

General Electric Advanced Technology Manual

Chapter 5.1

Introduction to Transients

TABLE OF CONTENTS

5.1	INTRODUCTION TO TRANSIENTS	5.1-1
5.1.1	Introduction.....	5.1-1
5.1.2	Transients.....	5.1-2
5.1.2.1	Normal Operational Transient	5.1-2
5.1.2.2	Abnormal Operational Transient.....	5.1-2
5.1.2.3	Emergency Operational Transient Accident	5.1-2
5.1.3	Transients Analysis	5.1-3
5.1.3.1	Transient Example	5.1-4

LIST OF TABLES

5.1-1	Parameter Setpoint Aids	5.1-7
-------	-------------------------------	-------

LIST OF FIGURES

5.1-1	Chart Recorder
5.1-2	Recirculation Loop Instrumentation
5.1-3	Main Steam System
5.1-4	Main Steam System (continued)
5.1-5	Feedwater System
5.1-6	Core Flow Summing Network
5.1-7	EHC System Logic
5.1-8	Pressure Control Spectrum
5.1-9	Feedwater Control System
5.1-10	Recirculation Flow Control Network
5.1-11	Power/Flow Map
5.1-12	Balance of Plant

5.1 INTRODUCTION TO TRANSIENTS

Learning Objectives:

1. Given a transient curve:
 - At selected numbered points, explain what caused the parameter to change.
 - At selected numbered areas of the curve, explain why the parameter is trending in that area.
 - State the cause of the transient (initiating event).
2. Given a plant transient scenario, explain the behavior of selected plant parameters, control systems, and equipment for the time designated in the scenario.

5.1.1 Introduction

The following information is presented with the emphasis on analyzing given plant transients with respect to initiating conditions, transient events, end result and conclusions. The transient curves contained in this manual were compiled and analyzed by members of the NRC's Technical Training Division. They were produced from data supplied from the GE BWR/4 Simulator. Specific parameter responses of the simulator were recorded in a data file and converted into graphs with the use of Excel and Claris CAD computer programs. These graphs are **not** to be considered ***Engineering Simulator Model Quality***. Some minor editing of the original curves was performed.

The instructor explanations accompanying these curves are the result of analysis by the TTD Staff during the actual simulator runs and subsequent staff seminars.

Caution is advised when trying to apply these simulator curves to any operating plant. Even relative minor changes in set points, capacities, or piping runs could cause significant differences in indicated responses.

During analysis and study of the curves, the student should concentrate on explaining changes in various parameters caused by the initiating event, subsequent automatic operation of associated control systems or system response to the event. When explaining the identified points always try to relate cause and effect (e.g. power changing from flow change). Don't place too much emphasis on isolated portions of minor deviations in traces unless identified by the instructor.

5.1.2 Transients

In general, the term reactor transient applies to any significant deviation from the normal operating value of any of the key reactor operating parameters. Transients may occur as a consequence of an operator error or the malfunction or failure of equipment.

Operational transients are divided into three groups: normal, abnormal and emergency. This division groups transients according to their relative severity on plant operations and safety.

5.1.2.1 Normal Operational Transient

Includes the events that take place during a normal plant startup, shutdown, or load change. These events do not take into effect equipment failure or operator error.

5.1.2.2 Abnormal Operational Transient

Anticipated (Abnormal) transients are deviations from the normal operating conditions that may occur one or more times during the service life of a plant. Anticipated transients range from trivial to significant in terms of the demands imposed on plant equipment. Anticipated transients include such events as a turbine trip, EHC failure, MSIV closure, loss of feedwater flow and loss of feedwater heating. More specifically, all situations (except for LOCA) which could lead to fuel heat imbalances are anticipated (abnormal) transients.

Many transients are handled by the reactor control systems, which would return the reactor to its normal operating conditions. Others are beyond the capability of the reactor control systems and require reactor shutdown by the reactor protection system (RPS) in order to avoid damage to the reactor fuel or coolant systems.

5.1.2.3 Emergency Operational Transient Accident

An emergency operational transient (accident) is a single event, not reasonably expected during the course of plant operations, that has been hypothesized for analysis purposes or postulated from unlikely but possible situations, and that causes or threatens a rupture of a radioactive material barrier. A pipe rupture is an accident. A fuel clad defect is not.

Design Basis Accident

A design basis accident is a hypothesized accident, the characteristics of which are utilized in the design of those systems and components pertinent to the preservation of radioactive material boundaries and restriction of the release of radioactive materials from these boundaries. The potential radiation exposures resulting from these accidents is greater than any similar accident postulated from the same

general assumptions. Design basis accidents include:

- control rod drop accident
- refueling accident
- main steam line break outside the drywell
- loss of coolant accident

5.1.3 Transients Analysis

Transient analysis begins with applying some fundamental rules:

1. Do not try and identify the initiating event.
2. Start with a parameter that you personally know more about.
3. Stay in the same time frame (i.e. do not continue on the same parameter trying to identify all the points prior to going to the next parameter).
4. Make a list of what would cause the parameter of interest to change.
5. Start with the first item on the list and decide what direction and how much of a change you would expect; then look at the change on the curve and see if it is reasonable.
6. If you are not sure continue down the list.
7. Go to the parameter that is affected by the one you have chosen (i.e. power effects pressure, pressure effects steam flow).
8. If you have done everything correctly you will end up with the initiating event.
9. Move to the next time frame and continue the process until all points are identified.
10. Test to see if all points agree with the initiating event.

Figures 5.1-1 represents a blank recorder paper. Each horizontal line is spaced 30 seconds apart and are the same for each parameter. The chart recorder moves from top to bottom, making the top the 6 minute and the bottom time zero.

The following are general notes applicable to all transients unless otherwise indicated:

- Reactor power is from one APRM channel. Assume that if this channel changes the other APRM channels also change.
- Total steam flow is from the FWCS's summations of the individual flow from the flow restrictors on each steam line.
- Total feedwater flow is from the FWCS's summed feed flow from the individual flow measurement devices down stream of the last high pressure feedwater heater.
- Total core flow is the summation of all of the jet pump flows.
- Turbine steam flow is the turbine first stage pressure converted to steam flow.
- Reactor pressure is from one of the reactor vessel pressure monitoring devices.

Transient one is a normal operational transient that will be used during the introduction for purposes of indicating how the various parameters change and the use of the rules identified above. ***All other transients covered will fall in the abnormal transient category***

5.1.3.1 Transient Example

Starting with reactor power (rule 2), make a list of things that could change reactor power.

1. Recirculation flow
 - a. Pump speed change
 - b. Tripping of a recirculation pump
2. Control rod movement
 - a. normal rod movement
 - b. scram
3. Loss of feedwater heating
4. Pressure increase/decrease
5. Standby liquid control system initiation

Starting with the first item, decide how power should change and how much, then look at the total core flow and APRM curves. At the same or near the same time frame it appears that everything matches, a change in total core flow caused a change in reactor power.

The next step is to move to the next parameter. By applying rule number 7, move to reactor pressure. But, before looking at reactor pressure, decide how pressure should change. If power decreases at a steady rate, pressure should also decrease at that same rate. Look at the pressure curve; it appears that indeed pressure is following reactor power as expected.

Applying rule number 7 again, if pressure changes, the EHC system should respond by adjusting the control and/or bypass valves. Adjusting control valves/BPVs will have an effect on main steam flow. So the next logical parameter is turbine steam flow, and to compare main steam flow to turbine steam flow.

Continuing this process should answer all the questions for the initial change. If you did not start with the parameter that changed first, the above procedure will bring you around to the initiating event. This process is used on each time frame of interest until all points are identified.

A synopsis of transient number one takes place in the following manner:

- Recirculation flow decreases due to the decrease in recirculation pump speed. The decrease in core flow results in a higher void fraction and a negative net core reactivity. The power decrease causes fuel temperature, moderator temperature, and the void fraction to decrease. This continues until the core net reactivity again equals zero. During this transient, the power decrease starts immediately after the core net $DK/K < 0$.
- Power decreases below the steady state value due to the fuel time constant. Before the power generated in the fuel can affect moderator density, fuel temperature must change along with heat transfer to the coolant. The fuel in BWRs responds relatively slow with a time constant between 6 and 10 seconds.
- When reactor power decreases, the EHC system responds by closing down on the CVs to throttle reactor pressure decrease.
- Reactor water level increases due to the recirculation system removing less water from the annulus than is being supplied by the moisture separator, steam dryers and feedwater.
- Prior to a recirculation flow increase, reactor power increases due to the decrease in feedwater temperature. The increase in reactor power produces an increase in reactor pressure and subsequent increase in steam flow, both total and turbine.
- Following the power decrease with flow, recirculation pump speed is returned to its

original value, causing power to increase.

- The increase in reactor power produces a corresponding increase in reactor pressure.
- The increase in reactor pressure is sensed by the EHC system which responds by throttling open the turbine control valves.
- The increase in steam flow is monitored by the feedwater control system along with the level decrease and it adjusts feedwater flow to maintain reactor water level.
- The decrease in reactor level is caused by the steam flow/feedwater flow mismatch and the recirculation system removing a larger volume of water from the annulus area.

Table 5.1-1 Parameter Setpoint Aids

Reactor Vessel Level (inches)	
Level 1 (-132.5)	Initiate CS AND LPCI, Start EDG, ADS signal, AND Isolate MSIVs
Level 2 (-38)	Initiate RCIC and HPCI, RWCU and other selected system isolation s AND ATWS-ARI AND ATWS-RPT
Level 3 (12.5)	Reactor scram, Recirc pump runback to 30%, ADS signal AND RHR Isolation signal
Level 4 (33)	Low level alarm, AND permissive for Recirc pump runback to 45%
Level 7 (40.5)	High level alarm
Level 8 (56.5)	Trip of main turbine, RFP, RCIC, AND HPCI
Reactor Pressure (psig)	
50 & 100	RCIC & HPCI Isolations
125	RHR SDC Isolation
310	Reactor Recirculation loop discharge valves close during LOCA
338 & 465	Permissive for LPCI AND CS injection valve opening on a LOCA
1025	High Pressure Alarm
1043	High Pressure Reactor Scram
1115/1125/1135	4/4/3 SRVs Safety Mode Opening Pressures
1120	ATWS-RPT AND ATWS-ARI
Main Steam Line Pressure (psig)	
825	Closes MSIVs in RUN Mode
Condenser Vacuum (inches of Hg)	
25.0	Low Condenser Vacuum alarm
22.5	Turbine trip
20.0	RFP trip
8.5	MSIV closure
7	BPV closure
Turbine First Stage Pressure (%)	
30%	Bypass EOC-RPT AND Reactor Scrams (due to TSV closure & TCV fast closure) if <30% power as sensed by first stage pressure
Drywell Pressure (psig)	
1.5	High pressure alarm
1.69	LOCA Signal: Initiate HPCI, CS AND RHR, Start D/G and RBSVS, AND isolation signal for selected plant systems
FWCS Steam Flow (%)	
20%	RWM rod blocks bypassed at > 20% power as sensed by steam flow
30%	RWM Alarms bypassed at > 30% power as sensed by steam flow

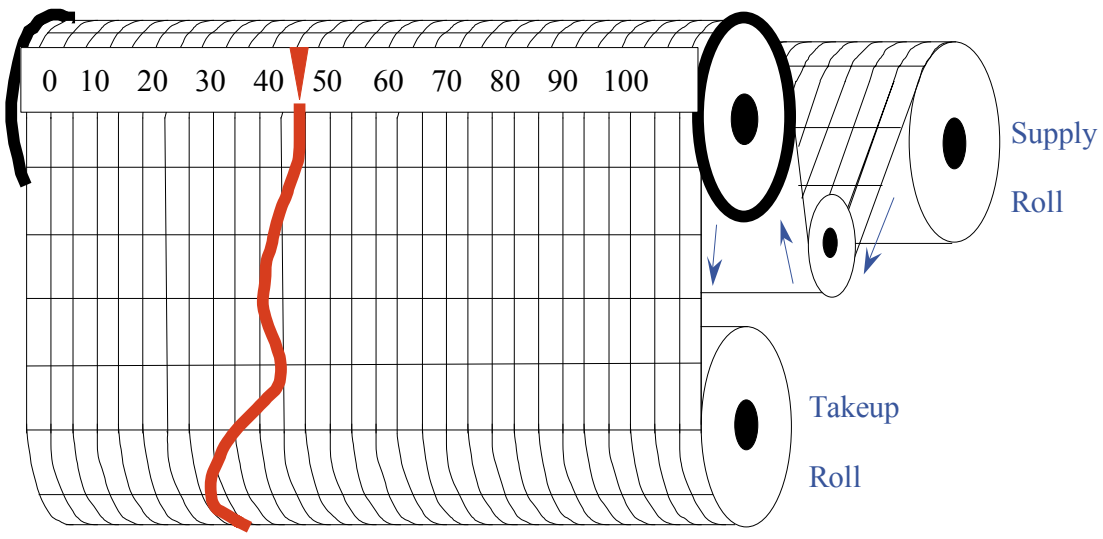
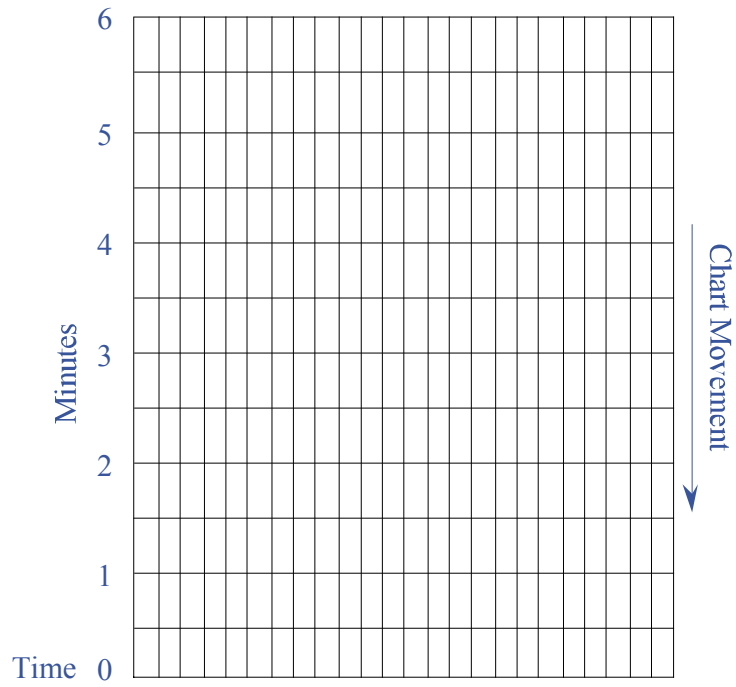


Chart Recorder

Figure 5.1-1 Chart Recorder

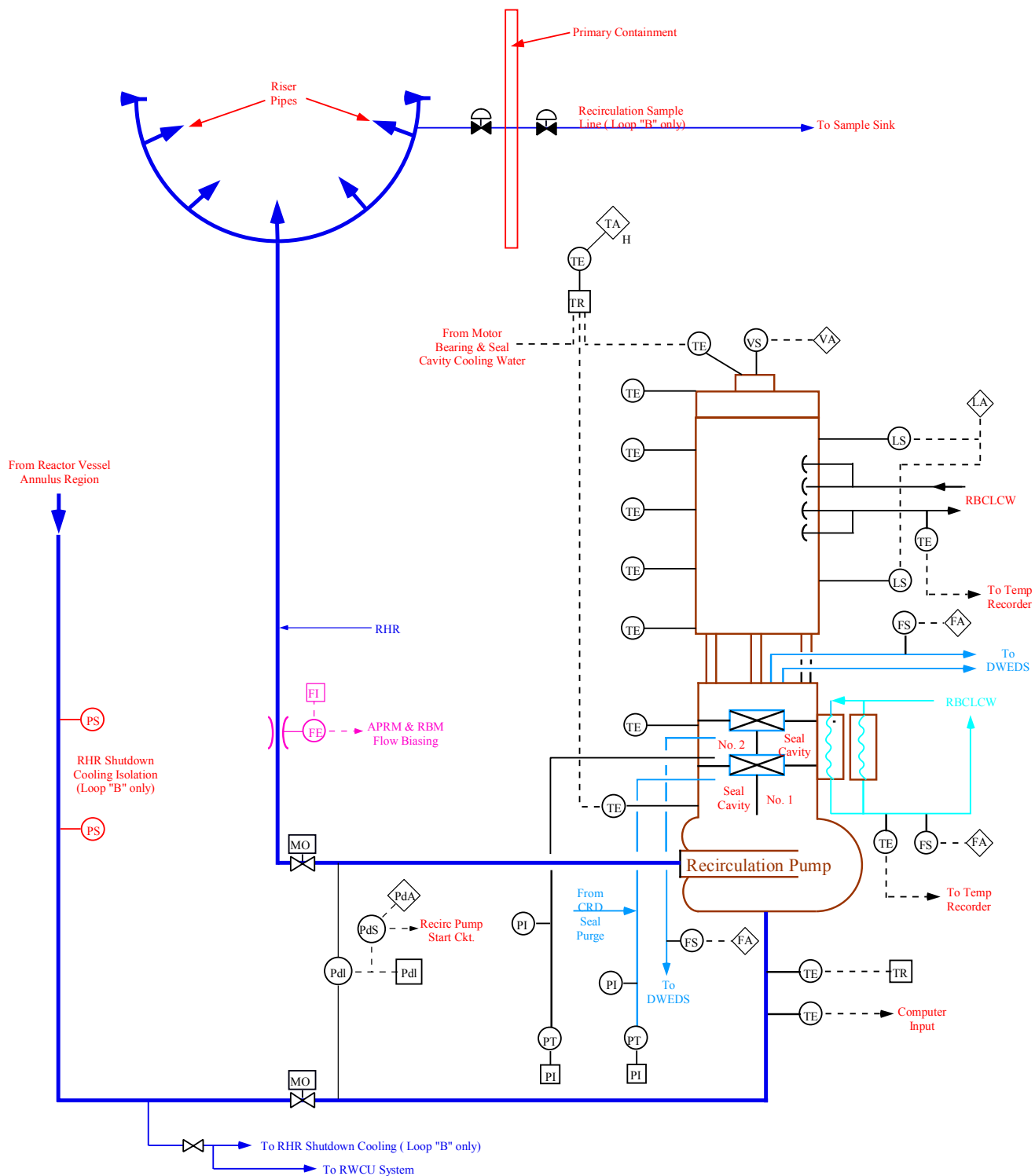


Figure 5.1-2 Recirculation Loop Instrumentation

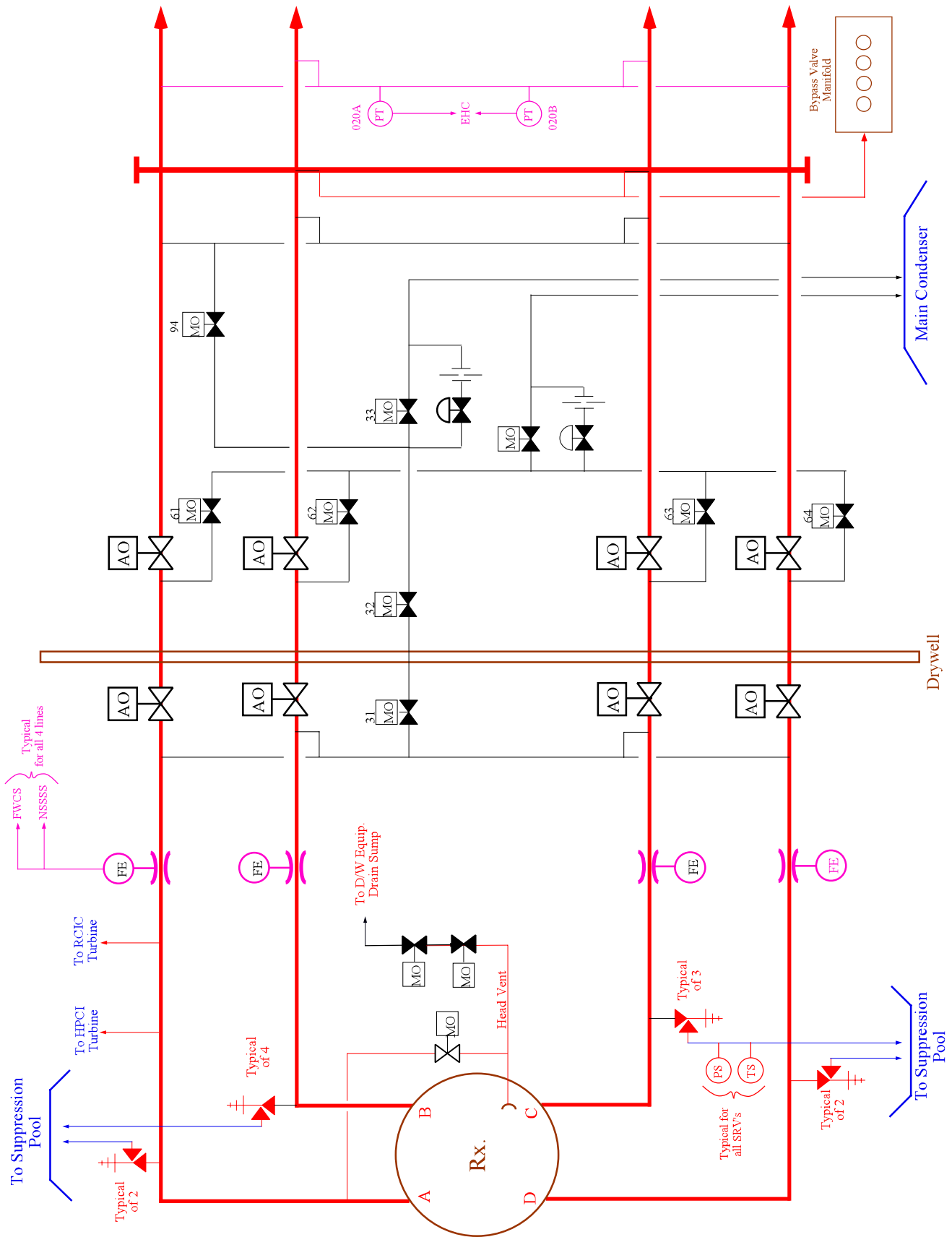


Figure 5.1-3 Main Steam System

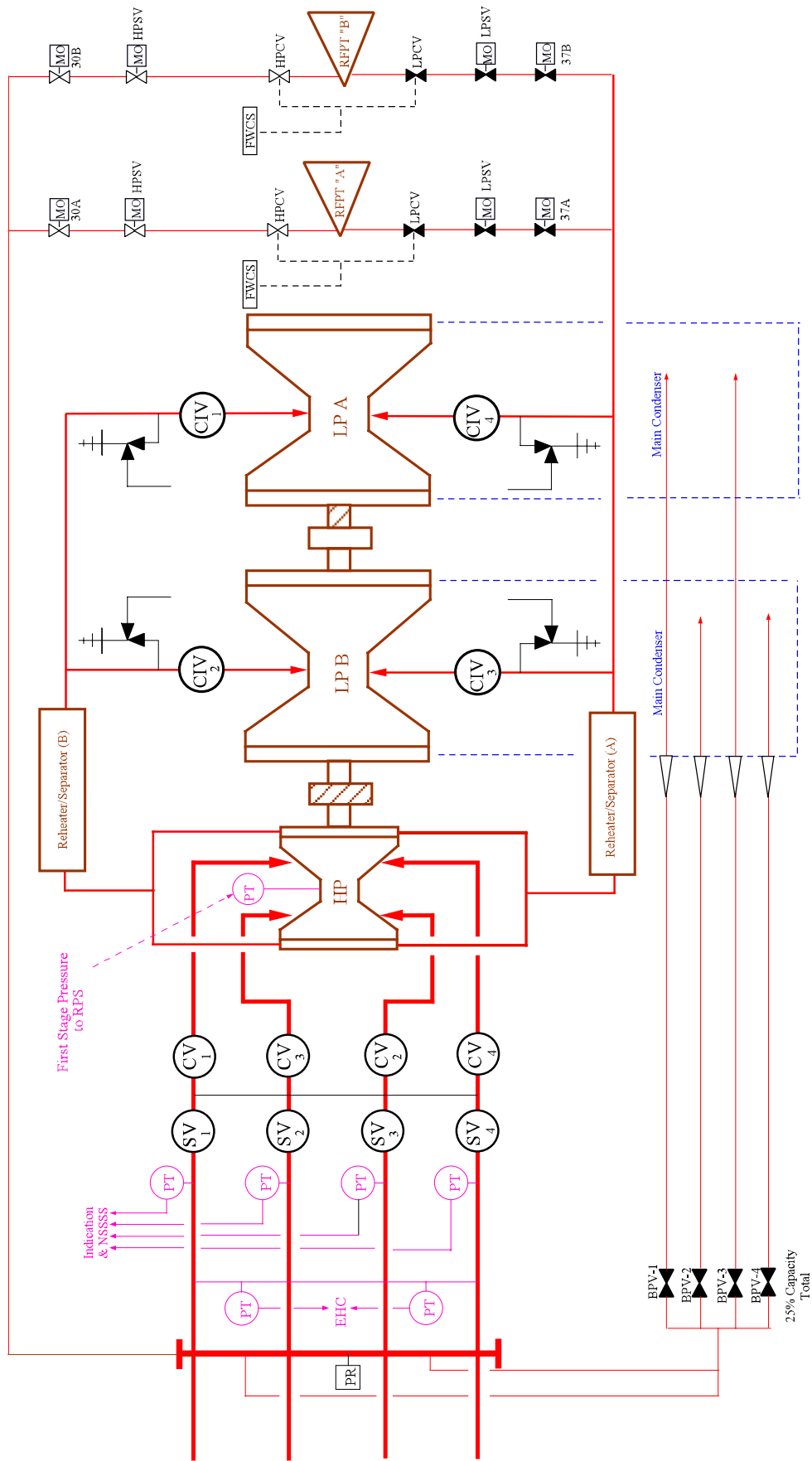


Figure 5.1-4 Main Steam System (Cont.)

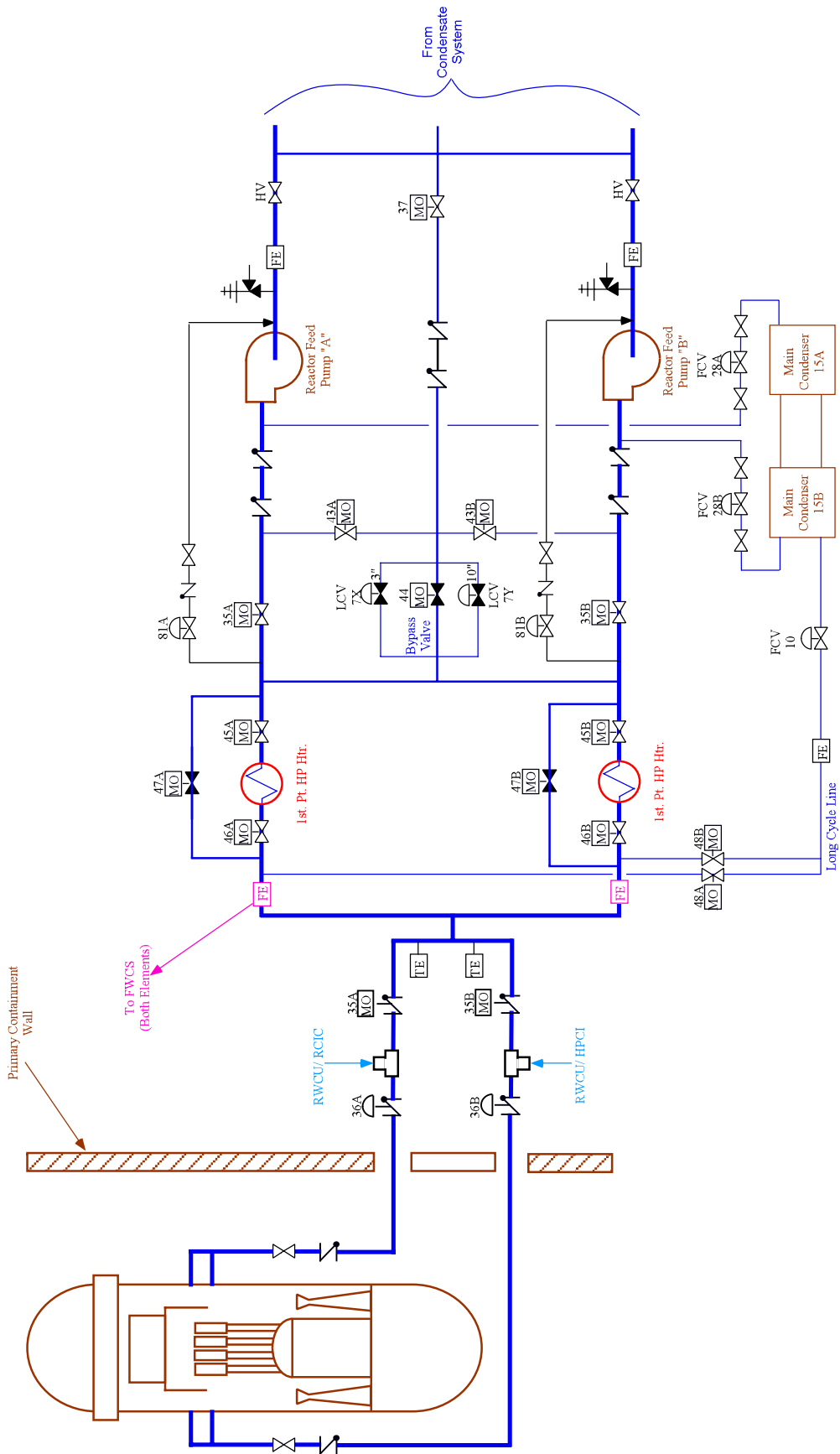
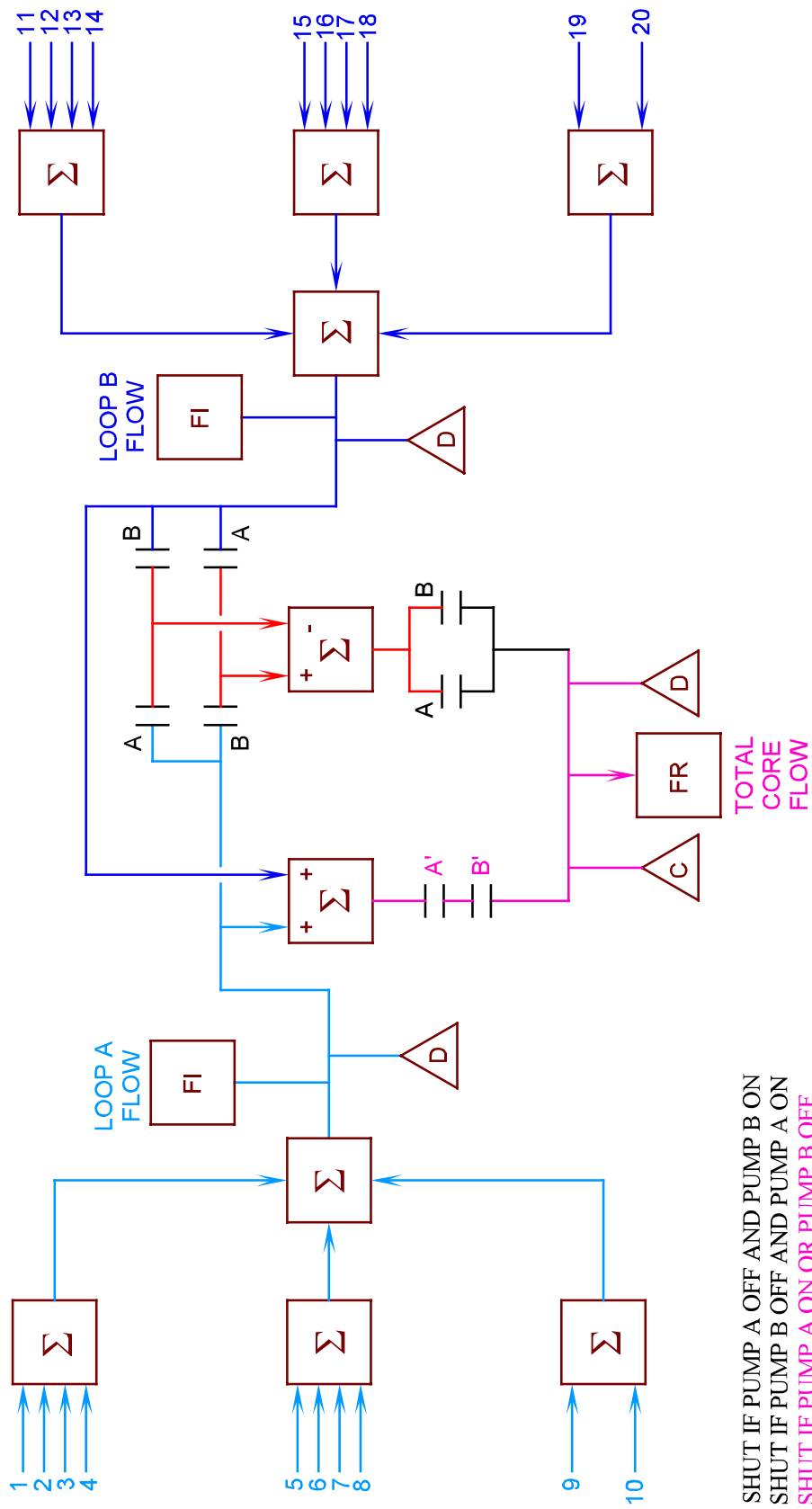


Figure 5.1-5 Feedwater System



- A - SHUT IF PUMP A OFF AND PUMP B ON
- B - SHUT IF PUMP B OFF AND PUMP A ON
- A' - SHUT IF PUMP A ON OR PUMP B OFF
- B' - SHUT IF PUMP A OFF OR PUMP B ON

Figure 5.1-6 Core Flow Summing Network

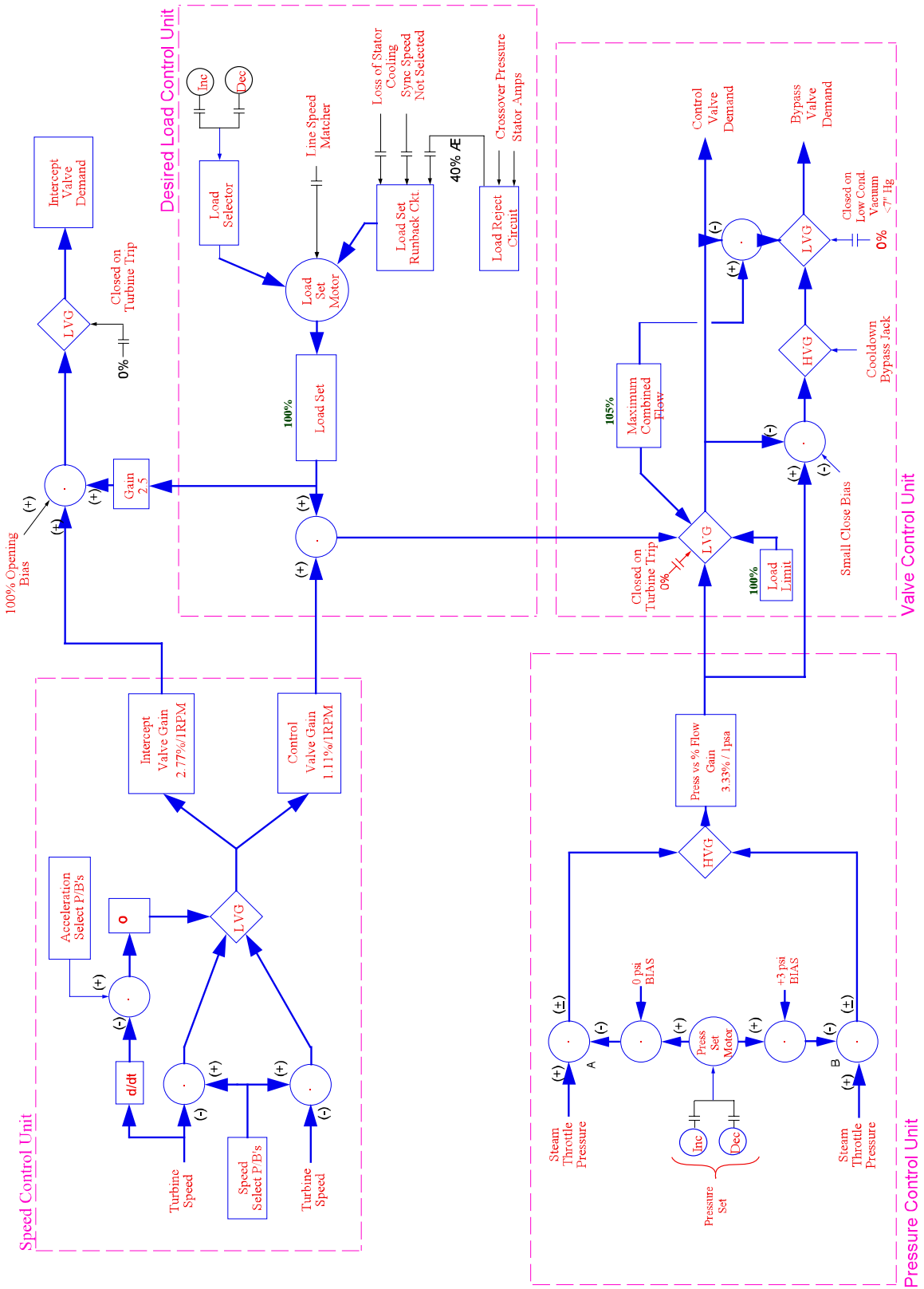


Figure 5.1-7 Electro Hydraulic Control System Logic

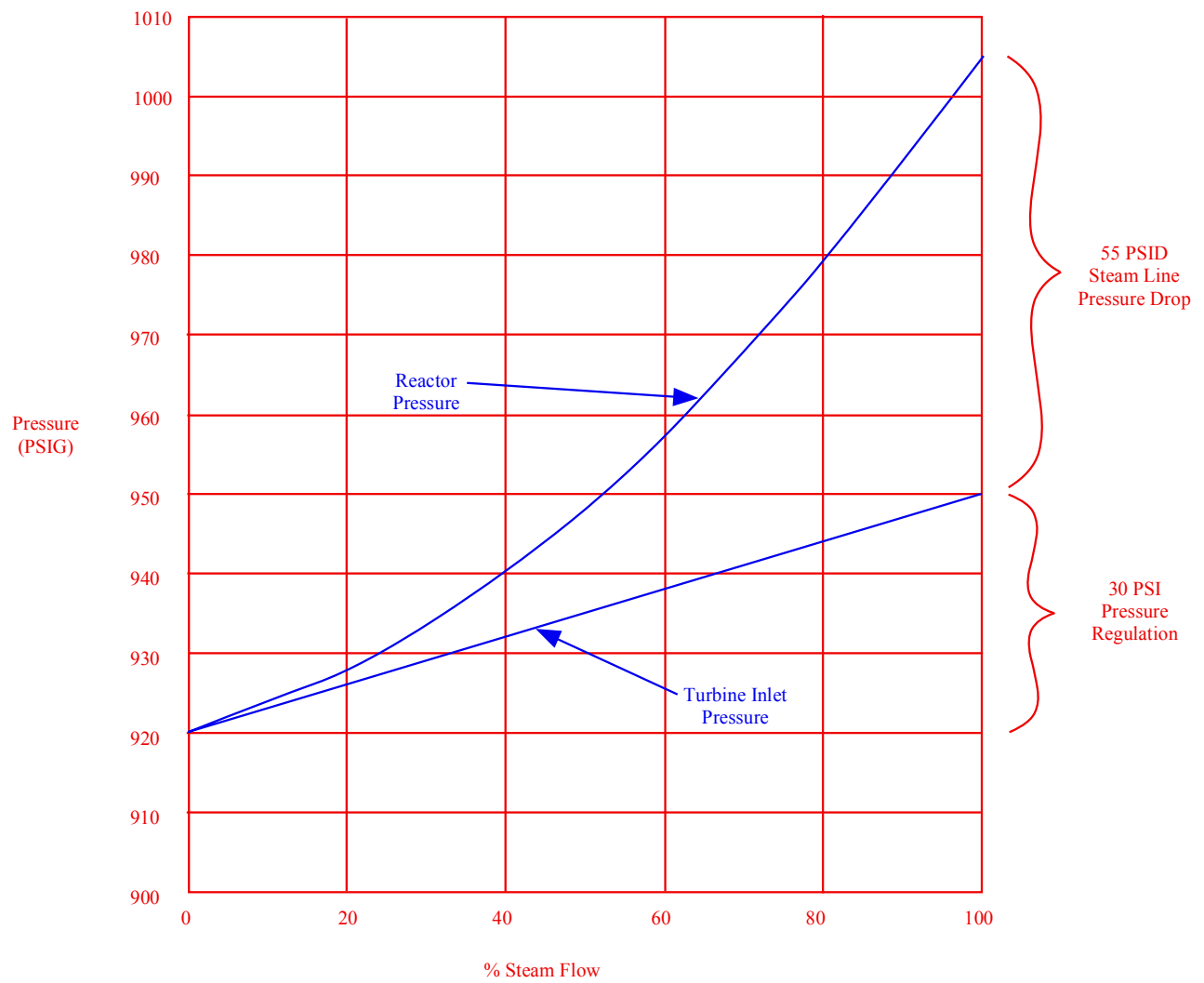


Figure 5.1-8 Pressure Control Spectrum

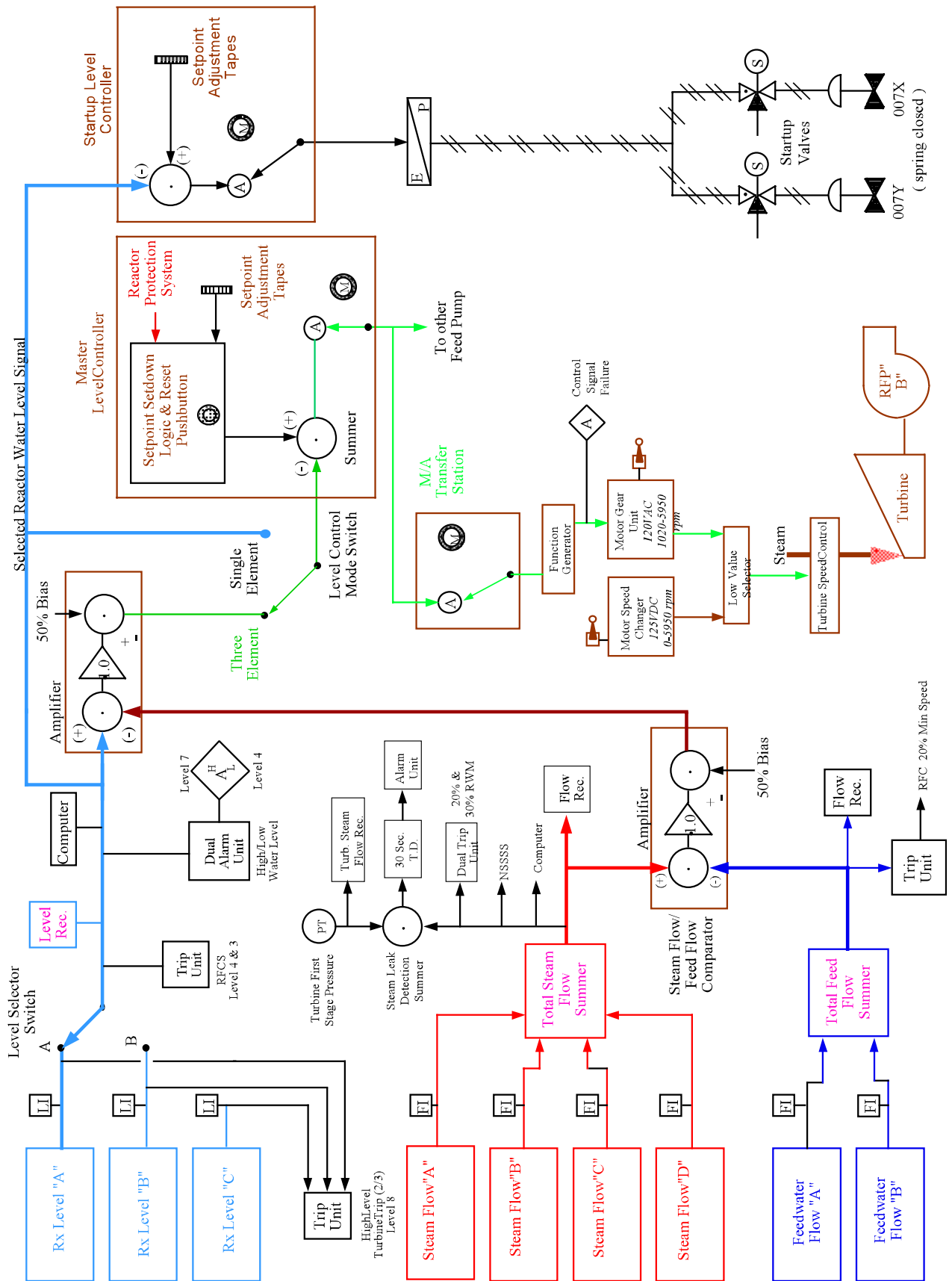


Figure 5.1-9 Feedwater Control System

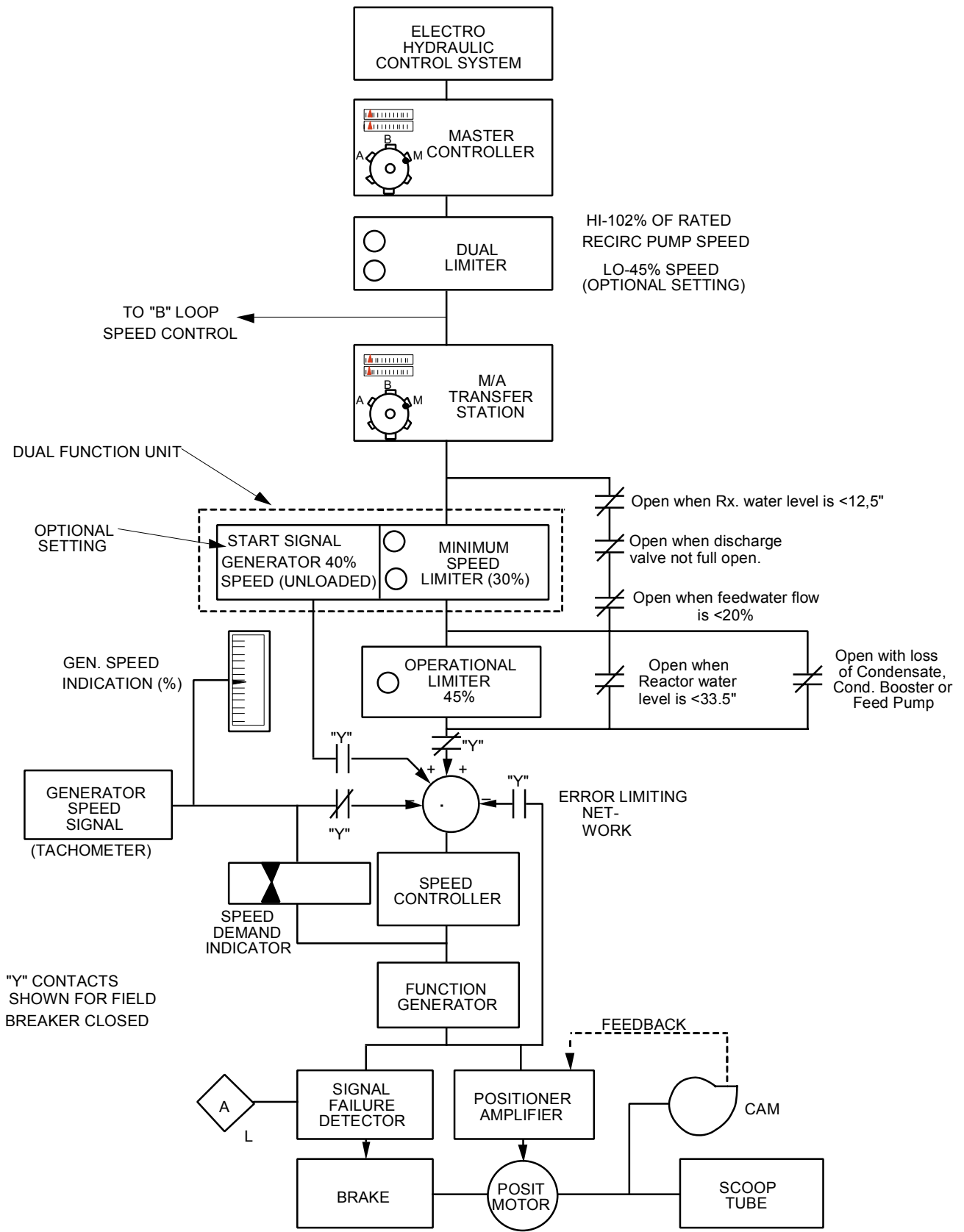


Figure 5.1-10 Recirculation Flow Control Network

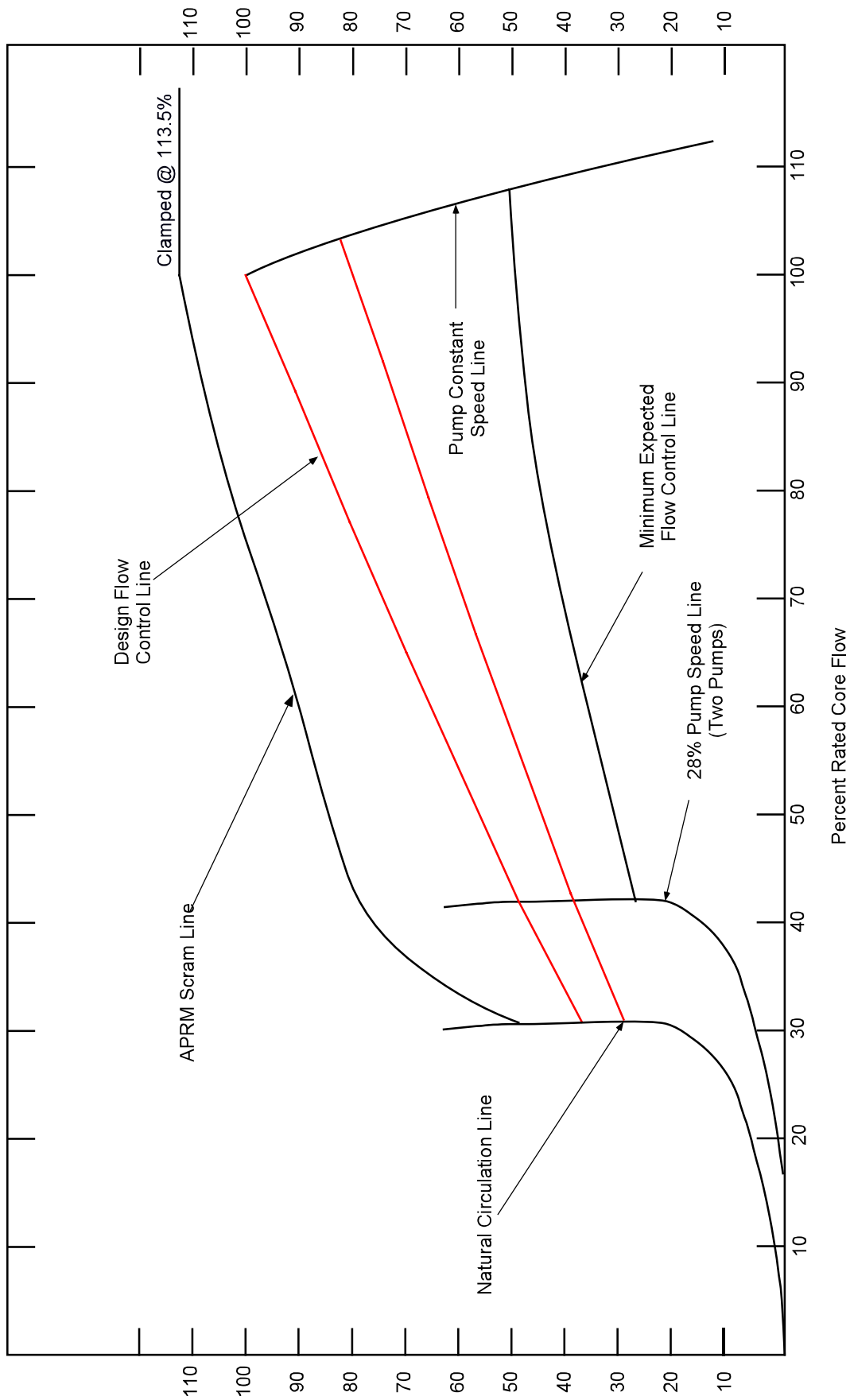


Figure 5.1-11 Power/Flow Map

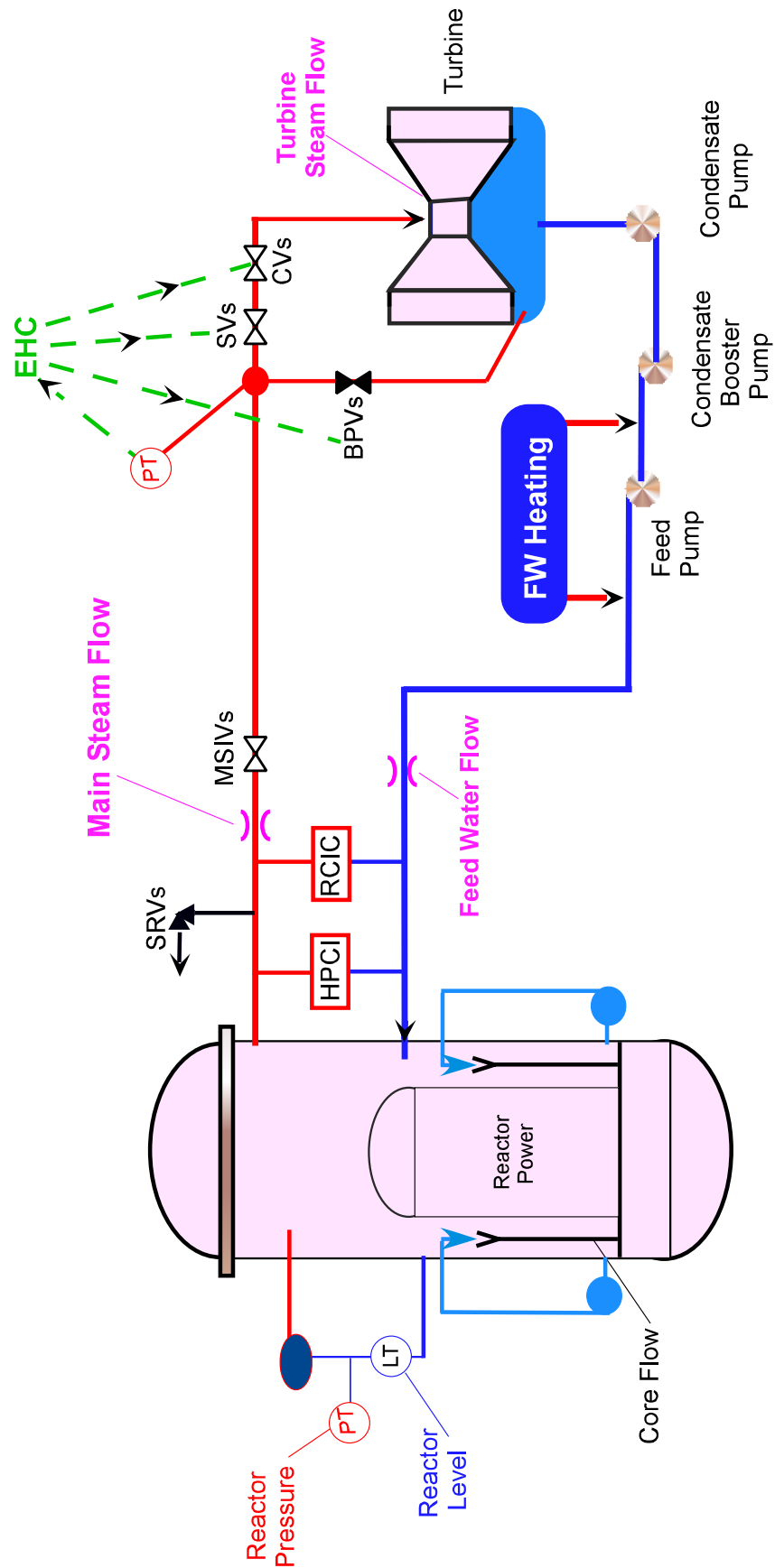


Figure 5.1-12 Balance of Plant