CHAPTER 3: STEAM GENERATOR CONTROL

MODULE 2: PRESSURE CONTROL

MODULE OBJECTIVES:

At the end of this module, you will be able to:

1.   Sketch a graph of the turbine setpoint vs. reactor power for the BPC routine.

2 .   Sketch a simple line diagram representing the main steam transport system from the boilers to the H.P. turbine (include safety valves, SRVs, GSVs, and the BPC logic blocks). State the purpose of each device indicated on the sketch.

3 .   Describe the negative feedback and the feedforward components of the turbine control section of BPC

4 .   Sketch a graph of the SRV setpoint ramp vs. reactor power for the BPC routine (include the turbine setpoint ramp).

5 .   Describe the negative feedback and the feedforward components of the steam reject valve control section of the BPC.

6 .   State the general function and operation of the BPC system in the "at-power" mode. Include a block diagram to show the measurements and the manipulated variables.

7 .   What is the purpose of the FBPC? Why does it only control the SRVs?

8 .   Describe the control room indications available which can be used to verify that steam demand is matching the reactor power and that BPC is operating normally.

Overall Unit Control

The following equipment are of particular importance to boiler pressure control:

- **Boilers**
- **Governor valves**
- **Speeder motor**
- **Reject valves**
- **Boiler pressure transmitters**
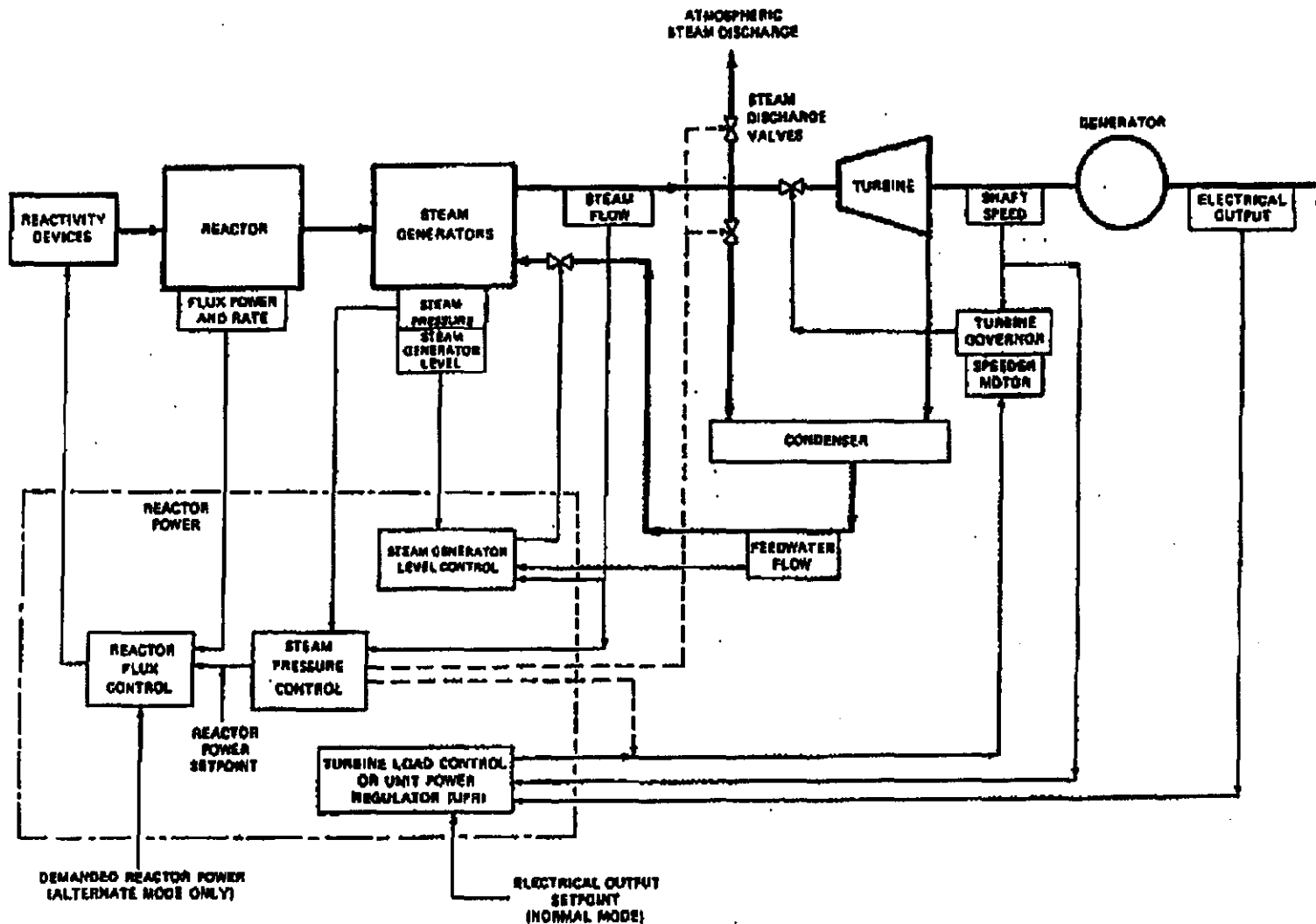- **Pressure after governors transmitters.**

Figure 1: Overall Unit Control Block Diagram.

The boiler pressure control system is designed to balance the energy supplied (from the heat transport system) with the energy given up to either the turbine or the reject valves.

Ramped Boiler Pressure

- The boiler pressure setpoint as a function of reactor power is a constant value at some plants, while at others it is ramped negatively (Figure 2).
- For the example we have been considering, the ramp is from approximately 5 MPa (at 0% FP) to approximately 4 MPa (at 100% FP).
- This ramped boiler pressure (and corresponding temperature) minimizes the heat transport inventory swell and shrink (as the reactor power is changed) by maintaining a relatively constant average heat transport temperature.

- For a station having an overall plant control scheme of reactor leading the turbine, the boiler pressure control provides the means for the unit power output to follow the reactor.
- As the reactor power is increased, the energy supplied to the boilers is raised. At the same time, a lower boiler pressure setpoint is calculated to satisfy the ramp of Figure 2.
- These two factors (higher energy input, lower pressure setpoint) combine to produce a positive boiler pressure error.
- The higher boiler pressure must be reduced by increasing the steam flow to the turbine.
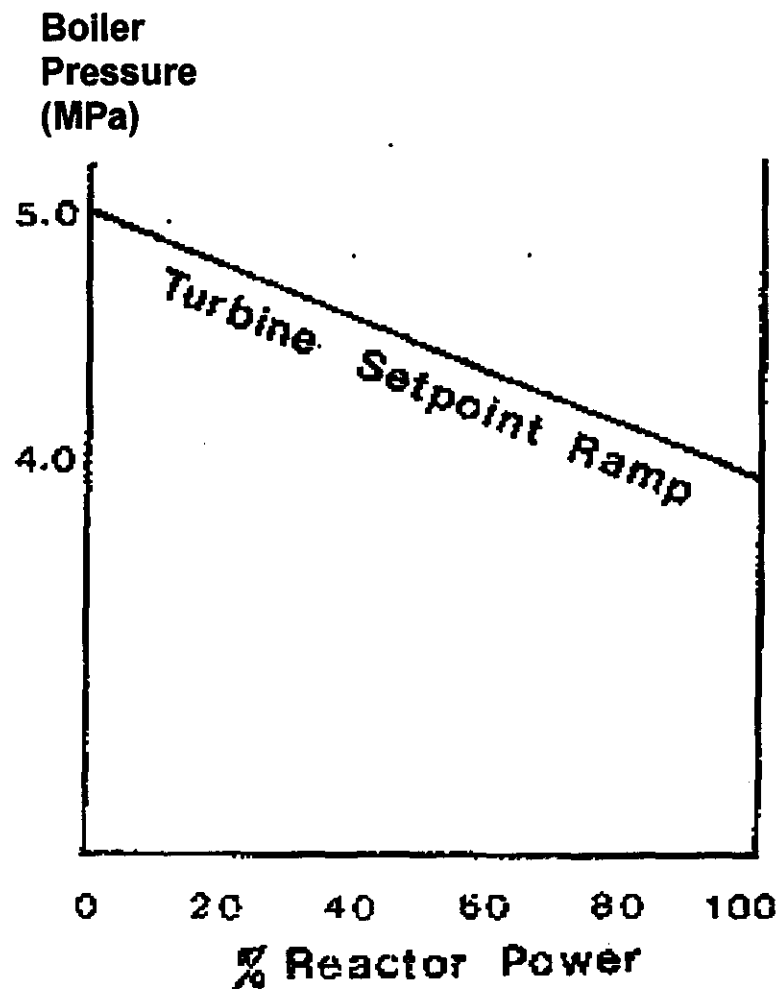
Boiler
Pressure
(MPa)

Figure 2: Ramped Boiler Pressure.
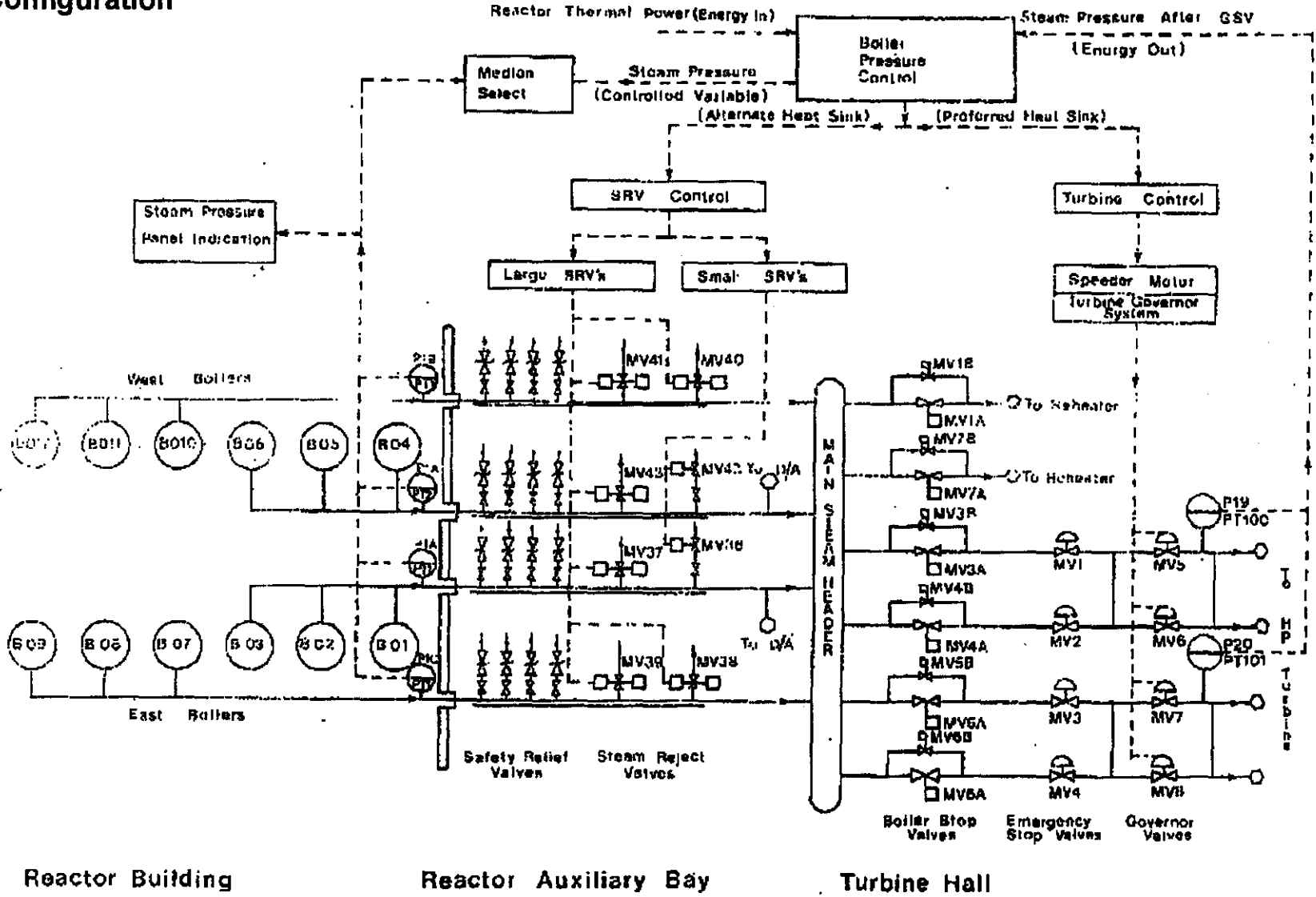
System Configuration

Figure 3: Boiler Pressure Control System.

The main components of the boiler pressure control system are outlined in Figure 3. The steam pressure is sensed by electronic transmitters which develop the measurement signal for the boiler pressure control routine. The setpoint is computed as a function of the reactor power.

The difference between the steam pressure and the steam pressure setpoint is the boiler pressure error:

Boiler Pressure Error = Steam Pressure - Steam Pressure Set Point

The boiler pressure error is used to develop a proportional feedback control signal to manipulate the boiler heat sink. The boiler pressure control has two control output routines:

1.   turbine governor control
2.   steam reject valve control

Turbine Governor Control

In the "at power" mode, the turbine is used as the principle heat sink for controlling the boiler pressure. If the boiler pressure should rise above the turbine setpoint ramp, the speeder gear is run up to increase the steam flow to the turbine. When the pressure drops below the setpoint ramp, the negative boiler pressure error drives the speeder gear down. The steam flow to the turbine is reduced and the boiler pressure should recover. BPC will manipulate the speeder gear in a negative feedback control fashion to attempt to maintain the boiler pressure on the turbine setpoint ramp.

If the system was functioning normally and the reactor was setback, a feedforward turbine control signal would then be developed. The feedforward term is proportional to the difference in the computed reactor power now, and the reactor power two seconds previously.

This negative signal will run the speeder back anticipating that the boiler pressure will begin to drop due to the lower reactor power. If the reactor is not setback, the feedforward term is set to zero.

Steam Reject Valve Control

Should the steam pressure rise more than approximately 100 kPa above the steam pressure setpoint, the reject valves (Figure 3) will begin to stroke open to supplement the heat sink provided by the turbine. The steam reject valve control setpoint is offset from that of the speeder gear by 100 kPa as shown in Figure 4.

- The SRVs act as a back up to the turbine to maintain a sufficient heat sink for the boilers. The reject valve (Figure 3) control scheme will throttle the SRVs proportional to the boiler pressure error.
- If the SRV control signal is greater than 5%, the small SRVs are set fully open while the larger valves are stroked proportionally.
- A reactor setback will be initiated by the large reject valves driving open.
- If the control signal was less than 5%, the large SRVs are kept closed and the small SRVs are stroked proportionally.

- If the turbine is off steam pressure control and the reactor is not tripped, the SRVs control routine will also develop a feedforward term.
- The average steam pressure after the governor valves (Figure 3 - PT100, PT101) is used to compute the reactor power as a function of the steam pressure.
- The difference between the reactor power and this computed power is used to determine the energy mismatch between reactor output and the energy sink available at the turbine.
- This positive feedforward signal effectively anticipates that the boiler pressure is going to rise and begins to drive the SRVs open.
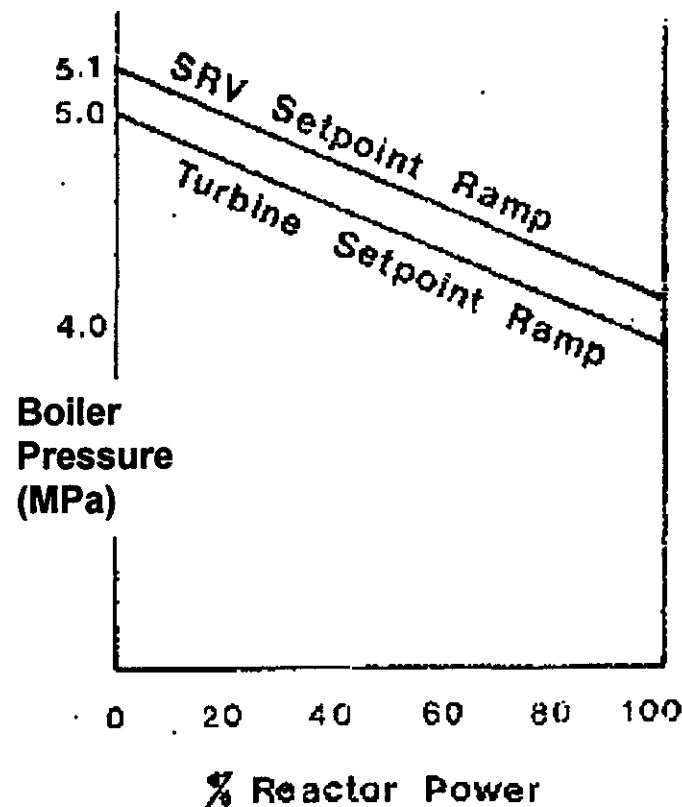

Figure 4: Turbine and SRV Setpoint Ramps

Fast Boiler Pressure Control

The boiler pressure control routine is called up every two seconds in an attempt to maintain stable boiler pressure control. This control sampling time frame may be too slow if the turbine is subjected to a disturbance such as a fast runback or a loss of load

To avoid this situation, a core resident routine similar to the SRV control program is run every 0.5 seconds. This program is called the Fast Boiler Pressure Control (FBPC) routine. The FBPC routine is activated by a priority interrupt that will come in from the logic circuits of either the fast or the slow turbine runbacks (if the reactor is not tripped).

In this fashion, the normal program execution will be temporarily interrupted and a fast SRV routine will be run to guarantee that the SRV control scheme is serviced frequently enough to maintain pressure control.

The boiler steam pressure operating diagram is illustrated in Figure 5. The pressure should be controlled by the turbine to the turbine pressure control ramp. If the 100 kPa pressure offset is exceeded, the SRVs would begin to operate.
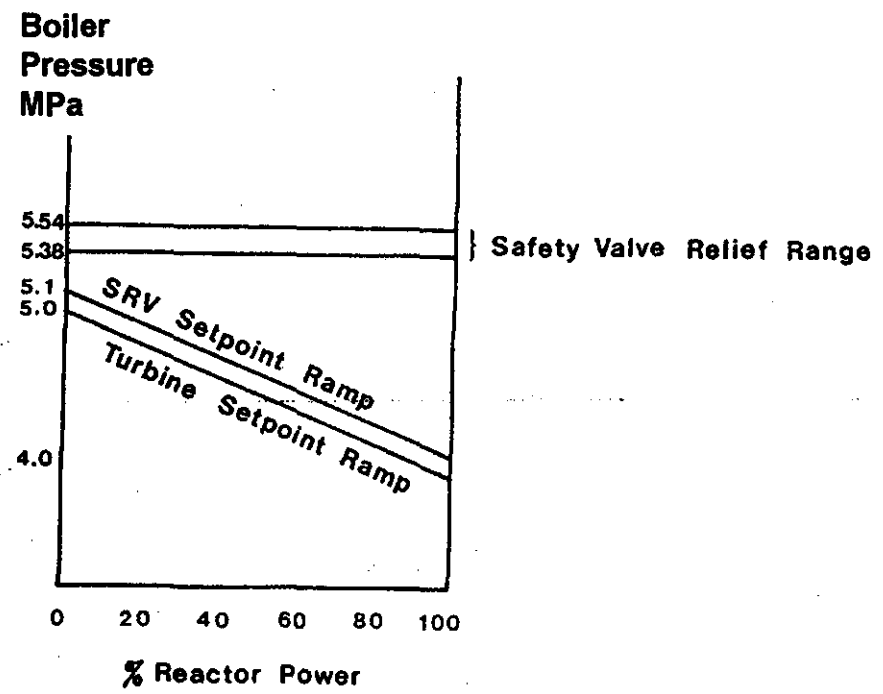
Steam system overpressure protection is provided by the sixteen safety valves (Figure 3). These valves are set to relieve at pressures ranging from 5.38 to 5.54 MPa(g) and can each release approximately 6% of the full power steam flow.

In summary then, the BPC attempts to manipulate the speeder gear or SRVs in order to balance the reactor power output. The success of the BPC operation can be determined by examining the boiler pressure panel indication or by calling up the boiler pressure error on the computer display.

Figure 5: Steam Pressure Operating Diagram.