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NONDESTRUCTIVE EXAMINATION

LP1, LP2, AND LP3 TURBINE ROTOR DISKS

ENRICO FERMI UNIT 2

DETROIT EDISON COMPANY

JUNE 6, 1994

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B/10

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1.0 SUMMARY

The disc bores and dowel drive pins of the low pressure turbines (LP1, LP2, and LP3) of Detroit Edison's Fermi Unit #2, were ultrasonically examined from May 6, through May 18, 1994 at the Westinghouse Turbine/Generator shop in Charlotte, NC by Wesdyne International Inc.

This report defines the results of the examinations; LP1 in Section A, LP2 in Section Band LP3 in section C.

LP1 ROTOR

Six indications were noted on the disk bore areas of disks 5G, and 3G,. All noted indications appear to be <.050" in radial depth. See Table A for a listing of indications.

No indications were reported on the dowel drive pins.

LP2 ROTOR

Four indications were noted on the disk bore areas of disks 4T, 2T, and 1T,. All noted indications appear to be <.050" in radial depth. See Table B for a listing of indications.

No indications were reported on the dowel drive pins.

LP3 ROTOR

Four indications were noted on the disk bore areas of disks 3T, 1T, and 2G. All noted indications appear to be <.050" in radial depth. See Table C for a listing of indications.

No indications were reported on the dowel drive pins.

2.0 DISC ULTRASONIC INSPECTION METHODOLOGY

The ultrasonic inspection of LP turbine shrunk on disk bores and drive pins is geometrically complex, but an ultrasonically simple task. Ultrasonically, the materials are quiet, acoustically non-dispersive ferritic steel forgings.

The geometric complexity imposed by the design of the individual disks create a number of problems. The major problems to be overcome are:

- Design and fabrication of a multiple degree of freedom scanner that permits manipulation of the transducers over as large a fraction of disk surfaces as possible.

- Proper selection of transducer wedge and/or skew angles.

- Observation of as much of the disk bore and drive pin surfaces as possible. There may be "dead zones", areas of non-observation along the axial extent of some disks. Although it is not always physically possible to observe one hundred percent of all disk bore surfaces or drive pins these areas were 100% examined on the Fermi LP disks.

The scanner/manipulator is mounted on a scaffold platform and the turbine is rotated passed the transducers. Thus, circumferential bands of observation are made, 360 degrees around the turbine. Pulse echo techniques are used under the hub and trough areas, pitch/catch techniques are used in the mid plane of the web; e.g. the plane of the disk. Pulse echo techniques may also be used in selected web faces. These later observations are not as sensitive when made from the surfaces that are inclines at less than ten (10) degrees with respect to the mid plane of the disk.

The disk bore surfaces and the dowel drive pins were each examined with the sound beam aimed in a clockwise and then a counter clockwise direction with an approximate 45° angle to the areas of interest. Additionally the pin areas were examined with an approximate 80° angle. See following Figures 1, 2, and 3 for examples of data from each type of scan.

A few definitions are in order. The turbines were examined as looking from the generator end toward the turbine end. Clockwise and counterclockwise senses of rotation are defined from this viewpoint. The definition of terms is aided by Figure 1 in the Appendix.

The angles used and angles of incidence employed are shown in the accompanying Table 1 of the Appendix.

The data were digitized and fully recorded using the UDRPS 2 system. These data form a permanent record of the inspection for future reference. The data were reviewed and analyzed for presence of indications and nature of the indication and dimensions.

The accuracy of sizes assigned to indications is limited by a number of factors. Among these are:

- Minimum resolution element of the data collection:

- The transducer response characteristics limit depth resolution to .031 inches. Depth resolution cell size was 0.028 inches. The digitization of the data was set to match this inherent limit. The sampling rate in the direction of travel was set by a combination of factors. Each recorded ultrasonic pulse, represents an average of four consecutive pulses. Each average pulse was recorded at an interval of 0.030 to 0.036 inches of transducer travel as measured on the ID surface of the disk depending on the specific data set.

These dimensions define the limits of resolution independent of all other factors. Other uncertainties exist which may contribute to sizing errors. Among these are:

- Inaccuracies in image display scaling factors and rotor physical dimensions.

- Errors in assigning an association between tip diffraction and corner trap signals. That is, indications are detected by reflections from the intersection of the crack and the disc surface (the corner trap). The tip diffraction signal must be located closer to the transducer, approximately radially aligned or displaced toward the edge of the keyway for indications on the extreme of keyways. Clear association between a tip diffraction and a corner trap signal can be inferred but not positively proven from the data.

Sizing of indications is primarily done with the tip diffraction method. Although the tip diffraction method is the most accurate sizing means, not all cracks exhibit tips. Because of this provisions have to be made for sizing and are generalized into three classes:

The class of highest confidence is that when a clear corner trap and top signal are observed in the angle beam data and a "zero degree tip" signal is also observed.

If the former two signals are observed in the angle beam data, but nothing is present in the zero degree data, the indication is either very shallow or not multiple branched. Confidence in sizing is reduced, but the detection remains firm. When a tip signal is observed, but no corner trap, some confidence in detection and sizing is lost. Indications originating on the curved top of the pin (near the edge) can exhibit this behavior in the angle beam data due to the fact that the corner trap may not be illuminated.

The second class of indication is that where no tip signal is observed but the corner trap signal is clearly of greater amplitude response than the ID roll. Reported size for these types of indications is calculated on an amplitude based model using the following points:

1) amplitude is not in general a measure of size
2) keyway cracks have fixed orientation, therefore amplitude is a measure of surface area
3) the model is limiting to comparing areas of two reflectors based on amplitude
4) the reflector used as a basis is an assumed ID roll reflector of 0.030".

Thus the formula for reported depth is:

$$D=\sqrt{\frac{amp1}{amp2}\times 2.25\times 10^{-4}}$$

where:

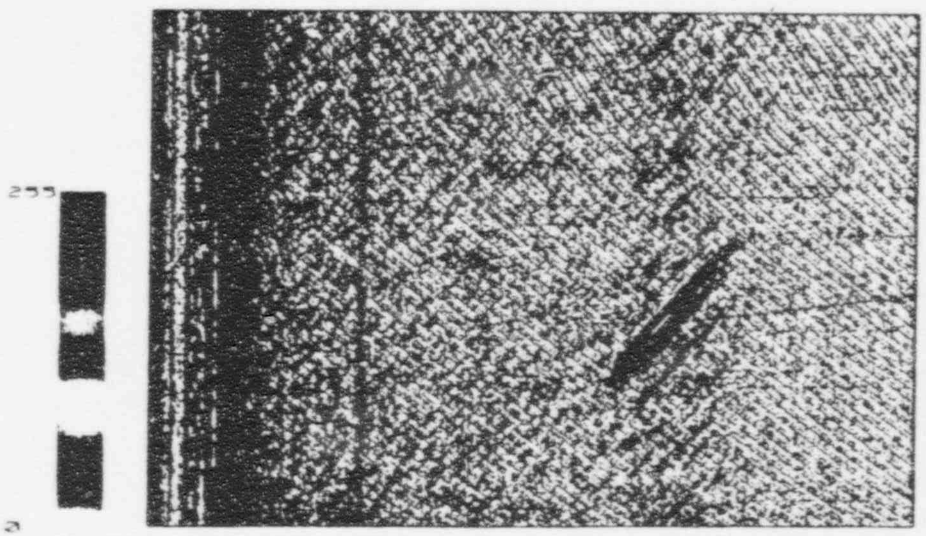
D = depth of indication
a1 = signal amplitude of indication
a2 = signal amplitude of ID roll

The third class of indication is again where no tip signal is observed but the corner trap signal is either saturated and or spatially longer than the ID roll. In this case the size is estimated by comparing it to a database of indications which has been collected from inspections and subsequently the disk destructively tested for validity.

Thus, sizing accuracy in general is estimated to be +0.00" to +.125". The later due to possible gross over estimates of tip signals that are not actually associated with a corner trap. Individual sizing accuracies, may differ from this general estimate, and is noted where the data so indicates. The axial coverage obtained in the data has also been estimated at near 100%. Here a criteria of -12 decibels drop from the beam center has been used. This criteria may be somewhat conservative due to the high gains employed in the data collection.

Data File : /data2/DHST02B
Time Stamp: Sun May 08 1994
Pulse Echo:
Raw Data : Sweep 2
1 0 Inch SML 1

TYPICAL DISK BORE
(ID ROLL) SIGNAL



DISK BORE INDICATION
<.050" RADIAL DEPTH

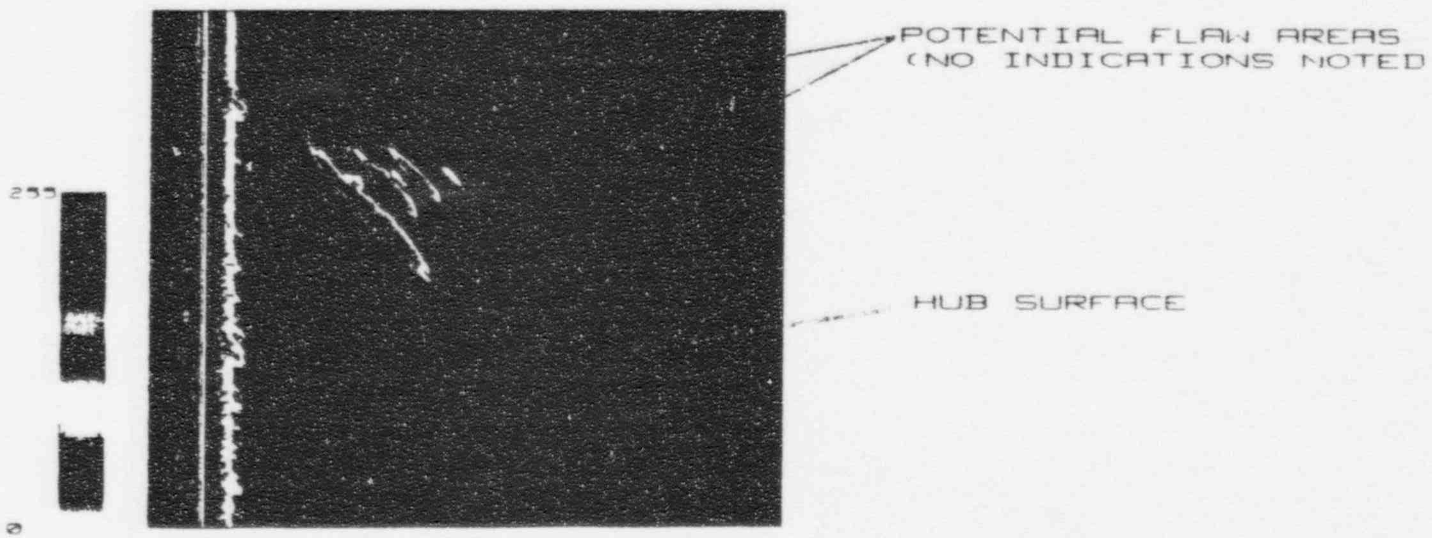
(C) DSI 1990-1993; REV 2.6

FIGURE 1

2.790 ...
Withheld from Public Disclosure

Data File : /data2/DFL1043B   Part Number : DETROIT EDISON
Time Stamp: Mon May 16 1994   IRP : FERM.
Pulse Echo: Zone Number :
Raw Data : Sweep 1   Serial Number: 3-IN-T-PIN
1.0 Inch SML 1

TYPICAL RESPONSE
FROM DRIVE PIN WITH 45 DEG.
SEARCH UNIT



(C) DSI 1990-1994; REV 3.0

Figure 2

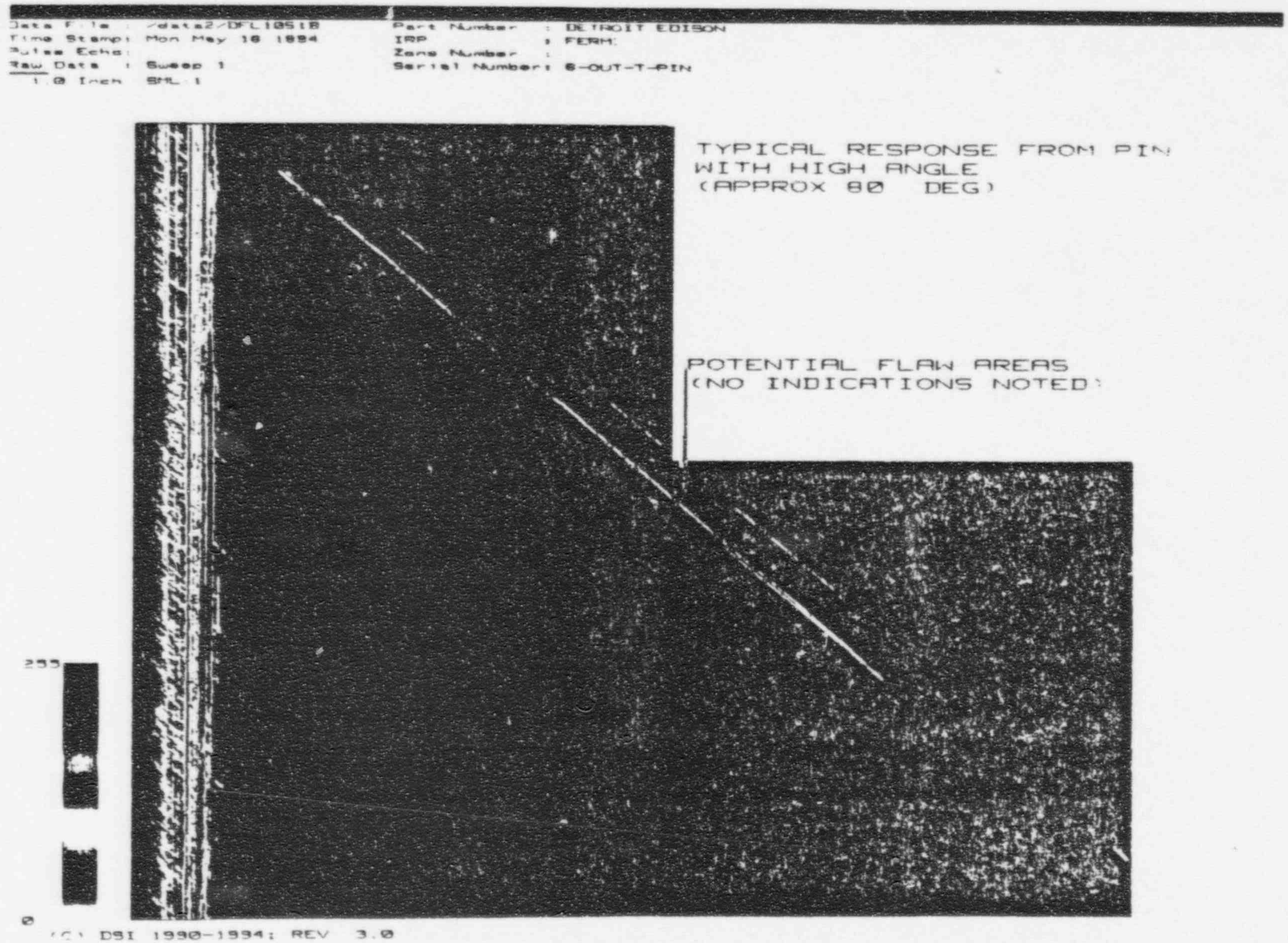

Data File : /data2/DFL10518
Time Stamp: Mon May 16 1994
Pulse Echo:
Raw Data : Sweep 1
1.0 Inch SML:1
Part Number : DETROIT EDISON
IRP : FERM:
Zone Number :
Serial Number: 6-OUT-T-PIN
TYPICAL RESPONSE FROM PIN
WITH HIGH ANGLE
(APPROX 80 DEG)
POTENTIAL FLAW AREAS
(NO INDICATIONS NOTED)
255
0
(C) DSI 1990-1994; REV 3.0

Figure 3

3.0 EXAMINATION RESULTS

TABLE A

LP1 INDICATIONS

DISK #	BORE/PIN	INDICATION DEPTH	CIRC. LOCATION	AXIAL LOCATION
6T	No Indications	-		
5T	No Indications	-		
4T	No Indications	-		
3T	No Indications	-		
2T	No Indications	-		
1T	No Indications	-		
6G	No Indications	-		
5G	4 Bore Indications	< .050"	2.7" CCW of 0 Ref.	In area from 0" to 1" from inlet side
		< .050"	59" CCW of 0 Ref.	In area from 0" to 1" from inlet side
		< .050"	13.4" CW of 0 Ref.	In area from 2" to 3" from inlet side
		< .050"	35.9" CW of 0 Ref.	In area from 2" to 3" from inlet side
4G	No Indications	-		
3G	2 Bore Indications	< .050"	4.3" CCW of 0 Ref.	In area from 0" to 2" from outlet-side
		< .050"	18.6" CCW of 0 Ref.	In area from 0" to 2" from inlet side
2G	No Indications	-		
1G	No Indications	-		

Note: CW/CCW defined as looking from the Generator End.
0 Reference is the centerline of #1 bolt hole on the Turbine End coupling.

TABLE B

LP2 INDICATIONS

DISK #	BORE/PIN	INDICATION DEPTH	CIRC. LOCATION	AXIAL LOCATION
6T	No Indications	-		
5T	No Indications	-		
4T	2 Bore Indications	< .050"	88.4" CCW of 0 Ref.	In area from 0" to 1.25" from inlet side
		< .050"	95.5" CCW of 0 Ref.	In area from 0" to 1.25" from inlet side
3T	No Indications	-		
2T	Bore Indication	<.050"	80.5" CCW of 0 Ref.	In area from 0" to 1.25" from outlet side
1T	Bore Indication	< .050"	72.5" CCW of 0 Ref.	In area from 0" to 3" from outlet side
6G	No Indications	-		
5G	No Indications	-		
4G	No Indications	-		
3G	No Indications	-		
2G	No Indications	-		
1G	No Indications	-		

Note: CW/CCW defined as looking from the Generator End of the rotor.
0 Reference is a "0" stamped on the Generator End coupling.

TABLE C

LP3 INDICATIONS

DISK #	BORE/PIN	INDICATION DEPTH	CIRC. LOCATION	AXIAL LOCATION
6T	No Indications	-		
5T	No Indications	-		
4T	No Indications	-		
3T	Bore Indication	< .050"	8.0" CCW of 0 Ref.	In area from 0" to 2.0" from outlet side
2T	No Indications	-		
1T	Bore Indication	< .050"	50.5" CCW of 0 Ref.	In area from o" to 2.0" from outlet side
6G	No Indications	-		
5G	No Indications	-		
4G	No Indications	-		
3G	No Indications	-		
2G	2 Bore Indications	< .050"	52.0" CW of 0 Ref.	In area from 3" to 5" from outlet side
		< .050"	16.5" CCW of 0 Ref.	In area from 8.3" to 11.3" from inlet side
1G	No Indications	-		

Note: CW/CCW defined as looking from the Generator End of the rotor.
0 Reference is a "0" stamped on the Generator End coupling.

APPENDIX

DISK DIMENSIONS AND SCAN PLAN

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TABLE 1

DISC DIMENSIONS

SCAN PLAN PLANT FERMI UNIT 2 ROTOR LP1, 2, 3

DISC NUMBER	HUB RADIUS	SHAFT RADIUS	FACE ANGLES	DISK WIDTH
1	28 / 38.5	20	0°	18
2	28 / 38	19.5	0° / 20°	19.25
3	28	19	6	12.5
4	28	18.5	9	15.15
5	28	18	19	19.9
6	28	17.5	18	26.4
PINS	DIAMETER	1.6"		
	LENGTH	0.9"		
	DEPTH	0.8"		

I

$$IPP = \frac{\text{Scan Velocity}}{\text{PRF}} \times \text{Recirculations} \qquad IPP = \frac{\frac{\pi(\text{DIA})}{\text{velocity}}}{\text{PRF/Recircs}}$$

to check: $$IPP = \frac{\text{Circumference}}{\text{\# A-Scans}}$$

II Dimensions required from drawings and/or physical measurements:

A. Shaft radius
B. Hub radius
C. Radial offset from shaft to hub or break (H)
D. Disc thickness ($W - Z_1, - Z_2$)
E. Face angles of discs (α)

(See Figure 1)

III To calculate refracted beam angle necessary at the outside surface to obtain a required angle at the ID. (45 degree nominal for disc inspections):

$$SIN^{-1} \{I/O\ (SIN\ A)\} = B$$

Where

I=Inner radius
O=Outer radius (of hub, trough or transducer offset: see Section IV)
A=Required angle
B=Necessary angle

The above formula is also used to calculate the skew angle for web exams with O (outer radius) = the distance to the shaft from the transducer offset as calculated in Section IV.

IV To calculate required angles of the transducer wedges to ensure maximum pitch-catch coverage of the area of interest for WEB exams:

$$\theta = TAN^{-1}\left\{\frac{2(X + H)}{W - Z_1 - Z_2 - 2Tan\alpha(x)}\right\} - \alpha$$

(See Figure 1)

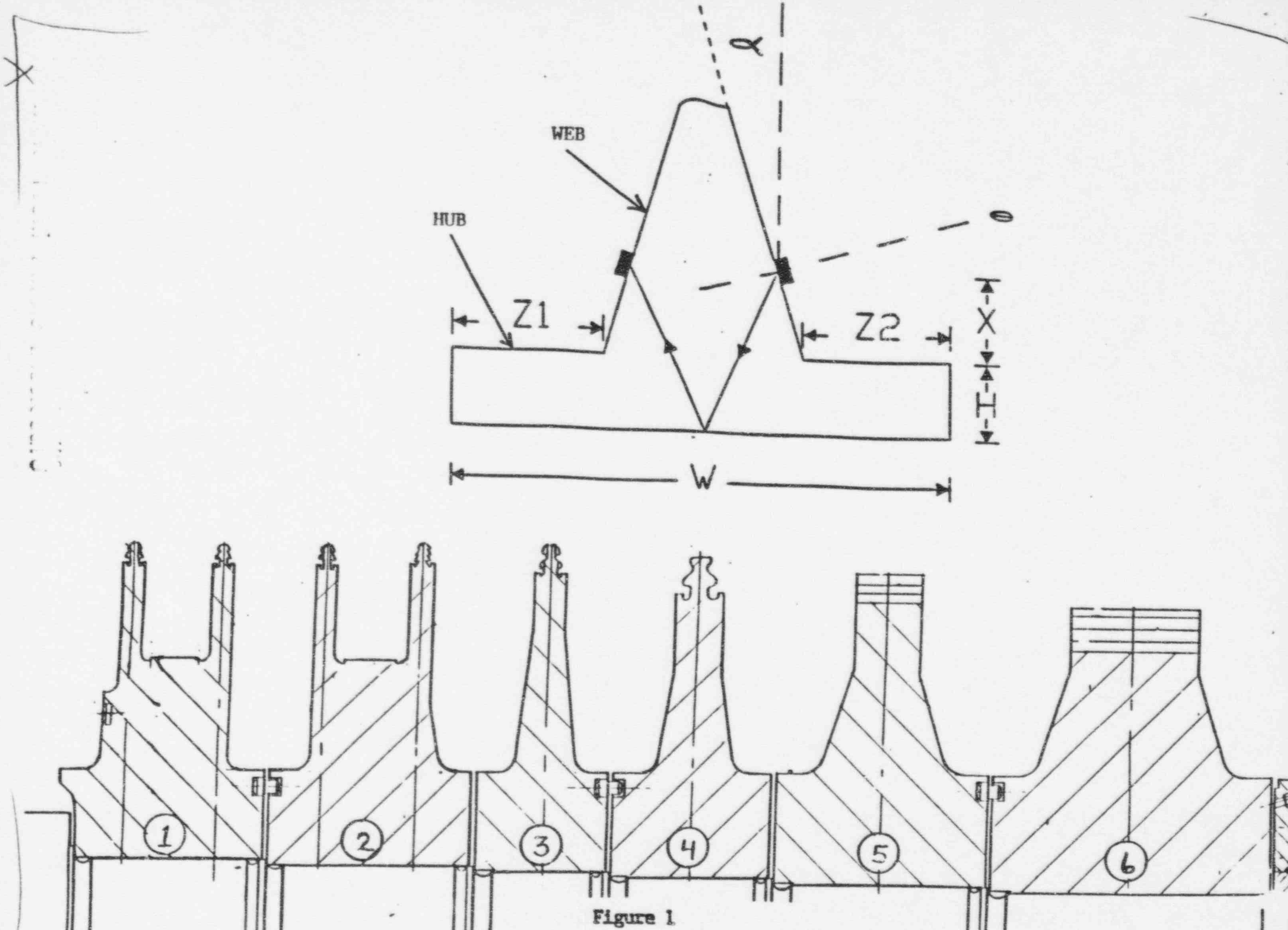

Figure 1
Required Dimensions

TABLE 2

Scan Plan   Plant FERMI   Unit 2   Rotor LP1, 2, 3

DISC NUMBER	SIDE	EXAM TYPE	WEDGE ANGLE	SKEW ANGLE	RADIAL OFFSET	AXIAL POSITION
1	O	HUB(PIN)	64(73)	N/A	HUB	2.0
	I/O	HUB(PIN)	43(47)	N/A	HUB	.5, 1.0
	I/O	HUB	30(44)	N/A	HUB	1.0, 2.0
	I/O	P/C	60	28.1	2.0	℄
2	I/O	HUB(PIN)	64(73)	N/A	HUB	.5, 1.0
	I/O	HUB(PIN)	43(47)	N/A	HUB	.5, 1.0
	I/O	HUB	30(46)	N/A	HUB	1.0, 2.0
	O	PE	73	27.4	2.0	375
	O	PE	73	24.2	5.6	5.1
	I	PE	80	26.4	3.0	6.0
	I/O	P/C	60	27.4/24.2	2.0/5.6	℄
3	I/O	HUB(PIN)	70(83)	N/A	HUB	.5, 1.0
	I/O	HUB(PIN)	43(46)	N/A	HUB	.5, 1.0
	I/O	HUB	30(47)	N/A	HUB	[illegible]
	I/O	PE	80	26	2.5	[illegible]
	I/O	PE	80	21.6	8.5	[illegible]
4	I/O	HUB (PIN)	70(83)	N/A	HUB	[illegible]
	I/O	HUB (PIN)	43(46)	N/A	HUB	[illegible]
	I/O	PE	80	25.9	2.0	[illegible]
	I/O	PE	80	22.7	5.9	[illegible]
	I/O	P/C	64	25	3.0	[illegible]
	I/O	HUB	43(46)	N/A	HUB	1.0, 2.0

TABLE 2

Scan Plan   Plant FERMI   Unit 2   Rotor LP1,2,3

DISC NUMBER	SIDE	EXAM TYPE	WEDGE ANGLE	SKEW ANGLE	RADIAL OFFSET	AXIAL POSITION
5	I/O	HUB (PIN)	70(83)	N/A	HUB	.5, 1.0
	I/O	HUB (PIN)	43 (46)	N/A	HUB	.5, 1.0
	I/O	HUB	27.5(46	N/A	HUB	1.0, 2.0
	I/O	PE	73	24.8	2.3	4.4
	I/O	PE	73	21.4	6.9	6.0
	I/O	P/C	50	23.4	4.0	℄
6	I/O	HUB(PIN)	70 (83)	N/A	HUB	.5, 1.0
	I/O	HUB(PIN)	43(46)	N/A	HUB	.5, 1.0
	I/O	HUB	30 (48)	N/A	HUB	1.0, 2.0
	I/O	PE	73	23.4	3.1	5.0
	I/O	PE	73	19.8	8.3	6.75
	I/O	PE	64	19.8	8.3	[illegible]
	I/O	P/C	50	21.3	6.0	℄