WCAP-10746 WESTINGHOUSE NON-PROPRIETARY CLASS 3

V. C. SUMMER PRESSURE PULSATION ANALYSIS REGARDING FATIGUE USAGE OF STEAM GENERATOR PREHEATER MODIFICATION

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1.0 INTRODUCTION

Continuous pressure oscillations are present in the feedwater system whenever the plant is above 0 percent power. These oscillations are not induced by any particular transient event but are relatively small, high frequency deviations from the mean pressure value and are inherent to the feedwater system (e.g., pump vane pass frequencies, pump vibrations, pipe vibrations, turbulence, etc.).

These pressure oscillations propagate throughout the secondary loop and act upon internal steam generator parts, and any modifications to this system, such as the D3 preheater modification, shown in Figure 1.

In plants where preheat steam generators have been installed, pressure transducers were placed in each feedwater line adjacent to each feedwater nozzle for monitoring of continuous pressure oscillations. The transducers are used to verify that the plant feedwater system pressure oscillations are equal to or less than those shown to be acceptable by the steam generator structural analysis.

2.0 OBJECTIVE

The objective of this report is to familiarize the reader with the various methods of continuous pressure oscillation analysis and to collect, reduce and analyze test data taken during power escalation following the preheater inlet modification.

3.0 DATA REDUCTION

Data recorded at the plant site were reduced by Westinghouse personnel in Pittsburgh. The objective of the reduction was to provide information that would determine the pressure fluctuation amplitudes, and the frequency content of the signals.

Signal analyses were performed using a Westinghouse Digital Data Analysis Package.

Two types of displays were used; power spectral density vs. frequency; and real time fluctuating pressure vs. time. The frequency domain displays represent the average of a number of samples of data (typically 64). Averaging of the result from each data sample leads to the identification of signal frequency content to which statistical evaluations could be applied.

The power spectrum is the magnitude squared of the rms spectrum. The result is a real valued function containing magnitude information only (no phase).

The power spectrum can be represented in different ways. As a power spectrum, it has units of volts squared and is useful for analyzing spectra with discrete spectral components. However, with broad band signals, such as random noise or transients, the spectrum level will vary depending upon the analysis band width. To avoid this, the power spectrum is normalized to a 1 hz band width so that analysis with different analysis frequency ranges are directly comparable one to another. This normalized power spectrum is referred to as power spectral density (PSD) measurement. This type of plot is used as input for the fatigue analysis discussed in this report.

3.1 Interpretation of Frequency Spectra Plots

Figure 2 illustrates a typical linear frequency spectrum produced using the Westinghouse Digital Data Analysis Package. The power spectral density spectra were plotted with frequency along the abscissa and PSD amplitude as the ordinate. The plot origin is at the bottom left corner. The full scale

frequency value is indicated at the bottom right corner of the plots. The full scale amplitude is indicated on each plot.

3.2 Interpretation of Instantaneous Time Histories

The instantaneous time histories are time domain plots of the transducer signal for the given time interval (Figure 3). Instantaneous time histories were produced using a Westinghouse Digital Data Analysis Package. Time is represented along the abscissa and pressure is represented along the ordinate. The signal responses have plus and minus values centered about zero. The zero to full scale amplitudes are indicated on each plot.

The instantaneous time histories contain amplitude and frequency information of transducer signals, but are not normally used to determine the frequency content because the spectral plots are more accurate for that purpose. The determination of signal peak-to-peak amplitudes is a major use of these time domain plots.

Maximum peak-to-peak pressures are determined from these time histories in the following manner: for each power level and plant loop, the maximum positive pressure and the minimum negative pressure is found from the recorded time history trace. This maximum positive to negative value is determined to be the maximum peak-to-peak pressure. It should be noted that this is a conservative approach, which gives pressure values slightly higher than the actual.

4.0 ACCEPTANCE CRITERIA DEVELOPMENT

Figure 4 shows the continuous pressure oscillation acceptance curve for the modified Westinghouse Model D3 steam generator. This curve represents the frequency response function between pressure pulsations in the feedline at the inlet of the steam generator and deflection (stress) of the limiting preheater component at that particular frequency. It represents a composite of the previous D3 acceptance curve for an unmodified D3 steam generator and the acceptance curves for the various preheater modification components. The lowest value from each component acceptance curve at each frequency was used to form the acceptance curve for the modified generator.

a,c,e

a,c,e

5.0 FEEDWATER PRESSURE PULSATION ANALYSIS METHODS

Two methods are used to compare measured feedline oscillation data to the acceptance criteria.

Method 1 This technique of demonstrating acceptability is to compare the maximum peak-to-peak (p-p) pressure pulsation determined from the pressure time-history plots for each power level to the minimum value of the acceptance curve of Figure 4. If the measured value is less than [ ]^{a,b,c,e} psi peak-to-peak, the fluctuation levels are acceptable. This is a simple, although very conservative method of evaluation.

Should the maximum peak-to-peak pressure pulsation exceed [.]^{a,b,c,e} Method 2 is used to analyze the pressure pulsation data.

Method 2 This technique involves a frequency domain fatigue analysis of the feedline pressure oscillations. This technique requires a spectral analysis of the time history data to produce a power spectral density plot.

Experience has shown that the simpler method of evaluating the pressure oscillation data rarely gives acceptable results. The pressure fluctuations are usually distributed over a fairly broad range of frequencies and the maximum value of peak-to-peak variation in the time signal is usually greater than the minimum value of the acceptance curve. Therefore, a frequency domain analysis (Method 2) of the measured feedline oscillations must be performed to evaluate the measured data against the acceptance criteria.

The acceptance curve of Figure 4 represents the locus of points which give a stress equivalent to the endurance limit of a particular structure. Hence, this curve can be thought of as relating the input pressure oscillations to the structural response representing negligable fatigue usage. Therefore, the demonstration of satisfactory feedline pressure oscillations is obtained by evaluating the composite effect of the contributions of pressure components

from all frequencies to the structural response of the preheater and verifying that the root mean square structural response is some number of standard deviations less than the endurance limit for the material.

6.0 MATHEMATICAL DISCUSSION

The method employed in evaluating the feedline pressure oscillation data is essentially a steady state frequency domain analysis in which the composite effect of the contributions of the pressure components from all frequencies is considered.

a,c,e

a,c,e

7.0 ANALYSIS RESULTS

Time history data was analyzed at 0, 19, 51, 81, 90, and 100 percent power (Figures 9 thru 26). The measured maximum peak-to-peak pressure pulsation values for the analyzed power levels is shown in Table 1.

Method 1 was used for 0, 19, and 51 percent power levels since the maximum peak-to-peak pressure pulsation values were all below [ ].[a,b,c,e] Loop 2 at 81 percent power also had a pressure pulsation value less than [ ].[a,b,c,e]

Method 2 was used to analyze the pressure fluctuations for the remaining power levels and loops.

As varying input, the analysis uses a series of points from the power spectral density plot for the specific power level and loop. This series of points is taken from the plot and forms an enveloping conservative curve of that plot.

The results of method 2 analysis are shown in Table 2. The highest RMS value of response was calculated to be [ ][a,b,c,e] normalized units, found at 100 percent power in loop 3. Since this is less than [ ][a,c,e] that the structural response of any component in the preheater will not be above the respective material's endurance limit due to all feedwater pressure fluctuations.

The power spectral density plots for the power levels and loops analyzed using Method 2 are given in Figures 27 thru 34.

8.0 CONCLUSIONS

This report has shown that the measured continuous pressure oscillations in the feedwater system at the Virgil C. Summer Nuclear Station are acceptable at the power levels analyzed. The analysis indicates that there will be negligable fatigue usage on the preheater or the preheater modification due to the measured pressure oscillations.

Table 1

MAXIMUM PEAK TO PEAK PRESSURE PULSATION VALUES

(Given in psi)

Power Levels

Loop	0 Percent	19 Percent	51 Percent	81 Percent	90 Percent	100 Percent
1	.155	.264	2.0	4.0	4.8	6.4
2	.058	.173	1.0	2.4	2.7	3.3
3	.132	.342	2.3	5.0	5.6	6.6

Table 2

NORMALIZED LIMITS OF STRUCTURAL RESPONSE

	Power Levels		
Loop	81 Percent	90 Percent	100 Percent
1	[		] a,b,c,e
2			
3			

D3 PREHEATER
INLET MODIFICATION

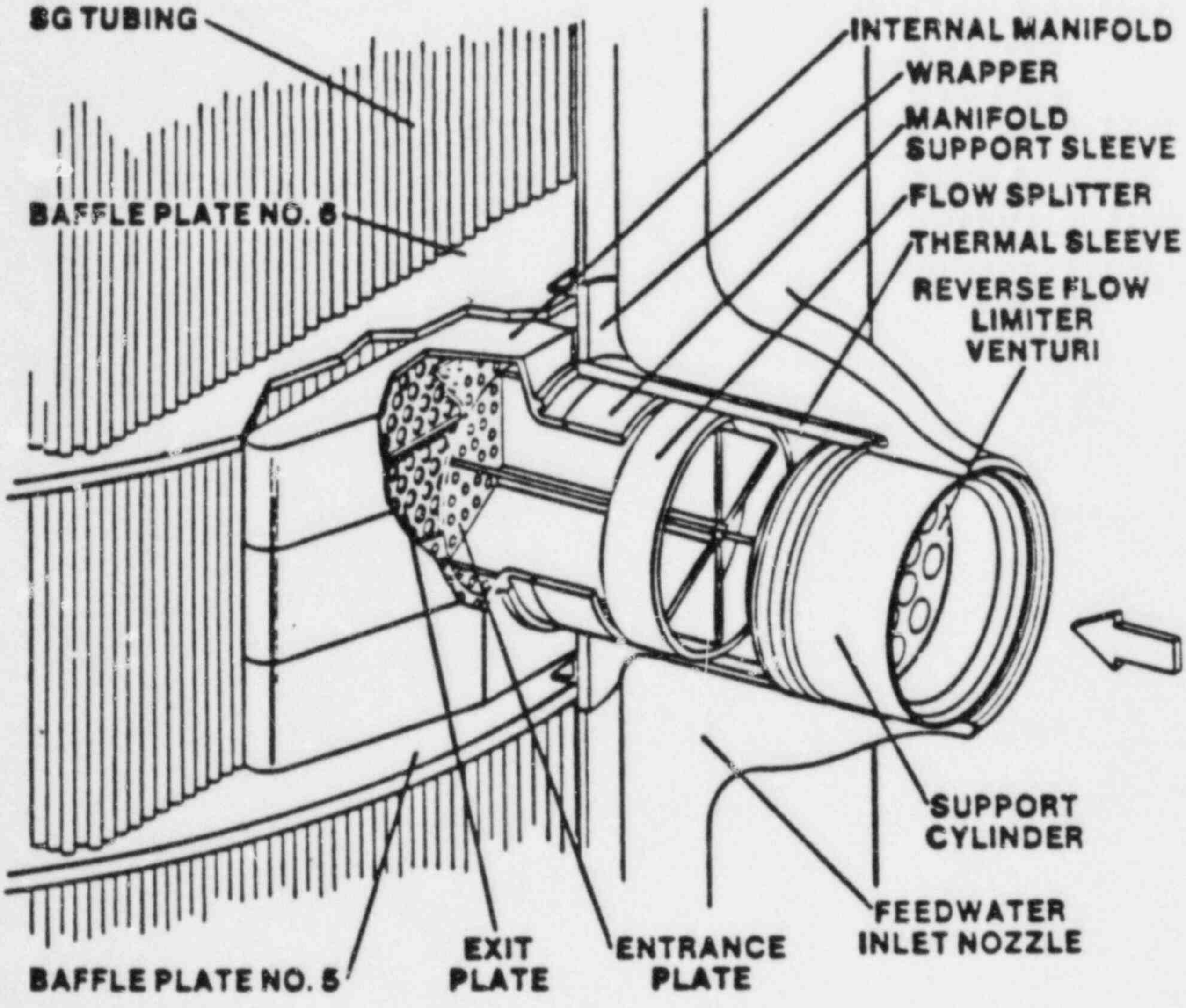


FIGURE 1

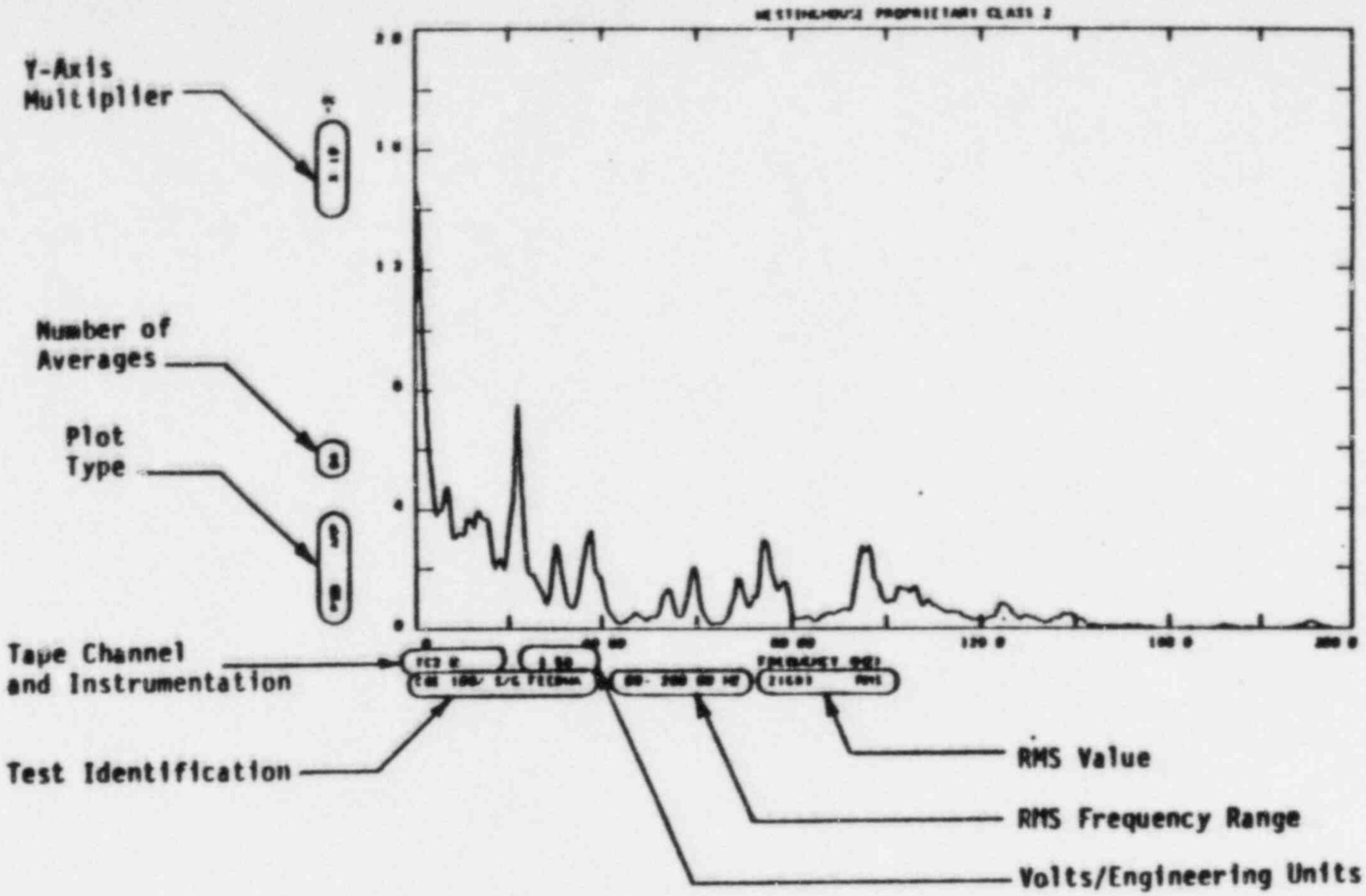


Figure 2 **PLOTTING NOMENCLATURE FOR DIGITAL DATA ANALYSIS PACKAGE**

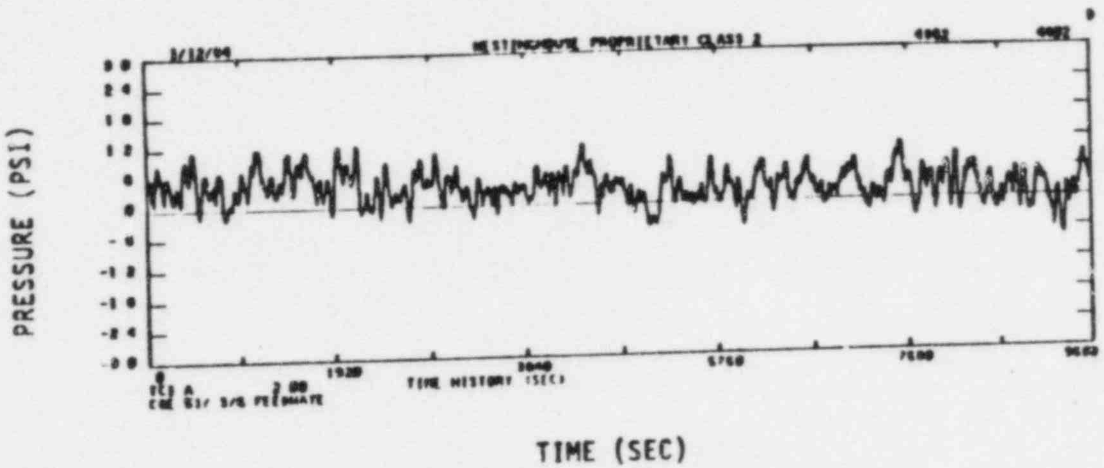
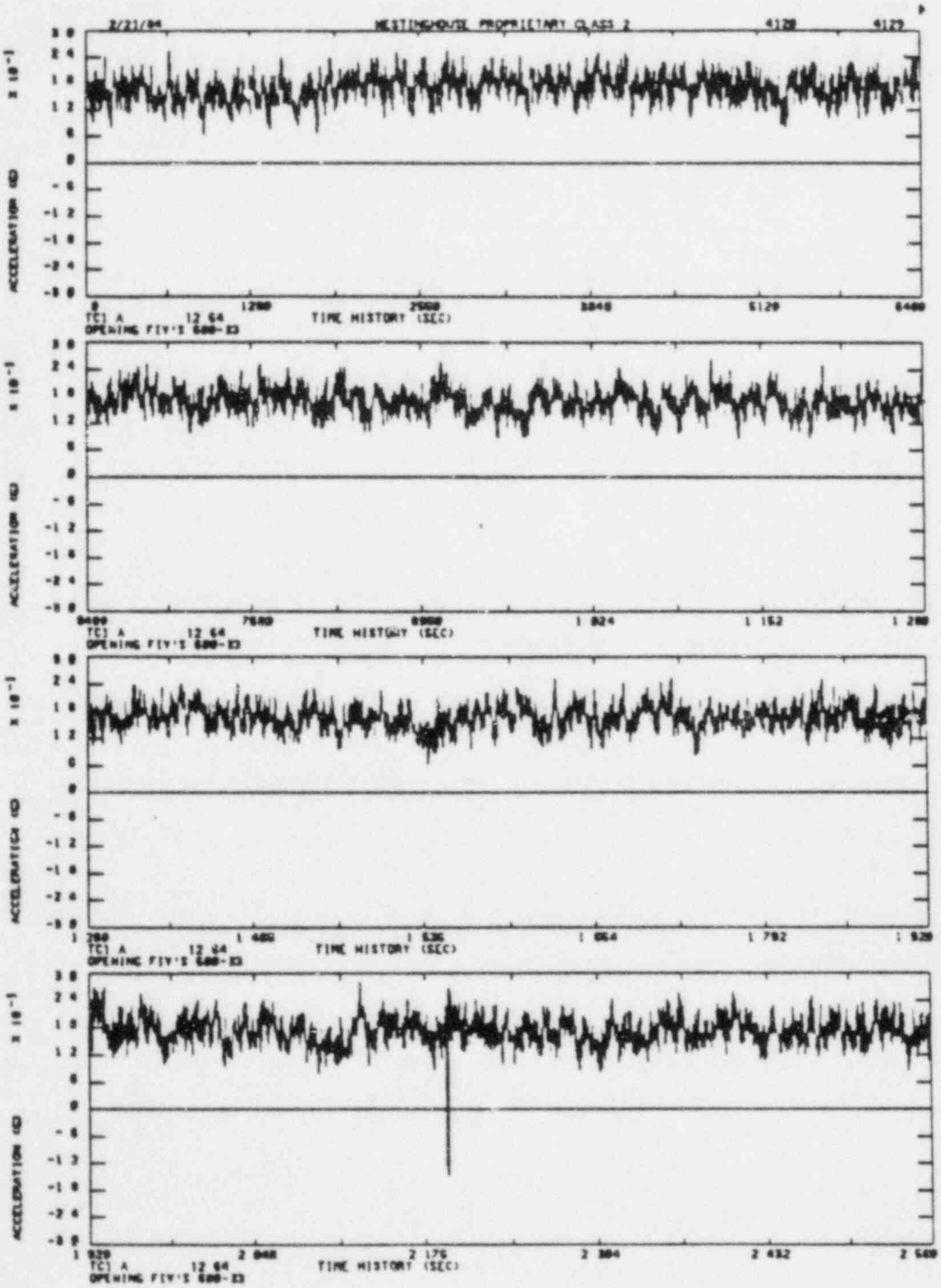


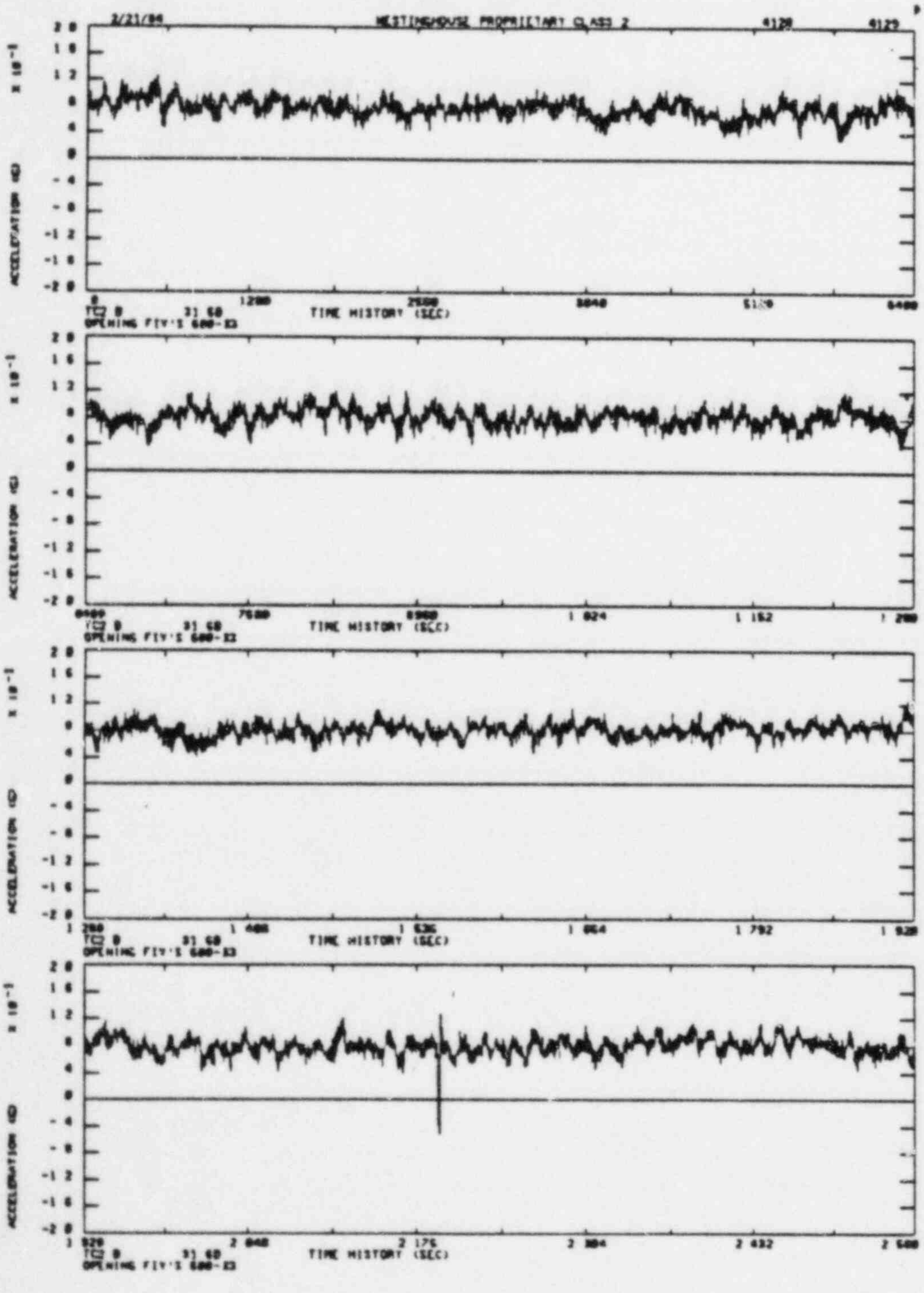
Figure 3 **PLOTTING NOMENCLATURE FOR DIGITAL DATA ANALYSIS PACKAGE**

Figures 4 thru 8 are allowable continuous oscillation curves for the Westinghouse Model D3 steam generator components and are considered proprietary to Westinghouse.



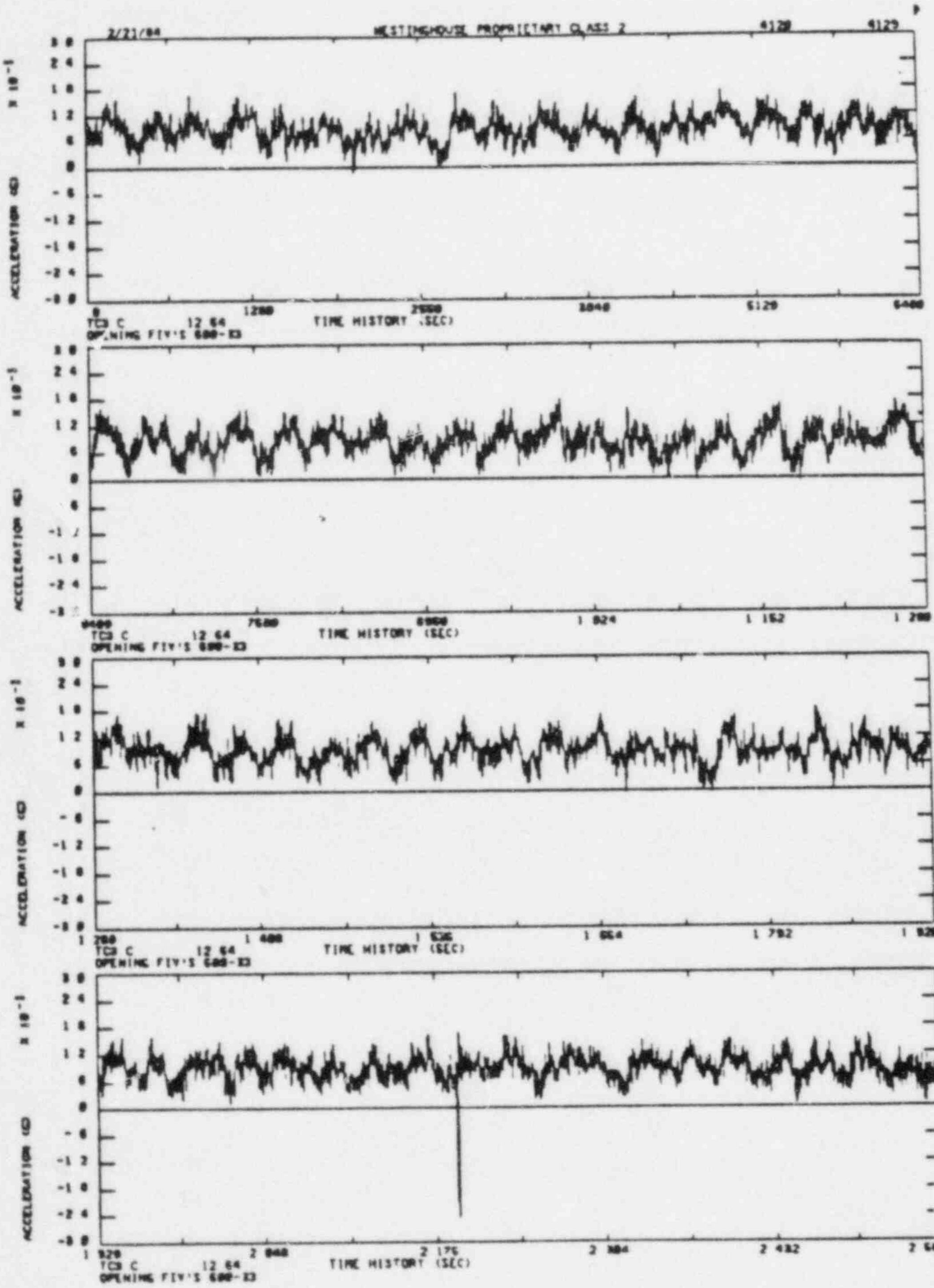
0% Power Loop 1

Figure 9

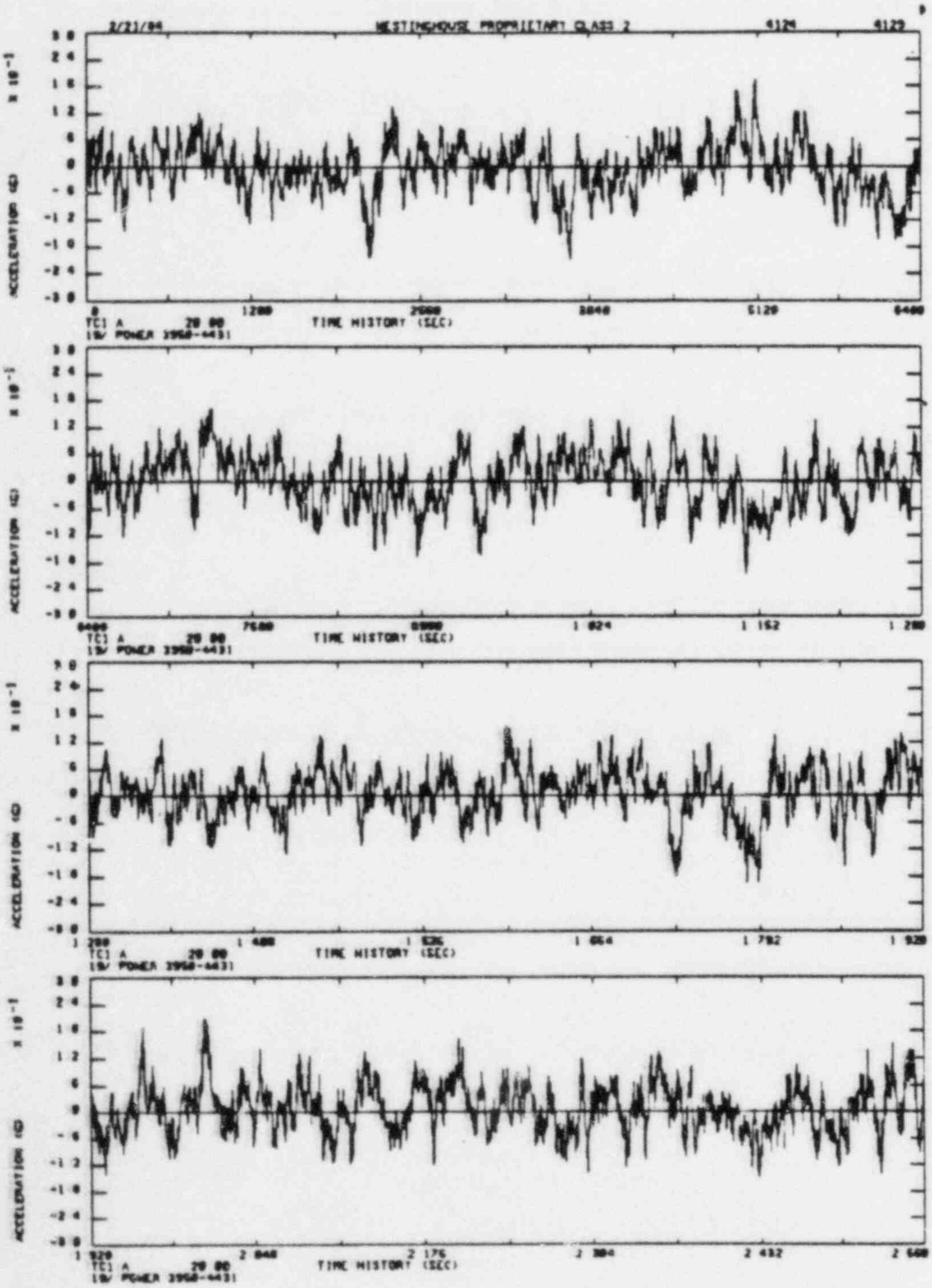


0% Power Loop 2

Figure 10

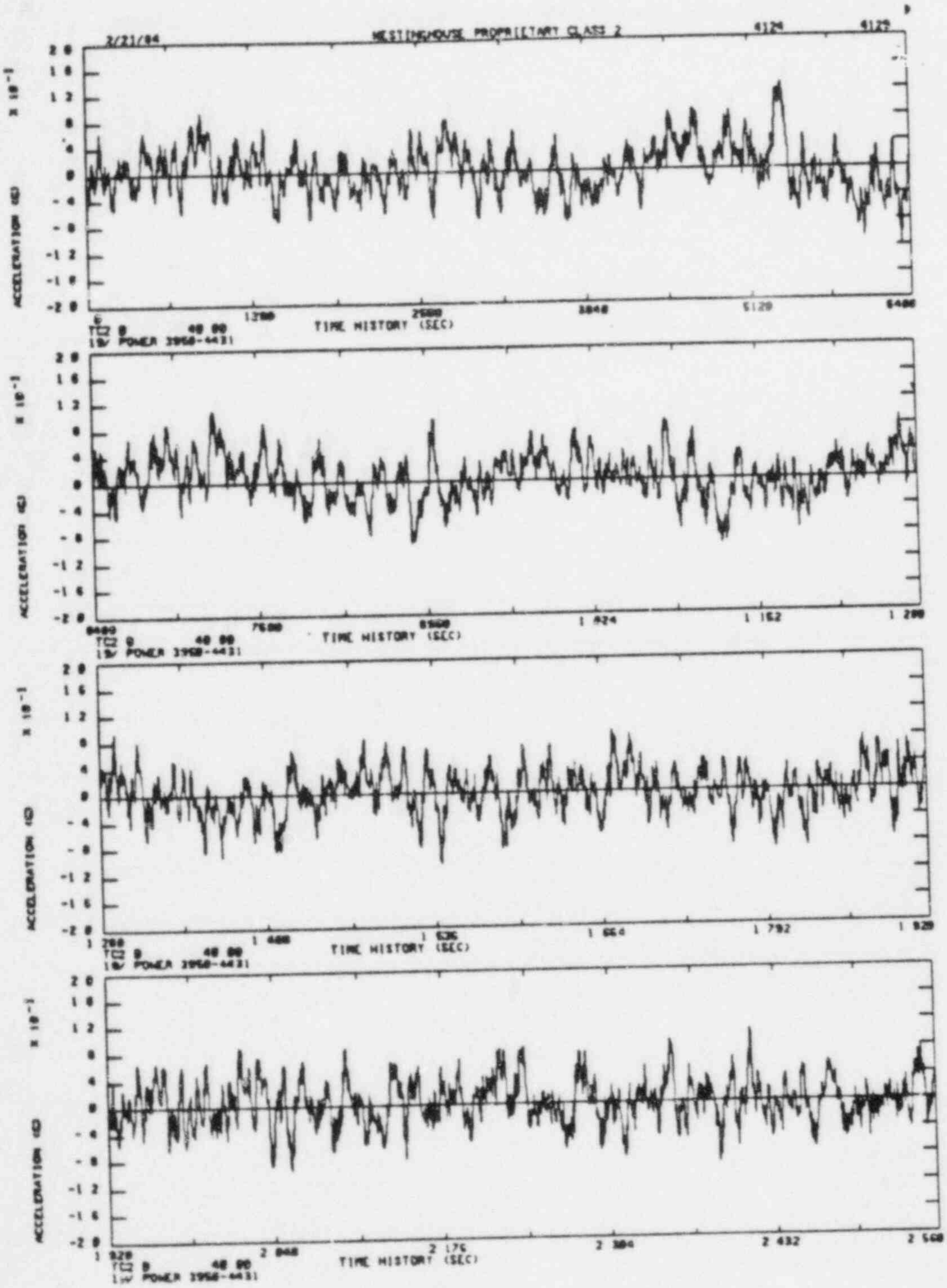


0% Power Loop 3
Figure 11



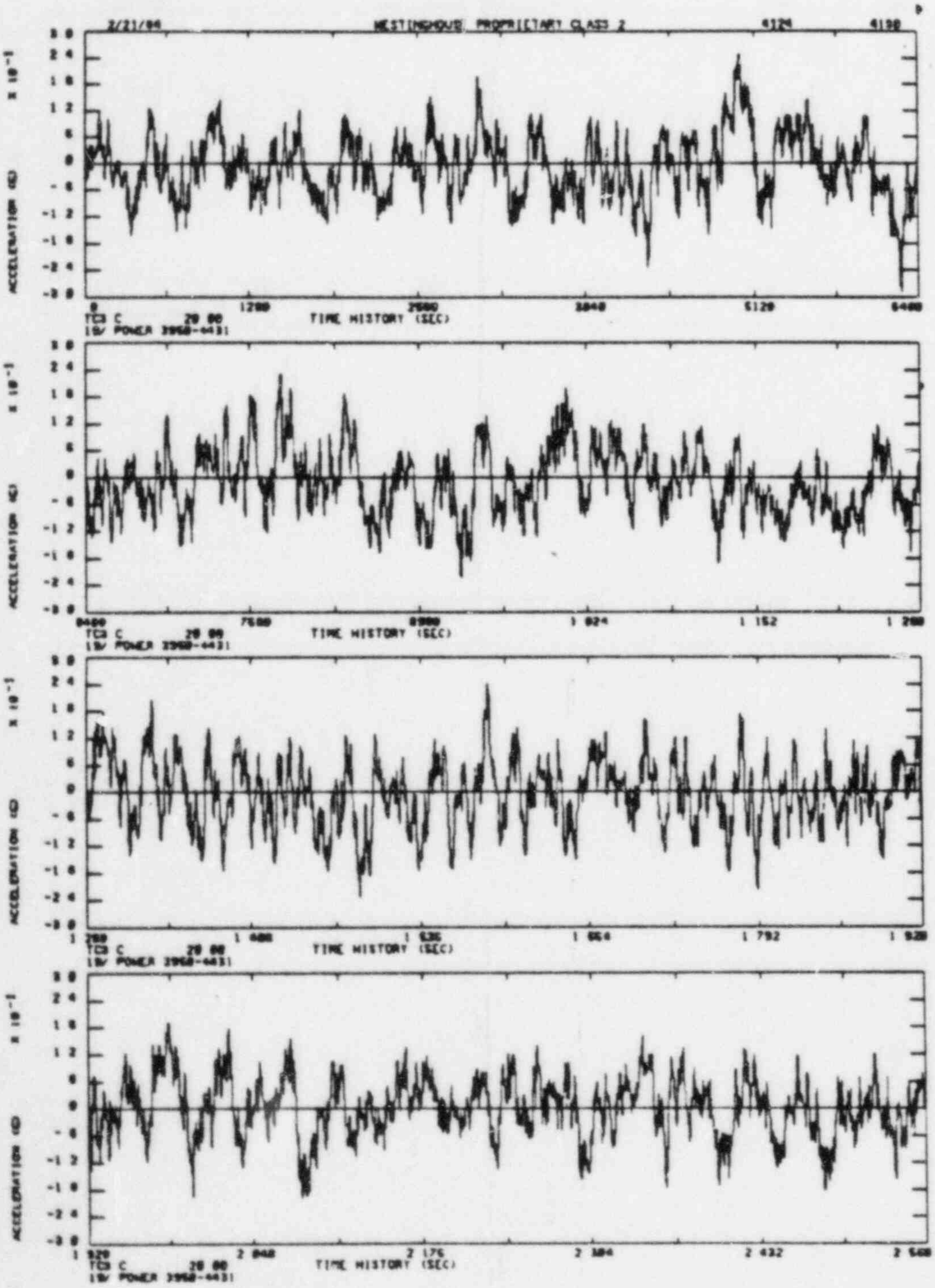
19% Power Loop 1

Figure 12

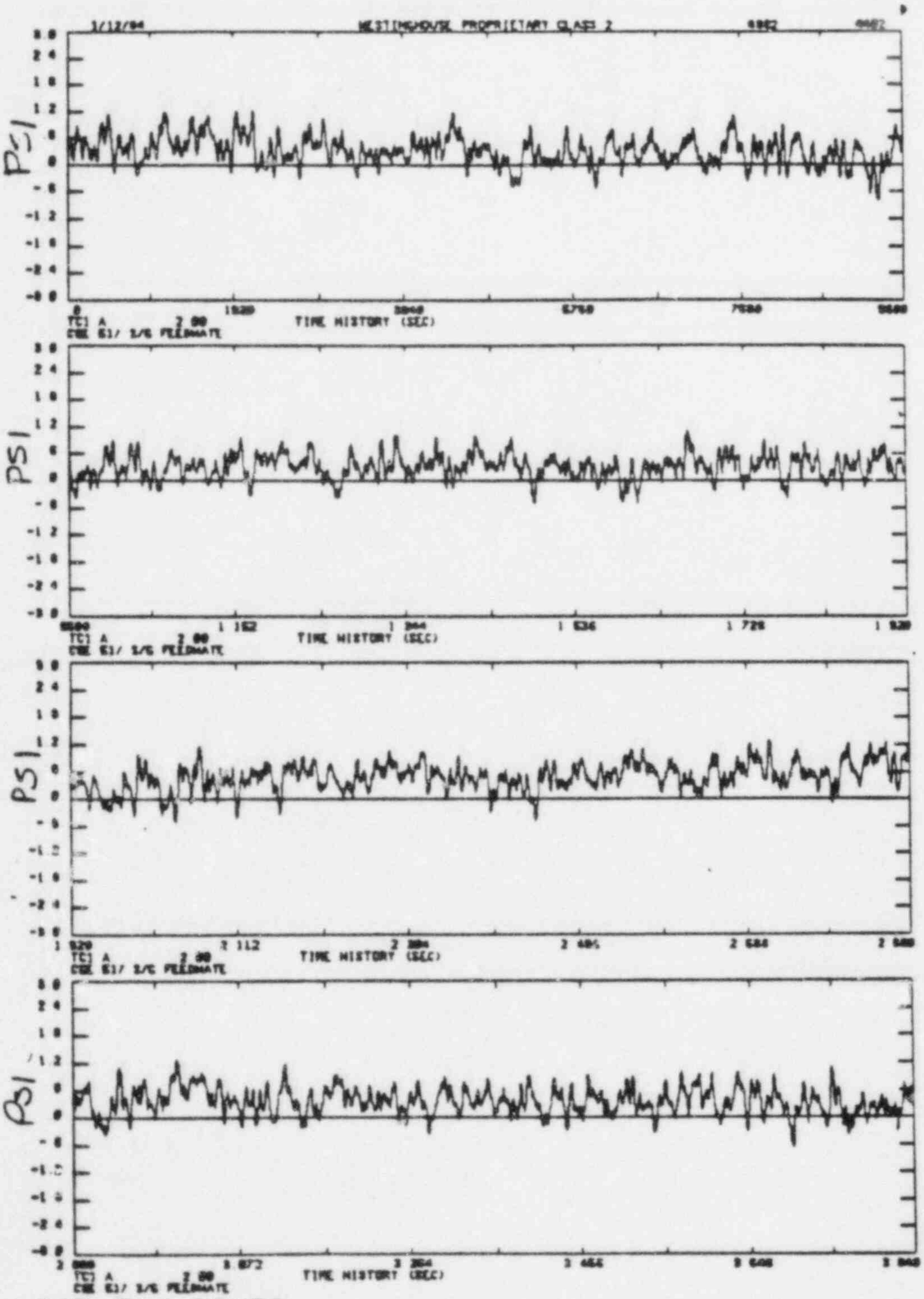


19% Power Loop 2

Figure 13



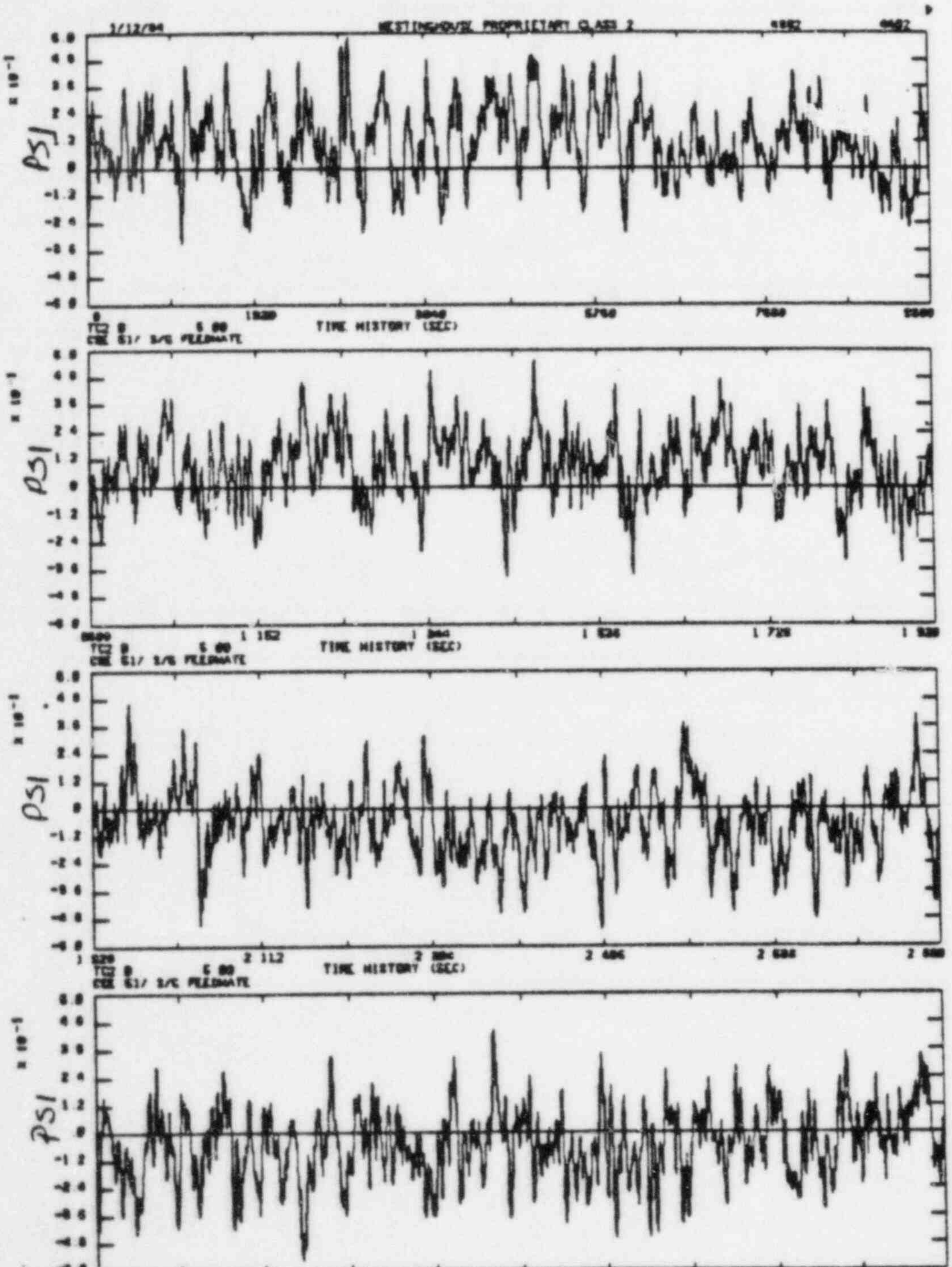
19% Power Loop 3
Figure 14



CGE 51/ POWER
S/G FEEDWATER

Figure 15

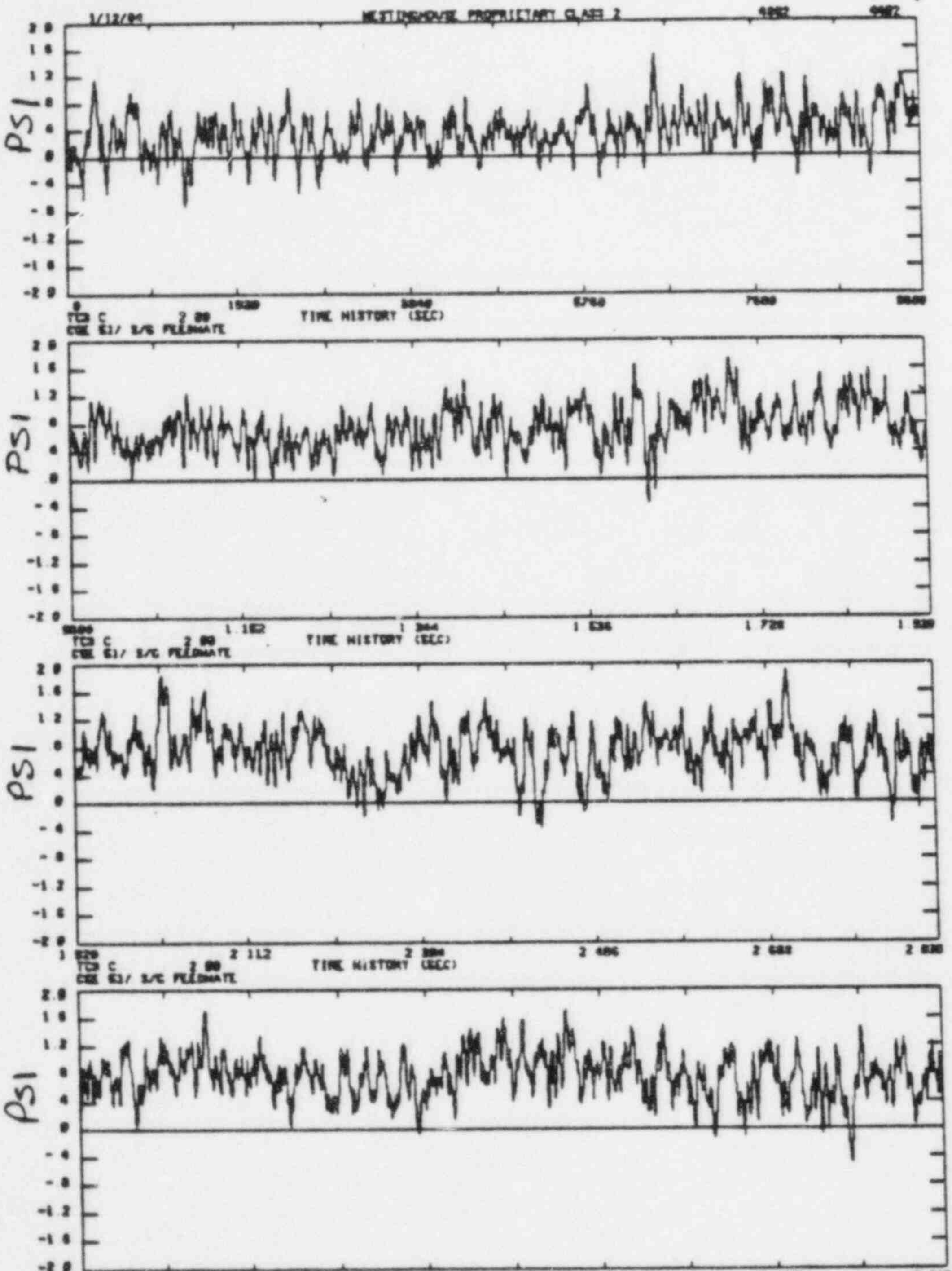
Loop 1



CGE 51/ POWER
S/G FEEDWATER

Figure 16

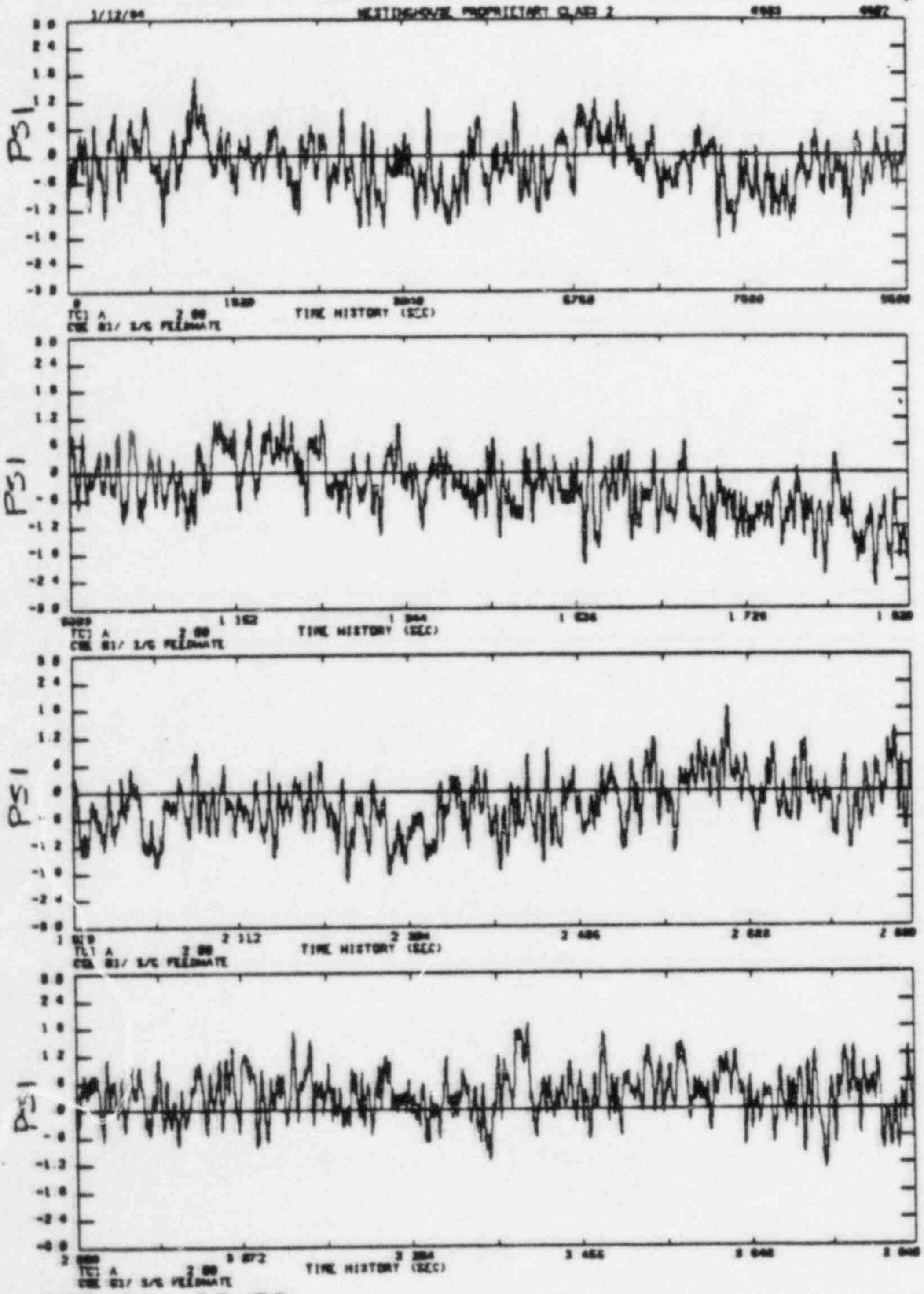
Loop 2



CGE 51/ POWER
S/G FEEDWATER

Figure 17

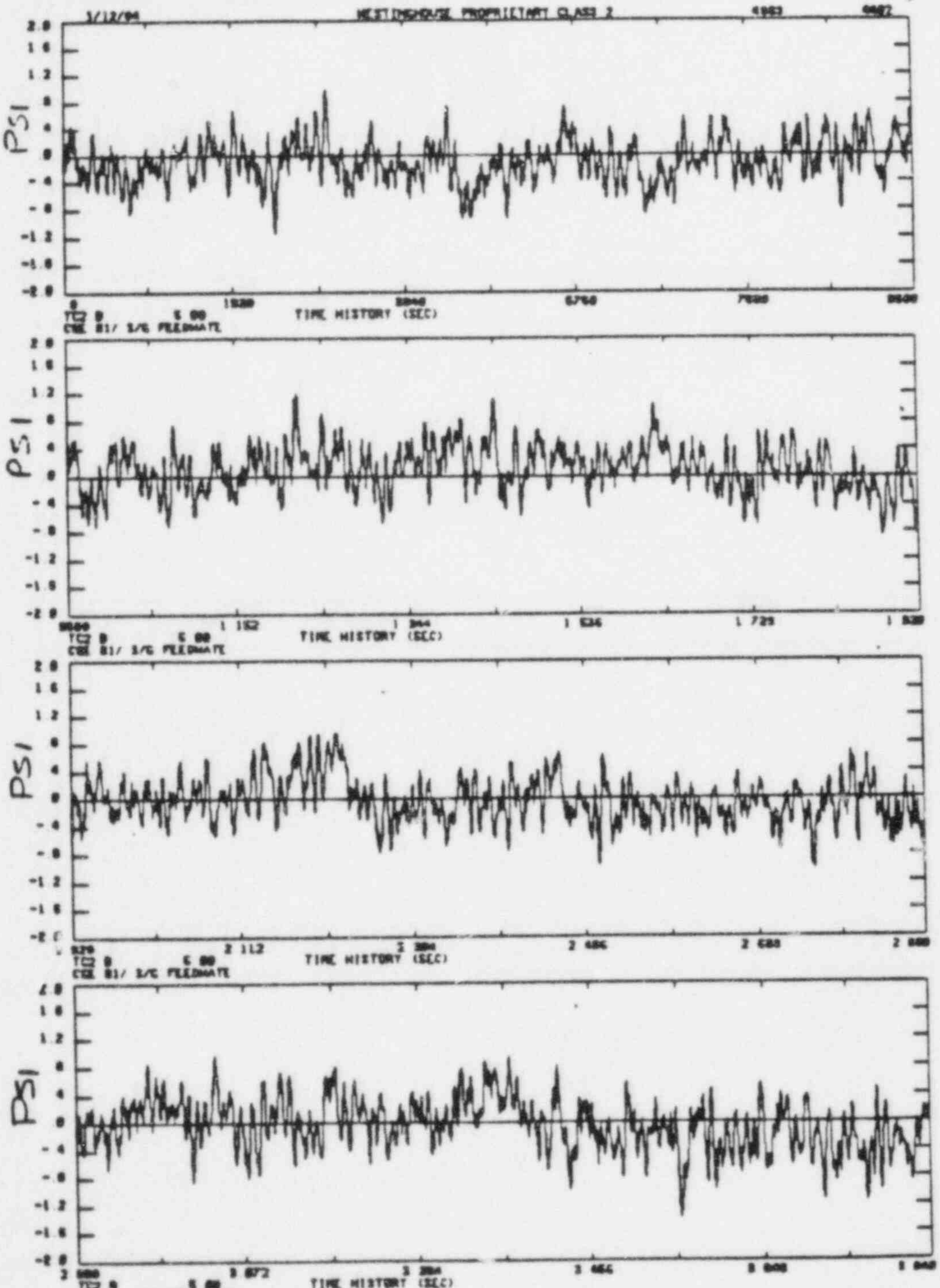
Loop 3



CGE 81/ POWER
S/G FEEDWATER

Figure 18

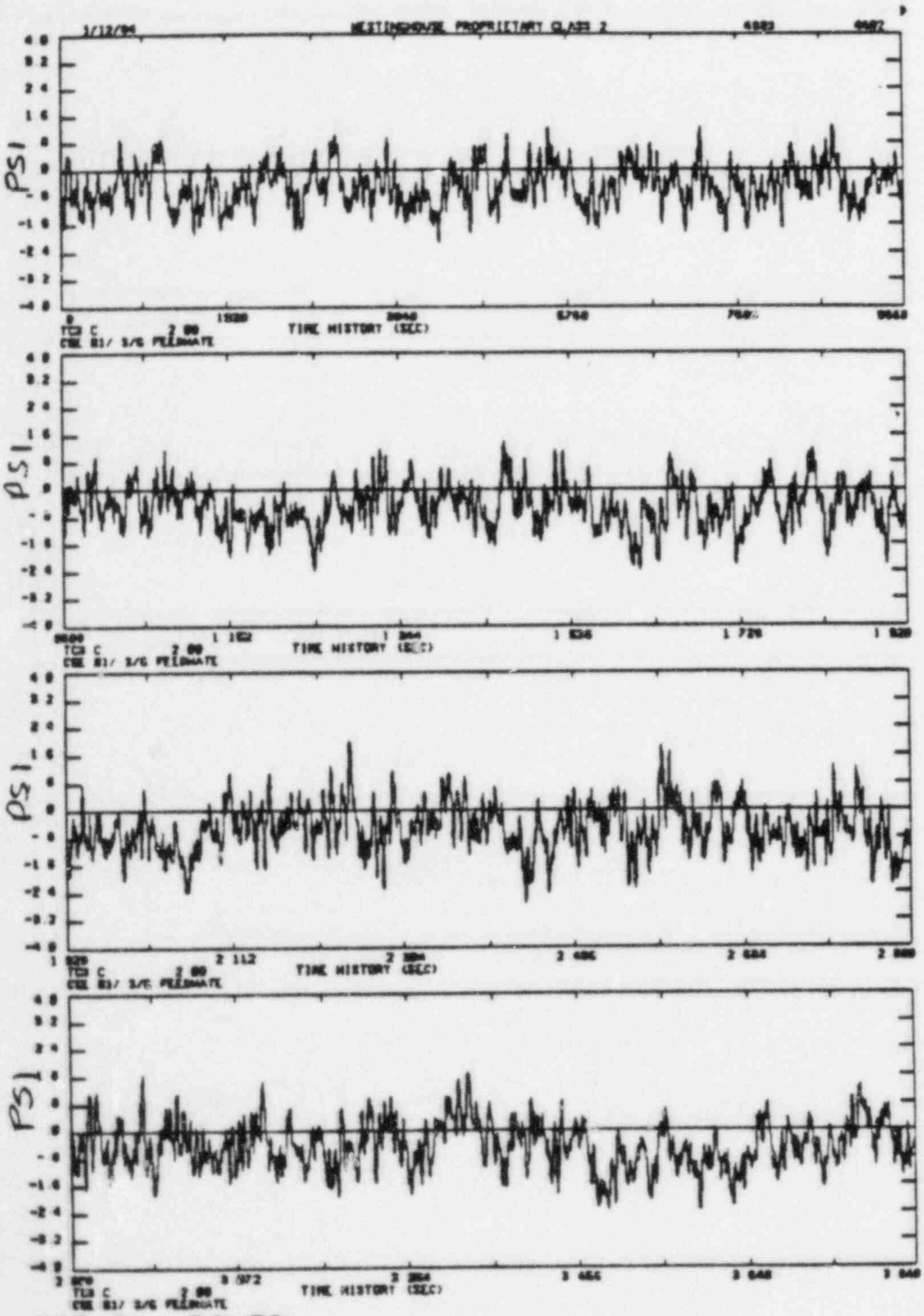
Loop 1



CGE 81/ POWER
S/G FEEDWATER

Figure 19

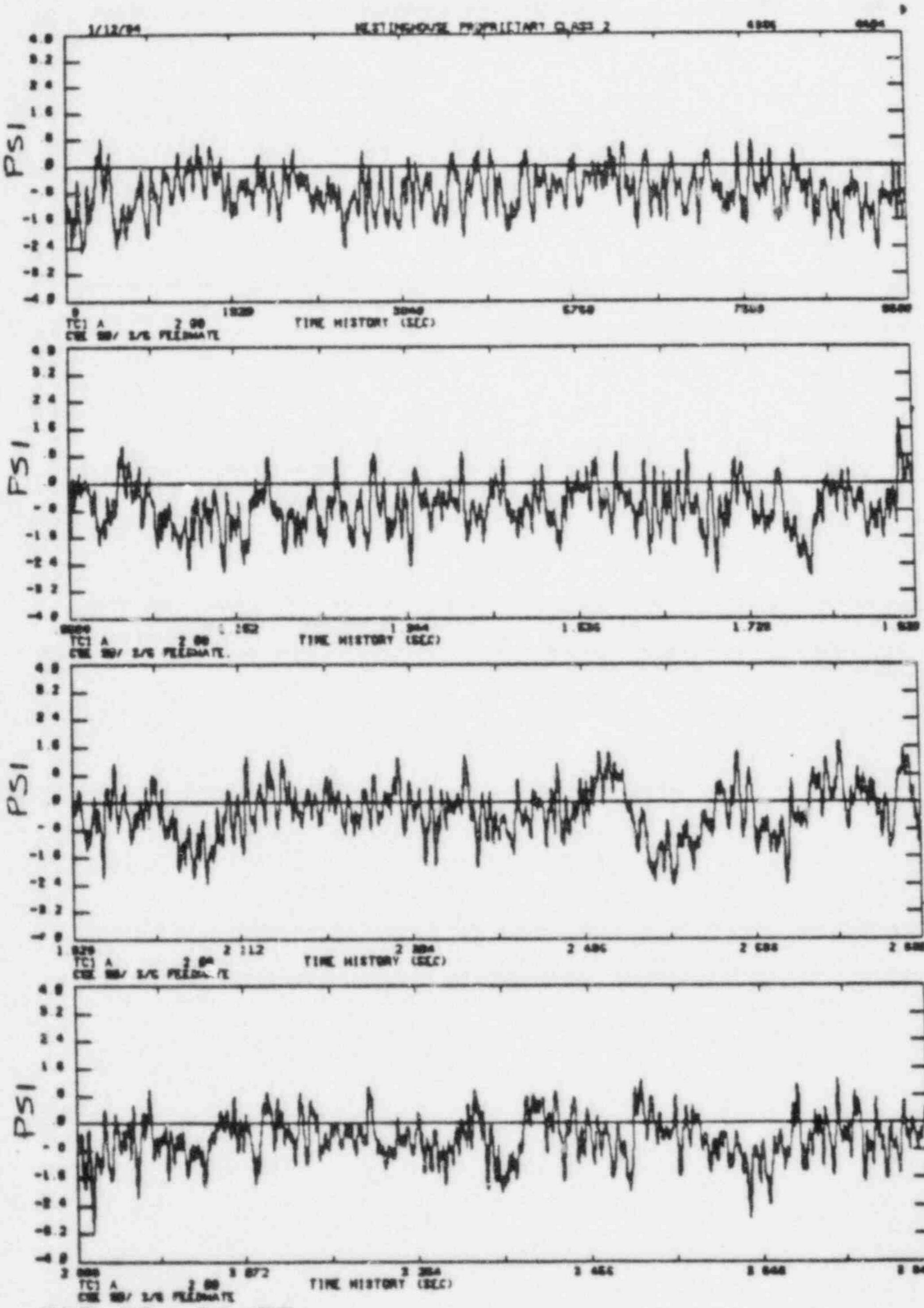
Loop 2



CGE 81/ POWER
S/G FEEDWATER

Figure 20

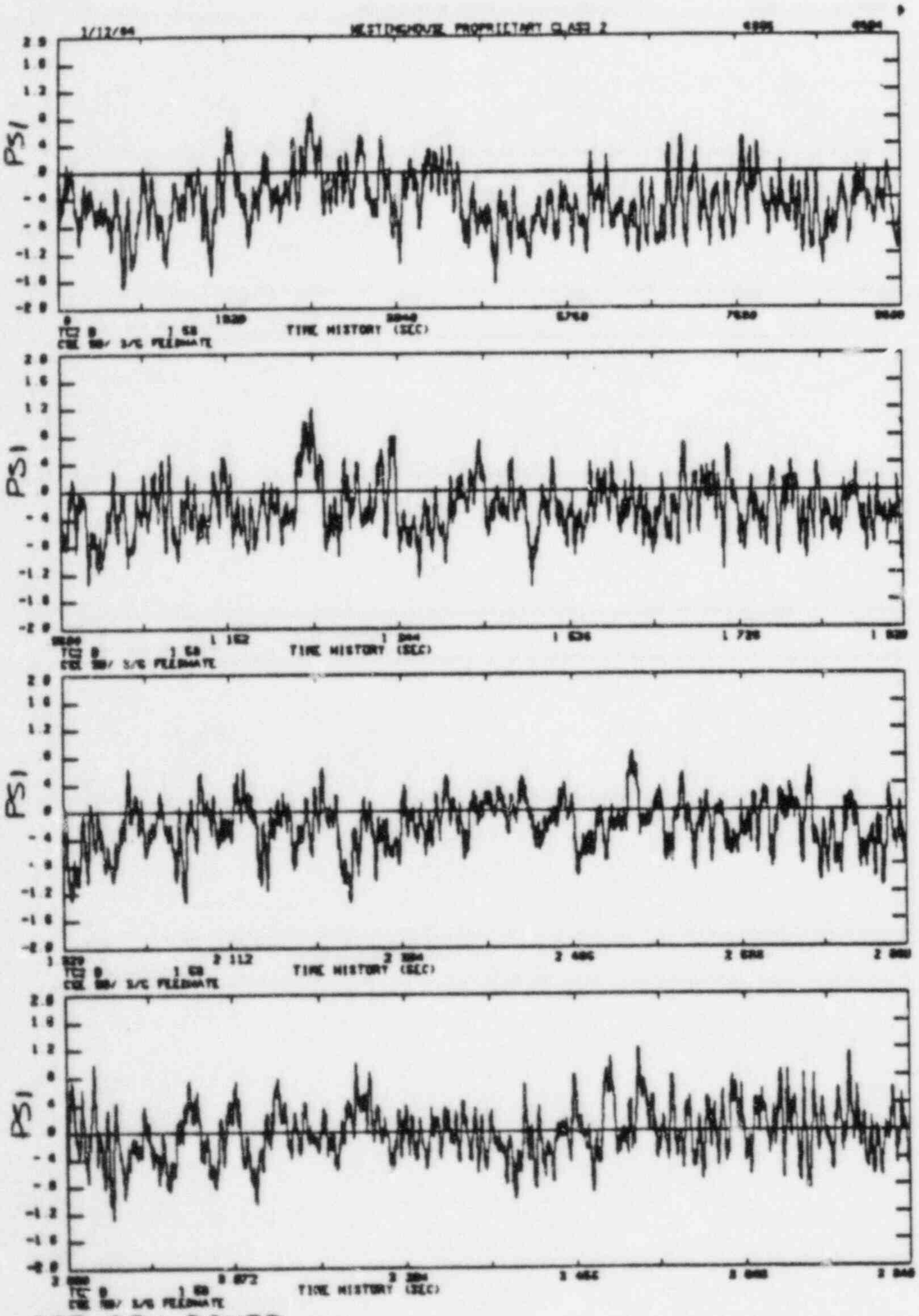
Loop 3



CGE 90/ POWER
S/G FEEDWATER

Figure 21

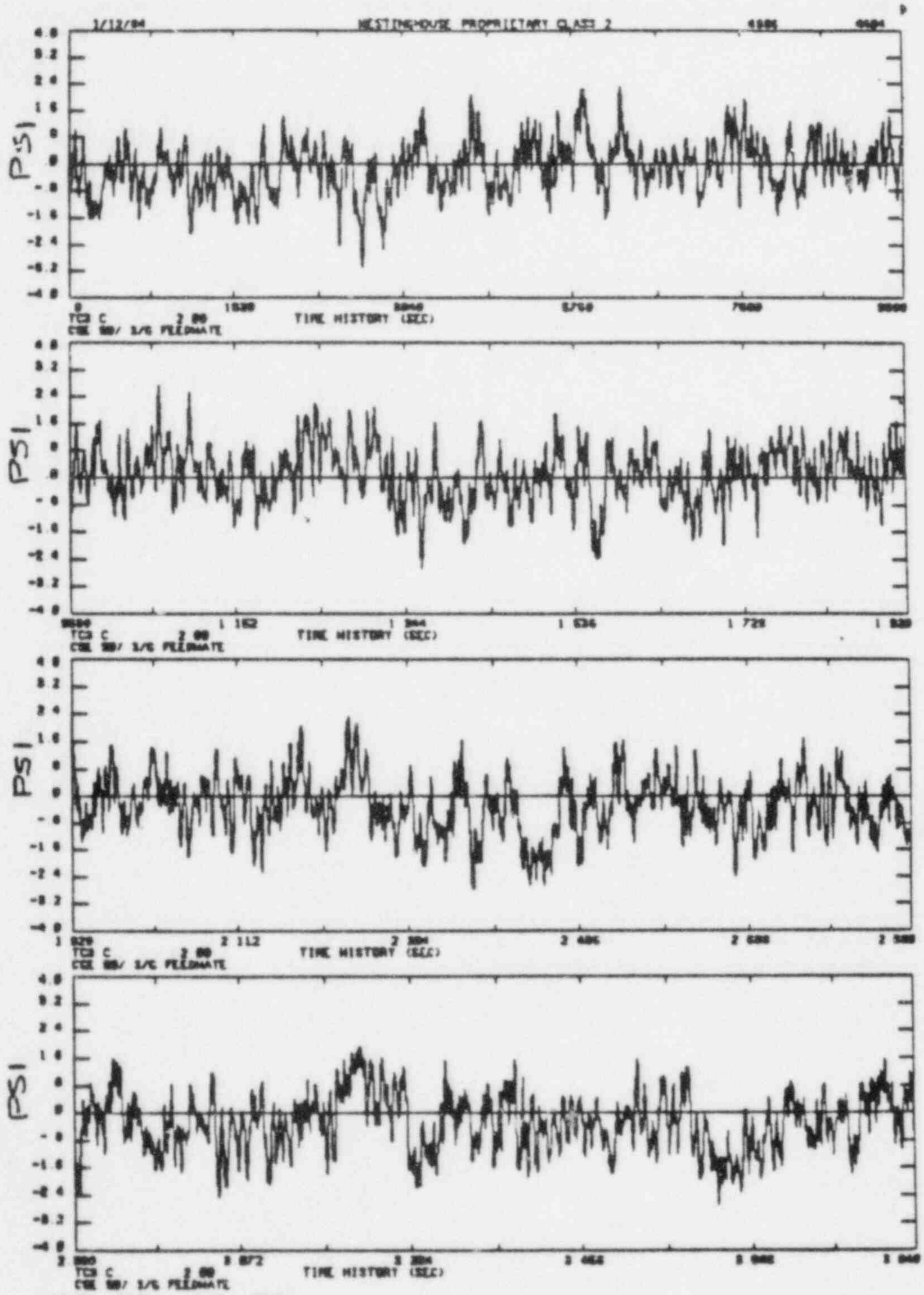
Loop 1



CGE 90/ POWER
S/G FEEDWATER

Figure 22

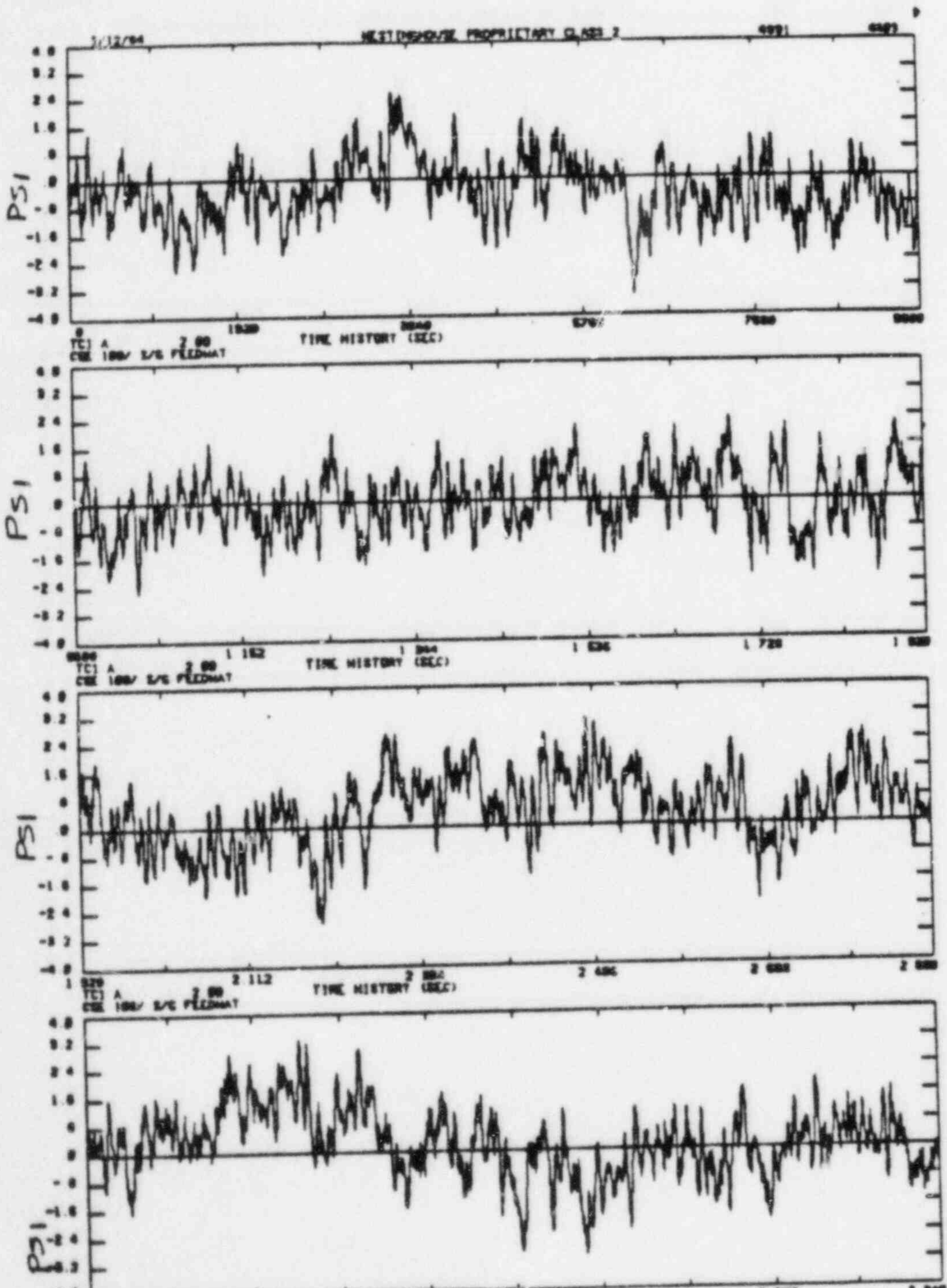
Loop 2



CGE 90/ POWER
S/G FEEDWATER

Figure 23

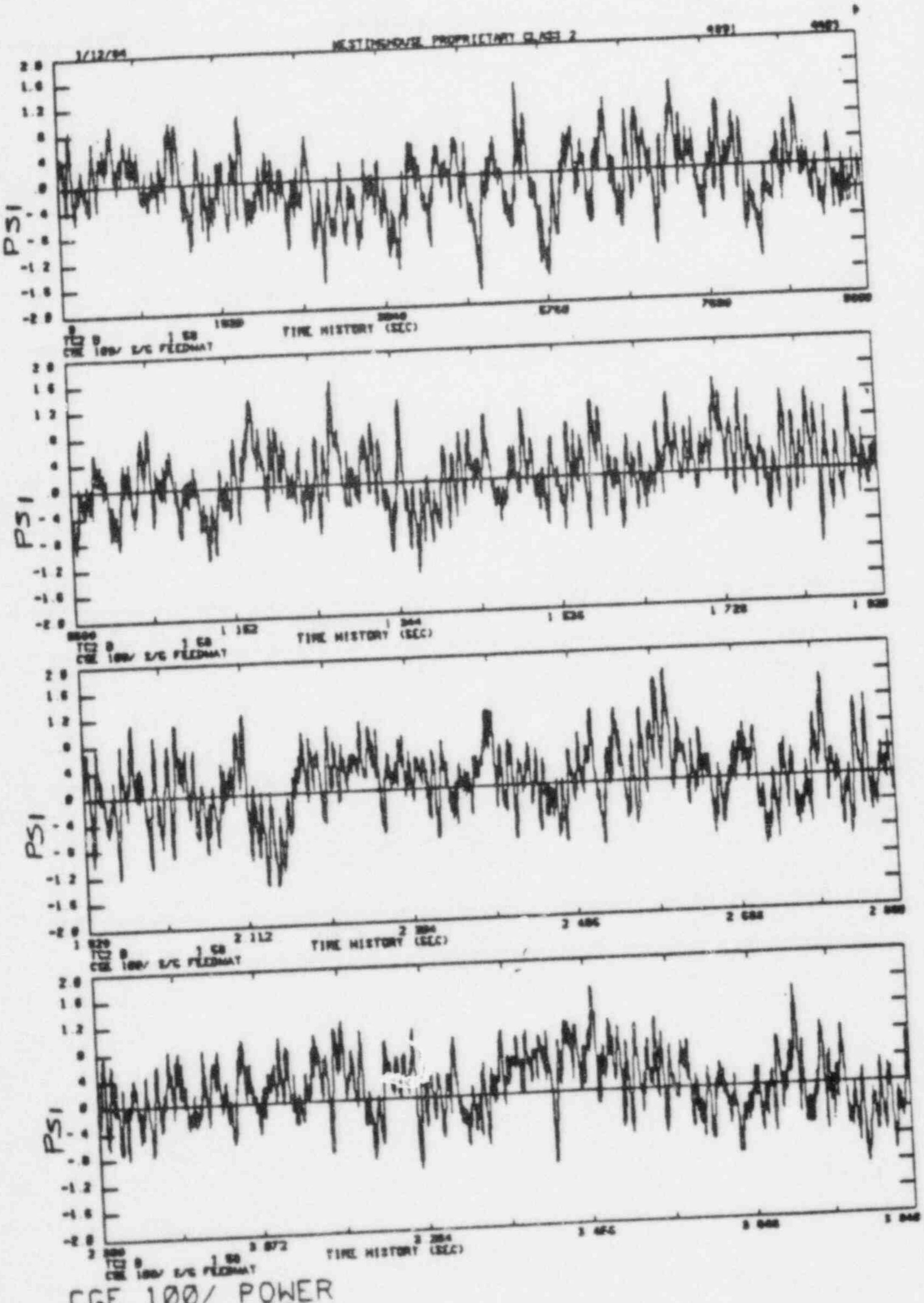
Loop 3



CGE 100/ POWER
S/G FEEDWATER

Figure 24

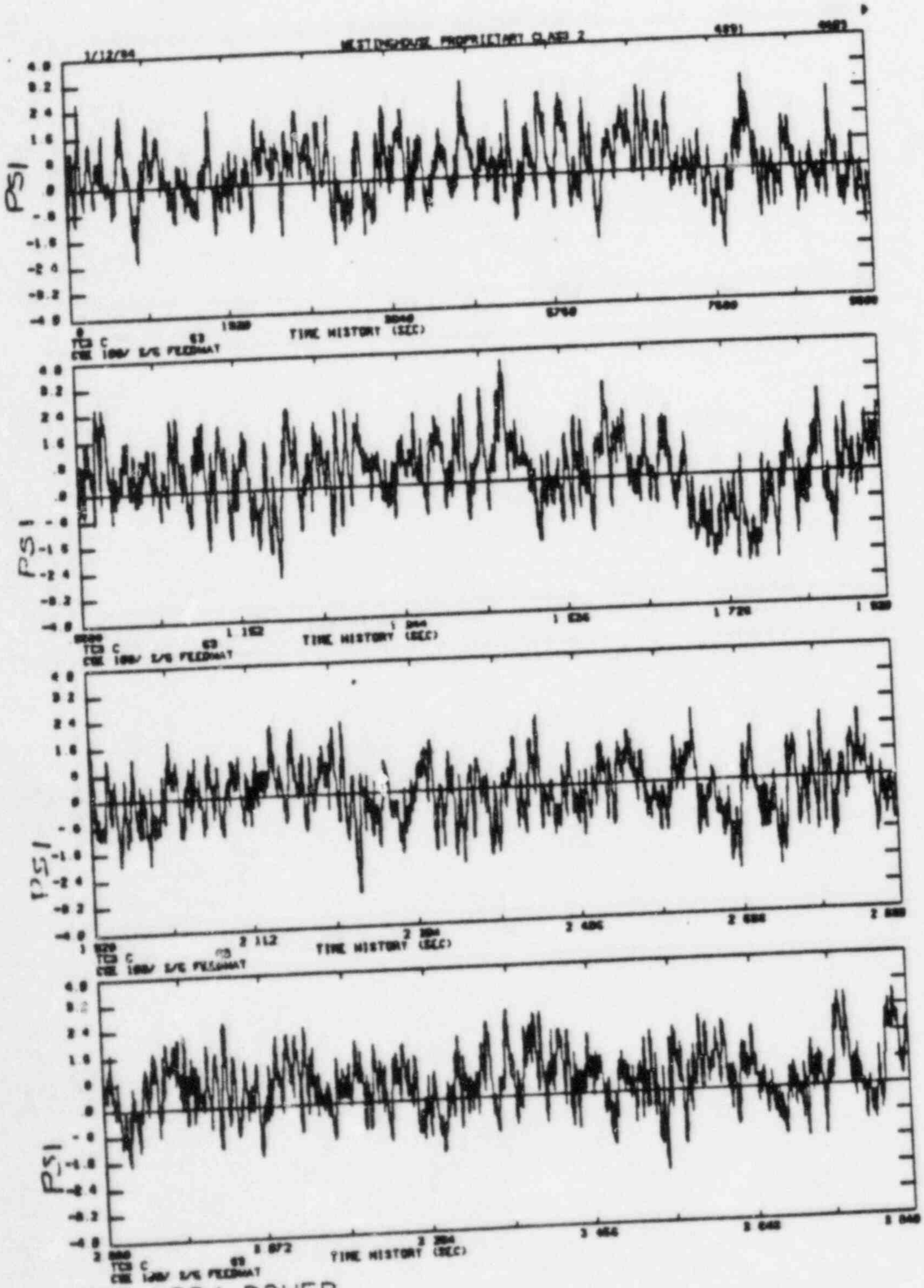
Loop 1



CGE 100/ POWER
S/G FEEDWATER

Figure 25

Loop 2



CGE 100/ POWER
S/G FEEDWATER

Figure 26

Loop 3

Figures 27 thru 34 are power spectral density plots for continuous pressure oscillation data taken at various power levels at V.C. Summer and are considered proprietary to Westinghouse.