BASIC FUNCTIONS OF ELECTROHYDRAULIC CONTROL (EHC) SYSTEM

NUCLEAR (BOILING WATER REACTOR) UNITS

FUNCTIONS

The electrohydraulic control system has been organized into several major subsystems to present an orderly flow of signal information and, thereby, permit an orderly system description.

For the interrelationship of these subsystems, refer to Figure 1.

The speed control unit compares actual turbine speed with the speed reference and actual acceleration with the acceleration reference, and provides one speed error signal to the load control unit.

The load control unit combines the speed error signal with the load reference signal, biases, and limits to determine desired steam flow signals to the control valves and intercept valves. The load control unit also provides load signals to the automatic load following circuit.

The pressure control unit compares the main steam pressure with the pressure reference to determine the total steam flow signal which is provided to the bypass control unit and the automatic load following circuit. The total steam flow signal is also gated with the load control unit control valve flow signal to arrive at the desired control valve flow signal.

The bypass control unit compares the desired control valve flow signal with the total steam flow signal and combines the resulting signal with a bias and limits to provide the desired bypass valve flow signal.

The automatic load following circuit compares the total steam flow signal from the pressure control unit with the load signals from the load control unit, and combines the resulting difference with a bias and amplitude limits to provide a command signal to the recirculation flow control system and the automatic pressure set-point adjust circuit.

The automatic pressure set-point adjust modifies this command signal and provides it to the pressure control unit to alter the pressure reference.

The flow control unit consists of the various valve positioning units used to accurately position the applicable valve with its respective flow signal.

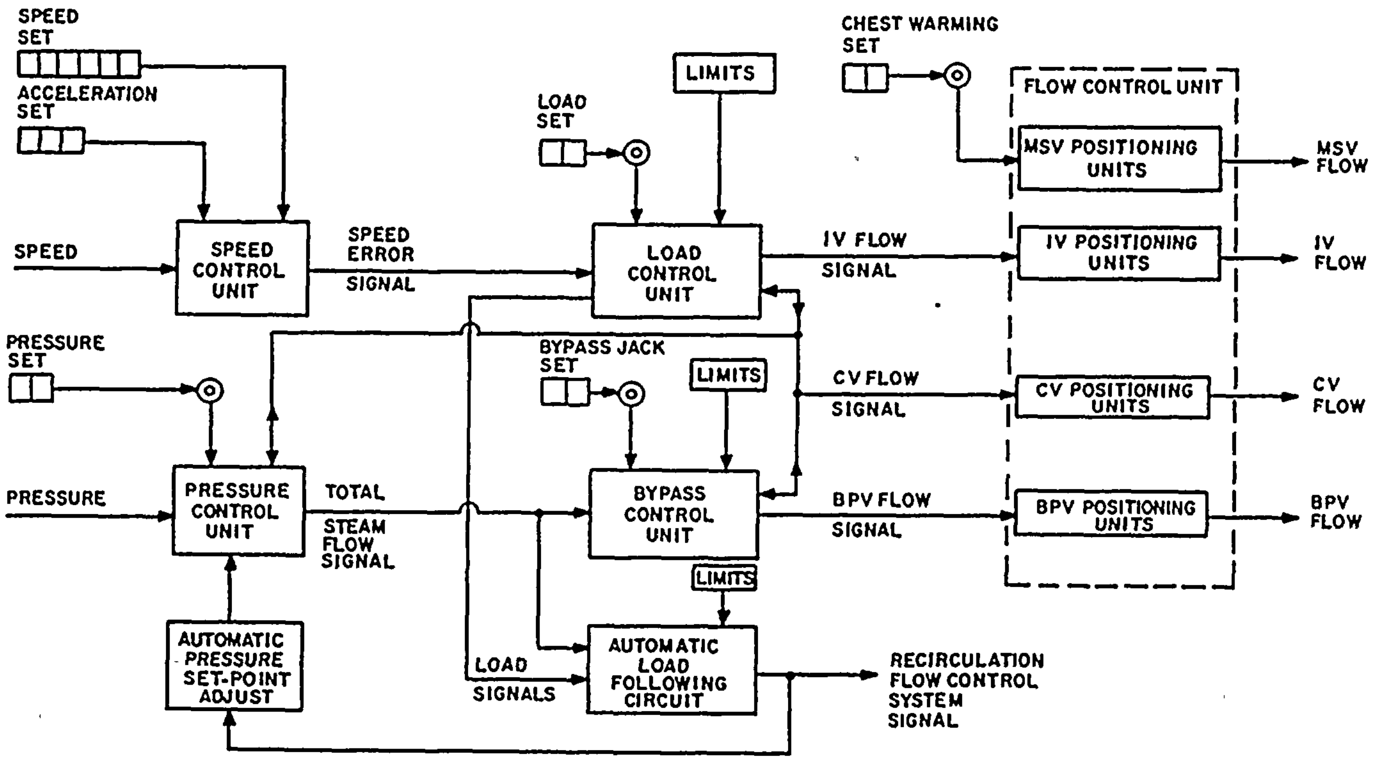


Fig. 1. Block diagram of electrical turbine initial pressure regulator and control system for single-cycle, boiling water reactor

SPEED CONTROL UNIT

The speed control unit, shown in Figure 2, produces the speed/acceleration error signal that is determined by comparing the desired speed with the actual speed of the turbine at steady-state conditions, or the desired acceleration with the actual acceleration during startup.

When the speed reference signal is increased in a step, the acceleration control will take over and accelerate the turbine at the selected rate up to the value of the new speed reference, at which point, the speed control will automatically take control.

Upon decrease of the speed reference, the turbine will coast down with the valves closed. The valves will reopen only when the new set speed has been reached. There is no deceleration limit.

During normal operation at rated speed, the speed error signal is essentially zero regardless of the load.

Because of the extreme importance in safeguarding against overspeed, the speed control unit has two redundant channels. Loss of both speed signals will shut down the turbine.

LOAD CONTROL UNIT

The purpose of the load control unit is to provide flow control signals to the control valves and intercept valves, and modified speed error and load reference signals to the automatic load following circuit. The valve flow signals are based upon the proper combination of speed error and load reference signals as modified by bias and limiting signals. The signal flow in the load control unit is shown in Fig. 3.

The load reference signal is produced by a motor-operated device that can be operated by local push buttons or remote control signals. The rate of increase of the load reference signal is limited by load reference motor speed. Further reduction in the rate of load reference signal increase must be accomplished by jogging or pulsing the load reference motor.

The speed/acceleration error signal from the speed control unit is first amplified by an amount inversely proportional to the appropriate valve regulation to establish the proper speed loop gain for the applicable valve. This modified speed/acceleration error signal is summed with the load reference signal.

Introducing the load reference signal after the modification for speed regulation permits calibra-

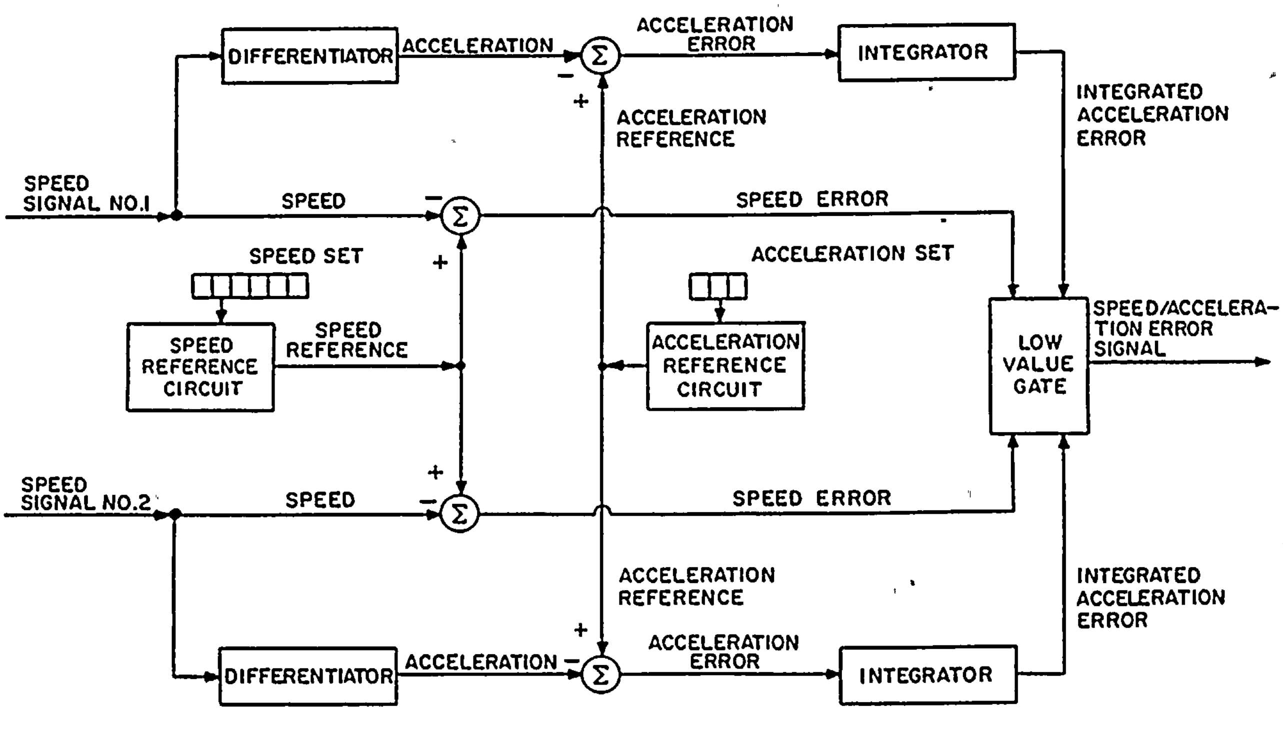


Fig. 2. Electrical speed control unit

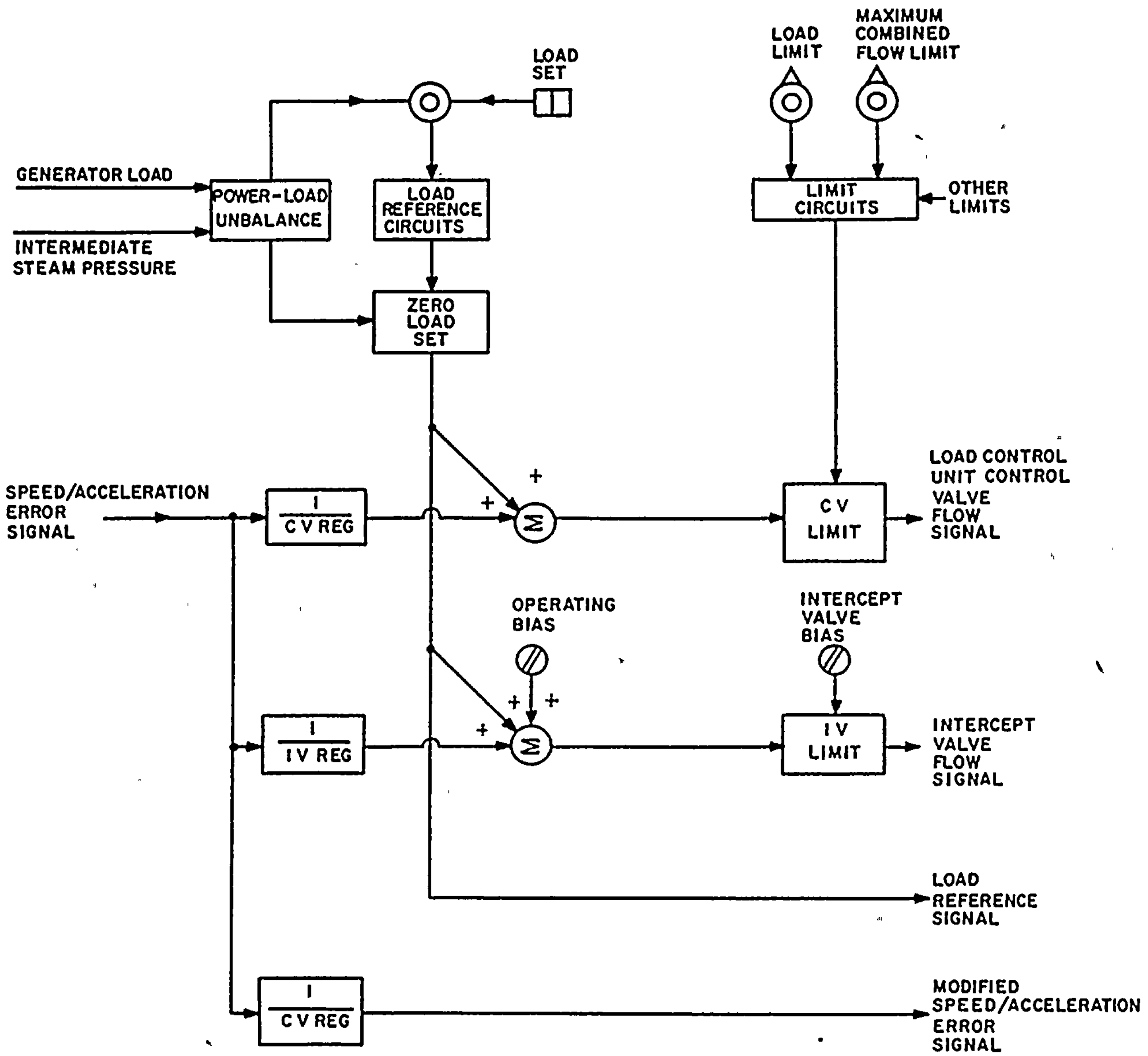


Fig. 3. Electrical load control unit

tion of the load reference device for rated speed and steam conditions that is independent of speed regulation. When the generator is not on the line, the load reference signal is a speed adjustment and is therefore used for synchronizing the turbine.

When the turbine speed increases over rated speed, the negative speed error will decrease the flow signal to the controlling valve(s) an amount defined by the applicable valve regulation. For example, if the control valve regulation were five percent, a five-percent speed error would cancel a 100 percent load reference signal. This would result in reducing the control valve position from the fully-open to the no-load position.

A bias is used to hold the intercept valves in the wide open position. This bias is proportional such that on a slow acceleration the flow signal to the intercept valves will just begin closing the intercept valves when the flow signal to the control valves reaches the closed valve position.

Limit signals are produced in the limit circuits by the load limit, the maximum combined flow limit, and other (generator or main stop valve position) signals. This limit is applied to the control valve flow signal. An intercept valve limit is used only to set the cross-around safety valve; normally it is in the valve wide open position.

When the generator loses the electrical load, it is necessary to quickly close the control valves and intercept valves to essentially stop the steam flow to the turbine. The power-load unbalance circuit senses the cause of high accelerations and initiates action to keep the peak speed to a minimum.

A measure of unbalance or accelerating torque is obtained by sensing intermediate steam pressure (power) and comparing it with generator load. When this unbalance exceeds a specified level, the power-load unbalance immediately reduces the load reference signal to zero, runs the load reference motor back to the zero load reference position, and operates the fast-closing valves for the control valve positioning units. The result is to rapidly reduce steam flow to both turbine sections to limit the peak speed that results from a loss of load.

PRESSURE CONTROL UNIT

The pressure control unit shown in Fig. 4 produces a total steam flow signal. It provides this signal to the bypass control unit and the automatic load following circuit. It also compares the total steam flow signal with the load control unit control valve flow signal in a low value gate to provide the resulting control valve flow signal.

The pressure control unit senses the main steam pressure upstream of the main stop valves and compares it with the desired pressure reference. The resulting pressure error signal is modified by lead and lag compensation networks to provide for stabilization of the pressure control loop.

The pressure reference signal is produced by a motor-operated device that can be operated by local push buttons or remote control signals. The pressure set-point motor speed determines the maximum rate of pressure set-point change.

The modified pressure error signal is produced twice by redundant devices. These two modified pressure error signals are gated in a high value gate to provide the desired control by the one operating at the lowest pressure with the other operating as a backup at a slightly higher pressure. A pressure set-point bias is provided to permit transfer of the operating and backup roles between the redundant channels.

The gated modified pressure error signal is amplified by an amount inversely proportional to the pressure loop regulation to provide the total steam flow signal.

The total steam flow signal is compared with the load control unit control valve flow signal in a low value gate to provide the control valve flow signal.

The total steam flow signal is also provided to the bypass control unit and the automatic load following circuit.

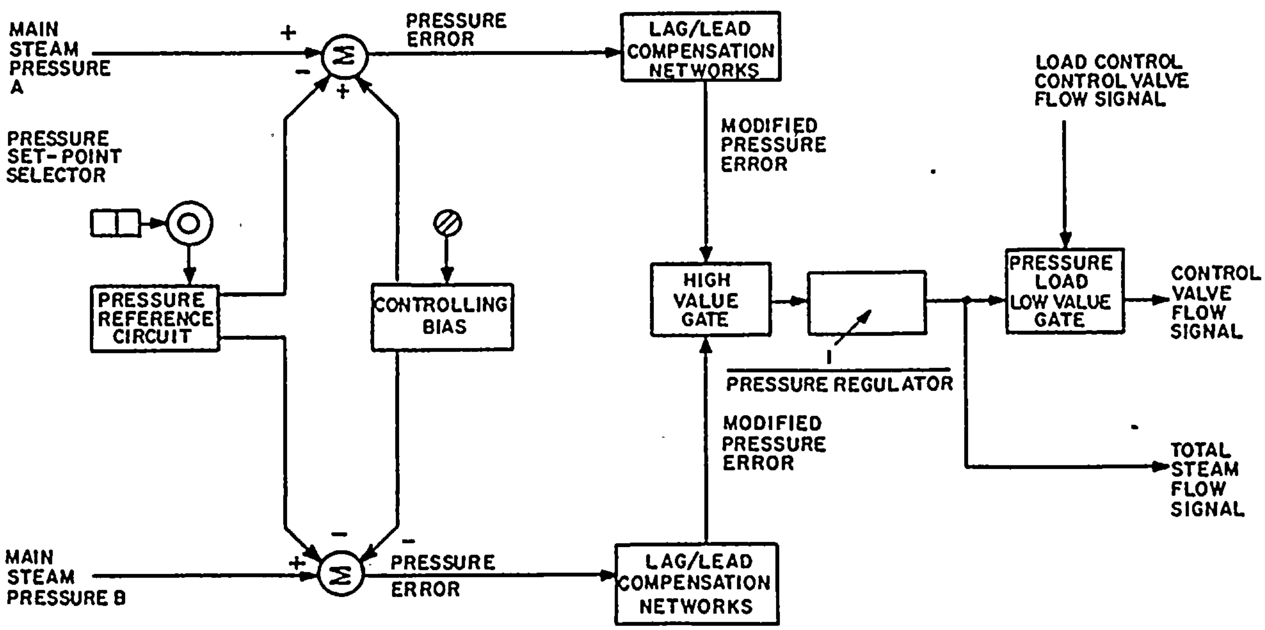


Fig. 4. Pressure control unit

BYPASS CONTROL UNIT

The bypass control unit shown in Fig. 5 is used to produce a bypass valve flow signal.

The bypass control unit compares the total steam flow signal with the control valve flow signal. The resulting error signal is biased slightly to prevent continuous opening and closing of the bypass valves. The biased error signal is the total flow error signal. The total flow error signal is the bypass valve flow signal unless overridden by the limit circuits or the bypass valve jack.

The bypass valve jack is a motor-operated device used for setting a bypass valve position reference during startup and shutdown of the reactor. This motor-operated device can be operated by local push buttons or remote control signals. The rate of increase or decrease is accomplished by jogging or pulsing the jacking motor. The bypass jack reference signal is compared with the total flow error signal in a high value gate such that the one calling for the more open valve position will predominate.

Limit signals are produced in the limit circuits by the maximum combined flow limit and the condenser vacuum pressure switches. This limit is applied to the bypass valve flow signal.

AUTOMATIC LOAD FOLLOWING CIRCUIT

The automatic load following circuit shown in Fig. 6 is used to produce an automatic load following signal for use by the customer as a command signal to the reactor recirculation flow control system.

The modified speed/acceleration error signal is summed with the load reference signal and a bias to establish the steam flow load demand signal. The bias signal is necessary to permit the load demand to be at a fixed level above the actual steam flow load demand at steady-state conditions.

The steam flow load demand signal is compared with the total steam flow signal. The resulting error signal is amplitude limited. This limited signal is fed to a buffer amplifier with an adjustable gain whose output is the recirculation flow control signal.

AUTOMATIC PRESSURE SET-POINT ADJUSTMENT

The automatic load following signal provided to the recirculation flow control system is also used to speed up the initial response to a step load de-

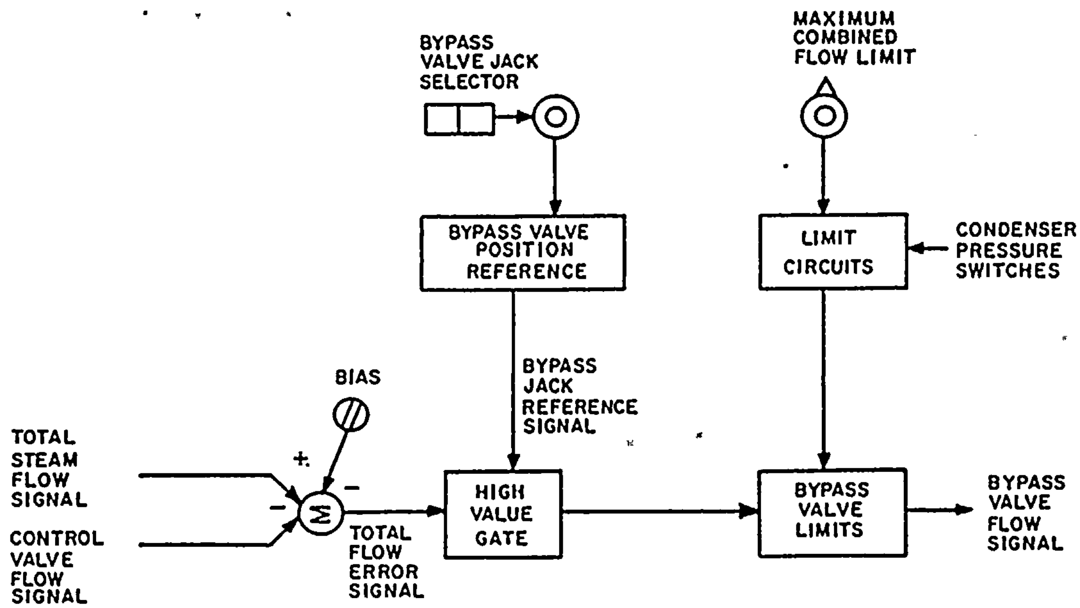


Fig. 5. Bypass control unit

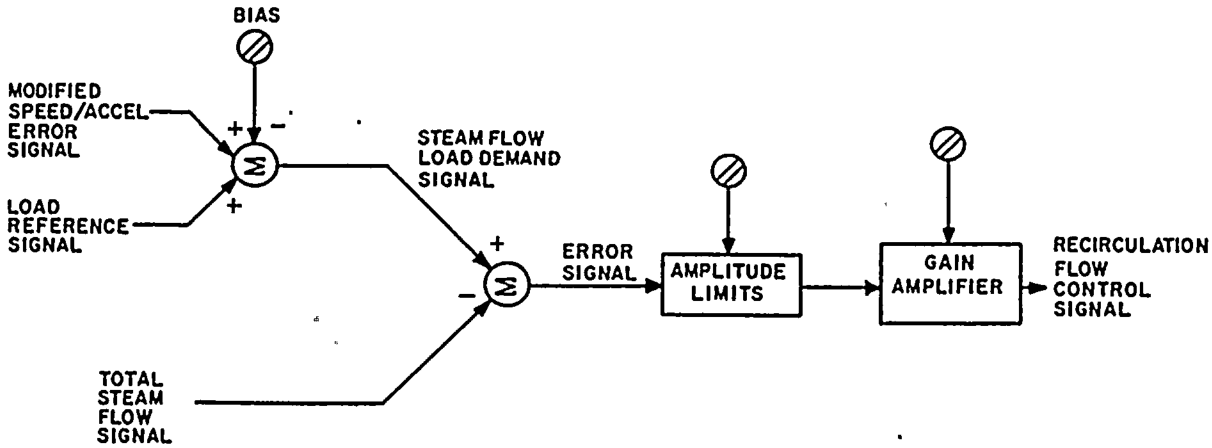


Fig. 6. Automatic load following circuit

mand. An increasing flow automatic load following signal is used to decrease the pressure setpoint in the pressure control unit. A decrease in the pressure setpoint will immediately call for an opening of the control valves. This automatic pressure setpoint adjust signal returns to zero when the load demand is satisfied. The automatic pressure setpoint adjust functions for either increasing or decreasing signals.

The automatic pressure set-point adjust circuit has a rate limit and an amplitude limit to limit the maximum rate of the automatic pressure set-point change and the maximum pressure set-point change.

FLOW CONTROL UNIT

The purpose of the flow control unit is to position the steam valves to establish the steam flows commanded by the load control unit, the pressure control unit, and the bypass control unit. Non-linear circuits are sometimes introduced in series with or in the feedback of the valve position loops to obtain essentially linear steam flow with respect to the steam flow signal.

The main stop valve positioning unit used for valve chest warming is shown in Fig. 7. The position

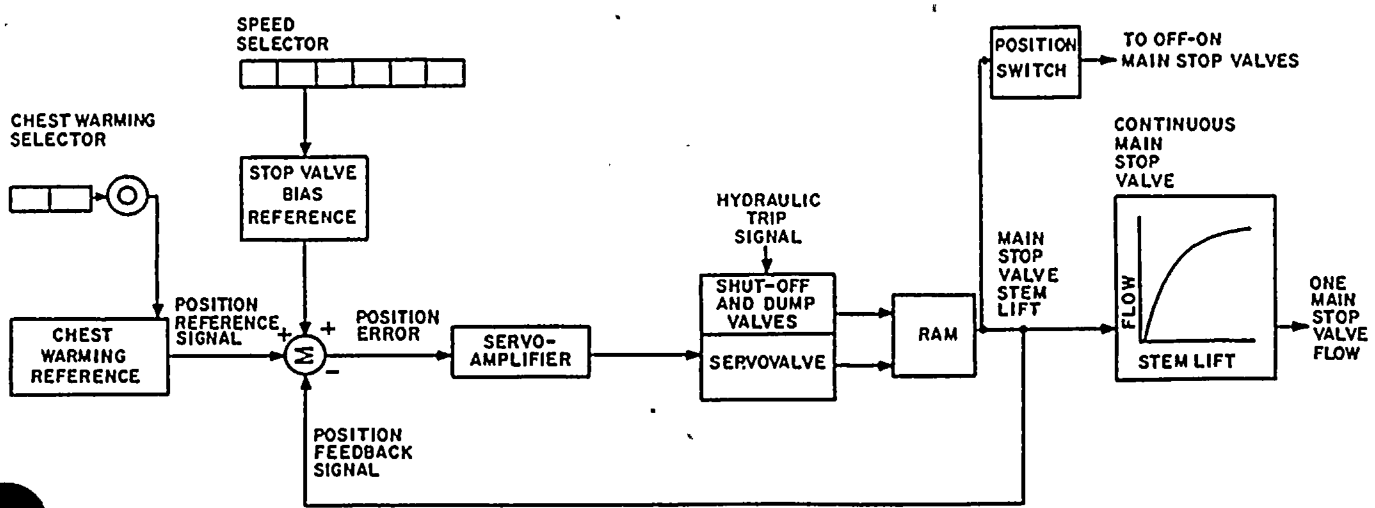


Fig. 7. Main stop valve positioning unit for valve chest warming

reference is established through the chestwarming selector by the operator for continuous control of the main stop valve over the range of the main stop valve bypass valve.

The main stop valve position reference signal is compared with the position feedback signal with the resulting error signal applied to a servo-amplifier. The output of the servoamplifier operates the servovalve that will position the ram if the trip valve is reset.

When the hydraulic signal from the emergency trip system trips the shutoff valve, the main stop valve will close regardless of electrical signals to the servovalve.

Speed selection, other than the all valves closed selection, will apply a bias reference sufficient to fully open the main stop valve. The full open position switches on this main stop valve positioning unit will operate the remaining main stop valves for open and closed positioning by means of their test solenoids.

The control valve positioning units are shown in Fig. 8. The position loops are linear and each functions in the same manner as the main stop valve positioning unit for valve chest warming. However, the dump valve for fast closing is operated primarily by the power-load unbalance signal, but can also be operated by a hydraulic trip signal from the emergency trip system.

The two electrical cams at the input of the position loop provide a three-slope, electrical cam to offset the extremely nonlinear steam flow characteristics of the control valves. The control valve positioning units operate in parallel and are shown for full-arc operation in Fig. 8.

Each low-pressure turbine is supplied steam through a pair of intercept valves operating in parallel. One of these intercept valves will be controlled continuously by means of a position loop, while the other is operated on-off by means of position switches on the intercept valve operated by the position loop. This configuration is shown in Fig. 9.

The position loop functions in the same manner as the main stop valve position unit for valve chest warming, except that a nonlinear circuit is introduced into the position feedback to offset the nonlinear steam flow characteristics of the intercept valves. The dump valve for fast closing is operated by an excessive position loop error in the closing direction as well as the hydraulic trip signal from the emergency trip system. An excessive position loop closing error on any one of the intercept valve position loops will operate the fast-closing valves on all intercept valves.

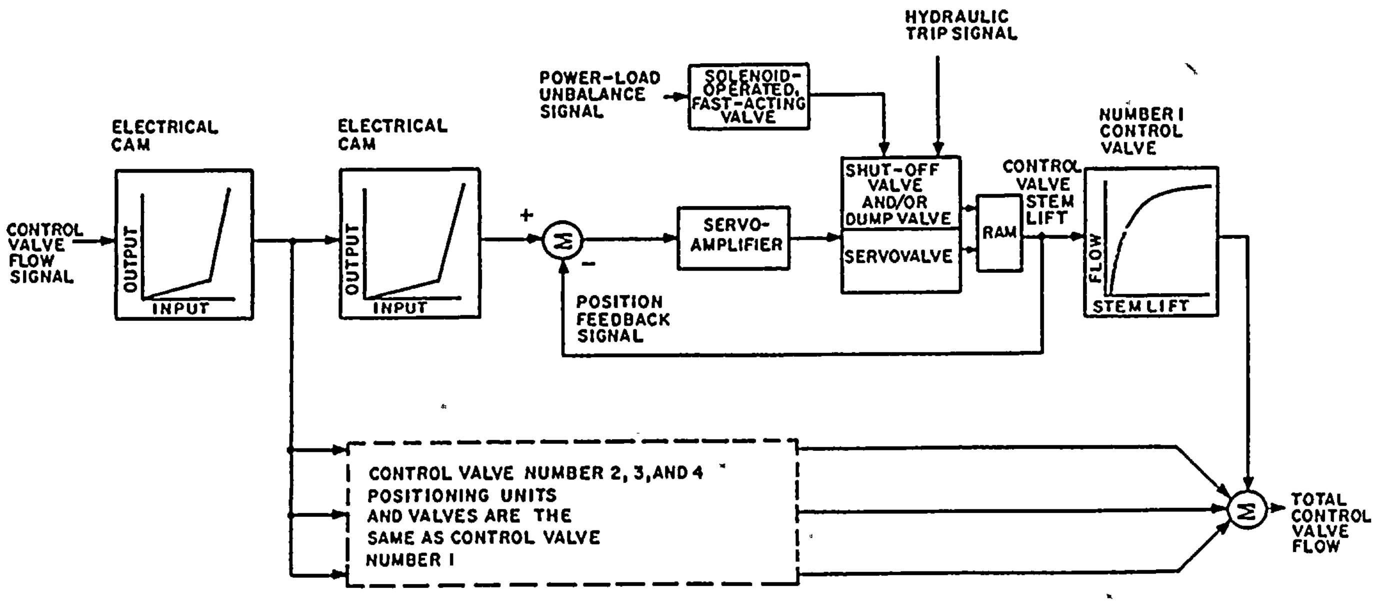


Fig. 8. Control valve positioning units

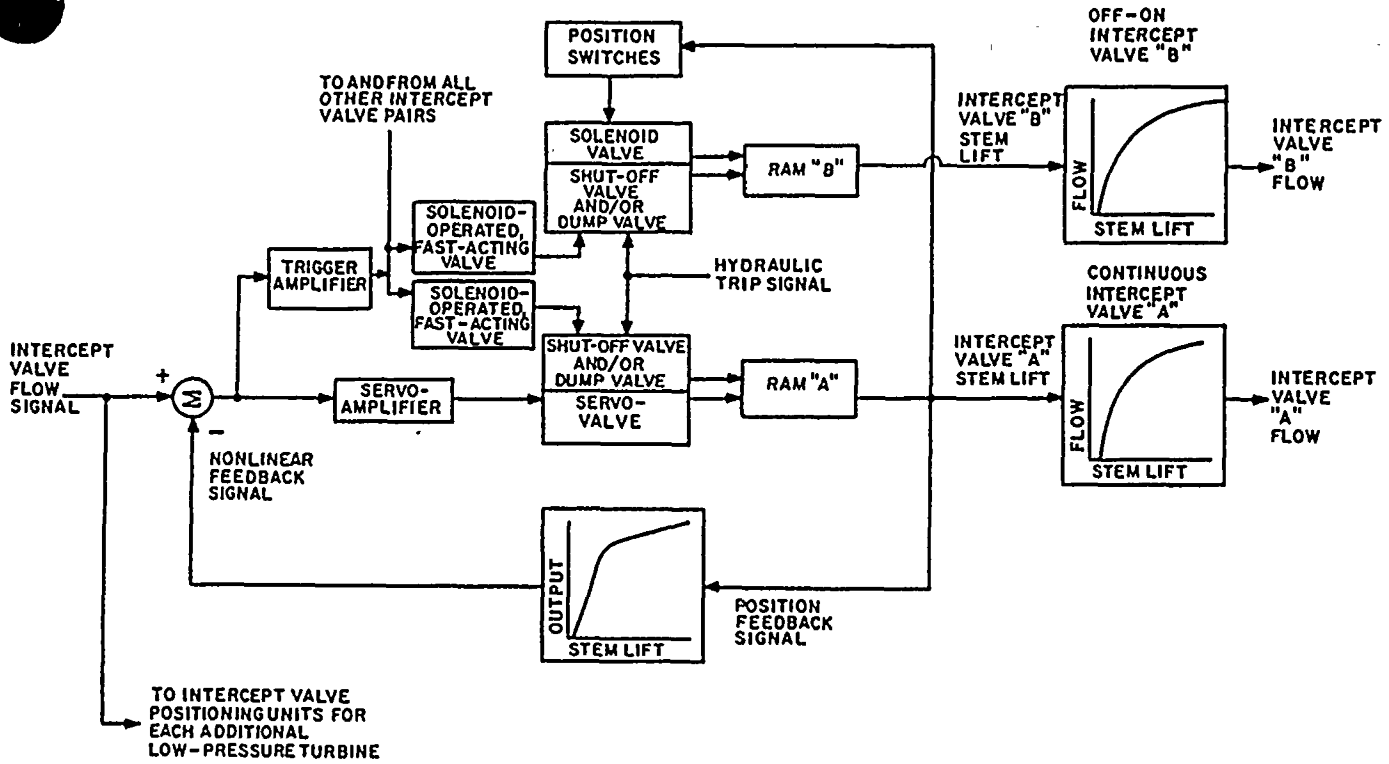


Fig. 9. Intercept valve positioning units for a low-pressure turbine intercept valve pair

The bypass valve positioning units are all the same except that they are opened sequentially. One bypass valve positioning unit is shown in Fig. 10. The position loops are linear and function in the same manner as the main stop valve positioning unit for valve chest warming. The bypass valves will close upon loss of hydraulic pressure.

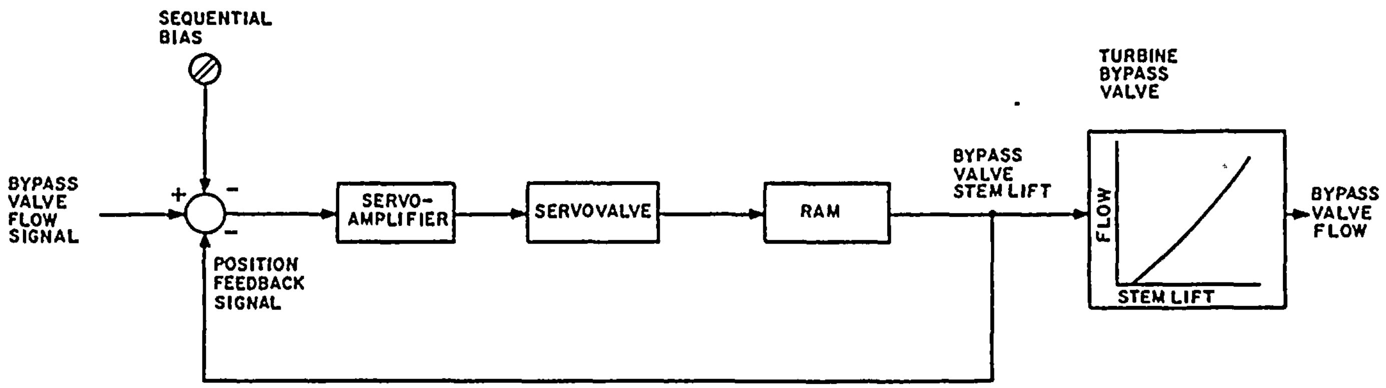
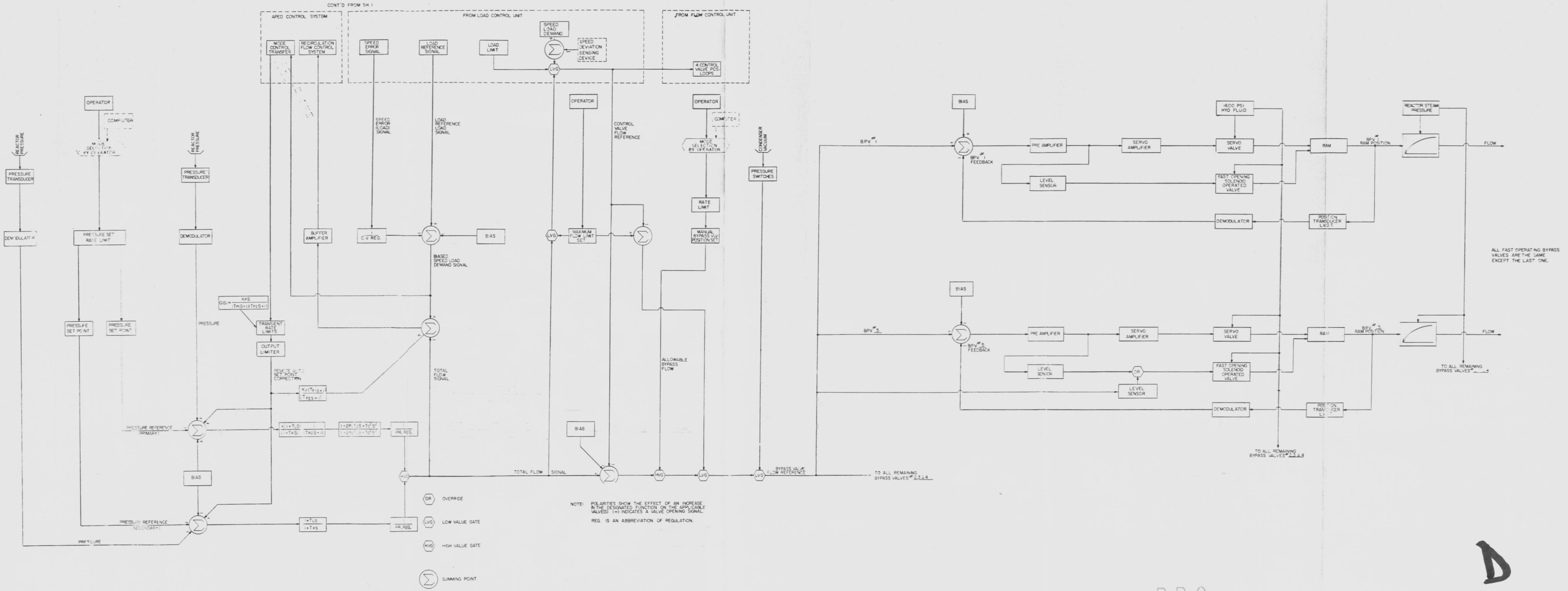


Fig. 10. One turbine bypass valve positioning unit



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PRC APERTURE CARD

8312280475-01

EHC Block Diagram
Dwg. ?51R998 (Rev. 2) Sh. 1

Fig. 41-1

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8312280475-02

EHC Block Diagram
Dwg. 251R998 (Rev. 2) Sh. 2

Fig. 41-1A