to get this point very well so that I will see what'll happen when the command signal is given.

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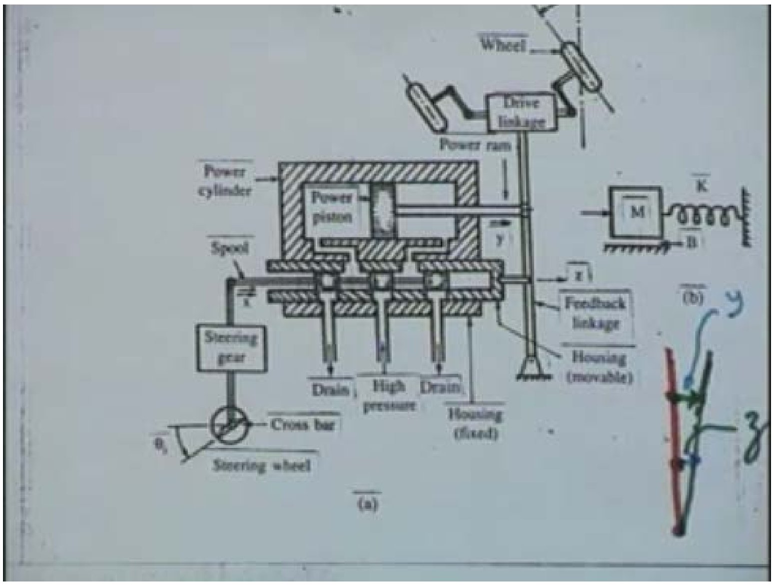

I repeat here, well, this is the signal from here (Refer Slide Time: 22:51) the steering command signal, translation of this steering command signal through the steering here into the spool displacement with this horizontal position this high pressure oil is stopped to the power cylinder and corresponding to this particular position the wheels are along the longitudinal axis of the vehicle.

Now let us look at the command, the commanded position. I give an anticlockwise command over here. So with this command the spool now let us say moves to the right, x movement, follow the movement please, it moves to the right. When it moves to the right what will happen, this spot gets opened, the high pressure oil flushes into the system onto the left hand side of the power piston. Now, with this now there will be pressure on the power piston, the power ram will move to the right. Let us say this was the earlier neutral position of this feedback linkage (Refer Slide Time: 23:56) this was the earlier position of the feedback linkage. What is the new position now in response to x movement? The new position of the feedback linkage in response to x movement is going to be this way and therefore this movement is the movement of the power ram.

Let me say that this is your y variable. Now, in response to this y variable, please see, the drive linkage over here is going to develop a suitable torque; this torque is going to move the wheels in an appropriate direction so that the wheels follow this steering command. Look at the feedback action now. Once this feedback linkage, this point in the feedback linkage moves by a distance y what will happen to this joint (Refer Slide Time: 24:55) this is going to be this is going to have a movement by a distance let us say z. now this is a movable housing, this one please. This one is a movable housing. when this feedback linkage moves by a distance z what will happen, this housing will move to the right so what is the effect please; the effect will be to shut off the oil supply to the cylinder and therefore in the new steady state when this variable becomes equal to the commanded variable the oil supply to the power cylinder will be stopped and the wheels will come to the commanded position. So this way through the feedback link we have been able to get what is called the command following system or a tracking system wherein the system is required the output is required to follow the commands.

Now when I come to the analysis and design of this system I like to make this point clear here that the plant in this particular case is going to consist of the load with the suitable drive linkage, the piston and the cylinder here. The modeling of this, as I told you earlier I will like to capture this into a suitable mathematical model. So a suitable mathematical model I will be able to get if I first get a suitable physical model of the system. A suitable physical model for this mechanical system will consist of a suitable interconnection of a mass element a spring element and a friction element. So a suitable interconnection of mass, spring and friction element is going to constitute a load for me and this will come in our mathematical modeling.

Now since I am interested in a block diagram structure, to see that well, I really get a feedback system. Let us see let us translate this system into a suitable block diagram, you will help me please.

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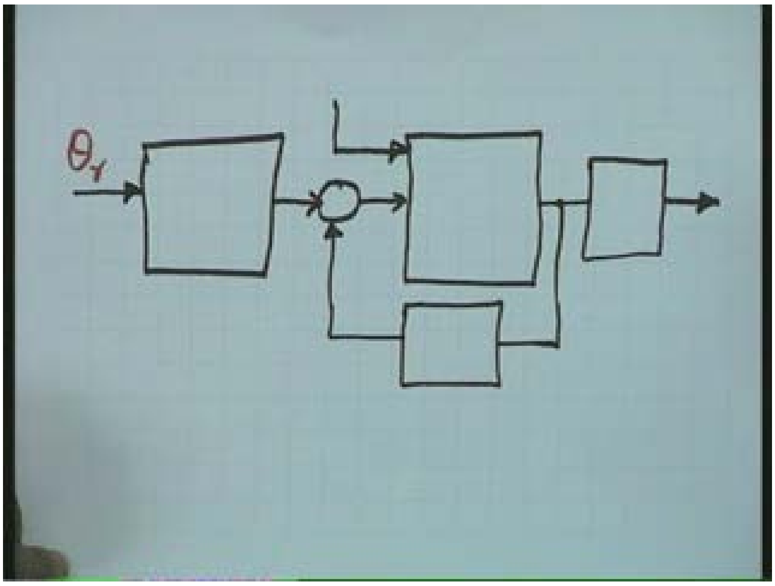

So the command signal, let us start with the command signal. In this particular case I can give this steering command as the command signal theta is the command signal for the system. So here there is a little change in comparison to the earlier block diagram. I put here the steering mechanism or the steering gear let me call it. This command signal through this steering gear will be translated into this spool displacement x, well, an error detector. So let us say that this spooled displacement x is going to be compared with a signal coming from a feedback element that is the sensor.

What is the sensor here and what is the controlled variable? The controlled variable in this particular case is going to be the displacement of the power ram y. This displacement y is going to be measured by the sensor which in this case is the feedback linkage and the signal generated as you see is z. This x is compared with z. A suitable actuating error signal is generated and this particular error signal is going to act on the plant. As I mentioned earlier, the plant in this particular case is going to be the piston plus the load on the system.

Now, as I said in the earlier lecture, there is no need of a feedback mechanism unless there is a disturbance. You will find that there is a disturbance signal coming over here; the disturbance signal is the load disturbance acting on this system which could be the wind disturbance signal. The variations in the load on the vehicle are the disturbances acting on the system and the objective is this that the y should follow the command in spite of the disturbance signal which is outside our control.

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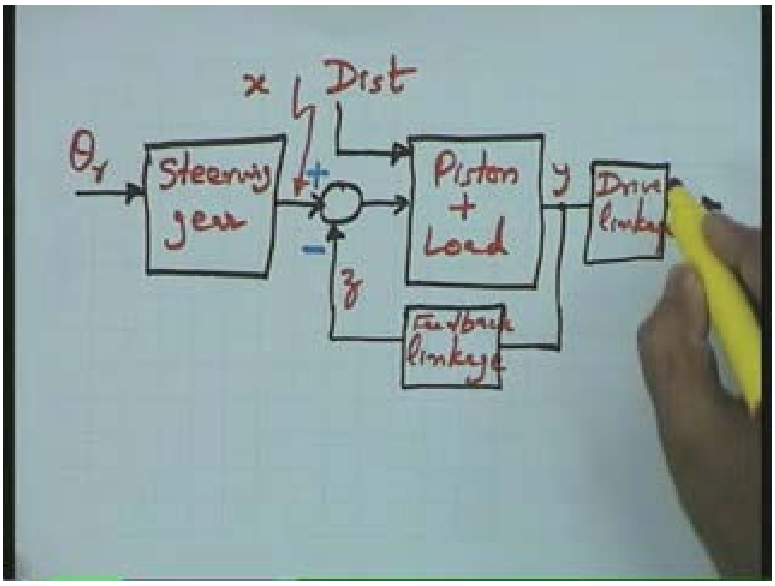

Now look at this y, here I have the block the drive linkage and this signal theta naught that is the output signal which is the position of the wheels. As I said that there is going to be a difference between this tracking system and the earlier tracking system as far as the basic block diagram is concerned. The basic feedback system as is obvious is enclosed this way (Refer Slide Time: 30:09). It really requires a signal here, a controlled signal here and a basic feedback loop.

You will please note that the systems study, the study of the feedback control system will center around this particular portion of the system. However, to generate this particular signal which is proportional to the command signal you have the steering gear. And similarly this is actually the controlled variable and this particular signal is directly a translation of the controlled variable to the actual work to be done on the system. So I may say that as for as the feedback properties of the system are concerned we will be worried about this particular system and therefore let me say let me give different names to these variables, I will call this variable to be the reference variable to be very carefully noted please though this was earlier referred to as the command variable or command signal. It may be noted that your command signal and the reference variable in a particular system may be one and the same thing.

Similarly, on the other side this particular variable let me refer to as the controlled variable. As we have already defined. Well, this variable I will refer to as indirectly controlled variable (Refer Slide Time: 31:47).

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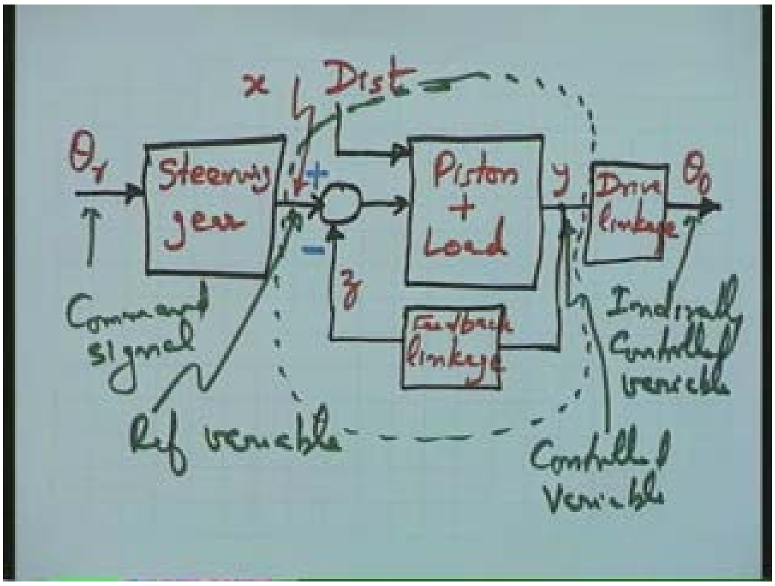

If you are not over loaded with the terminology here I may refer to this as this particular block consisting of the steering gear here in this particular case which translates the commanded signal into a reference signal may be referred to as the adjustment mechanism or set of reference input elements. Well, this particular block (Refer Slide Time: 32:23) which translates the controlled variable into an indirectly controlled variable are the actual work done may be referred to as a set of indirectly controlled system elements. So every diagram or every system example is bringing out something new and you will see that all the system examples I will be able to interconnect through a general basic feedback structure. Before I come to a general feedback structure I like to give one more example here and the example is that of a residential heating system.

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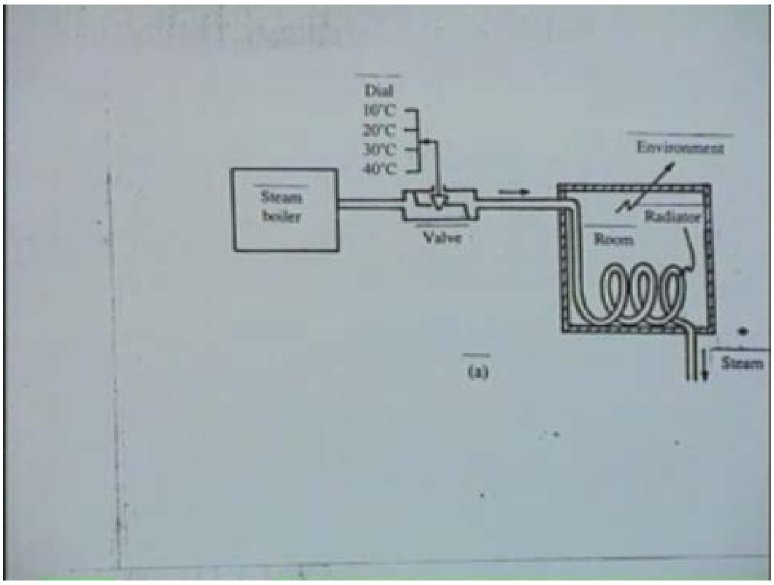

In this particular case you will find that I have a room radiator here. This is the valve which controls the flow of steam into the radiator (Refer Slide Time: 33:15). So, in this scheme as is visible before you I have this dial setting. This dial setting is going to control, is going to exert a proportional control on the valve opening and depending upon the valve opening the flow of steam is going to be controlled. So if you really want 10 degrees centigrade temperature inside the room there will be one setting over here switching over to 20 degrees you will do it by, the operator will readjust the setting and you are going to get the control corresponding to 20 degrees command. So I can say that the block diagram of this particular system looks like this structure which obviously is an open-loop structure.

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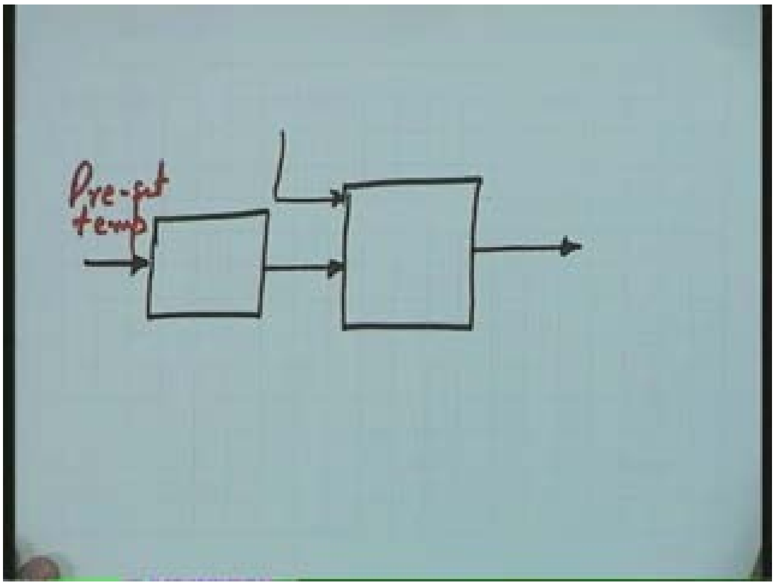

In this particular case I have a command. What is the command in this case? It is preset temperature. Please note that the system is going to be a regulator system. Preset temperature is a constant value you are not going to change with time. So here in this particular block let me say it is adjustment mechanism because proportional to the preset temperature you are going to have here the valve opening or you can say that you can translate this variable into steam flow rate. So this steam flow rate becomes my reference variable in this particular case. The plant is the room radiator. And the controlled variable is the actual temperature inside the room.

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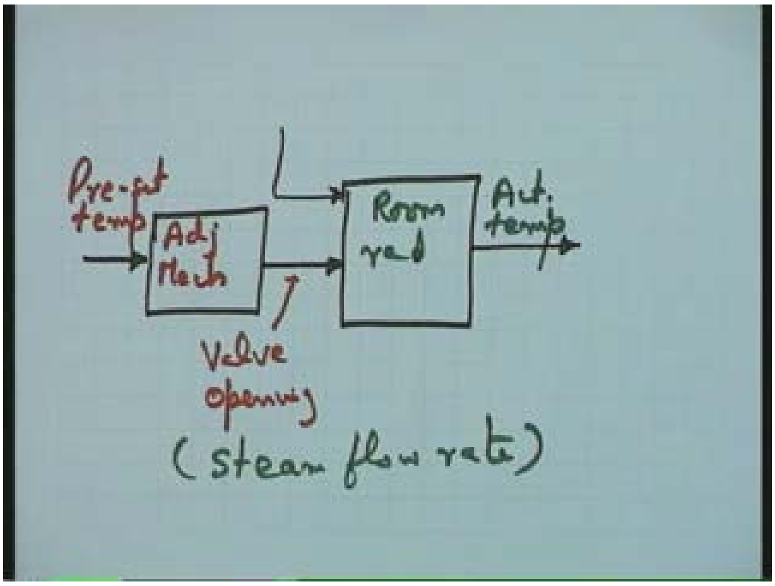

Well, I will say that it is a system which will perfectly work without any difficulty provided there is no disturbance on the system. However, unfortunately in this particular system there is uncontrolled disturbance. The disturbance in this case is the environmental temperature. What are the other sources of disturbance please? Well, the falling of the radiator tubes with age will create disturbance within the process. The design which you have carried out with respect to a particular radiator that design will not work with time because of the change in the system parameters, change in this process parameters the aging effect will appear. So in this example as you see there are disturbances within the system and disturbances are generated outside the process environment.

You can see that if you have designed the setting of the valve opening for a particular environmental temperature and your system is working satisfactorily the system will give poor response as soon as the environmental temperature appreciably changes because in that particular case the proportional controller you have set for the valve opening is no more applicable. In that particular case either the operator should sense this change of environmental temperature, should go back to the valve setting, should readjust the valve setting so that the valve setting now corresponds to the new environmental temperature seen. However, this will not be an automatic control system. This is why a feedback system or an automatic control system becomes important in industry. An open-loop system may work satisfactorily where the performance requirements are not very stringent. Therefore, that is why in a residential heating systems, maybe in your houses even, well, this type of system maybe working because the requirements on the accuracy of residential heating are not as stringent as to warrant a feedback structure. However, if we go for a feedback structure let us see how it will look like. Some of the residential buildings do have this type of feedback structure wherein the accuracy requirements are more.

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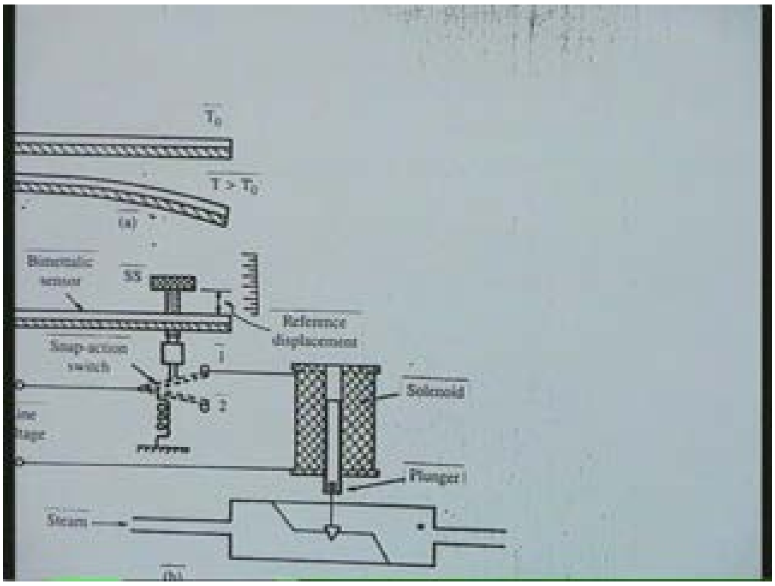

In this particular case you will please note again, you follow me as far as every element of the system is concerned. The bimetallic strip over here two metals joint together having grossly different thermal expansion characteristics so that this strip (Refer Slide Time: 38:04) when heated is going to curl and the curling profile is a function of the temperature. This bimetallic strip not shown in this particular the diagram is there in the room so it is going to respond to the room temperature. This strip is going to control this snap actions switch. Now this snap action switch is going to control the current to the solenoid. The solenoid in turn is going to control the plunger and hence the valve opening.

Now please see the feedback action in this particular case. Let me assume that again it is a regulator system as I said. This is the desired temperature the preset command input the set point. And let me assume that the strip that is the thermostat is in horizontal position corresponding to this desired temperature and corresponding to the horizontal position of this particular thermostat the snap action switch is in position 1, the current is supplied to the solenoid, the plunger is pulled in and the steam supply is on, this is situation 1.

Now assume that the temperature rises beyond the set point value because of the environmental effects or because of other disturbances beyond your control. So in that particular case what will happen, the thermostat will curl downwards, let us say, it depends upon our design. So when the thermostat curls downward the snap action switch will be moving to position to the current to the solenoid will be cut off and the plunger because of its gravity will be down and it is going to close the valve and therefore the steam supply to the room or to the room radiator will be discontinued as the temperature of the room goes beyond goes above the set point temperature.

Take the other extreme. The temperature now, if the steams supply is discontinued after sometime what will happen, after sometime the temperature of the room will go down, will be lower than the set point value. If the temperature is lower than the set point value the thermostat will curl backwards. The curling of the thermostat this way will bring this particular switch to position 1. So in this particular case the connection will be restored, the electrical circuit will be complete, the current will flow, this plunger will be pulled in and therefore the steam will flow into the steam radiator and the effect will be to increase the temperature of the room. So you can see in this particular case, let us say that in this case let me say T 0 is your desired temperature the set point value and you start from this point lower than the set point value; the situation is like this now: the temperature of the room is rising, it will exceed the set point value, the control action will take place, the temperature of the room will reduce, it will come to the set point value, however, the temperature will keep on reducing if the steam supply is cut off.

Now, after sometime when the thermostat becomes active the steam valve is opened again and the temperature of the room rises and this way you will find that the temperature of the room will oscillate between two limits and setting of the thermostat and the snap action switch can be controlled so as to control this particular limit. Naturally in an application like residential heating system if your requirement is 20 degree centigrade the limit plus minus 2 degrees can be tolerated and it is possible to design a control feedback control system wherein the limit is within this particular acceptable range.

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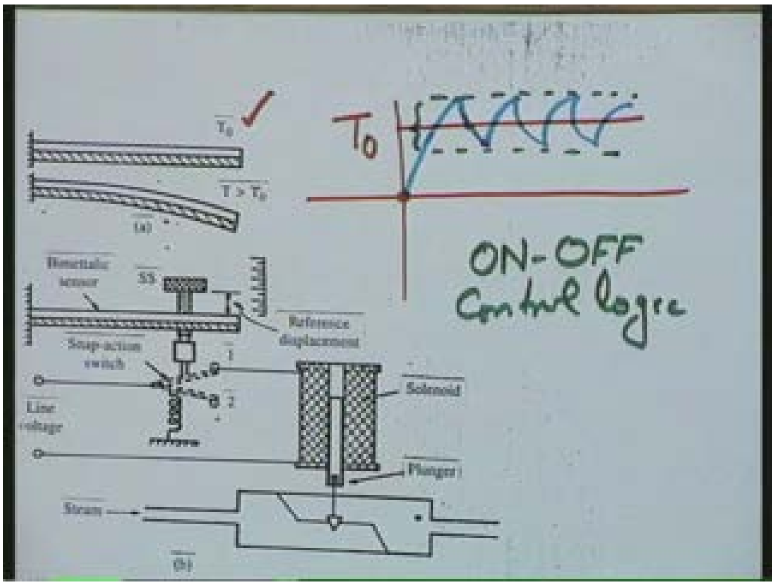

The control logic in this particular case as we will see later is referred to as on off control logic. Because you see in this scheme there is no proportional control, the valve is either on or off, it just takes one two positions and these two positional control is going to give us this oscillating behavior. However, in many feedback control situations this oscillating behavior is acceptable to us.

It will be quite interesting if we translate this diagram into a block diagram. So, if I look at this system, let me start with the command signal. The command signal in this particular case is going to be preset temperature T 0.

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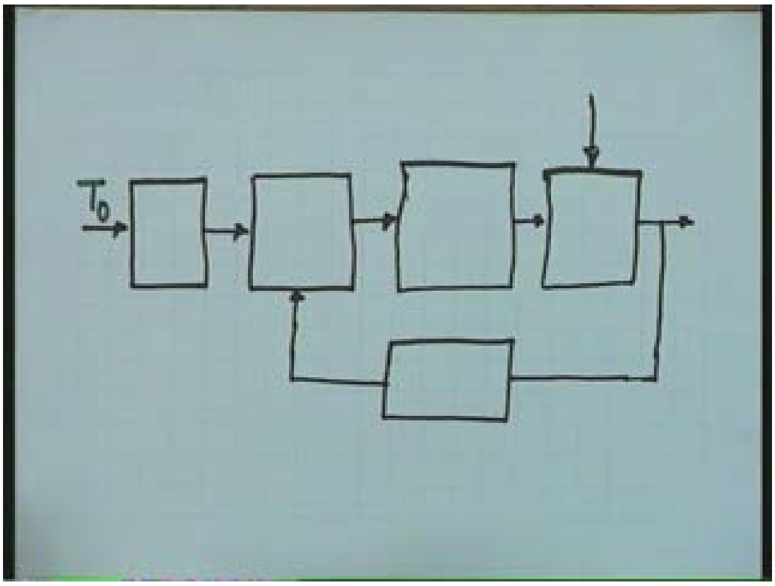

How would the reference variable, the reference variable is a signal over here which is going to be……… I will like to bring back the original style original slide (Refer Slide Time: 43:30) in this case. Please see, the reference variable is the reference displacement of the set screw. The reference displacement of this set screw is going to adjust the opening between the distance between the thermostat and this snap action switch. So the command temperature the set point temperature can be translated into this reference displacement and therefore let us come to this particular block; this I can say is the set screw adjustment (Refer Slide Time: 44:08) and this could be the displacement x which is the reference displacement in this particular system.

Now this reference displacement, what is the feedback action; this I will say is the sensor which is the thermostat and the controlled variable theta the desired room temperature the actual room temperature theta is sensed by this thermostat. This is your controller which is nothing but your thermostat plus the switch is your controller. This controller is going to control the current.

What is the actuator?
The actuator is that component of this system please note which generates a suitable manipulated signal for the plant. The actuator is the solenoid plus valve and the actuator is going to generate the signal over here which is nothing but the steam flow and the plant obviously is the room radiator and disturbance is the environment temperature.

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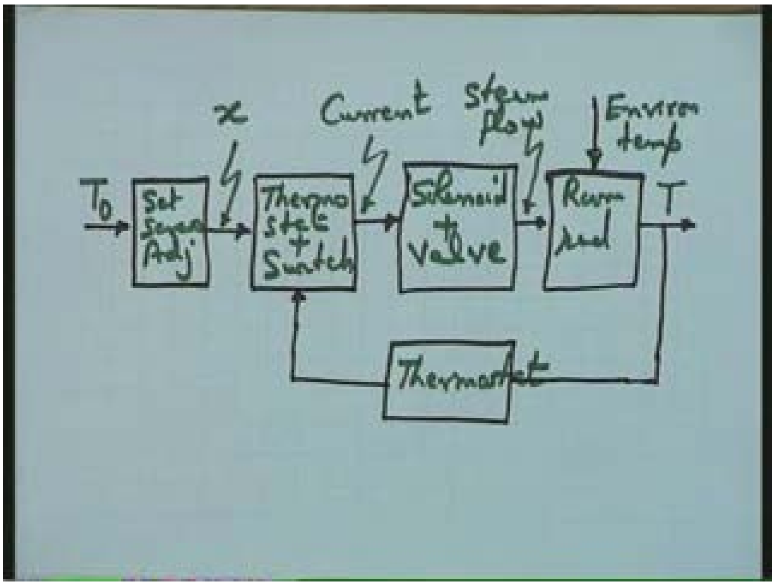

You will please note that in this regulator we have all the ingredients of a feedback structure. The feedback loop the basic feedback loop is here with input as the reference variable and with the output as the controlled variable T. Now looking at the available time I like to conclude my discussion though couple of examples I have yet to give. But before I conclude let me quickly give the basic feedback structure.

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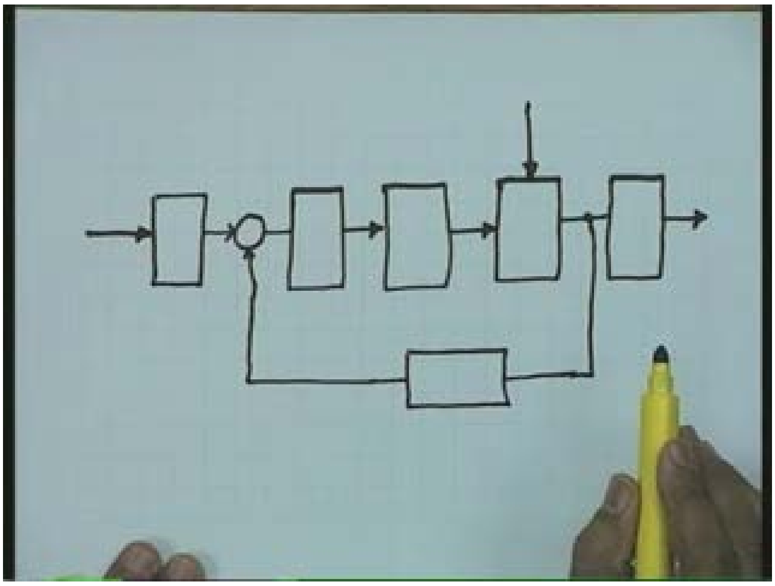

In the basic feedback structure you will see you keep all the four examples we have discussed in mind and you will find that all the four examples can easily be put can easily be cast into the base basic feedback structure we are going to discuss now. And the variables that I am going to use over here, the system symbols I am going to write over here we will be really using these symbols all through our course and you have to take note of these symbols very carefully.

I say that y r in general it could be temperature, it could be displacement, it could be the water level or any other variable this is the command signal and here I have…. let me put the system variables by different color representation A (Refer Slide Time: 47:07) you can note down I will speak out slowly. This block A corresponds to reference input elements. The function of the reference input elements is to generate the reference signal which in a general structure I am going to represent by the variable r. This is going to be my error detector symbol whose objective is to compare the reference signal with the feedback signal. You will please note over here the feedback signal I am going to represent in general by b is going to be my feedback signal. So when the error detector compares this signal r with the feedback signal b it generates an actuating error signal which I will like to represent by e cap. Why do I represent it by e cap and not by e will become we clear later and I name this signal e cap as the actuating error signal.

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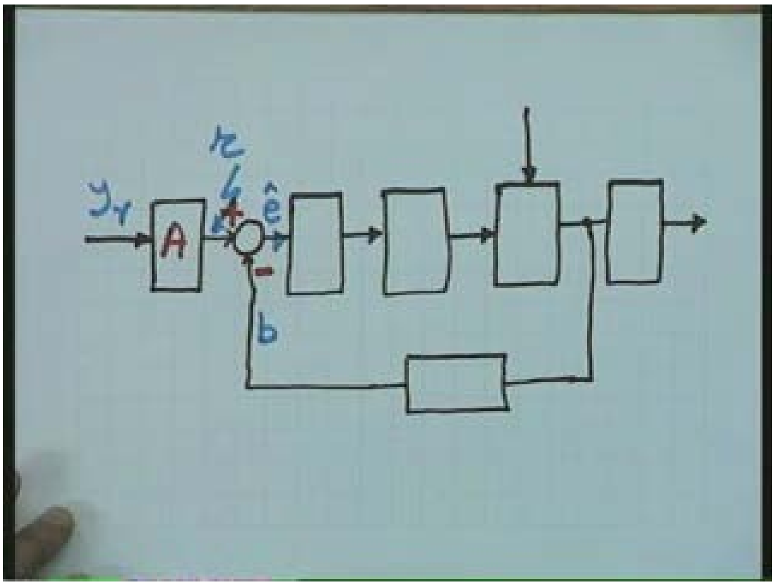

The error signal which is yet to be defined I will like to represent it by the symbol e. Let me proceed further. This error signal is given to this particular block and this particular block corresponds to the control logic block and the control logic let me represent it by D; controller block or control logic block. This total the control logic block and the controller block may be referred to as the controller for the system controller for the system.

Let us proceed further and see how the signal flows. The control logic block depending upon the actuating error signal generates a control signal let me represent it by the symbol u. This control signal x own the actuator block. You have seen through the example what the objective of the actuator is. The objective of the actuator is actually to increase the power level of this particular signal. This signal may be a signal which is not able to drive the plant and therefore the actuator block is a block which is going to give me the manipulated signal which is going to drive this particular plant. The actuator block I am going to represent by GA. As has been said the objective of the actuator block is to give me the manipulated signal and I reserve the symbol be m for the manipulated signal. Manipulated signal is the signal controlled by the controller and this particular signal is going to act on the plant and this plant or the process or the controlled system is going to be a represented by GP.

On this GP the disturbance is going to act and the symbol w will be used all through for the disturbance variable. You will please note, different books give difference symbols so we have to make our discussion uniform and therefore we will stick to these symbols only all through; the symbols for the system blocks and the system variables. Now this GP is the output of this (Refer Slide Time: 51:03) your controlled variable and let me use y for the controlled variable.

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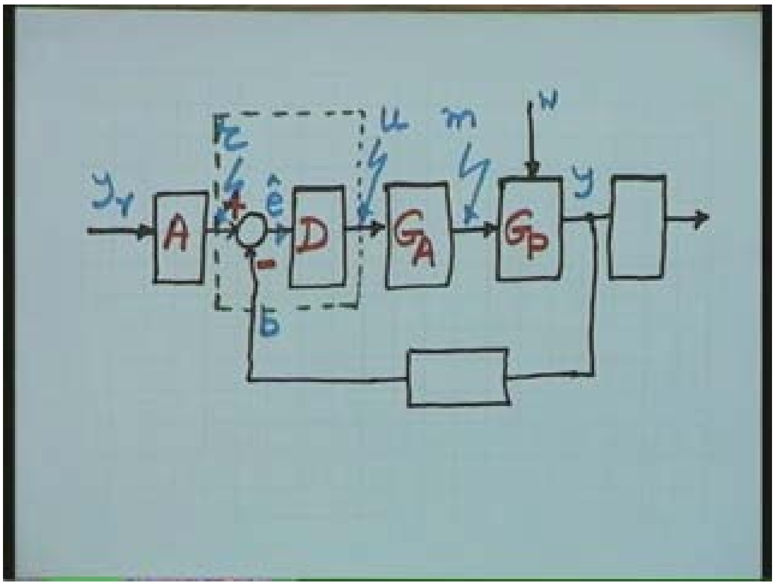

The controlled variable is going to be sensed by the feedback system elements. Note the block feedback system elements, the sensor elements in most of the cases and I use H to represent the feedback system elements. The output of the feedback system elements is the variable b called the feedback signal.

Coming to this block diagram this portion of the block diagram the controlled variable in most of the cases is the actual output desired. But in some cases as we have seen in one example you may have another system block represented by Z and I call this as indirectly controlled system elements. These elements do not come in the feedback loop. These indirectly controlled system elements control a variable and I use the……. let us have q for this and this becomes for me indirectly controlled output variable of the feedback system and this becomes a general feedback structure of a control system of an automatic control system. I will like to conclude with the comment that any feedback control system may not have all the ingredients of these variables and the blocks. However, the general essence of the flow of information will be as per this feedback structure. Thank you.

[52:47 to 57:30……… foreign language]

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The first step is the preparation of sand for mould making. After removing the unwanted metal pieces the sand is carefully shifted.

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Once the molding sand is prepared it has to be tested for permeability, hardness and strength. So a standard specimen is first made. In this case it is the green sand specimen since it has got water in it. Standard weight is dropped from a fixed height three times.

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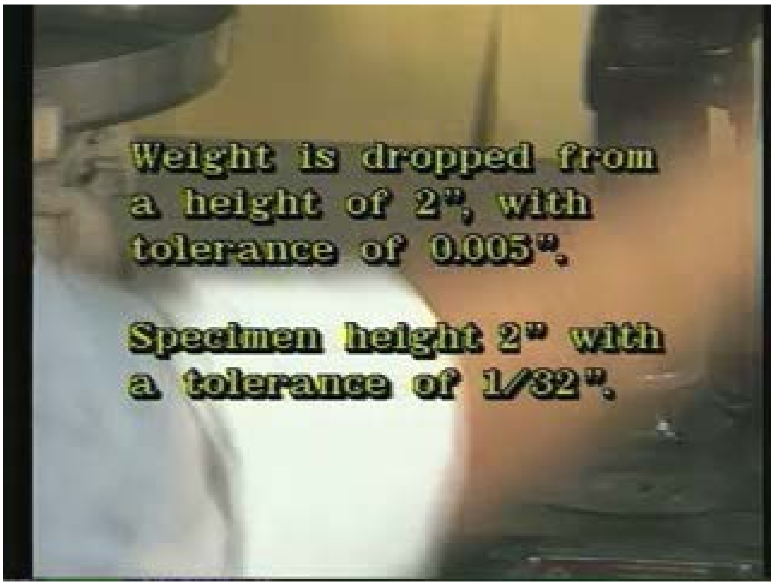

After the standard specimen is made it is first tested to determine the permeability of sand. The permeability is determined by noting the time of passage of fixed volume of air through the specimen under standard conditions.

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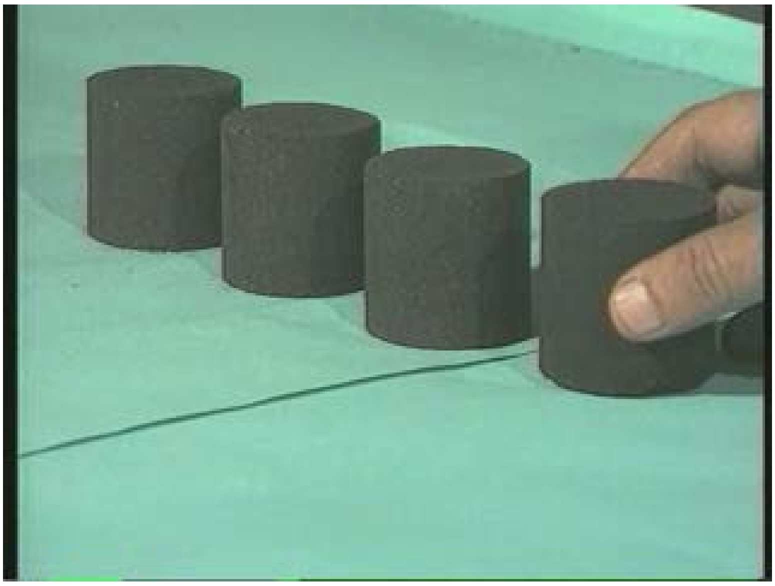

The sand specimen is placed between two fixtures.

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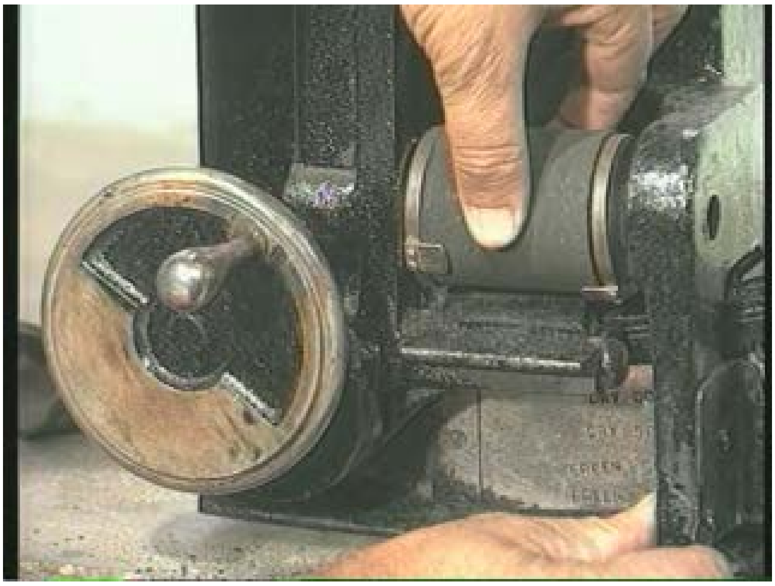

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This is the magnetic bit which indicates the strength of the sand at the point of the yielding of the specimen.

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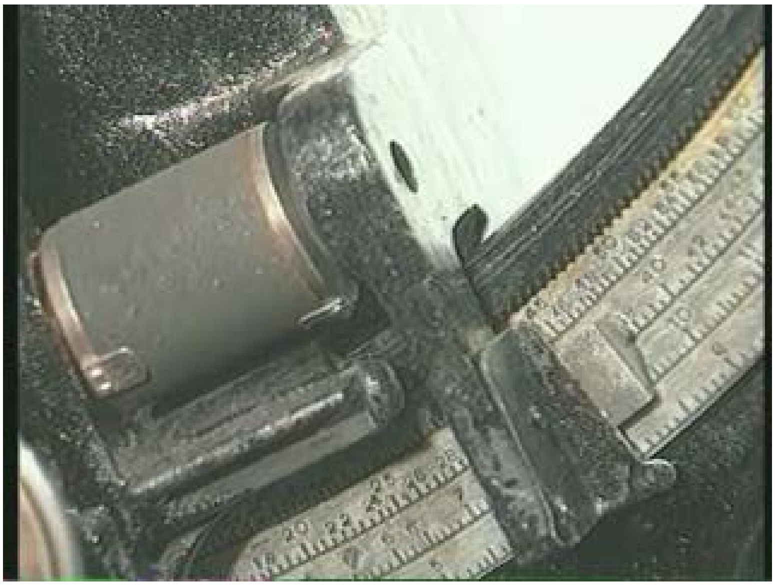

The position of the magnetic bit indicates the green compression strength.

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The metal is melted in a crucible which is heated in a heat furnace.

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