Appendix 1

General Electric Company
Nuclear Energy Report
MDE-199-0985-NP, Rev. 1

Susquehanna - 1
Steam Dryer Vibration
Steady State and Transient Response

January 1986

(GE Non-Proprietary)

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GENERAL ELECTRIC COMPANY

Non-proprietary Version

SUSQUEHANNA - 1 STEAM DRYER VIBRATION STEADY STATE AND TRANSIENT RESPONSE

FINAL REPORT

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ACKNOWLEDGEMENT

The analyses and tests reported herein were performed by (in alphabetical order) J. Choi, B. Haaberg, M. L. Gensterblum, and T. A. Venkatramani. Their contributions are gratefully acknowledged.

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ABSTRACT

The Susquehanna-1 Steam Dryer was instrumented after a crack was observed at the dryer support bracket located at 184° azimuth in the reactor pressure vessel. Data was collected during the reactor operation from cold conditions to 100% power. Test conditions consisted of: (a) steady state vibration of 0 to 100% power levels at

This report describes the test instrumentation system and the test results. These results are used to assess the dryer adequacy under steam flow induced vibrations. The results indicate that:

ABSTRACT - Continued

[redacted]

Based on the above results, it is concluded that all instrumented dryer components (including the dryer support brackets) except the unpatched second bank end panel, are structurally adequate to resist the measured vibratory loads during normal operation. Due to the large scatter in fatigue data and construction variability, the unpatched dryer panel weld may sustain fatigue usage during normal operation as well as during the [redacted] closure plant operational modes. Therefore, it is recommended that Pennsylvania Power and Light Company make preparations to patch the second bank end panel locations.

1. BACKGROUND

Pennsylvania Power and Light Company's Susquehanna-1 plant is a General Electric BWR/4, 251-in. vessel diameter, in a Mark II containment.

1.1 Susquehanna-1 Steam Dryer

The positioning of the steam dryer at Susquehanna-1 is shown in Figure 1.1-1. The steam dryer design is given in Reference 4.1. The dryer is fabricated entirely of 304 stainless steel. The original stress analysis of the steam dryer is given in Reference 4.2.

form a circular ring. The ring is supported by four support brackets welded to the RPV wall (Figure 1.1-2) The dryer units, which dry the wet steam, are formed into banks which are supported by the support ring. There are six banks of steam dryer units symmetrically arranged with three on either side of the dryer centerline.

1.2 The Problem

After the first fuel cycle, crack-like indications were reported after visual examination at several locations on the Susquehanna Steam Electric Station Unit 1 steam dryer. One dryer support bracket was found to be cracked and was replaced. The inspection results, metallurgical examination of the dryer, structural evaluation of the dryer and dryer repairs are described in References 3 and 4. The steam dryer is classified as not safety-related.

Crack indications were initially reported in the dryer support ring, welds between hoods, end plates and the support ring, and in the tack welds of nuts and washers to the dryer units.

1.2 The Problem (Continued)

The indications in the support ring were confirmed to be cracks by liquid penetrant (LP) examination. Crack depths were shown to be less [redacted] by ultrasonic (UT), electrical resistance (smack gage), and by grinding. Structural analyses were performed to show that bounding crack growth during the next 10 month fuel cycle would not result in the cracks reducing the load carrying ability of the support ring below its required value, therefore, the cracks were not repaired. LP of the indications in the welds between hoods, end plates and support ring did not reveal any cracks. The nut and washer tack welds were not further examined. They were presumed to be cracked, and since they are a fabrication device not related to performance, they were repaired by welding a capture plate over them. The capture plate will prevent any loose pieces from being generated. Further details can be found in Reference 5.

The steam dryer support brackets are Inconel 600 forgings which are full penetration welded to Inconel 182 butter which was applied to the low alloy steel reactor pressure vessel wall (Reference 6). The load-carrying cross-section of the bracket is [redacted] The four brackets are located on vessel azimuths of 4°, 94°, 184°, and 274°. The bracket at 184° was severely cracked, as is shown on Figure 1.2-1. The other three brackets were not cracked, as determined by liquid penetrant examination.

The 184° bracket was removed and replaced with a new bracket of the same material and essentially the same design as the original. The two design differences between the original and replacement brackets are the weld prep angle and the location of the bracket. The weld prep in the original design was a double bevel with a 25° nominal prep angle. The weld prep in the replacement design was a double bevel with a 45° nominal prep angle. The larger angle approximately doubles the amount of weld deposited metal. It is judged that the welding residual stresses are slightly increased due to the larger weld. The fatigue characteristics of the bracket should not significantly change due to the slightly high residual stress. The stresses caused by vibration are not affected by this change.

The replacement bracket was installed in a manner to minimize the difference in location from the original bracket. There are small (<0.1") differences in location between the original and replacement brackets. These differences are judged not to change the fatigue characteristics of the bracket.

The bracket crack both initiated and propagated by fatigue. There was no evidence of stress corrosion. The source of the alternating loads which caused the bracket fatigue is not known at this time.

The mating portion of the steam dryer was modified to reduce the bracket stress, which will increase bracket fatigue life. In addition, the steam dryer was instrumented to aid in the determination of the alternating loads. A test program during the startup after the refueling outage was conducted to measure dynamic response of the dryer. The rest of this report is devoted to this test program, test results, analysis and interpretation.

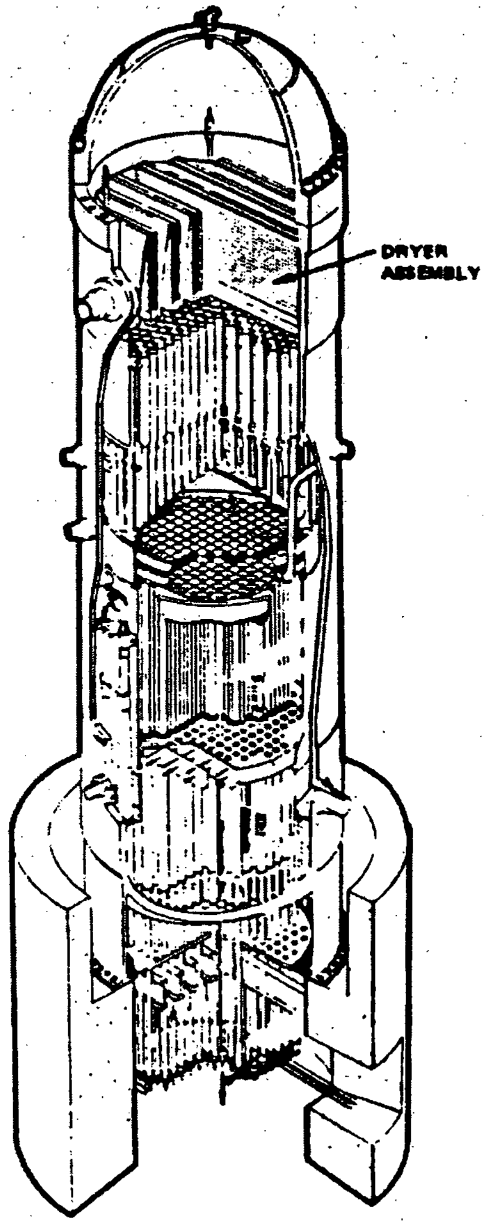

FIGURE 1.1-1 - Steam Dryer at Susquehanna-1

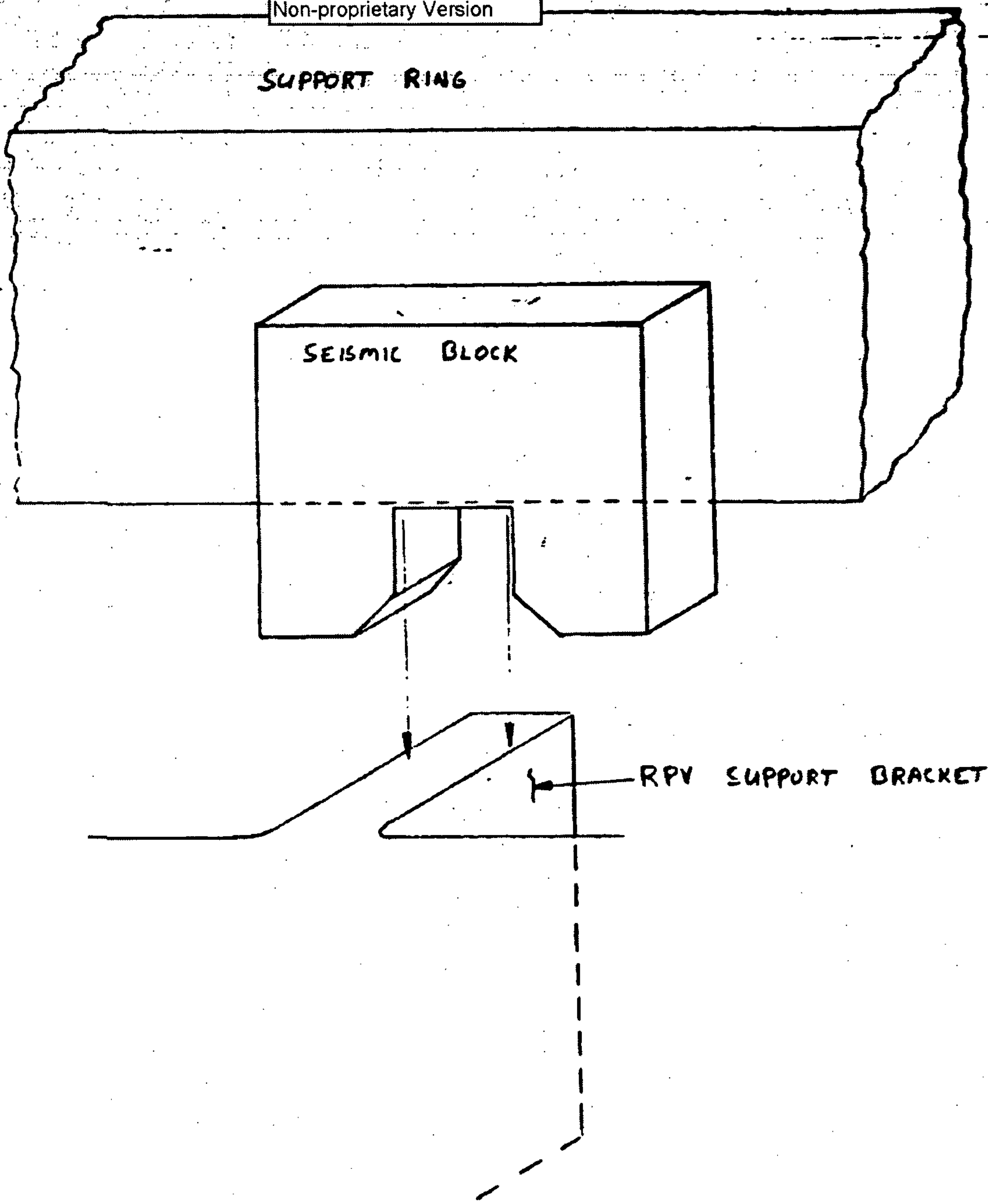

FIGURE 1.1-2 - Seismic Block

FIGURE 1.2-1 - Bracket Crack

2. TEST DESCRIPTION

2.1 Sensor Locations

A total of [redacted] accelerometers were installed as described below. (See figure 2.1-1 and 2.1-2).

[redacted]

The sensor locations are summarized in Tables 2.1-1 and 2.1-2 and are shown in Figures 2.1-1 and 2.1-2.

2.2 Data Acquisition System

The data acquisition system consists of the strain gages and accelerometers, a signal conditioning unit, and a magnetic tape recorder and chart recorders. The connection diagram for the data acquisition system is shown in Figure 2.2-1 for the strain gages and Figure 2.2-2 for the accelerometers. An oscilloscope, signal generator, frequency counter and multimeter were used for calibration and trouble shooting. A sprectrum analyzer and plotter were used for data reduction.

The strain gages are calibrated by the strain gage shunt calibrator manufactured by General Electric. This equipment provides the electrical equivalent of mechanical strain by shunting a 1-megohm resistor across the dummy resistor. This change in bridge balance resistance provides a precalculated microstrain equivalent signal for calibrating the recorders. The strain gage calibrator is maintained with the system throughout the experimental period.

The strain gage is excited by a 5-volt 3 kHz voltage from a module case. This oscillator is manufactured by Validyne, Model MC1-20. The modulated 3 kHz signal was converted to a ± 1.0 volt d-c by the demodulator for ± 100V microstrains at the gage. There is one demodulator for each strain gage and each accelerometer. These are "plug-in" type of carrier demodulators, manufactured by Validyne, Model CD-90. For accelerometers [redacted]

The signals from the demodulators go into the switching circuit (Record/Reproduce) which is a special component designed by GE. It consists of passive elements (toggle switches, multiposition switches, and relays). From this control unit, the signal branches out to two output devices, namely the chart (Brush) recorder and the tape recorder. The chart recorder is a Brush 260 model recorder manufactured by Gouldline, Instruments Division. The tape recorder is a model 101 recorder by Honeywell. The tape is run at a speed of [redacted]

2.3 Test Conditions

The test conditions are listed in PP&L Specification No. G-1008 and for convenience, a summary of the major tests are shown in Table 2.3-1. Basically, the tests can be classified into three major groups as follows:

2.3.1 Steady State Conditions at various power levels including feedwater pump operations.

2.3.2 [redacted] Operations.

2.3.3 Valve Closure Tests.

The chronological sequence of conducted test is shown in Table 2.3-2. The test point number shown in Table 2.3-2 corresponds to the paragraph number in PP&L Specifications G-1008. For example, Test Point 5.7.4.10 is the test described in Paragraph 5.7.4.10 of the PP&L Specification.

TABLE 2.1-1 - LOCATION OF SENSORS BY SENSOR NUMBER

SENSOR	LOCATION	DIRECTION

TABLE 2.1-2 - LOCATION OF SENSORS BY COMPONENT

LIST OF TEST CONDITIONS

TABLE 2.3-1 - SUMMARY OF PP&L SPECIFICATION NO. G-1008

NO.	ITEM
5.2	
5.3	
5.4	
5.5	Feedwater Pumps
5.6	Safety/Relief Valves
5.7	Turbine Valve Sets
	Turbine Overspeed Test (5.7.1)
	Main Steam Stop Valves (5.7.2.1 to 5.7.2.4)
	Intermediate Valves (5.7.2.5 to 5.7.2.10)
	Control Valves (5.7.2.11 to 5.7.2.14)
	Bypass Valves (5.7.3.1 to 5.7.3.5)
	Steady State
	Baseline (5.7.4.1)
	150 psig (5.7.4.2)
	Rated Pressure (5.7.4.3)
	20% (5.7.4.4)
	30% (5.7.4.5)
	40% (5.7.4.6)
	50% (5.7.4.7)
	60% (5.7.4.8)
	70% (5.7.4.9)
	80% (5.7.4.10)
	90% (5.7.4.11)
	100% (5.7.4.12)

TABLE 2.3-2 - TEST SEQUENCE LOG

TABLE 2.3-2 - TEST SEQUENCE LOG - Continued

FIGURE 2.1-1 - Location of Sensors in Plan View of Steam Dryer (S=Strain Gages, A = Accelerometers)

FIGURE 2.1-2 - Location of Sensors in Elevation View of Steam Dryer
(S= Strain Gage, A= Accelerometer)

FIGURE 2.2-1 - Data Acquisition System Block Diagram
for Strain Gages

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Figure 2.2-2 - Data Acquisition System Block Diagram
for Accelerometers

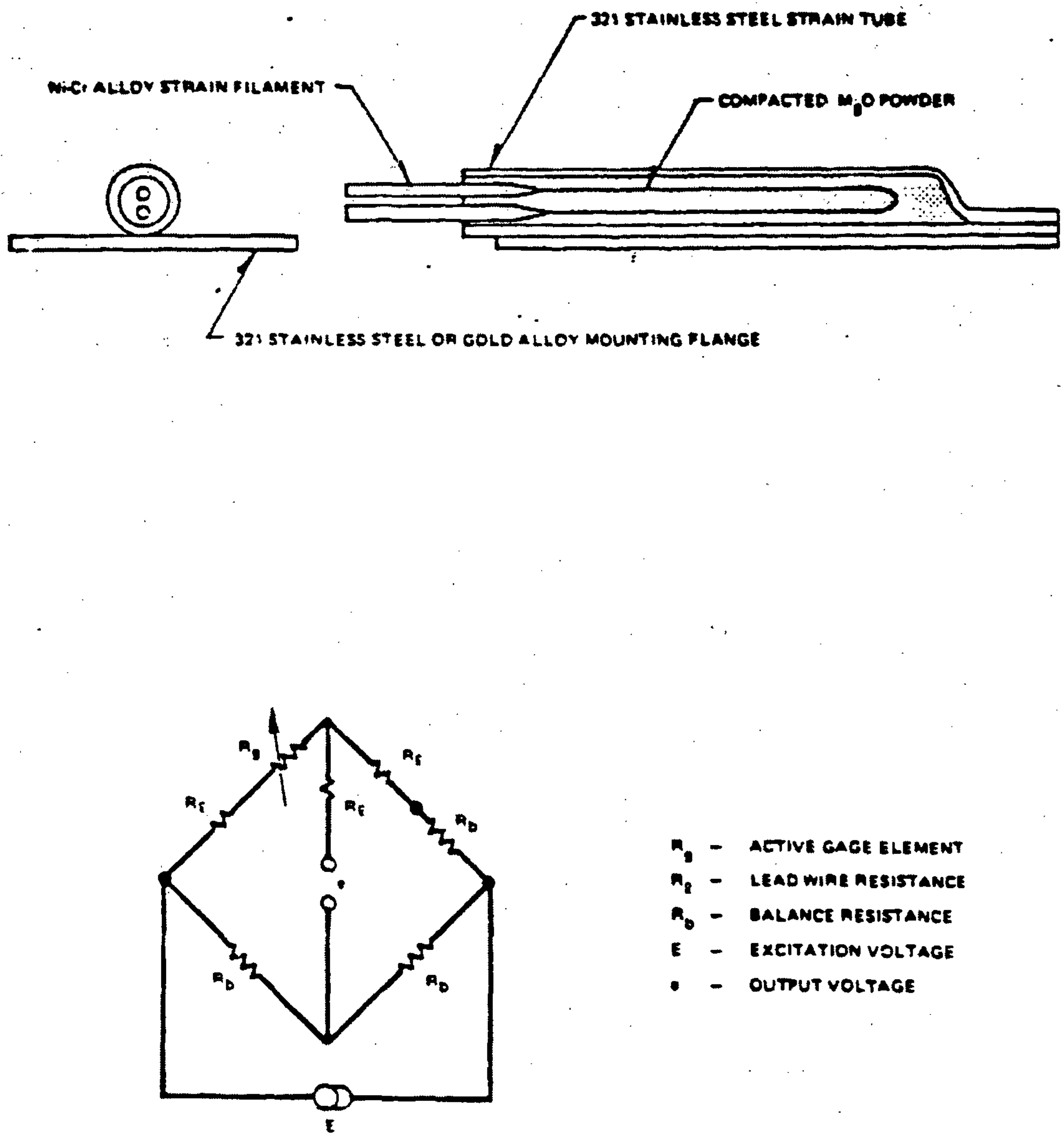

FIGURE 2.2-3 - Strain Gage Construction and Circuits

FIGURE 2.2-4 - Pressure Drum Strain Gage Circuits
(For Nomenclature, See Fig. 2.2-3)

3. TEST RESULTS

3.1 Steady state 0-100% Power Test Results

Spectrums of all the sensors were made at the following steady state conditions:

1. Baseline
2. 150 psig
3. Rated Pressure
3. 20% Power to 100% Power at [redacted]

The spectrums for most of the steady state conditions were included as Appendices A through I in the preliminary report and are not included here.

The predominant frequency of oscillation is around [redacted] for the dryer. The variation of the amplitudes at the [redacted] frequency with the power level is shown in Figures 3.1-1 through 3.1-5. The amplitudes vary approximately as [redacted] which is characteristic of flow induced vibrations. All the sensors reach their maximum amplitude during 100% power conditions. Hence, only this case (100% power) will be discussed in detail.

3.1.1 Seismic Block

[redacted]

[redacted] These results are summarized in Table 3.1-1. Section 4.1 identifies the physical motion of the dryer causing these strains and relates the measured strains to peak stresses in the support bracket.

3.1.2 Ring

[redacted]

place. These results are summarized in Tablé 3.1-2. Section 4.4 relates the measured strains to peak stresses in the ring.

3.1.3 Panel Hood

[redacted] These results are summarized in Table 3.1-3. Section 4.2 relates the measured strains to peak stresses in the panel hood.

3.1.4 Accelerometer Motion

[redacted]

Table 3.1-4 summarizes the responses of the horizontal and vertical accelerometers.

3.1.5 Pressure Gages

[redacted]

[redacted] The results (at 100% power) are presented in Appendix B, Figures B.31 to B.36. The peak-to-peak microstrains read from brush charts are as follows:

[redacted]

[redacted]

[redacted] Section 4.3 discusses whether the pressure drum readings are genuine or are caused by vibrations.

3.2 [redacted] Test Results

[redacted]

3.3 [redacted] Test Results

[redacted]

3.4

3.5 [redacted]

The ADS manual valve actuation at [redacted] was studied. The results of this indicate that there was no significant change in dryer vibration at this test condition.

3.6 [redacted]

[redacted]

3.7 TURBINE TRIP

A turbine trip was experienced on 10/30/85. Table 3.7-1 summarizes the results of the trip data. [redacted]

[redacted]

TABLE 3.1-1 - SEISMIC BLOCK GAGE RESPONSES AT 100% POWER

SENSOR	FREQUENCY Hz	PEAK RMS

SENSORS	FREQUENCY Hz	COHERENCE	PHASE

TABLE 3.1-2 - RING GAGE RESPONSE AT 100% POWER

SENSORS	FREQUENCY Hz	PEAK RMS

SENSORS	FREQUENCY Hz	COHERENCE	PHASE

TABLE 3.1-3 - PANEL HOOD GAGE RESPONSES AT 100% POWER

SENSOR	FREQUENCY HZ	PEAK RMS

SENSOR	FREQUENCY HZ	COHERENCE	PHASE

TABLE 3.1-4 - ACCELEROMETER RESPONSES AT 100% POWER

DRYER

SENSOR	FREQUENCY HZ	PEAK RMS Acceleration g	PEAK RMS

SENSOR	FREQUENCY HZ	COHERENCE	PHASE

TABLE 3.1-5 - PRESSURE DRUM GAGE RESPONSES AT 100% POWER

PRESSURE DRUM

SENSOR	FREQUENCY HZ	PEAK RMS

SENSOR	FREQUENCY HZ	COHERENCE	PHASE

TABLE 3.2-1 - COMPARISON OF RMS MAGNITUDES BEFORE AND DURING

TABLE 3.3-1 - COMPARISON OF RMS MAGNITUDES BEFORE AND DURING

TABLE 3.4-1 - COMPARISON OF RMS MAGNITUDES DURING [redacted]

[redacted]

TABLE 3.4-1 - COMPARISON OF RMS MAGNITUDES DURING

TABLE 3.4-2 - PERCENT INCREASE IN [redacted]

[redacted]

TABLE 3.7-1 - COMPARISON OF FILTERED PEAK-TO-PEAK MAGNITUDES BEFORE AND DURING TURBINE TRIP

SENSOR	HZ	STEADY STATE BEFORE SCRAM MV p-p*	DURING SCRAM MV p-p*

FIGURE 3.1-1 - Ring Surface Response

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FIGURE 3.1-2 - SEISMIC BLOCK RESPONSE

FIGURE 3.1-3 - SECOND BANK PANEL RESPONSE

FIGURE 3.1-4 - Accelerometer Response

FIGURE 3.1-5 - Pressure Response

4. ANALYSIS AND COMPARISON WITH CRITERIA

Static and dynamic structural analyses are performed to relate peak stress intensities to the measured strains or accelerations at sensor locations. There are many steps in this process as described below.

[redacted]

Different types of analysis are performed on the models, depending on the application. Generally a modal analysis is performed whereby the natural vibration modal displacements, stresses and frequencies are calculated for each of the modes. Then the location of the highest peak stress intensity is identified, including the effects of stress concentration factors. [redacted]

[redacted]

The analysis method used here is conservative, because the vibration limits are based on the assumption of vibration at a constant sustained maximum peak-to-peak amplitude, whereas actual vibration amplitudes are generally narrow band random and only sometimes reach the maximum recorded values.

In addition to the modal analysis, other analyses are made for specific conditions to evaluate and confirm certain results. [redacted]

4.1 Seismic Block Model

A three-dimensional model of the seismic block, as shown in Figure 4.1-1, was constructed using the ANSYS finite element computer code to correlate the strain gage readings on the seismic block to various static loads transferred to the dryer support bracket. The steam dryer support bracket was simulated with horizontal and vertical spring elements along the thickness of the seismic block. The spring stiffnesses were calculated based upon the bracket acting as a cantilever spring. Four unit load cases in particular were analyzed:

[redacted]

The centered bracket and bracket in seismic block corner conditions are illustrated in Figures 4.1-2 and 4.1-3. [redacted]

The calculated strains were correlated to the applied loads. The applied loads were correlated to a maximum stress intensity in the support bracket as presented previously in Reference 4. These results are shown in Table 4.1-1 and Figures 4.1-2 and 4.1-3.

Based on the analytical results, it can be concluded that the stress intensity in the instrumented bracket is no more than which is well below the value which would lead to fatigue initiation in the instrumented bracket.

4.2 Second Bank Hood Model

The second bank hood was modeled using NASTRAN. One half of the second bank hood was modeled as shown in Fig. 4.2-1. The dimensions were taken from Ref. 1. Linear shell elements of quadrilateral and triangular types were used. The model

TOTAL 22263

Figure 4.2-5

4.3 Pressure Drum Model

shown in Fig. 4.3-2. The pressure drum itself is modeled as shown in Fig. 4.3-3. The sizes of the elements were chosen so as to adequately describe the stress distribution on the drum and correlate the observed strain gage readings.

4.4 Support Ring Model

A three-dimensional model of the steam dryer support ring between two steam dryer support brackets, as shown in Figures 4.4-1 and 4.4-2, was constructed using the

shown in Fig. 4.4-1, is reasonable, based upon the difference in the stiffness of the dryer parallel and perpendicular to the steam dryer banks. For the above reasons, the support ring finite element model was considered a reasonable approximation of the actual support ring.

The ratio of the peak stresses in the ring to the gage stresses was obtained by

4.5 Whole Dryer Motion

The half-dryer model was analyzed with the dryer resting on all of its supports. The displacements on the ring due to the weight of the dryer are shown in

In order to find the vertical stiffness of the support bracket, it was modeled by three dimensional elements using ANSYS. A layout of the model is shown in Fig.

simplified calculations, it is inferred the 94° bracket is structurally adequate to withstand the dryer vibration.

TABLE 4.1-1 - COMPARISON OF TEST AND ANALYTICAL RESULTS FOR THE STEAM DRYER SEISMIC BLOCK

Applied Loads		Maximum Stress Intensity Ksi

TABLE 4.1-2 – ANALYSIS OF SEISMIC BLOCK AND ACCELEROMETER SENSORS

TABLE 4.2-1 - Natural Frequencies of Symmetric Half Second Bank Hood Model

TABLE 4.2-2 - Natural Frequencies of Refined Model

TABLE 4.2-3 - Natural Frequencies of Refined Model with Patch

TABLE 4.5-1 - COHERENCE OF

COMPONENT	SENSOR	COHERENCE

Figure 4.1-1 - Steam Dryer Seismic Block Model

A. CENTERED BRACKET

I. BRACKET IN CORNER

FIGURE 4.1-2 Predicted S_2 and S_3 Reading for Unit Horizontal Force of 9500 lbs for two bracket locations (* corresponds to maximum stress intensity in Bracket of 3.24 ksi)

A. CENTERED BRACKET

B. BRACKET IN CORNER

FIGURE 4.1-3 Predicted S2 and S3 Reading for Unit Vertical Force of 10,000 lbs for two Bracket Locations.

(* corresponds to maximum stress intensity in bracket of 1.62 ksi)

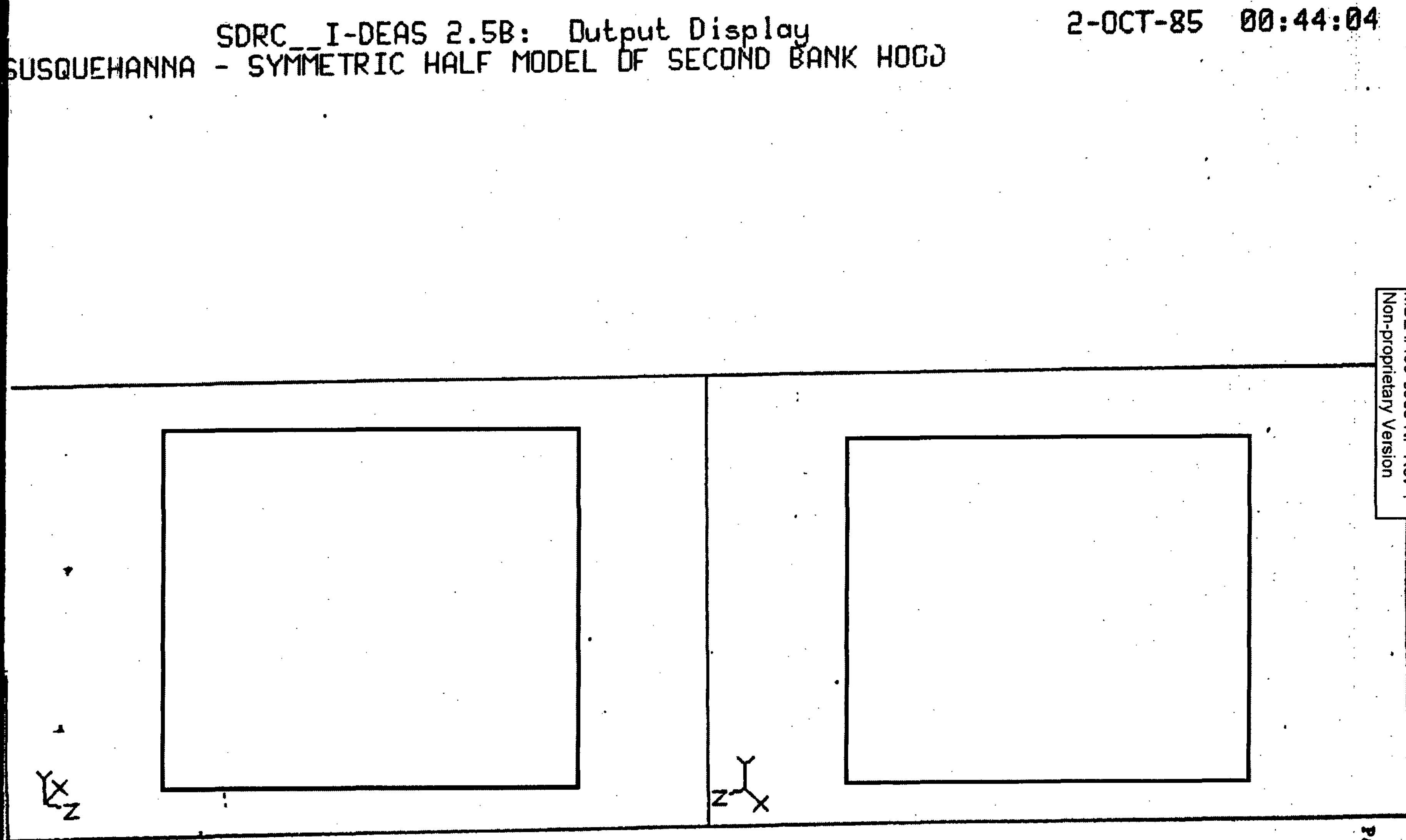

Figure 4.2-1 - Symmetric Half Model of Second Bank Hood

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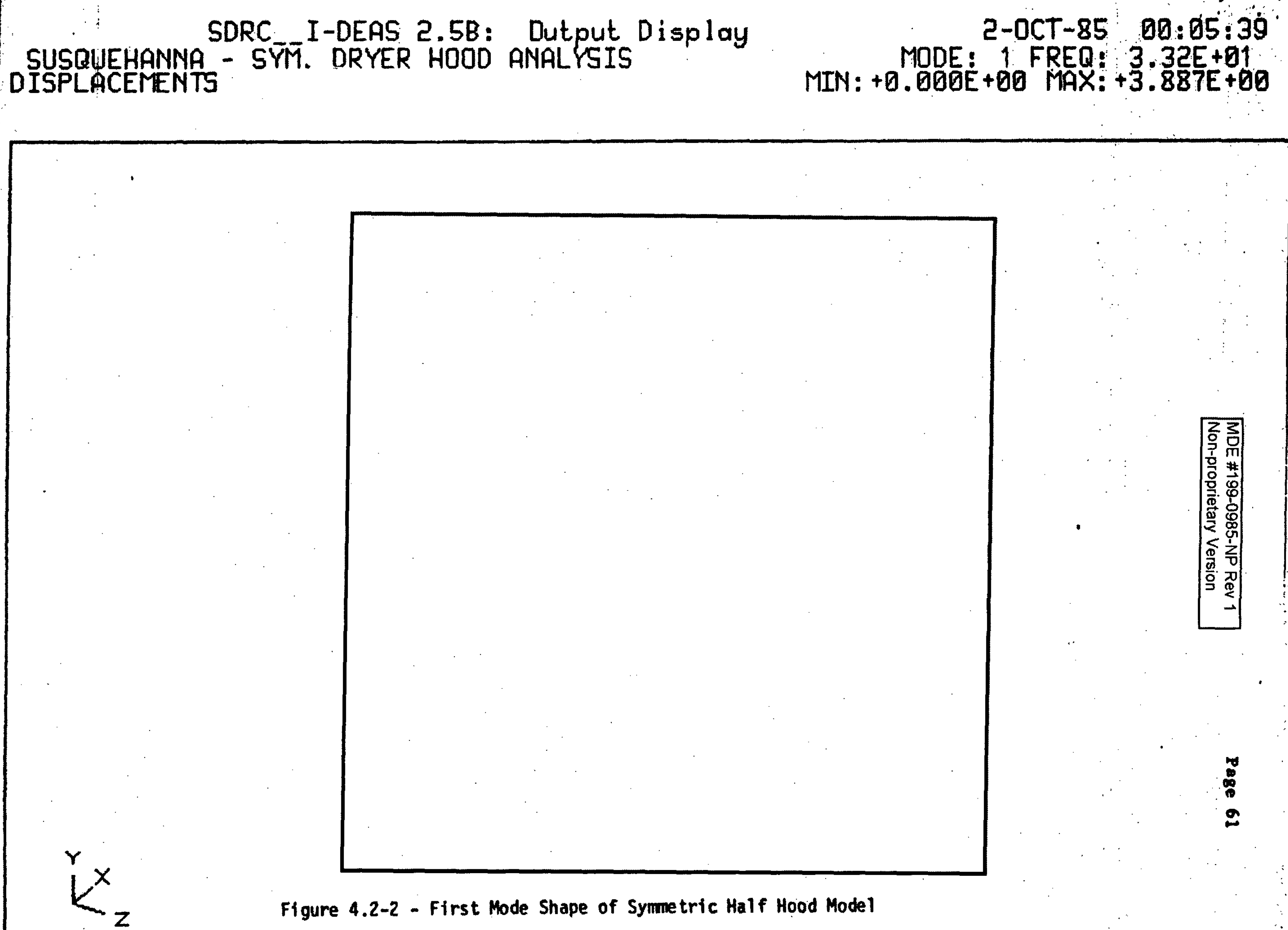

Figure 4.2-2 - First Mode Shape of Symmetric Half Hood Model

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SDRC__I-DEAS 2.5B: Output Display 2-OCT-85 00:14:36
SUSQUEHANNA - SYM. DRYER HOOD ANALYSIS MODE: 2 FREQ: 3.67E+01
DISPLACEMENTS MIN: +0.000E+00 MAX: +5.521E+00

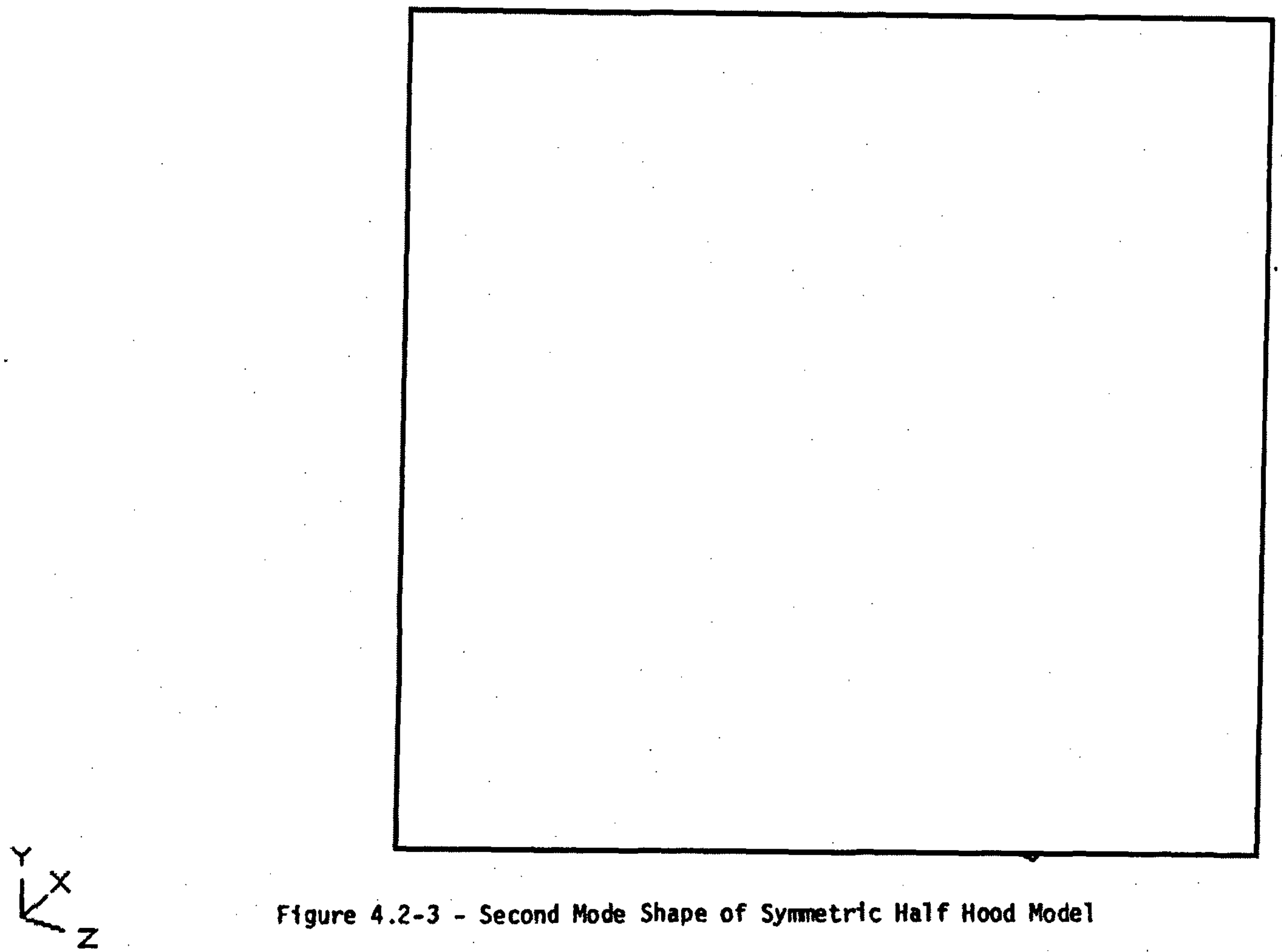

Figure 4.2-3 - Second Mode Shape of Symmetric Half Hood Model

SDRC__I-DEAS 2.5B: Output Display 2-OCT-85 00:25:21

SUSQUEHANNA - SYM. DRYER HOOD ANALYSIS MODE: 27 FREQ: 1.13E+02

DISPLACEMENTS MIN: +0.000E+00 MAX: +2.077E+01

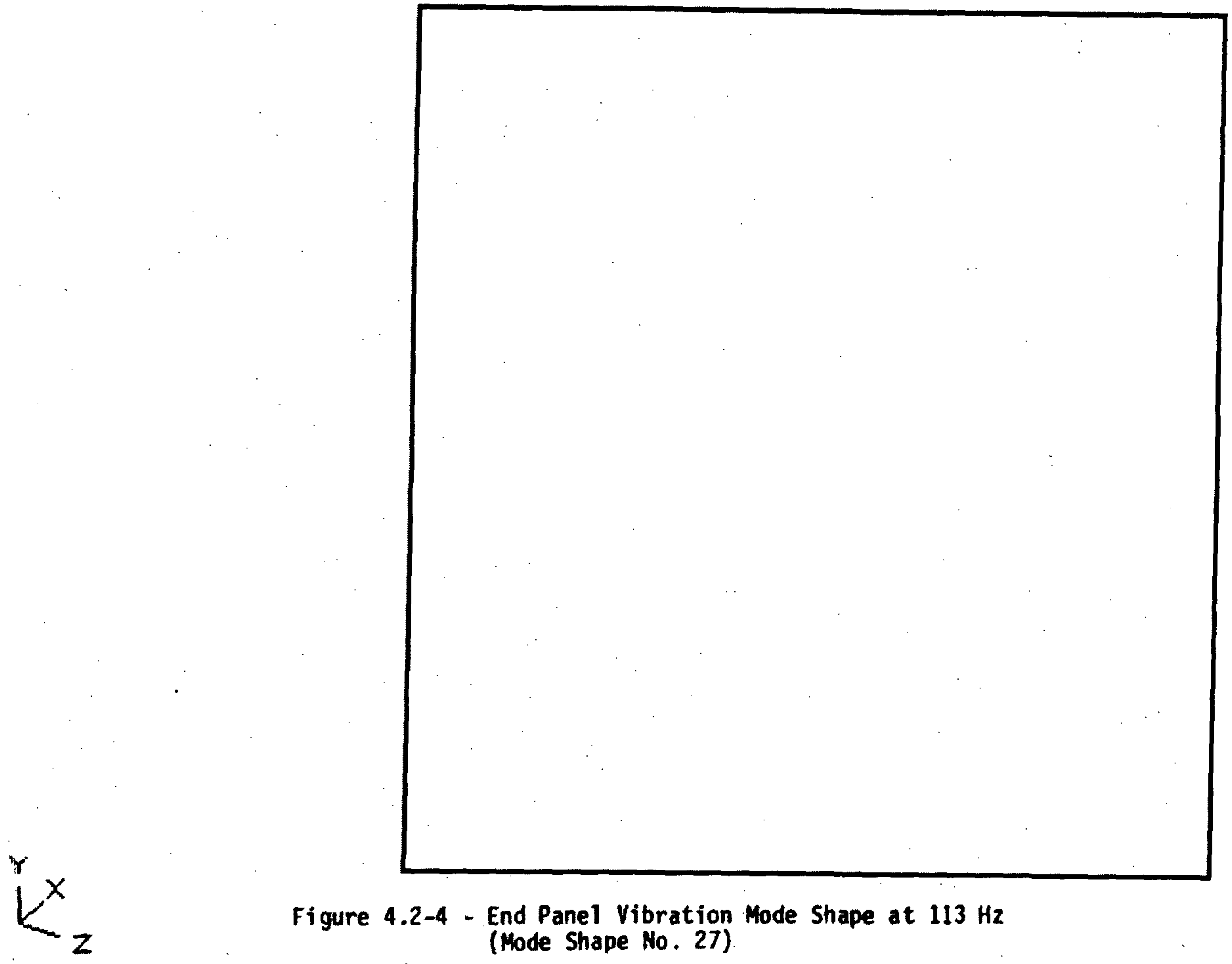

Figure 4.2-4 - End Panel Vibration Mode Shape at 113 Hz
(Mode Shape No. 27)

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SDRC__I-DEAS 2.5B: Output Display 2-OCT-85 00:33:16
SUSQUEHANNA - SYM. DRYER HOOD ANALYSIS MODE: 33 FREQ: 1.22E+02
DISPLACEMENTS MIN: +0.000E+00 MAX: +2.077E+01

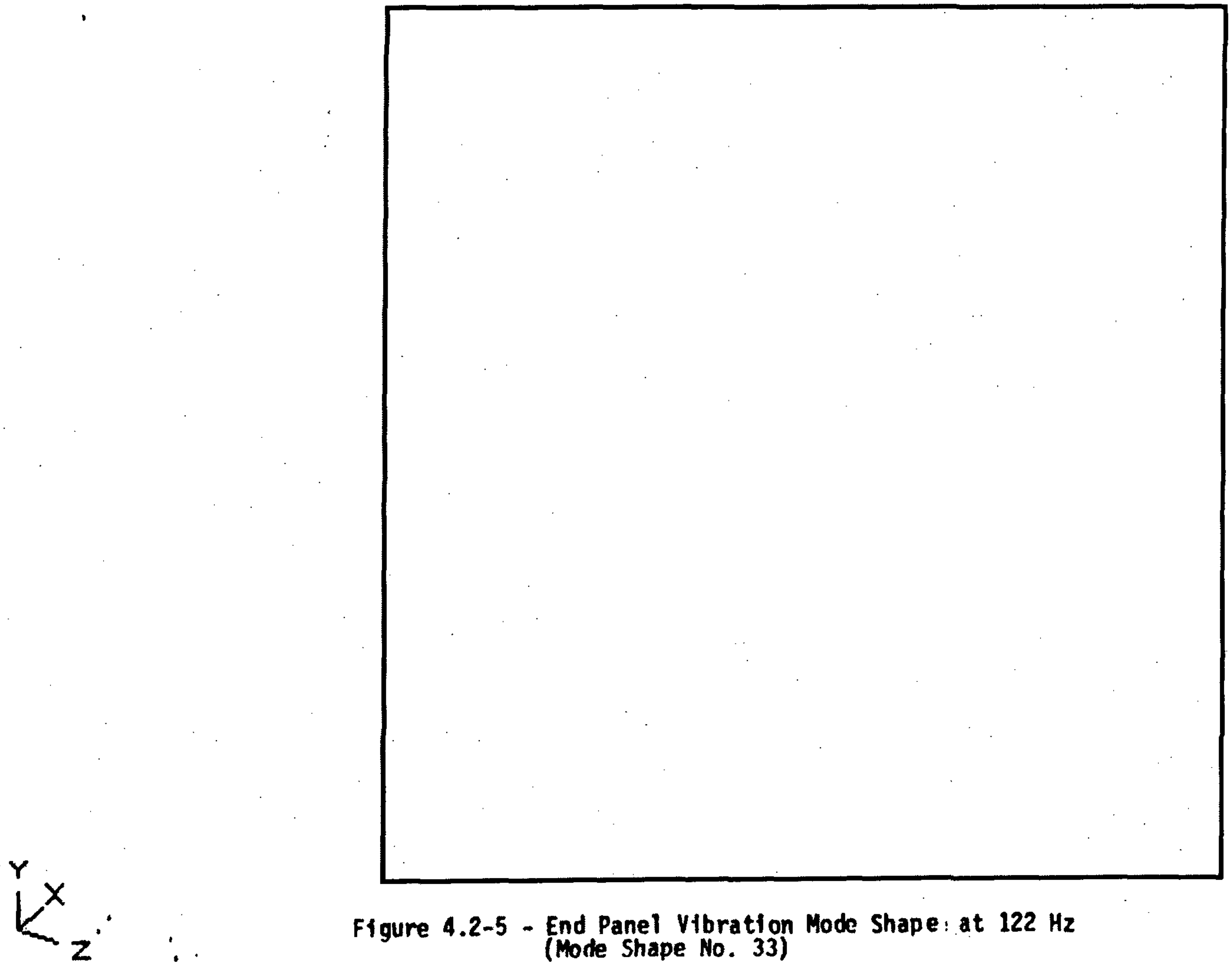

Figure 4.2-5 - End Panel Vibration Mode Shape at 122 Hz
(Mode Shape No. 33)

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SDRC__I-DEAS 2.5B: Output Display 1-OCT-85 22:34:53

SUSQUEHANNA - REFINED MODEL OF SECOND BANK HOOD END REGION (UNPATCHED)

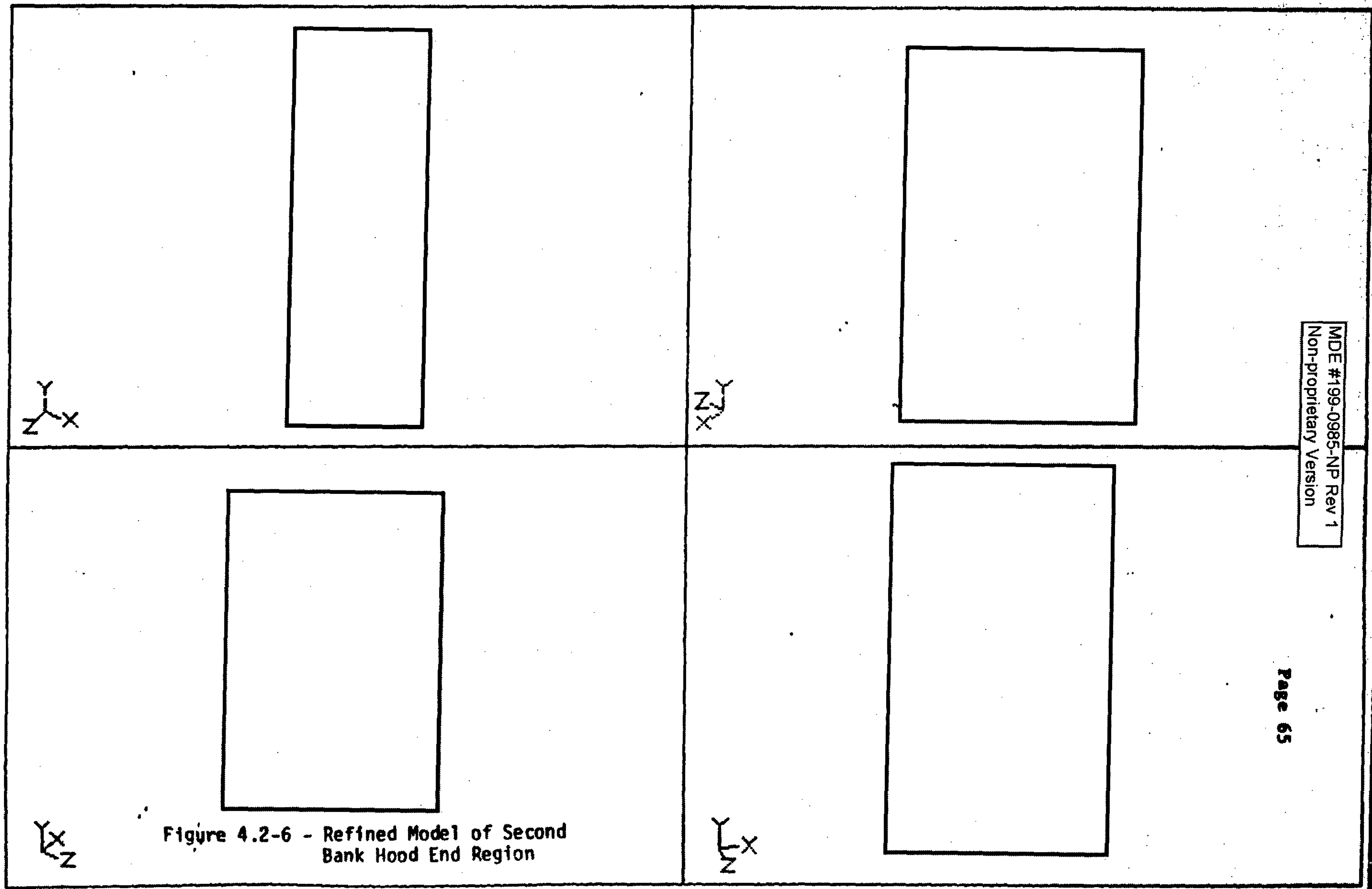

Figure 4.2-6 - Refined Model of Second Bank Hood End Region

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SDRC__I-DEAS 2.5B: Output Display 1-OCT-85 21:42:33

SUSQUEHANNA - UNPATCHED DRYER HOOD MODE: 1 FREQ: 1.10E+02

DISPLACEMENTS MIN: +0.000E+00 MAX: +1.180E+01

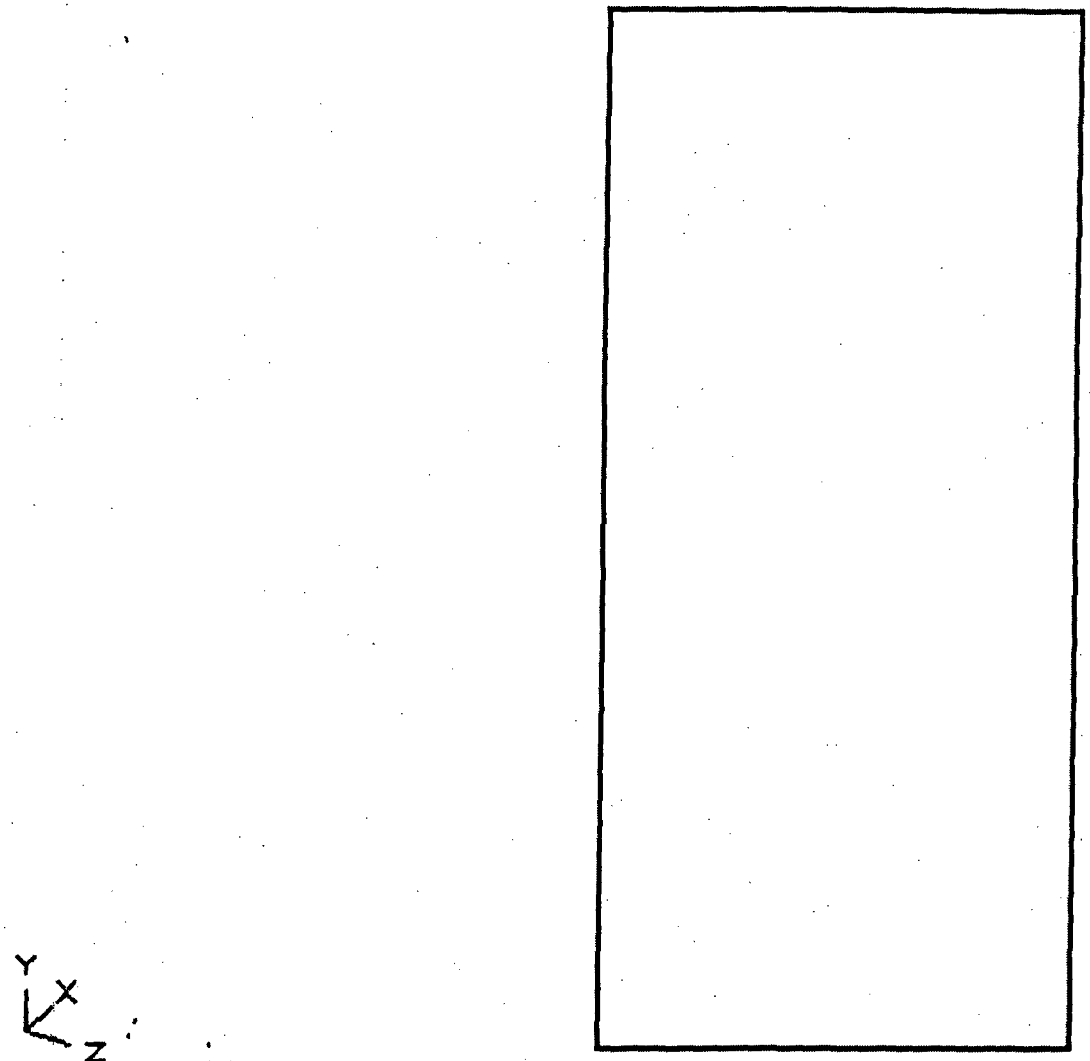

Figure 4.2-7 - First Mode Shape of Refined Model

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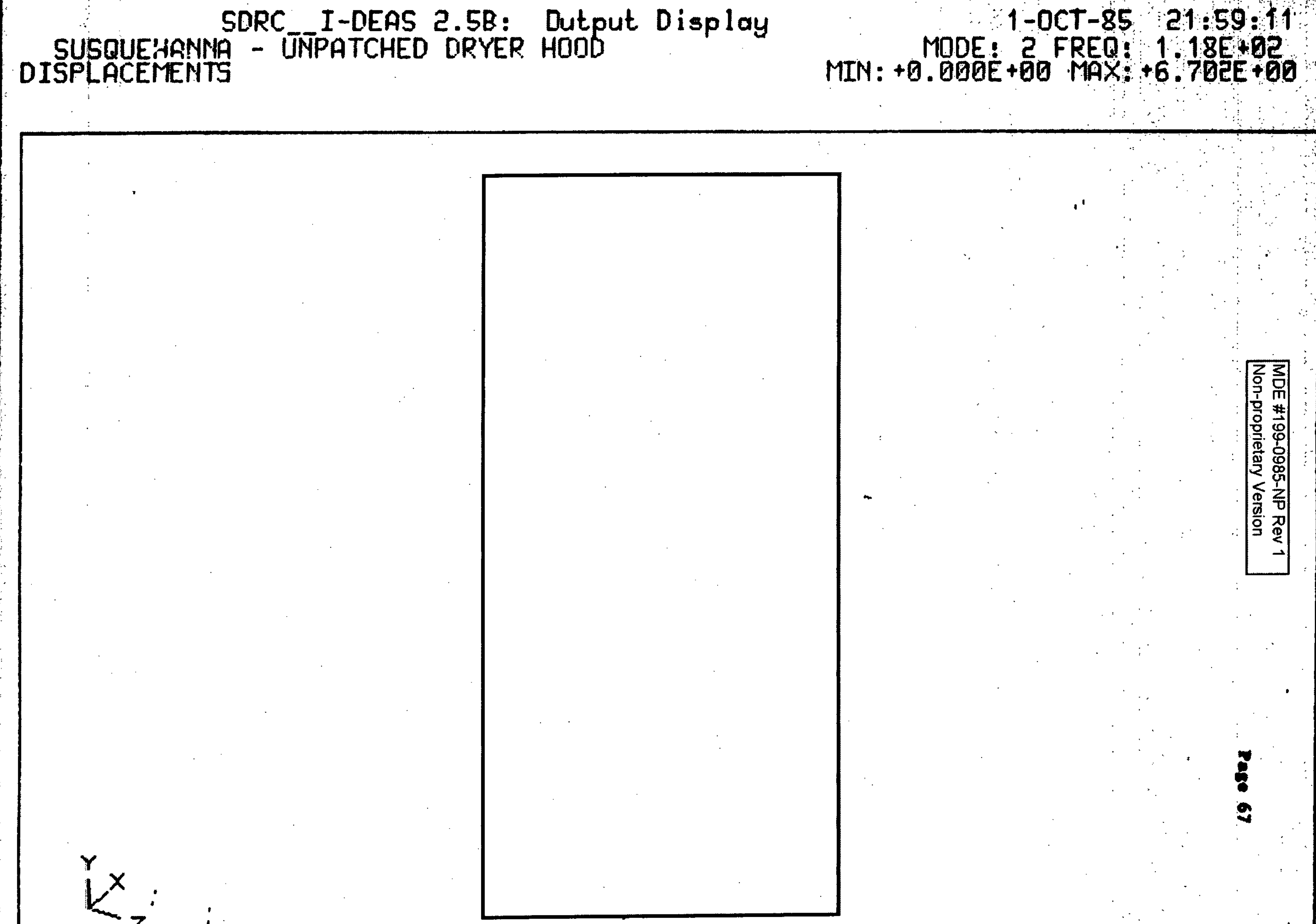

Figure 4.2-8 - Second Mode Shape of Refined Model

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SDRC__I-DEAS 2.5B: Output Display 1-OCT-85 22:06:34
SUSQUEHANNA - UNPATCHED DRYER HOOD MODE: 3 FREQ: 1.25E+02
DISPLACEMENTS MIN: +0.000E+00 MAX: +1.247E+01

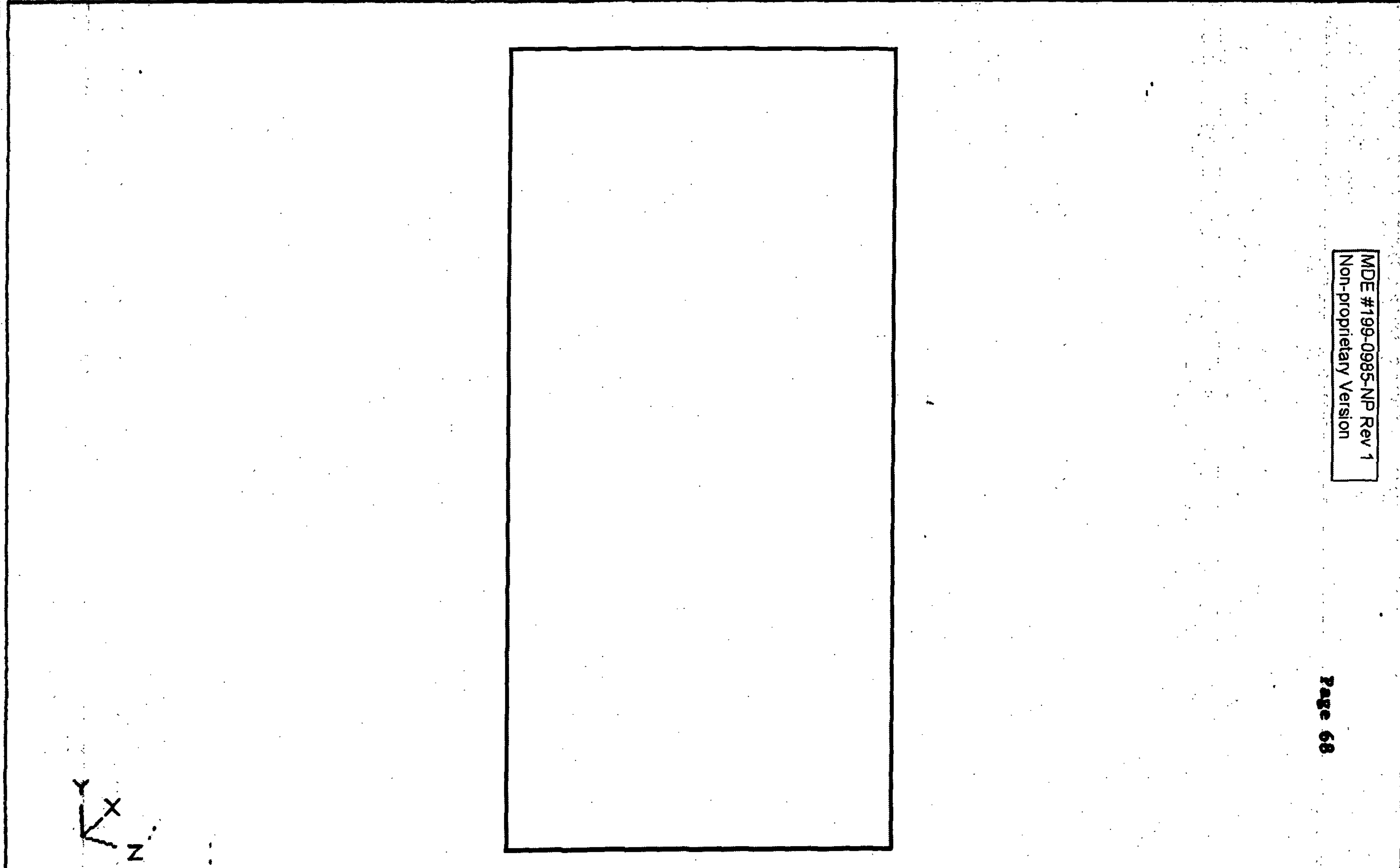

Figure 4.2-9 - Third Mode Shape of Refined Model

SDRC__I-DEAS 2.5B: Output Display 1-OCT-85 22:13:24
SUSQUEHANNA - UNPATCHED DRYER HOOD MODE: 4 FREQ: 1.37E+02
DISPLACEMENTS MIN: +0.000E+00 MAX: +1.247E+01

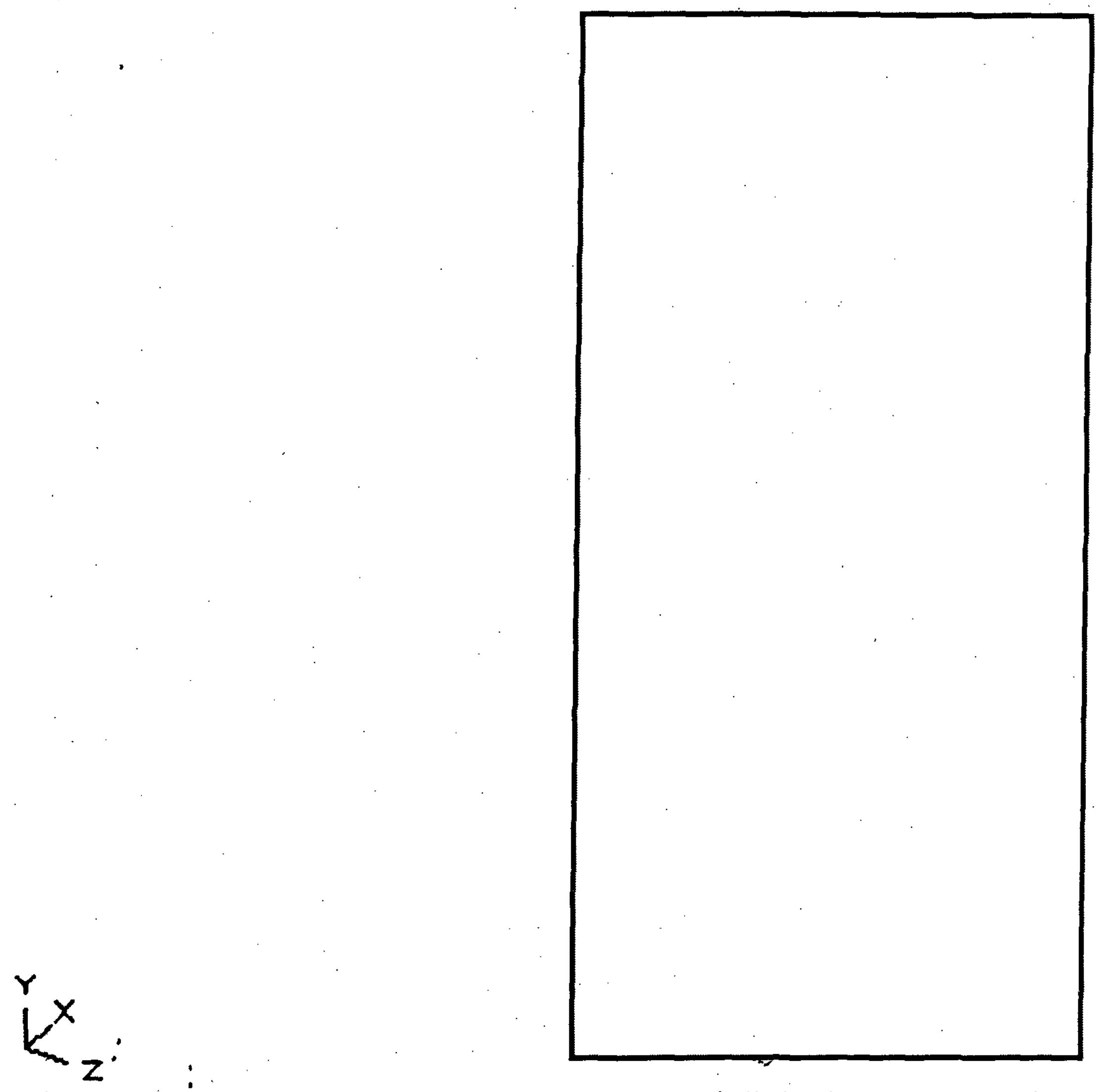

Figure 4.2-10 - Fourth Mode Shape of Refined Model

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SDRC__I-DEAS 2.5B: Output Display 1-OCT-85 14:14:12

SUSQUEHANNA - DRYER HOOD WITH PATCH MODE: 1 FREQ: 1.20E+02

DISPLACEMENTS MIN: +0.000E+00 MAX: +6.650E+00

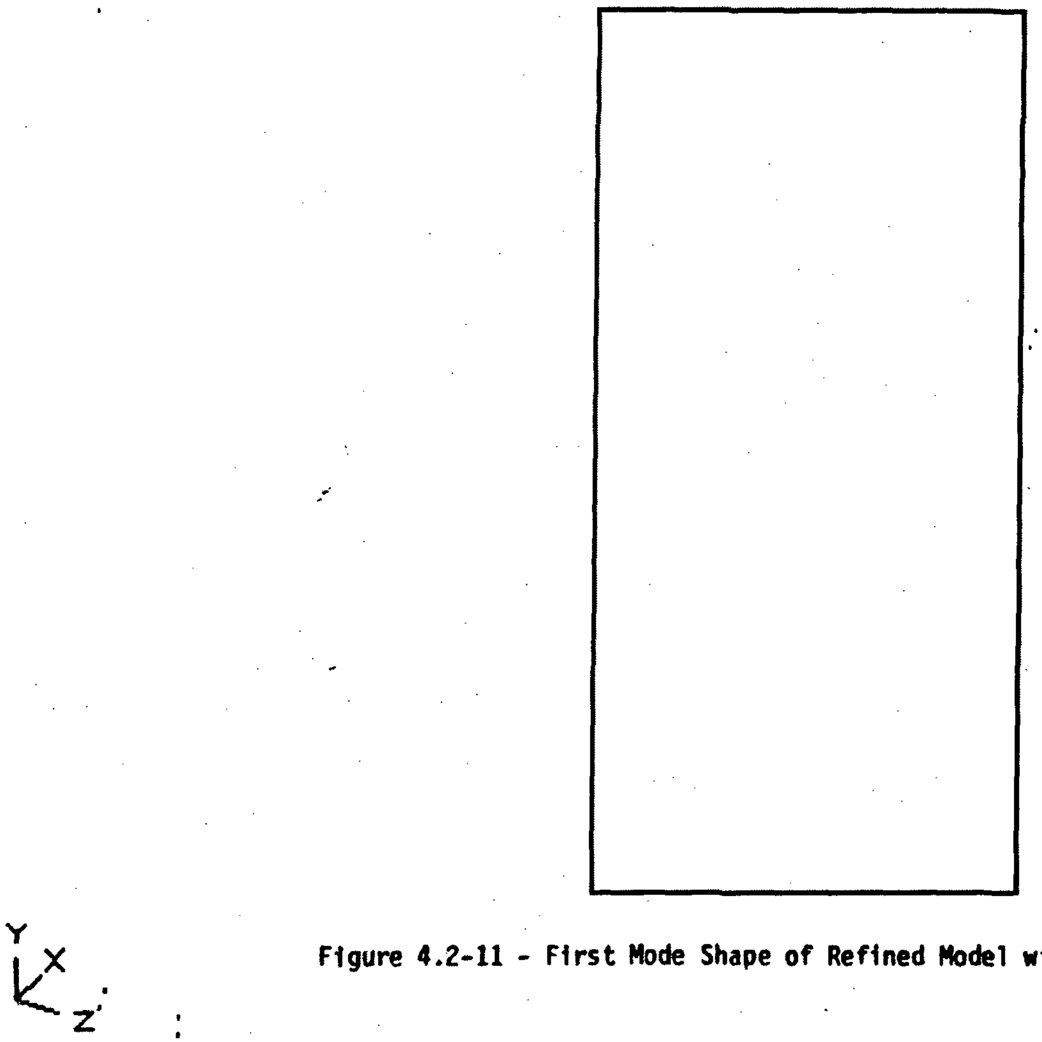

Figure 4.2-11 - First Mode Shape of Refined Model with Patch

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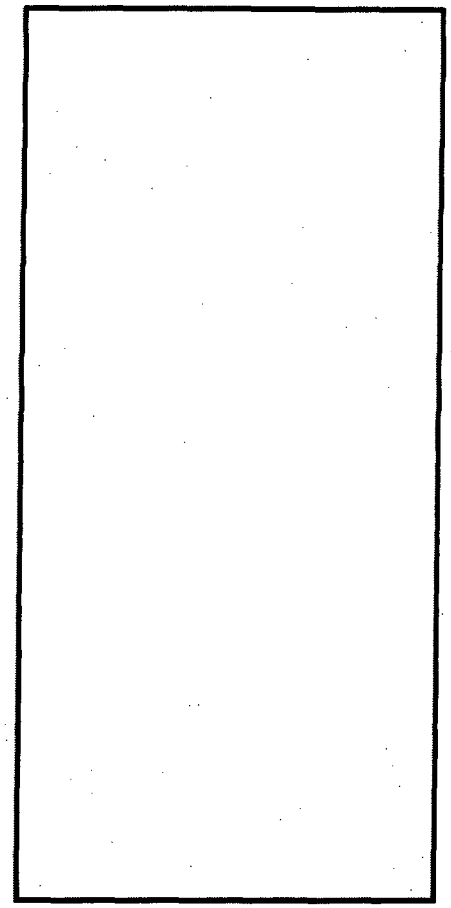
SDRC__I-DEAS 2.5B: Output Display 1-OCT-85 14:27:28

SUSQUEHANNA - DRYER HOOD WITH PATCH MODE: 2 FREQ: 1.22E+02

DISPLACEMENTS MIN: +0.000E+00 MAX: +1.556E+01



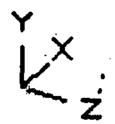


Figure 4.2-12 - Second Mode Shape of Refined Model with Patch

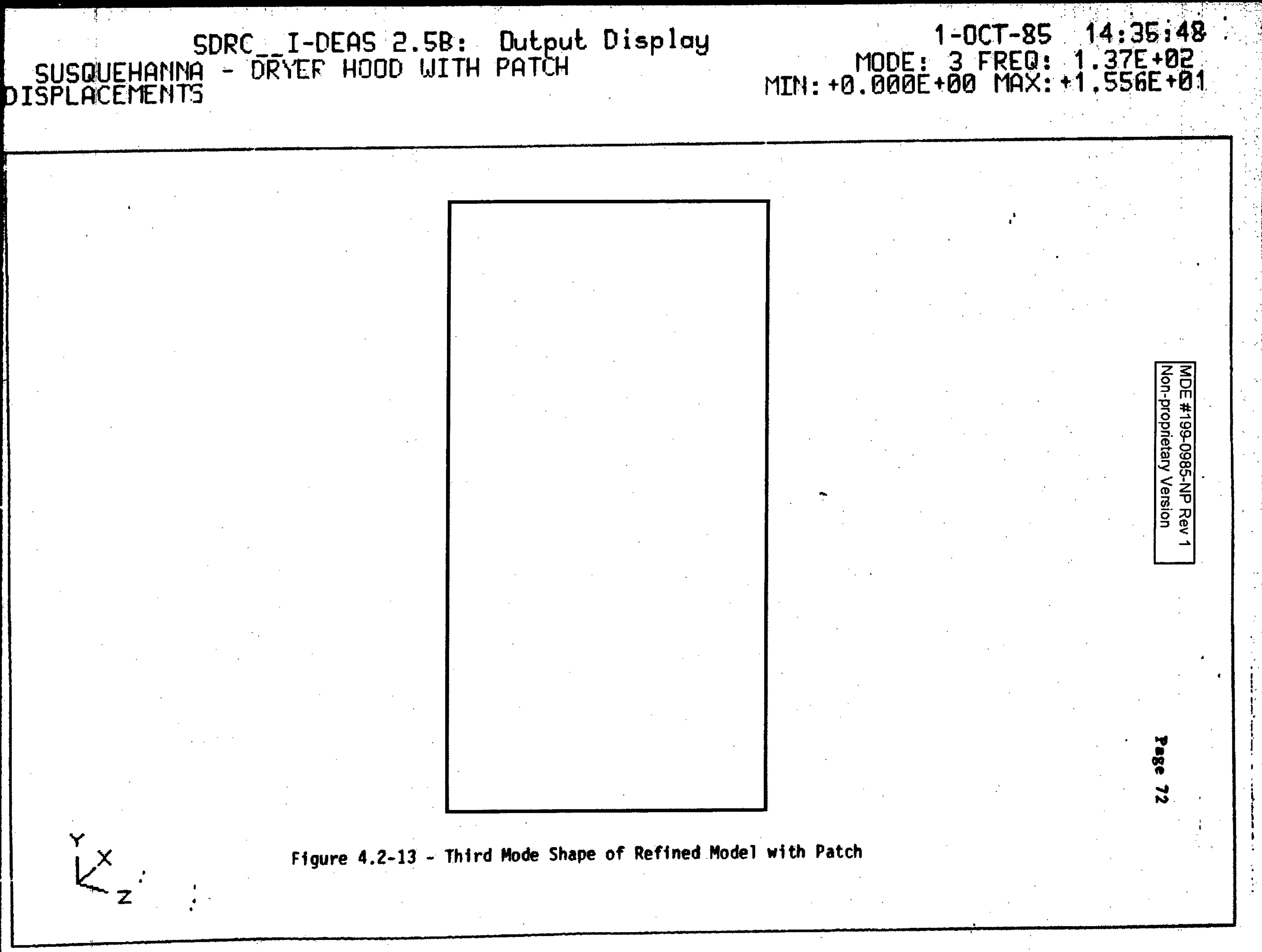


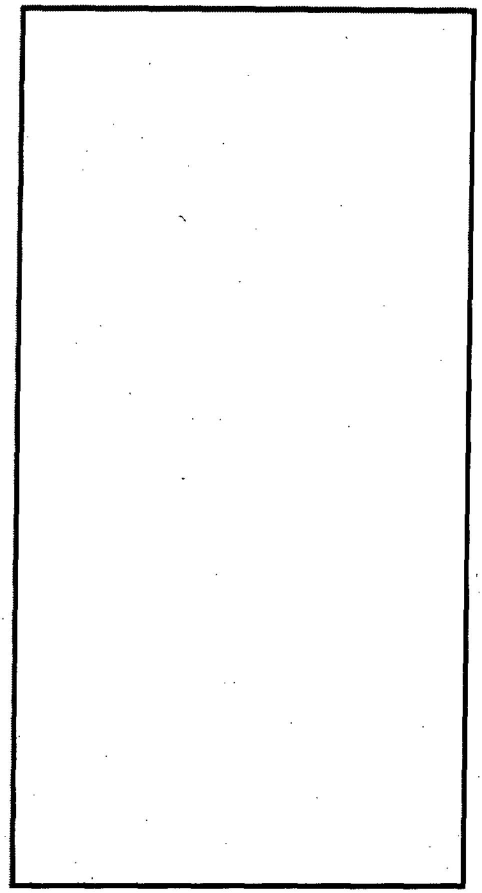
Figure 4.2-13 - Third Mode Shape of Refined Model with Patch

MDE #199-0985-NP Rev 1
Non-proprietary Version

SDRC__I-DEAS 2.5B: Output Display 1-OCT-85 22:51:23

SUSQUEHANNA - DRYER HOOD WITH PATCH MODE: 4 FREQ: 1.44E+02

DISPLACEMENTS MIN: +0.000E+00 MAX: +7.789E+00



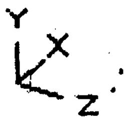


Figure 4.2-14 - Fourth Mode Shape of Refined Model With Patch

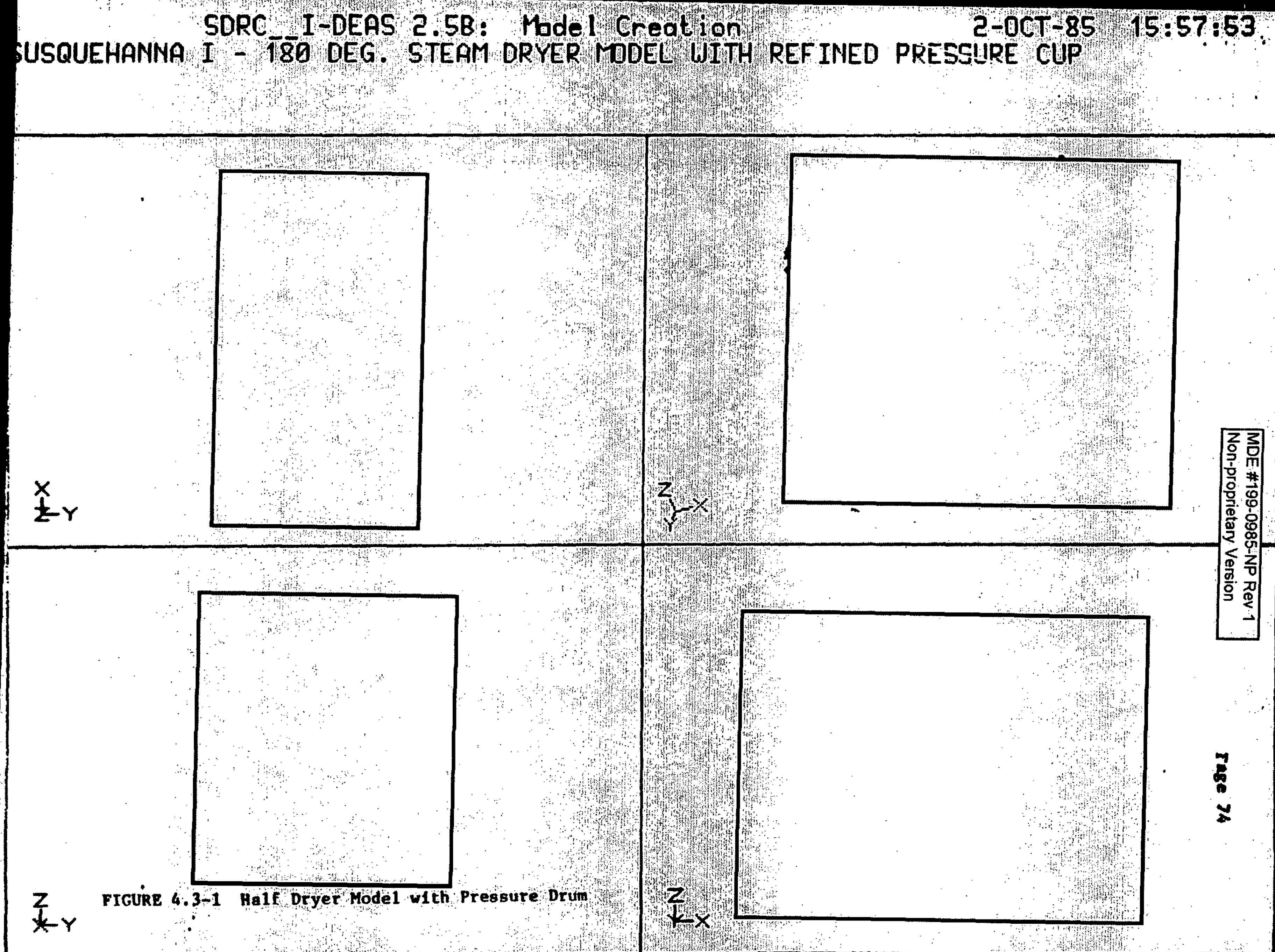


FIGURE 4.3-1 Half Dryer Model with Pressure Drum

MDE #199-0985-NP Rev 1
Non-proprietary Version

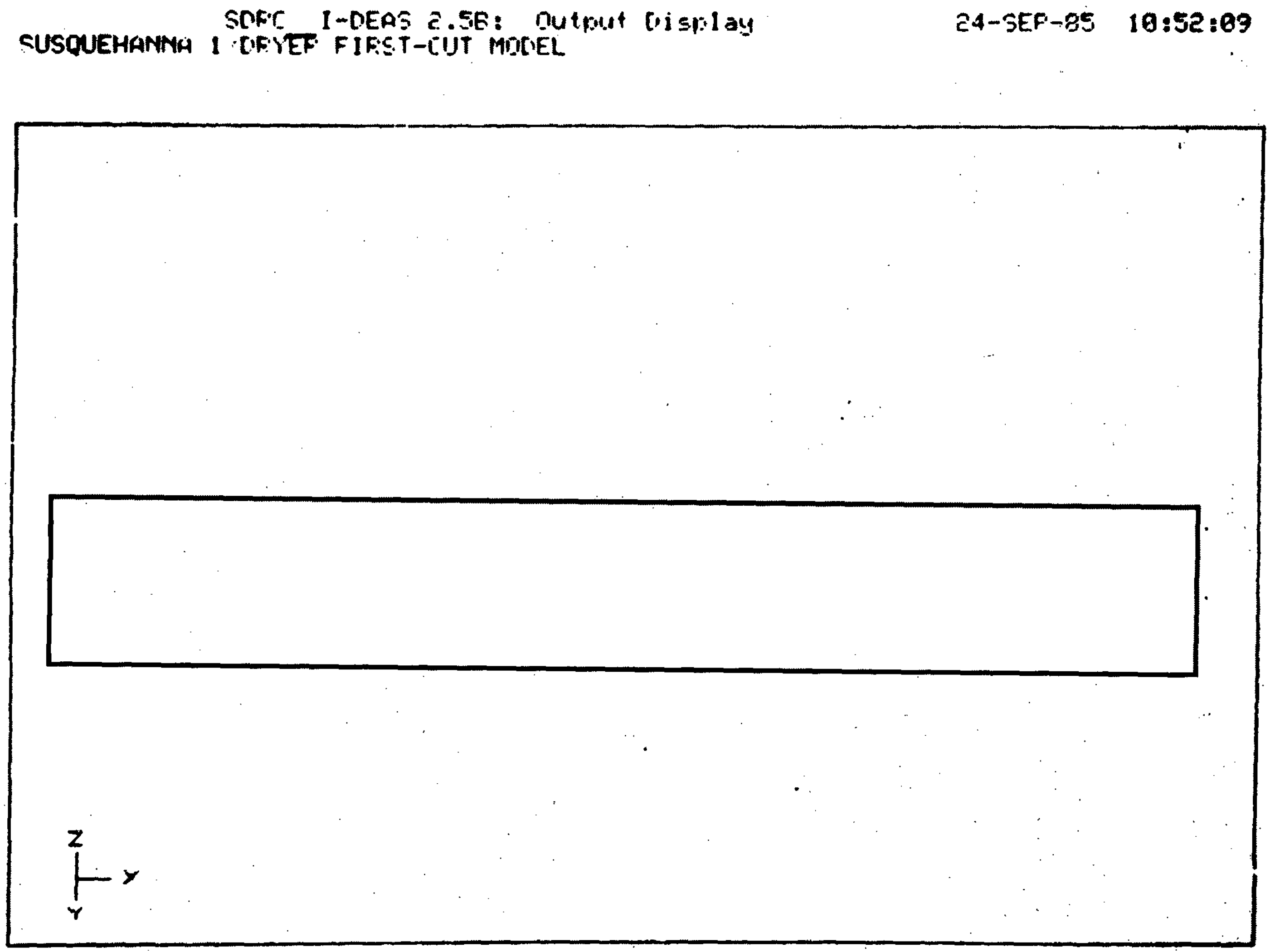


Figure 4.3-2 - Region around Pressure Drum

SDRC I-DEAS 2.5B: Output Display 24-SEP-85 11:05:49

SUSQUEHANNA 1 DRYER FIRST-CUT MODEL

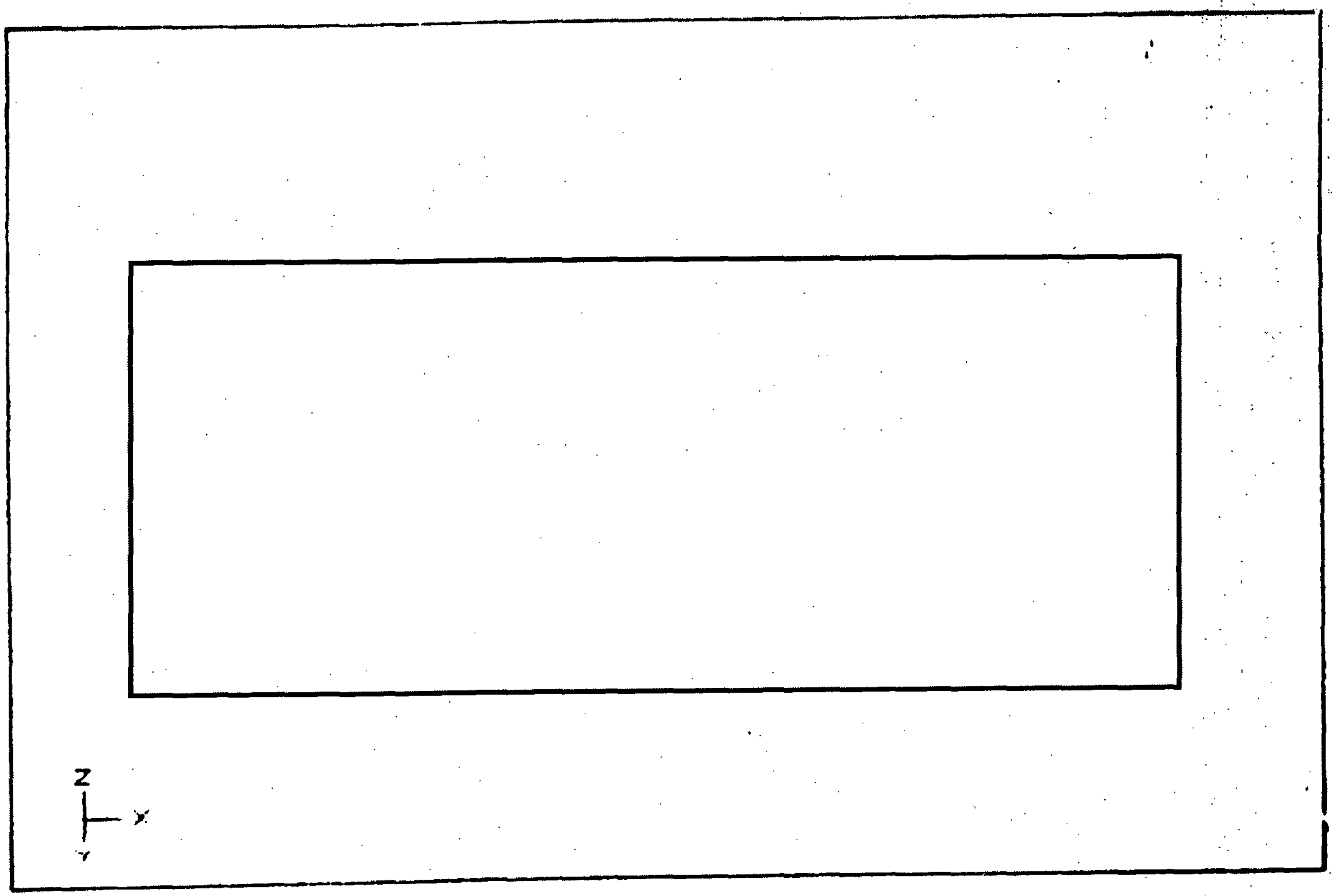


Figure 4.3-3 - Details of Pressure Drum Model

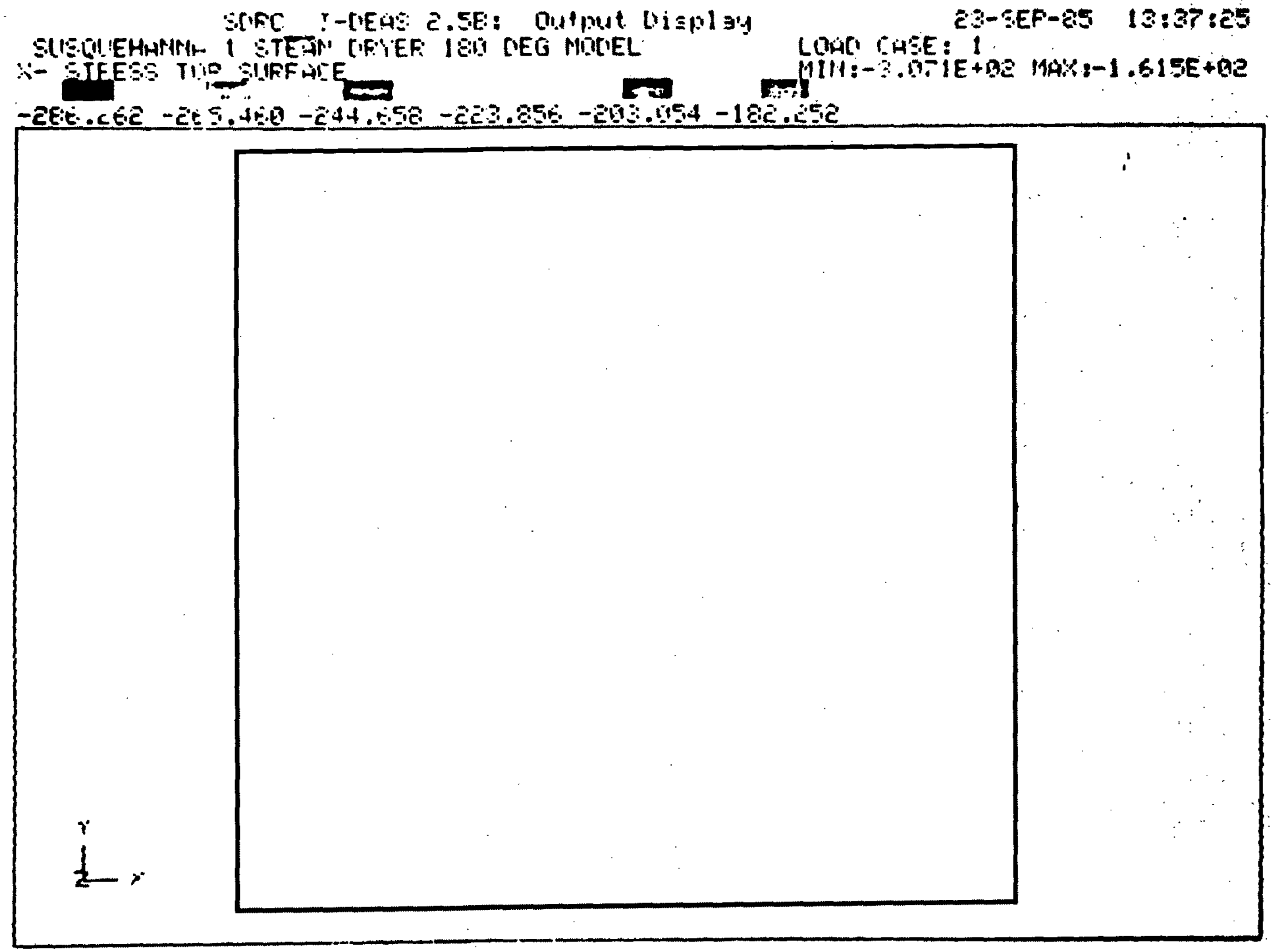


Figure 4.3-4 - X-Stresses on the Top Surface of the Pressure Drum

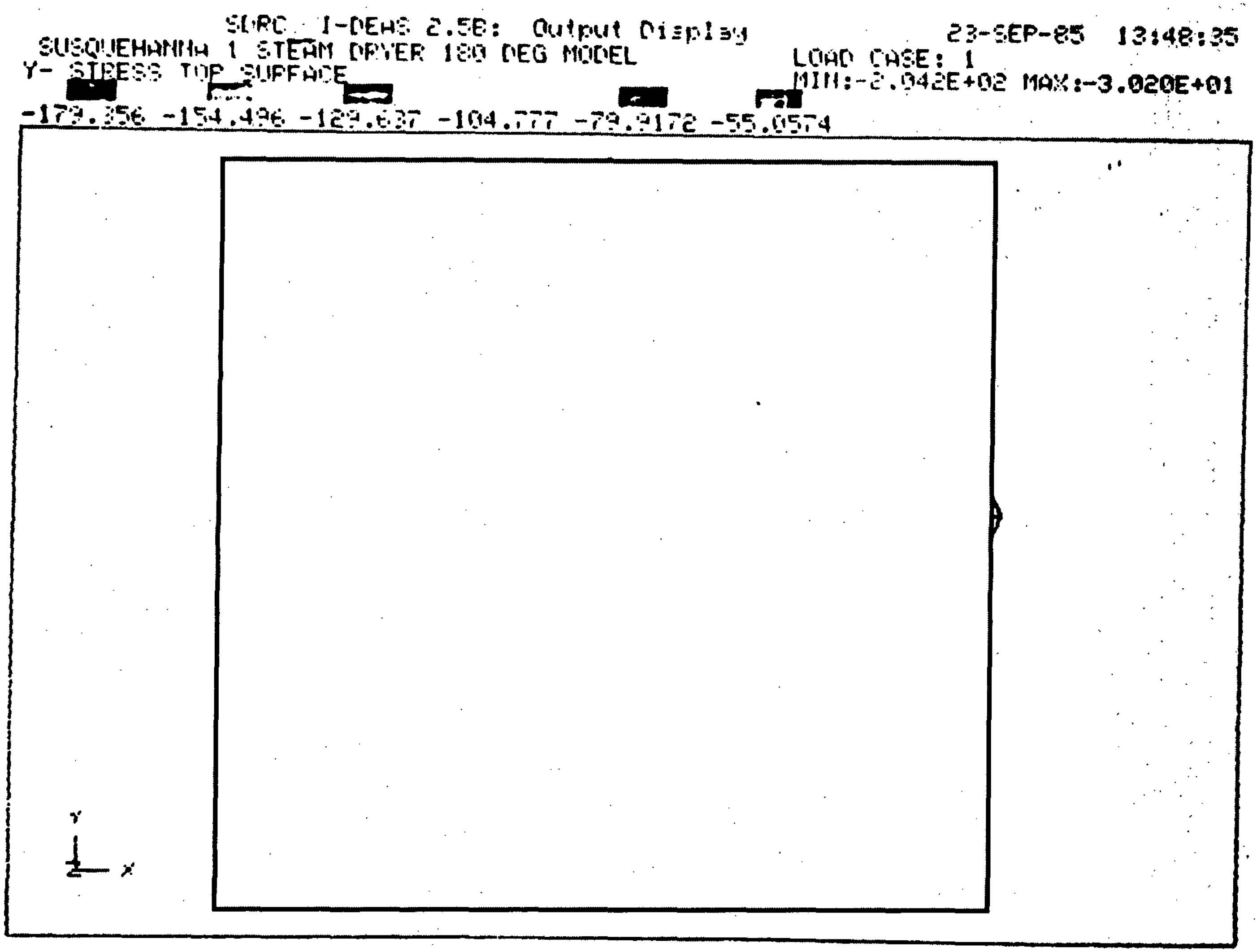


Figure 4.3-5 - Y-Stresses on the Top Surface of the Pressure Drum

MDE #199-0985-NP Rev 1
Non-proprietary Version

Figure 4.4-1 - Comparison of Support Ring Model (Top) and First Mode Shape at 15 Hz (Bottom) in Horizontal Plane

Figure 4.4-2 - Comparison of Support Ring Model (Top) and First Mode Shape at 15 Hz (Bottom) in Vertical Plane

Figure 4.4-3 - Symmetric Second Mode Shapes
of the Support Ring Model

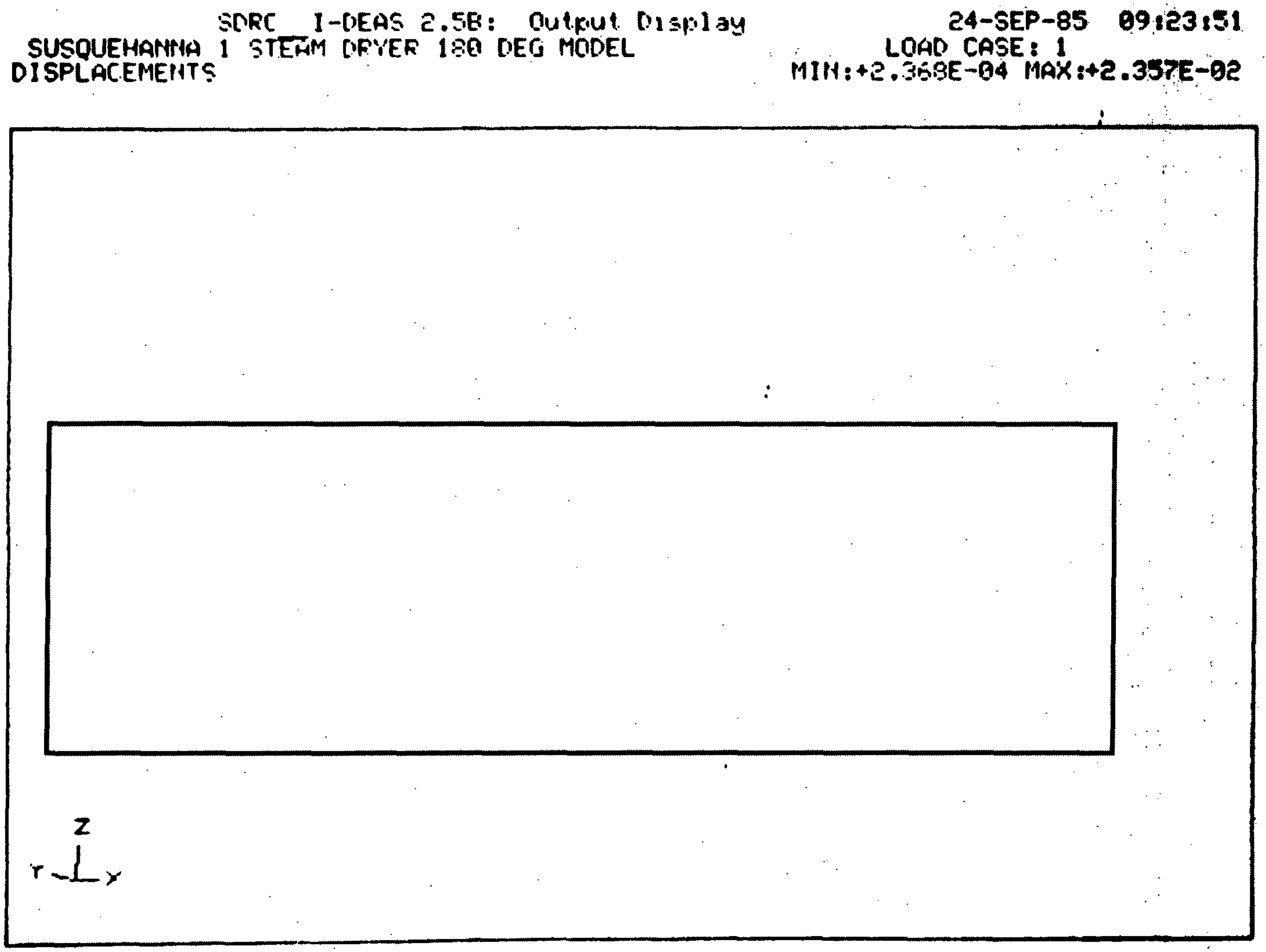


Figure 4.5-1 - Displacements of Ring due to Weight

MDE #199-0985-NP Rev 1
Non-proprietary Version

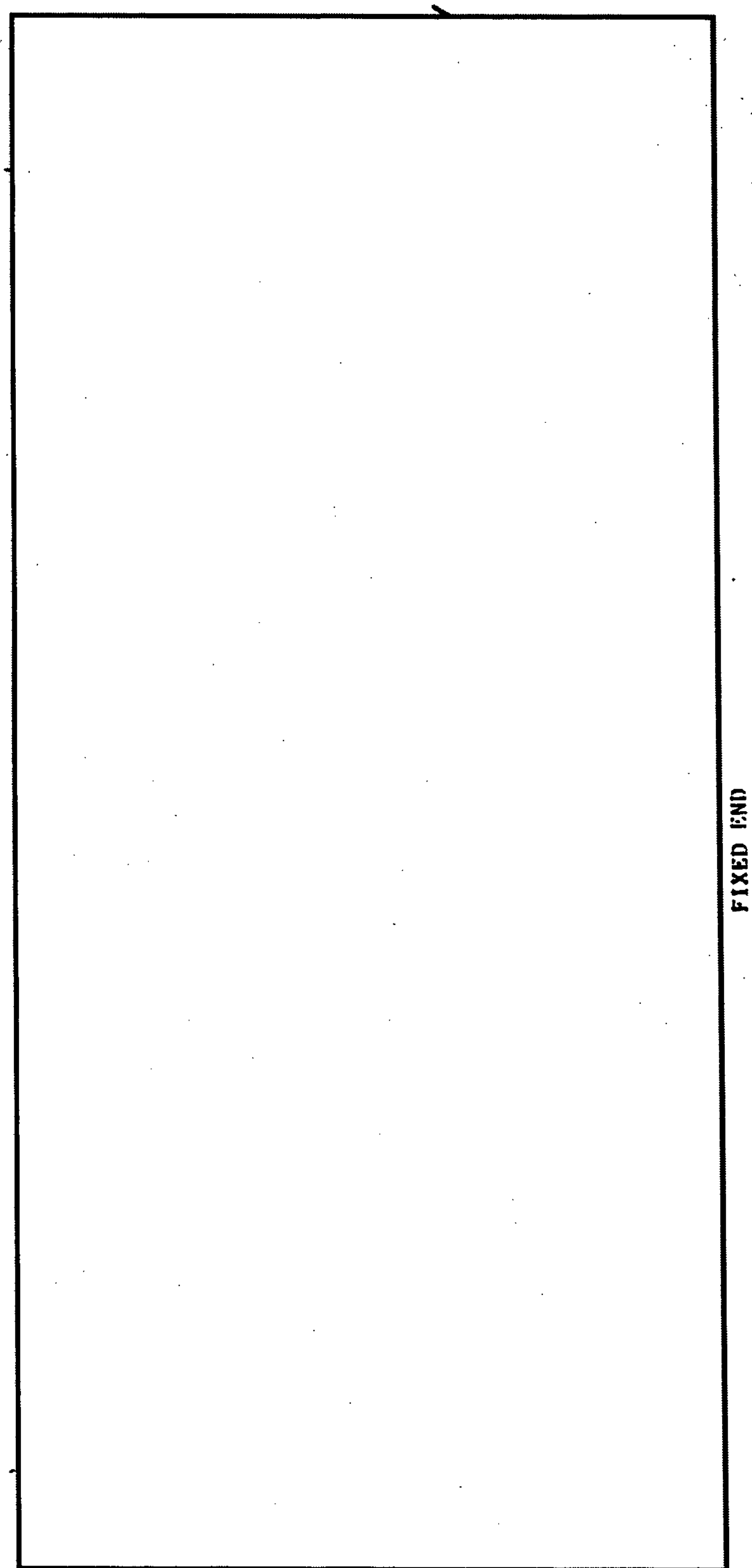


Figure 4.5-2 Support Bracket Model

5. SUMMARY OF RESULTS AND CONCLUSIONS

The following results are inferred from the instrumented vibration program conducted on the Susquehanna-1 dryer:

Based on the above results, it is concluded that all instrumented dryer components, (including the dryer support brackets) except the unpatched second bank end panel, are structurally adequate to resist the measured vibratory loads during normal

REFERENCES

1. General Electric Drawing #761R700, "Steam Dryer."

2. General Electric Design Report #385HA770, "Steam Dryer."

3. Susquehanna Steam Electric Station, Unit 1 - Evaluation of Steam Dryer Repairs, MDE-123-0585, Rev. 0, May 1985.

4. Susquehanna Steam Electric Station, Unit 1 - Evaluation of Replaced Steam Dryer Support Bracket, MDE-120-0585, Rev. 0, May 1985.

5. General Electric FDDR's: KR1700, Rev. 4, KR1 7001, Rev. 3, KR1-7002, Rev. 2, KR1-7003, Rev. 1.

6. General Electric VPF 3269-297-3, "Steam Dryer Support Bracket."

APPENDIX A

SPECIFICATION AND RESPONSE CHARACTERISTICS OF VIBRATION INSTRUMENTATION COMPONENTS

Strain Gage

Manufacturer: Ailtech

Model: SC 125

Specifications:

Resistance: 120 ±3.5 ohms

Gage Factor, Nominal: 1.80

Related Strain Level: ±600 μ inch per inch

Fatigue Life: Exceeds 10^6 cycles at ±1000 μ inch per inch

Transverse Sensitivity: Negligible

Operable Temperature Range - Static: -425 to +650°F

- Dynamic: -452 to +1500°F

Gage Factor Change with Temperature: Varies inversely with temperature approximately 1 percent per 100°F

Nuclear Radiation: Negligible effect

Material: Type-321 stainless steel

Strain Gage Shunt Calibrator

Manufacturer: General Electric

Model: Drawing 117C460

Specifications:

To provide electrical equivalent of mechanical strain by shunting a 1 megohm resistor across the dummy resistor. This change in bridge balance resistance provides a pre-calculated microstrain equivalent signal for calibrating the chart recorder.

Balance/Calibrate Unit

Manufacturer: Validyne

Model: CD-19-529 (specially built for General Electric)

Demodulator

Manufacturer: Validyne

Model: CD-19, CD-90 plug-in carrier demodulators

Specifications:

Power Requirements: 5V, rms, 3 kHz, ±15 Vdc from MC1

Input Sensor Sensitivity: 1 MV/V, 2.5mV/V, 25 mV/V selector switch with 0 to 100 percent vernier potentiometer

Output: 10±Vdc @ 10 mA

Nonlinearity: ±0.05 percent full-scale maximum

Frequency Response: 0 to 10, 0 to 50, 0 to 200 and 0 to 1000 Hz, flat ±10 percent

Module Case

Manufacturer: Validyne

Model: MC1-20

Oscillator: Output voltage -5V rms, center tapped adjustable

Frequency: 3000 Hz ±1 percent

Power Supply: Output -7.5, 15 volts, dc, 25 watts

Switching Circuit (Record/Reproduce)

Manufacturer: General Electric

Model: Special component designed by General Electric Company

Specifications: Passive elements (toggle switches and multiposition switches and relays)

Chart Recorder

Manufacturer: Gouldline, Instrument Division

Model: Brush 260 Recorder

Specifications:

General: Number of channels: 6 analog, 4 event

Channel Width: 40 mm, 50 div/channel

Writing Method: Pressurized fluid

Chart Speeds: eight; 1, 5, 25, 125 mm/sec; 1, 5, 25, 125 mm/min

Chart Speed Accuracy: ±0.25 percent

Electrical - Measurement Range: 1 mV per chart division to 500 volts d-c full scale

(Chart Recorder (Continued)

Maximum Signal Input: 500 volts dc or peak-to-peak

Frequency Response: 50 div. ±1 div. to 40 cps; 10 div. ±1 div. to 100 cps; 3 dB down at 125 cps

Sensitivity: 1 mV/div. to 10 volts/div. (0.8 mm/div.)

Tape Recorder

Manufacturer: Honeywell

Model: 101

Type: FM Intermediate Band, 14 data channels and up to 2 voice channels.

Tape Speeds: 8 speeds (120, 60, 30, 15, 7.5, 3.75, 1.87, and 0.937 ips). All speeds are bidirectional and electrically selectable by pushbutton switches.

Tape Width: 1/2 and 1 in.

Tape Thickness: 0.7 to 1.5 mil

Tape Reels: 10-1/2 to 15-inch dia. coaxially mounted

Tape Speed Accuracy: 0.1% when servoed from capstan tachometer with 1.0 mil tape, 0.01% when servoed from tape

Input Level: 0.5 to 10V pk

Input Impedance: 20 kΩ or 75Ω, selectable by pin jumper.

Harmonic Distortion: 1.2% max for IB and WB

Output Impedance: 50 Ω

Output Level: 1V rms into 50Ω

Data Bandwidth at 15 ips: 0 to 5 kHz

Accelerometer

Manufacturer: Validyne

Model: A14-532

Specifications:

Nominal Sensitivity: 3.5 (mV/V)/g

Frequency Response: 0 to 350 Hz

Resonant Frequency: 335 Hz

Maximum Acceleration ±500 g

Linearity: ±1/2 percent

Spectrum Analyzer

Manufacturer: Nicolet Scientific Corporation

Model: 444A-16, OPT-07

SPECIFICATIONS...

DISPLAY (on built-in CRT)

Data: Repetitive readout of one of the following:

- Time function, continuous or captured
- Instantaneous spectrum of time functions
- Averaged power spectrum A or B
- Instantaneous spectrum and averaged power spectrum A (dual display)
- Instantaneous spectrum and averaged power spectrum B (dual display)
- Averaged power spectrum A and averaged power spectrum B (dual display)
- Averaged power spectrum A plus averaged power spectrum B
- Comparison by displaying difference - Averaged power spectrum A minus averaged power spectrum B, or B minus A
- Comparison by displaying ratio - Averaged power spectrum A divided by averaged power spectrum B, or B divided by A

Electronic Graticule: Non-parallax rectangular graticule is generated; 10 marks on frequency axis for linear and 2 marks for log (at 1 and 2 decades below full scale); for single displays, 10 marks on amplitude axis for linear and 6 marks for log (at 10 dB intervals); for dual displays, twice as many amplitude marks are produced; for time, eight marks for horizontal and ± 5 marks around zero center for vertical, top and bottom correspond to input amplitude full scale; rear panel switch removes graticule.

Annotation: For frequency displays, letters and numbers indicate input sensitivity in VRMS, frequency range, type of data, averaging mode, number of spectra averaged, data weighting, display gain/attenuation, A-weighting on/off, mathematical calculation between averages, and 4-digit I.D. number; for time displays, full-scale input amplitude read as volts (zero to peak); horizontal time scale indicated by "SEC" and frequency scale by "HZ," rear panel switch removes annotation.

Overall rms Level: Shown on CRT for single spectrum displays (when cursor is on).

Measurement Cursor: Cursor line moved left or right continuously or by single resolution element; intensified dot where line intersects spectrum (if intersection is within graticule); can be turned off.

Amplitude at Cursor: Referenced to 1 VRMS and read in units of V, V^2, or dB with respect to 1V (dBV); or read in engineering units directly by reference to any voltage from 1.00×10^{-9} to 999×10^{9} set by front panel GAIN controls: for dual spectra displays amplitudes of each and their ratio at cursor location.

Frequency at Cursor: For 400-line spectra, frequency read in Hz (cycles/sec) or CPM (cycles/minute); also reads 1/3-octave band number if within bands 8 to 49 or approximately 6 Hz to 94 kHz in ORDERS (external sampling), reads % FS; reads in annotation only when cursor is on.

Harmonic Marks: Additional intensified dots illuminate multiples of cursor setting on 400-line spectra; number of dots indicate harmonic number up to a maximum of five dots.

Display Scales: Lin or log, frequency or amplitude of spectrum

Display Gain: Linear - gain of 512 ("X512") to attenuation of 512 ("/512") in binary steps; log - gain of +50 dB to attenuation of -50 dB in 10 dB steps; set by front panel GAIN control.

ANALYSIS CHARACTERISTICS (400-Line)

Frequency Ranges: 1, 2, 5, 10, 20, 50, 100, 200, 500, 1,000, 2,000, 5,000, 10,000, 20,000, 50,000 and 100,000 Hz with built-in anti-aliasing filters (1, 2, 5 Hz ranges filtered with 10 Hz filter).

Number of Resolution Elements: 400 per spectrum (generated from 1024 input time samples); nominal bandwidth, B, is 1/400 frequency range; noise bandwidth is 1.5B (1.0B when data automatically captured or armed).

Amplitude Linearity: ±0.1 dB or ±0.05% of FS to 66 dB below FS, whichever is greater

Frequency Accuracy and Stability: ±0.01 percent of full scale without warmup.

Minimum Detectable Signal: -70 dB typical, -75 dB with background subtraction

Two-Tone Dynamic Range: Typically better than 66 dB

Intermodulation Distortion: -70 dB typical

Amplitude Measurement Stability: ±0.1 dB from 10°C to 50°C (50°F to 120°F)

TRANSIENT DATA

Data Hold: Manual HOLD/REL button holds data in input memory or allows new data to enter; AUTO ARM (or remote signal) allows next signal over preset level to automatically actuate hold; in auto-hold, 1/8 of memory period before trigger can be viewed; polarity and amplitude of auto-hold triggering selected as ±1/16, ±1/8, ±1/4, or ±1/2 of full input amplitude, lights indicate data being held or unit is armed, one spectrum of held data can be transferred to averager A memory by pushing START A after capture.

TRANSIENT DATA (Continued)

Viewing Hold Data: Time signal can be displayed and plotted; in automatic hold, trigger level indicated by brightened dot on CRT.

Data Weighting: Weighting removed automatically in ARMED or when data captured (in AUTO position of rear panel switch), or can be manually controlled using rear panel switch.

Memory Period: Length of data stored in the input memory in seconds is 400/frequency range (Hz).

Automatic Transient Averaging: Rear panel jumper provides automatic arm, capture and averaging of a succession of input transients.

INPUT CHARACTERISTICS

Input Impedance: 100 kilohms

Input Coupling: AC (-3 dB at less than 0.5 Hz), DC

Test Signal: Sinewave at 64 percent of display, replacing input signal

Input Amplitude Sensitivity: (Volts RMS full scale) 100 mv (-20dB), 200 mv, 500 mv, 1V (0 dB), 2V, 5V, and 10V (+20dB).

Input Amplitude Monitor: Lights indicate peak signal levels - OVERLOAD, -6 dB (greater than 1/2 full scale), -12 dB (between 1/4 and 1/2 FS), -18 dB (between 1/8 and 1/4 FS), and -24 dB (between 1/16 and 1/8 FS); all lights below the signal level illuminated (in overload, all lights are on).

INPUT CHARACTERISTICS (Continued)

Input Sampling: 12-bit A/D conversion at 2.56 times maximum frequency of range selected on internal sampling (FREQ); external sampling input (ORDERS) sets frequency coverage at 1/2.56 of sampling rate. (Display in orders of rotation requires 2.56 pulses/revolution/order.)

Input Filters: Lowpass anti-aliasing filters matched to each range with an initial rolloff of 120 dB/octave (7-pole elliptic); 10-Hz filter on 1, 2 and 5 Hz ranges; frequency response ±0.5 dB (except ±1.0 dB on 100-kHz range).

Digital Input: External digital data can be loaded in 2's complement form directly into memory (through rear connector).

Weighting Window: Flat or Hanning

AVERAGING

Modes:
SUM - power spectra are added (true power averaging)
DIFF - power spectra are subtracted linearly from the previous average (negative amplitudes clipped at display bottom but retained in memory).
EXPON - average changes in time as the signal spectrum changes (N sets exponential time constant); operation equivalent to a "leaking integrator:."
PEAK - stores maximum spectrum amplitude at each frequency location during an averaging cycle, producing a profile of maxima.

Averaging Control:
STOP A - manual stop of averaging in A memory

Averaging Control (Continued)

START A - resets number of measurements count, erases A averager memory (unless in DIFF mode), and starts averaging in A memory.

CONT (Continue) A - starts averaging an A memory without erase; in SUM, DIFF, or PEAK mode, if actual number of spectra averaged is equal to or greater than setting of N, resets count.

TRANSFER A→B - transfers the contents of memory A to memory B, either during averaging in A memory or after averaging has stopped.

Number of Averager Memories: Two for 400-line spectra.

Number of Spectra Averaged - N: Determines time of averaging or time constant of exponential averaging; set from 1 to 512 in binary steps; in CONT, averaging continues until STOP button is pushed.

IN-PROCESS Light: Flashes to indicate averaging is taking place; flashes in EXPON until N is reached, then is lit continuously.

OUTPUT CHARACTERISTICS

CRT Outputs: X, Y, Z outputs for external annotated display

X-Y Plotting (without interruption of display): X, Y and pen lift outputs for analog X-Y plotter; plots single spectrum or time function; ORIGIN (zero volts) and FULL SCALE buttons position pen at lower left and upper right of scale; for 400-line log frequency, ORIGIN is first resolution element; in AT CURS, X and Y outputs follow cursor horiz and vert position; during PLOT, cursor follows pen while full display is simultaneously produced on CRT; can plot averaged spectra in B memory while averaging is taking place in A.

OUTPUT CHARACTERISTICS (Continued)

Store CRT: Slows display to match storage output for annotated plots using a Tek 4662 digital plotter.

Digital Input/Output: 16-bit parallel with 4-bit ID code.

Remote Control and Sense: Can sense all front panel switches and amplitude lights; can control all front panel switches; 8-bit parallel ASCII output.

MISCELLANEOUS

Weight: 19 kgm (42 pounds) nominal with typical plug-in.

Power: 90 - 130 volts or 180 - 260 volts, 48-66 Hz, nominal 150 watts.

Size: 32.6 cm (12-7/8 inches) high including feet and handle, 25.3 cm (10 inches) wide, 51.9 cm (20-7/16 inches) long including maximum front and rear protrusions.

Storage Temperature: -55°C to +85°C (-67° to +185°F)

Operating Temperature: 0°C to 55°C (+32°F to +130°F)

APPENDIX B

FIGURE **TITLE**

FIGURE B.1 - S2 Peak Spectrum at 100% Power

FIGURE B.2 - S3 Peak Spectrum at 100% Power

FIGURE B.3 - S2 Stable Spectrum at 100% Power

FIGURE B.4 - S3 Stable Spectrum at 100% Power

FIGURE B.5 - S2-S3 Coherence at 100% Power

FIGURE B.6 - S2-S3 Phase at 100% Power

FIGURE B.7 - S1 Peak Spectrum at 100% Power

FIGURE B.8 - S7 Peak Spectrum at 100% Power

FIGURE B.9 - S8 Peak Spectrum at 100% Power

FIGURE B.10 - S8 Stable Spectrum at 100% Power

FIGURE B.11 - S1 Stable Spectrum at 100% Power

FIGURE B.12 - S7 Stable Spectrum at 100% Power

FIGURE B.13 - S1-S7 Coherence at 100% Power

FIGURE B.14 - S1-S7 Phase at 100% Power

FIGURE B.15 - S1-S8 Coherence at 100% Power

FIGURE B.16 - S1-S8 Phase at 100% Power

FIGURE B.23 - S4-S5 Coherence at 100% Power

FIGURE B.24 - S4-S5 Phase at 100% Power

200.00

FIGURE B.25 - S9/10 Peak Spectrum at 100% Power

FIGURE B.26 - S11/12 Peak Spectrum at 100% Power

FIGURE B.27 - A1 Peak Spectrum at 100% Power

FIGURE B.28 - A3 Peak Spectrum at 100% Power

FIGURE B.29 - A2 Peak Spectrum at 100% Power

FIGURE B.30 - A4 Peak Spectrum at 100% Power

FIGURE B.31 - S9 through S13, Time History at 100% Power

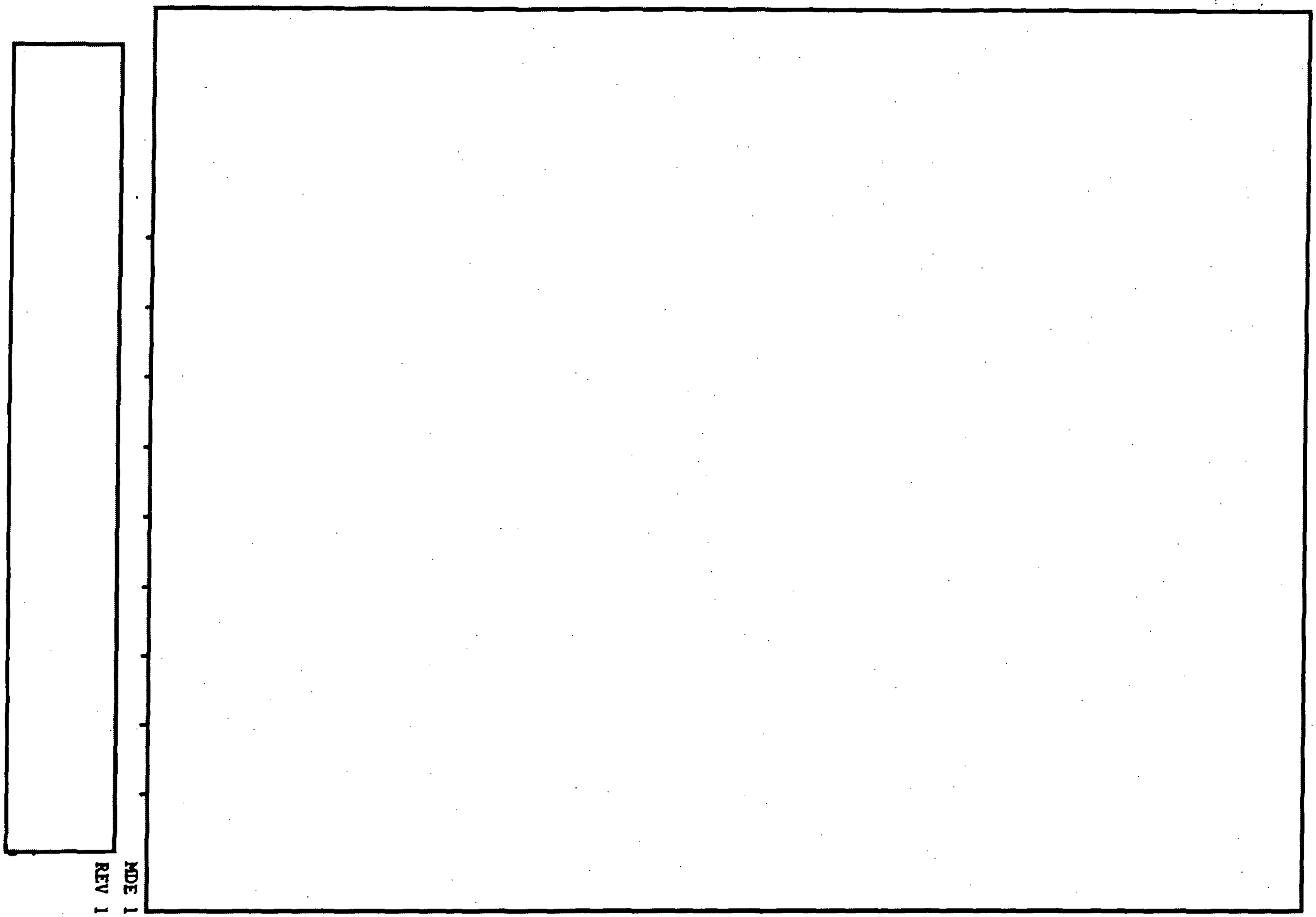
FIGURE B.32 - Peak Spectrum at 100% Power

FIGURE B.33 - S10 Peak Spectrum at 100% Power

FIGURE B.34 - S11 Peak Spectrum at 100% Power

FIGURE B.35 - S12 Peak Spectrum at 100% Power

FIGURE B.36 - S13 Spectrum at 100% Power



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REV 1 (1/86)

Figure B.37 - S6 Spectrum During at a Different Time

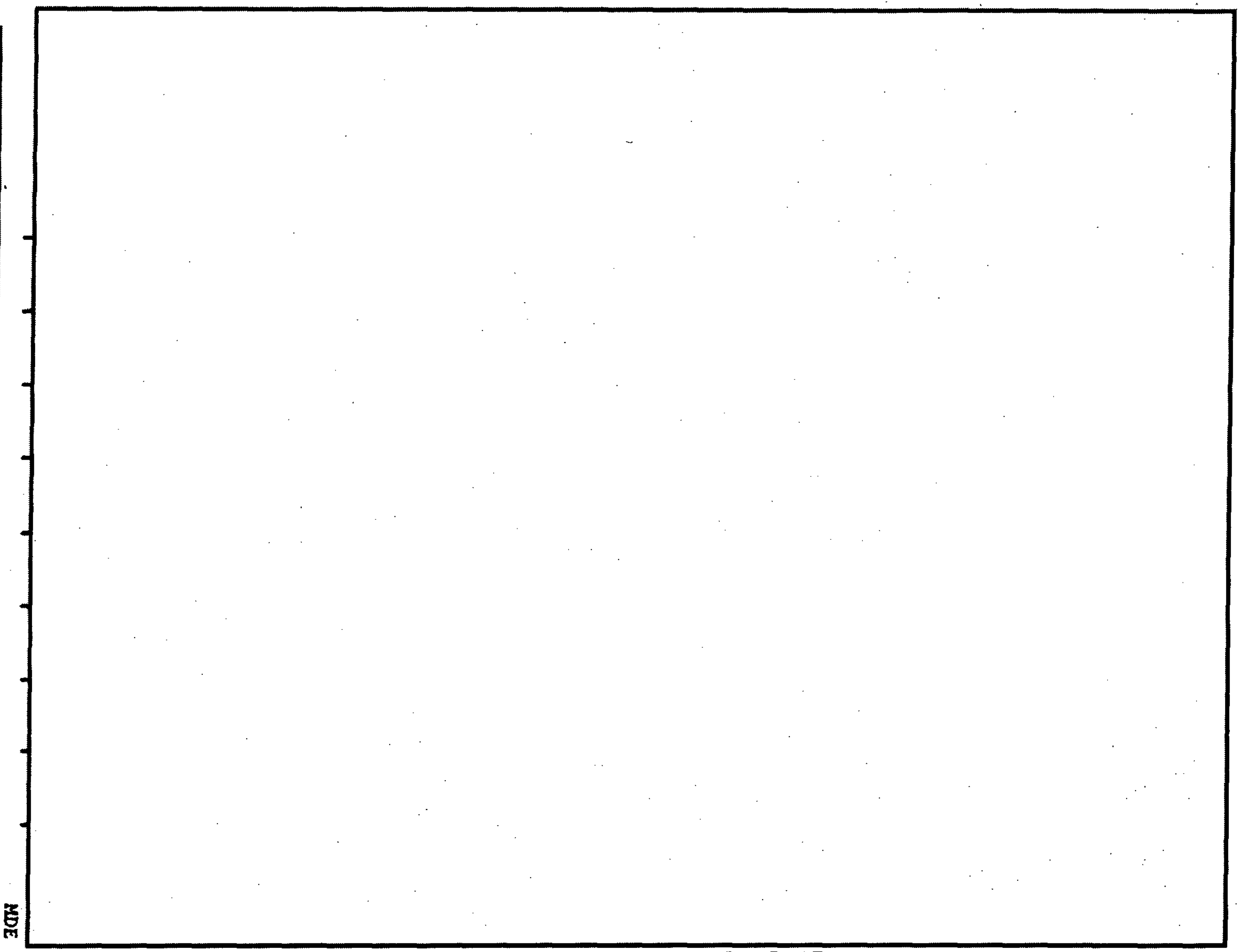

Figure B.38 - S6 Spectrum During

APPENDIX C

CONTROL ROOM DATA SHEETS

1 2 3 4

APPENDIX C

CONTROL ROOM DATA SHEETS

5 6 7 8

APPENDIX C

CONTROL ROOM DATA SHEETS

9 10 11 12

APPENDIX C

CONTROL ROOM DATA SHEETS

13 14 15 16

APPENDIX C

CONTROL ROOM DATA SHEETS

17 18 19 20

APPENDIX C

CONTROL ROOM DATA SHEETS

21 22 23 24

APPENDIX C

CONTROL ROOM DATA SHEETS

25 26 27 28

APPENDIX C

CONTROL ROOM DATA SHEETS

29 30 31 32

APPENDIX C

CONTROL ROOM DATA SHEETS

33

APPENDIX D

Attachment 2 to PLA-6138

Non-Proprietary Version of the PPL Responses

In order to provide technical information that will allow the NRC staff to proceed with its technical review, the following is provided:

Acceptance Comment 1

Operating experience shows that previous applications of an acoustic circuit analyses have determined pressure loads on steam dryers based on pressure fluctuation measurements in the main steam lines caused by downstream sources in the steam lines. The licensee indicates in Attachment 10, Section 4.2.5.1 of their submittal, that the pressure pulses measured in the main steam line are generated by hydrodynamic sources. The licensee's application does not provide the technical justification to show that the acoustic circuit analysis is reliable in determining SSES steam dryer pressure loads caused by such hydrodynamic sources.

PPL Response

Attachment 10 of PPL's CPPU submittal (PLA-6076) acknowledges that the acoustic circuit model (ACM) by itself does not reliably predict the pressure loading from hydrodynamic sources. The results of the SSES benchmarking effort and the ACM benchmark report (Appendix 4 to Attachment 10) both indicate that the ACM will produce frequency spectra representative of hydrodynamic stresses. Therefore, PPL developed a "stress under prediction" factor to provide a reliable, predictive methodology (ACM and a "stress under prediction factor") which bounds the stresses produced by the hydrodynamic loads.

CDI Report No. 04-09P Revision 6 (ML050960049), "Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes," indicates that there exists at least two mechanisms which result in dryer pressure loads; vortex shedding from the dryer and "whistling" of safety valve standpipes (standpipe resonance). Previous analysis of other plants indicate that when significant dryer loadings are observed or predicted from the Acoustic Circuit Methodology (ACM), these loads result from safety valve standpipe resonance. Periodic vortical flow is ingested into the steam lines and is the hydrodynamic source of the acoustic pressure oscillations. By the very nature of the assumptions made in the ACM, the portion of the dryer pressure loading that is dependent on the square of the steam velocity is not predicted by the ACM. The ACM predicts dryer pressure loading that is dependent on the first power of steam velocity. The ACM predicts dryer loading to the order of the Mach Number. The hydrodynamic loading is a Mach Number squared loading.

Since the ACM was not developed to predict loads that are dependant on the square of the steam velocity, a benchmarking effort was conducted to determine if the ACM methodology would identify significant hydrodynamic frequency loading on the steam dryer and determine if the resulting generated stresses were of an appropriate magnitude. This effort included a review of the ACM benchmark report (Appendix 4 of Attachment 10), and the results from a finite element analysis (FEA) which used an ACM predicted load at the Original Licensed Thermal Power Level (OLTP). The FEA results were then benchmarked against SSES steam dryer strain gauge data obtained in 1985. The benchmarking effort is detailed in Section 4.2.5.1.1 of Attachment 10 of PPL's CPPU submittal. The results of the SSES benchmarking effort contained in Attachment 10 and the ACM benchmark report (Appendix 4 to Attachment 10) both indicate that the ACM will produce frequency spectra representative of hydrodynamic loads. While the SSES benchmarking effort determined that the frequency spectra is representative of hydrodynamic loads, it also concluded that the ACM loading produced stresses which were lower than actual measured strains. Therefore, a stress under prediction factor was applied to the peak loads for all dryer components to address the non-bounding stress bias that results from using the ACM to predict hydrodynamic loads. The determination of the stress under prediction factor is detailed in Section 4.2.5.1.1 of Attachment 10 of PPL's CPPU submittal.

It should be noted that the SSES benchmarking effort revealed a significant spectral stress at 110Hz. This spectral stress peak was not modeled using the ACM pressure loading. A review of the SSES 1985 test data has concluded that this stress peak is not the result of or dependant on steam flow. The 110Hz stress peak is discussed in detail in the response to the staff's supplemental comment #2 below.

Acceptance Comment 2

The Final Element Analyses (FEA) in Attachment 10, Section 4.3 of the licensee's submittal is incomplete as it does not include the application of sufficiently small variations in the steam dryer load definition's time step size to evaluate the potential for more significant stress areas in the steam dryer. As indicated during the public meeting on November 6, 2006, the licensee plans to include the smaller variations in the time step size as part of the final FEA in January 2007.

PPL Response

A review has been completed of modifications required to resolve the over stress conditions identified with the current Susquehanna steam dryer design. The review has concluded that structural modifications to the existing steam dryer are not justifiable when economic and ALARA factors are considered. As a result, PPL directed GE to design and fabricate two new steam dryers for the Susquehanna units. The new Unit 1 steam dryer will be installed during the 2008 refueling outage and the new Unit 2 steam dryer will be installed during the 2009 refueling outage.

Table 1 below presents the results of finite element analyses (FEA) at small time steps that correspond to frequency shifts of [[

]]. The FEA model used to generate the stress intensities presented in Table 1 below represents the new steam dryer design. Resultant stress intensities from the frequency shifted FEAs have been included into the structural uncertainty calculations. The results presented in Table 1 below have been verified in accordance with a 10 CFR 50 Appendix B Quality Assurance Program.

TABLE 1 - SSES Replacement Dryer Stress Summary (FIV Response under 113% OLTP Loads)

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Acceptance Comment 3

The licensee's calculations indicate that the fatigue stress limits will be exceeded within the SSES 1 and 2 steam dryers during CPPU operation. The licensee indicates that the overstressed areas will require further analysis and modifications to, or replacement of, the steam dryer. The pending analysis is needed by the NRC staff to assure no different or additional stresses result from the modification or new dryer, that the overstress results will be resolved, and that steam dryer structural integrity will be maintained at the full CPPU conditions.

PPL Response

The new Susquehanna steam dryer has resolved the over stress conditions identified in Attachment 10 of PPL's CPPU submittal. The new Susquehanna steam dryer design maintains the current curved hood configuration and the current geometry and dimensional envelope. Critical structural components have had their thickness increased to improve the overall stiffness of the steam dryer. The critical component changes are:

[[

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The Figure 1 below is a graphic representation of these structural changes.

FIGURE 1 - Structural Enhancements for the New Susquehanna Dryers

[[

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GE has constructed a finite element model for the new steam dryer and has completed the required fatigue analysis. The 113% OLTP ACM loads (based on Susquehanna main steam line strain gauge data) calculated for the existing steam dryer were input to the new FEA model. Weld factors were then applied to the component maximum stress intensities if applicable. The maximum stress intensities were then increased by applying the stress under prediction factor. The 113% stress intensities were then scaled, as described in Attachment 10 of PPL's CPPU submittal, to the full CPPU steam flow conditions. The results of this analysis are presented in Table 2 below:

TABLE 2 - Predicted Maximum Stresses and Fatigue Margin under EPU

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Table 2 above illustrates that the maximum stress intensities for all components are below the ASME 13,600 PSI fatigue design limit for 304 stainless steel with adequate margins. The highest stressed component has a 11.9% margin to the ASME fatigue design limit with all "end to end" uncertainties included. PPL Susquehanna will instrument the new Unit 1 steam dryer with strain gauges at selected high stress locations. These strain gauges will be used to confirm the adequacy of the fatigue analysis performed on the new Susquehanna steam dryers.

The results presented in Table 2 have been verified in accordance with a 10 CFR 50 Appendix B Quality Assurance Program.

The following responses are provided to address the NRC's request for additional technical discussion, as presented in Reference 2 of the cover letter for this response.

Supplemental Comment 1

Significant uncertainties exist in determining the stress in the steam dryer from scale model testing and main steam line pressure fluctuation analysis. The licensee should address its means of estimating the uncertainties and bias errors, and applying those uncertainties and bias errors in calculating stresses, attributed to acoustic dryer pressure loads calculated based on acoustic circuit model assumptions (Table 4-13 component symbol U2b of Attachment 10 of the application) to provide confidence that the allowable limits will not be exceeded in the SSES 1 and 2 steam dryers at CPPU conditions.

PPL Response

Scale model test results were not used in the determination of the Susquehanna steam dryer loads. The benchmarking discussed in Attachment 10 of PPL's CPPU submittal did identify an under prediction bias of the ACM. This bias was accounted for by the use of a stress under prediction factor. The Susquehanna steam dryer loads were determined as discussed in the response to Acceptance Comment 1 above.

Rather than calculating a negative bias due to the under-prediction of the dryer loads by the ACM, the stress under prediction factor was used directly as a multiplier for the dryer stresses calculated by the FEA. As a result, it is not appropriate to include the bias value for this component. Table 4-13 of Attachment 10 of PPL's CPPU submittal is modified as shown below to clarify the dryer analysis uncertainties.

PLA-6076 Attachment 10 - Table 4-13 (Revised)

List of Uncertainty Components for Susquehanna Steam Dryer FIV Load and Stress Calculations

Uncertainty Component	Symbol	Bias (see Note 1)	Precision (see Note 2)
MSL acoustic pressure measurement	U1	0%	±6.2%
Difference in MSL strain gauge locations between Susquehanna and Quad Cities Unit 2	U2a	0%	±16.9%
Ability of ACM to determine acoustic dryer pressure loads	U2b	(See Component U3b)	(See Component U3b)
Measurement of dryer pressures in 1985 Susquehanna measurements	U3a	0%	±10%
Ability of ACM to determine spatial distribution of dryer pressure loads	U3b	(See Note 3)	±7.6%
Use of a two-second time history in FE calculations	U4a	-2%	0%
Ability of FEA to Model Dryer Structure	U4b	(See Note 4)	(See Note 4)
Determination of CPPU scale factor	U5a	[[	]]
Conservatism in 113% OLTP load definition	U5b	+24%	0%

Notes:

1. A negative bias value indicates an under-prediction of the dryer loads or stress intensities and a positive bias value indicates an over-prediction.
2. The precision value indicates either an over-prediction or an under-prediction of the dryer loads or stress intensities.
3. The stress under prediction factor is determined in Section 4.2.5.1.1 of Attachment 10. The stress intensities determined by the FEA are adjusted by this factor and therefore it is not appropriate to include the bias value for this component in this table. Approximately 70% of this factor is attributed to the limited ability of the ACM to predict hydrodynamic loads.
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Supplemental Comment 2

The licensee's submittal indicates the presence of a strong spectral peak at about 110 Hz in the SSES 1 and 2 plant measurements on the steam dryer. The licensee should discuss the source of this peak and the absence of its prediction in the analysis.

PPL Response

The frequency of the observed panel resonance matches the recirculation pump vane passing frequency corresponding to the core flows and recirculation pump speeds present when the measurements were made. The 110 Hz peak observed in the second bank hood panel strain gauge measurements is due to a local structural resonance in the panel where strain gauges S4 and S5 were located. The dryer panels are responding to a strong vibration response in the recirculation loop piping that is excited by the recirculation pump vane passing frequency. The piping vibration is transmitted through the vessel to the dryer supports. This recirculation piping vibration response was first observed in SSES Unit 2 when the plant entered the Increased Core Flow (ICF) region for the first time following licensing of the ICF region.

The recirculation pump vane passing frequency matched a structural mode of the panel at the core flow conditions when the measurements were taken (110 Hz at 100% OLTP and 113 Hz at 90% OLTP). The 110 Hz response was noted at that time of the measurements, as determined in MDE-199-0985-P, Revision 1, which is provided as Appendix 1 of this letter. At that time, the source of the resonance was not investigated. Structural analyses in MDE-199-0985-P, Revision1 determined that the 110 Hz frequency was a structural mode of the second panel. These conclusions were confirmed by performing a vibration analysis using the current whole dryer finite element model. The fatigue evaluation presented in Attachment 10 considered flow-induced vibration resulting from pressure loads applied directly to the dryer. Because the 110 Hz vibration load was transmitted mechanically through the dryer supports, it was not predicted in the pressure load Flow Induced Vibration (FIV) analysis presented in Attachment 10 of PPL's CPPU submittal.

Figures 2 and 3 show the frequency spectra for the second bank strain gauges for power levels from 70% to 100% OLTP. In Attachment 10, a scaling factor was developed in order to adjust the predicted stress results from the finite element analysis to be equivalent to the stresses indicated by the in-plant dryer instrumentation. The scaling factor was based on a comparison of the predicted strains to the measured strains for S4 and S5 at the 100% OLTP power case where the 110 Hz peak is the highest. As discussed above, the 110 Hz peak shown in Figures 2 and 3 were correlated to the recirculation pump vane passing frequency. Because this dominant peak is based on the recirculation pump vane passing frequency and a local structural resonance, a stress under prediction factor based on it will be bounding for the other power levels. Without the 110 Hz peak, the stress under prediction factor would be approximately 30% lower. The rest of the frequency spectrum is proportional to steam flow during the power ascension. The pressure loads, as shown by the pressure drum (Figure 4) and steam line pressure measurements (Figure 5) are also proportional to steam flow as power increases. If the 110 Hz peak were not present, a scaling factor based on the measured strain gauge response would be relatively constant as power increased. Strain gauges S4 and S5 were located on the second bank panel near the high stress location where the weld seam cracked during the first cycle. It is most likely that the 110 Hz peak is a local structural resonance in this panel caused by the vibrations introduced by the recirculation pump vane passing frequency. The structural performance of the dryer over more than 20 years suggests that there are no other locations on the dryer that are experiencing high stresses as a result of the recirculation pump vane passing vibration.

Figure 2 - Second Bank Strain Gauge S4 Response as a Function of Power

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Figure 3 - Second Bank Strain Gauge S5 Response as a Function of Power

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Figure 4 - Pressure Drum Response as a Function of Power

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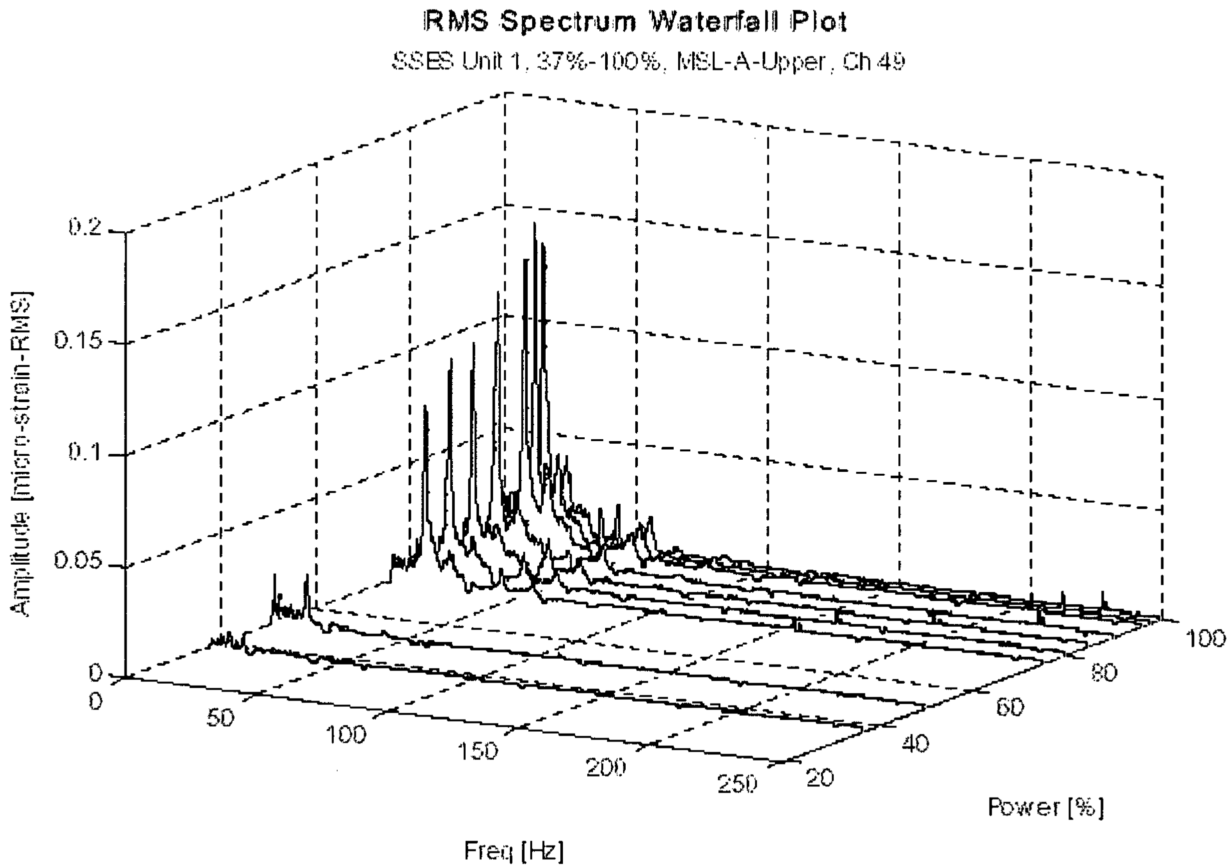
Note: The 110 Hz peaks shown in the plot are due to the mechanical excitation of pressure drum diaphragm by the recirculation loop vibration (confirmed by a vertical accelerometer mounted next to one of the pressure drums).

Figure 5 - Main Steamline Pressure as a Function of Power



Supplemental Comment 3

Operating experience has not revealed past significant concerns with hydrodynamic loads in low frequency ranges on steam dryer performance. The licensee should discuss the presence of a hydrodynamic excitation source at SSES 1 and 2 that predict steam dryer stresses near fatigue limits at power uprate conditions.

PPL Response

Section 2.4 and Table 2-2 of BWRVIP-139 summarize the past dryer structural performance for the BWR fleet. Of the cracking observed in the dryers, a significant number of the observations was attributed to high cycle fatigue. However, the root cause evaluations for these observations did not determine the specific frequency ranges of the loads responsible for the cracking. Section 3 of GE-NE-0000-0049-6652-01P (ML 060720354) provides an overview of the frequency characteristics of the pressure loading and structural response observed in the in-plant measurement data taken from instrumented dryers. Specifically, Figures 16-19 show the similarity in both the low and high frequency pressure loads acting on several dryers. Figures 14 and 15 show that the dryer structure is responding to both the low frequency and high frequency loads. Based on these in-plant measurements, it must be concluded that the full frequency range of pressure loads must be considered when evaluating the steam dryer structural performance.

The characteristics of the low frequency (15-30 Hz) pressure loading observed in SSES are discussed in Sections 3.3.1.3 and 3.3.1.4 of GE-NE-0000-0049-6652-01P. The low frequency hydrodynamic loads are due to turbulent buffeting, but have characteristics that are acoustic in nature. As can be seen by the sharp, well-defined peaks in Figures 5-21 and 5-22 of Attachment 10 of PPL's CPPU submittal, these loads exhibit the controlled frequencies associated with acoustic loads. It is believed that the source of the low frequency loading is related to the stationary vortex observed between the outer hood of the dryer and the vessel steamline nozzle. The wavelengths associated with the frequencies of these loads suggest that the main steam lines, or some portion thereof, are the resonating chamber providing the frequency control, though this has not been confirmed. These low frequency peaks are established at low plant power levels and grow in amplitude while maintaining constant frequencies as the plant comes up in power. A detailed assessment of the measured SSES dryer structural response to the low frequency loads observed in SSES is provided in MDE #199-0985-P, Revision 1 (See PPL response to supplemental comment #6 below).

Supplemental Comment 4

The licensee's submittal indicates spectral peaks near 15 Hz in the two main steam lines at SSES with "dead" legs. The licensee should discuss the source of these peaks and the reason that they do not appear for the other two steam lines. Also, the licensee should discuss how the 15 Hz loading is considered in the FEA of the SSES 1 and 2 steam dryers under CPPU conditions.

PPL Response

The source of the 15 Hz loading is the turbulent flow over the surfaces of the steam dryer. The "A" and "D" main steam lines contain dead legs, on which safety relief valves are installed. Fifteen Hz periodic vortical flow down the "A" and "D" main steam lines over the junction of the dead legs results in energy being stored in the dead leg. The largest amount of energy can be stored at 15 Hz, since this is a resonant frequency of the dead legs, thus sustaining the oscillation. Vortical flow at 15 Hz ingested into the steam lines which do not contain dead legs have no means of storing energy at this frequency, and hence the 15 Hz loading is much lower in amplitude.

The 15 Hz loading is accounted for in the ACM, which maps this load across the surfaces of the dryer. These loads are used as inputs for the FEA structural model, as discussed in Sections 5.2, 5.3, 5.4, and 6.3 of the GE dryer FEA (Appendix 5 of Attachment 10 of PPL's CPPU submittal).

Supplemental Comment 5

In Attachment 10, Section 4.2.1, the licensee discusses its selection of Strouhal number to identify the steam velocities for acoustic resonance to occur in the SSES steam lines. The licensee should discuss the basis for application of the same Strouhal number for various steam line branch openings, including the dead leg.

PPL Response

Typical Strouhal numbers are discussed in Section 4.2.1 of Attachment 10 of PPL's CPPU submittal. These values were used as a preliminary indicator in determining the potential for acoustic loading on the dryer. However, Strouhal numbers were not used in the final dryer structural analysis, since actual plant data was used. The purpose of the Strouhal analytical prediction was to support that the results of subsequent scale model testing and the final analysis were reasonable and in line with current understanding.

Section 4.2.1 in Attachment 10 of PPL's CPPU submittal suggests that the onset of resonance occurs at a Strouhal number of about 0.55 and peak of resonance occurs at a Strouhal value of about 0.4. Ziada & Shine have done research on the onset and peak of shear wave resonance. Ziada & Shine note that as the diameter ratio (d/D) of branch line diameter (d) to main line diameter (D) increases, the Strouhal number associated with onset and peak also increases. Ziada & Shine also point out that for a diameter ratio of about 0.57, the Strouhal number associated with peak resonance is about 0.5. Higher increases in diameter ratios above 0.57 do not affect the onset and peak Strouhal numbers much - according to Peters (1993). For the most part, Susquehanna has branch lines that have diameter ratios less than 0.5. This is true for the SRV standpipes, RCIC, HPCI, and drain lines branches even when the sweepolet radius is included which makes the Strouhal number scale with the branch diameter plus the sweepolet radius. Section 3.3.2 of GE-NE-0000-0049-6652-01P describes the characteristics of the SRV standpipe resonances observed in plant measurements observed on the various dryers that GE has instrumented. Table 4 of GE-NE-0000-0049-6652-01P provides a summary of the Strouhal numbers determined for the peak SRV standpipe resonances in these in-plant measurements. GE used bounding Strouhal numbers in its Strouhal evaluation of the SRV standpipes, the RCIC, HPCI, and drain line branch connections that consider these in-plant measurements. Bounding Strouhal numbers in this case refers to a prediction that will yield lower velocities for resonance (i.e., earlier onset and peak of shear wave resonance). The SRV standpipe, RCIC, HPCI, and drain line branch geometries are all a simple right angle tee off of the main steam line carrying the flow. Therefore, the Strouhal numbers discussed in Attachment 10, Section 4.2.1 of PPL's CPPU submittal are reasonable to estimate onset and peak of shear wave resonance.

Strouhal calculations for the dead legs were not specifically performed. However, 1/8-scale model testing confirmed the presence of a 15 Hz response, which is attributed to the dead legs on the "A" & "D" main steam lines.

Supplemental Comment 6

In Attachment 10, Section 3.7, the licensee discusses anomalies in the steam dryer in SSES Unit 1 upon initial plant operation, and the installation of steam dryer instrumentation to evaluate dryer performance during testing in 1985. The licensee should provide its report regarding the instrumented steam dryer test performed at Susquehanna in 1985, and the related steam dryer issues.

PPL Response

The non-proprietary version of GE Report MDE #199-0985-NP Revision 1, which describes the results of an instrumented dryer test performed at Susquehanna in 1985 is provided as Appendix 1 of this response.

Attachment 3 to PLA-6138

General Electric Company Affidavit

General Electric Company

AFFIDAVIT

I, George B. Stramback, state as follows:

(1) I am Manager, Regulatory Services, General Electric Company ("GE") and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosure 1 to GE letter GE-SSE-EP-312, Larry King to Mike Gorski (PPL), *GE Review of draft PPL letter, PLA-6138,* dated December 2, 2006. The Enclosure 1 (*GE Review of PPL Letter PLA-6138*) proprietary information is delineated by a double underline inside double square brackets. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the sidebars and the superscript notation{3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner, GE relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, <u>Critical Mass Energy Project v. Nuclear Regulatory Commission,</u> 975F2d871 (DC Cir. 1992), and <u>Public Citizen Health Research Group v. FDA</u>, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by General Electric's competitors without license from General Electric constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future General Electric customer-funded development plans and programs, resulting in potential products to General Electric;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a., and (4)b, above.

(5) To address 10 CFR 2.390 (b) (4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GE, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GE, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within GE is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GE are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it contains details of steam dryer loading analyses of the design of the Susquehanna BWR Steam Dryer. Development of this information and its application for the design, procurement and analyses methodologies and processes for the Steam Dryer Program was achieved at a significant cost to GE, on the order of approximately two million dollars.

The development of the dryer performance evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GE asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GE's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GE's

comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GE.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GE's competitive advantage will be lost if its competitors are able to use the results of the GE experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GE would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GE of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 2nd day of December 2006.

George B. Stramback

George B. Stramback
General Electric Company