PRELIMINARY RESULTS OF SEQUOYAH-1 INTERNALS VIBRATION MEASUREMENT PROGRAM

The UHI upper internals prototype vibration measurement program is described in Reference 1. Data for this program were obtained from strain gages mounted on upper support columns and guide tubes during hot functional testing of the Sequoyah-1 plant. From a preliminary analysis of these data it is concluded that the upper internals have adequate factors of safety against flow induced vibrations.

Data were acquired at five coolant temperature plateaus with four reactor coolant pumps (RCP) in operation, at four coolant temperature plateaus with several combinations of three, two, and one RCP in operation and during pump start-up and shutdown transients.

The near zero to 1000 Hz strain levels for nominal reactor conditions (approximately 545°F and 2250 psi) were less than [ ]b,c for guide tube strain gage signals and less than [ ]b,c for strain gages mounted on support columns.

The frequency content of signals from lower guide tube strain gages is shown in Figure 1. The response consists of broadband random strains that have the highest levels near zero frequency, narrowband random signals centered on the guide tube natural frequencies, and nearly sinusoidal RCP-speed related components. The major RCP-speed related responses are at 19.8 Hz (rotating speed) and at 277 Hz (second harmonic of the blade passing frequency). The 277 Hz component will be discussed further, later in this report.

A summary of the response characteristics of the lower guide tube is shown in Table 1. The first beam mode natural frequency is 71-75 Hz in the 0°-180°

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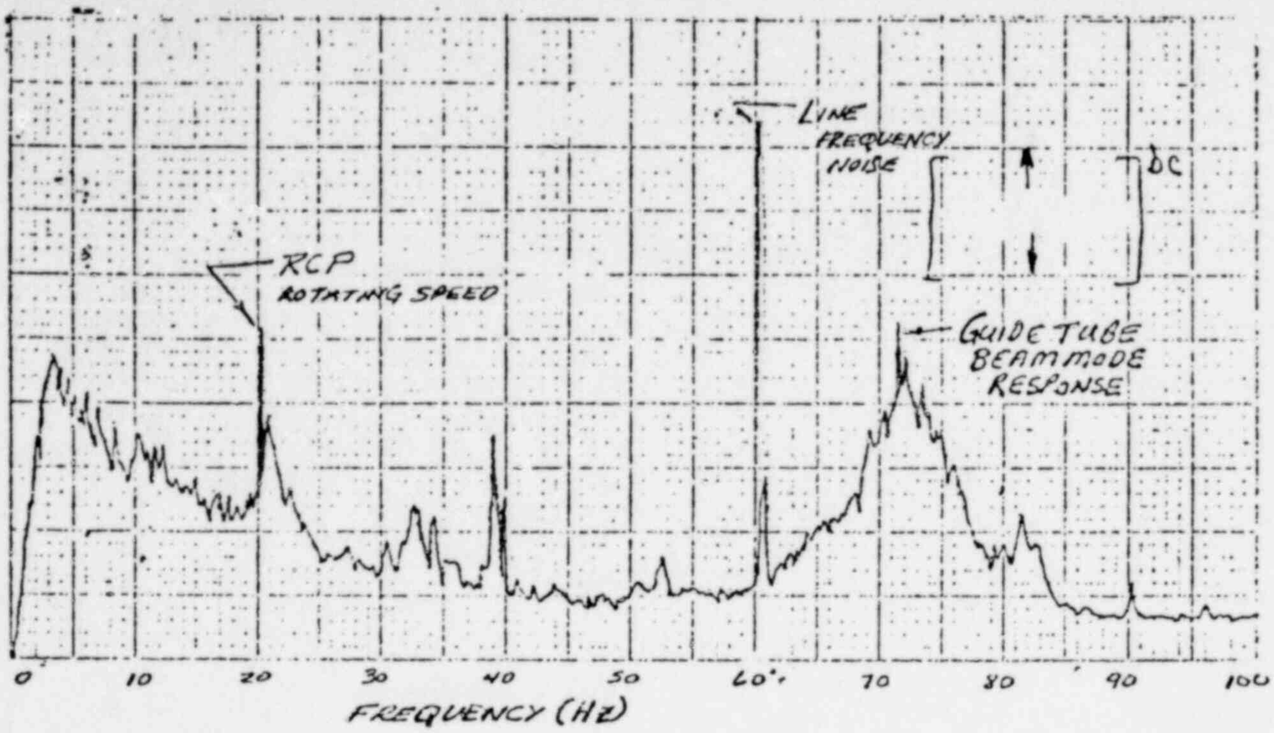

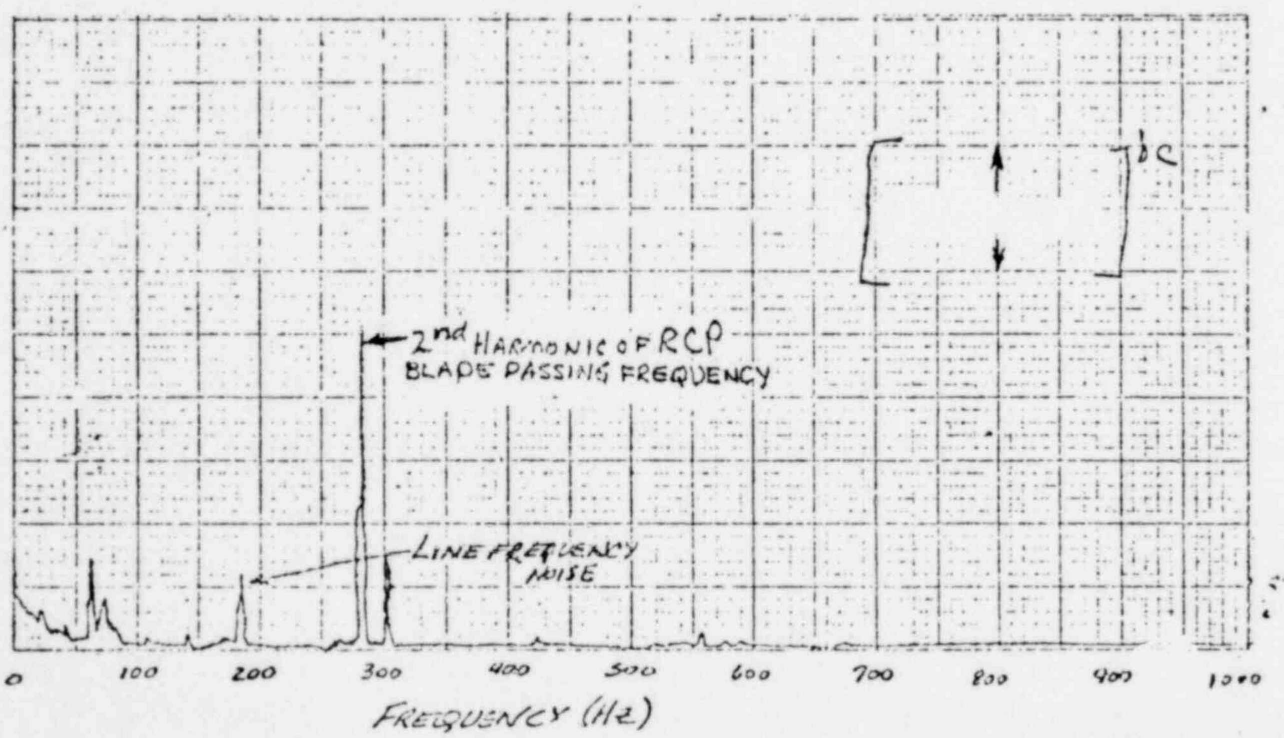

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LINEAR FREQUENCY SPECTRA OF A LOWER GUIDE TUBE STRAIN GAGE SIGNAL, 4 PUMPS, 539°F.

FIGURE 1

Table 1

SUMMARY OF RESULTS FROM PRELIMINARY DATA ANALYSIS

b,c

[1]Square root of the sum of the squares of the amplitudes in two perpendicular directions, four pumps in operation, full temperature.

[2]From various temperature and pump operation combinations.

[3]At fatigue test failure point.

[4]For locations at which failure did not occur in the fatigue test.

[5]To design allowable stress levels.

direction and 65-66 Hz in the 90°-270° direction. This difference is consistent with previous test results and is due to unequal support stiffnesses along these axes at the lower end of the guide tube.

The damping of the lower guide tubes inferred from the bandwidth at the first mode natural frequency for several plant conditions is 1.2 to 5.9 percent of critical damping. Four pump, hot vibration amplitudes are approximately [ ]b,c inches rms for this mode.

Factors of safety for the lower guide tubes for four pumps in operation, 548°F (see Table 1), have been determined using the data acquired at Sequoyah-1 and the guide tube fatigue test results reported in Reference 1. As expected, higher responses were measured on the guide tube at core location M-2 than on the guide tube at core location K-2. For the guide tube at core location M-2, the factor of safety to failure at the failure point of the fatigue test is 6.7.

To determine the factor of safety at other locations on the guide tube at which there was no failure during the fatigue test, the procedure was as follows:

1. The moment distribution, shear, and end forces of the guide tube were calculated for the mode shape and maximum vibration amplitude of the fatigue test.

2. The moment distribution, shear, and end forces for the guide tubes instrumented at Sequoyah-1 were calculated from response levels and mode shapes indicated by the hot functional strain data.

3. A factor of safety at key locations was determined by forming the ratio of the moment or force determined from the fatigue test data (extrapolated to plant lifetime) to the corresponding moment or force determined from the hot functional data.

This procedure is conservative from the standpoint that it assumes that failure was imminent at all locations analyzed.

With this approach, the minimum factor of safety for the four pump, 548°F case is 3.2. Factors of safety for other cases reviewed are higher than those given above.

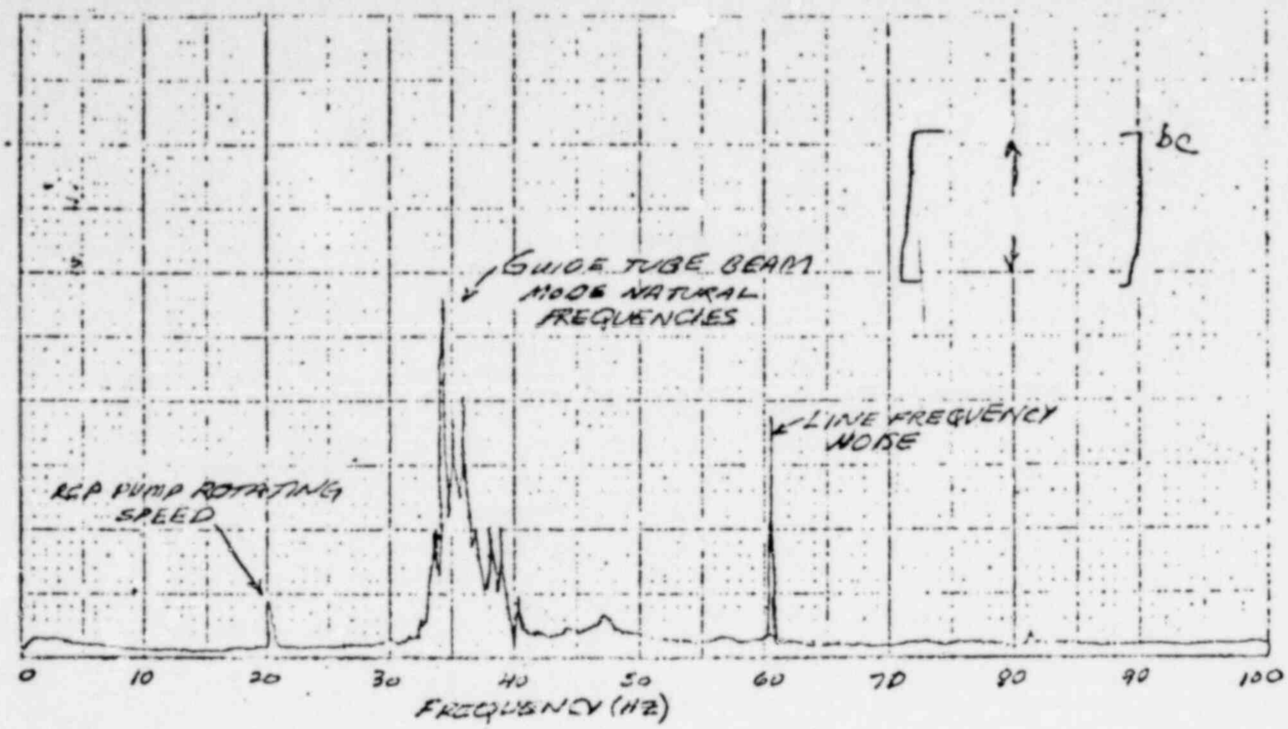
Spectra typical of signals from upper guide tube strain gages are shown in Figure 2. The spectra show that the major response of this component is in cantilever beam modes. Since the upper guide tube is essentially an axisymmetric structure, several modes occur between 33 and 39 Hz. The flow velocities around the upper guide tube are low resulting in low vibratory amplitudes [ ][b,c], low damping (approximately one percent), and a high factor of safety (12.6 to an allowable stress of 16,300 psi).

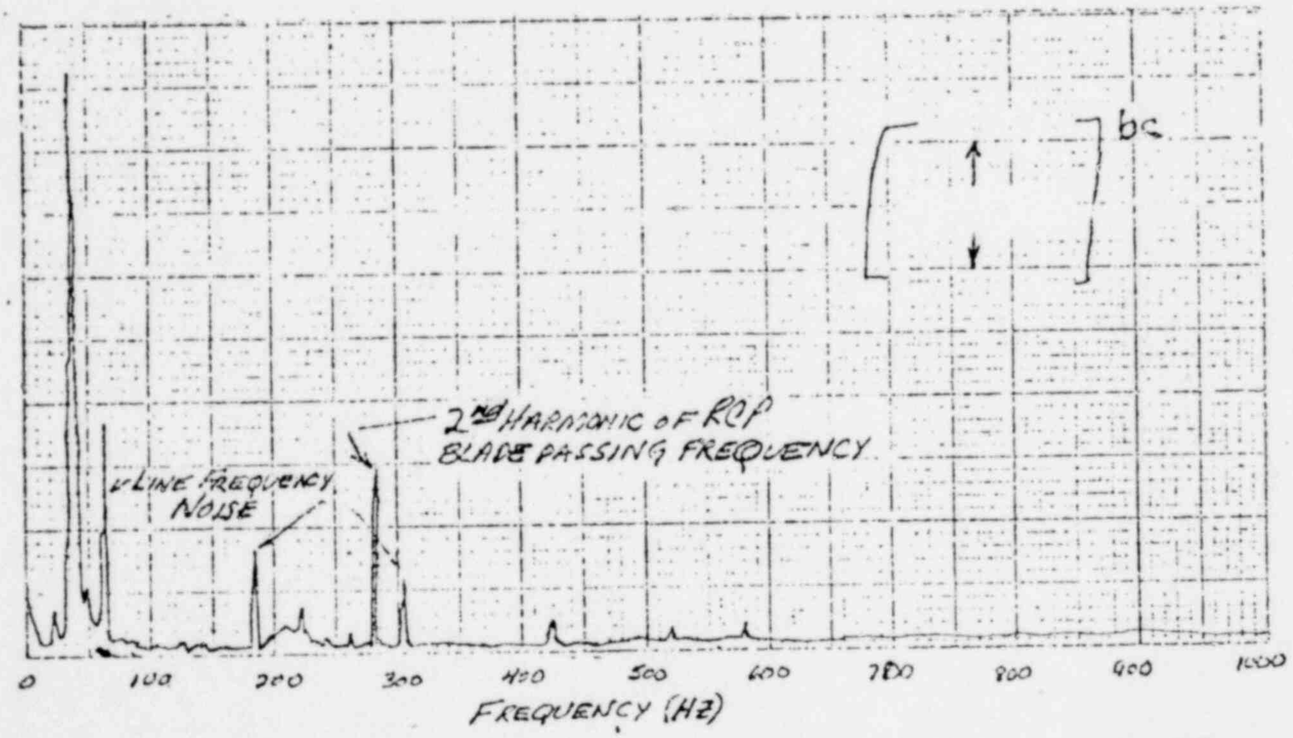
Signals from upper support column strain gages (Figure 3) indicate broadband random responses, narrowband random responses centered on structural natural frequencies, and RCP-speed related responses. The major response is the low frequency (near zero to 50 Hz) random response. Narrowband responses at structural natural frequencies are in the 100 to 150 Hz frequency band. Results of mechanical-dynamic testing carried out on the upper internals at Sequoyah-1 prior to hot functional testing show that the support column deflection shape in these modes is that of the [ ].[b,c]

As shown on Table 1, the damping of the upper support columns is 0.3 to 1.0 percent of critical damping for the small vibratory amplitudes (approximately [ ][b,c] inches rms) of the support columns.

The factor of safety of support columns has been calculated using allowable stress levels given in Reference 1. The minimum factor of safety has been determined to be approximately 8 to these allowable levels for 548°F, four RCP operation. For other temperature and pump combinations, support column strain levels are lower so that higher factors of safety will result. 1262 149

The RCP induced frequency component at 277 Hz (which has been detected in all previous plant data) has a significant level in the lower guide tube response and, to a lesser extent, in the support column response. The levels of this





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LINEAR FREQUENCY SPECTRA OF AN UPPER GUIDE TUBE STRAIN GAGE SIGNAL, 4 PUMPS, 539°F.

FIGURE 2

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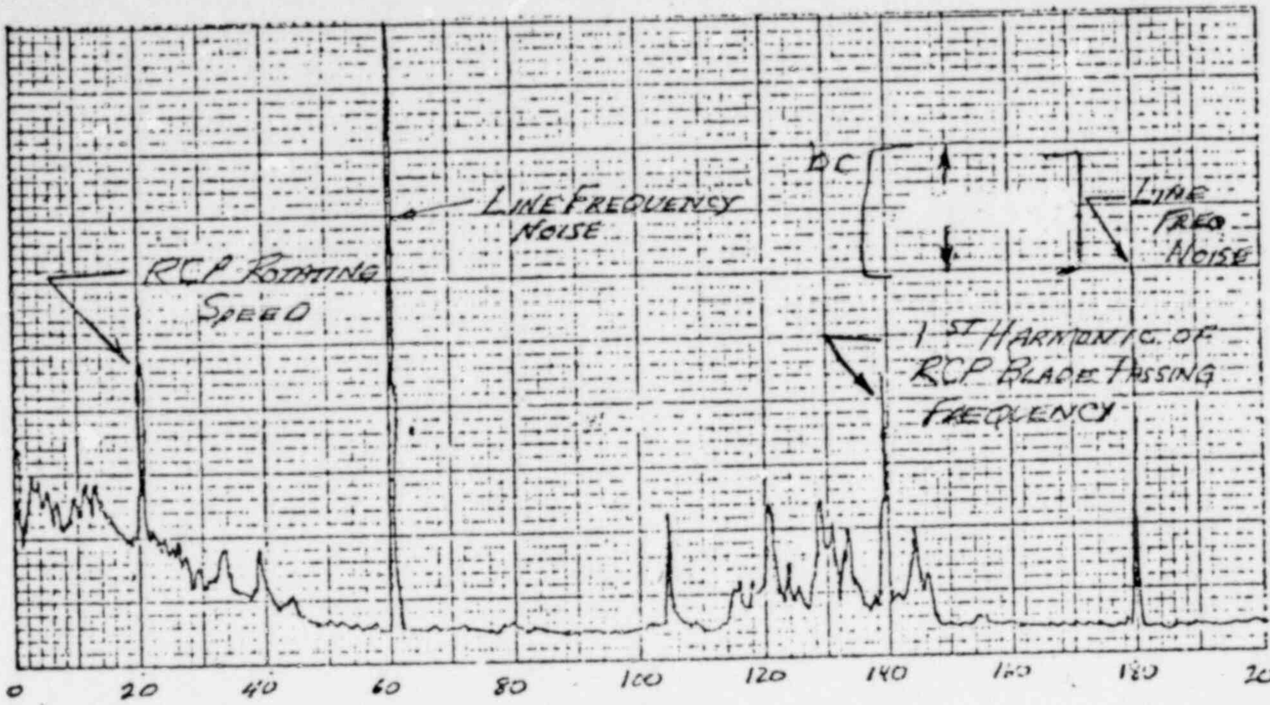

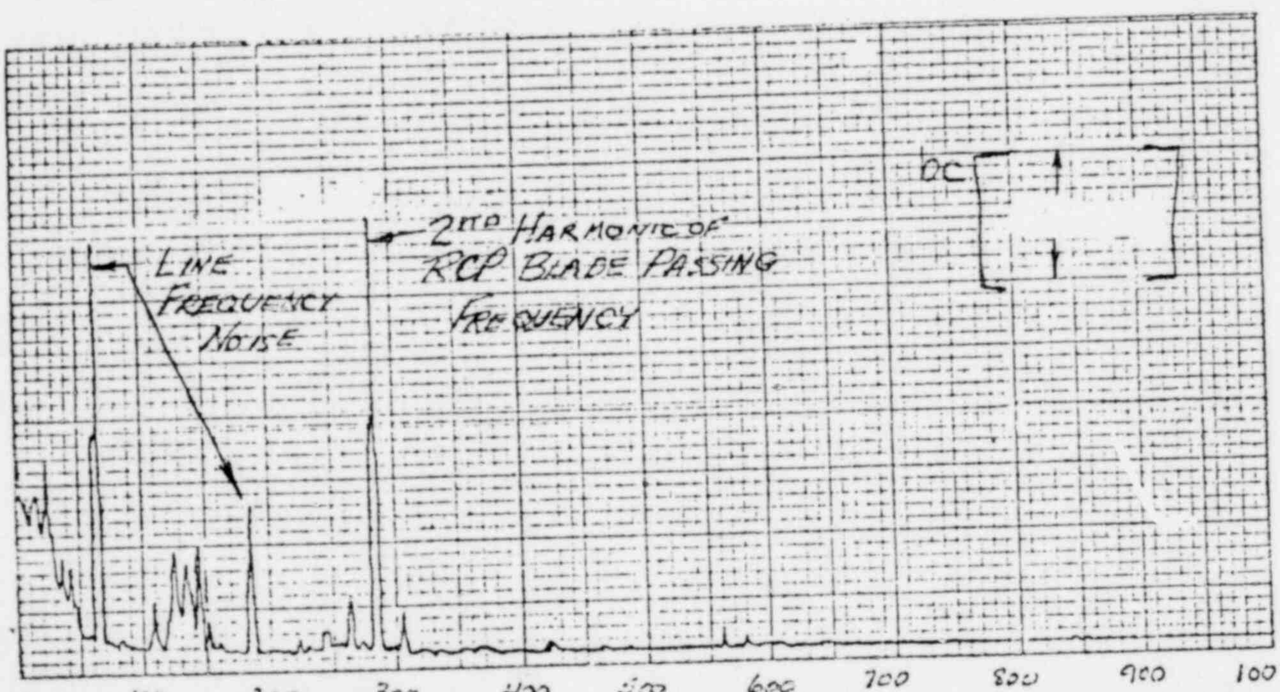

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LINEAR FREQUENCY SPECTRA OF AN UPPER SUPPORT COLUMN STRAIN GAGE SIGNAL, 4 PUMPS, 539°F

FIGURE 3

frequency component are temperature dependent with the highest levels occurring in data taken at 539°F and 548°F. These maximum levels, which are included in the computation of the safety factors shown on Table 1, correspond to a maximum vibration amplitude of [ ]^{b,c} rms. Previously, data have shown that internals responses due to this frequency component are generally reduced by the addition of the core and drive lines.

In conclusion, the preliminary analysis of the hot functional data show random responses and natural frequencies that are in good agreement with expected results. Factors of safety are acceptable for the life of the plant.

As done for other plants in the past, further guide tube data will be acquired during the initial heat-up. These measurements with the core and drive lines in place will provide further information on vibration responses of guide tubes.

References

1. WCAP-8516-P (and WCAP-8517, non-proprietary), "UHI Plant Internals Vibration Measurement Program and Pre- and Post-Hot Functional Examinations," C. N. Bloyd, N. R. Singleton, March 1975.