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Nuclear Operations

April 29, 1992
NRC-92-0049

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D. C. 20555

References: 1) Fermi 2
NRC Docket No. 50-341
NRC License No. NPF-43

2) Detroit Edison letter, NRC-90-0135, dated August 17, 1990

3) Detroit Edison letter, NRC-91-0011, dated February 7, 1991

4) Detroit Edison letter, NRC-91-0124, dated October 10, 1991

Subject: Response to NRC Request for Information Concerning Low Pressure Turbine Blade Failures and Disc Inspections

The purpose of this letter is to: (1) document answers to NRC questions concerning the Fermi 2 low pressure (LP) turbine blade failures and disc inspections; (2) provide before and after vibration characteristic diagrams for the LP turbine fifth stage blades; (3) discuss the improvements made to correct the blade failures; and (4) discuss the fact that the broken blades did not damage the LP turbine casing. Information concerning the LP turbine disc inspection results and Number 3 LP Turbine fourth stage blade failures and corrective actions has been previously submitted to the NRC in References 2, 3, and 4.

The NRC questions concern the turbine service hours prior to the blade failures, total turbine service hours, the configuration of the blade failures, and the dates of the next LP turbine disc inspections. These questions were posed, discussed, and satisfactorily answered during a teleconference on February 4, 1992 with Messrs Tim Colburn, Gene Carpenter, and Simon Sheng of the NRC. The NRC requested that DECo document these answers in a letter.

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LP turbine blade improvements and the fact that the broken blades did not damage the LP turbine casing were also discussed during the teleconference. The NRC requested additional information on these items including before and after Number 2 LP Turbine fifth stage blade vibration characteristic diagrams.

Detroit Edison Company (DECo) understands that this information will be used by the NRC in their review and closeout of Fermi 2 actions to fulfill the inspection requirements of License Condition 2.C.(11), "Low Pressure Turbine Disc Inspection (Section 10.2.2, SER)". It is DECo's position that the LP turbine blade failures are not related in any way to NRC LP turbine rotor disc concerns.

It is understood that, upon finding Fermi 2 actions satisfactory, the NRC will issue a safety evaluation stating that Fermi 2 meets the requirements of License Condition 2.C.(11).

The subject responses are included in Attachments 1 and 2. If there are any questions concerning this subject, please contact Mr. David H. Brown at (313) 586-4213.

Sincerely,

Attachments (2)

cc: T. Colburn
A. B. Davis
M. P. Phillips
S. Stasek

Attachment 1

Responses to NRC Questions and Discussion
of
Turbine Blade Failures

Introduction

On February 4, 1992, a teleconference was held between NRC staff and DECo personnel to discuss past turbine blade failures and low pressure (LP) turbine disc inspections. The purpose of the discussion was to provide the NRC with additional information concerning the review and closeout of Fermi 2 actions to fulfill the LP turbine inspection requirement of License Condition 2.C.(11), "Low Pressure Turbine Disc Inspection (Section 10.2.2, SER)" of the Fermi 2 Operating License. Information concerning the LP turbine disc inspection results and Number 3 LP turbine fourth stage blade failures and corrective actions has been previously submitted to the NRC in References 2, 3, and 4. During the teleconference, the NRC requested that DECo submit a letter to the NRC documenting the answers to selected NRC questions answered by DECo during the teleconference; before and after Number 2 LP Turbine fifth stage blade vibration characteristics diagrams; a discussion of improvements made to correct the blade failure problems; and a discussion of the fact that the broken blades did not damage the turbine casing. This attachment presents the requested information.

Item 1

How many service hours did the turbine have prior to the turbine blade failures?

DECo Response:

The turbine had 14,600 service hours prior to the fifth stage turbine blade failures.

Item 2

What are the turbine service hours to date?

DECo Response:

The turbine service hours as of April 1, 1992, are 30,672 hours.

Item 3

Were the five failed Number 3 LP Turbine fourth stage blades clustered together or separated?

DECo Response:

The failed Number 3 LP Turbine fourth stage blades were found during the December, 1990, unit outage (Outage 90-05). Four failed blades were clustered on the turbine end of the fourth stage at one end of a blade packet. The fifth failed blade was located on the generator end of the fourth stage at the end of a blade packet.

Item 4

What are the next scheduled LP turbine disc inspection dates?

DECo Response:

The next LP turbine disc inspection dates are as follows:

LP Turbine Number 1 - April, 1997 (Sixth Refueling Outage)

LP Turbine Number 2 - September, 1995 (Fifth Refueling Outage)

LP Turbine Number 3 - April, 1994 (Fourth Refueling Outage)

These dates are within the turbine disc inspection intervals recommended by the turbine vendor.

Item 5

Provide before and after vibration characteristic diagrams for the LP turbine fifth stage blades.

DECo Response:

The turbine vendor supplied before and after vibration characteristic diagrams for the LP turbine fifth stage blades are provided in Attachment 2 of this letter. Figure 1 shows the frequency response results of stationary vibration tests on the Number 2 LP Turbine fifth stage as originally installed. Figure 2 shows the predicted frequency response for various blade designs and shroud configurations. Figure 3 shows the frequency response results of stationary vibration tests on the Number 2 and Number 3 LP Turbines after the modifications were completed during the second refueling outage in 1991.

Item 6

Provide a discussion of the improvements made to correct the blade failure problems.

ECo Response:

The following improvements were made to correct the blade failure problems:

A. Blade Frequency Response

Metallurgical examinations of the failed Number 2 LP Turbine fifth stage blades by DECo and the turbine vendor indicate that the failures were due to high cycle fatigue in the axial direction. This is suspected to have been associated with wheel or packet blades excited at frequencies above those equivalent to 10 nodal diameters. Figures 1 and 2 of Attachment 2 show an intersection of blade frequency response and the impulse line at approximately 11 nodal diameters or 330 Hz. In order to avoid the axial mode resonance frequencies, the replacement blades are wider and the tip stiffness is increased by widening the shroud. The blades are assembled with a continuous connection at the blade tips to eliminate the effects of the packets. Vibration tests were performed on the new fifth stage blades during the second refueling outage. Figure 3 of Attachment 2 shows the results of these tests. The actual blade frequency response lies above the impulse line over the range of multiples of running speed up to and above 20 nodal diameters as predicted by the frequency line for 2.5 in. blades with continuous shroud shown in Figure 2. Although not shown on Figure 3, the actual frequency response line crosses the impulse line at approximately 28 nodal diameters or 840 Hz. However, the in-service excitation forces are negligible in this region.

Metallurgical examinations of the failed Number 3 LP Turbine fourth stage blades by DECo and the turbine vendor also indicate that the fourth stage blade failures were caused by high cycle fatigue in the axial direction. Fourth stage overload due to operation with the fifth stage blades removed was considered as a probable cause of the failure. With the reinstallation of the fifth stage blades, the calculated stress is approximately half the stress calculated with the fifth stage blades removed. As a result, the turbine vendor considers the probability of fatigue failure to be sufficiently reduced such that a fourth stage redesign is not required. A continuous shroud was installed on the fourth stage blades to modernize the design.

B. Metallurgical Improvements

Metallurgical analysis of the fourth and fifth stage blades indicated that the blades had up to a 20% ferrite microstructure. The turbine vendor has conducted fatigue tests that show no influence on fatigue strength with ferrite levels in the range of 5-40%. However, DECo experience with another blade manufacturer has shown that a 5% ferrite limit should be maintained to avoid affecting fatigue strength. The fourth and fifth stage replacement blades have been analyzed and have a ferrite content less than 5%. Therefore, the ferrite content of the

replacement blades meets both the turbine vendor criteria and new DECo requirements.

Metallurgical analysis also indicated that localized hardening had occurred during the manufacture of the fourth stage blades. This is presumably due to the machining process. The fourth stage replacement blades were manufactured using an improved machining process that eliminates localized hardening. In addition, the blade roots were shot peened as a stress performance improvement.

C. Horizontal Joint Leakage Repairs

Leakage across the inner cylinder horizontal joint allowed steam impingement on the fourth and fifth stage rotating blades which possibly contributed to the excitation forces. Mitigation and reduction of this leakage has been accomplished by the installation of a deflector plate to deflect any leakage that might occur from directly impinging on the fifth stage blades and by repairs to the horizontal joint to limit steam leakage. The deflector plate is installed just upstream of the fifth stage stationary blades. The eroded area of the horizontal joint has been weld clad using an erosion resistant metal to limit steam leakage.

D. Elimination of Water Induction

The turbine vendor has associated the fifth stage blade failures with the evidence of water found in the Number 2 LP turbine between the inner and outer cylinder. The cylinder drains for all three LP turbines have been cleaned and enlarged to allow adequate drainage.

Item 7

Provide a discussion of the fact that the blade failures did not damage the turbine casing.

DECo Response:

Inspection of the LP turbine casings indicated that the broken blades did not damage the casings. Damage to the LP turbine internals was limited to impingement damage to the downstream diaphragms from failed blade and shroud fragments. Damage was limited to nicks, dents, and tears in the fixed blades of the diaphragms. No cracks were found on the cast rings of the diaphragms or the inner or outer casings. This damage was repaired during the second refueling outage.

Attachment 2

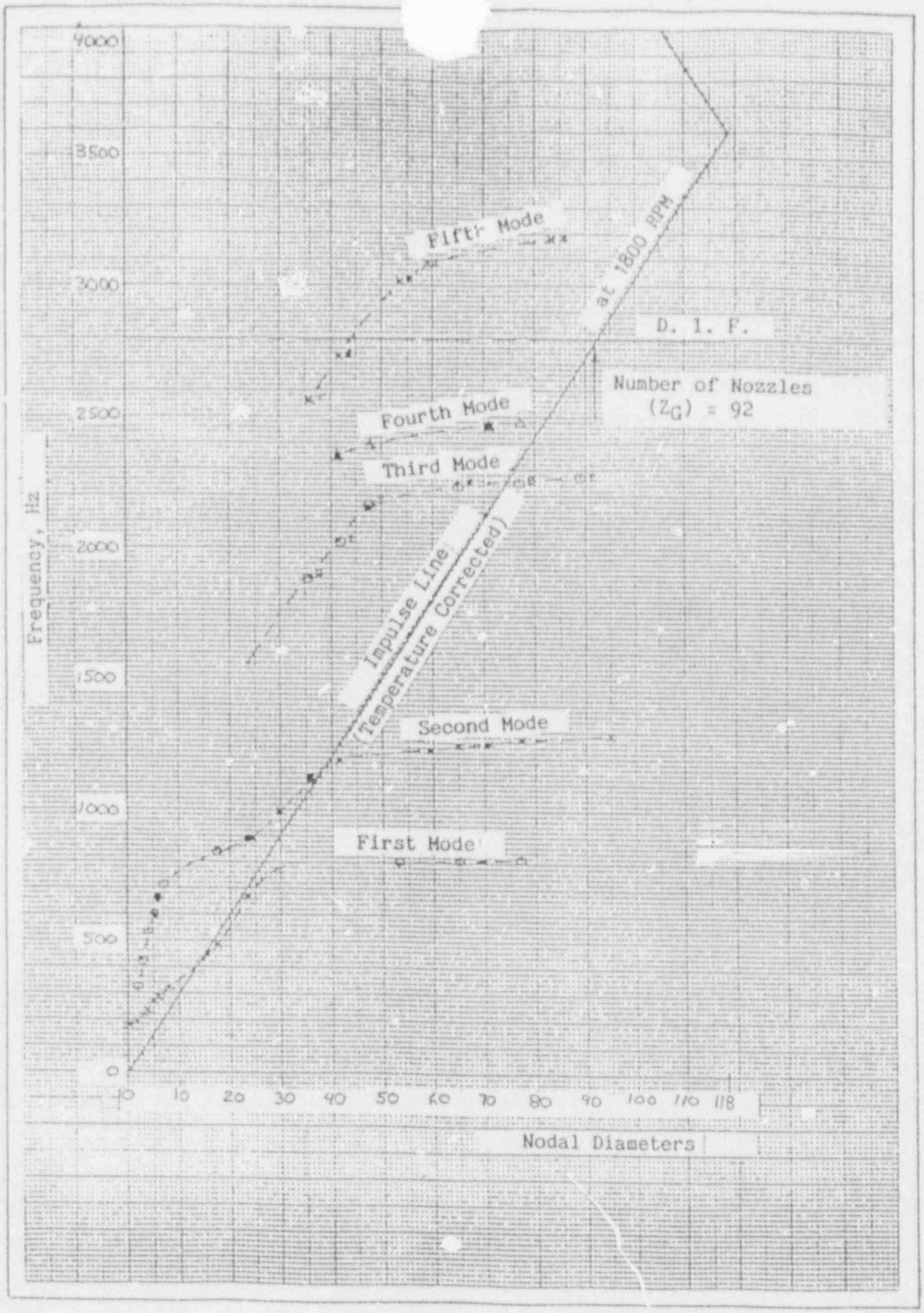
Before and After
Vibration Characteristic Diagrams

Low Pressure Turbine - Fifth Stage

Figure 1 Results of Vibration Tests on Stationary Rotor - Original Design

Figure 2 Predicted Vibration Characteristics at 1800 RPM

Figure 3 Results of Vibration Tests on Stationary Rotor - Current Design

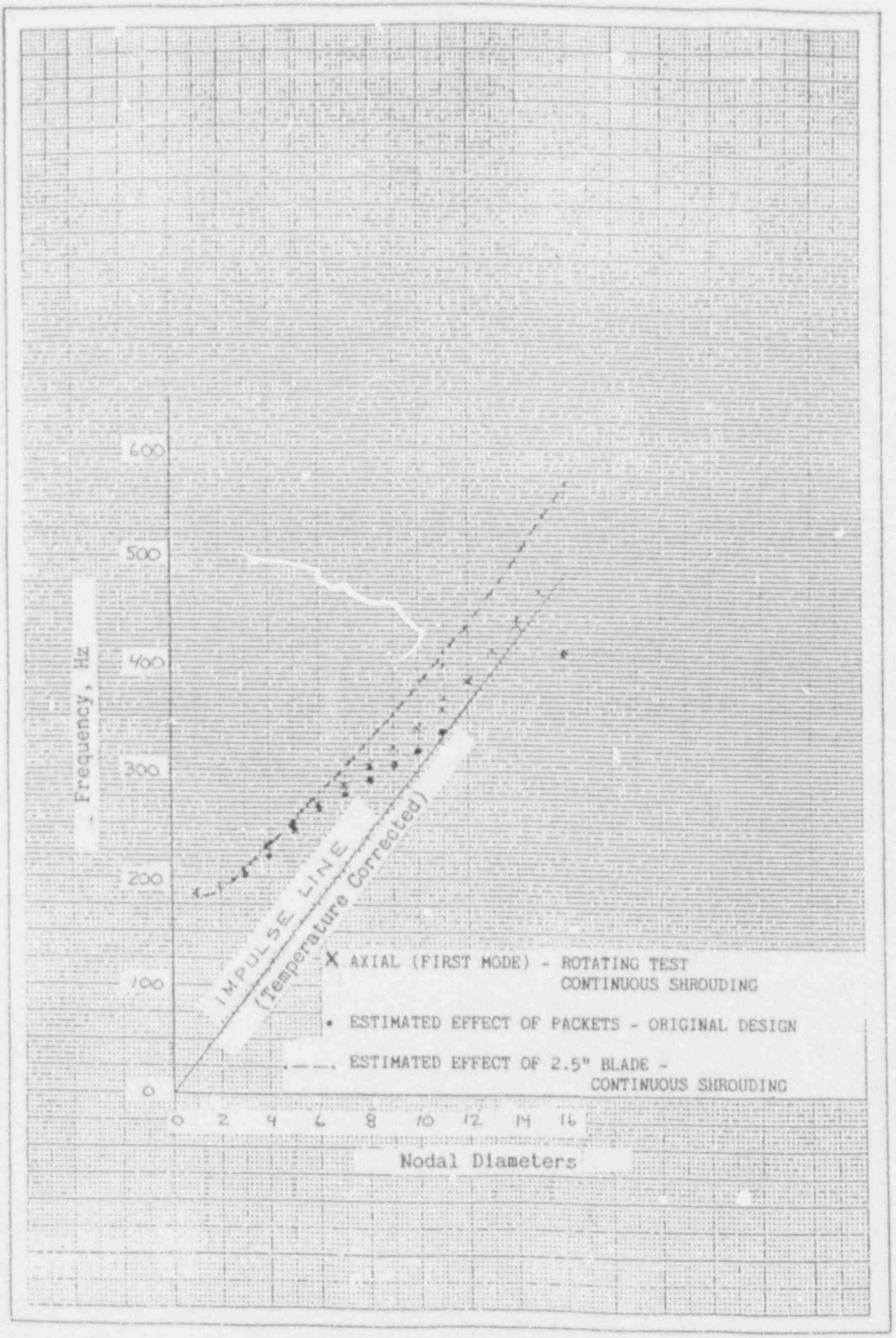


ENRICO FERMI SET 2: LP2 TURBINE END: STAGE 5

RESULTS OF VIBRATION TESTS ON STATIONARY ROTOR

ORIGINAL DESIGN

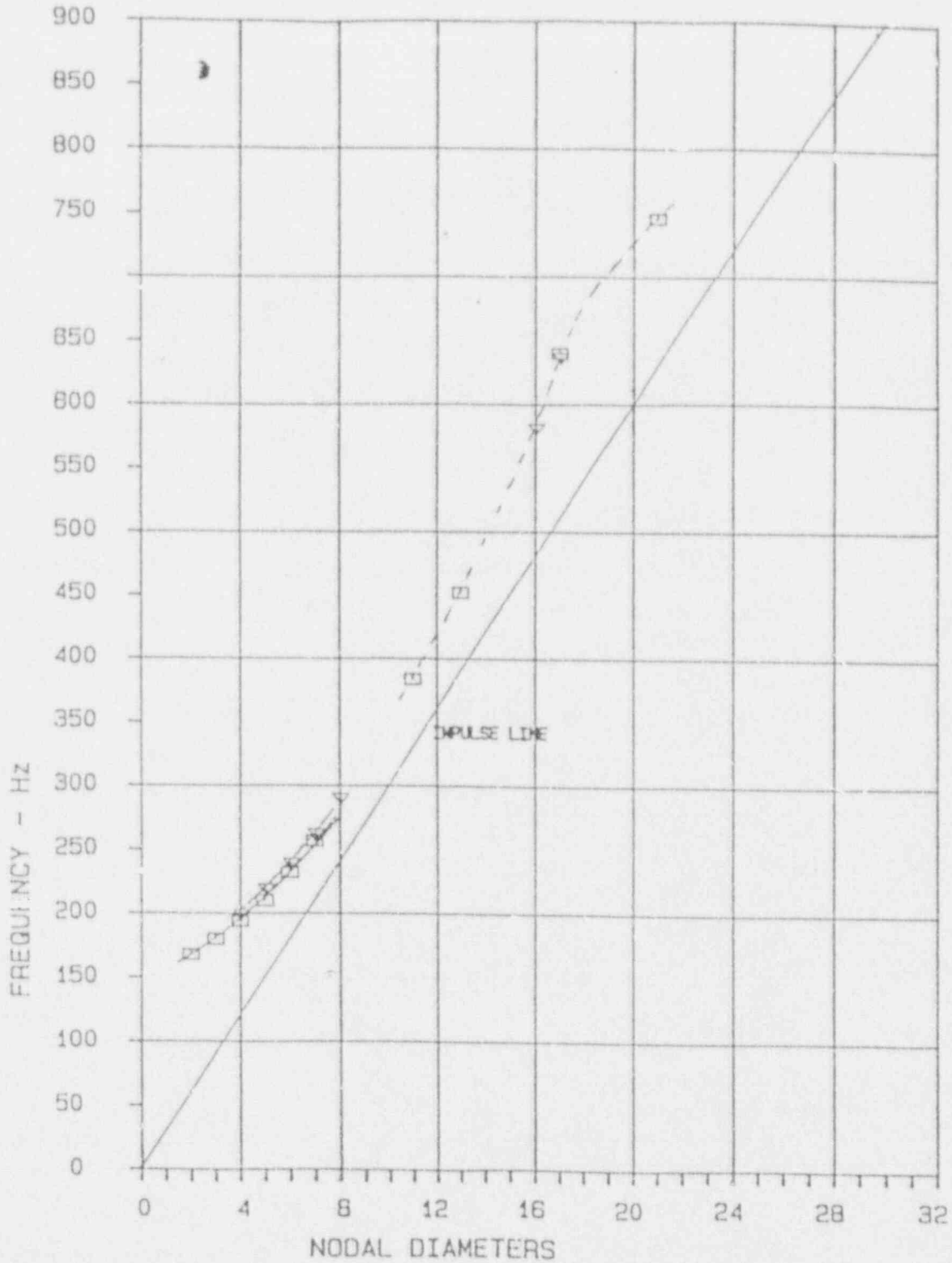
FIGURE 1



ENRICO FERMI L.P. STAGE 5

PREDICTED VIBRATION CHARACTERISTICS AT 1800 RPM

FIGURE 2



FERMI 2 : STATIC VIBRATION TESTS : MAY 1991

STAGE 5LP : FIRST FAMILY DIAMETRAL MODE

□ LP2 GENERATOR END

▽ LP3 TURBINE END

RESULTS OF VIBRATION TESTS ON STATIONARY ROTOR

CURRENT DESIGN

FIGURE 3