ATTACHMENT 1

REACTOR PROTECTION SYSTEM
SETPOINT METHODOLOGY

1.0 INTRODUCTION

This document discusses the methodology used in RPS setpoint generation for CPCo. Included in the document will be error combination techniques, the allowable value philosophy and calculation methodology.

The error combination techniques are highlighted with a discussion of the error components as well as justification of the techniques utilized. The error components are important since they provide a direct link between the accident analysis setpoints, the Tech Spec Trip Setpoints, the allowable values, and the allowable tolerances identified for The Channel Functional Test and The Channel Calibration.

The discussion of the accident analysis setpoints includes a description of the delay time philosophy used with the accident analysis setpoints. This is important since the time to control rod insertion is the limiting factor in analysis and not specifically the time to trip condition in the system.

The document is divided into four sections: definitions, error components, error combination techniques, setpoint and delay time relationships for accident analysis. Through these discussions, this document provides an overview of the setpoints used to generate Tech Spec Section 16.2 for the RPS trips.

2.0 DEFINITIONS

Acceptance Criteria - Transient conditions and consequences expressed in engineering units used to define successful mitigation of a given transient.

Accuracy - The degree of conformity of an indicated value to a real value.

Allowable Value - The sum of the Tech Spec SETPOINT value plus the maximum instrument DRIFT which could occur over the calibration interval(s) of instruments involved in generating a bistable trip plus applicable measurements and test equipment accuracies. Refer to Figure 1.

Allowable Tolerance

The allowable tolerance shall be the maximum instrument drift plus the instrument reference accuracy plus the inaccuracy of the measuring and test equipment. The technical specifications contain specific allowable tolerances which are defined as follows.

a. 30 Day Allowable Tolerance (Channel Functional Test)
   The maximum drift over 30 days of that portion of the instrument channel (e.g. logic cabinet equipment and instrument modules, excluding sensor and bistable) which is tested every 30 days plus the reference accuracy of the appropriate portion of the instrument channel plus the maximum inaccuracy of the measuring and test equipment used for the Channel Functional Test.

b. 18 Month Allowable Tolerance (Channel Calibration)
   The value of the 30 day allowable tolerance plus the reference accuracy and maximum drift over 18 months of that portion of the instrument channel (e.g. sensor) which is not tested during the Channel Functional Test, plus the inaccuracy of the measuring and test equipment (used every 18 months for the Channel Calibration) that is not already included in the 30 day allowable tolerance.

Calibration Band - The band between the upper and lower field setting limits within which a setpoint will be adjusted during calibration. Refer to Figure 1.

Constraints - Restrictions placed on setpoints due to instrumentation and plant safety (i.e. reactor trip prior to pressurizer safety valves opening).

Safety Limit - Safety limits for nuclear reactors are limits upon important process variables which are found to be necessary to reasonably protect the integrity of certain of the physical barriers which guard against the uncontrolled release of radioactivity.

Tech Spec Trip Setpoint - The Tech Spec trip setpoint is a trip setpoint listed in Table 2.2-1 of Tech Specs, and is intended to be used to limit RPS instrument settings to provide adequate protection for physical barriers consistent with accident analysis.

Instrument Inaccuracy - The inaccuracy associated with an RPS instrument or instrument string due to manufacturing tolerances, environment, and power supply effects, or other effects which cause instrument input-output relationships to change during operation.

Instrument Drift - A change in an instrument or instrument string input-output relationship over the calibration interval of interest independent of environmental effects. As instrument strings are tested monthly during the Channel Functional Test, instrument drift based on monthly test data should be used in setpoint calculation.

Sensor Drift - A change in a sensor input-output relationship over the calibration interval of interest independent of environmental effects. For those sensors which are tested only every 18 months, sensor drift based on 18 month test data should be used in setpoint calculations.

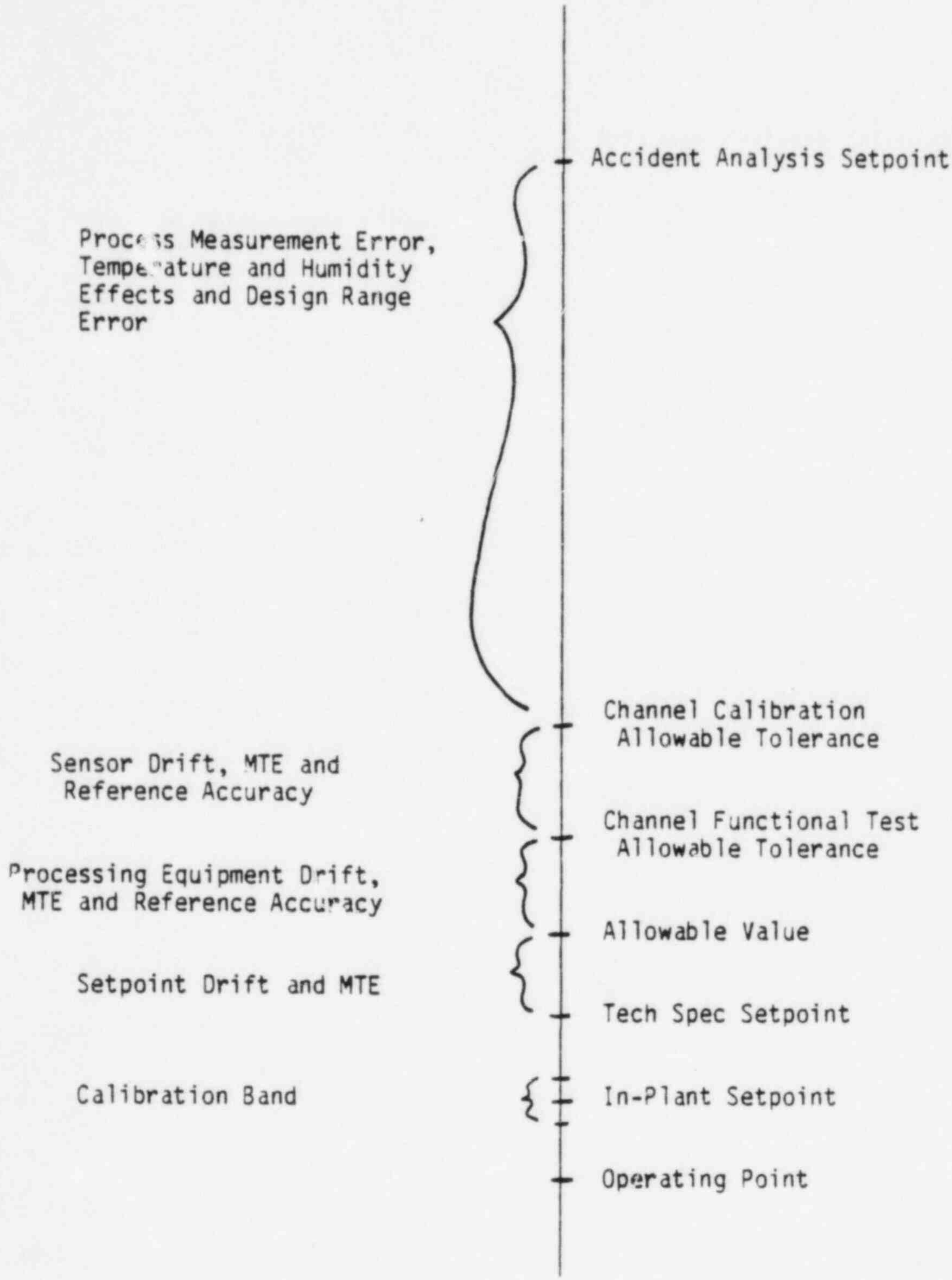

Figure 1. Setpoint and Error Relationships

Period of Operability (POO) - Maximum time from accident initiation to reactor trip signal in which a trip string is required to operate.

Accident Analysis Setpoint - Analytical setpoint limit on a real value of a system process variable expressed in engineering units. The accident analysis setpoint differs from the Tech Spec trip setpoint by at least an amount equal to the total instrument string error plus process measurement error as shown below:

[Accident Analysis Setpoint] = [Tech Spec Trip Setpoint] + [Total String Error] + [Process Measurement Error]

[Total String Error] = [Instrument Sensor Inaccuracy] + [Instrument Drift] + [Sensor Drift] + [Measurement & Test Equipment Inaccuracy]

The measurement and test equipment inaccuracy is included in the total string error, since it is present when instuments are calibrated and when setpoints are verified during Tech Spec surveillance testing. The instrument and sensor drift are identified separately for use in allowable value calculations.

3.0 ERROR COMPONENTS

Certain error components are important in calculating Tech Spec trip setpoints, accident analysis setpoints and allowable values. Figure 1 depicts these components, and this section will expand on their definitions. Four major error components can be identified: instrument errors, instrument drift, measurement and test equipment errors and process measurement errors.

Instrument Errors

The term, instrument errors, refers to a combination of module errors into a total string error. Specific items included in each module error include environmental effects, calibration errors, reference errors and design range errors. In addition, the inaccuracies of equipment assumed for calibration and testing are also included.

Process Measurement Errors

Certain parameter measurements produce an error, due to non-instrumentation effects, which must be included in the accident analysis modelling of the same parameter measurement. The error can be caused by differences in where the RPS measures a parameter for trip and how that same parameter was modelled in analysis or also by the measurement of the process itself. Examples of these would be, the pressure difference value which is used to adjust the pressure trips modelled at core outlet to the pressure measurement trip location in the hot leg, and the RC flow noise which is caused by the RC flow measurement based on the pressure drop across a venturi. In each case an error in the measurement is introduced which is independent of the instrumentation. This error must be included between the accident analysis setpoint and the Tech Spec setpoint.

Measurement and Test Equipment (MTE) Inaccuracy

Whenever a setpoint is verified during surveillance testing, the accuracy of the test equipment effects how the setpoint in the instrument is perceived by the technician and may influence the "as left" trip setting. Therefore,

the test equipment inaccuracy must be accounted for during error combination and setpoint generation to ensure conservative trip settings. The inclusion of these errors is also important in determining the allowable value to be used for the Channel Functional Test and the Channel Calibration. This is discussed further in the section on setpoint relationships.

Instrument Drift

Instrument drift is a random phenomenon which causes instrument output to vary slightly with a constant input independent of environmental effects. The instrument drift is separated into two parts: cabinet drift and sensor drift. This separation is necessary since the sensor drift is required for calculating the Channel Calibration allowable value but is not required for the Channel Functional Test allowable value. The use of drift values in this manner is based on the definitions of Tech Specs surveillance tests as discussed earlier.

4.0 RELATIONSHIPS BETWEEN ACCIDENT ANALYSIS AND TECH SPEC SETPOINTS

The relationship between an RPS accident analysis setpoint and an RPS Tech Spec trip setpoint can best be described by presenting the setpoint adjustment method. For the RPS, four setpoint adjustment techniques are generally used: a simple adjustment, a line equation adjustment, a flux adjustment, and a power/imbalance/flow adjustment. These adjustment techniques differ in the types of assumptions and errors used are well as the actual adjustment that is made. In each case, the adjustments show that the Tech Spec setpoints will maintain the conservatisms of the accident analysis setpoints, so that the reported FSAR accident consequences are conservative.

Simple Adjustment

The simple adjustment is used for single variable trips, excluding the high flux trip. The simple adjustment adds the instrument and process measurement errors conservatively to arrive at the difference between the Tech Spec setpoint and the accident analysis setpoint. This calculational method is used for the high and low RC pressure, the high RC outlet temperature, and the high reactor building pressure trips.

Generally, a Tech Spec setpoint is determined that will not restrict normal plant operation, and then errors are conservatively added to generate an accident analysis setpoint. This accident analysis setpoint is used in Chapter 15 FSAR analysis to conservatively model the latest time to rod insertion caused by RPS errors and time delays. Figure 2 depicts this technique. An additional 15 psi factor for pressure trips is included to account for psia units in the computer code analysis and the setting of instrumentation to gauge pressure. In an equation form the adjustment becomes:

$$SP'' = SP + e + e_m \; (+15 \text{ psi})$$

where

SP'' = the accident analysis setpoint used in computer code,

SP = Tech Spec Trip setpoint,

e = instrumentation errors,

e_m = process measurement error,

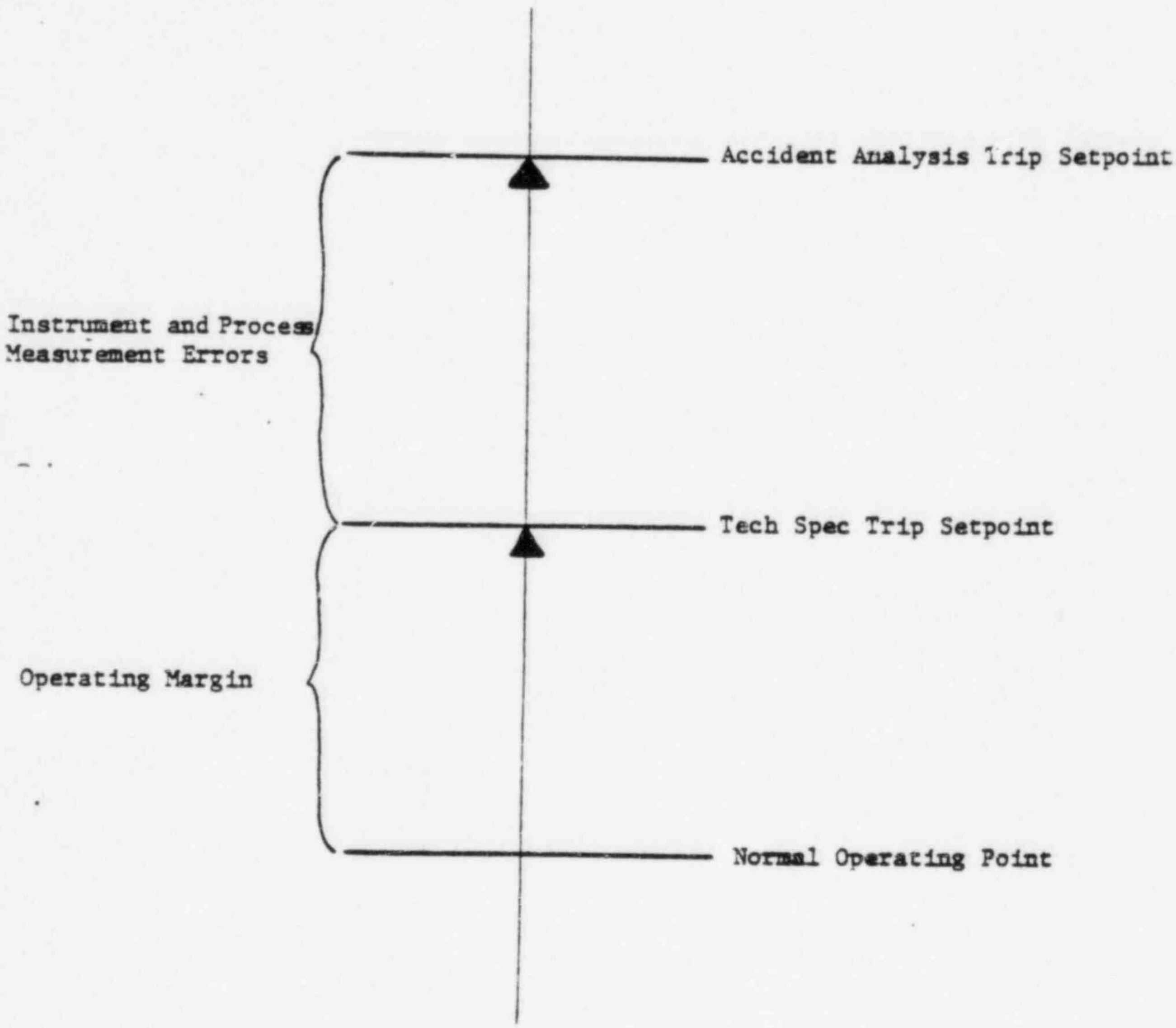

Figure 2. Simple Setpoint Adjustment

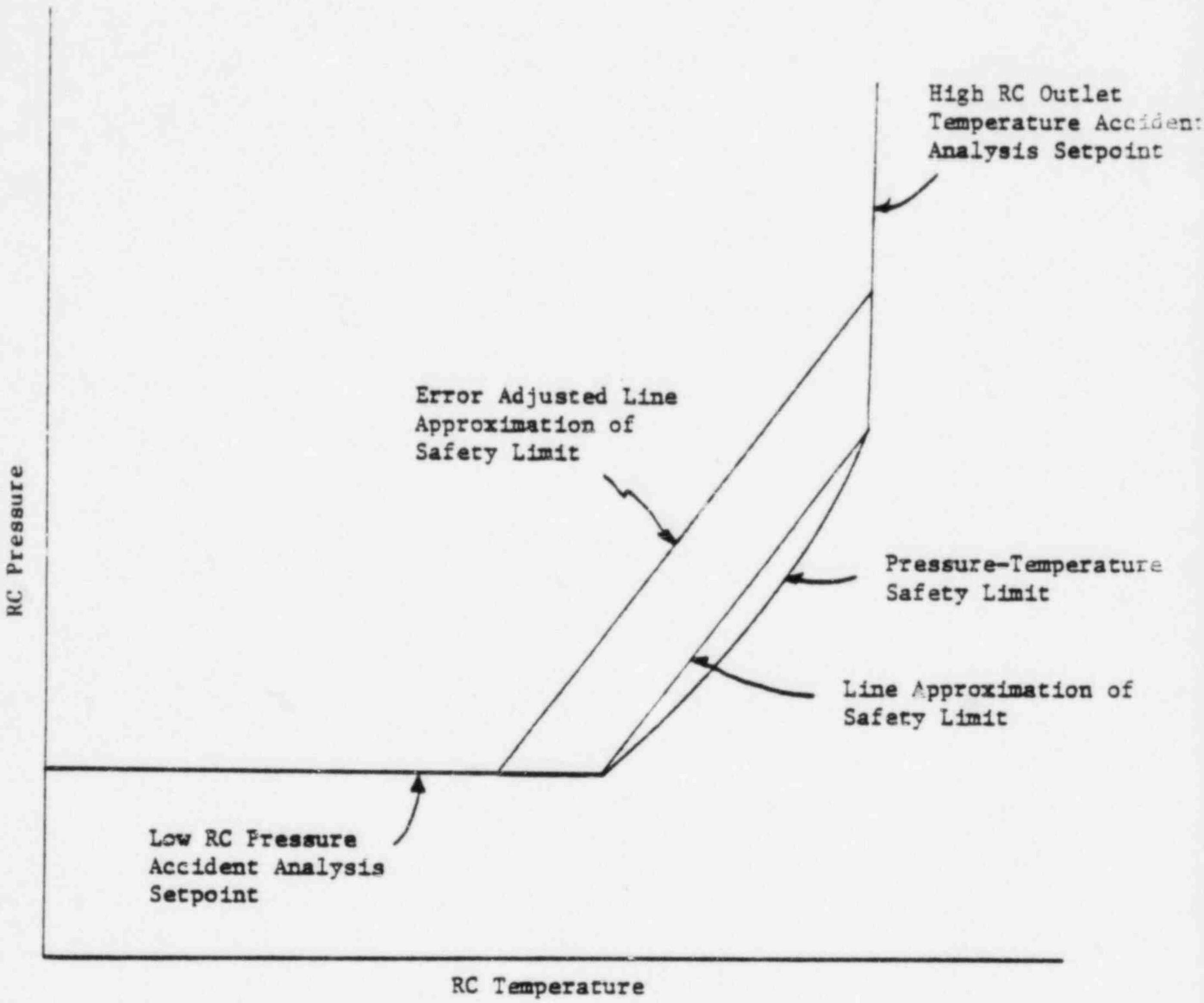

Figure 3. Example of Variable Low Pressure Adjustment

and the 15 psi adjustment is used for pressure trips where units of psia are used in computer codes.

Line Equation Adjustment

The line equation adjustment differs from the simple adjustment in that two parameters, RCS pressure and RC outlet temperature, must be considered in adjustment. The pressure and temperature instrumentation and process measurement errors are combined into one pressure error which represents the difference between the pressure temperature safety limit and the Tech Spec setpoint. Unlike the simple adjustment which begins with the Tech Spec trip setpoint, the line equation adjustment starts from an approximation of a safety limit and then adjust to the variable low pressure trip setpoint with the errors.

Figure 3 depicts the adjustment process graphically. The adjustment is done for each allowable pump status (4, 3 and 2 pump operation) with the variable low pressure trip setpoint being the most conservative of the 3 error adjusted lines. In cases where one line is not most conservative over the entire span of interest, a combination of the lines is made to arrive at a single line which provides conservative protection throughout the region of interest.

Flux Adjustment

The flux adjustment combines an assumed process measurement error, instrument error, and a required heat balance error to arrive at the difference between Tech Spec setpoint and the accident analysis setpoint. This adjustment differs from the simple adjustment in that measurement and instrument errors are assumed to be less than a given value, and both plant operation and instrument calibration must follow rigid criteria to ensure that the assumption remains conservative. Three trips, high flux, power/imbalance/flow, and power/pump monitors, use this adjustment technique. The flux adjustment often receives special attention since generated thermal power is a significant input in most fuel response analyses. Most important is the 112% FP design overpower concept, where the plant is designed for operation

at 112% FP under certain conditions. To ensure thermal power does not exceed 112% FP, the high flux trip Tech Spec setpoint is calculated by subtracting all high flux trip errors from 112% FP. The resulting setpoint will prevent plant operation above 112% FP real power, while permitting plant operation at 100% FP.

Figure 4 shows the setpoint adjustment for the high flux trip. This adjustment is similar to the variable low pressure adjustment in that the adjustment begins with a design limit and proceeds to the trip setpoint. In equation form, the adjustment is defined as follows.

$$SP = SP'' - e_\phi$$

where

SP = flux setpoint, Tech Spec value, % FP

SP" = accident analysis flux setpoint, 112% FP

e_ϕ = total assumed flux trip errors, % FP

The same adjustment is used for the power/imbalance/flow and power/pump monitors trip but with the accident analysis setpoint defined by conditions other than design overpower.

<u>Power/Imbalance/Flow Adjustment</u>

The final adjustment used for the power/imbalance/flow trip, is unique in that error adjustments are performed separately on power-flow and power-imbalance relationships. (Imbalance is defined as the power in the top half of the core minus the power in the bottom half of the core.) This adjustment procedure utilizes the linear flux adjustment as well as non-linear offset and flow adjustments. The technique is based upon the fact that the trip provides transient RC pump coastdown protection with the flux/flow ratio, while providing steady-state protection by the flux-imbalance envelope. As an imbalance condition (i.e., imbalance ≠ zero) is not considered a required condition for flux/flow ratio analysis, imbalance errors are ignored during flux/flow ratio calculations. The established flux/flow ratio is then used to generate an initial power level for power-imbalance analysis. Steady-state RC flow errors are considered to calculate these

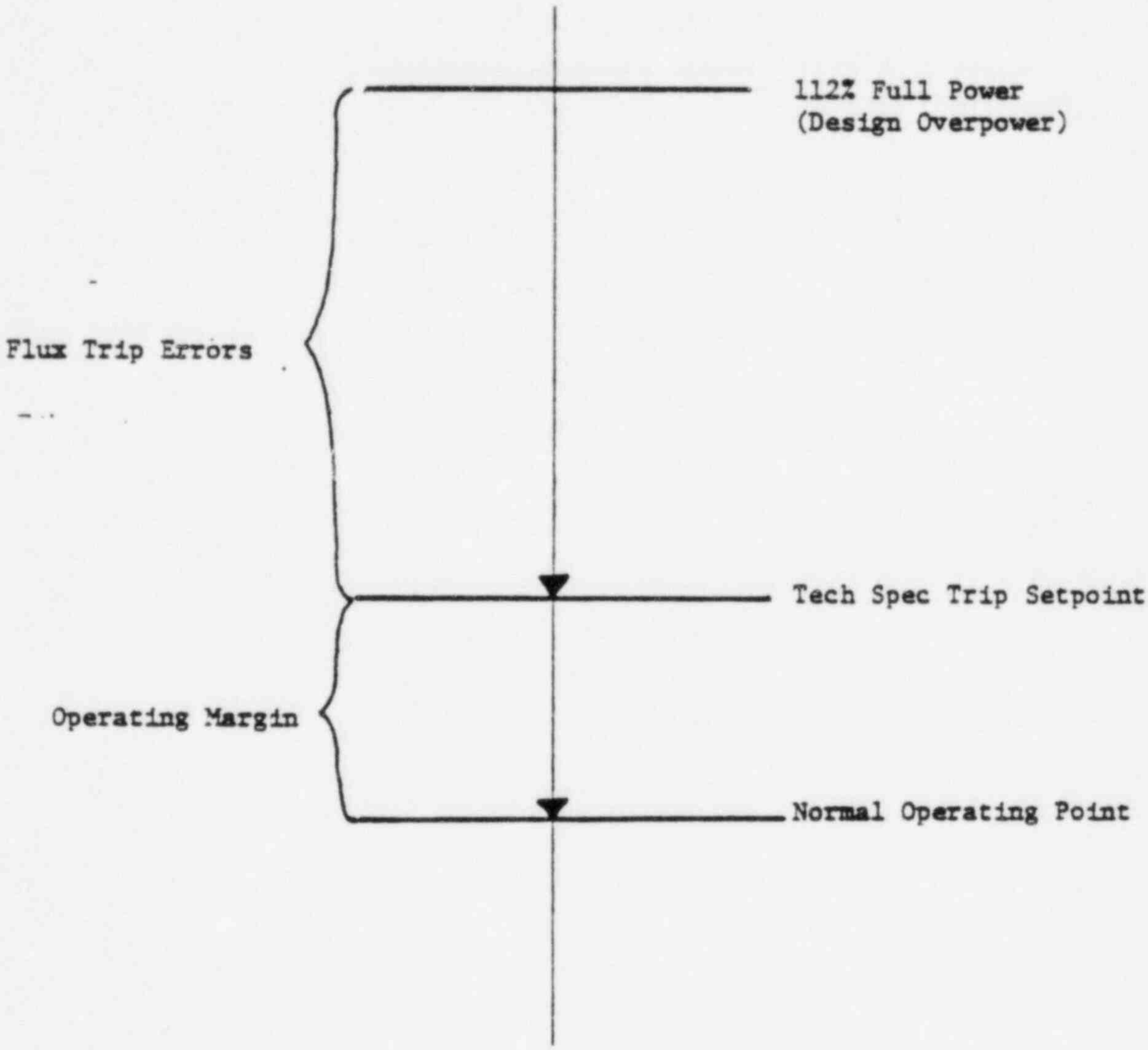

Figure 4. Flux Adjustment

initial power levels, but RC flow noise is ignored. Finally, after the power offset limits are adjusted for power offset errors, the use of the parameter imbalance requires additional adjustments for the accuracy of the imbalance related setpoint generation equipment.

The power/imbalance/flow trip combines two relationships, power/flow and power-imbalance, to arrive at a setpoint which limits power based on axial imbalance and measured RC flow. The two relationships will be discussed separately in describing the relationship between the accident analysis and Tech Spec setpoints.

Flux/Flow Setpoint

The flux/flow setpoint is initially generated to provide protection for the 4→3 RC pump coastdown accident. For the 4→3 RC pump coastdown, the transient initial power level is first established, incorporating all flux measurement and instrumentation errors. The transient is then analyzed for DNBR response, and the flux/flow ratio needed to prevent DNB is determined (S_m). The S_m flux/flow ratio does not include RC flow measurement or instrumentation errors; however, these errors are added in the following equation to determine S_{ew}, a flux/flow ratio including RC flow errors.

$$S_{ew} = \frac{\emptyset_i - e}{\emptyset_i/S_m + w}$$

where,

S_{ew} = flux/flow setpoint, adjusted for flow instrumentation errors and flow noise, Tech Spec value, % FP/% flow,

S_m = maximum allowable flux/flow ratio needed to prevent DNBR for the RC pump coastdown accident analysis, % FP/% flow,

$\emptyset_i$ = indicated power level for pump coastdown analysis, % FP,

e = RC flow instrument error for the 4 3 pump coastdown, % FP,

w = RC flow noise, % flow.

The calculated S_{ew} value is now the flux/flow setpoint for use in the steady-state protection.

Power-Imbalance

The power-imbalance portion of the power/imbalance/flow trip provides a means by which the RPS determines a power penalty based on imbalance to be applied to the $\emptyset_{max}( )$ value generated by the flux/flow setpoint. [$\emptyset_{max}( ) = S_{ew}$ x (real RC flow for pump status , = 4, 3 or 2 pump operation)].

A power error adjustment accounts for a heat balance error of 2.0% FP, a requirement stated in Regulatory Guide 1.49, and instrument errors corresponding to the different modules of the power/imbalance/flow instrument string.

An offset error is used to account for the accuracy of the neutron detectors in determining the axial power distribution in the core.

The RPS cannot calculate offset so the error adjusted power-offset limits are changed to error adjusted power-imbalance limits by the following relationships:

Imbalance = Offset * Power

The generated error adjusted power-imbalance limits determine an envelope of allowed 4 pump operation. (See Figure 5)

The power/imbalance/flow setpoint will be a three line segment approximation of the error adjusted limits determined by four breakpoints (see Figure 6). The upper segment is the $\emptyset_{max}(2/2)$ value. An additional break point error is applied in chosing the setpoints as shown below:

$e_{B1} = e_{B4} = 0.625\%$ imbalance, for breakpoint setpoints B_1 and B_4

$e_{B2} = e_{B3} = 0.275\%$ imbalance, for breakpoint setpoints B_2 and B_3

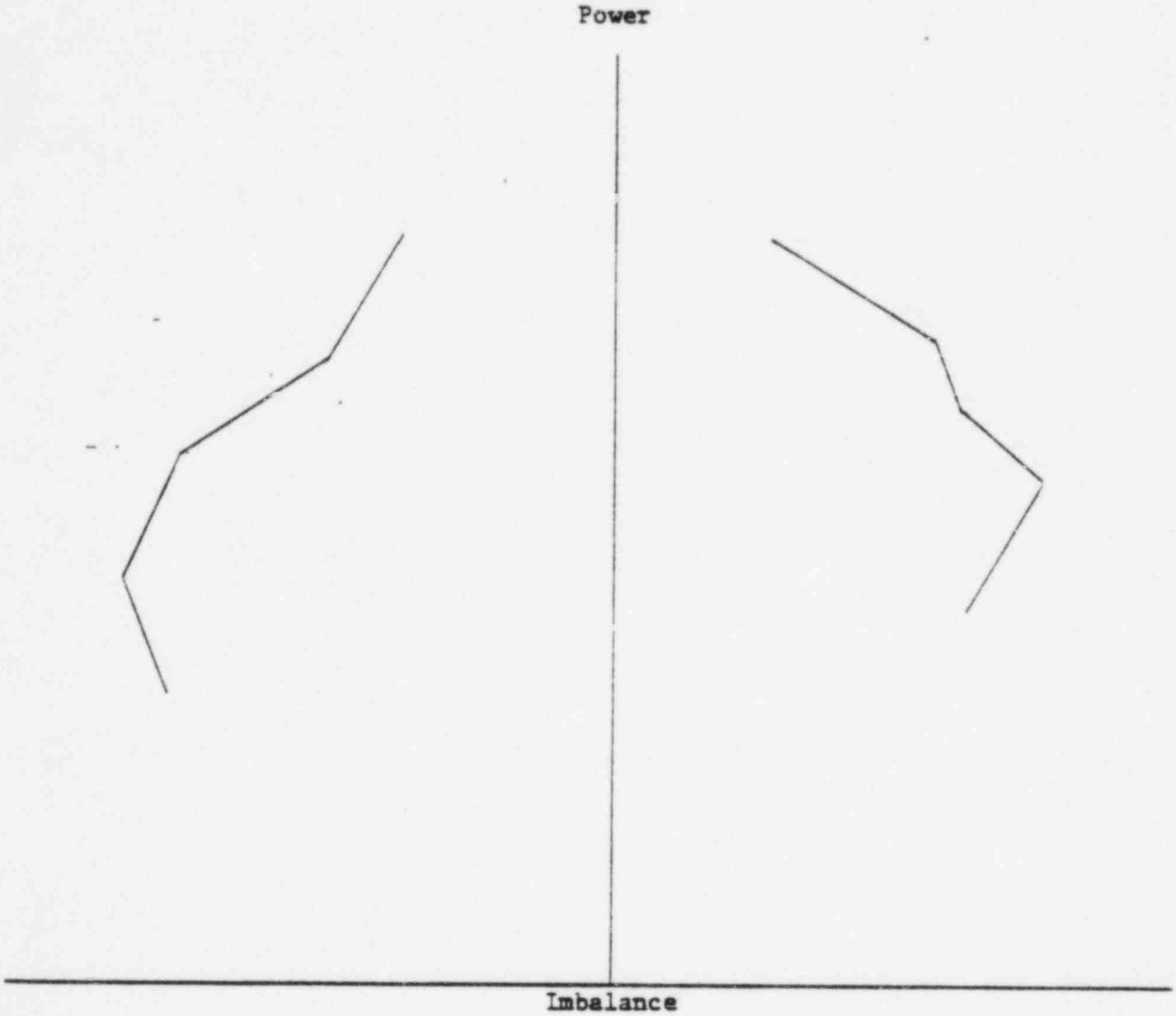

Figure 5. Sample Error Adjusted Power/Imbalance Envelope

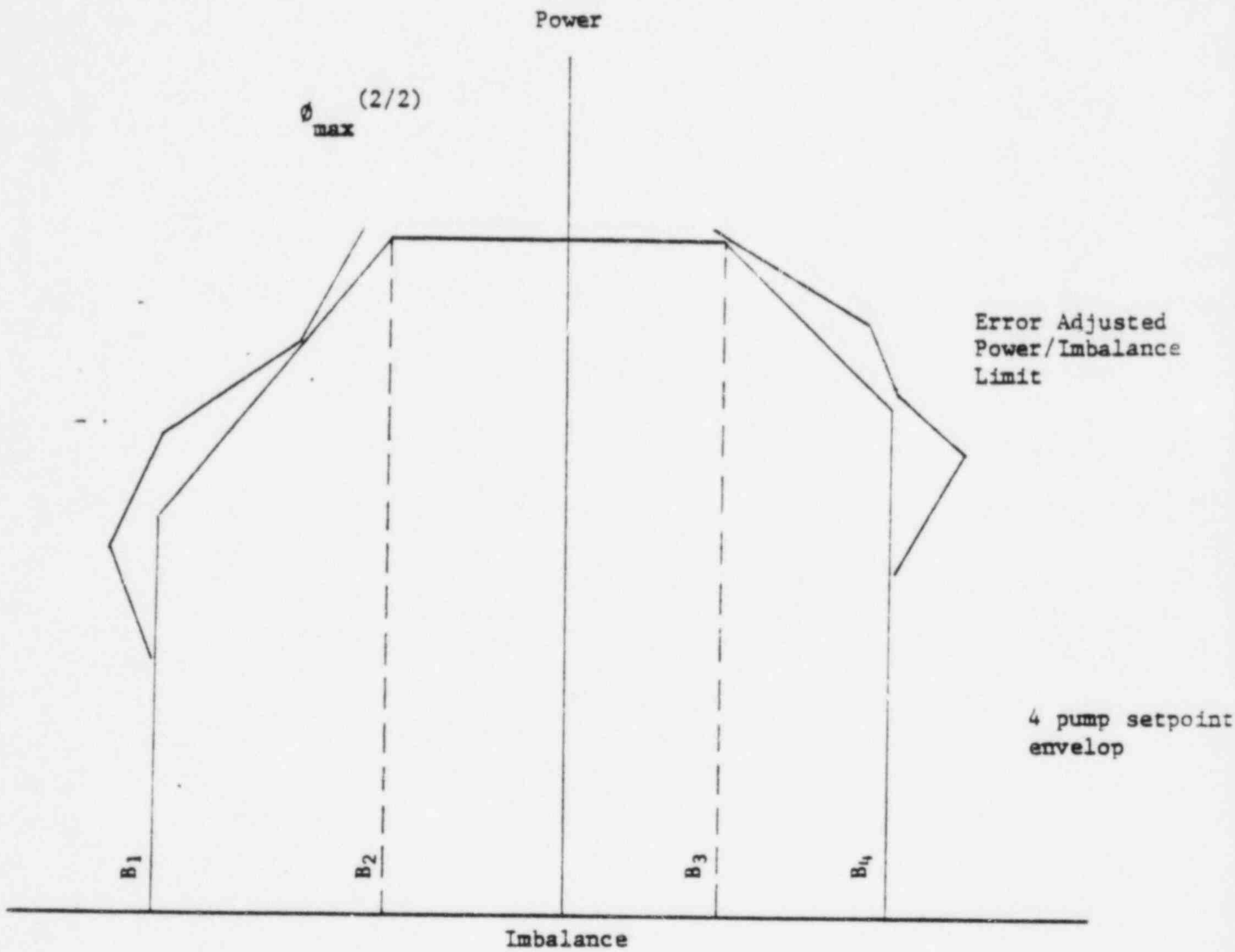

Figure 6. Sample Setpoint Envelope Placement

With the four pump setpoint defined, the three and two pump setpoint envelopes are determined based on the $\emptyset_{max}(2/1)$ and the $\emptyset_{max}(1/1)$ values and the breakpoints and slopes of the four pump setpoint. In the same manner as the setpoints were determined with the error adjusted power-imbalance limits and the $\emptyset_{max}$ values, the corresponding 4, 3 and 2 pump safety limits are generated from the real power-imbalance limits and the $\emptyset_{max}$ values which include the appropriate flux and flow errors. By generating the safety limits to be entered in Tech Spec Figure 2.1-2 in this way, a close correspondence between the setpoint and the safety limit can be shown.

Allowable Values and Allowable Tolerances

The allowable values and allowable tolerances in Tech Spec are intended for use during the Tech Spec surveillance tests, namely, the Channel Functional Test, required every 30 days, and the Channel Calibration required every 18 months. The allowable values and tolerance account for the expected instrument drift, the instrument reference accuracy, and the measurement and test equipment inaccuracies present when instrument strings are observed during surveillance testing. This prevents accounting for these errors both within the accident analysis and within plant field settings. The overall effect will be a reduced frequency of drift related License Event Reports, while ensuring the high reliability of the RPS instrumentation.

In the previous section, the instrument drift, sensor drift, instrument reference accuracy and the measurement and test equipment inaccuracies were shown to be included in the total assumed error between the accident analysis setpoint and the Tech Spec trip setpoint. The allowable values lie between these two setpoints, differing from the Tech Spec setpoint by an amount equal to the setpoint drift plus measurement and test equipment inaccuracies. Figure 1 illustrates this as was shown in the definition section.

Each allowable value is determined by accounting for the drift and measurement and test equipment error for the instrument module in which the

setpoint is located. In most cases this is the bistable, but for the variable low pressure trip it is the signal converter, and for the power/imbalance/flow trip it is the function generator. Figure 2 shows that the allowable value lies between the Tech Spec setpoint and the accident analysis setpoint. Thus a margin for setpoint drift is used for the surveillance tests. As the setpoint is tested every 30 days, the Channel Calibration and Channel Functional Test allowable values are the same.

Figure 2 also shows two allowable tolerances: one for the Channel Function Test and one for the Channel Calibration. The allowable tolerances provide values to be used in verifying instrument string accuracy separate from the setpoint verification. The Channel Functional Test allowable tolerance consists of the instrument string drift, reference accuracy and measurement/test equipment accuracy excluding the sensor, since the sensor is not tested. The Channel Calibration allowable tolerance includes the Channel Functional Test allowable tolerance plus the sensor drift, reference accuracy and measurement/test equipment accuracy. For strings where the sensors cannot be tested, the two allowable tolerances will be equal.

The allowable values and allowable tolerances support the following test procedures for the Channel Functional test. First, the setpoint is measured and compared to a setpoint allowable value from Tech Specs to verify its conservatism. Next, the processing equipment error is checked by simulating the sensor output, by injecting an electrical signal in the circuit, and measuring the input to the bistable. The difference between the simulated input and the measured value at the bistable input is compared to an allowable tolerance to verify that the magnitude of the instrument error is less than the assumed value used in accident analysis

Delay Times

The RPS instrumentation not only has error associated with it but also response time characteristics. The response time characteristics provide an error in the time dimension when determining the time of trip initiation and is associated with the accident analysis setpoints. Tech Specs require response time testing to verify the accident analysis assumptions supporting

the time of control rod drop. These values are located in Tech Spec Table 16.3.8-2.

The response times are generated from the following description of the trip delay time.

Total Trip Delay Time	=	Sensor & RPS Delay	+	Control Rod Drive Breaker Delay	+	Control Rod Drive Mechanism Release Delay

The sensor and RPS delay accounts for measurement and processing delays within the RPS instrumentation. Added to this value are the control rod drive breaker delay and the delay added for the control rod drive mechanism to unlatch before control rod is free to begin insertion into the reactor core.

The total trip delay time is then used to model the time of insertion of the control rods after the presence of the trips condition of the trip conditions are detected in the system parameters. Thus, the time of trip condition is determined and then after a time equal to the total trip delay time the control rod insertion is begun.

The response times given in Tech Specs differ from the total trip delay time used in accident analysis as the control rod drive mechanism delay is tested separately. Thus the response times reported in Tech Specs are defined as follows:

Response Time	=	Sensor & RPS Delay	+	Breaker Delay

During surveillance testing, response times equal to or less than the Tech Spec value must be shown to properly verify the accident analysis assumptions. Since the major portion of the response time is the sensor and some sensors such as the neutron detectors and temperature sensors cannot be tested in the plant, strings utilizing these sensors are exempt from testing. This is also indicated in Tech Spec Table 16.3.3-2.

Summary

The preceding sections have described the setpoint adjustments used in generating the Tech Spec setpoints and the errors used in those adjustments. Additionally, the accident analysis delay time concept and its relationship with the response time given in Tech Specs was also shown. Using the above methodologies, the RPS instrumentation reliability is ensured while also providing for operability margins through the allowance of instrument drift in the allowable values. The result is a decreased frequency of LERs while still ensuring safe plant operation.