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SCHWENCER,A. Licensing Branch 2

SUBJECT: Forwards Burns & Roe review of BNL comments re effects of desynchronization methodology used in generic & plant-unique chugging load specs,per Mark II owners group 820209 meeting. Structural responses not significant.

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Docket No. 50-397

March 15, 1982
G02-82-324

Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Schwencer:

Subject: NUCLEAR PROJECT NO. 2
DESYNCHRONIZATION METHODOLOGY
IN CHUGGING LOAD SPECIFICATION

On February 9, 1982, the Mark II Owners met with the NRC staff and consultants to discuss the issue raised by Professor George Bienkowski of Brookhaven National Laboratory, regarding the desynchronization methodology utilized in the generic and plant unique chugging load specifications. Studies by Professor Bienkowski have concluded that the frequency content of the chugging load is sensitive to the specific set of chug start times used in the load specification, and that the potential non-conservatisms associated with this effect are more pronounced in the asymmetric load case than in the symmetric load case. Professor Bienkowski concluded further that the desynchronization methodology used for WNP-2 is more conservative than that used by the other Mark II plants, due to the grouping of three vents together for assignment of chug start times.

B001
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At the February 9th meeting, studies performed by Burns and Roe for the WNP-2 plant were presented, which concluded that structural responses outside the wetwell due to the asymmetric load case are not significant, and that sufficient margin exists in the WNP-2 chugging load definition to accommodate the concerns raised by Professor Bienkowski. Following that presentation, the NRC indicated this issue was resolved for WNP-2, but requested that the results of Burns and Roe's evaluation be documented in report form and formally submitted to the NRC. The attachment provides the information requested.

Very truly yours,

G. D. Bouchey
Deputy Director, Safety and Security

EAF:kjf

Attachment: "Review of Professor Bienkowski's Concern Regarding Effects of Desynchronization on the Chugging Load Specification Used for WPPSS - Nuclear Project No. 2"

cc: R. Auluck - NRC w/att.
WS Chin - BPA
F. Eltawila - NRC w/att.
R. Feil - NRC Site

# REVIEW OF PROF. BIENKOWSKI'S CONCERN REGARDING EFFECTS OF DESYNCHRONIZATION ON THE CHUGGING LOAD SPECIFICATION USED FOR WPPSS - NUCLEAR PROJECT NO. 2

The chugging load specification developed by Burns and Roe, Inc. for WPPSS - Nuclear Project No. 2 (WNP-#2)[1] consists of:

- a single-vent design "source" load, and
- a spatial distribution of "source" loads in a multi-vent Mark II containment geometry, including desynchronization between individual vent loads.

As illustrated in Figure 1, the single-vent design "source" load bounds the test data by a good margin since, as originally developed, the design load was to envelope the entire 4TCO test data base[2]; it was later concluded that, in view of the random nature of chugging, it is more realistic yet still adequate to bound the data base in a "statistical" sense only[1,3].

The spatial distributions prescribed for WNP-#2 (a nearly symmetrical load case and an asymmetric load case)[1] conservatively paralleled the Mark II generic load cases (symmetric and asymmetric)[3] and the desynchronization between individual vent loads specified in the generic chugging load definition[3] was retained for WNP-#2[1] in order to maintain uniformity in methodologies: generic vs WNP-#2. Design "source" loads are to be applied desynchronized at individual vent exits using a set of chug start times having the smallest variance in one thousand Monte Carlo trials drawn from a uniform distribution of start times having a width of 50 milliseconds.

Prof. Bienkowski, as consultant to the NRC, has reviewed the effects of desynchronization on the chugging load; specifically he evaluated the sensitivity of the frequency content of the load to the selection of a <u>single</u> set of start times recommended by the load specification.

Starting, on the basis of "physical" intuition (actually rather historical precedence and practical considerations), with the vertical force and overturning moment acting on the suppression pool bottom as parameters that adequately describe the "major" structural excitations and using the results of calculations based, by necessity, on simplifying assumptions, Prof. Bienkowski reached the tentative conclusion that the desynchronization specification may result in frequency "holes" at some frequencies, mainly in the 20 Hz to 50 Hz range. It thus appears that the present chugging load specification may be deficient in this frequency range.

Burns and Roe, Inc. has reviewed Prof. Bienkowski's concern and in what follows, our findings and conclusions are summarized.

A. The total force (incident pressure or "rigid wall" load) applied over the containment wall wetted perimeter was found to control the structural responses of WNP-#2 reactor building. Since, in the case of hydrodynamic pressures, the vertical force is a representative measure of the total force acting over the containment wall wetted perimeter, it may be viewed as a parameter critical for assessment of chugging load specification (desynchronization effects).

The total overturning moment on the other hand was found not to correspond to a "major" component of the structural response of WNP-#2 reactor building and thus, it cannot be viewed as a representative (or critical) parameter when assessing the chugging load specification. Indeed, the rocking of the WNP-#2 reactor building under chugging loads was found to be negligible. The analytical proof has been developed as described below. The wetted boundary of the WNP-#2 suppression pool was assumed acted upon by an incident pressure ("rigid wall" load) distributed circumferentially according to eq. (1):

$$p = \begin{cases} p_o \cdot \frac{z}{z_1} \cdot \cos\theta & \text{for } 0 \leq z \leq z_1 ; \quad R_1 \leq r \leq R_2 ; \\ p_o \cdot \cos\theta & \text{for } z_1 \leq z \leq z_2 ; \quad R_1 \leq r \leq R_2 ; \end{cases} \qquad (1)$$

thus simulating a "pure"overturning moment loading condition (for geometric notations see Figure 2). The load was assumed harmonic with the forcing frequency in the range of 0 to 60 hz varying in increments of 1 Hz. The maximum structural response accelerations calculated at different locations and corresponding to a peak pressure $p_o$ = 1 psi are displayed in Figure 2. As may be seen from Figure 2, the calculated structural responses indicate that rocking of the reactor building under the assumed "pure" overturning moment loading conditions is negligible and that responses of significance are computed only on the containment wall in the wetwell (loaded) area. Even on the basis of the unrealistically conservative assumption that the maximum calculated "rigid wall" load for WNP-#2 of 30.8 psi peak pressure (see Table 5-2 of Reference 1) is harmonic with a frequency anywhere in the range of 0 to 60 Hz and distributed according to eq. (1), the resulting maximum reactor building structural response accelerations would still be very small outside the primary containment wetted boundary.

This analytical finding should not come as a surprise; indeed, on physical grounds, significant structural responses are expected at, or in the immediate vicinity of, the applied load; furthermore, with the load applied near the foundation mat of a large and heavy structure with the geometry and inertial and stiffness properties of the WNP-#2 reactor building the soil-structure interaction modes (rocking and translational) are not likely to be exited to any significant degree. On the contrary, under seismic excitation, the WNP-#2 reactor building would respond largely in the soil-structure interaction modes, i.e., rocking and translating about the foundation material.

It is noteworthy to mention here the responses recorded during SRV tests performed at CAORSO (Italy), a BWR plant with a concrete containment of Mark II configuration. Single valve actuations resulted in maximum peak pressures on the suppression pool boundary of the order of 9 psi at one end and almost nil at the diametrically opposite end, thus simulating an overturning moment loading on the building's base mat. Under this loading condition the reactor building response accelerations were very small; as reported in Table 8.1 of Reference 4 a representative sensor (AMN Sensor A'06 y) recorded a maximum building acceleration of .007g. Similar results were reported[4] from SRV tests performed at Tokai 2 (Japan).

It is concluded, on the basis of all the above, that the vertical force may be viewed as a parameter critical for assessment of chugging loads, but not the overturning moment.

B. As discussed earlier in this letter-report the single-vent design "source" loads derived for application to WNP-#2 enveloped the 4TCO test data base by a good margin (see Figure 1). When this conservatism in design loads is duly accounted for, the desynchronization methodology used with the chugging load definition is shown to be adequate. Indeed, Figure 3 shows a comparison, frequency by frequency, for WNP-#2 vertical force in terms of the ratio = (PSD for desynchronized application/PSD for synchronized application) between:

a) required design values (or "true" bound of 1000 Monte Carlo trials) estimated by Prof. Bienkowski,

b) (three) possible design outcome values (Prof. Bienkowski's estimates), and

c) the same (three) possible design outcome values adjusted to account for conservatism in single-vent design "source" load definition.

The adjusted possible design outcome values were simply obtained by multiplying the possible design outcome values estimated by Prof. Bienkowski with a factor representing the conservatism embedded in the single-vent design "source" load definition and obtained as the ratio between the "design spectrum"* and the "required average spectrum"** of Figure 1, at each frequency.

As seen from Figure 3, when adjusted for conservatism in the design load definition, the possible design outcome values envelope by a good margin the required design values.

It should be noted here that the comparisons of Figure 3 are only estimates since the analytical procedures implemented on WNP-#2 (including software package) were not available to Prof. Bienkowski for use. It is believed that if these analytical procedures were to be used the comparison will be even more favorable.

It is therefore concluded that the present chugging load specification (including desynchronization) is adequate.

C. The multi-vent full scale test facility most representative of the Mark II suppression pool geometry is JAERI's seven vent tank. The NRC staff has previously requested to apply the WNP-#2 chugging load specification to the JAERI test facility and to compare the pressures calculated on its boundary with those recorded during the JAERI chugging tests. A number of chugging tests were already completed in this facility and some of the recorded data already processed, including data from Test 0002 during which some of the largest chugs were recorded[3].

If the chugging load specification derived for WNP-#2 (including desynchronization) is applied to the JAERI tank the "rigid wall" pressures calculated on its walls at the vent exits elevation bound, and by a significant margin, the

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* The "design spectrum" is the envelope (in terms of Fourier amplitude spectra) of the 4TCO bottom center pressure time histories obtained when the design "source" loads are applied at vent exit over the steam water interface.[1]

** The "required average spectrum" is the envelope (in terms of Fourier amplitude spectra) of all the "average" or "mean" chugs obtained for the time windows for which 4TCO chugging data were supplied. An "average" or "mean" chug was obtained by averaging (in terms of Fourier amplitude spectra) each strongest ("key") chug with the largest neighboring ("companion") chug for each time window of data supplied.

recorded test data. This is illustrated in Figure 4. The JAERI test data represents the envelope of the eight largest chugs from Test 0002. The envelope is obtained as described in Reference 3, with the exception that the spatially averaged pressure history was computed only from four wall sensors located on the concrete walls of the tank: WWPF-202, 302, 602 and 702 instead of the six wall sensors available (WWPF-202 to 702) used in the Reference 3 comparison. The result thus obtained is more representative of the incident pressure (or "rigid wall" load) and, therefore, comparable with the incident pressure predicted/calculated using the WNP-#2 chugging load specification.

Comparative examination of the results plotted in Figure 4 leads to the conclusion that the present chugging load specification (including desynchronization) of WNP-#2 is adequate.

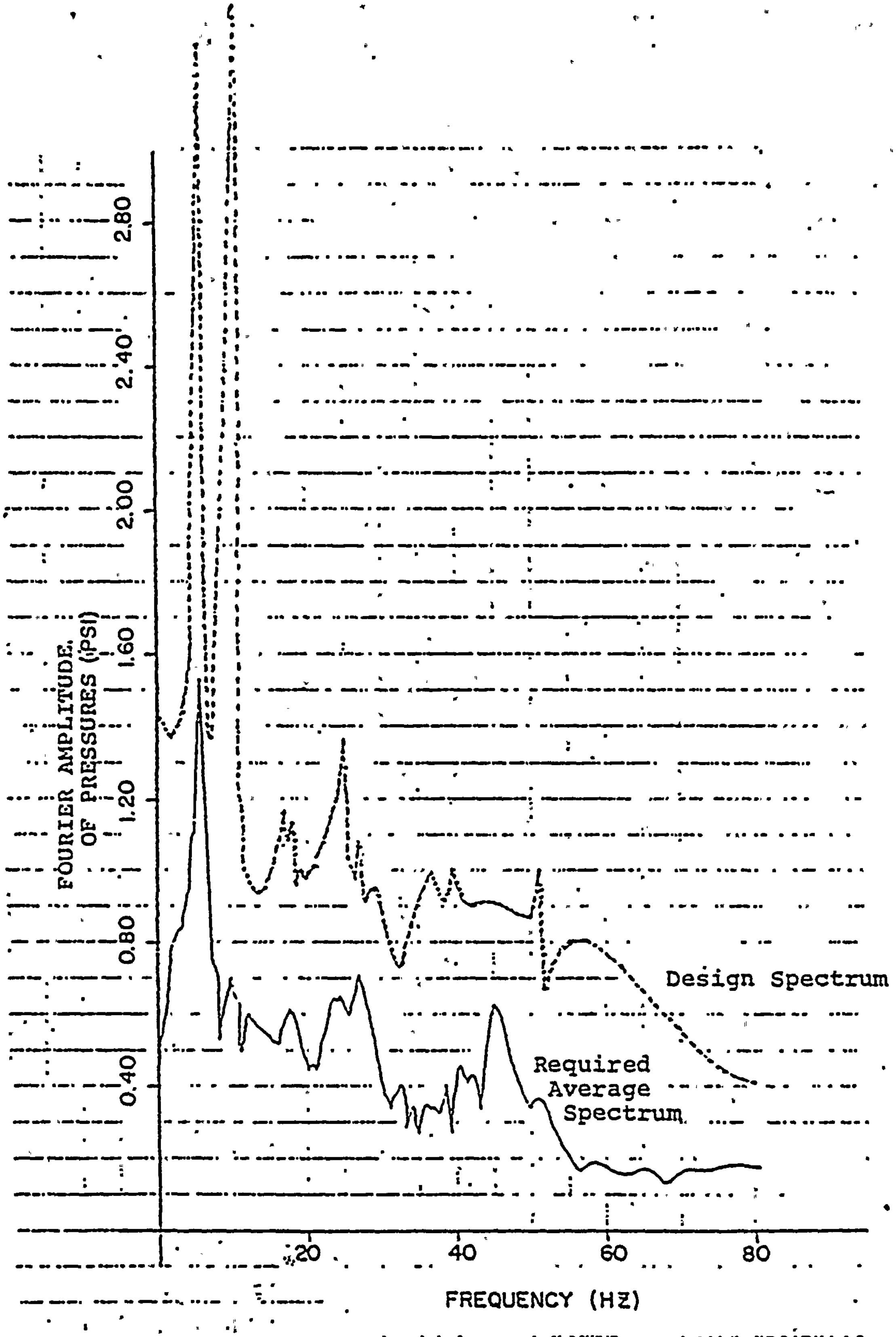
References:


1. "Chugging Loads - Revised Definition and Application Methodology for Mark II Containments (Based on 4TCO Test Results)," Technical Report prepared by Burns and Roe, Inc. for application to Washington Public Power Supply System, Nuclear Project No. 2, dated July 21, 1981.

2. "Transmittal of Computer Tapes Containing 4TCO Test Data," General Electric Company letter MkII-1814-E (including the two referenced letters dated 1/2/80 and 4/29/80) to Mark II Consultants, dated July 15, 1980.

3. "Generic Chugging Load Definition Report," General Electric Company Document NEDE-24302-P, dated April 1981.

4. "SRV Loads - Improved Definition and Application Methodology for Mark II Containments," Technical Report prepared by Burns and Roe, Inc. for application to Washington Public Power Supply System, Nuclear Project No. 2, dated July 29, 1980.




| WASHINGTON PUBLIC POWER SUPPLY SYSTEM<br>NUCLEAR PROJECT NO. 2. | DESIGN SPECTRUM AND REQUIRED AVERAGE SPECTRUM - 4TCO BOTTOM CENTER (CHANNEL 28). | FIGURE<br>1a |
|---|---|---|

(Figure 4-3 from Reference 1 Report)

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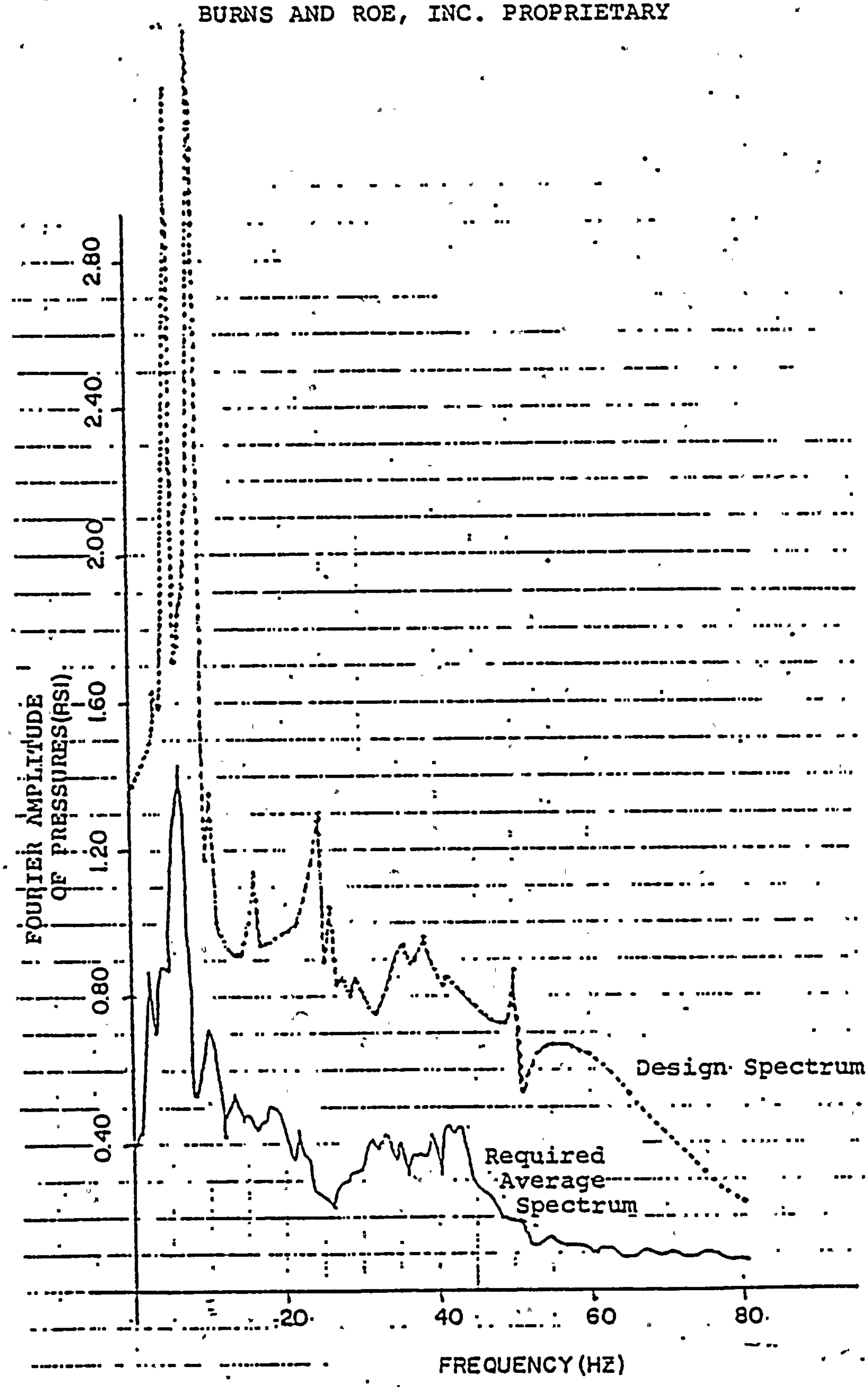


| WASHINGTON PUBLIC POWER SUPPLY SYSTEM<br>NUCLEAR PROJECT NO. 2 | DESIGN SPECTRUM AND REQUIRED AVERAGE SPECTRUM - 4TCO WALL, ELEV. 6 FT. ABOVE BASE (CHANNEL 24) | FIGURE<br>1b |
|---|---|---|

(Figure 4-5 from Reference 1 Report)

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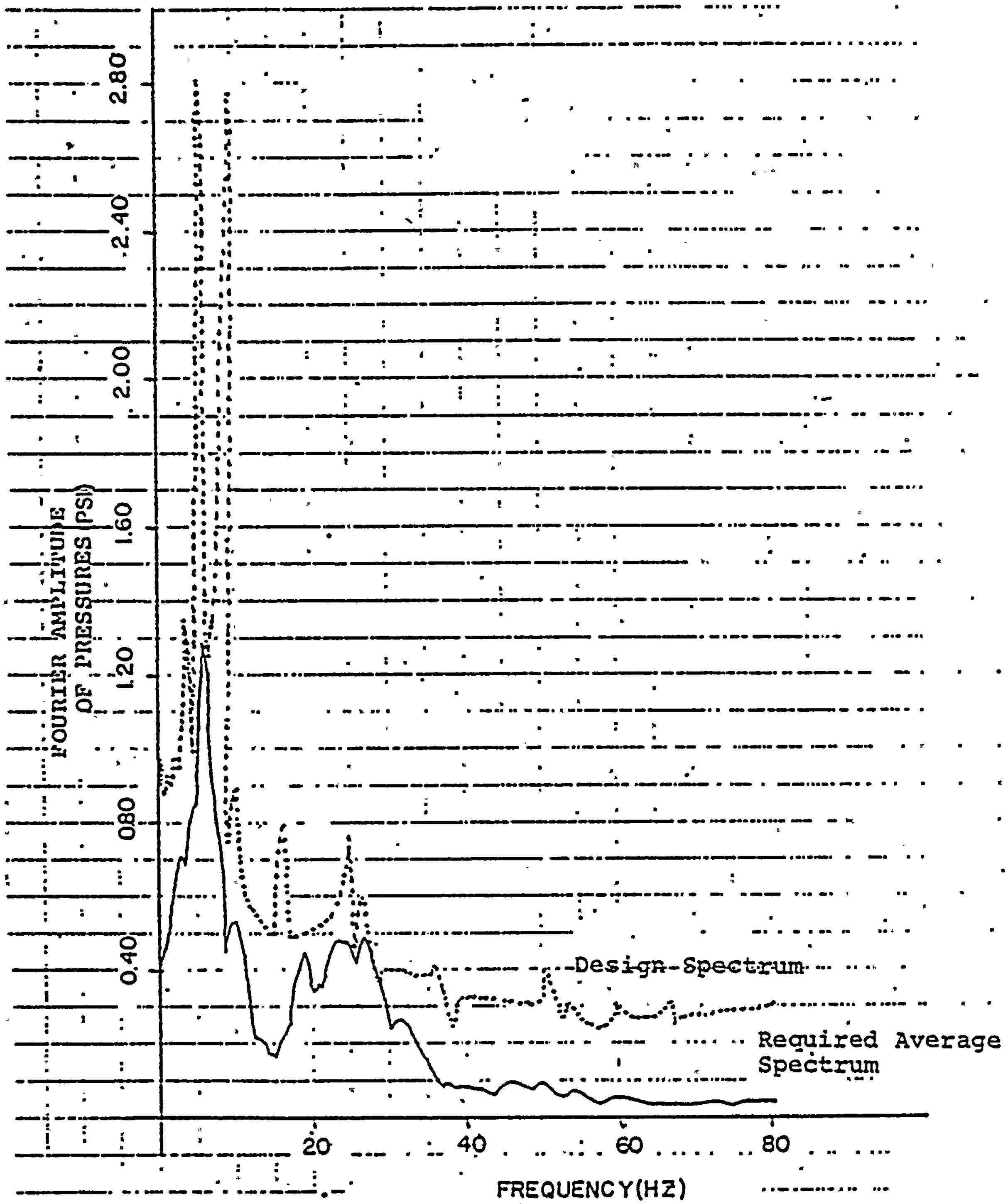



| WASHINGTON PUBLIC POWER SUPPLY SYSTEM<br>NUCLEAR PROJECT NO. 2 | DESIGN SPECTRUM AND REQUIRED AVERAGE SPECTRUM - 4TCO WALL, VENT EXIT ELEV.: 12 FT. ABOVE BASE (CHANNEL 20) | FIGURE 1c |
|---|---|---|

(Figure 4-6 from Reference 1 Report)

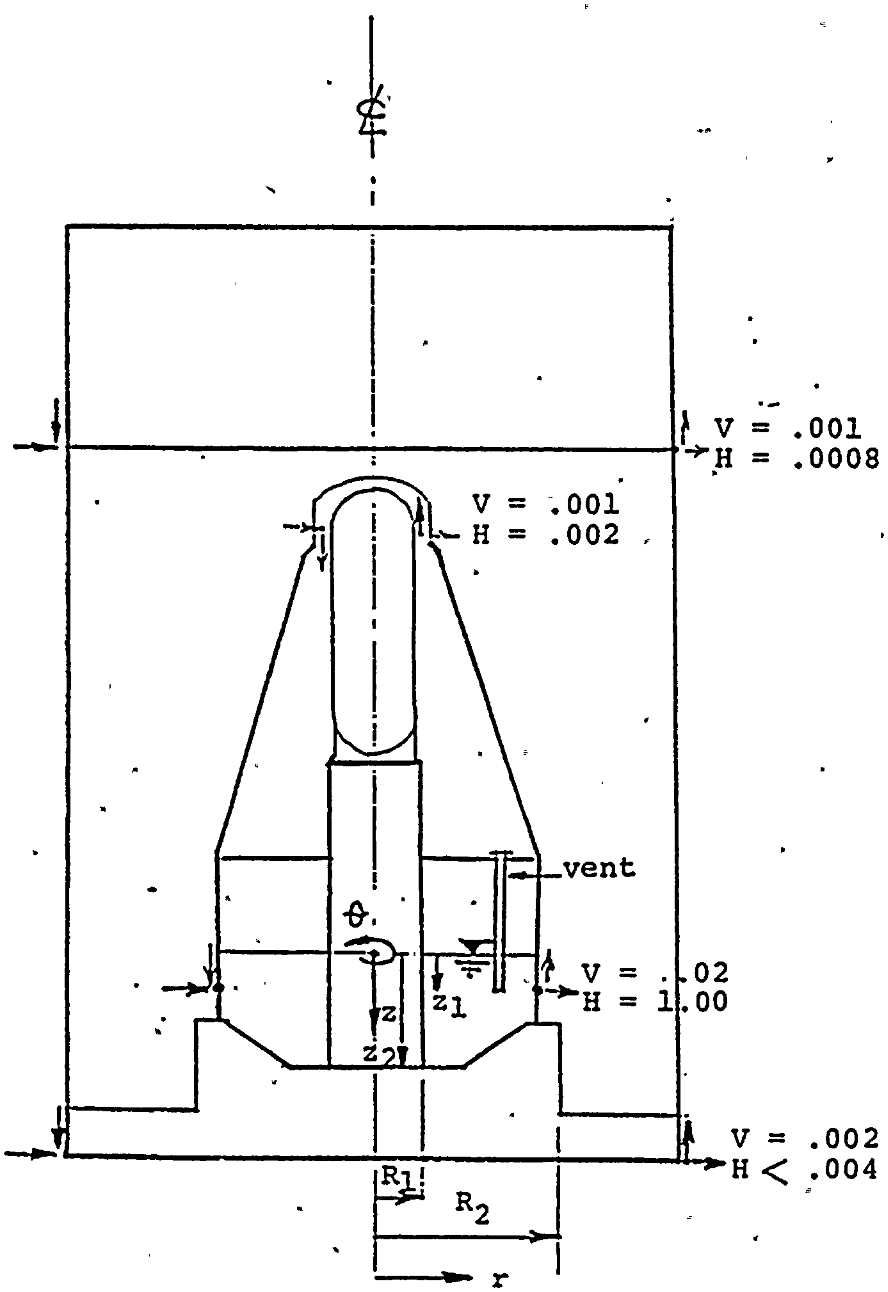



Fig. 2: MAXIMUM STRUCTURAL RESPONSE ACCELERATIONS (in g's) OF WNP-2 REACTOR BUILDING DUE TO AN INCIDENT PRESSURE ($p_o$ = 1 psi) SIMULATING OVERTURNING MOMENT, HARMONICALLY APPLIED.

Fig. 3a-1: WNP-2
VERTICAL FORCE COMPARISON:
DESIGN REQUIRED vs POSSIBLE DESIGN OUTCOME
1st TRIAL

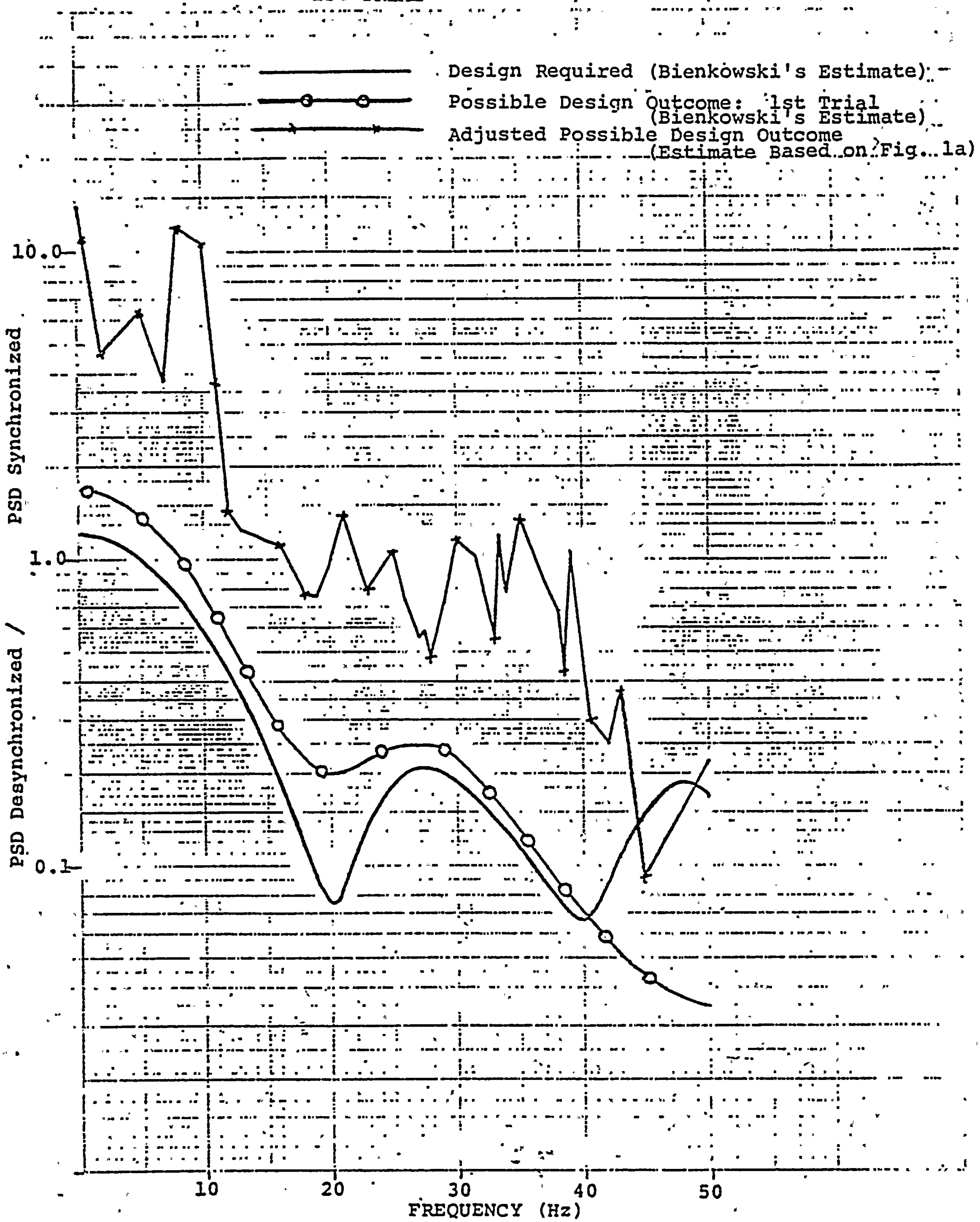


Fig. 3a-2: WNB-#2
VERTICAL FORCE COMPARISON:
DESIGN REQUIRED vs POSSIBLE DESIGN OUTCOME
2nd TRIAL

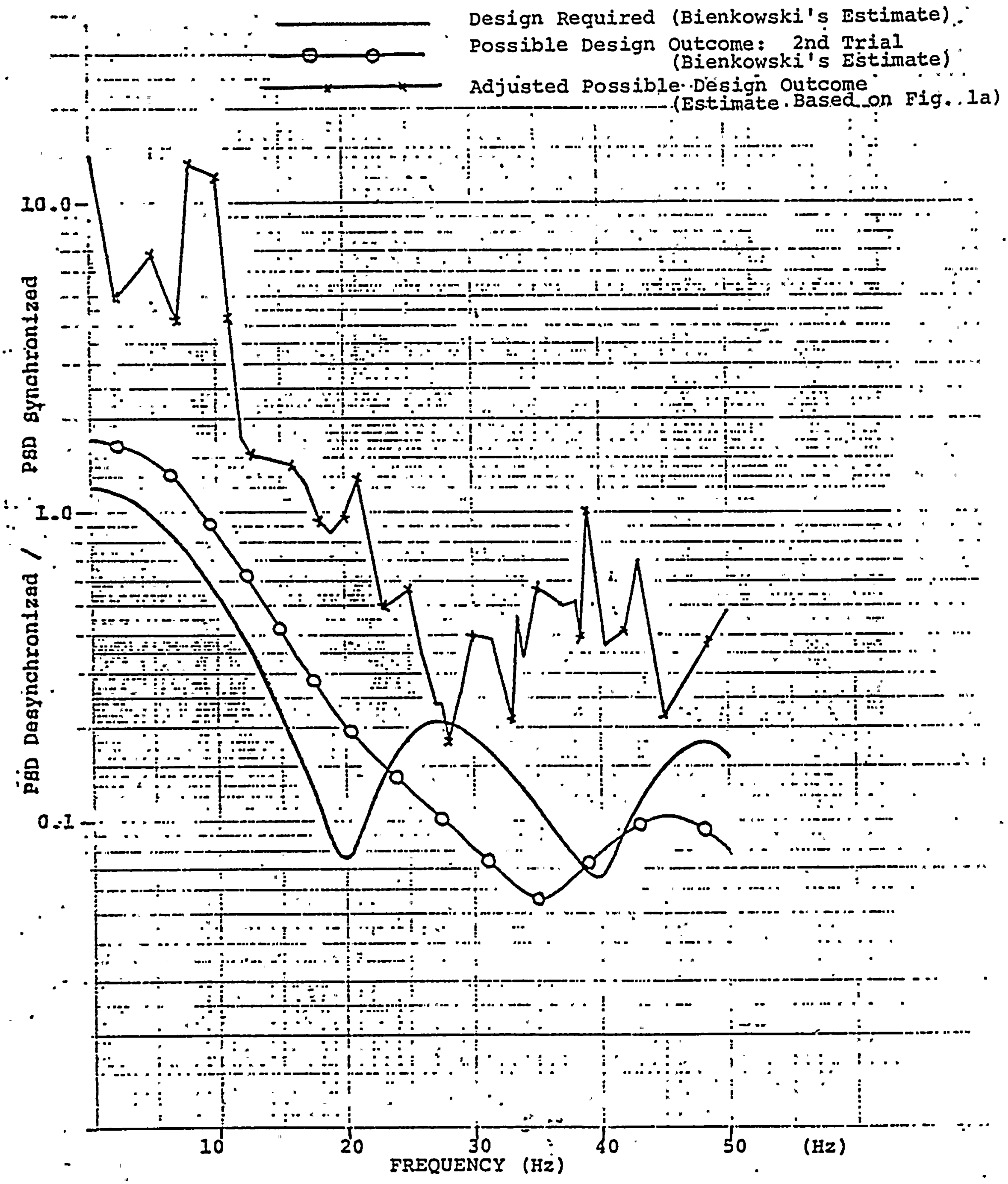


Fig. 3a-3: WN #2
VERTICAL FORCE COMPARISON:
DESIGN REQUIRED vs POSSIBLE DESIGN OUTCOME
3rd TRIAL

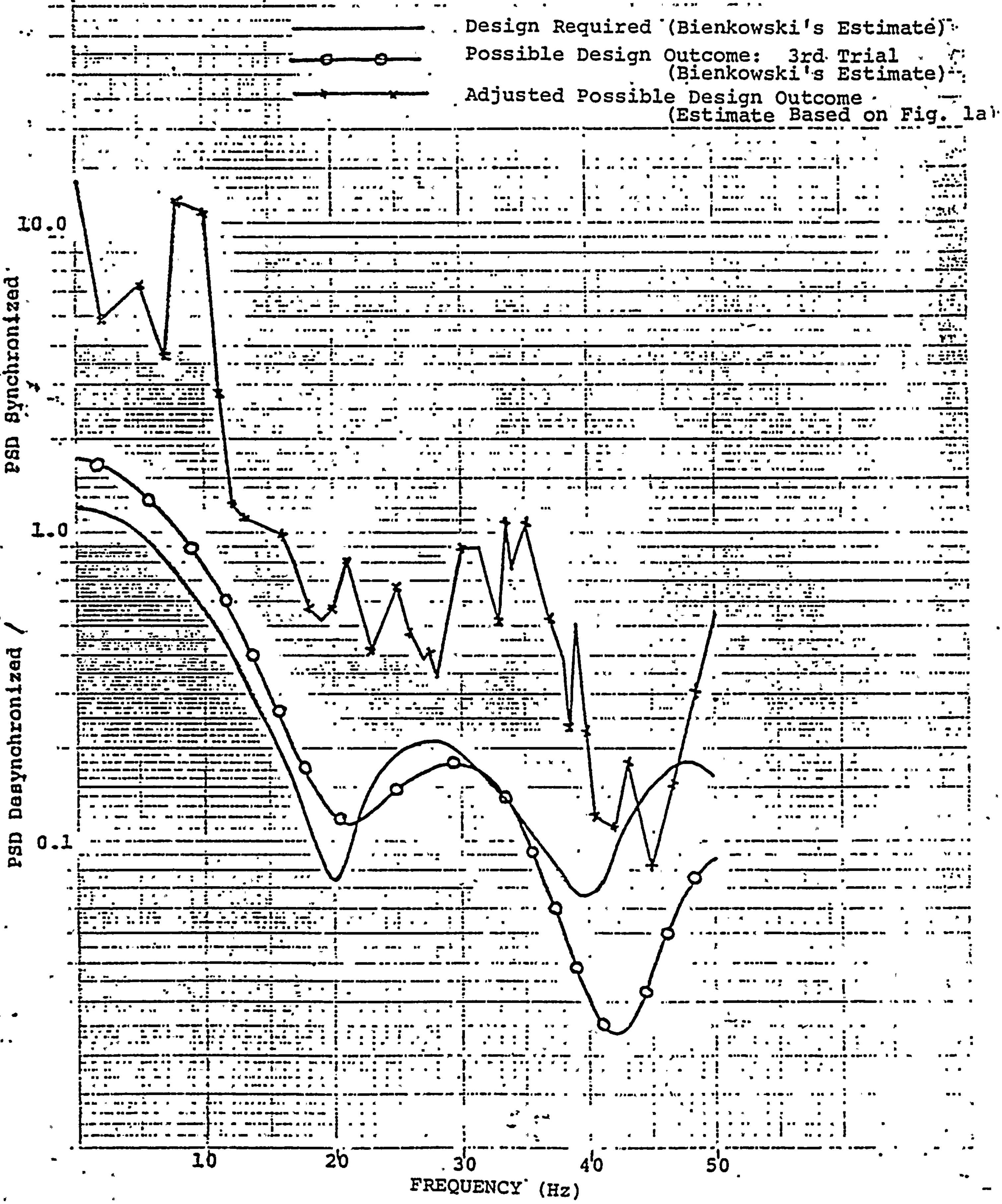


Fig. 3b-1: WN 2
VERTICAL FORCE COMPARISON
DESIGN REQUIRED vs POSSIBLE DESIGN OUTCOME
1st TRIAL

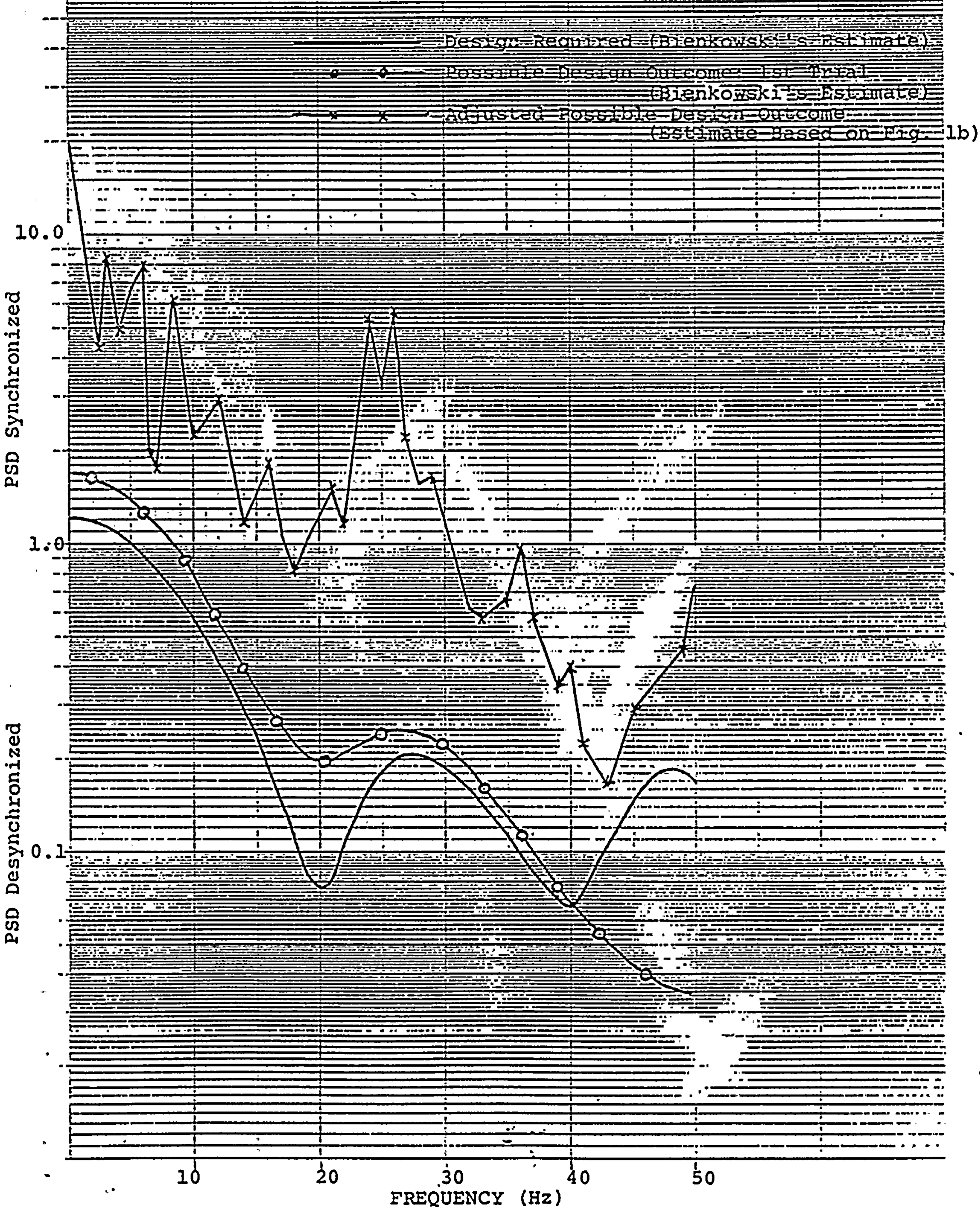


Fig. 3b-2: W[illegible]#2
VERTICAL FORCE COMPARISON:
DESIGN REQUIRED vs POSSIBLE DESIGN OUTCOME
2nd TRIAL

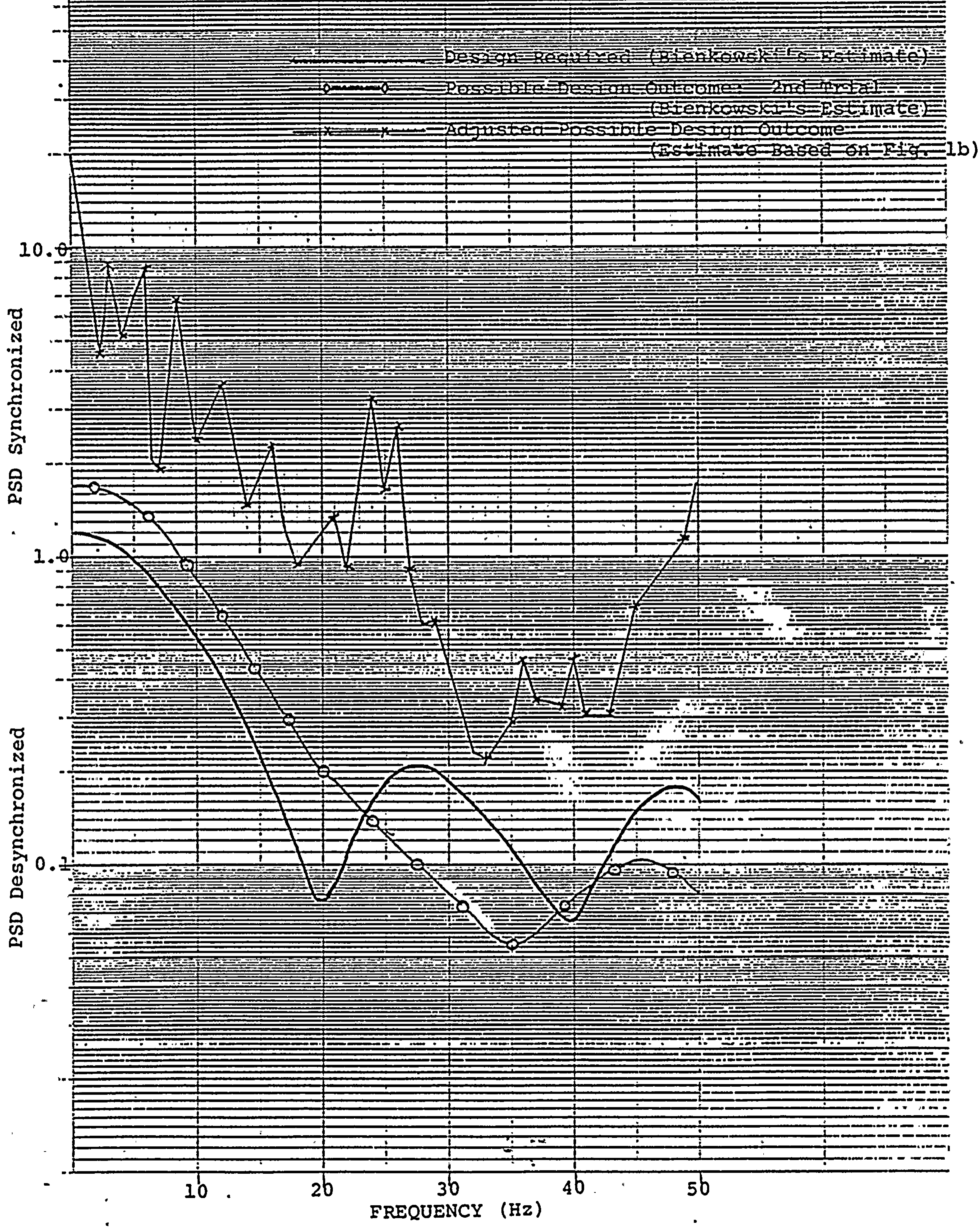


Fig. 3b-3: WNP-#2
VERTICAL FORCE COMPARISON
DESIGN REQUIRED vs POSSIBLE DESIGN OUTCOME
3rd TRIAL

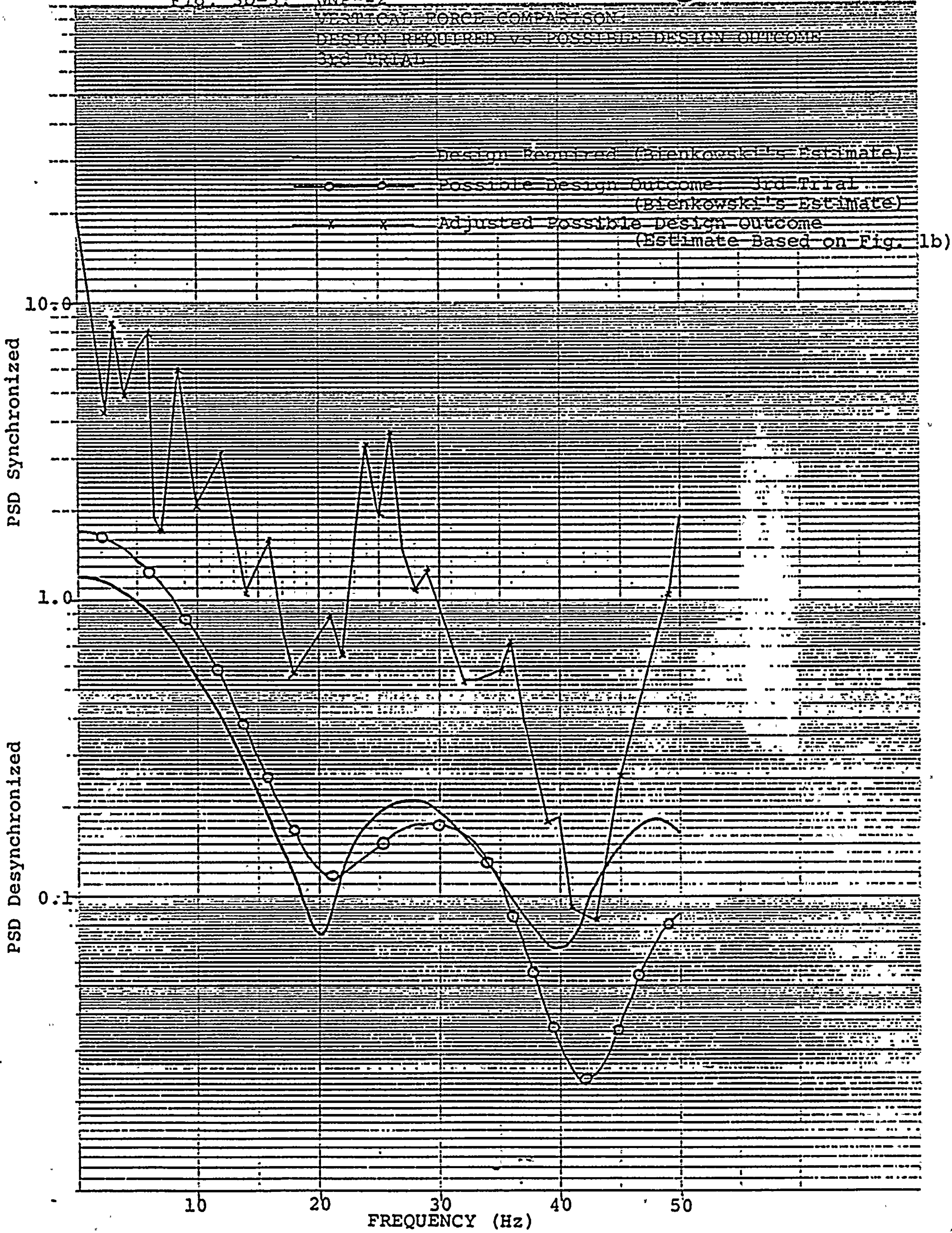


Fig. 3c-1: WNP-#2
VERTICAL FORCE COMPARISONS
DESIGN REQUIRED vs POSSIBLE DESIGN OUTCOME
1st TRIAL

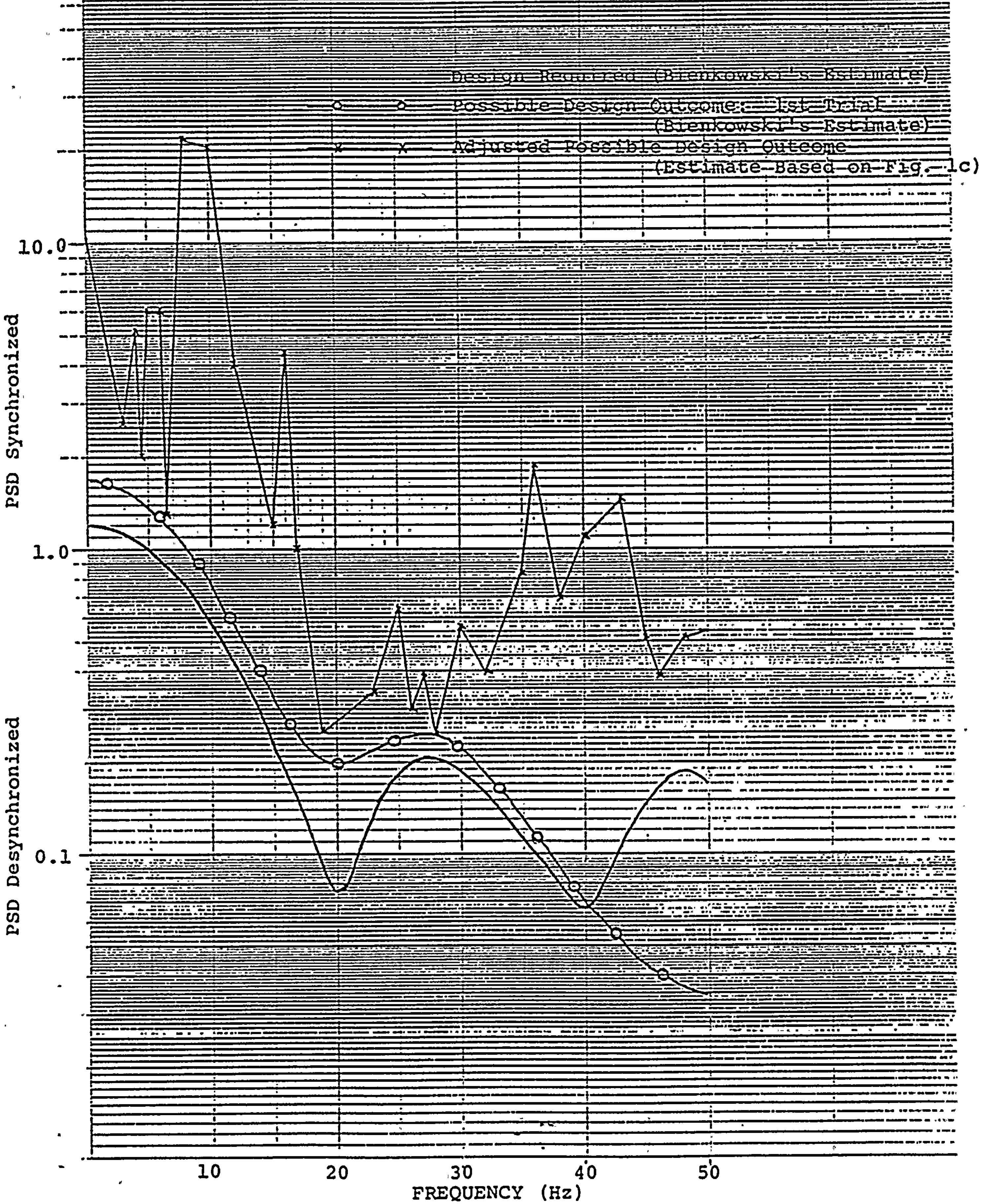


Fig. 3c-2: W[illegible]-#2

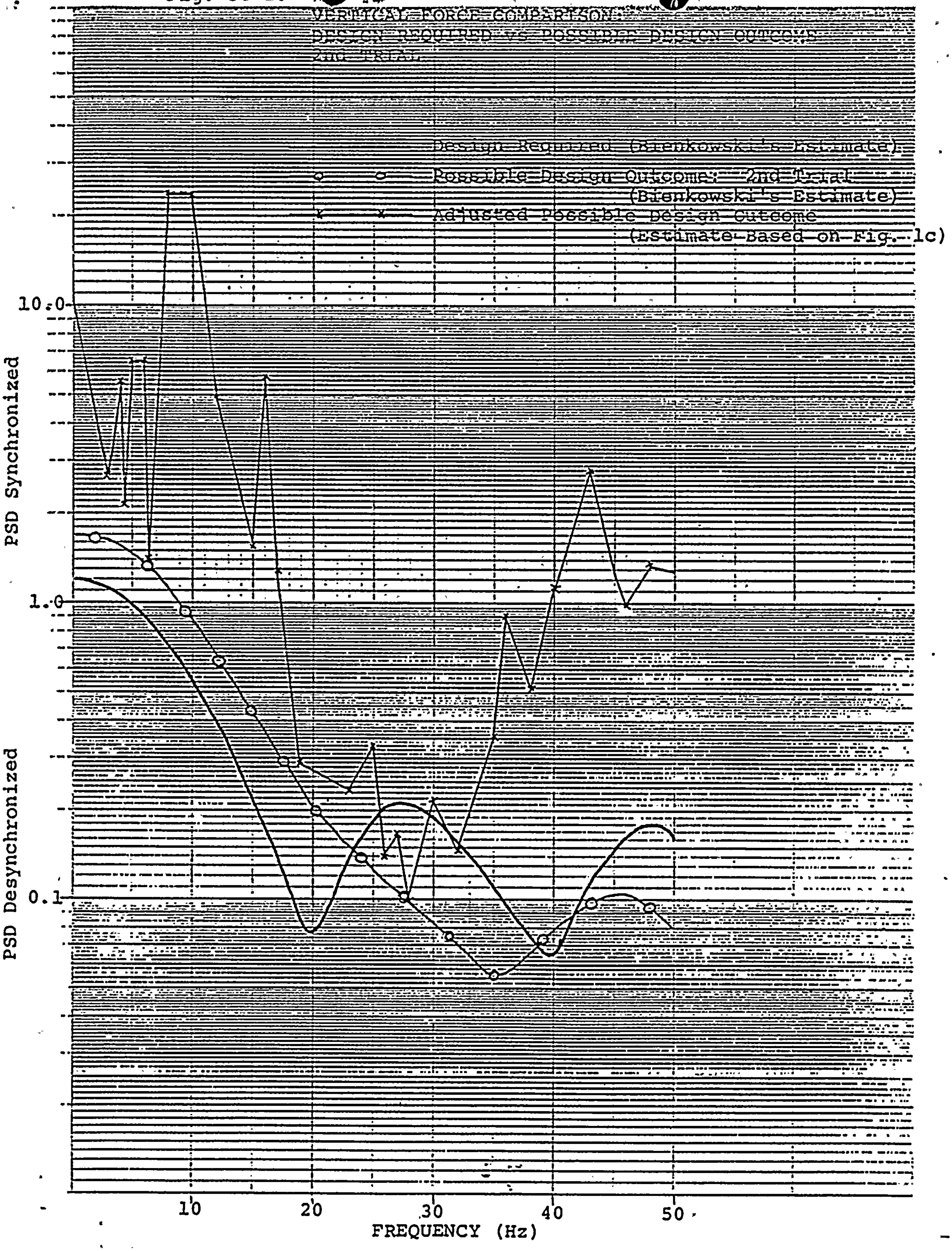

VERTICAL FORCE COMPARISON:
DESIGN REQUIRED VS POSSIBLE DESIGN OUTCOME
2nd TRIAL
Design Required (Bienkowski's Estimate)
Possible Design Outcome: 2nd Trial (Bienkowski's Estimate)
Adjusted Possible Design Outcome (Estimate Based on Fig. 1c)
10.0
1.0
0.1
PSD Synchronized
PSD Desynchronized
10
20
30
40
50
FREQUENCY (Hz)

Fig. 3c-3: WN -#2
VERTICAL FORCE COMPARISON:
DESIGN REQUIRED vs POSSIBLE DESIGN OUTCOME
3rd TRIAL

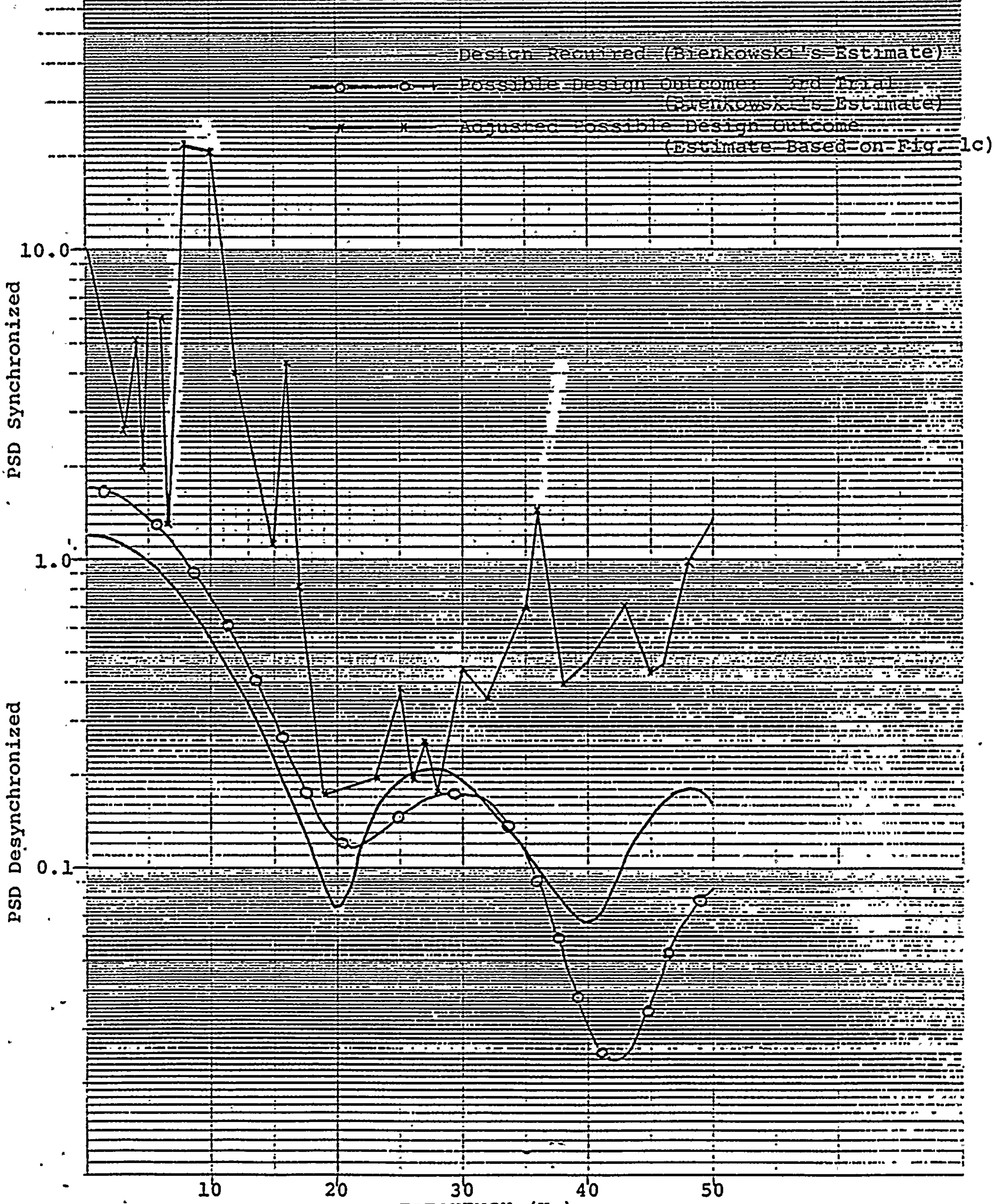
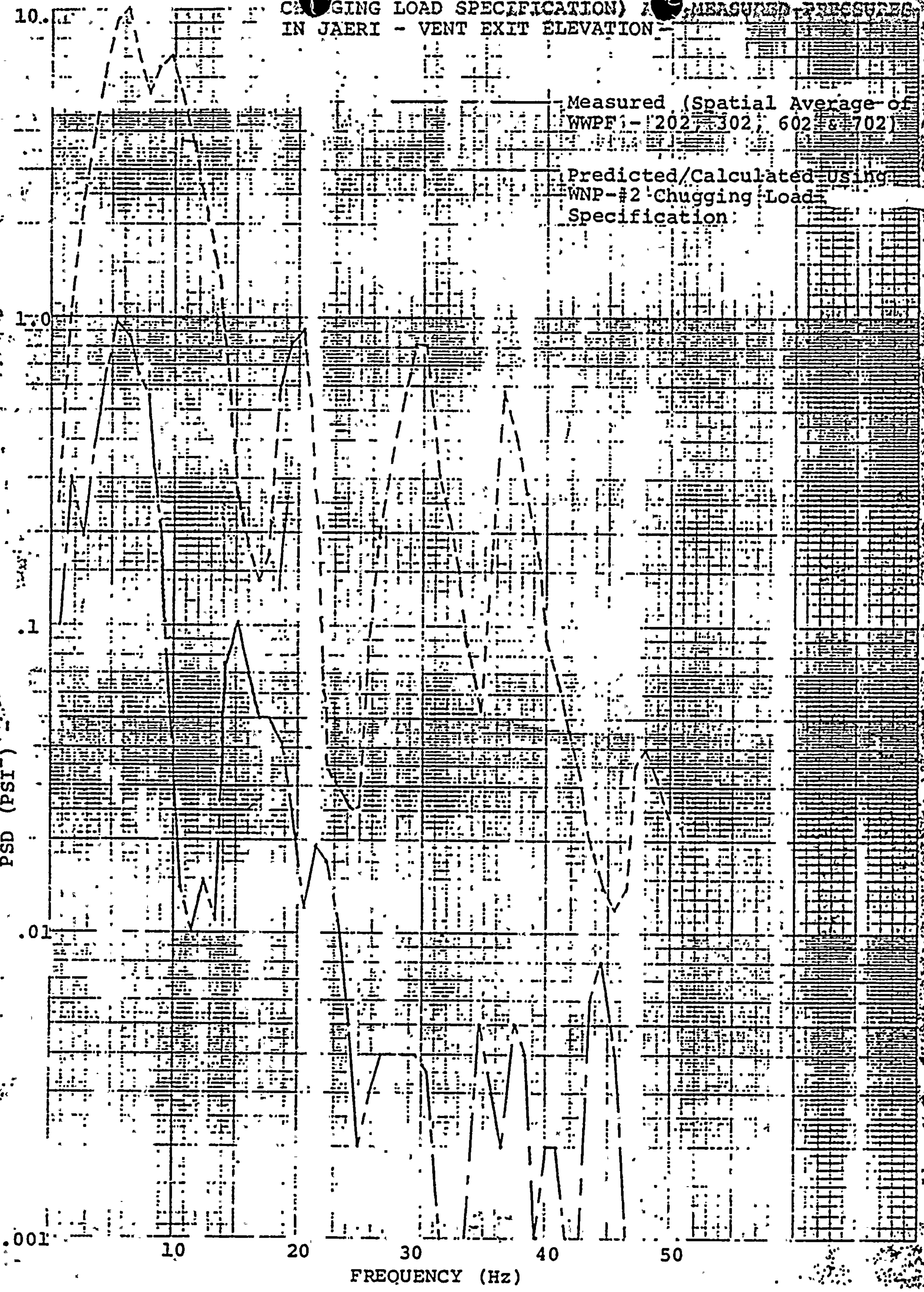


Fig. 4: COMPARISON OF PREDICTED/CALCULATED (USING WNP-#2 CHUGGING LOAD SPECIFICATION) AND MEASURED PRESSURES IN JAERI - VENT EXIT ELEVATION



[illegible]