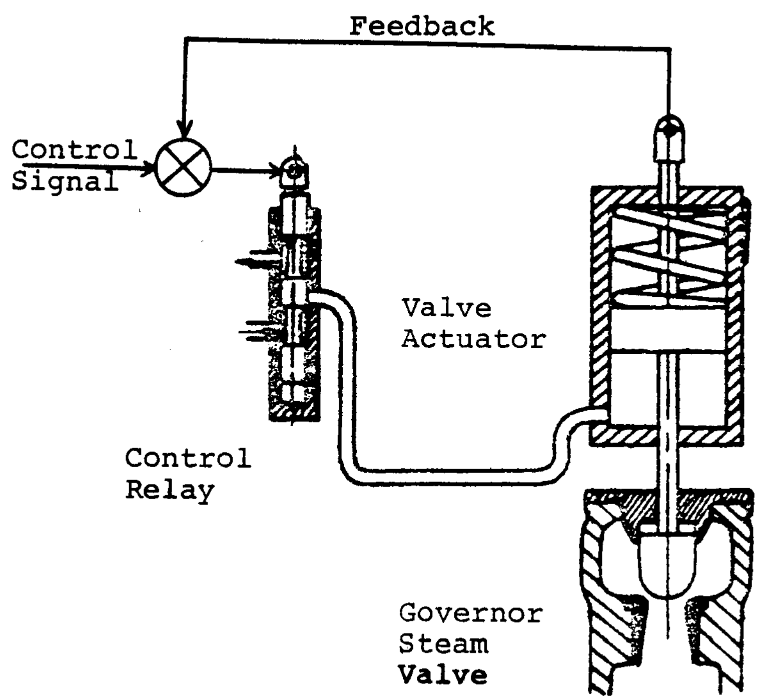
Turbine, Generator & Auxiliaries - Course 234

STEAM VALVE HYDRAULIC CONTROL

The movement of large control valves to regulate the steam supply to modern steam turbines, requires amplification of the control signals in both force and displacement to provide sufficient force to actuate the valves. Whether the control signal from the governor is mechanical or electrical, the signal is converted to a hydraulic fluid pressure for movement of the governor steam valves. The hydraulic relay and actuator has no competitor as a force amplifier for governor steam valve actuation. No other form of mechanical or electrical amplifier can develop the very high force demanded by the speed at which the governor steam valves, of modern turbines, must operate.



Steam Valve Actuation

Figure 3.1

Figure 3.1 shows the basic hydraulic relay and actuator associated with a governor steam valve. The governor steam valve is opened by increasing the hydraulic pressure on the underside of the actuator piston and compressing the spring; the governor steam valve is shut by draining oil from the underside of the actuator piston and allowing the spring to expand and force the valve shut. The control relay is positioned either mechanically or electrically to supply fluid to, or drain fluid from, the actuator. Mechanical or electrical feedback is provided to position the control relay to neutral and stop the flow of fluid when the governor steam valve has moved to the desired position.

There are two hydraulic fluids which are used for governor steam valve actuation:

(a) turbine lubricating oil, and
(b) a phosphate ester, fire resistant fluid.

Turbine lubricating oil has been used for many years as the hydraulic fluid for governor steam valve actuation. Lubricating oil is readily available and does not require a separate pumping system nor a separate purifying system, when used as a control fluid. In addition, if the lubricating oil system should fail, the governor steam valves will shut since it is lubricating oil which is holding them open. Lubricating oil has several disadvantages, although they were not serious enough to preclude its use as a control fluid:

1. The control fluid has to be compatible with bearing lubrication. That is, the fluid is chosen not for its properties as a control fluid but rather for its properties as a lubricant.

2. The lubricating oil is subject to all manner of contamination which tends to degrade its purity. These include: fibres, water, chlorides, dirt, rust and sludge.

The principle disadvantage of using lubricating oil, as a control fluid, did not become apparent until turbines became fairly large.

The larger the steam flow handled by turbines, the larger the governor steam valves had to be and the greater the force necessary to move the valves at the required speeds. Since Force = (Pressure) (Area), the larger force could be gained in one of two ways:

1. increase the pressure of the control oil, or

2. make the actuators larger.

The upper limit of control oil pressure is about 1,000 kPa(a). This is determined by the fire hazard involved in lubricating oil leaking from the system and soaking thermal insulation in contact with hot steam pipes. Since it is virtually impossible to prevent oil leaks in high pressure hydraulic systems, the only effective way to eliminate this fire hazard is to keep the lubricating oil under low pressure. In addition, since the flow through the control oil system is a very small percentage of the flow to the bearings, the use of high pressure control oil requires needlessly pressurizing a large volume of oil intended for the bearings.

The alternative method of developing a large force, that of making the actuator larger, also has its limitation. As the actuators get larger, the volume of oil which must be moved to effect a response becomes greater and greater. This "reservoir effect", as it is called, results in significant time delays between the initiation of a control signal and the response, as large quantities of oil are moved about the control oil system. The time between the initiation of signal and its execution is known as the dead time or time delay and in large turbine governing systems the combined effects of mechanical inertia and oil reservoir effect can result in significant dead time.

The governing system on the 540 MW Pickering NGSA turbine represents nearly the limit to which lubricating oil control systems can be pushed. Even in this system the exclusive use of lubricating oil for control valve actuators would have resulted in unacceptable dead times. As a result, while the governor steam valves and emergency stop valves have hydraulic actuators, the intercept valves and steam release valves are air operated. This eliminates the long runs of control oil piping which would be necessary to supply these valves with control oil. In addition, the control oil system at Pickering NGSA is equipped with anticipator devices, to decrease the response time of the control oil system. While the use of a lubricating oil control oil system, at Pickering NGSA has proved entirely acceptable the use of lubricating oil on larger units has not been possible.

The dead time associated with large turbines using lubricating oil control oil systems has been virtually eliminated by use of high pressure, hydraulic systems, using a fire resistant fluid. The fire resistant fluid used in most electrical-hydraulic governing systems is a synthetic phosphate ester hydraulic fluid. The fluid looks like and feels like a light mineral oil. It has good lubricating properties and excellent stability. The FRF used by Ontario Hydro has an excellent combination of chemical and physical properties: low particle count, low chlorine content, high electrical resistivity and negligible corrosion of most metals. This makes it a good fluid for use in the close tolerance valves, limit switches and overrides which are used in electrical-hydraulic governing systems. Above all, FRF virtually eliminates the fire hazard associated with conventional petroleum oils leaking onto hot steam lines.

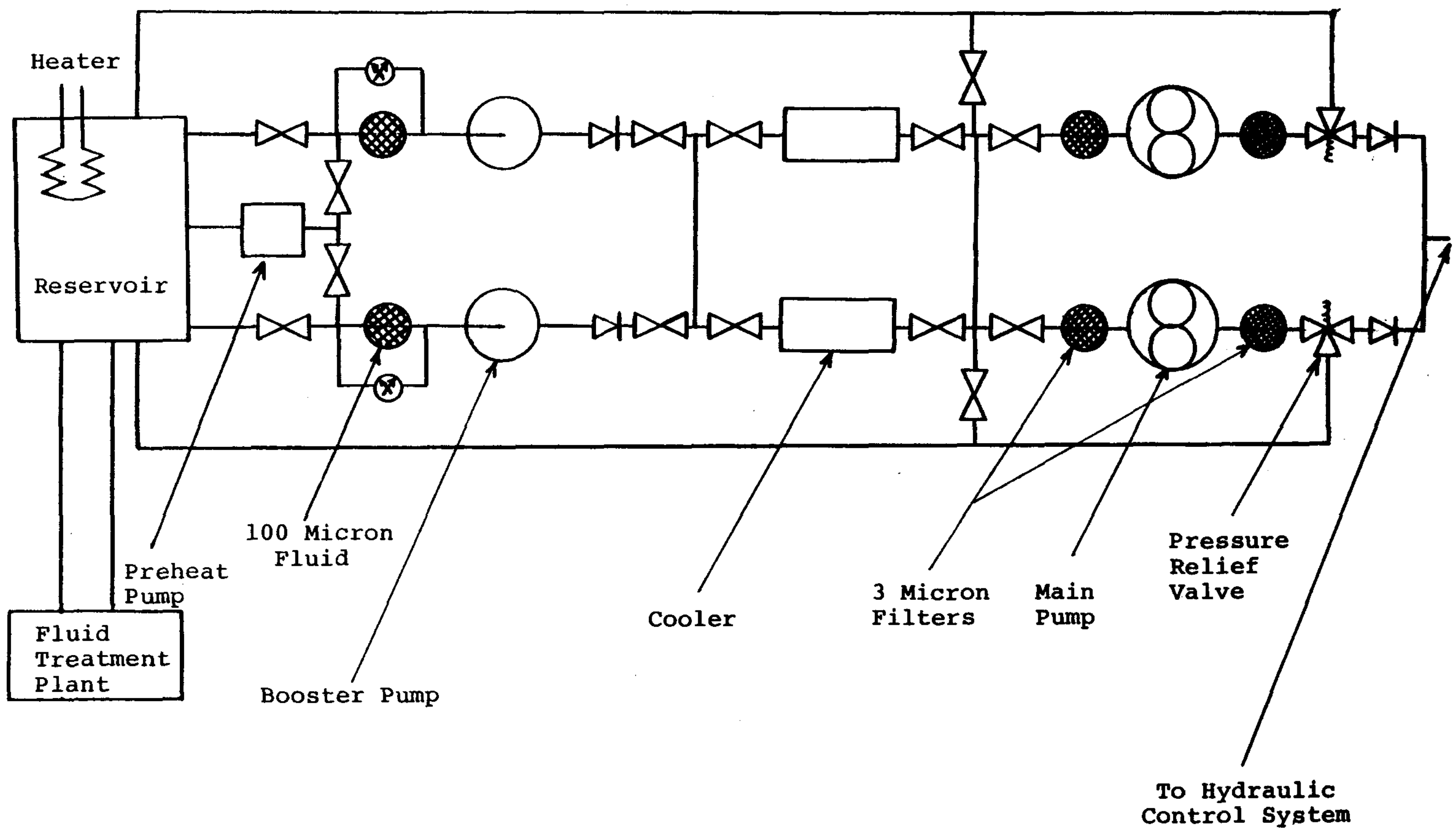
Figure 3.2 shows a typical FRF hydraulic power plant. The pumping system consists of two 100% duty centrifugal booster pumps which supply fluid at 680 kPa(g) to either of two 100% duty coolers and hence to either of two 100% duty positive displacement screw type main pumps which boost the pressure to 6800 kPa(g). Isolation valves permit maximum plant availability during on-load maintenance.

All oil, and particularly the synthetic, phosphate esters used in FRF systems, have a tendency to pick up impurities, notably grit, sludge, water and chlorides which tend to accelerate system corrosion and wear. Because of the use of small, high pressure components, with close tolerances, the cleanliness of FRF systems is particularly critical.

A 100 micron suction strainer is located in each centrifugal pump suction line. Full flow three micron absolute disposable element filters, fitted with differential pressure switches and internal by-passes, are located upstream and downstream of each main pump. This arrangement ensures all the fluid is filtered before entering the main pump and before entering the main hydraulic system. In addition, the fluid in the reservoir is continuously purified of moisture and acid via a fluid treatment plant which includes a vacuum dehydrator and a fuller's earth filtration plant.

Immersion heaters within the fluid reservoir are used to warm the fluid during a cold start. A low capacity, low pressure pump circulates the fluid through the coolers and returns it to the reservoir. When the fluid temperature has reached a safe minimum the centrifugal and main pumps may be started.

By using a separate control hydraulic system it is possible to maintain a much higher standard of fluid control, regarding temperature, viscosity and purity. It is not subject to variation in temperature to suit bearing requirements or seal oil requirements, and it is not subject to metallic pick up from bearings or moisture pick up from steam glands. However, the need for system cleanliness and hydraulic fluid purity, in high pressure, FRF governing systems is considerably more critical. Removal of impurities which could foul and eventually score the electrical-hydraulic control valves is essential in any high pressure hydraulic system. Control valve clearances are extremely small and the valves are particularly susceptible to sticking, scoring and eventual internal leakage. In addition, electrically actuated valves



FRF Power Plant

Figure 3.2

generally have little reserve power to free galled or sticking stems. The requirement for periodic testing of an electrical-hydraulic governing system, to insure freedom of valve movement, is doubly beneficial, in that fluid flow through the control valves keeps the valves clean. There is a great amount of practical experience which indicates that if a hydraulic control valve is not exercised for several months it will probably not operate.

FRF is reasonably non-toxic to the skin and exposure through soiled clothing presents a minimal hazard although FRF entering the eyes can cause a burning sensation and cause subsequent irritation. Phosphate esters can cause fatal poisoning, however, if inhaled in large quantities or if ingested in even moderate amounts. Under usual station operating conditions, inhalation of the vapor is almost impossible due to the low volatility of the fluid. From a personal safety standpoint, FRF can be harmful and special care should be taken to prevent ingestion, inhalation or absorption through the skin by persons who handle it. However, it can be handled safely if certain precautions are taken. These include no smoking or eating while handling the fluid, use of rubber gloves and safety glasses and availability of an eye wash fountain.

From an environmental standpoint, FRF can present a potential problem due to its toxicity and relative stability. For this reason disposal procedures for this fluid should be carefully adhered to.

ASSIGNMENT

1. Define "dead time" and "reservoir effect".
2. Explain why there is a limit to the size to which turbines with lubricating oil fluid control systems can be built.
3. Why is hydraulic oil used for governor steam valve actuation?
4. What are the advantages of an FRF fluid control system over a lubricating oil control system?
5. What are the problems associated with an FRF control system?
6. Discuss the need for fluid purity and cleanliness in an FRF control system.

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