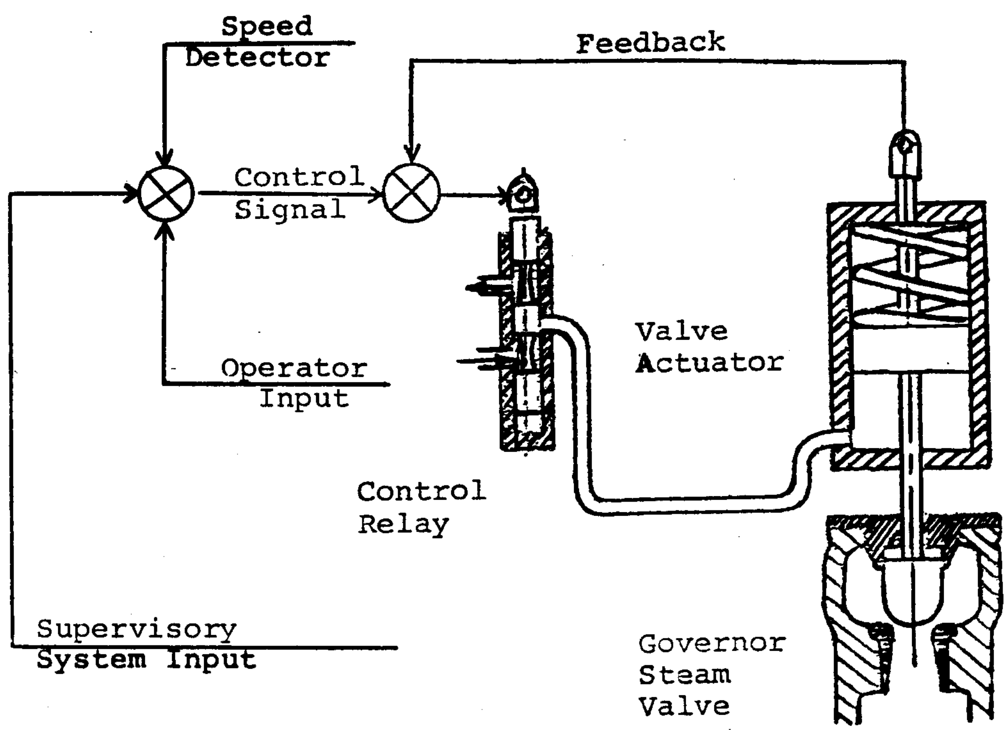
Turbine, Generator & Auxiliaries - Course 234

TURBINE GOVERNORS

We have seen in the preceding lesson how a basic governing system must function to control the steam supply to a turbine. This lesson will concentrate on the method by which two governing systems achieve this control. The two governing systems we will examine are the mechanical governor (used on all NGD turbines up through Pickering NGS-A) and the electrical governor (used on Bruce NGS-A and subsequent units).



Basic Governing System

Figure 5.1

Whatever the type of governor, it must meet certain basic requirement:

(a) There must be a method for the operator to vary the "no-load speed" of the turbine (this enables the operator to shift the position of the governor speed droop curve);

(b) There must be a speed sensor;

(c) There must be a control relay to admit hydraulic fluid to the governor steam valve power pistons;

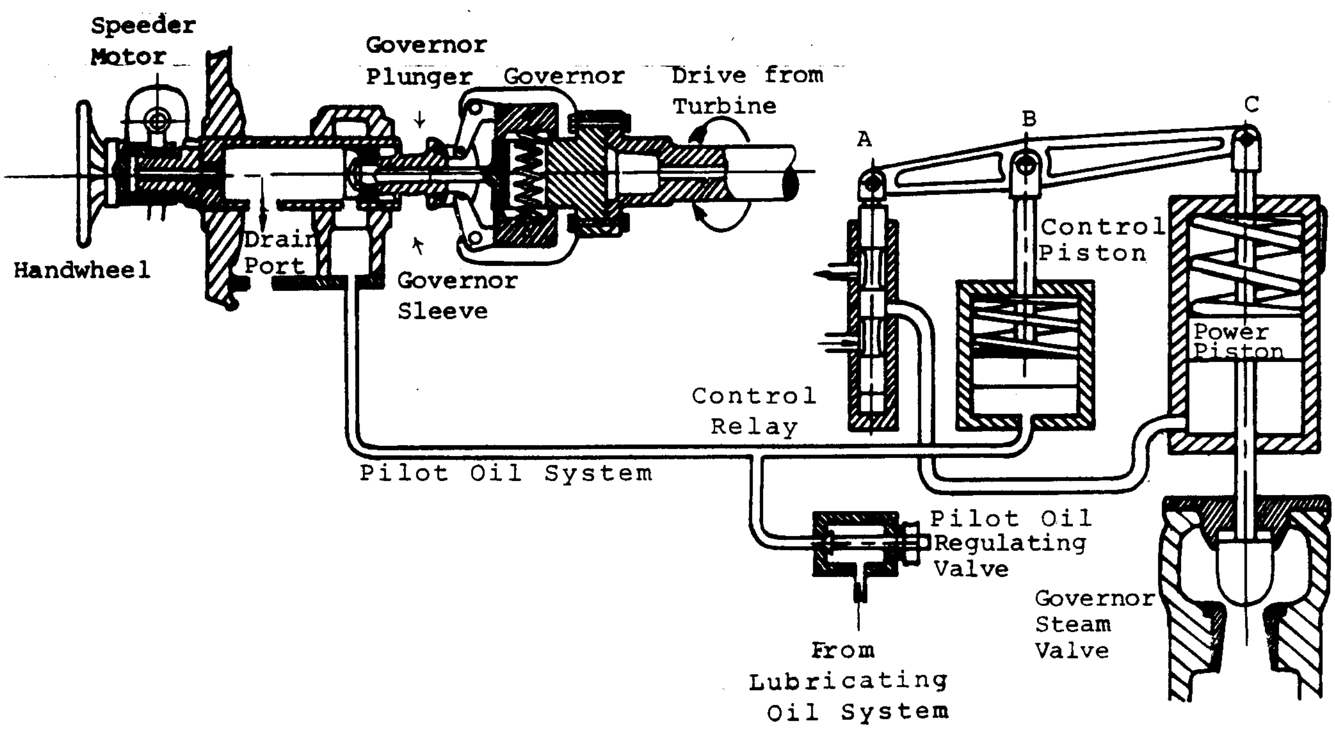
(d) There must be a method of feedback from the governor steam valve position to the control relay;

(e) There must be a method of rapidly closing the governor steam valves to shut off steam in the event the generator load is lost;

(f) There must be a method of shutting the governor steam valves during certain casualties.

The relationship of these components is shown in Figure 5.1.

Mechanical Governor



Basic Mechanical - Hydraulic Governing System

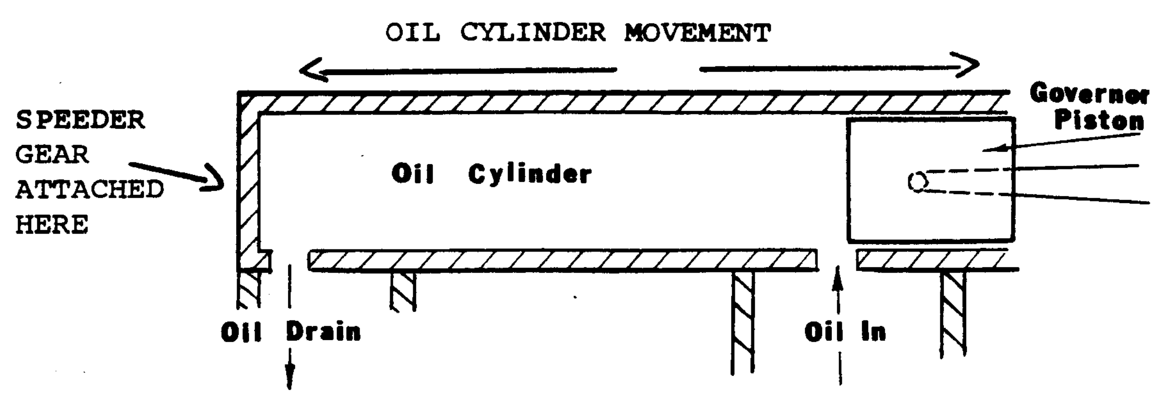
Figure 5.2

Basic Mechanical Hydraulic Governor

Figure 5.2 shows a basic mechanical governing system. Control oil is supplied at a constant rate through a Pilot Oil Regulating Valve and discharged at a variable rate through the Governor Oil Cylinder. The pressure in this Pilot Oil System is thus a function of the rate at which pilot oil is drained from the system. Depending on the opening in the governor oil cylinder, the pilot oil pressure may vary from about 200 KPa(g) to about 600 KPa(g). It is the value of this pilot oil pressure which is the control signal for governor steam valve operation.

If pilot oil pressure increases, oil pressure forces the Control Piston up against spring tension. The lever pivots on the top of the power piston (C) and pulls up the spool of the control relay. This admits Power Oil to the underside of the power piston and forces it up against spring tension. The lever now pivots on the top of the control piston (B) and pushes the spool of the control relay back to the neutral position, thus, shutting off power oil to the power piston. Therefore, the system regains equilibrium, with the governor steam valve more fully open and passing more steam.

The reverse occurs when pilot oil pressure is reduced. As oil pressure under the control piston decreases, spring tension pushes the piston down. The level pivots on the top on the power piston (C) and pushes down the spool of the control relay. This allows power oil to drain from the underside of the power piston and the power piston moves down. The lever now pivots on the top of the control piston (B) and pulls the spool of the control relay back to the neutral position, thus, shutting off the drain of oil from the power piston. Therefore, the system regains equilibrium, with the governor steam valve less fully open and passing less steam.



Governor Piston and Cylinder

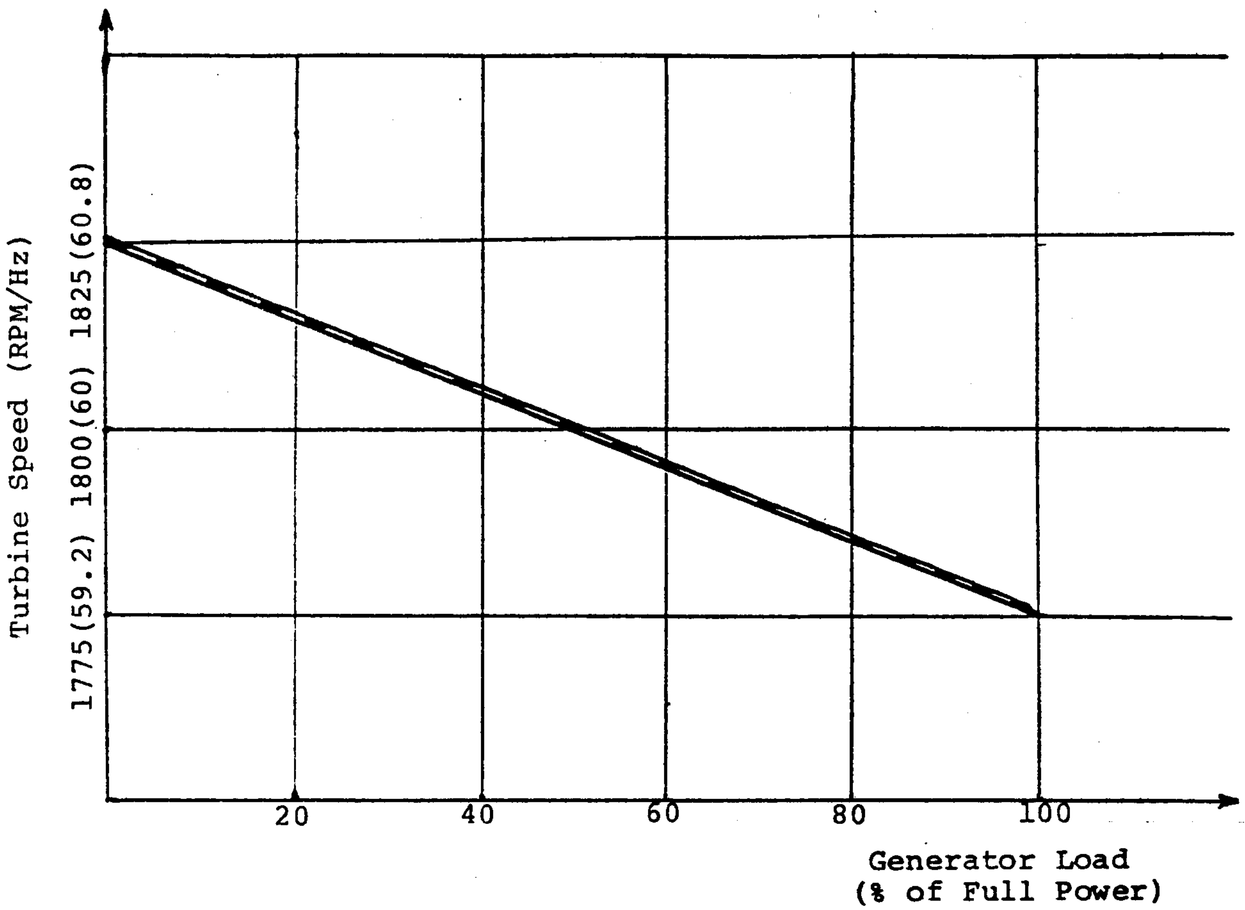
Figure 5.3

We will now turn our attention to how the governor varies pilot oil pressure. The method by which the mechanical governor senses turbine speed is by the position of the Flyballs. The flyballs are connected to the Governor Piston. As the governor piston moves, it varies the size of the opening from the pilot oil system to the governor oil cylinder (Figure 5.3). If the flyballs move out (speed increasing), the piston is withdrawn, more oil drains out, the pilot oil pressure decreases, and the governor steam valve moves in the shut direction. If the flyballs move in (speed decreasing), the piston is inserted further into the cylinder, less oil drains out, the pilot oil pressure increases, and the governor steam valve moves in the open direction.

In addition to the effect of speed on pilot oil pressure (via the flyballs and governor piston), the operator can vary pilot oil pressure through the position of the governor sleeve. The governor sleeve is moved by the Speeder Gear which is powered by an electric motor. A control signal (initiated by the operator or the computer) drives the motor to move the governor sleeve. This increases or decreases the size of the drain port, thereby varying pilot oil pressure.

It is important to keep in mind that all the governor can do is vary pilot oil pressure, and that all varying pilot oil pressure can do is open or shut the governor steam valve. The effect produced by varying governor steam valve position (varying steam flow) is dependent on whether the generator is synchronized or not synchronized to the grid, and has nothing to do with the design of the governor. For example, raising pilot oil pressure will open up on the governor steam valves and admit more steam to the turbine. Whether this increases speed or increases load has nothing to do with the governor but is a function of the external operating conditions.

You will recall from our discussion of governor operation in the last lesson that speed droop is a function of the design of the governor. Figure 5.4 shows a speed droop curve for a typical large turbine generator.



Speed Droop Curve

Figure 5.4

Consider the case of a turbine generator with this speed droop curve supplying a load. As the load is increased, the hydro-mechanical governor will respond as follows:

(a) load increases (current through generator armature increases);

(b) generator countertorque ($T = K\phi I$) increases;

(c) turbine/generator slows down;

(d) the flyballs move in (centrifugal force less than spring tension);

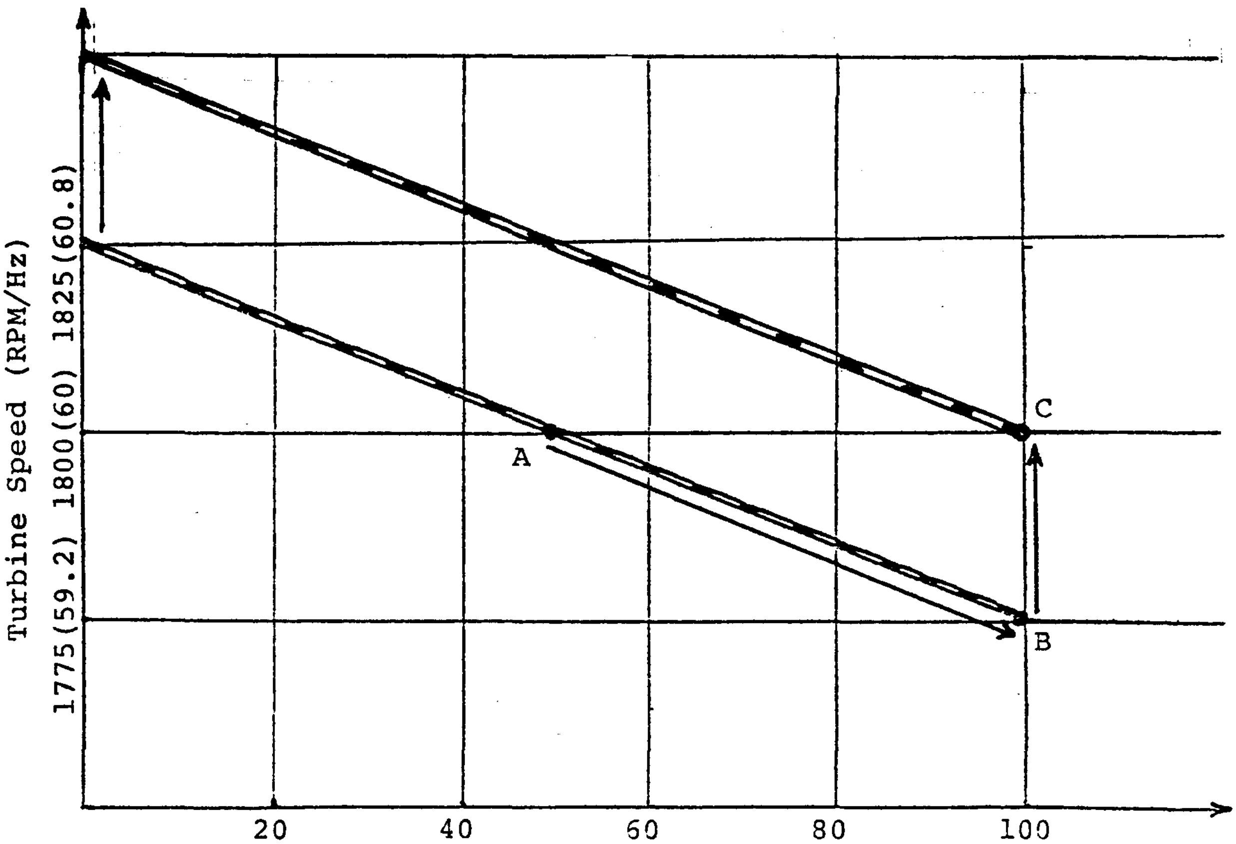
(e) the governor plunger is inserted into the governor sleeve, reducing the rate of drain from the pilot oil system;

(f) pilot oil pressure increases;

(g) the governor steam valve opens further, admitting more steam.

The turbine is now supplying the increased load. However, the speed does not return to the original value rather some lower value. This is, of course, speed droop and is a function of relative value of the spring force and flyball centrifugal force.

It is, however, desirable to keep the turbine/generator operating at a constant frequency. In order to restore the speed of the turbine (frequency) to its original value, the speeder gear is moved in the "raise speed" direction. This moves the governor sleeve to close off the drain port, increasing pilot oil pressure and opening up on the governor steam valves to supply the load at the original speed (frequency). This is shown in Figure 5.5.



Effect of Load Change

Figure 5.5

If a turbine generator with this speed droop is supplying the Ontario grid system, the grid frequency will not vary substantially from 60 Hz. This means that, under normal conditions, the speed of the turbine/generator will remain substantially at 1800 rpm for a 4 pole generator.

In this case (generator synchronized to an infinite bus), the effect of increasing steam flow is to increase the power out of the generator. Since speed cannot change, if more steam power is put in, more must be supplied by the generator.

Load Rejection

If the generator output breaker trips open due to an electrical fault, the speed of the turbine will start to increase. The flyballs will be thrown outward, withdrawing the governor piston from the governor oil cylinder. This dumps pilot oil to drain. As pilot oil pressure is reduced, the control piston is pushed down under spring tension. This lowers the spool of the control relay and dumps power oil to drain. This shuts the governor steam valve.

The mechanical hydraulic governor has two inherent weaknesses which decreases its ability to handle an overspeed following load rejection:

1. The dead time associated with the reservoir effect of low pressure lubricating oil. The time necessary to move the large volume of pilot oil and power oil to shut the governor steam valves, results in excessive overspeeds.

2. When the governor finally gets control of turbine speed, it will attempt to control speed at the no load speed determined by the speed droop curve. This no load speed may be as much as 5% above the normal operating speed. This means the governor has a built-in bias which works against holding speed down on a load rejection. Even though the speeder gear is driven back to the position corresponding to a no-load speed of 1800 rpm, it cannot move fast enough to eliminate the effect of speed droop.

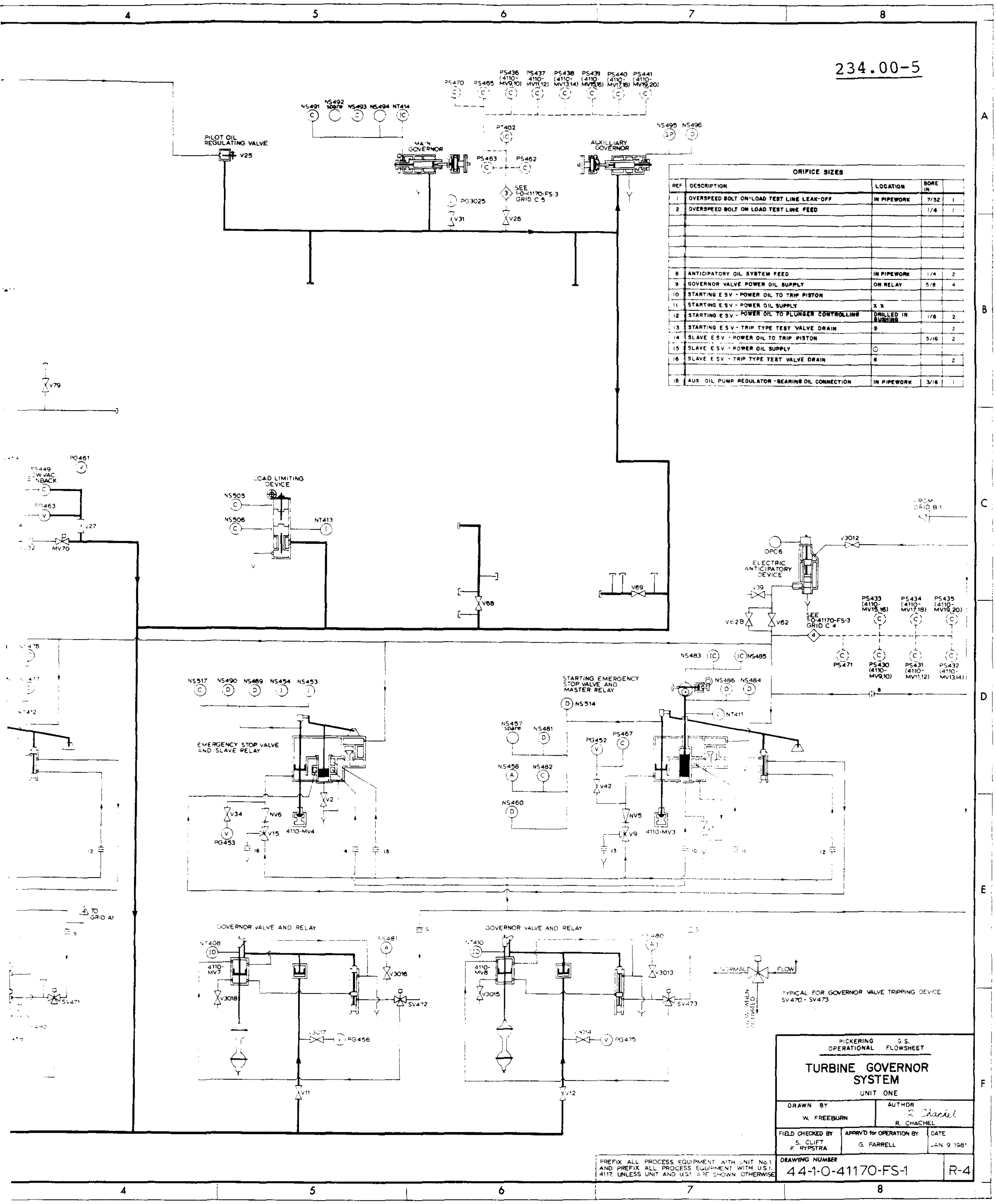
One method of attempting to eliminate both of these problems is the use of an auxiliary governor which operates in parallel with the main governor. This auxiliary governor has no speed droop and is set to spill oil at a constant 1% above normal operating speed. On an overspeed following a load rejection, the auxiliary governor begins to spill oil at 1% above operating speed (1818 rpm for an 1800 rpm turbine). The auxiliary governor not only aids the main governor in dropping pilot oil pressure but also will attempt to control speed at 1% overspeed until the speeder gear has run back to main governor. This effectively eliminates the speed droop bias of the main governor on an overspeed following load rejection.

In the upper, right hand corner of Figure 5.6 you can see the main and auxiliary governor of the Pickering NGS turbine. You can also trace the pilot oil system from the pilot oil regulating valve to the control relays of each of the four governor steam valves.

The unfortunate fact about the mechanical hydraulic governor is that on large turbines, the dead time produced by reservoir effect in the governing system is unacceptably long. The main and auxiliary governors together are not capable of limiting the overspeed following a load rejection to acceptable levels. To limit the amount of overspeed, the governing system must be aided by an electric anticipator.

The governor system shown in Figure 5.6 contains two electric anticipators which operate in parallel. If the generator output breaker opens under load, the electric anticipators are tripped by auxiliary contacts on the breaker. The electric anticipator dumps power oil to drain which shuts the emergency stop valves. At the same time, the low power oil pressure, trips pressure switches which shut the intercept valves and open the release valves.

After five seconds the main and auxiliary governors have regained control of turbine speed. At this time, the electric anticipators reset, and the emergency stop valves and intercept valves reopen and the release valves shut. The turbine will thus end up with the steam control valves (ESV, IV and RV) in their normal position, with the auxiliary governor controlling turbine speed. As the speeder gear is run back, the main governor will eventually gain control of the governor steam valves and lower speed from 101% (auxiliary governor) to 100% of operating speed. Figure 5.7 shows the response to a load rejection of a typical mechanical hydraulic governing system.



ORIFICE SIZES

REF	DESCRIPTION	LOCATION	BORE IN	
1	OVERSPEED BOLT ON-LOAD TEST LINE LEAK-OFF	IN PIPEWORK	7/32	1
2	OVERSPEED BOLT ON LOAD TEST LINE FEED		1/4	1
8	ANTICIPATORY OIL SYSTEM FEED	IN PIPEWORK	1/4	2
9	GOVERNOR VALVE POWER OIL SUPPLY	ON RELAY	5/8	4
10	STARTING E S V - POWER OIL TO TRIP PISTON			
11	STARTING E S V - POWER OIL SUPPLY	X X		
12	STARTING E S V - POWER OIL TO PLUNGER CONTROLLING	DRILLED IN BUSHING	1/8	2
13	STARTING E S V - TRIP TYPE TEST VALVE DRAIN	*		2
14	SLAVE E S V - POWER OIL TO TRIP PISTON		5/16	2
15	SLAVE E S V - POWER OIL SUPPLY	⊙		
16	SLAVE E S V - TRIP TYPE TEST VALVE DRAIN	*		2
18	AUX OIL PUMP REGULATOR - BEARING OIL CONNECTION	IN PIPEWORK	3/16	1

PICKERING G.S.
OPERATIONAL FLOWSHEET

TURBINE GOVERNOR SYSTEM

UNIT ONE

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FIELD CHECKED BY	APPR'V'D for OPERATION BY	DATE
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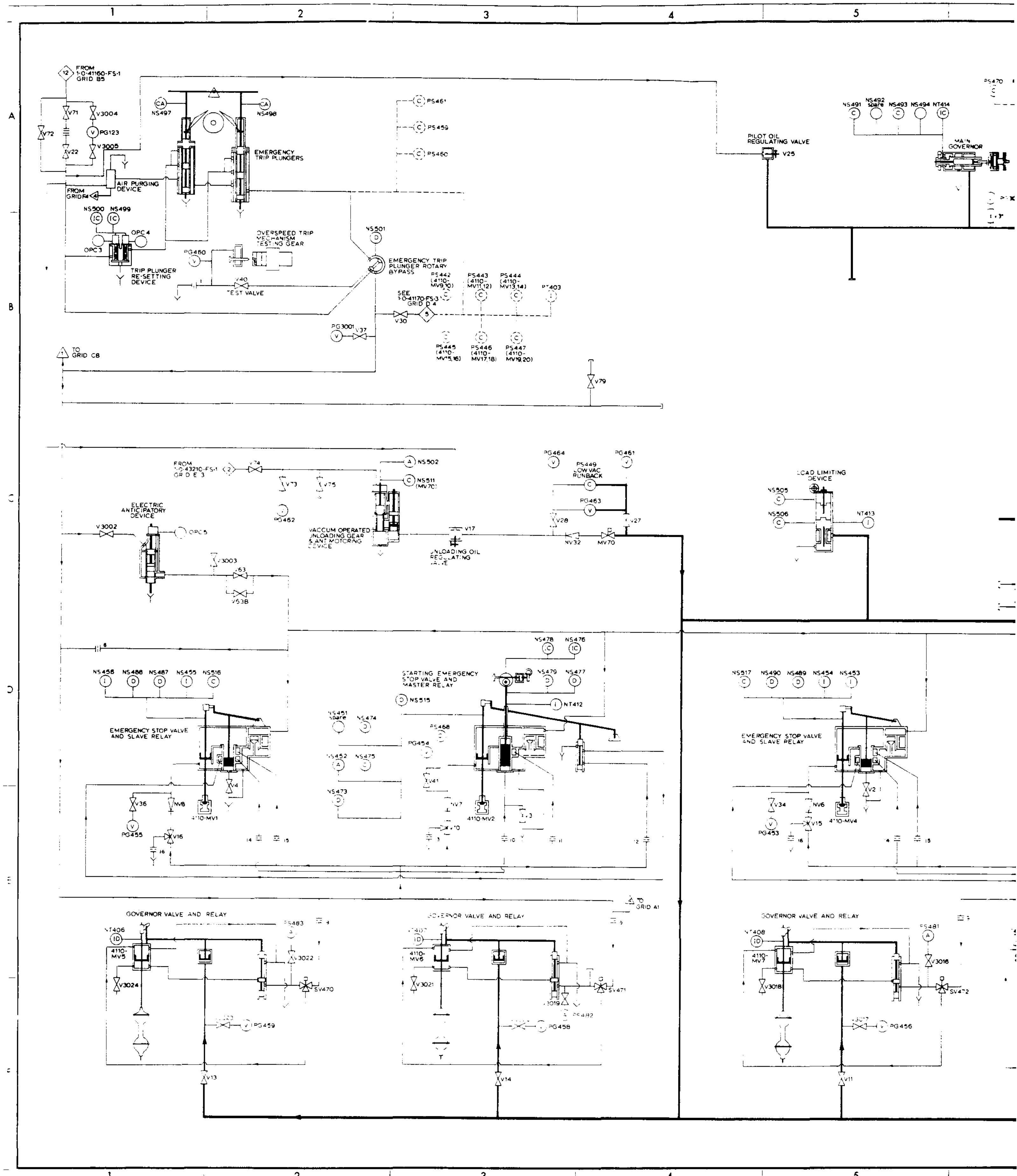

FROM 1-0-41160-FS-1 GRID B5
AIR PURGING DEVICE
FROM GRID F4
EMERGENCY TRIP PLUNGERS
TRIP PLUNGER RE-SETTING DEVICE
OVERSPEED TRIP MECHANISM TESTING GEAR
TEST VALVE
EMERGENCY TRIP PLUNGER ROTARY BYPASS
SEE 1-0-41170-FS-3 GRID D4
TO GRID C8
PILOT OIL REGULATING VALVE
MAIN GOVERNOR
FROM 1-0-43210-FS-1 GRID E3
ELECTRIC ANTICIPATORY DEVICE
VACCUM OPERATED UNLOADING GEAR & ANT MOTORING DEVICE
UNLOADING OIL REGULATING VALVE
LOW VAC RUNBACK
LOAD LIMITING DEVICE
EMERGENCY STOP VALVE AND SLAVE RELAY
STARTING EMERGENCY STOP VALVE AND MASTER RELAY
EMERGENCY STOP VALVE AND SLAVE RELAY
GOVERNOR VALVE AND RELAY
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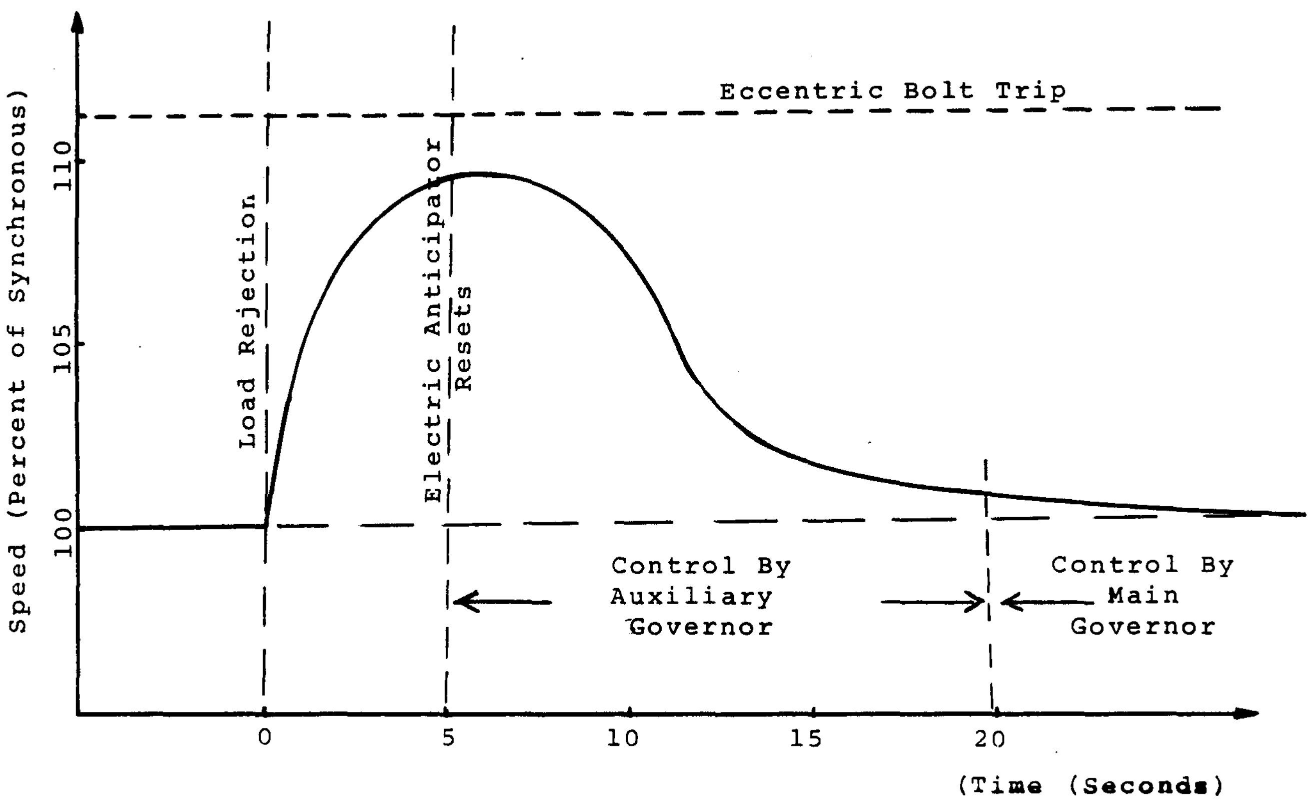
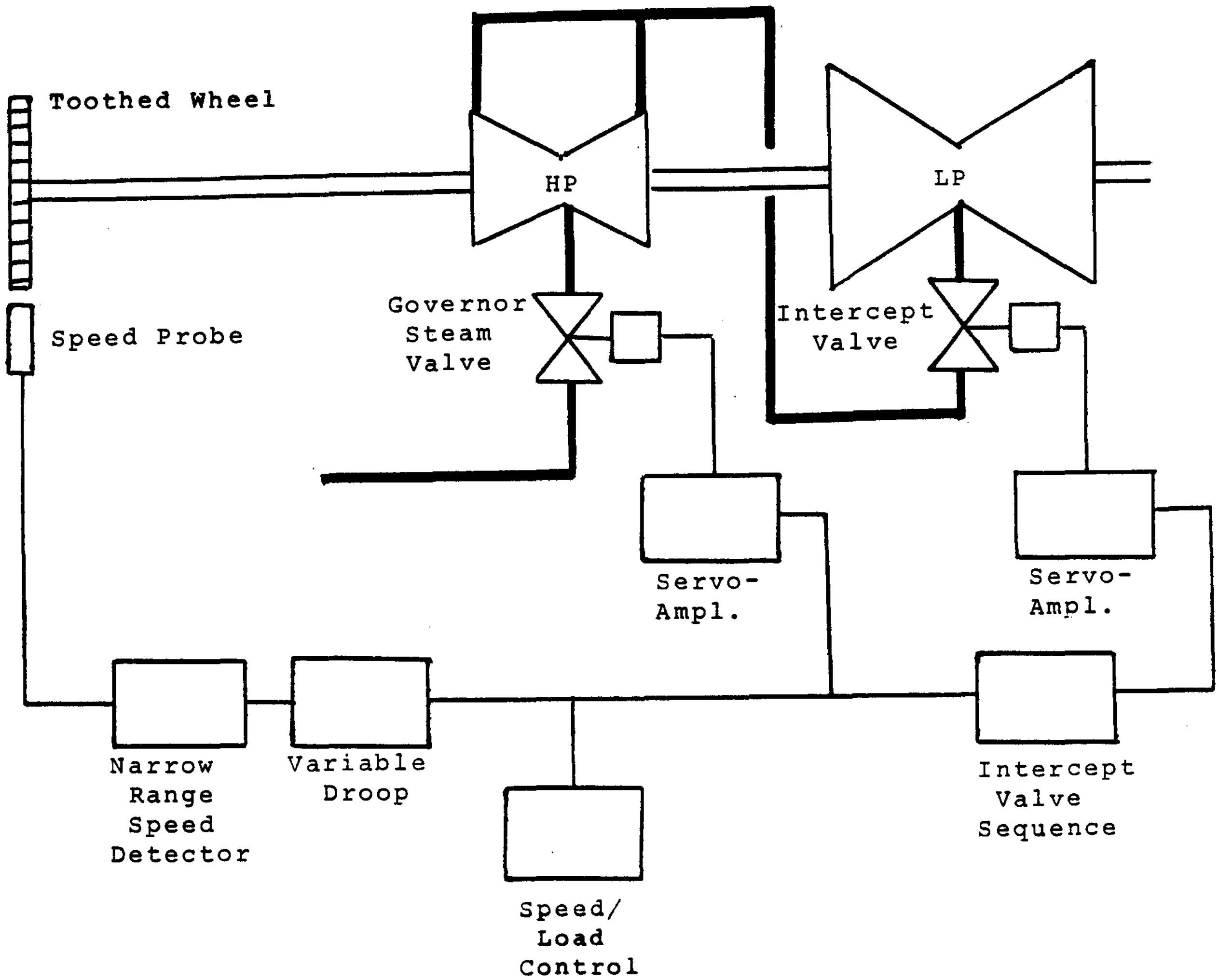
GOVERNOR VALVE AND RELAY
TO GRID A1



Mechanical Hydraulic Governing System on Load Rejection

Figure 5.7

Electrical Governor



Basic Electrical-Hydraulic Governing System

Figure 5.8

Basic Electrical - Hydraulic Governor

Figure 5.8 shows a basic electrical governing system. The turbine speed is sensed through a probe which counts the teeth passing it on a toothed wheel attached to the shaft. By calculating the rate at which the teeth pass the probe, the speed of the turbine can be calculated. The output of the narrow range speed sensor is fed through the speed droop control to the servo-amplifiers for the governor steam valves and intercept valves. A typical servo control system is shown in Figure 5.9. The intercept valves are sequenced so as to be fully open any time the governor steam valves are more than 25% open, and to be 50% open when the governor steam valves are fully shut.

The opening of the governor steam valves and intercept valves is accomplished through the speed/load control which is the electrical governing system's equivalent of the speeder gear. As with the mechanical governor, the input to the speed/load control may be either manual, computer loading or runback.

In the mechanical hydraulic governor the speed droop is a function of the design of the governor, and as such is virtually a constant. In the electrical governor, however, it is reasonably easy to vary the speed droop to obtain the most desirable droop setting for a particular operating condition. The droop setting is variable between 1% and 12%. Basically, the droop is high (12%) at operating speed when not connected to the grid. The droop is moderate (4%) when at operating speed and synchronized to the grid. The droop is low (1%) on a load rejection.

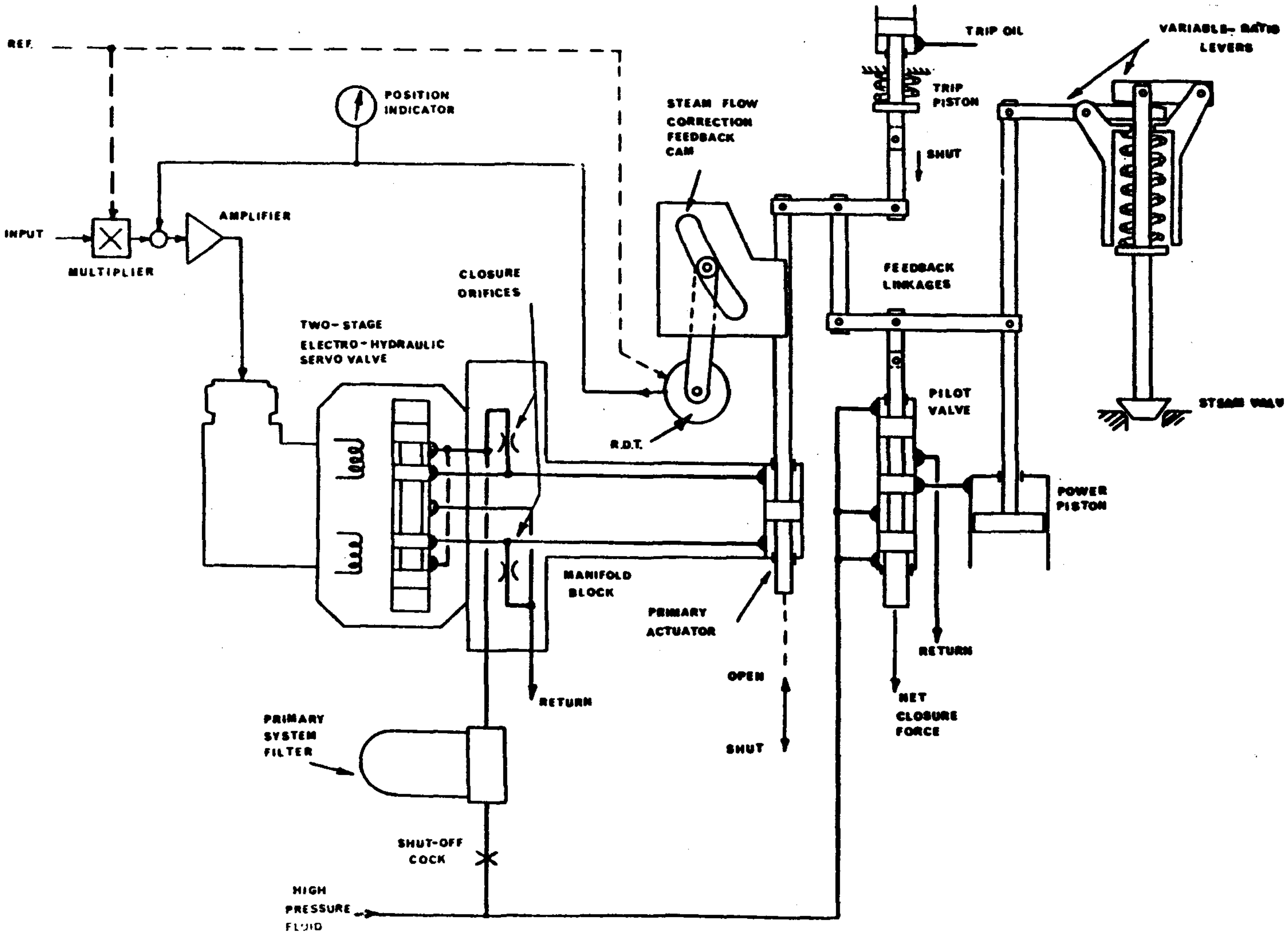
Figure 5.10 shows a schematic block diagram of the electrical hydraulic governing system. The wide range speed detector is used to control the emergency stop valves during run up to operating speed. Once at operating speed, the wide range speed detector plays no role in normal or abnormal speed control.

Load Rejection

The basic difference between the response of the electrical hydraulic governor and the mechanical hydraulic governor on a load rejection, is that the electrical hydraulic governor is so much faster. Because of the use of electrical signals and high pressure FRF, dead time is virtually eliminated. During a full load rejection, the governor can control the entire overspeed without operation of the emergency stop valves.

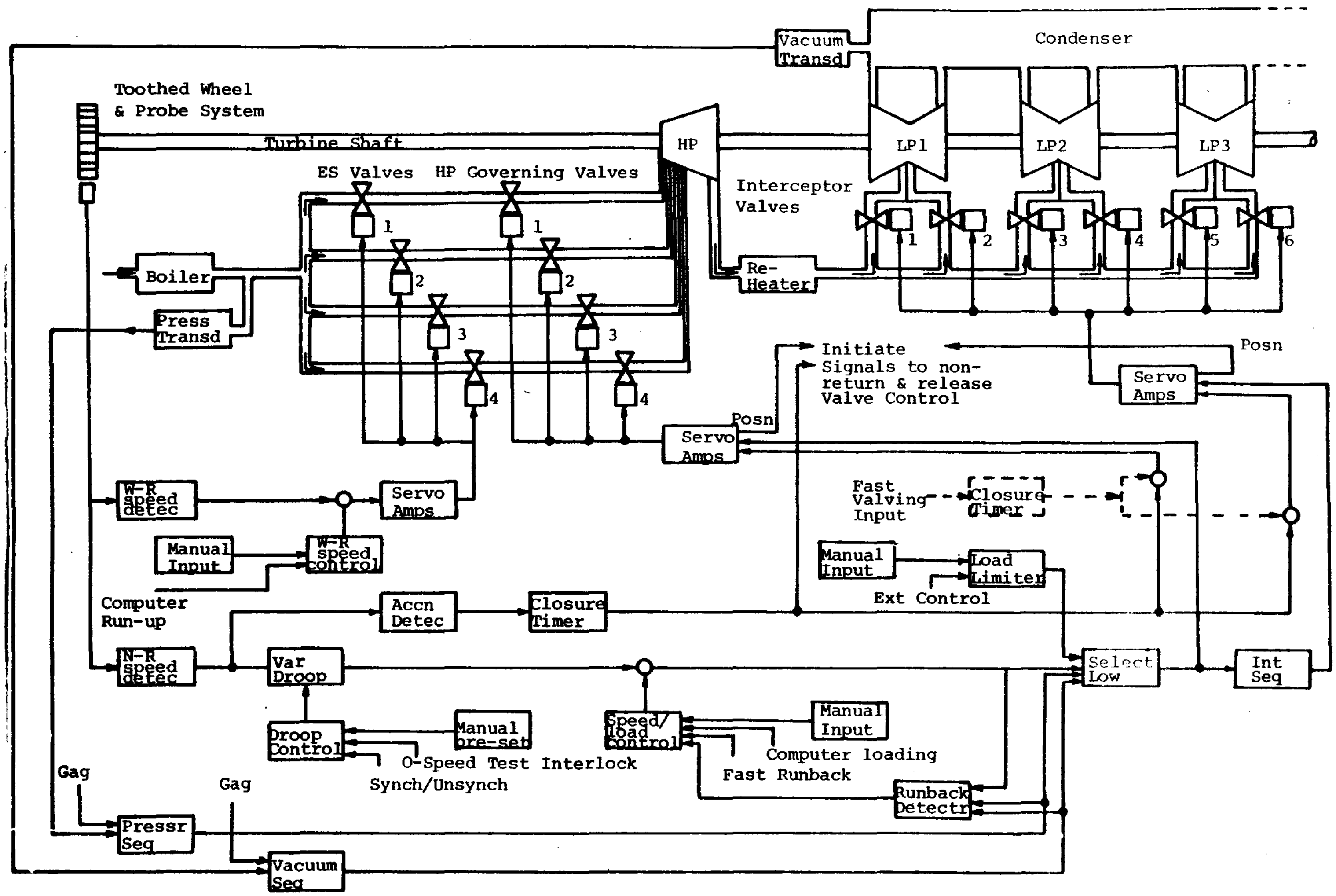
The electrical governing system has two features which come into operation during a load rejection:

1. An acceleration detector senses the rapid increase in speed from the narrow range speed detector. This rapid acceleration initiates a fast valving input which feeds an overriding signal to the governor steam valves and intercept valves. Regardless of what other mode the



Governor Steam Valve Control System

Figure 5.9



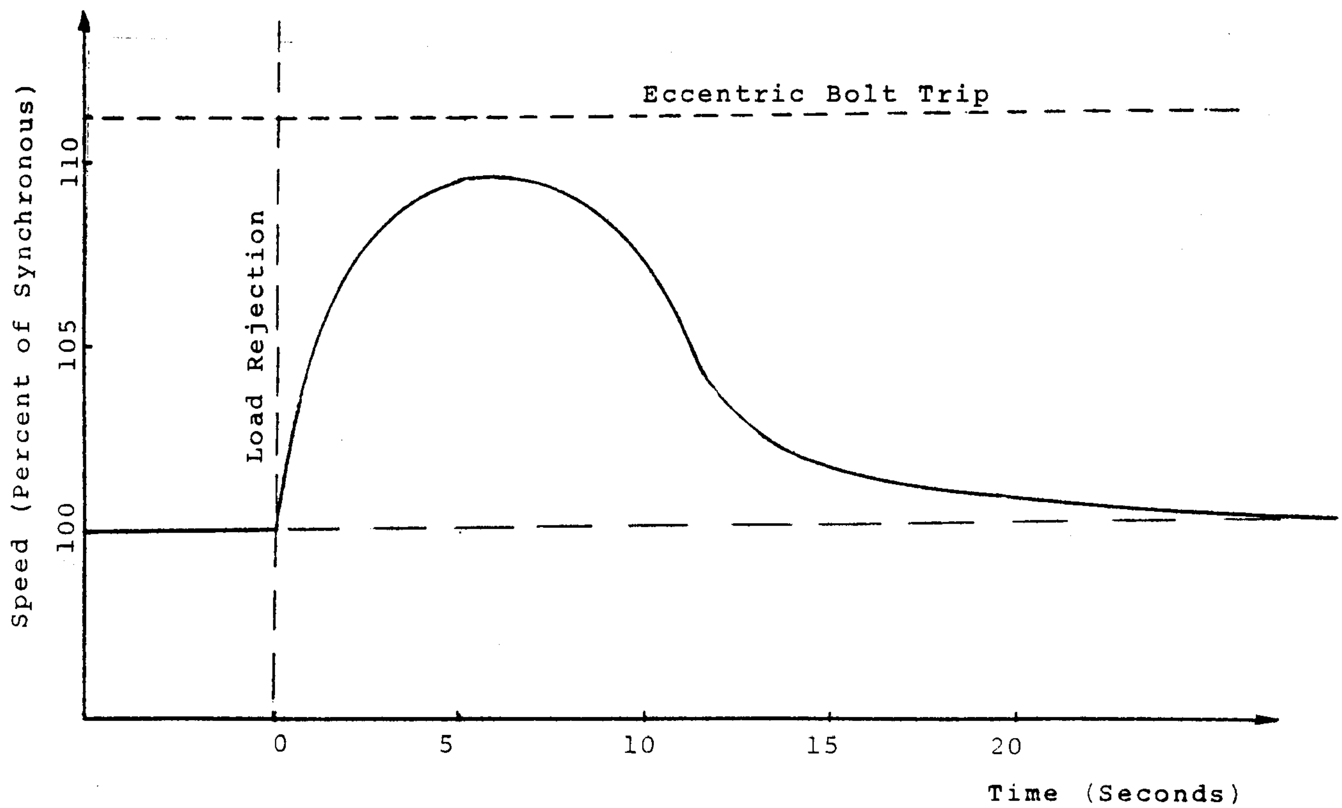
Block Diagram of Electrical-Hydraulic Governing System

Figure 5.10

valves may be in, this signal fully closes the valves at the fastest possible rate. The closure of the intercept valves and governor steam valves initiates the signal to close the extraction steam non-return valves and open the release valves.

2. When the generator becomes unsynchronized by a load rejection, the droop control shifts the speed droop to 1%. This serves the same function as the auxiliary governor in the mechanical hydraulic governing system. The shift in speed droop will insure the turbine returns to a no-load speed of only 1% overspeed until the speed/load control drives the no-load speed back to 1800 rpm.

Figure 5.11 shows the response to a load rejection of a typical electrical-hydraulic governing system.



Electrical - Hydraulic Governing System on Load Rejection

Figure 5.11

Eccentric Bolt Emergency Trip Plunger

Regardless of whether the turbine is equipped with an electrical or mechanical governing system, it will have an eccentric bolt emergency tripping device. This device will shutdown the turbine on overspeed and is set high enough (110%-112% of operating speed) to be required to operate only if the other overspeed devices don't control the speed. That is, if the normal overspeed devices operate properly, the eccentric bolt emergency tripping device should never have to operate.

The tripping mechanism of the eccentric bolt tripping device is shown in Figure 5.12. Spring tension holds the bolt in against centrifugal force. At the trip speed, centrifugal force overcomes spring tension and the bolt is thrown out, contacting a tripping latch. This action operates a plunger which directly or indirectly dumps the fluid holding open the steam admission valves.

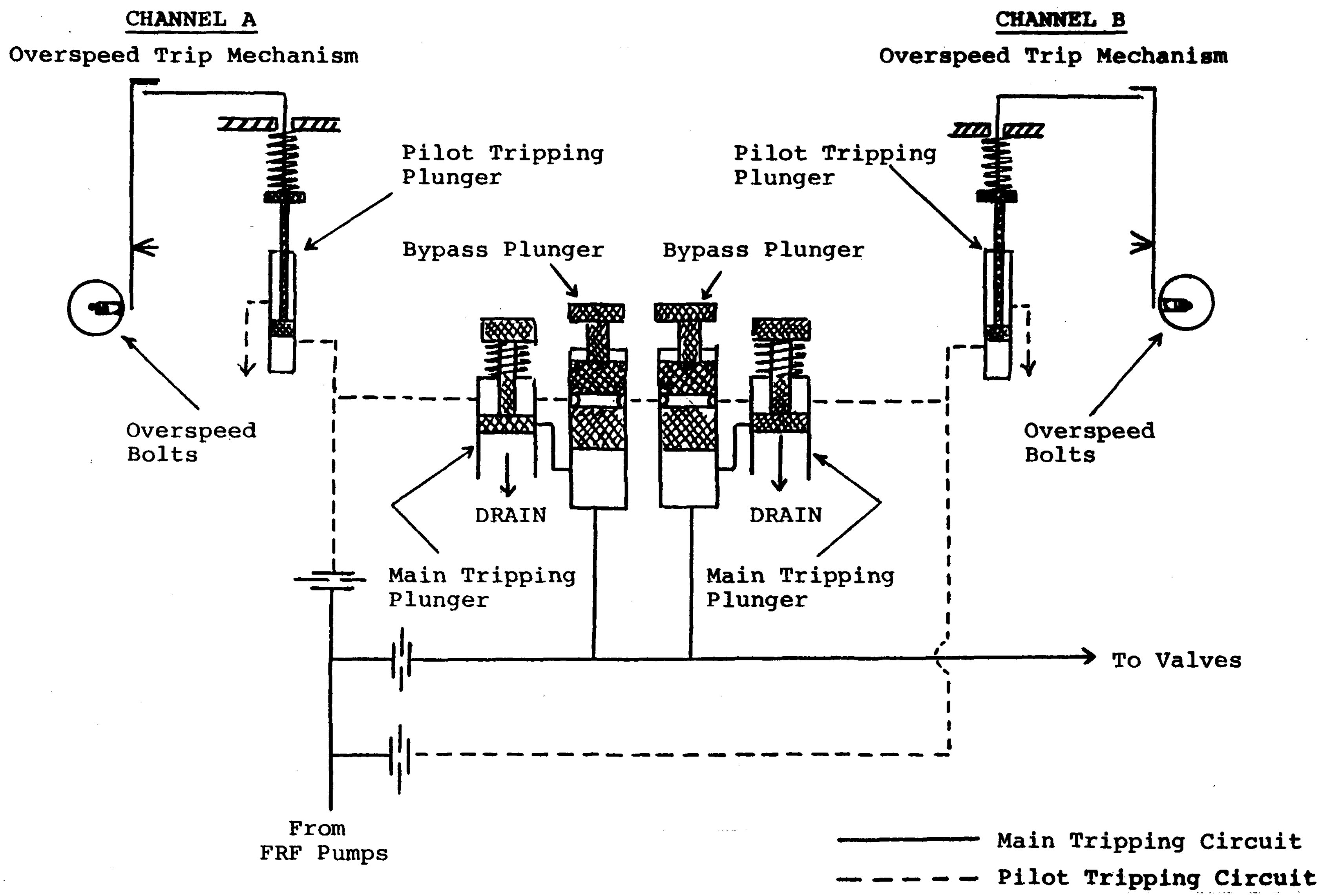
In the case of the mechanical hydraulic governor (Figure 5.6), the eccentric bolt tripping device dumps power oil which closes the emergency stop valves and governor steam valves. The decreasing power oil pressure in turn trips pressure switches which initiates air signals to shut the intercept valves and open the release valves.

In the case of the electrical hydraulic governor, the eccentric bolt tripping device dumps FRF which closes the emergency stop valves, governor steam valves, intercept valves and reheat emergency stop valves. The shutting of the GSVs and IVs initiates a signal to open the steam release valves and shut the extraction steam non-return valves.

Load Limiter

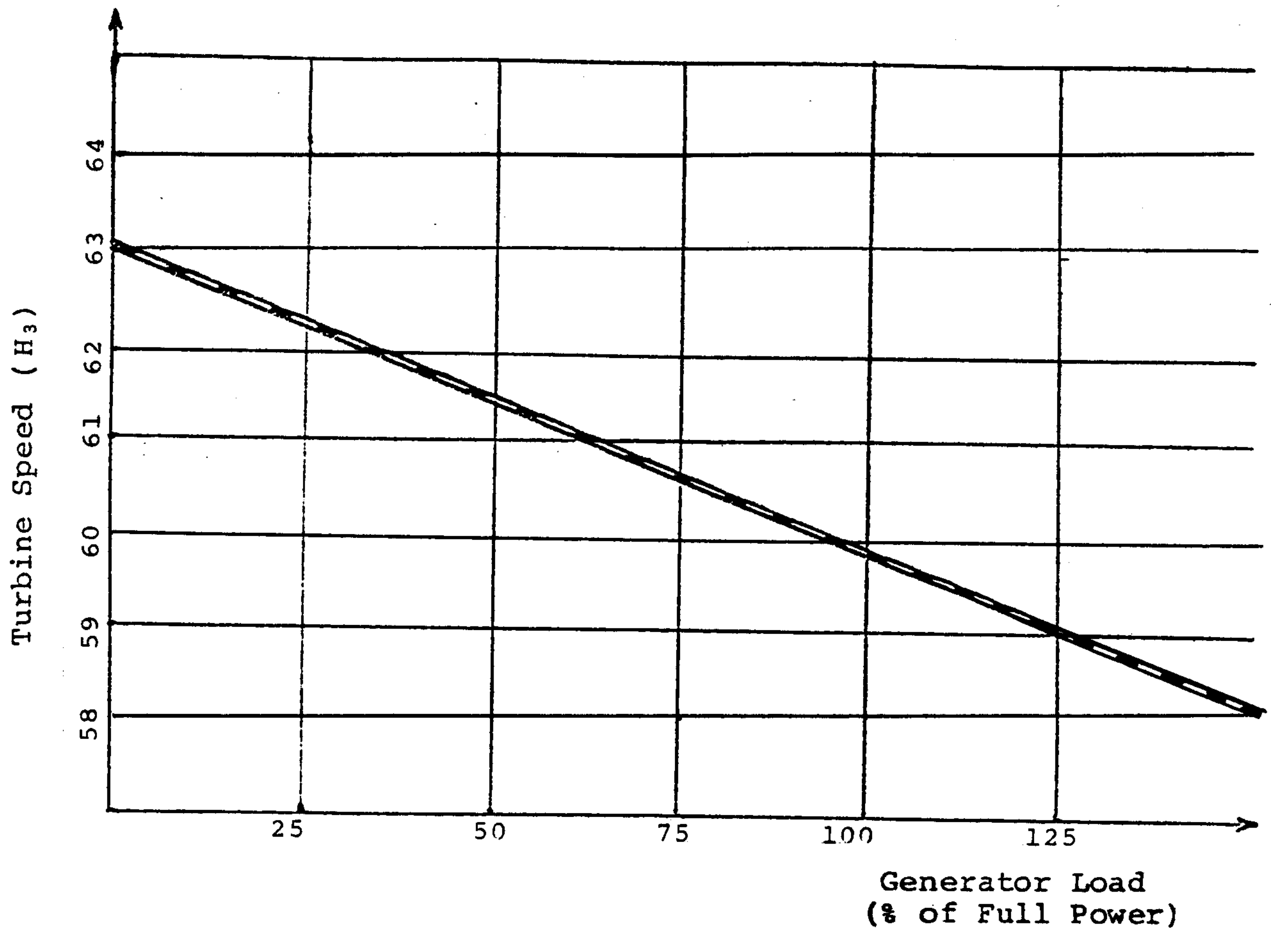
Figure 5.13 shows a typical speed droop curve. If grid frequency were to fall due to a system disturbance, the governor steam valves would open further. This overpowering of the turbine might cause physical damage to the turbine. It may also be necessary to limit load to some value below 100% maximum continuous rating. The load limiter can be adjusted to provide an upper limit to steam flow to the turbine by limiting the opening of the governor steam valves.

In the mechanical hydraulic governor this is done by restricting pilot oil pressure to a maximum value. In the electrical hydraulic governor this is done by a select low feature which limits the governor steam valve opening signal to the lower of that determined by the speed droop or the load limiter.



Overspeed Tripping Circuit

Figure 5.12



Speed Droop Curve

Figure 5.13

Anti-Motoring Device

Small turbine generators usually have a reverse power trip associated with their output breaker which opens the breaker on reverse power to prevent motoring. On large turbine generators, motor is permitted and such reverse power trips do not exist.

There must exist some feature, however, to prevent trying to start the turbine from the generator end by closing the output breaker when the turbine is shutdown. The generator is not designed to withstand the large overcurrents associated with starting the unit with the generator acting as an induction motor. The anti-motoring device prevents closing the output breaker if the emergency stop valves are shut.

ASSIGNMENT

1. For a mechanical hydraulic governing system, explain the part the following play in limiting an overspeed following load rejection:

   (a) electric anticipator,
   (b) main governor,
   (c) auxiliary governor,
   (d) speeder gear,
   (e) eccentric bolt emergency trip device.

2. For an electrical hydraulic governing system, explain the part the following play in limiting an overspeed following load rejection:

   (a) narrow range speed detector,
   (b) acceleration detector,
   (c) variable droop control,
   (d) speed/load control,
   (e) emergency trip plunger.

3. How is active load varied:

   (a) with a mechanical hydraulic governor?
   (b) with an electrical hydraulic governor?

4. Explain the advantages of an electrical hydraulic governor system using FRF over a mechanical hydraulic governor using lubricating oil.

5. What is the function of the load limiter?

6. What is the function of the anti-motoring device?

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