Final Report

NASA CR-179503

Fabrication of Cooled Radial Turbine Rotor

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SOLAR TURBINES INCORPORATED

Final Report

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Fabrication of Cooled Radial Turbine Rotor

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Under Contract NAS3-22513
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16. Abstract

A design and fabrication program was conducted to evaluate a unique concept for constructing a cooled, high-temperature radial turbine rotor. This concept, called "split blade fabrication" was developed as an alternative to internal ceramic coring. In this technique, the internal cooling cavity is created without flow dividers or any other detail by a solid (and therefore stronger) ceramic plate which can be more firmly anchored within the casting shell mold than can conventional detailed ceramic cores. Casting is conducted in the conventional manner, except that the finished product, instead of having finished internal cooling passages, is now a "split blade." The internal details of the blade are created separately together with a carrier sheet. The inserts are superalloy. Both are produced by essentially the same software such that they are a net fit. The carrier assemblies are loaded into the split blade and the edges sealed by welding. The entire wheel is Hot Isostatic Pressed (HIPed), braze bonding the internal details to the inside of the blades. Subsequently, the weld bead is removed, exposing the steel carrier which is leached away in an acid bath, leaving the superalloy details.

During this program, two wheels were successfully produced by the split blade fabrication technique. One of these wheels was successfully thermal shock, spin, and flow tested, and conformed to all dimensional and design requirements.

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EXECUTIVE SUMMARY

This program was concerned with the evaluation of a new concept for manufacturing air cooled blades called "split blade fabrication"*. The split blade manufacturing procedure was developed as an alternative to internal ceramic coring. In this system the internal cooling cavity is created without flow dividers or any other detail by a solid (and therefore stronger) ceramic plate which can be more firmly anchored within the casting shell mold than can conventional detailed ceramic cores.

Casting is conducted in the conventional manner, except that the finished product, instead of having finished internal cooling passages, is now a "Split Blade". The internal details of the blade are created separately together with a carrier sheet. The parts were created on a CAD/CAM wire EDM saw. The carrier is a low carbon steel. The inserts are superalloy. Both are produced by essentially the same software such that they are a net fit. The carrier assemblies are loaded into the split blade and the edges sealed by welding. The entire wheel is Hot Isostatic Pressed (HIPed), braze bonding the internal details to the inside of the blades. Subsequently, the weld bead is removed, exposing the steel carrier which is leached away in an acid bath, leaving the superalloy details.

Two wheels were successfully produced by the split blade fabrication technique. The main detriment to the process in the majority of other attempts was unsatisfactory welding closure of the blade edges (and a lack of reliable pressure testing method) resulting in leakage and unsound bonding in the HIPing operation. Of these wheels, one was successfully thermal shock, spin, and flow tested, and conformed to all dimensional and design requirements.

The rationale for the split blade approach is avoidance of excessive casting rejections in a multi-blade wheel. If the acceptance of a single cast blade is A percent, combining N blades within a single monolithic wheel generates a condition wherein acceptance of the wheel becomes $0.A^N$, often a prohibitively small number, unless A is unrealistically high. A number of conventionally cored bladed wheels procured (together with the split blade wheels) yielded no perfect castings and a projection of only about 5% in further production. The split bladed castings were 100 percent acceptable.

The second advantage of the evaluted manufacturing technique is the ease with which the design of the cooling passages can be modified, requiring only changes in the software which creates the flow dividers and carriers. Changes,

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*Patent application in process.

in conventional coring require, in most cases, alteration of hard tooling required to create the detailed ceramics.

In summary, production of multi-bladed wheel casting by the split blade technique proved to hold a significant advantage over conventionally cored wheel castings. The techniques for creating internal details within the split blade were shown to be sound in concept but suffering from reliable welding (and weld testing) procedures.

1

INTRODUCTION

The objectives of this program were to design, fabricate, and test an advanced air-cooled radial turbine wheel. Design constraints included the following as specified by NASA:

- 2.25 kg/sec (5 lb/sec) primary flow
- 190 newtons/cm^2 (280 psia) turbine inlet and coolant inlet pressure
- 745 kW (1000 hp) shaft power
- 780°K (950°F) cooling air temperature
- 0.45 kg/sec (1 lb/sec) maximum cooling air flow for stator and rotor
- 1500 hour life
- Rotor inlet temperature as close as possible to 1900°K (2960°F) with a minimum of 1600°K (2420°F)
- Convective cooling with the majority of ejection from the blade trailing edges

Five fabrication methods all involving casting were analyzed as to ease and cost of fabrication, and structural integrity. The five methods included three configurations suggested by NASA and two by Solar:

1. NASA Configuration 1 - Pie Slices. Cast identical rotor segments, equal in number to the number of blades, each of which includes the suction side of one blade, the hub segment, and the pressure side of the adjacent blade. The internal blade cooling passage would be integral with either or both sides of the blade. The joining surface between adjacent segments would lie within the blade and would approximate a mean camber surface with radial or near-radial elements.

2. NASA Configuration 2 - Cover Plates. Cast a monolithic rotor that includes all but one side of each blade. The mating blade sides would be cast separately and bonded to the rotor. The internal blade cooling passages would be cast into either or both surfaces.

3. NASA Configuration 3 - Radial Plane Sections. Cast the rotor in two or three parts, one including the radial-flow portions, and the other(s) the axial-flow portion.

4. Solar Configuration 4 - Split Blades and Inserts. Cast a monolithic rotor but one in which each blade is divided into two sections, pressure and suction sides, by a relatively thick, plain, ceramic core which can be anchored in the investment; (1) within the hub, at the (2) leading and (3) trailing edges, and (4) on the outer periphery of the blades, i.e., virtually entirely around. Subsequent to casting and removal of the core, a steel matrix fitted with superalloy insert pin fins, trip strips, and flow directors would be slipped into the split blade, welded gas tight around the periphery, and HIPed at the appropriate times, temperature and pressures to effect a liquid interface bond of the various inserts to the blade surfaces. Final leaching of the casting in appropriate acids would remove the steel matrix, opening the cooling passages, while leaving the inserts bonded in place.

5. Solar Configuration 5 - Segmented Blade Sections. Cast individual segmented sections, each comprised of a radial blade, an endwall platform, and a shank ending in a dovetail type of attachment to a central forged hub.

The initial tasks were the selection of method by design and analysis together with generation of enough fabrication data to perform the essential trade-offs with design. Principal considerations were:

- determination of velocity diagrams
- aerodynamic design of the rotor
- selection of the rotor material
- selection of the cooling configuration
- mechanical and thermal analysis of the rotor
- detailed mechanical design of the rotor
- joint strength

Subsequent work included casting and fabrication by the selected methods. Prototype wheels were produced and tested for cooling air flow, structural integrity, and by cold and hot spin tests.

Solar personnel involved in the program included: Dr. Arthur Metcalfe, Program Director; Alvin Hammer, Program Manager; George Aigret, Thermal Analysis; Tom Psichogios, Stress Analysis; and Colin Rodgers, Aerodynamic Design.

2
DETERMINATION OF PROGRAM DIRECTION

2.1 DESIGN CONSIDERATIONS - CASTING

A preliminary design was formulated for the aerodynamic shape and cooling passages applicable to the design constraints. The wheel has 10 blades, is 16.5 cm (6.5 in.) in diameter, and has a speed of 65,000 rpm. Table 1 presents preliminary data as to this design in comparison to other recent air-cooled rotors. Figure 1 shows a schematic representation of the wheel.

A meeting was held with technical and sales representatives of the foundry to discuss the five manufacturing approaches under consideration. The foundry reaffirmed the dificulty of attempting to cast a 10-bladed, monolithic rotor with cooling passages generated by internal ceramic coring. Unless the cores can be securely anchored at most edges the danger that one of the ten will slip creates odds which are prohibitive to economical production. NASA Configuration #3, Radial Plane Sections, more than halves the odds of this happening since the shorter cores can be supported in the investment much more securely.

Similarly, the foundry felt that the split blade approach offered significant advantages in that the core can be very securely anchored in the investment. There is a further advantage in that the positions of strip trips, pin fins, and cooling passages can be revised at will, without recourse to altering ceramic core tooling.

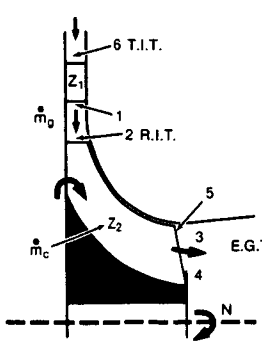
The third approach which the foundry favored was segmented blade sections. The fact that the blades are cast individually eliminates the chance that one bad blade can scrap an entire 10 blade wheel. This approach also has much to recommend it in facilitating cooling of the hub sections.

Of the several NASA- and Solar-suggested configurations there was general agreement that the best approach was the radial plane method, i.e., casting the wheel as separate star wheel and exducer sections. The exducer section can be produced using conventional ceramic cores for the internal cooling passages. The star wheel section is less easily produced by this method and the risk factor was estimated as high as 300%, e.g., casting 40 parts to get 10 good ones. Conventional monolithic, uncored wheels of about the same size, have a risk factor of only about 10% and a price of about $300 each in quantity production. Although no specific numbers or risk factors were assigned, the consensus of opinion was that fabrication of the star wheel portion by the split blade method would improve the chances of recovery. Conversely, the foundry estimated lower risk in producing the exducer with contoured ceramic cores.

Table 1

High-Temperature Cooled Radial Turbines

	Units	P.W.A.-AVLABS	Allison-AVRADCOM	Solar-NASA-Lewis
Reference	--	Okapuu-Calvert (AGARD 1970)	Monson-Ewing (1980)	Rodgers-Hammer-Aigret-Psichogios Conf 1 10-21-80
T.I.T. - Total temperature T_{00}	°F	2300	--	--
R.T.T. - Total temperature T_{02}	°F	2225	2300	2800
EGT	°F	1462	1730	2336
Enthalpy drop Δh	Btu/lb	219.6	171	139.6
Total pressure P_{00}	psia	257.5	172.0	280.0
Total pressure P_{03}	psia	50.0	52.14	128.8
Diameter D_2	in.	7.896	8.71	6.50
Diameter D_{3s}	in.	4.7	5.534	4.25
Diameter D_{3h}	in.	2.0	2.400	2.40
Blade tip height b_2	in.	0.38	0.438	0.30
Vane number Z_1	--	20	--	21
Blade number Z_2	--	12	12	10
Speed N	rpm	67,000	54 862	65,000
Tip speed U_2	ft/s	2,308	2,085	1,844
$U_2/c_{spouting,\ isentr.}$	--		0.67	0.65
$U_a/\sqrt{T_{02}}$	ft/S R^2	44.5	39.7	32.3
Gas flow rate $\dot{m}_g$	lb/s	4.9	5.20	4.933
Flow function $\dot{m}_g\sqrt{T_{02}}/P_{02}$	lb $R^{1/2}$/S psia	0.986	1.588	1.006
Shaft power	HP	1 522	1,258	974
Blading coolant flow ratio $O_g = \dot{m}_c/\dot{m}_g$	--	0.03	0.030	0.10
Bore and hub coolant flow ratio $O_g = \dot{m}_c/\dot{m}_g$	--	--	0.015	0.03
Coolant, in temperature	°F	850	800	950
Cooling scheme	--	2 passes, smooth	2 passes, smooth	
$A_{ann,3}N^2$	$(ft/min)^2$	443.10^6	408.10^6	284.10^6
Material	--	cast In-100	. airfoils assy; cast MAR-M247 . hub: PA101 PM	In-792
Design Life	hrs	?	1000 (100%) +6000 cycles	1,500
Results	--	fabrication problems; tested at 2045°F, at reduced rpm - waiting for final report	successful fabrication; 6000 cycles + spin test completed	
Specific speed N_S	$\left(\frac{ft.lbm}{lb_f}\right)^{3/4}\frac{1}{min.s^{1/2}}$	<66	65	63
Specific dia. D_S	$\left(\frac{lb_f}{ft.lb_m}\right)^{1/4} s^{1/2}$	1.66	1.60	1.61
Casting data				
Tip-L.E. thickness	in.		0.090	0.10
T.E. thickness	in.		0.052	0.10
Min. wall thickness	in.		0.025	0.025
Core thickness	in.		0.040 to 0.12	≥0.050



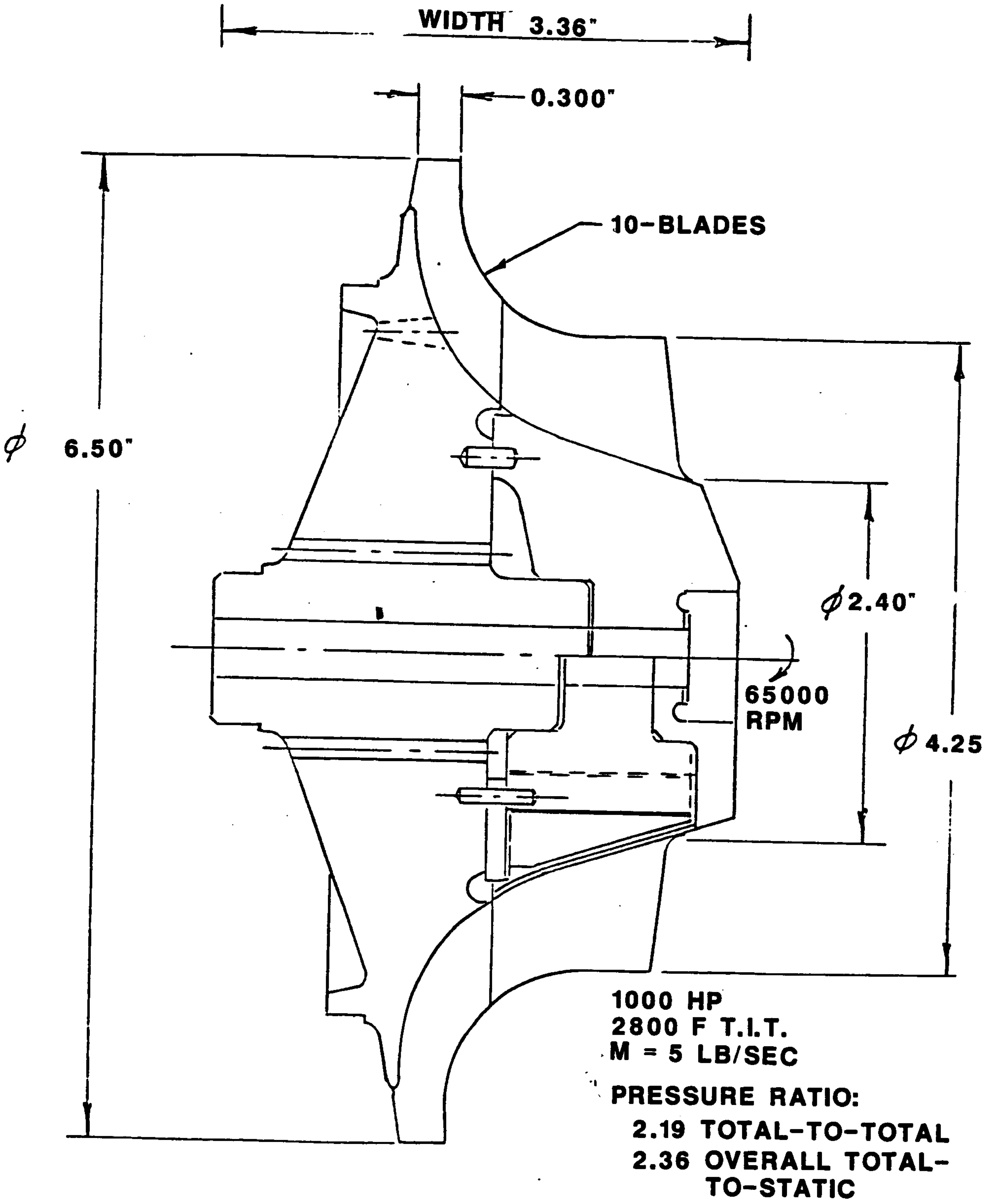


Figure 1. Air-Cooled Radial Turbine (Full Size)

Ceramic coring for the star wheel cooling passages is relatively more fragile than that for the exducer. It was decided, therefore, to proceed with split blade fabrication. The use of solid ceramic cores to produce split blades reduces the risk of rejection to the point where the castings can be made as monolithic units.

2.2 ECONOMIC CONSIDERATIONS

Table 2 is a compilation of costs quoted by several machining and assembly vendors for manufacture of the rotor by any of four methods, i.e., individually bladed exducer versus monolithic, and fabricated star wheel cooling passages versus cast-in-place. Also included are the quotations for ten castings of each of the various types received from the foundry, but no quotes could be obtained for larger quantities. These quotations are for best effort only and it is speculative as to what the costs would be for guaranteed production quality in larger amounts.

Based upon these data (and previously described casting considerations) it was decided to proceed with development of monolithic, rather than separately bladed, dual star wheel and exducer. The internal cooling passage would be cast into the exducer and fabricated in the star wheel. A number of star wheels with cast cooling passages also subsequently were ordered (at Solar expense) to verify casting production yield.

Table 2

Radial Air-Cooled Turbine Wheel Estimate

Part No.	Title	Part Cost - Qty 10			Part Cost - Qty 200+			Tooling		
		Material	Machining	Total	Material	Machining	Total	Casting	Machining	Total
1 131453-100	Rotor Assy, Cast Star Wheel - Assy		83	83	--	83	83			
131454-2	Turbine-Star Wheel	2000	480	2480	N/Q	397	--	65,920	8,500	8,500
131455-2	Exducer	1500	373	1873	N/Q	294	--	75,840	4,600	70,520
952137C2	Dowel Pin (2)	--	12	12	--	12	12	--	3,500	79,340
	TOTAL	3500	948	4448		786		141,760	16,600	158,360
2 131543-300	Rotor Assy, Cast Star Wheel, Exducer with Separate Blades - Assy	--	83	83	--	83	83	65,920	8,500	8,500
131454-3	Turbine Wheel	2000	480	2480	N/Q	480	--	63,040	4,600	70,520
131599-2	Blades (10)	2000	702	2702	--	653	--	--	61,450	124,490
131453-1	Dowel Pin	12	--	12	12	--	12	--	--	--
954959C1	Hub Exducer	--	380	380	--	288	288	--	15,800	15,800
954960C1	Ring Exducer	--	206	206	--	113	113	--	--	--
954961C1	Retainer, Exducer	--	145	145	--	95	95	--	--	--
	Assy & Balance Exducer	--	40	40	--	40	40	--	--	--
	TOTAL	4012	2036	6048		1669		128,960	90,350	219,310
3 131453-200	Rotor Assy, Fabricated Star Wheel, Cast Exducer - Assy.	--	83	83	--	83	83	--	8,500	8,500
131103-100	Turbine Wheel	1800	451	2251	--	390	--	59,200	10,300	69,500
131467-100	Insert Blade		550	550	--	370	--	--	3,500	3,500
131455-2	Exducer	1500	373	1873	--	294	--	75,840	3,500	79,340
952137C1	Dowel Pin (2)	12		12	--	12	12		--	--
	TOTAL	3312	1457	4769		1149		135,040	25,800	160,840

3
DETAIL DEVELOPMENT

3.1 CARRIER ASSEMBLY

The carrier assembly, i.e., the leachable component and integral superalloy flow passage dividers, flow straighteners, and trip strips, underwent several evolutions of change before development of the final configuration used for the prototype wheels. The initial configuration, seen in Figure 2, was produced by an electrodischarge machining (EDM) numerically controlled wire saw. The carrier (etchable) portion was low carbon, low silicon enameling steel.

Experiments were conducted in forming trip strips and passage partiitions by plasma spraying grooved and indented steel carriers. The plasma sprayed alloy employed was a NiCrAlY, with an approximate composition of 75 w/o Ni, 19 w/o Cr, and 6 w/o Al.

A second approach to forming the trip strips and partitions was filling the steel carrier grooves and slots with a superalloy/braze alloy powder blend and partially sintering in vacuum, prior to HIP bonding at higher temperature. Reproduction of details by this tehcnique was excellent. Figure 3 shows an example which has been partially acid leached to remove the steel carrier. No pressure was applied in braze bonding the superalloy details to the simulated blade halves, yet near 100 percent density is achieved.

With the addition of some pressurization, about 10 MPa (1500 psi), with a vacuum bellows fixture, the superalloy additions were converted to full density. The results were virtually porosity free and indicate that the actual HIP cycle will achieve a 100 percent dense structure.

Estimates were also sought for production of the carrier (used to hold superalloy inserts in place) as sintered powder metallurgy compacts. If these parts (which are ultimately etched or leached away) are made from molybdenum they would be strong enough during the HIP exposure to support small diameter wires which would serve as trip strips in the inner cooling passages. As a further advantage of moly, we found that it dissolves very readily in a fused salt bath, much more efficiently than does iron or steel in acid. There is no observable effect of the salt bath on the surface of the superalloy castings, as seen in Figure 4, a photomicrograph of a sample IN-792 casting after removal of the moly. The molybdenum can also be removed by exposure to air at temperatures of 760°C (1400°F) or more, but this method is much slower and tends to become ineffective in penetrating more than a fraction of a millimeter between the superalloy sidewalls where there is limited access to a fresh supply of air.

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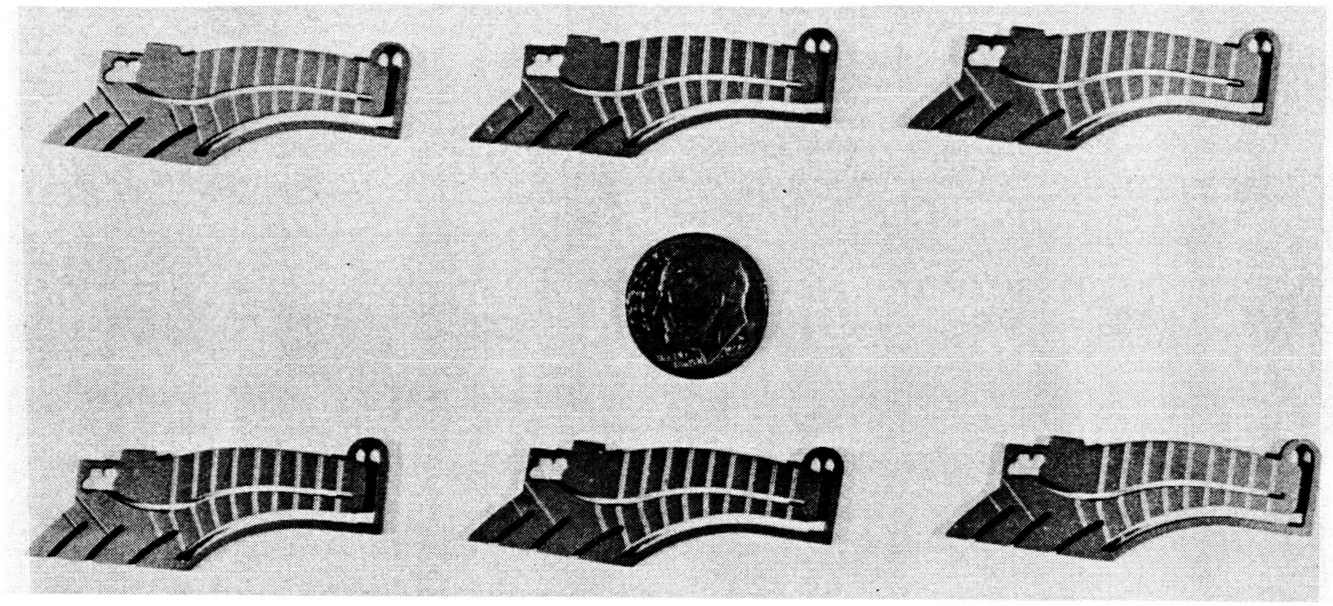

Figure 2. Carrier, Initial Design

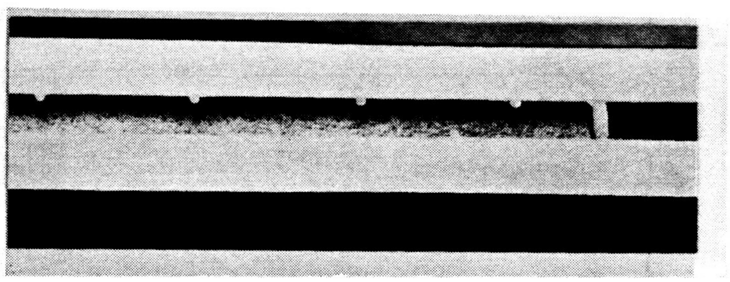

Figure 3. Partially Leached Composite Structure (Mag: 4X)

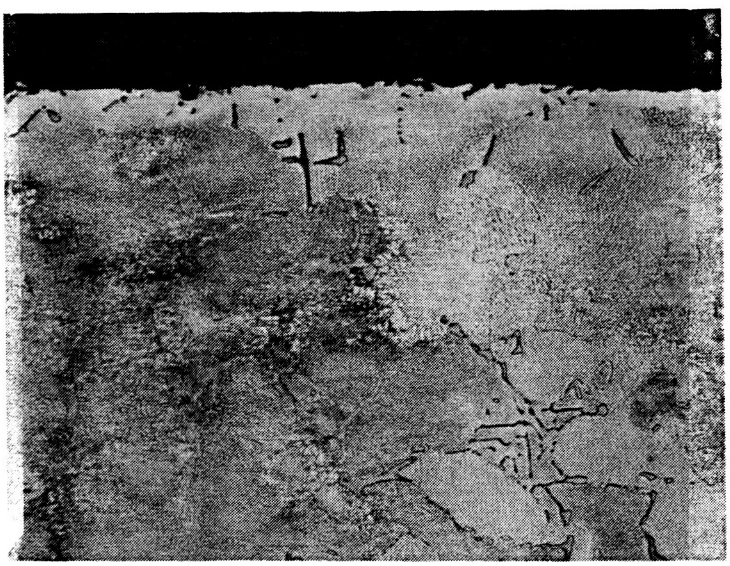

Figure 4.

Photomicrograph of IN-792 Casting Surface Cross Section Showing Negligible Effect of Removal of Molybdenum Carrier by Kolene DGS Fused Descaling Salt

Etchant: Kallings
Magnification: 250X

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Ultimately a procedure was developed, working with the subcontract wire EDM vendor, DATM of Santa Ana, CA, for producing both the steel carrier and the superalloy inserts used in fabrication of the split blade star wheel. Trip strip grooves in the steel carrier were produced by photo-resist chemical milling. In actual practice we decided to also wire EDM the superalloy flow dividers and edge closure from superalloy sheet, fit them into the machined slots, and fill the trip strip grooves with powder metal/braze mixtures. This was accomplished four parts to a panel which were then double disc sanded, both sides, and EDM wire sawed to final shape prior to insertion within the blade cavity.

At about $20 per piece, this system is more expensive than high production stamping and coining, but involves less in the way of hard tooling and is more flexible in terms of design change.

Figures 5 and 6 are photomicrographs showing 100 pecent dense trip strips and flow divider in the mild steel carrier by sintering a mixture of Hastelloy

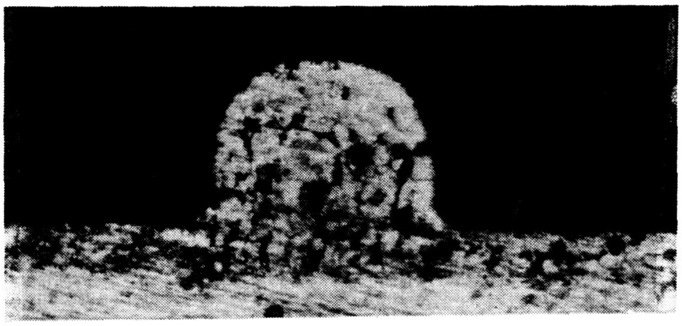

Figure 5.

Trip Strip Formed by Sintered Superalloy/Braze Powder Mixture

(Magnification: 75X)

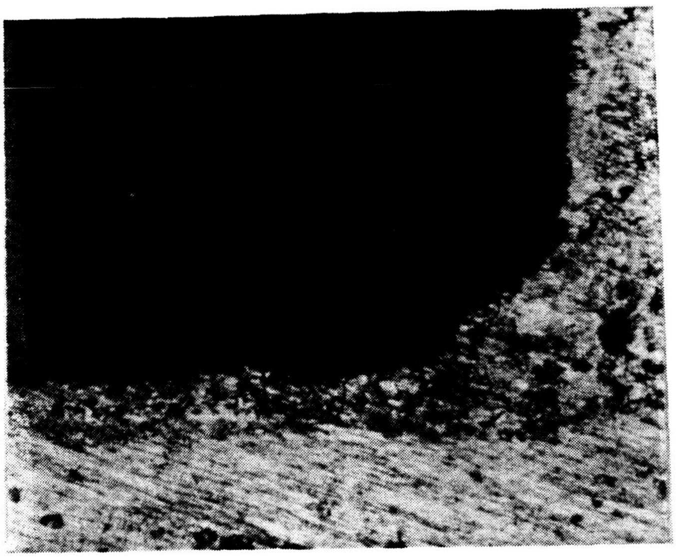

Figure 6.

Flow Divider Formed by Sintered Superalloy/Braze Powder Mixture

(Magnification: 75X)

X powder, -325 mesh, and nickel braze alloy powder. The resulting composite, including Inco 625 superalloy flow divider strips was subsequently braze-bonded between two samples of IN 792 castings and the steel removed by boiling in a refluxed solution of 50 percent nitric acid in methanol. Complete dissolution of the steel was achieved in less than one hour, and the definition of cooling passage and trip strips conformed to print requirements.

The etching medium selected for most efficient removal of the fabricated split blade steel core after bonding was:

50 v/o Nitric Acid, conc.
50 v/o Alcohol, (ethyl, methyl)*
50-65°C (120-150°F)

3.2 BRAZE-BONDING DEVELOPMENT

Four braze alloys, all in foil form, were selected as candidates for bonding the internal details to the split blades.

AMS 4777	Ni-Flex 77**	0.051 & 0.084 mm (0.002 & 0.0033 in.)
AMS 4778	Ni-Flex 78**	0.051 & 0.084 mm (0.002 & 0.0033 in.)
AMS 4779	Ni-Flex 79**	0.025, 0.051, & 0.10 mm (0.001, 0.002, & 0.004 in.)
	Ni-Flex 95**	0.025, 0.051, & 0.10 mm (0.001, 0.002, & 0.004 in.)

Tests included lap shear bonds, butt joint specimens, and simulated blade sections containing the carrier and HIP bonded inserts. All were prepared with cast samples of the candidate casting alloys, IN 792 and MAR-M-247 obtained from the foundry. Flat plates were used for double lap shear tests; dog bone tensiles, cut apart and subsequently rebonded, as butt joint specimens.

Initial bonding tests were conducted within a vacuum furnace using a fixture through which pressure could be supplied by an expandable bellows.
Despite several rebuilds to strengthen the mechanism, joining studies proceeded with great difficulty due to problems in pressurizing the specimens at the high bonding temperatures. The desired cycle is 1150°C/100 MPa/2 hours

*It is important to monitor the reaction and to keep the level of alcohol near the 50 percent level to avoid oxidation by the nitric acid. Equally important, only ethyl or methyl alcohols should be used. Other varieties, e.g., isopropyl, can react violently with nitric acid.

**Materials Development Corporation, Medford, Mass.

(2100°F/15 ksi/2 hours). We were not able to sustain a load above about 35 MPa (5 ksi) for more than a few minutes, however, and the fixture was abandoned. Subsequent bonding tests were conducted within evacuated, hermetically sealed tubes or boxes subjected to an actual HIP environment and cycle.

Figures 7 and 8 are photographs of HIP processed braze joint specimens returned from Pressure Technology, following 1175°C(2150°F), 103 MPa (15,000 psi) HIP processing. All of the double lap joint specimens contained in stainless steel boxes were bonded. One tube of the butt joint specimens apparently leaked due to an undetected crack in the closure weld, and consequently saw no differential pressure in the HIP cycle. The specimens in this tube were only superficially bonded, and could not be tested. Figure 7 also shows the IN 792/steel/IN 792 laminates, edge-welded and HIP bonded to simulate actual split blade fabrication of the wheels The internal cooling passage dividers, edge closures, and trip strips were filled with pre-sintered powders prior to bonding, as follows:

a) Hastelloy X powder -- -325 mesh
b) Hastelloy X powder -- -325 mesh plus 5 wt. % AMI 775 braze alloy
c) 80-20 Ni-Cr powder -- -325 mesh
d) 80-20 Ni-Cr powder -- -325 mesh plus 5 wt. % AMI 775 braze alloy

Of the two specimens evaluated metallographically, one was seen to be heavily contaminated and not bonded, due to what we suspect was a cracked weld. The second showed the powder to be fully compacted and bonded to the cast IN 792.

Table 3 is a compilation of tensile and shear strengths of the IN 792 cast specimens bonded with a variety of high temperature braze alloys in the HIP runs. Both the strongest and the most consistant results were demonstrated

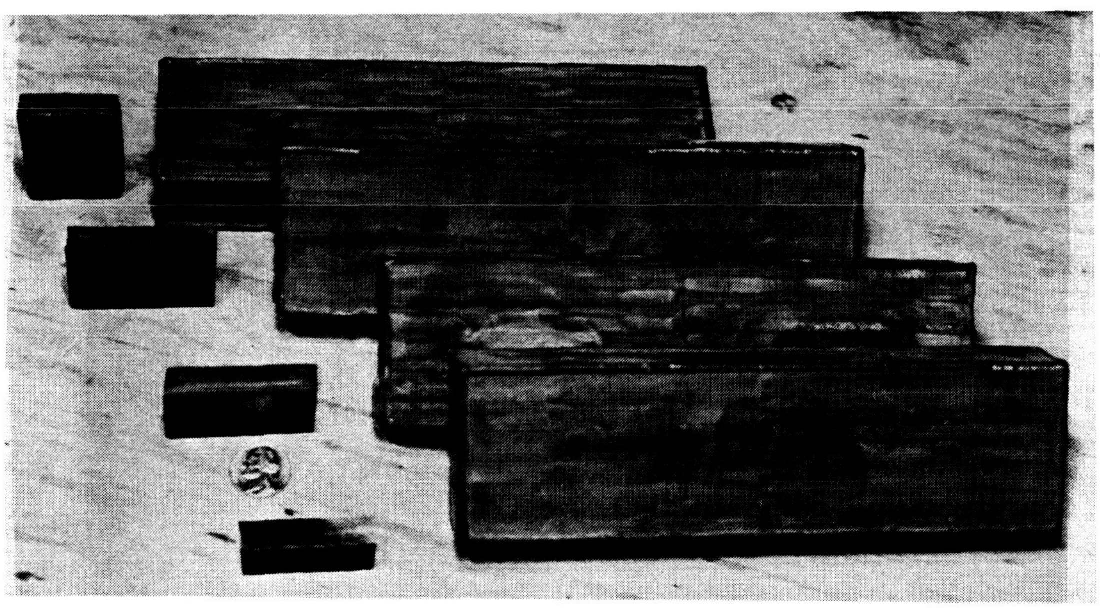

Figure 7. HIP Bonded Specimens

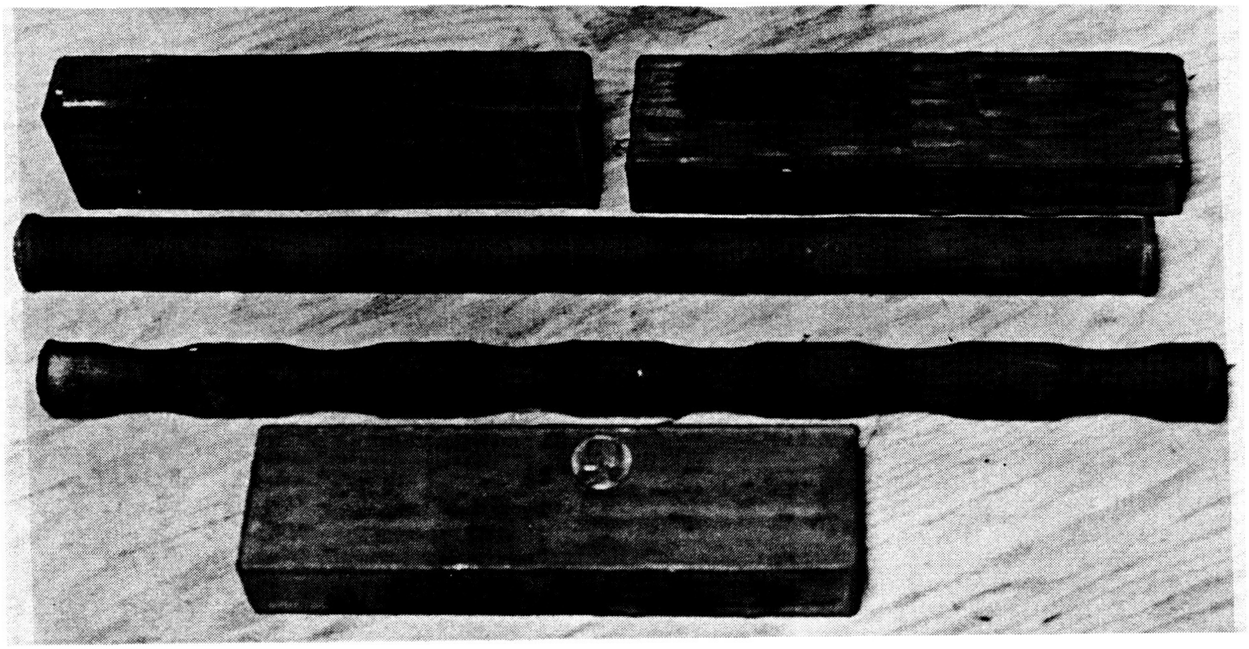

Figure 8. HIP Bonded Specimens

by Ni-Flex Alloy 77, 0.05 mm (0.002 in.) thick. Table 4 shows room temperature tensile data for two specimens of the IN 792 material in the as-HIPed condition. The alloy exhibits good ductility. Yield strength is approximately that of the braze alloy tensile test, Table 3.

Table 5 presents elevated temperature tensile data on five butt joint braze specimens which were given a brazing cycle simulating a HIP-bonding cycle and subsequently heat treated. The alloy is NI-Flex 77. The braze and heat treat cycles were as follows:

Braze	1177°C (2150°F)/Vac./2 hours/furnace cool
Heat Treat	1121°C (2050°F)/Vac./2 hours/fast cool*
Age	843°C (1550°F)/Vac./4 hours/furnace cool
Age	760°C (1400°F)/Vac./16 hours/furnace cool

*10 minutes or less to 538°C (1000°F)

Table 6 is a compilation of three shear strength tests conducted on brazed and heat treated IN 792 lap joints. Two values are noted for the first two specimens since the holes in the double leg of the specimen were mis-aligned, causing the joint to be loaded as a single lap, each side independently. As with previous results, the Ni-Flex 77 alloy provided the strongest and most consistent joint. These specimens were brazed with a simulated HIP cycle and subsequently vacuum heat treated as noted above.

Table 3

Braze Alloy Strength, Room Temperature

Braze Alloy Thickness mm (in.)	Base Material, IN 792 Casting			
	Tensile Strength MPa	(ksi)	Shear Strength MPa	(ksi)
Ni-Flex 77 0.05 (0.002)	782.6	(113.5)	348.9	(50.6)
Ni-Flex 77 0.083 (0.0033)			383.3	(55.6)
Ni-Flex 78 0.05 (0.002)	257.0	(37.4)	77.2 313.0	(11.2) (45.4)
Ni-Flex 78 0.083 (0.0033)			388.9	(56.4)
Ni-Flex 79 0.05 (0.002)			436.4 38.6	(63.3) (5.6)
Ni-Flex 95 0.025 (0.001)	594.3	(86.2)	342.7	(49.7)
Ni-Flex 95 0.05 (0.002)	415.8	(60.3)		
Ni-Flex 95 0.10 (0.004)	137.2	(19.9)		

Table 4

Tensile Properties, IN 792, As-HIPed

0.2% Yield Strength MPa	(ksi)	Tensile Strength MPa	(ksi)	Elongation % in 4D
813.6	(118.0)	1005.3	(145.8)	9.0
808.1	(117.2)	1065.9	(154.6)	9.8

Table 5

871°C (1600°F) Tensile Data, Ni Flex 77 Braze Alloy

Specimens Number	Ultimate Tensile MPa	(ksi)	Fracture
A02-8	826	(119.8)	50% Parent Metal
A01-7	799.1	(115.9)	65% Parent Metal
A06-9	700.5	(101.6)	35% Parent Metal
A02-10	759.8	(110.2)	65% Parent Metal
A06-11	797.0	(115.6)	75% Parent Metal

Table 6

Braze Alloy Shear Strength, 870°C (1600°F), IN 792

Specimen Number	Braze Alloy	Shear Strength (MPa)	(ksi)	Notes
DL-8	Ni-Flex 77 0.084 mm (0.0033 in.)	311.0 311.6	45.1 45.2	Opposite side of double lap joint broke independently.
DL-9	Ni-Flex 95 0.025 mm (0.001 in.)	194.4 295.1	28.2 42.8	Opposite sides of double lap joint broke independently.
DL-10	Ni-Flex 95 0.10 mm (0.004 in.)	110.3	16.0	

Eight split blade simulation specimens were electron beam (vacuum) welded and processed by HIPing. They are included in Table 7. These simulated split blade specimens were evaluated metallographically. There was no particular advantage or disadvantage noted in the integrity of any of the braze alloy, substrate combinations. In all cases the steel or molybdenum carrier etched away cleanly with no damage to the superalloy inserts or casting. Experience with preparation of these samples demonstrated that the placement of individual trip strip wires is an unworkable system. We therefore went to a method wherein the superalloy addition is made by filling the trip strip grooves

Table 7

HIP Bonded Joining Specimens

Test Bar Sample Number	Material	Braze Alloy	Etching	Insert
2_1	MAR-M247	Ni-Flex 95 0.050 mm thick (0.002 in. thick)	Nitric Acid	1010 steel, 1.5 mm (0.058 in.) carrier; 2 round plugs (Hast X) 7 mm (9/32 in.) dia.; 16 0.9 mm (0.035 in.) Hast X pins; 2 trip strips fabricated of Inconel 718 wire.
2_2	MAR-M247	Ni-Flex 95 0.05 mm thick (0.002 in. thick)	Nitric Acid	" "
3_1	IN-792	Ni-Flex 78 0.05 mm thick (0.002 in. thick)	Nitric Acid	" "
3_2	IN-792	Ni-Flex 79 0.05 mm thick (0.002 in. thick)	Nitric Acid	" "
4_s	IN-792	Ni-Flex 79 0.05 mm thick (0.002 in. thick)	Nitric Acid	6 trip strip wires, grooves at various depths; 1010 steel 1.5 mm (0.0589 in.) carrier
4_m	IN-792	Ni-Flex 79 0.05 mm thick (0.002 in. thick)	Kolene DGS fused salt	Molybdenum 1.2 mm (0.047 in.) carrier; 6 trip wires
5_s	MAR-M247	Ni-Flex 77 0.05 mm thick (0.002 in. thick)	Nitric Acid	1010 steel carrier; 6 trip wires at various depth
5_m	MAR-M247	Ni-Flex 77 0.05 mm thick (0.002 in. thick)	Kolene DGS fused salt	Molybdenum 1.2 mm (0.047 in.) carrier; 6 trip wires

with a powder/braze alloy mixture and sintering. This method results in about ten volume percent porosity, which the subsequent HIP densification corrects.

4

DESIGN

Four assemblies, comprised of two types of star wheel and two types of exducer, were designed. The engineering drawings and specifications of these various components can be made available to qualified parties for examination by application through NASA-Lewis.

Descriptions and drawing numbers are as follows:

131100	Proposal - engine assembly, with high temperature turbine wheel (full size to fit T-62)
131102	Layout - turbine wheel, air-cooled (two-piece 10X size)
131301	Proposal - air-cooled turbine wheel assembly (multi-piece construction 10X size)
131454	Wheel, turbine - air cooled (cast star wheel)
131103	Wheel, turbine - air cooled (brazed star wheel)
131467	Insert, blade - air cooled (brazed star wheel)
131455	Exducer, turbine - air cooled (cast one-piece)
131599	Blade, exducer - air cooled (cast and machined)
954959C1	Hub, exducer - air cooled (machined)
954960C1	Ring, exducer - air cooled (machined)
131453-100	Wheel assembly, turbine - air cooled (cast wheel and exducer)
200	Wheel assembly (brazed wheel and cast exducer)
300	Wheel assembly (cast wheel and multi-piece exducer) (includes assembly, balancing and spinning)
DSK 17073	Material specification

The mechanical and thermal design procedures are covered in Appendices A and B of this report.

5
PROTOTYPE PRODUCTION

5.1 APPLICATION OF PRINCIPLES

Following the definition of design manufacturing techniques, braze bonding cycles, thermal treatment, and sealing and leaching cycles, it was decided to proceed with the production of prototype wheels to demonstrate the practicality of these methods in simulated production. This section describes the course of the various tasks from procurement through final machining.

5.2 CASTING PROCUREMENT

Approval was received from the local DCAS administrator in 1982, to proceed with procurement of the tooling. Purchase orders were let for the exducer, P/N 131455, to be cast with integral ceramic cores; for the star wheel, P/N 131103, with split blade, fabricated passages; and an adaptor to allow fabrication of the star wheel, P/N 131454, with integral ceramic cores. The foundry contracted with a second source for all tooling.

The purchase order was let to cover the casting of the wheels on a best effort basis. The foundry was to make up to 25 pours to produce ten good castings in each of the components, star wheel and exducer. The exducer was cast only with detail ceramic cores. The first attempts at the star wheel were with the split blade type core. If a requisite number of good castings, 10, were attained in the initial attempts, the balance of the 15 pours could be devoted to detail type ceramic cored star wheels.

In casting the first (tool proof) star wheel plunger over-travel (during the wax injection) caused the solid cores to be cracked prior to assembly. The problem was corrected by restricting the stroke during subsequent operations.

Evaluation was conducted during subsequent production of cast star wheels, both the integrally cored and split blade designs, P/N's 131454 and 131103. A photograph of the sectioned blade of each is seen in Figure 9. The only difficulty reported was that some of the cores forming the air entry holes in P/N 131103 were broken in the wax injection process and that these castings needed reworking to reform the holes.

Figures 10, 11 and 12 are photographs of the total casting procurement, the leading faces, and the trailing faces of the wheels, respectively.

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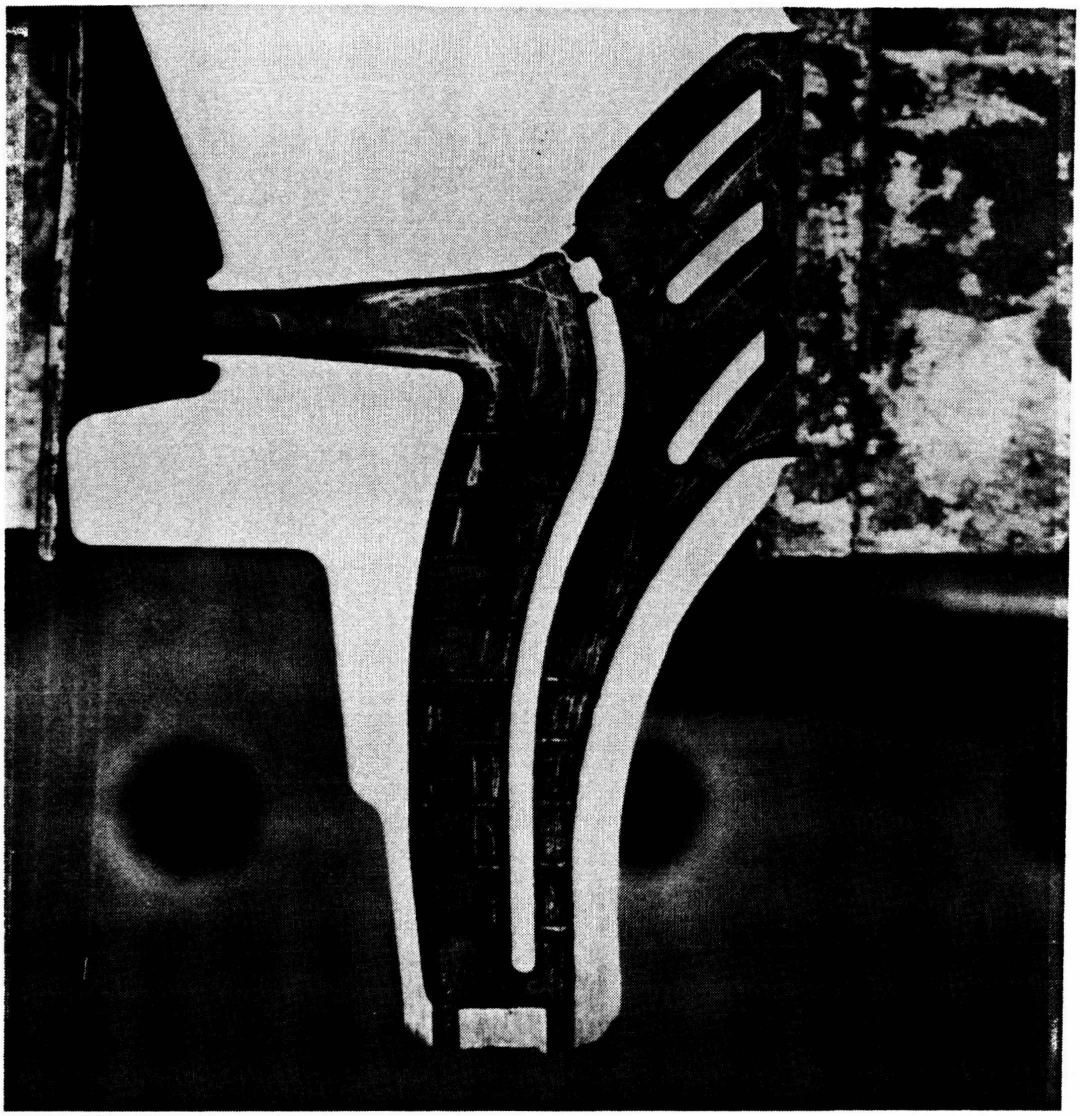

Figure 9A. Sectioned Blade Produced With Detail Core
P/N 131454

Seventeen conventionally cored star wheel were cast by the same foundry with the same cooling passage design as that of the split blade wheels, except that the passage was made 0.075 in. (1.9 mm) wide, rather than the specified 0.050 in. (1.27 mm), due to the need for more rigidity in the detailed core. Of the 17, four were supplied to Solar and the balance scrapped. Table 8 shows the relationship of unacceptable blades per wheel. No specific details are known for the 13 scrapped at the foundry so they are simply assumed to have had at least as many as six bad blades per wheel, one more than the worst of the four we received.

Figure 9B. Sectioned (Split) Blade Produced With Solid Core P/N 131103

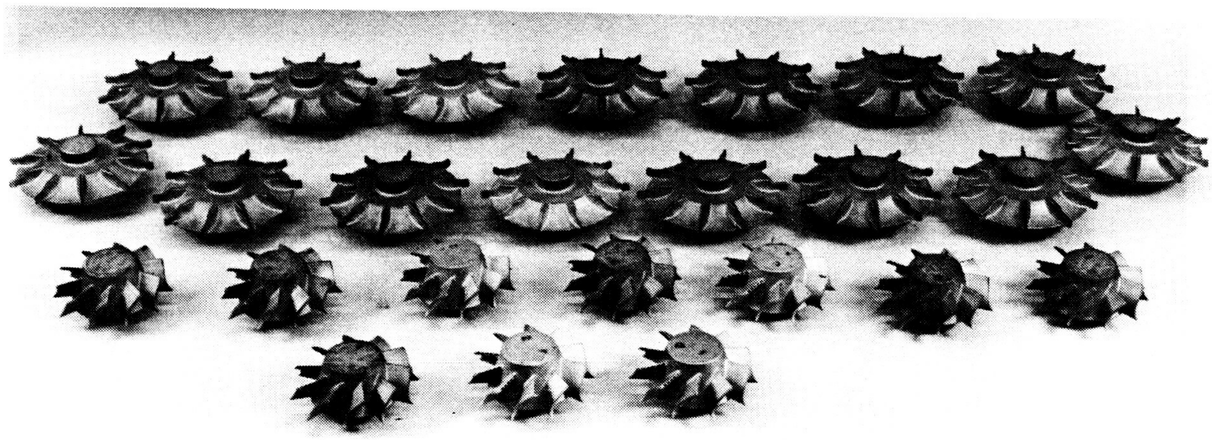

Figure 10. Total Casting Procurement: 4 Conventionally Cored Star Wheels (Solar Procurements); 11 Split Blade Star Wheels; and 10 Exducers

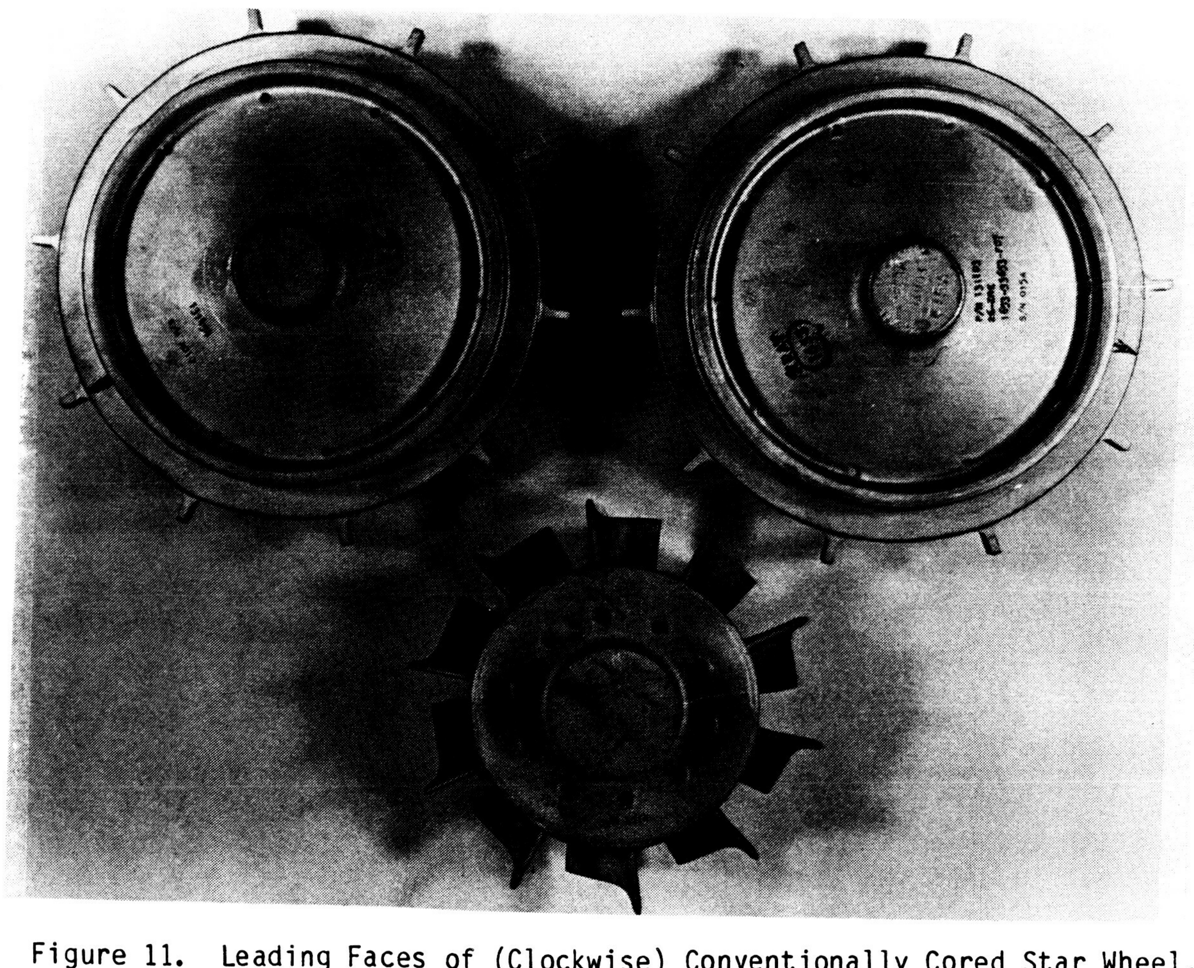

Figure 11. Leading Faces of (Clockwise) Conventionally Cored Star Wheel, Split Blade Star Wheel, and Exducer

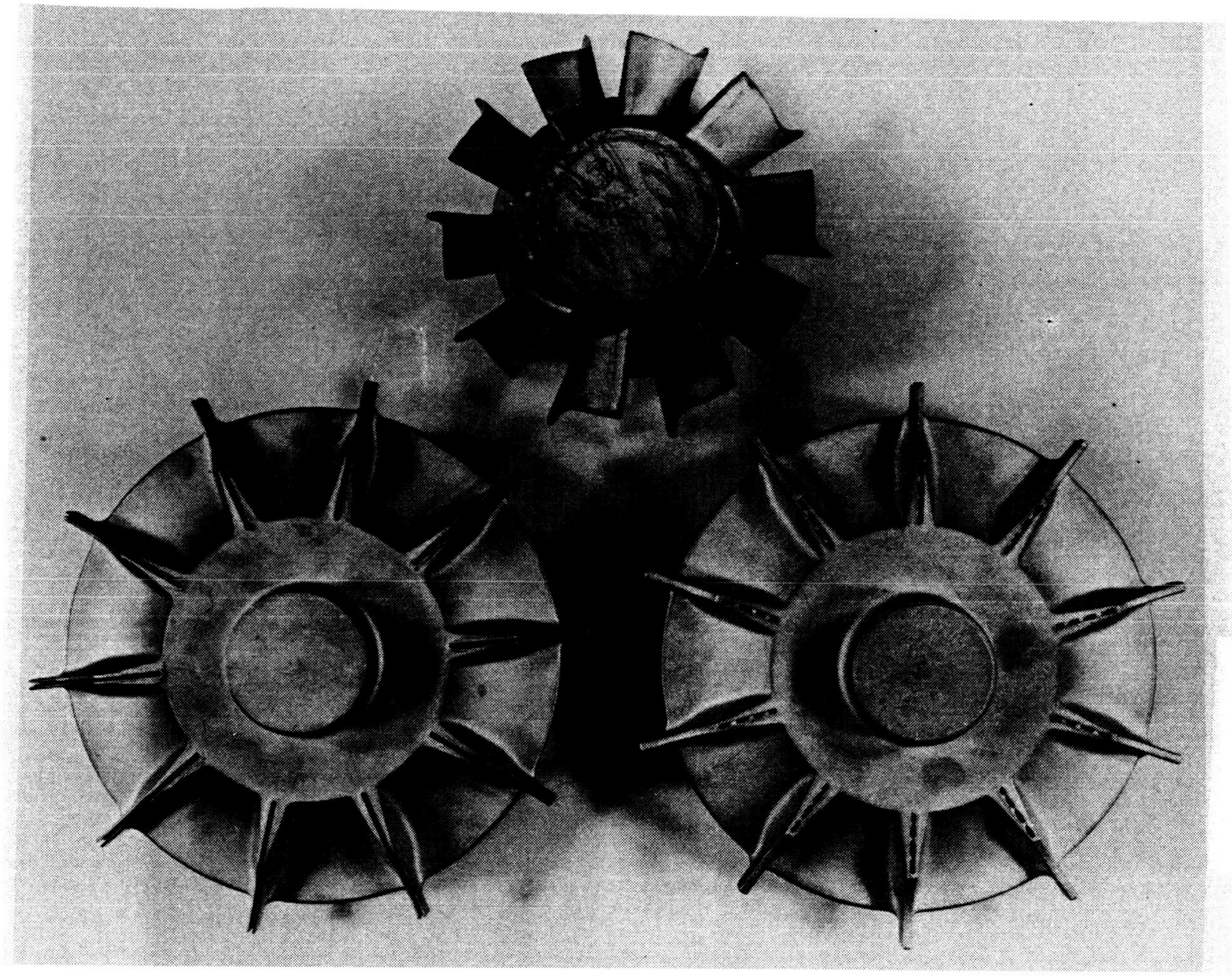

Figure 12. Trailing Faces of the Wheels

Table 8

Occurrence of Defects in Wheels

Number of Castings	Defects Per Wheel
1	1
1	2
1	3
1	5
13	6 or more

A very approximate Weibull analysis of these data (Fig. 13) show the probable acceptance rate to be less than 3%, corresponding to an acceptance rate, had they been single blades, of about 70%, not an unreasonable figure. Recognizing that this was the first production trial with this design, we will assume that subsequent production will bring some kind of improvement through a learning curve.

Of castings completed and shipped by the foundry, we received 4 pieces of P/N 131454, the conventionally cored star wheel; eleven pieces of 131103, the split blade star wheel; and 10 pieces of 131455, the exducer. The number of trials for the latter two castings were not reported. P/N 131455 and 131454 were HIPed and heat treated, without aging. P/N 131103 was not HIPed or heat treated as this will follow as a part of the fabrication procedure. The foundry supplied a complete record of certification, NDT records, HIP and heat treatment parameters.

Review of radiographs submitted with the castings show generally definable structures in the star wheels, both conventionally cast and those which were to be fabricated by the split blade technique. Several (Table 8) of the former had variations in the blade wall passages, however, examples of which (magnified and shown as a positive print) are shown in Figures 14 and 15.

Definition of the exducer blade detail is very much complicated by overlap of the blades and the central hub. For this reason, a casting was submitted to Aerojet Strategic Propulsion Company, Sacramento, CA, for an assessment of

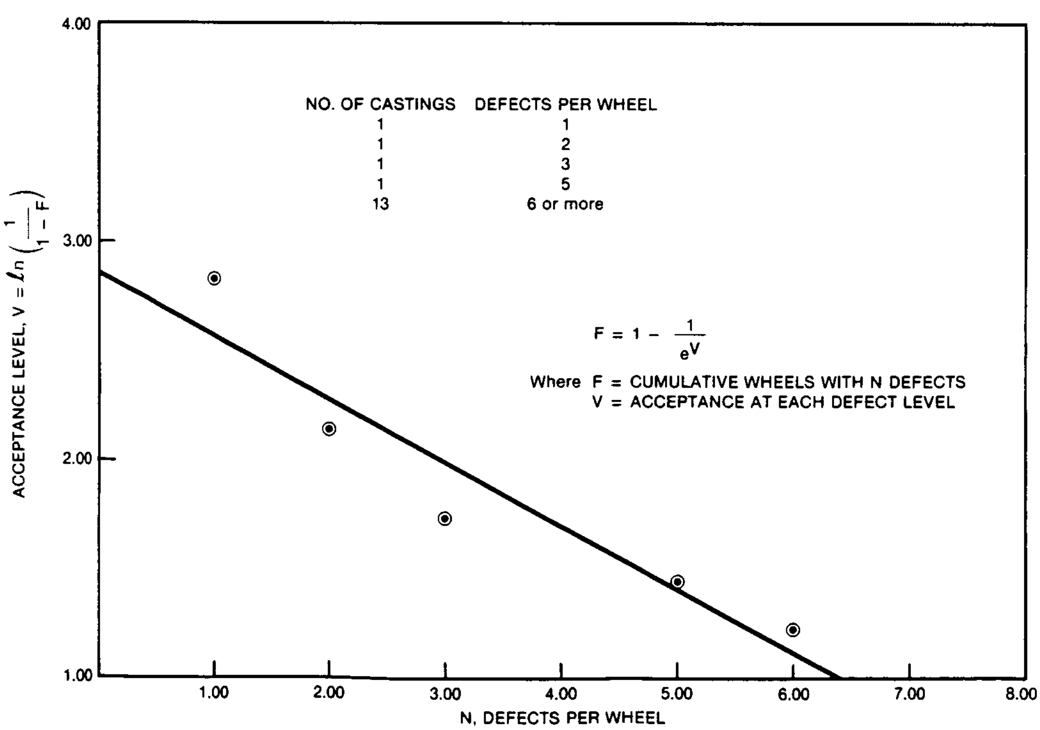

Figure 13. Modified Weibull Analysis

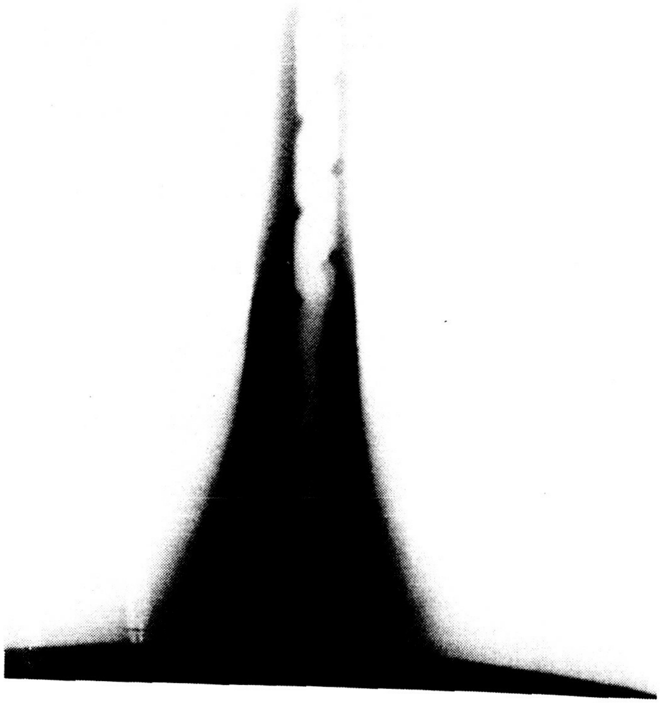

Figure 14.

Radiographic Positive Enlargement Showing Core Shift in Star Wheel Blade

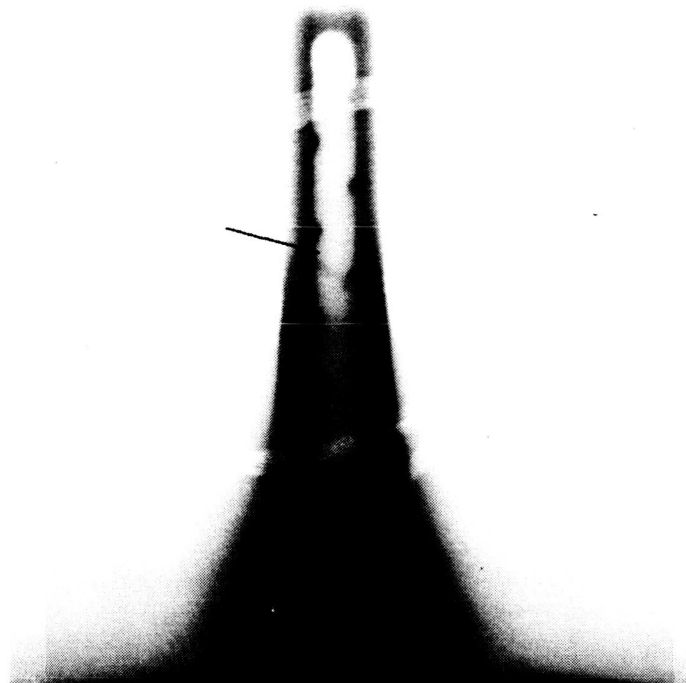

Figure 15.

Radiographic Positive Enlargement Showing Cracked and Metal Infiltrated Core in a Star Wheel Blade inspection by the Computed Tomography (CT) Process, developed under sponsorship of Materials Laboratory, Air Force Wright Aeronautical Laboratories. This system appears to have great promise in resolution of the complicated inner structures of the blades. A disadvantage was seen in the estimated cost of adapting the system to the exducer, e.g., two blades for $3,245; in the actual inspection of the first casting, all 10 blades, $1,849; and in the probable cost of prototype and/or production inspection, probably in excess of $1,000 each. For this reason further investigation of the process was put on hold, with the hope that further studies will eventually be made.

No surface defects were noted by fluorescent penetrant inspection in any of the castings supplied, nor were defects noted in visual examination.

5.3 ASSEMBLY

All wheels were lathe turned to locate the blade diameters. The star wheel casting split blades were milled internally with a carbide slitting saw to clean out the cavity between the blade halves, Figure 16.

Saw blade thickness was selected such that approximately 0.050 to 0.075 mm (0.002 to 0.003 in.) was removed on either side opening the slots to 1.27 mm (0.050 inch) minimum width. It was also necessary that an electro-discharge machining tool be fabricated to shape and deburr the oval air passage slots at the base of the split blades. The steel carriers, inserts and trip strip assemblies were prebrazed, sanded flat and parallel and cut to shape preparatory to assembly in the split-blade star wheels (Fig. 17). The carrier assemblies were, in this final lot, prepared with EDM wire saw fabricated inserts and a powder/alloy mixture prebrazed in photochemically milled grooves to form trip strips. The total configuration, seen in Figure 18, was comprised of:

- carrier - enameling steel
- flow dividers - Hastelloy X inserts
- trip strips - Hastelly X powder/AMI 775 braze powder, 95/5 mixture

Two wheels were assembled with the carrier-inserts and welded, preparatory to HIP-bonding.

These wheels, Numbers 1 and 5, were returned from the HIP-bonding operation, lathe machined to define the blade contours, and the blade tip holes (4) and air inlet holes electro-discharge machined to expose the steel core to acid leaching. The leaching operation proceeded satisfactorily, requiring about 10 hours exposure to warm [70°C (160°F)] nitric acid, alcohol 1/1 mixture. Subsequent destructive metallographic analysis revealed all traces of the steel to be gone and no evidence of reaction of the casting, superalloy inserts, or braze alloy with the acid.

The wheels were radiographed in two planes: axially, which did little to reveal the inner strucuture; and tangentially (after sectioning out the blade segments), which indicated the arrangement of the inner structures. The

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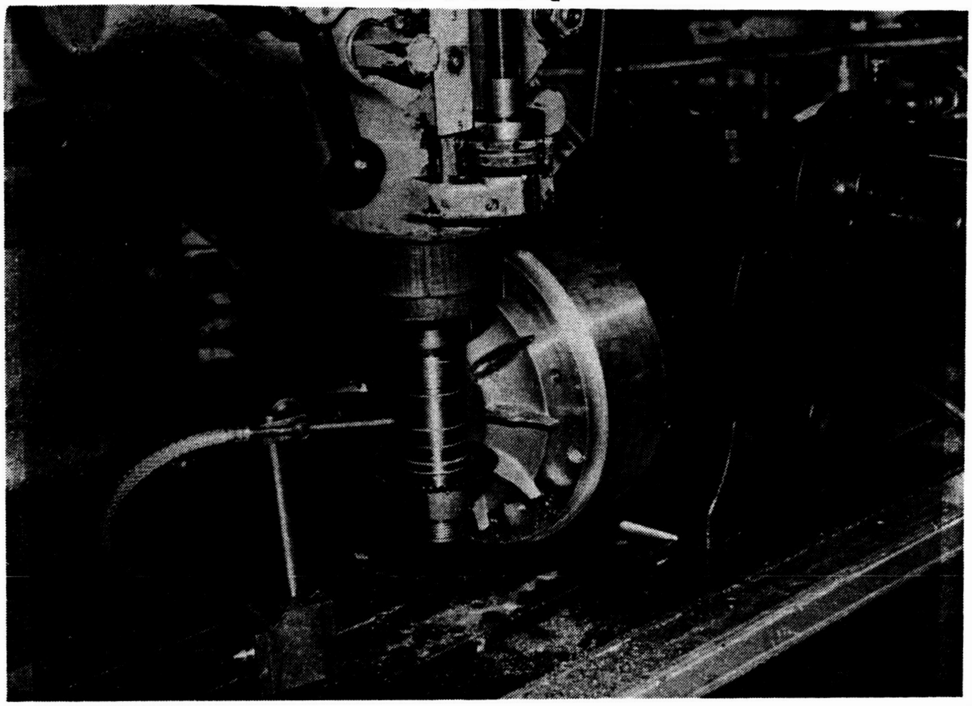
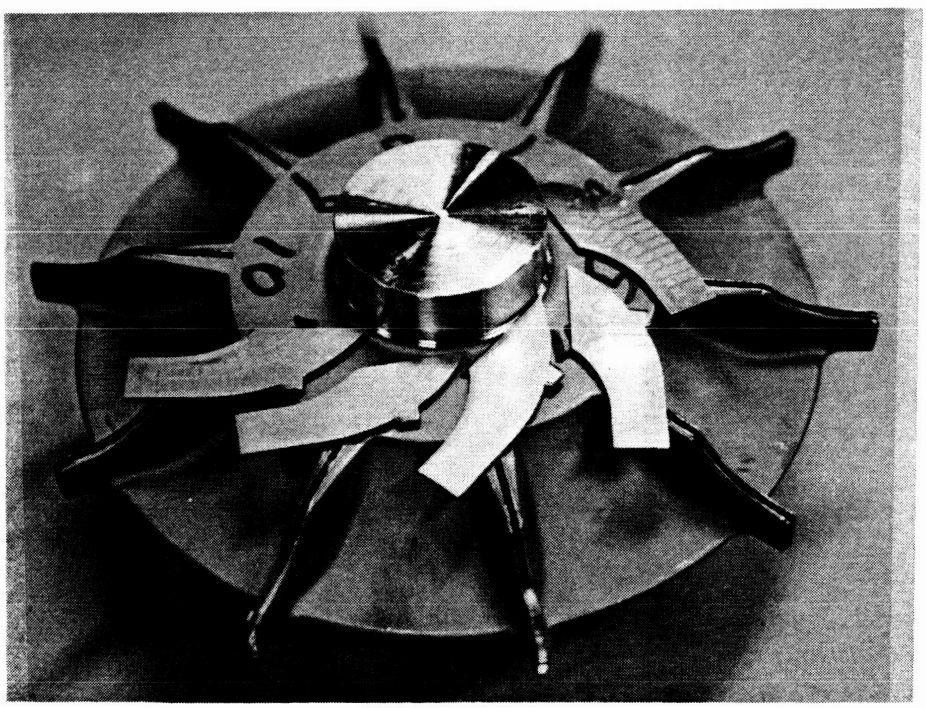


Figure 16. Milling Split Blade Cavities



Fiugure 17. Machined Wheel and Carrier Assemblies

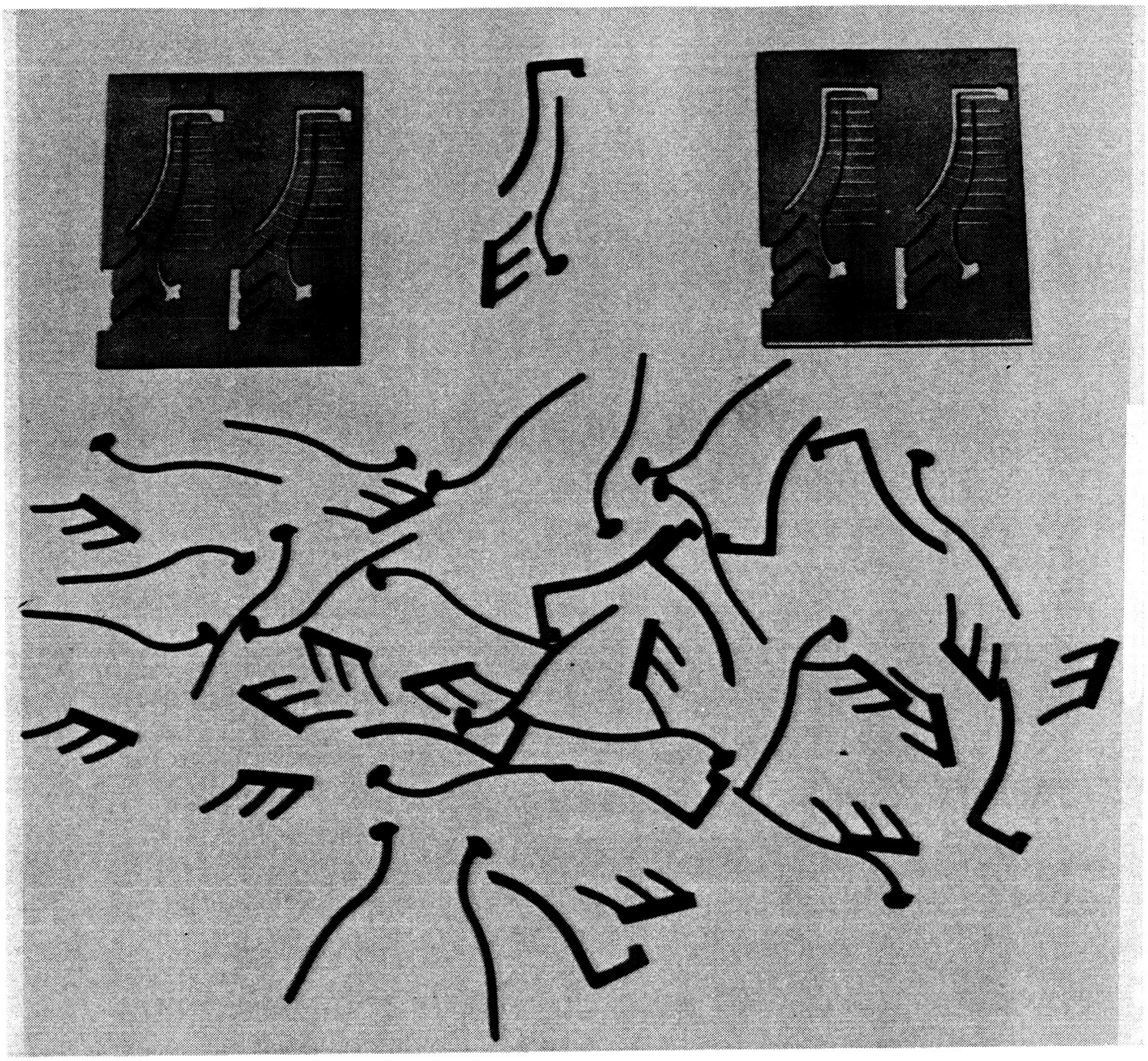


Figure 18. EDM Wire Sawed Carriers and Inserts

blades were subsequently sectioned and metallographically examined. Two discrepancies were noted in the results: firstly, the alignment of the carrier/insert assemblies within the slots was compromised by the inadvertent removal of the tab which should key into the air inlet passage. A shaped, steel tab was substituted to prevent passage collapse during HIPing, but since this was not an integral part of the carrier, the alignment was compromised. This caused four of the assemblies to protrude excessively from either the blade tip or trailing edge. Secondly, it was obvious that several of the closure welds had not been sound, resulting in lack of pressurization of the joints and a contaminated brazing atmosphere. It appears that four of the blades were so affected.

The first discrepancy resulted from misinterpretation of the instruction to "radius the tabs" on the carrier/insert assemblies, and therefore was corrected in subsequent production. The second discrepancy, unsound welding, was partially compensated for in sealing the second lot of wheels by variations in the technique. These included sealing the curved and trailing edges of the blade by conventional TIG welding, proofed by fluorescent penetrant inspection prior to final closure by EB welding of the blade tip. A 12-hour pumpdown of the vacuum chamber was included to compensate for the reduced area of the final sealed joint. The probable more ideal technique would be to core the air inlet hole in the casting directly into the slot and to use it for leak testing after sealing the blade edges. It could then be sealed, in a vacuum, by crimping a welded-in tube, or by a similar, more reliable technique.

The second batch of two wheels was assembled -- this time with the carrier tab intact -- welded, with the improved technique, HIP-bonded as before, and solution heat treated, preparatory to rough machining and acid leaching.

5.4 THERMAL TREATMENT

Bonding of the assembled and weld sealed wheels was conducted by an outside toll HIPing facility according to the schedule established in earlier tests, Section 3.2. Both the first lot, wheels S/N 1 and 15, and second lot, wheels S/N's 9 and 20, were processed identically:

1185°C (2165°F)
103.4 Mpa (15,000 psi) pressure
4 hours at temperature

Both runs were monitored by continuous recordings of temperature, pressure, and gas quality and conformed to requirements in every respect.

Upon receipt of the HIP-bonded wheels at Solar, they were each solution heat treated in vacuum, 1×10^{-5} Torr or better as follows:

1177°C (2150°F) for 2 hours at temperature
Argon fan cool to below 538°C (1000°F)
Reheat to 1121°C (2050°F) for 2 hours at temperature
Argon fan cool to below 538°C (1000°F)

5.5 LEACHING

Preparatory to acid leaching of the blade cores, the diameter and trailing edge contours of the blades were shaped to net dimension (removing the weld beads) by cutting on a numerically controlled EDM wire saw. One wheel, S/N 20, was damaged in the cutting process (Fig. 19) when the sensing mechanism of the wire saw mispositioned the back side of one blade tip and cut about 1.3 mm (0.05 in.) too deeply into the internal cooling cavity. The air inlet

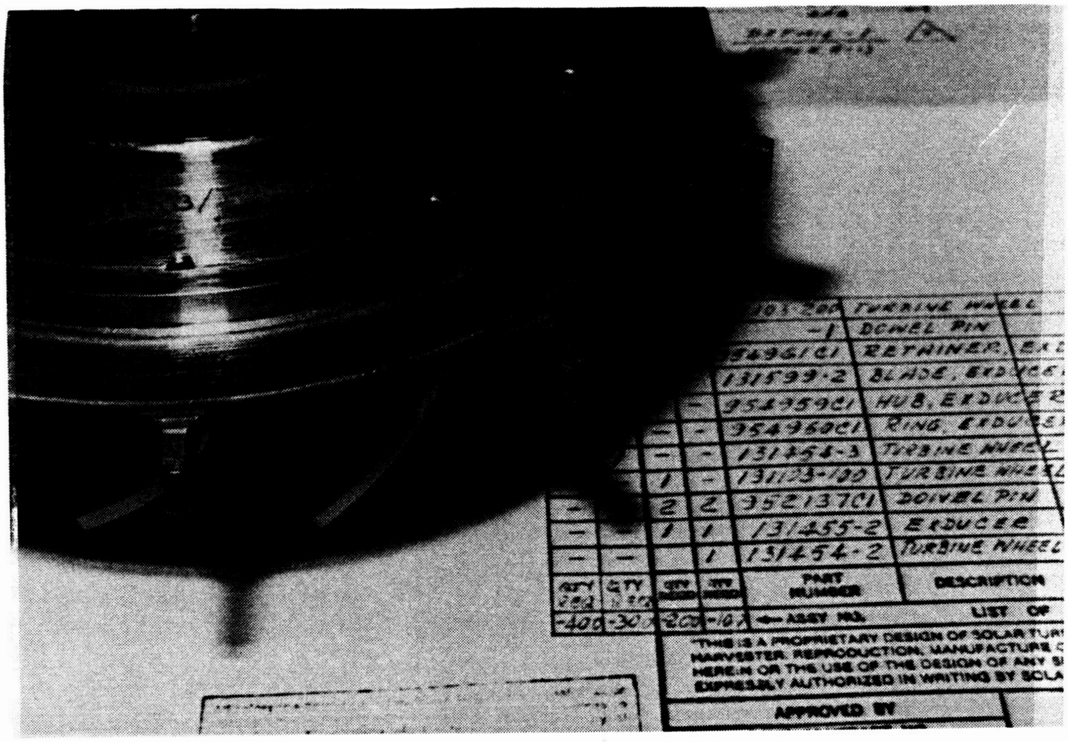


Figure 19. Mis-machined Blade Tip

passages and tip ejection holes also were opened by electro-discharge drilling. The parts were subsequently immersed in a refluxed nitric acid-methanol solution, 50-50 mixture, at approximately 70°C (160°F), for ten hours. Gas evolution was observed to stop after about six hours. For the final four hours of leaching, the obverse side of the wheel was placed uppermost in order to guarantee complete removal of the steel core in all interstices of the blades. At the cessation of etching, the blade were rinsed with pressurized cold water (serving as a flow test); with a dilute sodium bicarbonate solution; and with a final hot water rinse.

5.6 MACHINING, ASSEMBLY, AND AGING

Machining and assembly to final dimensions was conducted by an outside subcontractor. The majority of the effort was in producing the curvic couplings on the "back" face of the star wheel; the "front" face of the exducer; and mating and pinning the two to form the complete wheel. No machining was necessary on the blade contours or diameters.

The completed assemblies were returned to Solar for final aging (both sections being in the HIPed and double solution heat treated condition). Double aging was conducted in vacuum at 843°C (1550°F) for four hours plus 760°C (1400°F) for 16 hours.

6
INSPECTION

6.1 VISUAL AND DIMENSIONAL

Wheels S/N 1 and 5 which, as noted previously, had the internal spacers and details mispositioned through machining error, were exempted from final machining. It was decided, however, to destructively section wheel S/N 1 to survey the internal cavities. This confirmed the earlier suspicions as to poor quality of the closure welds. In several of the blades the internal details had failed to properly braze.

The second lot of HIP-brazed wheels, S/N's 9 and 20 both, after final machining, conformed to complete dimensional requirements. The completed wheel is seen in Figure 20.

6.2 NON-DESTRUCTIVE INSPECTION

The results of radiographic inspection of the blades were generally inconclusive. Except for delineating improper positioning of the internal components (see Section 5.2) no significant data could be obtained. Inadequate braze strength, for instance, could not be detected.

Liquid penetrant inspection of the blades, after removal of the closure welds, was effective in delineating areas of inadequate bonding, at least at the outer periphery of the blade. Inspection of the internal details was not possible by this method, although it was found (by destructive sectioning of wheel S/N 1) that the external bond quality was in all cases indicative of the internal.

6.3 FLOW TEST

Both wheels, S/N's 9 and 20 were flow tested after assembly and final machining. Water flow testing served to demonstrate that all cooling passages were open and free of obstruction.

Subsequently both wheels were subjected to dynamic pressure drop test with air, simulating more accurately actual operation in the engine. Results were as seen in Table 9. There is close similarity in comparison of the two wheels and in comparison of the cast-to-size cooling passages in the exducer section and the fabricated passages in the exducer.

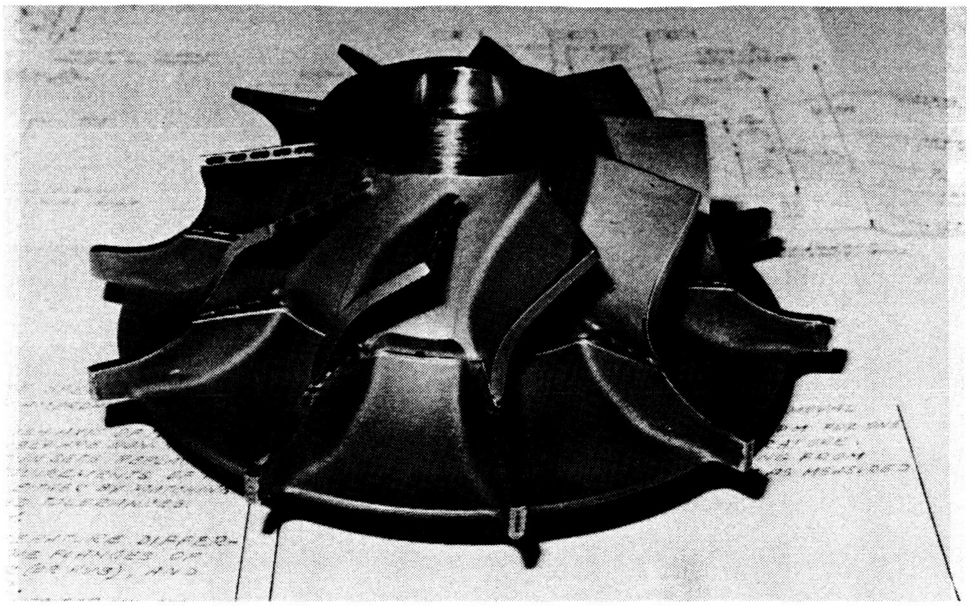


Figure 20. Completed Wheel

6.4 SPIN TEST

Wheel S/N 9 was spin tested (Fig. 21), incrementally at 50, 75, 90, 100, and 110 percent of operating speed, 65,000 rpm, holding one minute at each target speed. Measurements were taken at five diameters of the wheel, across the blade tips. The test was repeated after thermally cycling the wheel from room temperature to 900°C (1650°F) six times. Results, before and after thermal cycling, are seen in Table 10. Neither showed significant growth at any speed.

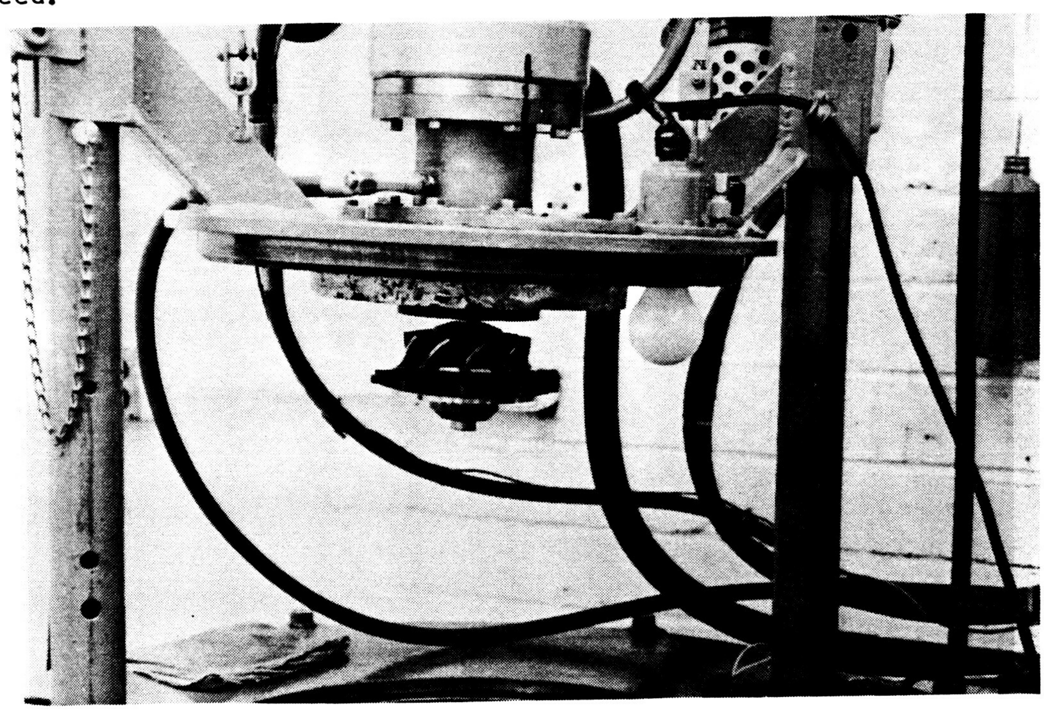


Figure 21. Spin Testing

Table 9

Flow Test Data

	Wheel S/N 9			Wheel S/N 20		
	Total	Exducer	Star Wheel (by difference)	Total	Exducer	Star Wheel (by difference)
Geometric Area, $in.^2$	1	1		1	1	
Wheel Pressure, in. H_2O	25.05	25.15		25.35	25.00	
Nozzle Pressure, in. H_2O	1.003	0.62		1.7	0.94	
Ambient Temperature, °F	80	80		80	80	
Ambient Pressure, in. Hg	30	30		30	30	
Number of Nozzles	1	1		1	1	
Effective Area, $in.^2$	0.0913	0.0718		0.1178	0.0885	
Flow Function	0.0248	0.0196		0.0323	0.0241	
Pressure Drop, %	6.1440	6.1686		6.2177	6.1318	
Wheel Mass Flow, lb/sec	0.0157	0.0214		0.0205	0.0153	
Discharge Coefficient	0.0913	0.0718	0.0195	0.1178	0.0885	0.0293

Table 10

Spin Test Results

Percent of Rated Speed (65,000 rpm)	Temperature		Before After Spin	Diameters, Inches				
	°C	°F		1	2	3	4	5
BEFORE THERMAL CYCLE								
50	24.4	76.0	B.S.	6.4990	6.4950	6.4983	6.4962	6.4951
	24.4	76.0	A.S.	6.4990	6.4951	6.4985	6.4962	6.4953
75	23.9	75.0	B.S.	6.4990	6.4951	6.4985	6.4962	6.4953
	26.1	79.0	A.S.	6.4990	6.4951	6.4985	6.4962	6.4953
90	25.6	78.0	B.S.	6.4990	6.4951	6.4985	6.4962	6.4953
	26.1	79.0	A.S.	6.4990	6.4951	6.4985	6.4962	6.4953
100	26.1	79.0	B.S.	6.4990	6.4951	6.4985	6.4962	6.4953
	27.2	81.0	A.S.	6.4990	6.4951	6.4985	6.4962	6.4953
110	27.2	81.0	B.S.	6.4990	6.4951	6.4985	6.4962	6.4953
	27.8	82.0	A.S.	6.4990	6.4950	6.4990	6.4970	6.4953
AFTER THERMAL CYCLE								
50	26.7	80.0	B.S.	6.4985	6.4945	6.4980	6.4950	6.4946
	26.1	79.0	A.S.	6.4985	6.4945	6.4980	6.4950	6.4946
75	25.6	78.0	B.S.	6.4985	6.4945	6.4980	6.4950	6.4946
	27.2	81.0	A.S.	6.4985	6.4945	6.4980	6.4950	6.4946
90	27.2	81.0	B.S.	6.4985	6.4945	6.4980	6.4950	6.4946
	27.2	81.0	A.S.	6.4985	6.4948	6.4983	6.4955	6.4950
100	26.7	80.0	B.S.	6.4985	6.4948	6.4983	6.4955	6.4950
	26.7	80.0	A.S.	6.4985	6.4948	6.4983	6.4955	6.4950
110	26.7	80.0	B.S.	6.4985	6.4948	6.4983	6.4955	6.4950
	27.2	81.0	A.S.	6.4985	6.4950	6.4983	6.4955	6.4953

APPENDIX A

MECHANICAL DESIGN SUMMARY

NASA AIR-COOLED RADIAL TURBINE ROTOR

INTER-OFFICE MEMO

September 21, 1981

To: [redacted]

cc: W. A. Compton
A. G. Metcalfe
W. D. Treece
G. L. Padgett
C. Rodgers
G. Aigret
T. P. Psichogios
J. V. Gallagher

From: A. W. August
A. W. August

Subject: MECHANICAL DESIGN SUMMARY -- NASA AIR-COOLED RADIAL TURBINE ROTOR

The objective was to design and manufacture a high temperature air-cooled radial inflow turbine rotor per Solar S. O. 6-4938-7.

The following contributors took part in the design of the rotor:

Aero	-	C. Rodgers
Heat Transfer	-	G. Aigret, N. Anderson
Stress	-	T. P. Psichogios, R. P. Barrow
Manufacturing	-	A. N. Hammer, Howmet Turbines Corp.
Cost	-	J. V. Gallagher
Mechanical Design	-	A. W. August, T. P. Psichogios

Based on cooling and manufacturing constraints, two-piece turbine rotor with separate star-wheel and exducer have been selected for design.

Layout Drawings 131101 and 131102 show two main configurations of the turbine rotor considered in the design; Drawing 131103 with one-piece cast star-wheel and one-piece cast exducer; Drawing 131101 with individually bladed star-wheel and exducer.

After final review of the above layouts, the following wheel assembly drawings have been prepared for cost analysis and manufacturing selection:

131453-100	-	Rotor Assy, with cast star-wheel & exducer
131453-200	-	Rotor Assy, with brazed star-wheel & cast exducer
131453-300	-	Rotor Assy, with cast star-wheel & bladed exducer
131453-400	-	Rotor Assy, with brazed star-wheel & bladed exducer

September 21, 1981

The following hardware drawings and specifications have been prepared and released to Solar file:

131454	-	Wheel, Turbine - Air-cooled (cast star-wheel)
131103	-	Wheel, Turbine - Air-cooled (brazed star-wheel)
131467	-	Insert, Blade - Air-cooled (brazed star-wheel)
131455	-	Exducer, Turbine - Air-cooled (one-piece cast)
131599	-	Blade, Exducer - Air-cooled (casting & mach.)
954959C1	-	Hub, Exducer - Air-cooled
954960C1	-	Ring, Exducer - Air-cooled
954961C1	-	Retainer, Exducer Blade
DSK-17073	-	Material Specifications for Turbine Wheel Castings
131100	-	Proposal, T-62 Engine Assy. with Ti-Temp Turbine Wheel

The geometrical description of the turbine wheel was based on C. Rodgers' data and blade coordinates with very slight changes required to optimize wheel cooling.

Cooling of the cast turbine wheel has been described by G. Aigret and N. Anderson in the report T-5500 -- "Heat Transfer and Aerodynamics Design Status." The stress analysis of the turbine wheel assemblies are described in Report T-5537 by T. Psichogios and P. Barrow.

It should be noted that for the individually bladed exducer assembly additional cooling air leakage through the side of blade seals can be expected. The effect of this additional leakage on the wheel cooling has not been reviewed by the heat transfer people.

AWA:gm

Engineering Report

2800°F, R.I.T. NASA COOLED RADIAL TURBINE ROTOR

STRESS ANALYSIS REPORT

REPORT T-5537 ISSUED October 27, 1981

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SOLAR REF S.O. 6-4938-7

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1.0 INTRODUCTION

This report summarizes the stress analyses of the radial inflow cooled turbine rotor designed to NASA RFP 3-188454 of April 22, 1980. Numerous stress and design iterations were completed prior to arriving at the configuration discussed in this report.

The radial turbine wheel design incorporates cast blades with internally cored passages for the flow of cooling air to maintain blade metal temperatures to an acceptable limit consistent with the required creep-rupture life of the metal. Because of the complexity of the blade cored passages and the requirement for multi-path cooling air supply, it was necessary to construct the rotor in two sections as follows:

1. A star wheel section in which the blades lie in axial-radial planes on the disc hub

2. An exducer wheel section in which the blades are axially cambered and disposed radially on the disc hub.

The design/analysis effort included two exducer configurations as follows:

1. A one-piece cast blade-disc design

2. Individually cast blades attached to a (forged) disc hub by conventional dovetail type attachments and shown in Figure 38.

The individual (inserted) blade design was included in case major problems were encountered in the production of sound one-piece blade-disc castings.

> Note: The star wheel design has been limited to a one-piece cast blade-disc configuration since no problems are anticipated in the production of sound castings. Fabriction of the star wheel blades can actually be accomplished by an alternate method as shown in Figure 39. This procedure will generate blades similar in design to the one-piece cast configuration and will be investigated along with the cast design.

The blade-disc configurations listed above have all been designed to meet the design and stress criteria listed in para 2.1.4 and para 2.1.5 of Proposal RFP 3-18454, QR 6-4938.

2.0 SUMMARY

The four rotor design configurations (integrally cast star wheel and blades, integrally cast exducer wheel and blades, individually cast exducer blades inserted into a forged hub and fabricated star wheel blades) all conform to the design requirements stipulated in para 2.1.4 and 2.1.5 of RFP 3-188454, QR 6-4938. The one exception to the design requirements is the 1500-hour stress-rupture life of the star blades. In order to meet this requirement, the blade (average) metal temperature must be reduced by 75° to 100°F. This can best be accomplished by reducing the turbine inlet temperature from the present 2800°F value. These rotor designs have been cleared for detailed design drafting and meet all the requirements of room-temperature spin, stress-rupture life, and gross yield speed.

Finite element analyses have been used in the computation of stress and of local metal temperatures, the respective computer programs for each analysis including all the parametric variables that affect the calculated values. A very high degree of confidence is, therefore, attached to the validity of the design analysis.

The IN-792 alloy (HIPed and heat treated) used in the investment casting of the star and exducer rotors is a proven material extensively used in the production of turbine blades for high-temperature applications in company turbine products. A 6.5 inch diameter uncooled radial turbine rotor integrally cast in IN-792 alloy is also presently used in a production engine. The IN-718 (AMS 5398) wrought alloy selected for the alternate exducer hub design is also extensively used in company turbine disc applications.

A concession was made in the overall design of the star wheel wherein the rear face was contoured radially rather than angled similar to the forward face. This was necessary since it had to be matched with the exducer wheel on assembly and also provide the air supply to the exducer blades. This concession increased the local (radial) stress across the air feed hole at the disc aft face to a value exceeding the material tensile strength. Since the value is, however, higher than what would actually occur in practice and because the high stress is localized on the disc surface, it is not regarded as affecting the wheel integrity for the required 1500-hour (steady-state) operation.

All rotor designs adequately meet the burst and gross yield speed requirements and the rupture life of the star wheel blades will also comply provided the metal temperature is reduced by the margin stipulated.

3.0 ANALYTICAL DESIGN

3.0.1 Design Analysis

The blade and disc designs were completed to comply with the stipulated requirements as stated in RFP 3-188454, QR 6-4938. Design stress analyses were done by use of a two-dimensional finite element program that allowed evaluation of [radial, tangential and axial] stresses in axisymmetric solids and [radial and axial] stress in plate sections. The program permitted evaluation of stresses (mechanical and thermal) in both disc and blade portions of the rotors. Certain hand analyses were also conducted to complete the design analysis. The resulting stress in all rotor components were limited to values that would comply with the requirements as mentioned above. These are:

(a) Minimum rotor burst speed shall be at least 140 percent of maximum continuous design speed.

(b) Gross yield speed of the rotor shall be at least 120 percent of maximum continuous design speed.

(c) Stress-rupture life shall be 1500 hours based on minimum rupture strength data.

(d) A 1500 start-stop cyclic life is targeted for the rotor and would be met. No component testing will, however, be done to confirm this requirement.

It should be noted that in the evaluation of thermal stress due to temperature gradients, only average (steady-state) temperatures through the blade thickness were used. The two-dimensional computer program does not permit the use of temperature variations in a tangential direction in either the rings or the plates and limited the analysis to the evaluation of average stress to ensure 1500 hours rotor stress-rupture life. For engine (start-stop) use, the analysis would be enlarged to include evaluation of transient metal temperatures and a rotor three-dimensional model to evaluate time-dependent stresses through the blade thickness and in the rotor hub sections.

3.0.2 METAL TEMPERATURES

Metal temperatures used in the overall stress analysis were supplied by the Heat Transfer group. The rotor (disc and blade) metal temperatures were evaluated for a total inlet temperature (T.I.T.) of 2800°F and a cooling flow of 13 percent of total air flow.

The metal temperatures evaluated are shown in Table 1 (disc metal temperatures) and Table 2 (blade metal temperatures). The geometry of the nodes at which temperatures are listed are shown in Figure 1 (disc node geometry) and Figure 2 (blade node geometry). The mid node temperatue values through the blade thickness, as shown in Figure 2, were used in the analysis (blade average metal temperature) as explained in para 3.0.1

The above blade and disc metal temperature input into the finite element computer program results in evaluation of thermal stress which adds to the centrifugal stress due to rotation.

3.0.3 ROTOR MATERIAL PROPERTIES

The materials used in the construction of the various blade-disc rotor configurations are listed in Table 3.

Material property data used in the design analysis are listed in Table 4. All material strengths are minimum design values based on -3σ statistical data.

3.0.4 ROTOR STRESS ANALYSIS

3.0.4.1 Operating Conditions

The rotors have been designed to operate at the conditions listed below:

(a) Maximum rotational speed of 65,000 rpm (1775 ft/sec tip speed)

(b) Metal temperatures as stipulated in para 3.0.2.

Both the above operating parameters were used as input into the finite element stress analysis program.

3.0.4.2 Star Wheel (One-Piece Casting) Analysis

The results of the stress analysis of the star wheel and blades are shown in Figures 7 through 13 which are computer plots of the input and output data as listed in Table 5.

Note: The numerical value of the Von Mises equivalent stress is

$$e = \frac{1}{\sqrt{2}}\left\{(\sigma R - \sigma Z)^2 + (\sigma R - \sigma T)^2 + (\sigma Z - \sigma \emptyset)^2 + 3\,\tilde{I}RZ^2\right\}^{1/2}$$

where:
σR = radial stress
σT = tangential stress
σZ = axial stress
$\tilde{I}RZ$ = shear stress in radial-axial plane.

In keeping with the theory of constant energy of distortion for ductile materials, elastic failure occurs when the equivalent stress value approaches the material yield strength (or elastic limit). This value is, therefore, used in computing the gross yield speed of a rotor subjected to multi-axial normal and shear stresses.

It should be noted that in the finite element analysis of the rotor, those elements that are not complete axisymmetric rings are treated as plates with appropriate thickness values. Hence the blades and the metal between the cooling air holes are treated as plates resulting in no tangential stress values being present at these elements (Fig. 11).

Direct (radial) stress on blade (axial) sections at constant radius were minimized by optimizing the blade area taper ratio. From the blade tip (3.25 Rad) down to section B-B (3.00 Rad) the area was held constant allowing the strss at section B-B to rise to 30 ksi. The areas at all other sections down to the disc hub line were increased in a manner to limit the stress at each section to the calculated maximum value of 40 ksi.

3.0.4.3 Exducer Wheel (One-Piece Casting) Analysis

The results of the stress analysis of the exducer wheel and blades are shown in Figures 14 through 20 which are computer plots of the input and output data similar to the values listed in Table 5.

As described in paragraph 3.0.4.2, non-axisymmetric elements (blades and metal between air holes) are treated as plates with appropriate thickness.

3.0.4.4 Inserted (Exducer) Blade Analysis

The stress in the blade (airfoil) section is similar to the values shown in Figures 17 through 19, para. 3.0.4.2. The stress in the blade and disc root fixing and the disc hub are as below.

3.0.4.4.1 Blade Root Fixing Analysis

The blade root fixing (half section) was modeled as a single plate and analyzed using finite element methods. This method allowed the evaluation of the peak fillet stress and was chosen over empirical methods that utilize photo-elastic data.

The centrifugal loading applied to the blade root dovetail fixing and the (hand) calculated average stress across the neck section are shown in Table 6.

The stresses in the blade root are shown in Figures 22 through 26.

Note: Figure 21 is a layout showing the blade and disc dovetail fixing and the location of the above Sections A-A and B-B.

3.0.4.4.2 Disc Stub Fixing Analysis

The disc stub fixing (half section) was modeled as a single plate and analyzed using finite element methods. The external loading applied to the disc stub for stress evaluation was as shown in Table 6. The stresses in the disc stub are shown in Figures 27 through 31.

3.0.4.4.3 Disc Hub Analysis

The results of the stress analysis of the (forged) disc hub are shown in Figures 32 through 37. The value of the load applied to the disc rim is shown in Table 6.

Note: The rim of an inserted blade disc is defined as the surface at the bottom of the blade slot. Material outside this surface is regarded as 'dead' weight contributing to the rim radial load (160,350 lbs).

4.0 DESIGN SPECIFICATIONS MARGINS OF SAFETY

The margin of safety on the design specifications listed in paragraph 3.0.1 are as follows.

4.0.1 Star Wheel

Maximum radial stress in blades 40,000 psi
Blade average temperature 1600°F

From Figure 4 stress rupture life of blade is evaluated as:

$$46 = (1600 + 460)\,(20 + \mathrm{Log}_{10}\ t) \times 10^{-3}$$

$$\mathrm{Log}\ t = 2.33 \qquad t = 214 \text{ hours}$$

To achieve the required 1500 hours stress-rupture life the blade (average) metal temperature must be limited to:

$$46 = (T + 460)\,(20 + \mathrm{Log}_{10}\ 1500) \times 10^{-3}$$

$$T = 1525°F$$

Since the blade stress cannot be further reduced (by increasing the area taper ratio) the blade average temperature should be reduced by 75° to 100°F to meet the stress-rupture life requirement.

The average tangential stress in the disc is calculated to be 59,370 psi.
Room temperature material tensile strength 150,000 psi.

Assuming a material casting burst factor of .85

$$\text{Disc burst speed} = 65{,}000 \times \left[\frac{.85 \times 150{,}000}{59{,}370}\right]^{1/2} = 65{,}000 \times 1.47 = 95{,}250 \text{ rpm.}$$

The required burst margin of 1.40 has hence been met.

The average equivalent stress in the disc is calculated to be 61,270 psi. Assuming a disc average temperature of 1200°F, material 0.2 percent yield strength is 120,000 psi.

$$\text{Gross yield speed} = 65{,}000 \times \left[\frac{.85 \times 120{,}000}{61{,}270}\right]^{1/2} = 65{,}000 \times 1.29 = 83{,}850 \text{ rpm.}$$

The required gross yield speed margin of 1.20 has hence been met.

Examining the values of equivalent stress contours, it is evident that the stress across the wheel cross section and in the blades are all of a progressively increasing and usual pattern, with no local areas of excessively high stress resulting due to the geometric shape of the rotor. Because of this characteristic of the rotor design, it is valid to use the values of average tangential and average equivalent stress of the wheel cross section to estimate the wheel burst speed and gross yield speed (as has been well substantiated in growth and burst spin tests). There is, however, one area of the wheel where the calculted radial stress in the plate section between the lower air holes are higher than desired. This area is toward the wheel aft face (contour J - 200,000 psi). This is due to a compromise in the wheel shape whereby the rear face was made radial to facilitate matching with the exducer wheel that is clamped to it. The high stress is, however, very localized and quickly reduces to 140,000 psi (contour G). This radial stress value is also actually fictitious since in reality tangential stresses will be in evidence in this area (flowing between and over the air hole boundaries) that will result in stiffening of the disc at this section and a consequent reduction in the radial stress. Tangential stress is not included in plate sections in the computer program analysis.

Cyclic fatigue life in the disc bore resulting from a calculated peak 'elastic' stress of 150,000 psi is estimated to be 10^4 cycles, which exceeds the 1500 cyclic start-stop value stipulated. These values are estimated from cyclic strain controlled material test data.

4.0.2 Cast Exducer Wheel

Maximum radial stress in blades 35,000 psi.
Blade temperature 1500°F.

From Figure 4 stress-rupture life of blade is evaluated as:

$$46.75 = (1500 + 460)\ (20 + \mathrm{Log}_{10}\ t) \times 10^3$$
$$\mathrm{Log}\ t = 3.25 \qquad t = 7110 \text{ hours}$$

The required 1500 hours stress rupture life has hence been met.

The average tangential stress in the disc is calculated to be 41,250 psi.
Room temperature material tensile strength 150,000 psi.

$$\text{Disc burst speed} = 65{,}000 \times \left[\frac{.85 \times 150{,}000}{41{,}250}\right]^{1/2} = 65{,}000 \times 1.75 = 114{,}280 \text{ rpm.}$$

The required burst margin of 1.4 has hence been met.

The average equivalent stress in the disc is calculated to be 38,335 psi. Assuming a disc average temperature of 1350°F, material 0.2 percent yield strength is 123,000 psi

$$\text{Gross yield speed} = 65{,}000 \times \left[\frac{.85 \times 123{,}000}{38{,}335}\right]^{1/2} = 65{,}000 \times 1.65 = 107{,}340 \text{ rpm.}$$

The required gross yield speed margin of 1.20 has hence been met.

Cyclic fatigue life in the disc bore resulting from a calculated peak 'elastic' stress of 130,000 psi is estimated in excess of 10^4 cycles which exceeds the 1500 start-stop value stipulated. The values are again estimated from strain controlled test data.

4.0.3 Blade Root Fixing (Exducer)

Table 6 shows that the average direct (radial) stress on blade fixing stem neck Section A-A is 53,290 psi. Figure 23 shows that the peak radial stress at root fillet is 150,000 psi dropping rapidly to 70,000 psi and to a value of 30,000 psi in the mid-section of the stem neck.

Under steady-state operating conditions, local yielding and time-dependent creep will result in a reduction of the calculated high 'elastic' stress at the fillet surface. For purposes of stress-rupture life evaluation the calculated average stress will be used to obtain a reliable (ball park) value. However, if the rotor is subjected to cyclic (stop-start) conditions, the resulting total strain range at the fillet surface must be evaluated and compared to the material (strain range) fatigue cyclic properties.

In keeping with the above statements the following are estimates of blade neck stress-rupture and cyclic fatigue life:

Average stress across blade neck (Section A-A)	53,290 psi
Blade neck metal temperature (estimated)	1300°F

Stress-rupture life from Figure 4:

$$44 = (1300 + 460)\ (20 + \log_{10} t) \times 10^{-3}$$
$$\log_{10} t = 5.00 \qquad t = 100{,}000 \text{ hours}$$

This value far exceeds the required 1500-hour life requirement.

For a peak fillet stress of 150,000 psi the total cyclic strain range generated at each start and stop cycle of the unit would be approximately 0.625 percent. Strain range cyclic data for the material indicates a cyclic life of 10^4 cycles (10,000 cycles) which exceeds the 1500 start-stop requirement.

4.0.4 Disc Stub Fixing (Exducer)

Table 6 shows that the average direct (radial) stress on the disc stub neck Section B-B is 74,000 psi. Figure 28 shows that the peak radial stress at stub neck fillet is 140,000 psi dropping rapidly to a value of 100,000 psi and to a value of 40,000 psi at mid-section. The same reasoning would apply to the reduction of local high 'elastic' stress at the disc stub neck fillet surface (para 4.0.3) under steady-state operating conditions. The resulting stress-rupture and cyclic fatigue life estimates are as follows:

Average stress across disc stub neck (Section B-B)	74,000 psi
Disc metal temperature (estimated)	1150°F

Stress-rupture life from Figure 7:

$$38 = (1150 + 460)\ (20 \log_{10} t) \times 10^{-3}$$
$$\log t = 3.60 \qquad t = 4000 \text{ hours}$$

This value exceeds the required 1500-hour life requirement.

For a peak fillet stress of 140,000 psi the cyclic strain range would be approximately 0.56 percent which would resultin a cyclic life in excess of 10^4 cycles which again exceeds the 1500 start-stop requirement.

4.0.5 Forged Disc Hub (Exducer)

The average tangential stress in the disc is calculated to be	57,490 psi.
Room temperature material tensile strength	185,000 psi.

$$\text{Disc burst speed} = 65{,}000 \times \left[\frac{.90 \times 185{,}000}{57{,}490}\right]^{1/2} = 65{,}000 \times 1.70 = 110{,}630 \text{ rpm}$$

The required burst margin of 1.40 has hence been met.

Note: A forging burst factor of .9 is used (as compared to .85 for the cast disc) because of the large ductility value of the IN-718 alloy (15 percent) as compared to the IN-792 alloy (5 percent).

The average equivalent stress in the disc is calculated to be 52,470 psi. With inserted blades it is estimated that the disc average metal temperature would not exceed 1150°F.

Material 0.2 percent yield strength is 120,000 psi.

$$\text{Gross yield speed} = 65{,}000 \times \left[\frac{.90 \times 120{,}000}{52{,}470}\right]^{1/2} = 65{,}000 \times 1.43 = 92{,}950 \text{ rpm.}$$

The required gross yield speed margin of 1.20 has hence been met.

4.0.6 'Balloning' of Blade Surface

A (hand) calculation has been performed to check on the problem of 'ballooning' of the blade surface due to the cooling air pressure internally being larger than the gas surface pressure externally on the cored blade. The blade surface chosen for the analysis is shown in Figure 40 (largest flat plate area) under the internal and external pressures shown in Figure 41.

The hand calculation included indicates a maximum bending stress in the blade wall of 5000 psi and no possibility of 'ballooning' of the blade wall.

5.0 CONCLUSION

Whereas it is anticipated that some (considerable) difficulty may be experienced in producing sound castings of the star and exducer rotors (because of the complexity of the internally cored passages in the blade sections of the two rotors) the mechanical integrity of the two rotors is assured. No drastic or sudden changes in section have been permitted or included in the design of the two rotors (either blade or disc sections) and excluding the above blade cored passage complexity, the design follows standard, state-of-the-art, company practice.

The spin testing of rotors that will commence at speeds (N) equal to:

$$N = 1.2 \times 65{,}000 \times \frac{\text{0.2 percent yield strength at room temperature}}{\text{0.2 percent yield strength at operating temperature}}$$

under which condition no measurable growth of the rotor must result will ensure that the gross yield speed requirement of the rotors have been met.

Note: The speed is increased in the above ratio since it is not possible to heat the disc to its operating temperature in the spin pit.

A second test will be conducted at a speed at which the tangential stress in the bore is brought up to the value which results under operating temperature conditions. Following this test no measurable growth must result in the bore.

Following the above tests, rotors will be spun at progressively higher speeds until burst failure results. At each speed disc growth values will be measured and plotted versus speed. Visual and other nondestructive testing (NDT) of the rotors will be conducted to ensure that no localized failures have occurred at either the blade or hub sections of both rotors.

The final bursting of the rotors will confirm the burst speed requirements and the nature of the burst segments will indicate the absence (or presence) of any localized weak elements in the rotor design.

In conclusion it can be stated that the detailed stress and thermal analyses conducted in the rotor design, together with the above testing, will ensure the integrity of the rotors to comply with and meet the operational requirements stipulated.

BLADE WALL BENDING DUE TO INTERNAL PRESSURE

The blade section analyzed is rectangular section shown hatched [.900 x .320] (Fig. 40). Assume plate is uniformly loaded and fixed on all sides.

Plate thickness assumed (constant) ≈ .040 inch
Assumed average internal pressure ≈ 240 psi (Fig. 41)
Assumed average external pressure ≈ 135 psi (Fig. 41)

From Roark "Formulae for Stress and Strain", pg. 203, Case 36.

$$\text{Max } s \text{ (at center)} = \frac{\beta \omega b^2}{t^2} \qquad \frac{b}{a} \approx 2.8$$

$$\text{Max } \Delta \text{ (at center)} \quad \frac{\alpha \omega b^4}{t^3} \qquad \beta = 0.750, \quad \alpha = 0.1422$$

$$s = \frac{0.750 \times 105 \times .320^2}{.040^2} = \underline{5040 \text{ psi}}$$

$$\Delta = \frac{0.1422 \times 105 \times .320^4}{24 \times 10^6 \times .040^3} = \underline{.0001 \text{ inch}}$$

NOTE: The remaining exducer areas have pins joining the two walls and the star portion wall thickness is considerably larger and plate areas smaller than above values. The above values are hence the maximum that can be expected.

NASA COOLED RADIAL TURB.DISC .HEAT TRANSFER.THETA=36DEGR.AXISYM.G.AIGRET.

--------	TIME HR	MINUTES	COUNT	PREV INC	NEXT INC	MIN RC
	1.1212E+02	6.7275E+03	300	3.7500E-01	3.7500E-01	1.5000E+00

PREVIOUS TEMPERATURES

1 1.3512E+03	2 1.3992E+03	3 1.4359E+03	4 1.2935E+03	5 1.3306E+03	6 1.3665E+03	7 1.4003E+03	8 1.2829E+03	9 1.3172E+03	10 1.3504E+03
11 1.3825E+03	12 1.2507E+03	13 1.2820E+03	14 1.3128E+03	15 1.3428E+03	16 1.3720E+03	17 1.4001E+03	18 1.2515E+03	19 1.2810E+03	20 1.3101E+03
21 1.3386E+03	22 1.3667E+03	23 1.3944E+03	24 1.4216E+03	25 1.0811E+03	26 1.0925E+03	27 1.1147E+03	28 1.1479E+03	29 1.1948E+03	30 1.2678E+03
31 1.3141E+03	32 1.3616E+03	33 1.4102E+03	34 1.4594E+03	35 1.0976E+03	36 1.1129E+03	37 1.1397E+03	38 1.1757E+03	39 1.2128E+03	40 1.2591E+03
41 1.3055E+03	42 1.3530E+03	43 1.4021E+03	44 1.4535E+03	45 1.1560E+03	46 1.1959E+03	47 1.2375E+03	48 1.2784E+03	49 1.3219E+03	50 1.3654E+03
51 1.4123E+03	52 1.4591E+03	53 1.4928E+03	54 1.1249E+03	55 1.1898E+03	56 1.2624E+03	57 1.3407E+03	58 1.4258E+03	59 1.5195E+03	60 1.1253E+03
61 1.1893E+03	62 1.2566E+03	63 1.3282E+03	64 1.4049E+03	65 1.4880E+03	66 1.5789E+03	67 1.1242E+03	68 1.1832E+03	69 1.2438E+03	70 1.3067E+03
71 1.3723E+03	72 1.4409E+03	73 1.5130E+03	74 1.5918E+03	75 1.0786E+03	76 1.1234E+03	77 1.1735E+03	78 1.2256E+03	79 1.2787E+03	80 1.3316E+03
81 1.3828E+03	82 1.4293E+03	83 1.4647E+03	84 1.4770E+03	85 1.0742E+03	86 1.1159E+03	87 1.1600E+03	88 1.2036E+03	89 1.2474E+03	90 1.2878E+03
91 1.3230E+03	92 1.3463E+03	93 1.3461E+03	94 1.0710E+03	95 1.1044E+03	96 1.1450E+03	97 1.1787E+03	98 1.2162E+03	99 1.2447E+03	100 1.2693E+03
101 1.2792E+03	102 1.2662E+03	103 1.2013E+03	104 1.0382E+03	105 1.0731E+03	106 1.1301E+03	107 1.1778E+03	108 1.2022E+03	109 1.1866E+03	110 1.0194E+03
111 1.0504E+03	112 1.0896E+03	113 1.1198E+03	114 1.1323E+03	115 1.1183E+03	116 1.0867E+03	117 9.9883E+02	118 1.0243E+03	119 1.0493E+03	120 1.0681E+03
121 1.0751E+03	122 1.0664E+03	123 1.0421E+03	124 9.6255E+02	125 9.7049E+02	126 9.8106E+02	127 9.9081E+02	128 9.9843E+02	129 1.0025E+03	130 1.0022E+03
131 9.9758E+02	132 9.6906E+02	133 9.6900E+02	134 9.6856E+02	135 9.7378E+02	136 9.8184E+02	137 9.9042E+02	138 9.9843E+02	139 1.0060E+03	140 1.0160E+03
141 1.0370E+03	142 1.0952E+03	143 1.1531E+03	144 1.1505E+03	145 9.6919E+02	146 9.6927E+02	147 9.7013E+02	148 9.7485E+02	149 9.8221E+02	150 9.9045E+02
151 9.9875E+02	152 1.0078E+03	153 1.0210E+03	154 1.0464E+03	155 1.0941E+03	156 1.1383E+03	157 1.1433E+03	158 1.1899E+03	159 1.2003E+03	160 1.2126E+03
161 1.2221E+03	162 1.2258E+03	163 1.1860E+03	164 1.1951E+03	165 1.2033E+03	166 1.2145E+03	167 1.2828E+03	168 1.3306E+03	169 1.1701E+03	170 1.1766E+03
171 1.1839E+03	172 1.1956E+03	173 1.2612E+03	174 1.3200E+03	175 1.3798E+03	176 1.4203E+03	177 1.4554E+03	178 1.5059E+03	179 1.1585E+03	180 1.1619E+03
181 1.1670E+03	182 1.1776E+03	183 1.2405E+03	184 1.2978E+03	185 1.3506E+03	186 1.3961E+03	187 1.4401E+03	188 1.4849E+03	189 1.5220E+03	190 1.5472E+03
191 1.5842E+03	192 1.1479E+03	193 1.1627E+03	194 1.2221E+03	195 1.2738E+03	196 1.3250E+03	197 1.3699E+03	198 1.4143E+03	199 1.4539E+03	200 1.4904E+03
201 1.5220E+03	202 1.5524E+03	203 1.5727E+03	204 1.5681E+03	205 1.1571E+03	206 1.2053E+03	207 1.2463E+03	208 1.3023E+03	209 1.3404E+03	210 1.3895E+03
211 1.4218E+03	212 1.4596E+03	213 1.4829E+03	214 1.5048E+03	215 1.5108E+03	216 1.4910E+03	217 1.1522E+03	218 1.1983E+03	219 1.2946E+03	220 1.3790E+03
221 1.4400E+03	222 1.4678E+03	223 1.4464E+03	224 1.4170E+03	225 1.1197E+03	226 1.1611E+03	227 1.2666E+03	228 1.3544E+03	229 1.4130E+03	230 1.4373E+03
231 1.4220E+03	232 1.4036E+03	233 1.1085E+03	234 1.2380E+03	235 1.3334E+03	236 1.3910E+03	237 1.4142E+03	238 1.4044E+03	239 1.3909E+03	240 1.0620E+03
241 1.2125E+03	242 1.3186E+03	243 1.3746E+03	244 1.3971E+03	245 1.3916E+03	246 1.3815E+03	247 1.3688E+03	248 1.0918E+03	249 1.1919E+03	250 1.3138E+03

Table 1

P-315 THERMAL TRANSIENT ANALYSER REVISION NO. 2.0 06/01/81 10.21.05 PAGE 62
NASA COOLED RADIAL TURBINE-HALF BLADE-HEAT TRANSFER-G.AIGRET

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-------- TIME HR	MINUTES	COUNT	PREV INC	NEXT INC	MIN RC
2.1825E+02	1.3095E+04	195	1.1250E+00	1.1250E+00	4.5000E+00

CURRENT TEMPERATURES

1	2	3	4	5	6	7	8	9	10
1.7070E+03	1.5188E+03	1.2661E+03	1.6873E+03	1.5150E+03	1.3150E+03	1.6735E+03	1.5201E+03	1.3524E+03	1.6517E+03
11	12	13	14	15	16	17	18	19	20
1.5188E+03	1.3763E+03	1.6191E+03	1.5054E+03	1.3835E+03	1.5821E+03	1.4862E+03	1.3836E+03	1.5452E+03	1.4661E+03
21	22	23	24	25	26	27	28	29	30
1.3820E+03	1.5149E+03	1.4500E+03	1.3812E+03	1.5046E+03	1.4501E+03	1.3915E+03	1.5570E+03	1.5053E+03	1.4528E+03
31	32	33	34	35	36	37	38	39	40
1.5682E+03	1.5185E+03	1.4670E+03	1.6072E+03	1.5513E+03	1.4926E+03	1.5841E+03	1.5283E+03	1.4702E+03	1.5965E+03
41	42	43	44	45	46	47	48	49	50
1.5410E+03	1.4835E+03	1.6266E+03	1.5714E+03	1.5151E+03	1.6643E+03	1.6110E+03	1.5566E+03	1.7145E+03	1.6611E+03
51	52	53	54	55	56	57	58	59	60
1.6072E+03	1.7585E+03	1.7029E+03	1.6475E+03	1.7778E+03	1.7186E+03	1.6593E+03	1.7845E+03	1.7216E+03	1.6587E+03
61	62	63	64	65	66	67	68	69	70
1.7876E+03	1.7145E+03	1.6409E+03	1.7964E+03	1.7085E+03	1.6230E+03	1.7940E+03	1.6834E+03	1.5765E+03	1.7653E+03
71	72	73	74	75	76	77	78	79	80
1.6308E+03	1.4897E+03	1.7733E+03	1.6398E+03	1.5285E+03	1.8254E+03	1.6410E+03	1.5288E+03	1.7175E+03	1.6192E+03
81	82	83	84	85	86	87	88	89	90
1.5312E+03	1.4350E+03	1.4050E+03	1.3880E+03	1.4000E+03	1.4150E+03	1.4470E+03	1.4550E+03	1.4650E+03	1.4800E+03
91	92	93	94	95	96	97	98	99	100
1.5050E+03	1.5530E+03	1.5700E+03	2.4740E+03	2.5500E+03	2.5460E+03	2.5380E+03	2.5290E+03	2.5170E+03	2.5060E+03
101	102	103	104	105	106	107	108	109	110
2.4950E+03	2.4850E+03	2.4740E+03	2.4650E+03	2.4560E+03	2.4480E+03	2.4390E+03	2.4320E+03	2.4240E+03	9.8100E+02
111	112	113	114	115	116	117	118	119	120
1.0058E+03	1.0174E+03	1.0299E+03	1.0428E+03	1.0555E+03	1.0678E+03	1.0795E+03	1.0908E+03	1.1021E+03	1.1152E+03
121	122	123	124	125	126	127	128	129	130
1.1285E+03	1.1422E+03	1.1587E+03	1.1587E+03	1.1754E+03	1.1903E+03	1.2050E+03	1.2200E+03	1.2354E+03	1.2520E+03
131	132	133	134	135	136	137	138	139	140
1.2694E+03	1.2895E+03	1.3086E+03	1.3258E+03	1.3412E+03	9.8100E+02	1.0200E+03	1.0564E+03	1.0863E+03	1.1069E+03
141	142	143	144	145	146	147	148	149	150
1.1587E+03	1.1648E+03	1.1723E+03	1.1813E+03	1.3979E+03	1.3360E+03	1.2785E+03	1.4521E+03	1.3590E+03	1.2649E+03
151	152	153	154	155	156	157	158	159	160
1.4691E+03	1.3872E+03	1.3020E+03	1.4806E+03	1.4055E+03	1.3277E+03	1.4778E+03	1.4117E+03	1.3425E+03	1.4790E+03
161	162	163	164	165	166	167	168	169	170
1.4214E+03	1.3604E+03	1.5135E+03	1.4631E+03	1.4100E+03	1.5849E+03	1.5509E+03	1.5162E+03	1.7535E+03	1.7378E+03
171	172	173	174	175	176	177	178	179	180
1.7250E+03	1.7210E+03	1.6881E+03	1.6553E+03	1.6621E+03	1.6207E+03	1.5775E+03	1.6357E+03	1.5922E+03	1.5473E+03
181	182	183	184	185	186	187	188	189	190
1.6299E+03	1.5816E+03	1.5321E+03	1.6254E+03	1.5704E+03	1.5143E+03	1.6046E+03	1.5432E+03	1.4802E+03	1.5900E+03
191	192	193	194	195	196	197	198	199	200
1.5138E+03	1.4368E+03	1.5535E+03	1.4608E+03	1.3627E+03	1.7540E+03	1.7179E+03	1.6808E+03	1.7587E+03	1.7218E+03
201	202	203	204	205	206	207	208	209	210
1.6848E+03	1.7291E+03	1.6892E+03	1.6476E+03	1.7312E+03	1.6880E+03	1.6444E+03	1.7117E+03	1.6594E+03	1.6059E+03
211	212	213	214	215	216	217	218	219	220
1.6750E+03	1.6132E+03	1.5490E+03	1.6493E+03	1.5706E+03	1.4864E+03	1.6506E+03	1.5640E+03	1.4740E+03	1.6276E+03
221	222	223	224	225	226	227	228	229	230
1.5510E+03	1.4647E+03	9.6500E+02	9.6721E+02	9.7291E+02	9.8120E+02	9.8996E+02	9.9894E+02	1.0083E+03	1.0182E+03
231	232	233	234	235	236	237	238	239	240
1.0182E+03	1.0664E+03	1.0763E+03	1.0182E+03	1.0300E+03	1.0424E+03	1.0424E+03	1.0577E+03	1.0718E+03	1.0718E+03
241	242	243	244	245	246	247	248	249	250
1.0868E+03	1.1002E+03	1.1125E+03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2

Table 3

COMPONENT	MATERIAL
One-piece cast (integral blades and disc) star wheel	IN-792 Mod 5A HIPed and heat treated
One-piece cast (integral blades and disc) exducer wheel	IN-792 Mod 5A HIPed and heat treated
Individually cast exducer blades	IN-792 Mod 5A HIPed and heat treated
Forged exducer hub retaining cast exducer blades	IN-718 (to AMS 5398)

Table 4

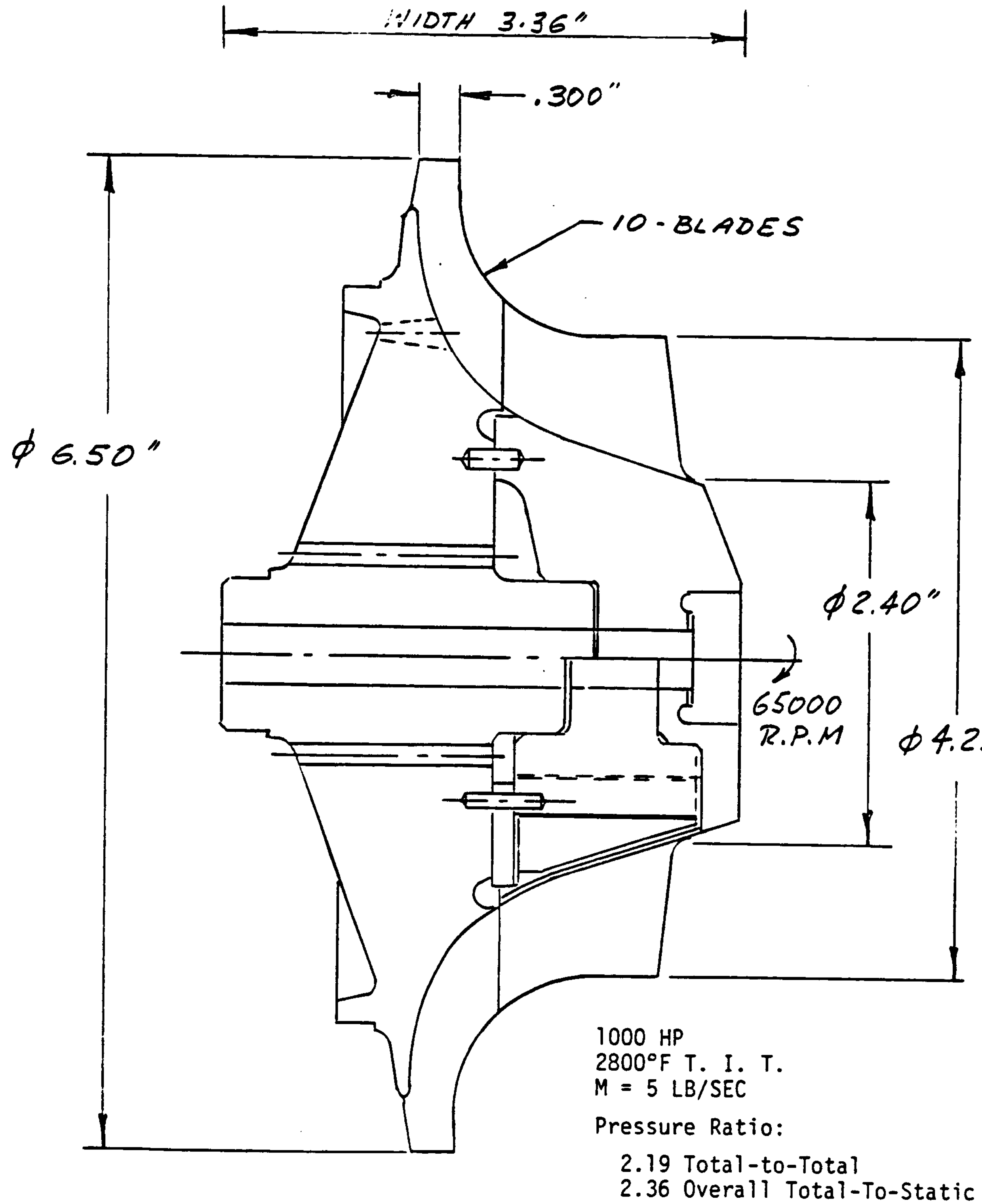
FIGURE NUMBER	PROPERTY
3	IN-792 minimum ultimate tensile strength and 0.2 percent yield strength versus temperature
4	IN-792 Larson-Miller stress rupture data
5	IN-718 minimum ultimate tensile strength and 0.2 percent yield strength versus temperature
6	IN-718 Larson-Miller stress-rupture data

Table 5

FIGURE NUMBER	COMPUTER PLOT DESCRIPTION
7	Finite element geometry node numbers
8	Finite element geometry element numbers
9	Rotor temperature isotherma
10	Rotor radial isostress lines
11	Rotor tangential isostress lines
12	Rotor equivalent isostress lines
13	Rotor operating deflection

Table 6

SECTION	TOTAL LOAD	AVERAGE STRESS
Blade stem neck (Section A-A)	13,480 lbs	53,290 psi
Disc stub neck (Section B-B)	17,575 lbs	74,000 psi
Dovetail fixing bearing surfaces	15,520 lbs	120,725 psi
Disc rim surface	160,350 lbs	



AIR-COOLED RADIAL TURBINE
(Full Size)

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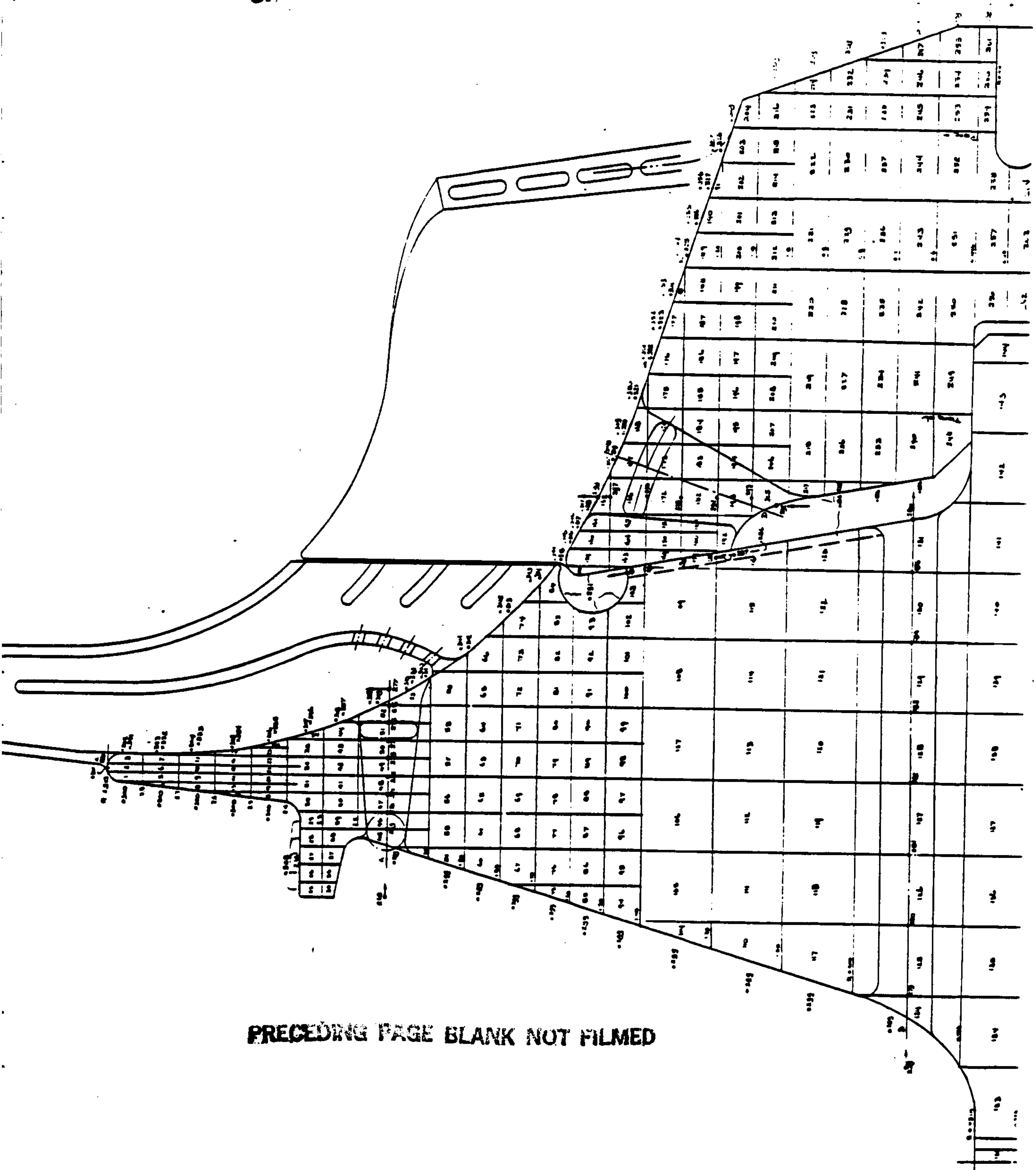
FIGURE 1



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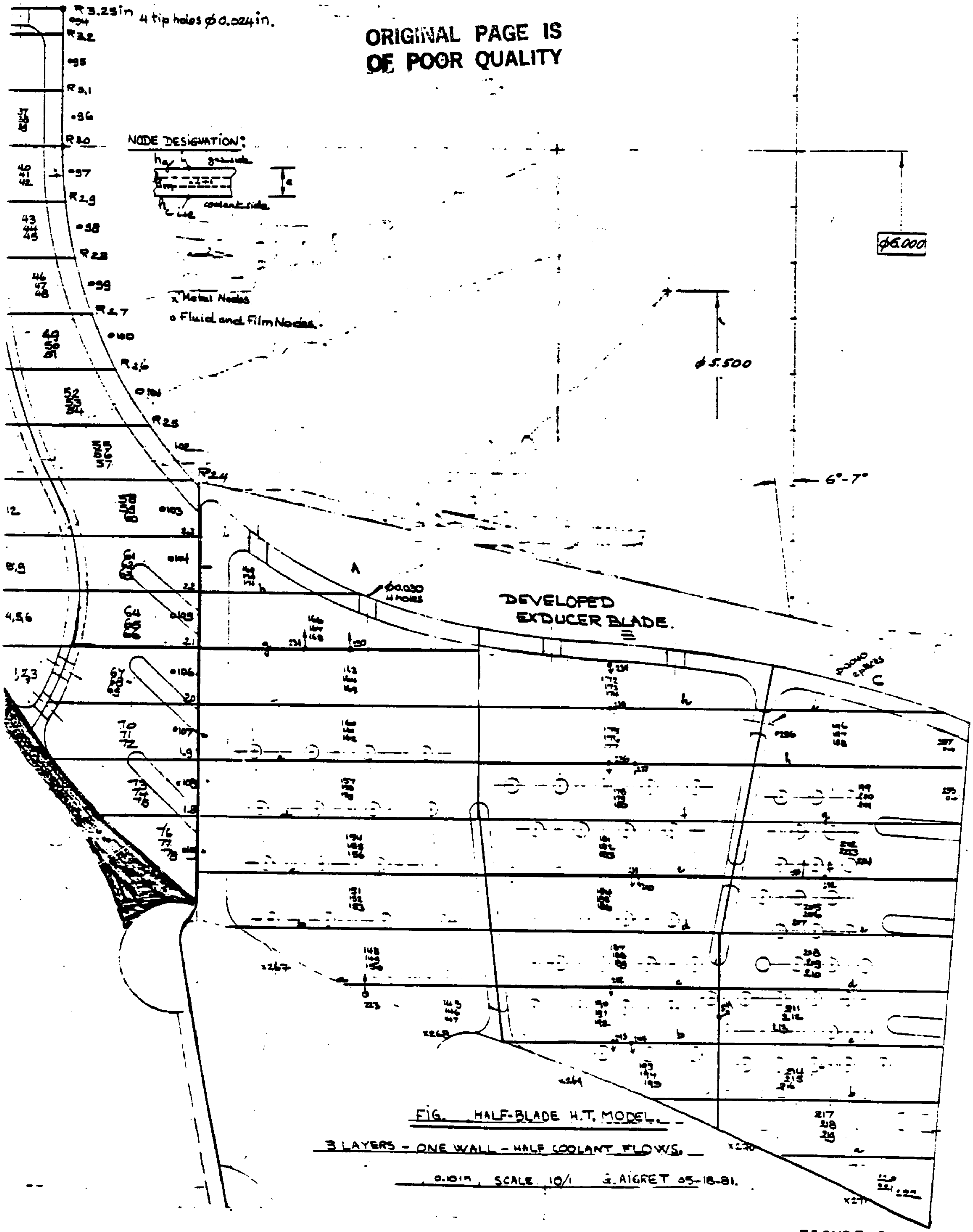

R 3.25in 4 tip holes ϕ 0.024 in.
NODE DESIGNATION:
x Metal Nodes
o Fluid and Film Nodes.
ϕ6.000
ϕ5.500
6°-7°
ϕ0.030 4 holes
DEVELOPED EXDUCER BLADE.
FIG. HALF-BLADE H.T. MODEL.
3 LAYERS - ONE WALL - HALF COOLANT FLOWS.
SCALE 10/1 G. AIGRET 05-18-81.

FIGURE 2

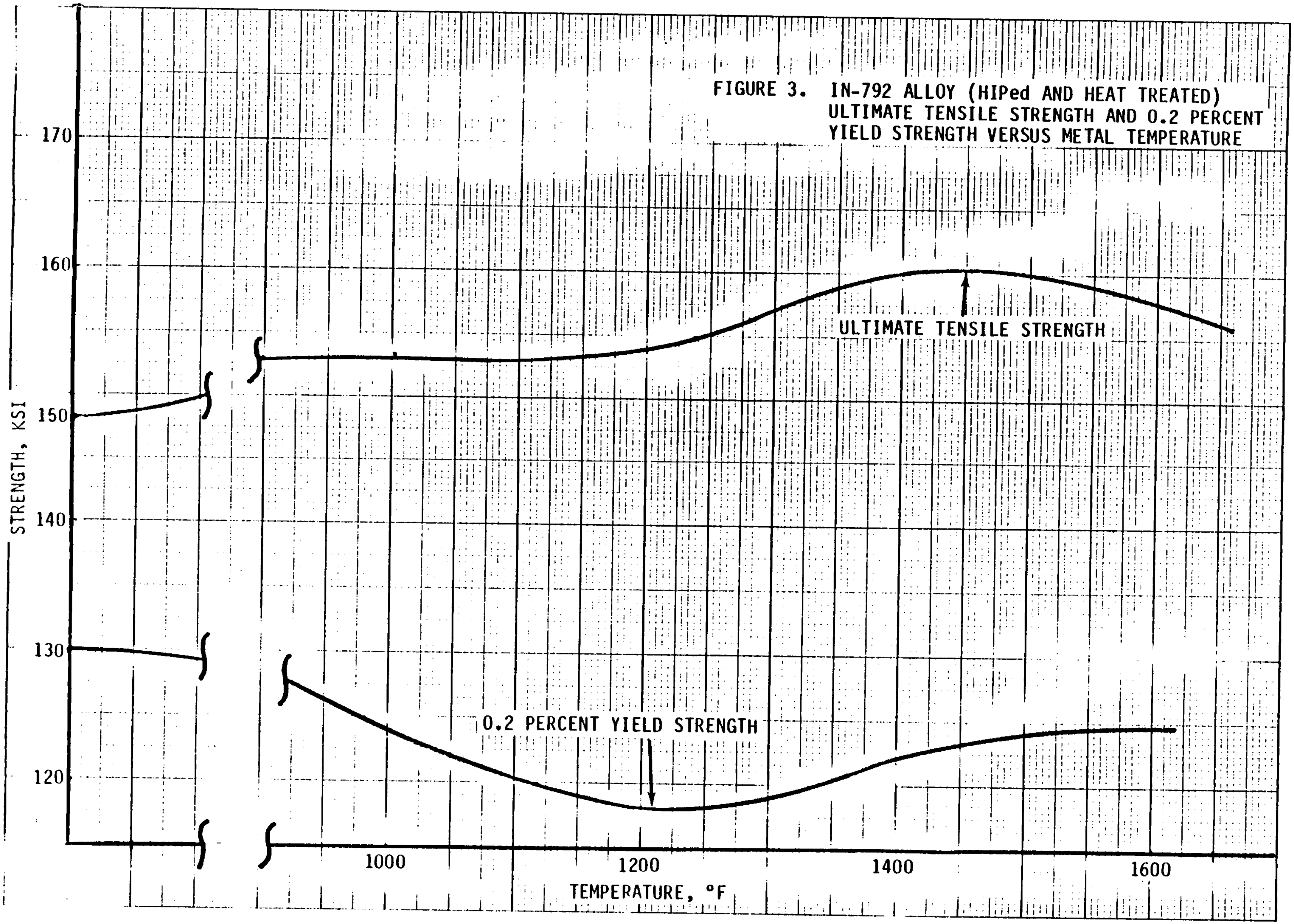


FIGURE 3. IN-792 ALLOY (HIPed AND HEAT TREATED) ULTIMATE TENSILE STRENGTH AND 0.2 PERCENT YIELD STRENGTH VERSUS METAL TEMPERATURE

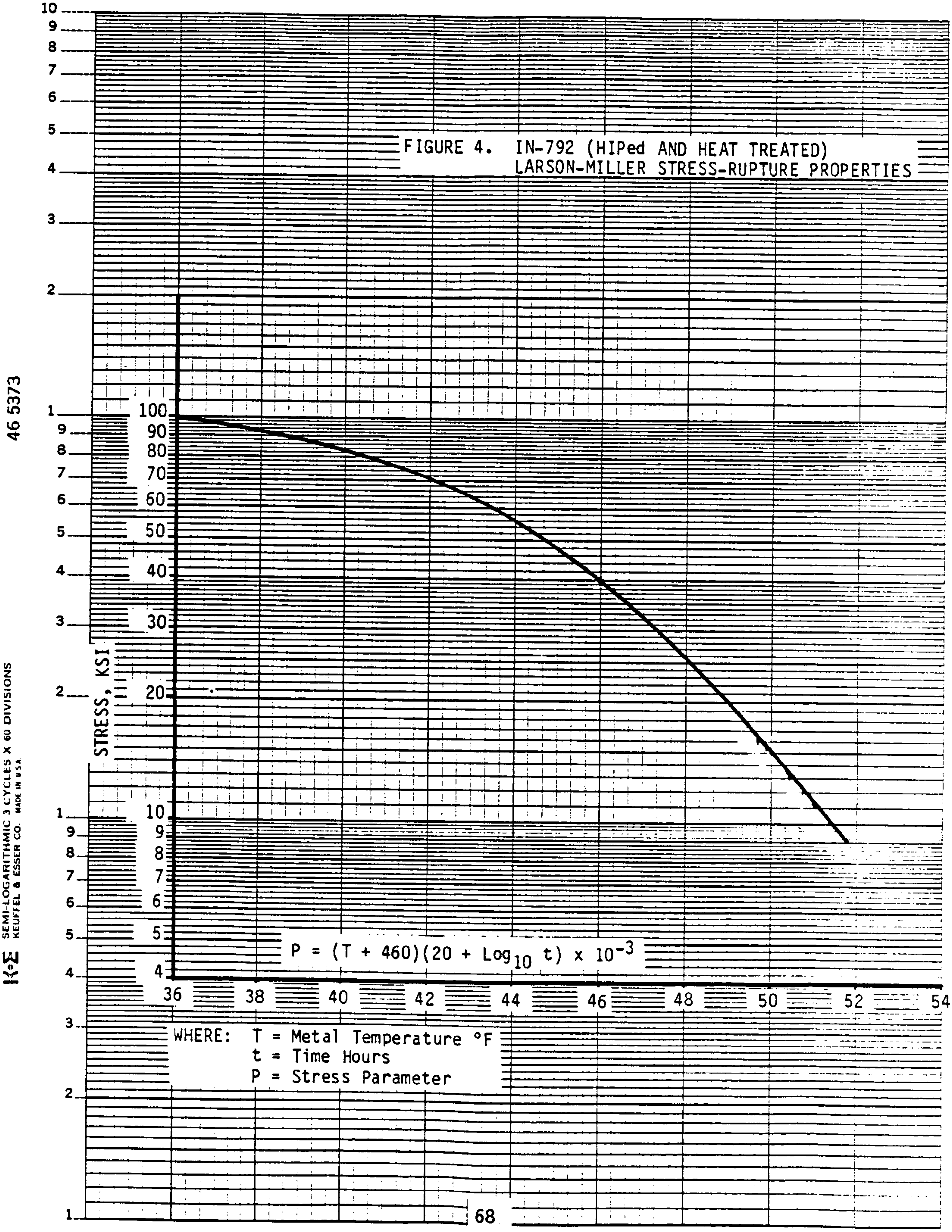


FIGURE 4. IN-792 (HIPed AND HEAT TREATED)
LARSON-MILLER STRESS-RUPTURE PROPERTIES
STRESS, KSI
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
36
38
40
42
44
46
48
50
52
54
P = (T + 460)(20 + Log10 t) x 10-3
WHERE: T = Metal Temperature °F
t = Time Hours
P = Stress Parameter
46 5373
SEMI-LOGARITHMIC 3 CYCLES X 60 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

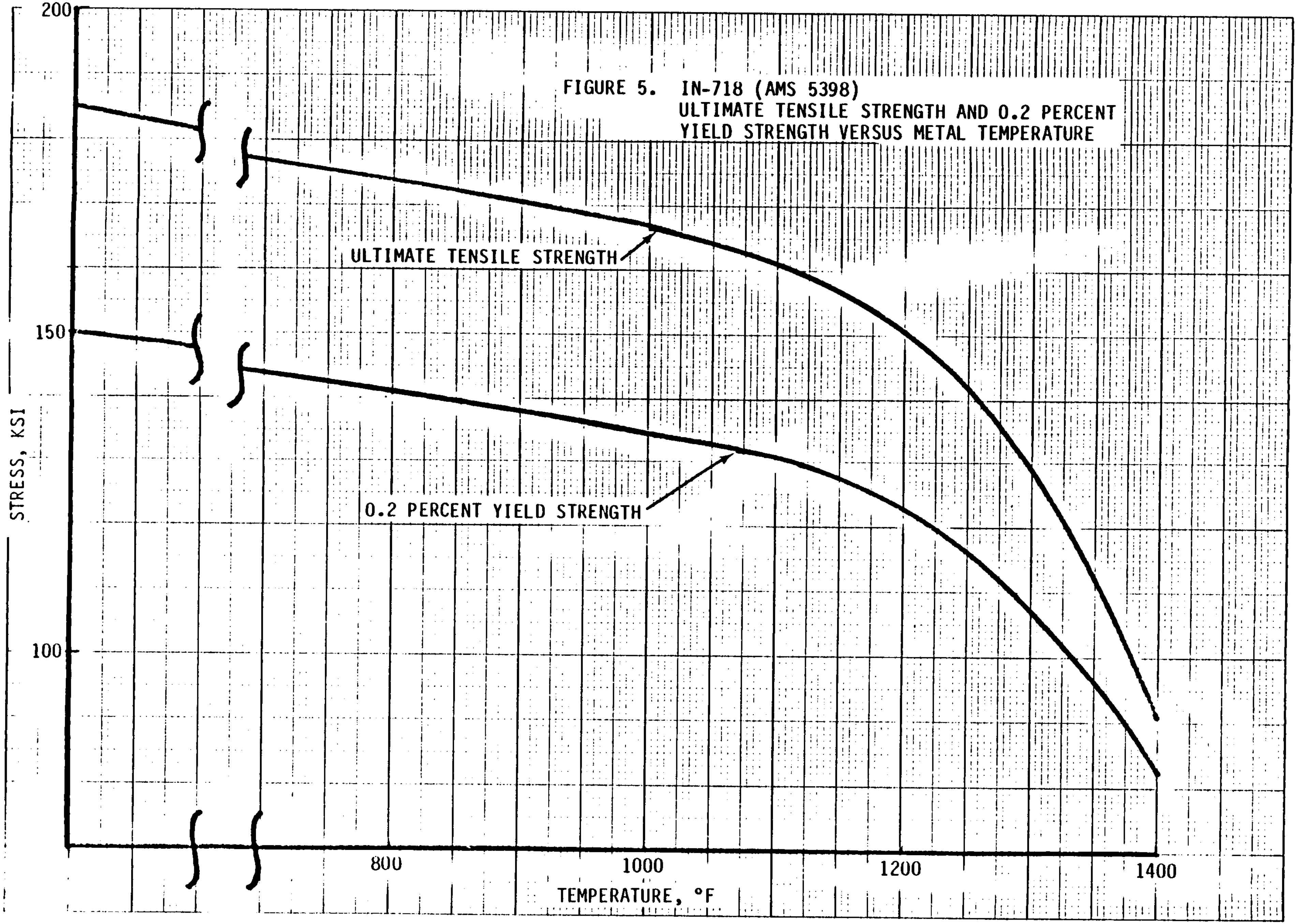


FIGURE 5. IN-718 (AMS 5398)
ULTIMATE TENSILE STRENGTH AND 0.2 PERCENT YIELD STRENGTH VERSUS METAL TEMPERATURE

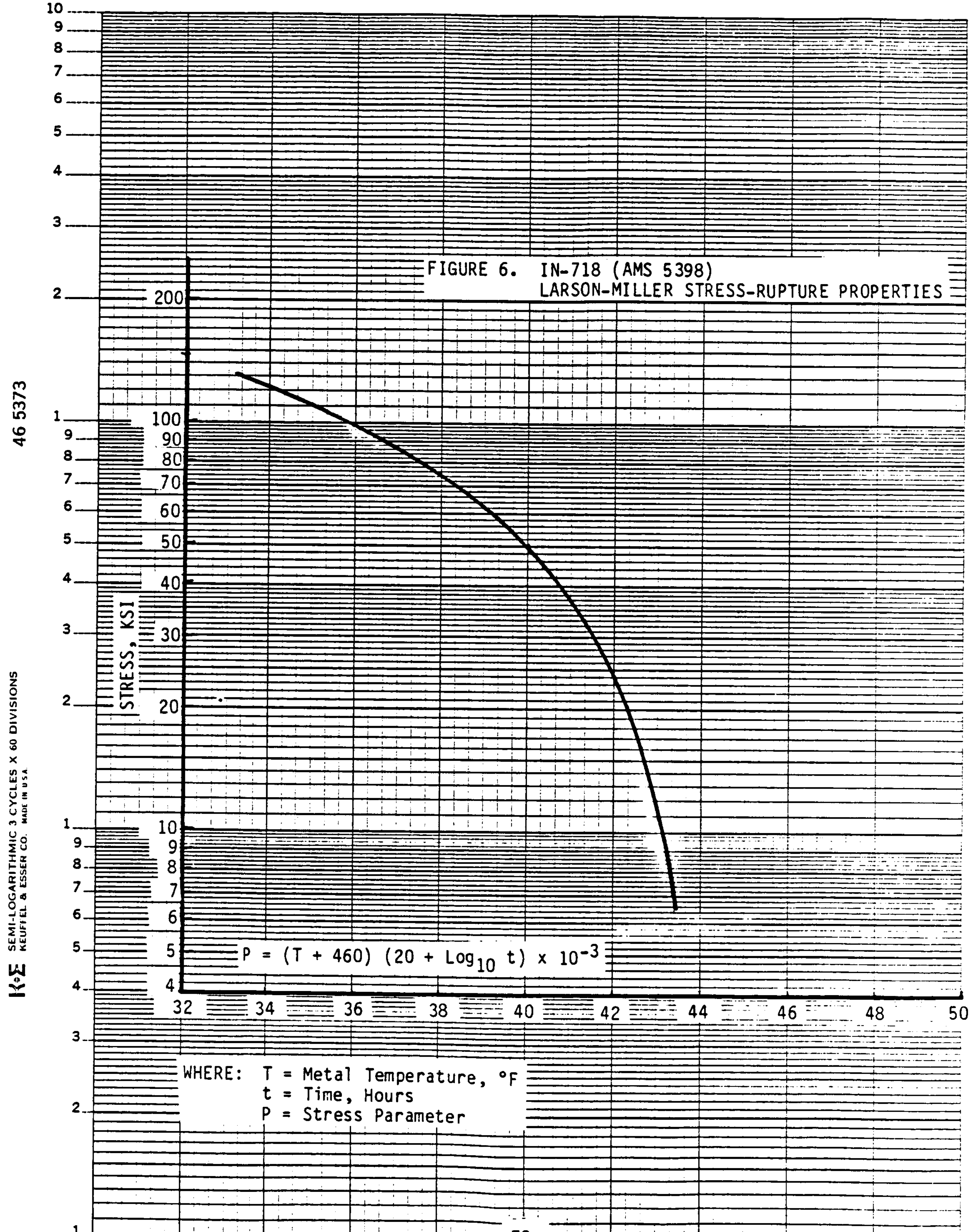


FIGURE 6. IN-718 (AMS 5398)
LARSON-MILLER STRESS-RUPTURE PROPERTIES
STRESS, KSI
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
P = (T + 460) (20 + Log10 t) x 10-3
32
34
36
38
40
42
44
46
48
50
WHERE: T = Metal Temperature, °F
t = Time, Hours
P = Stress Parameter
46 5373
SEMI-LOGARITHMIC 3 CYCLES X 60 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

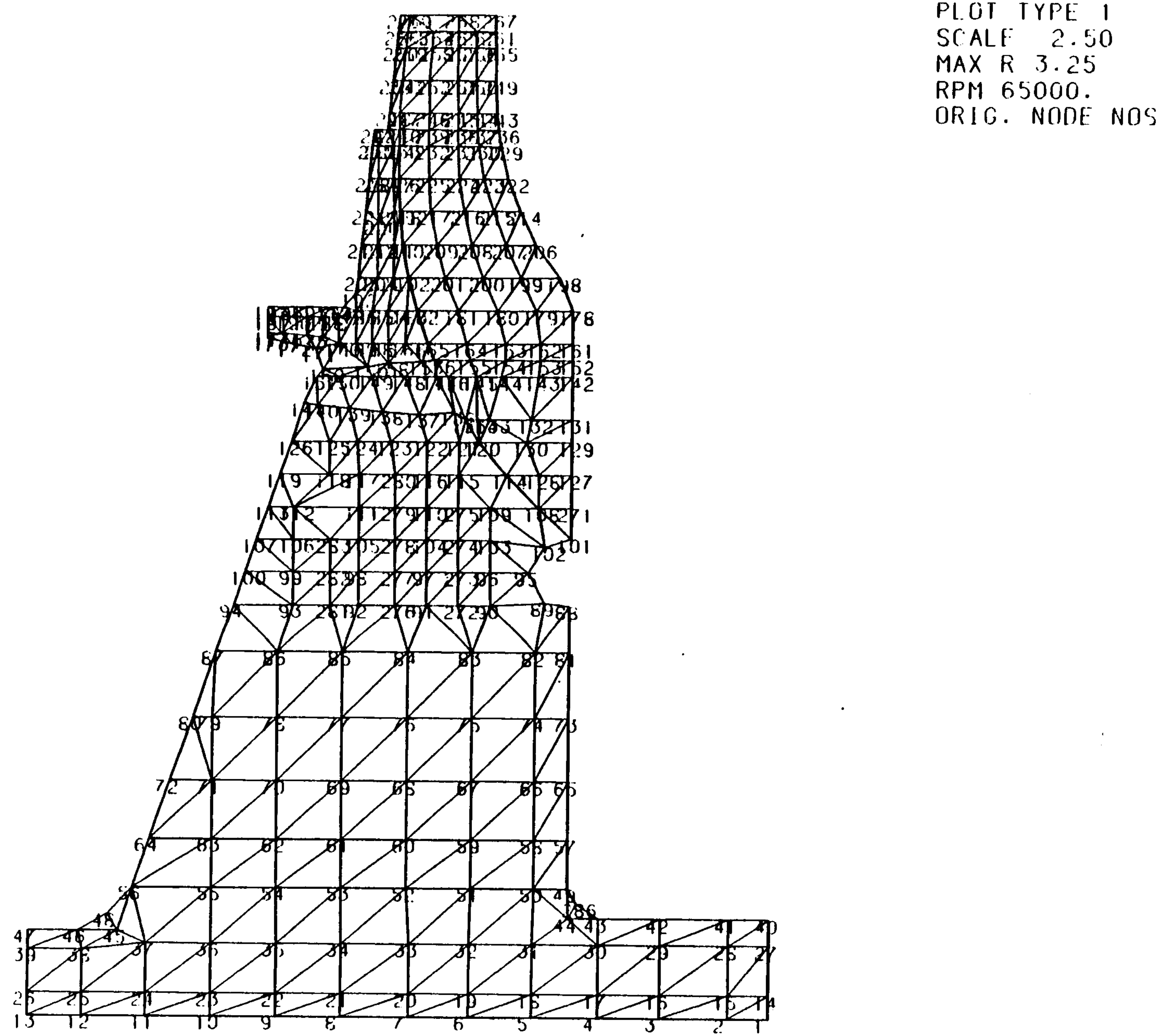
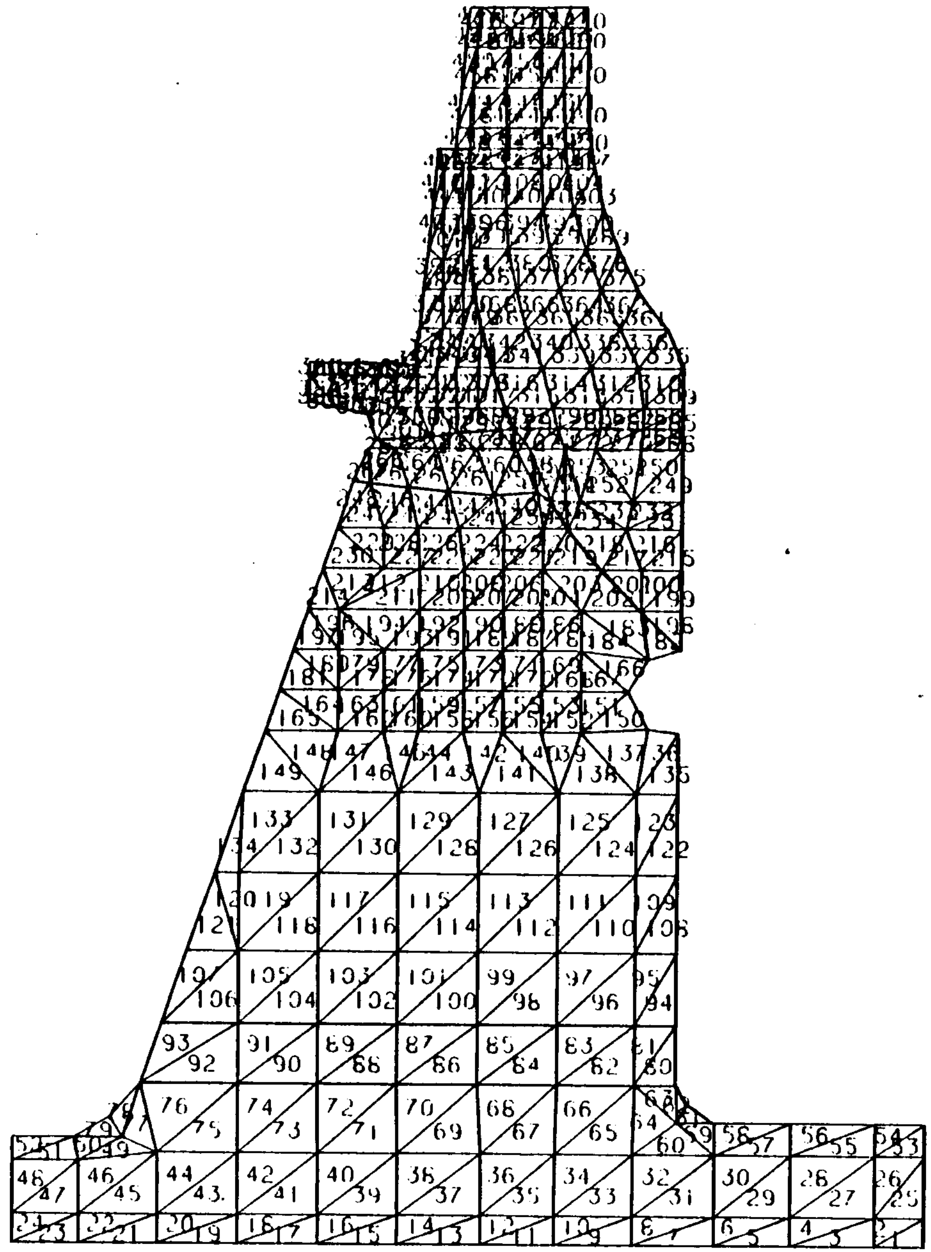


FIGURE 7



2D STRESS PROG.
PLOT TYPE 2
SCALE 2.50
MAX R 3.25
RPM 65000.
ELEMENT NOS.

FIGURE 8

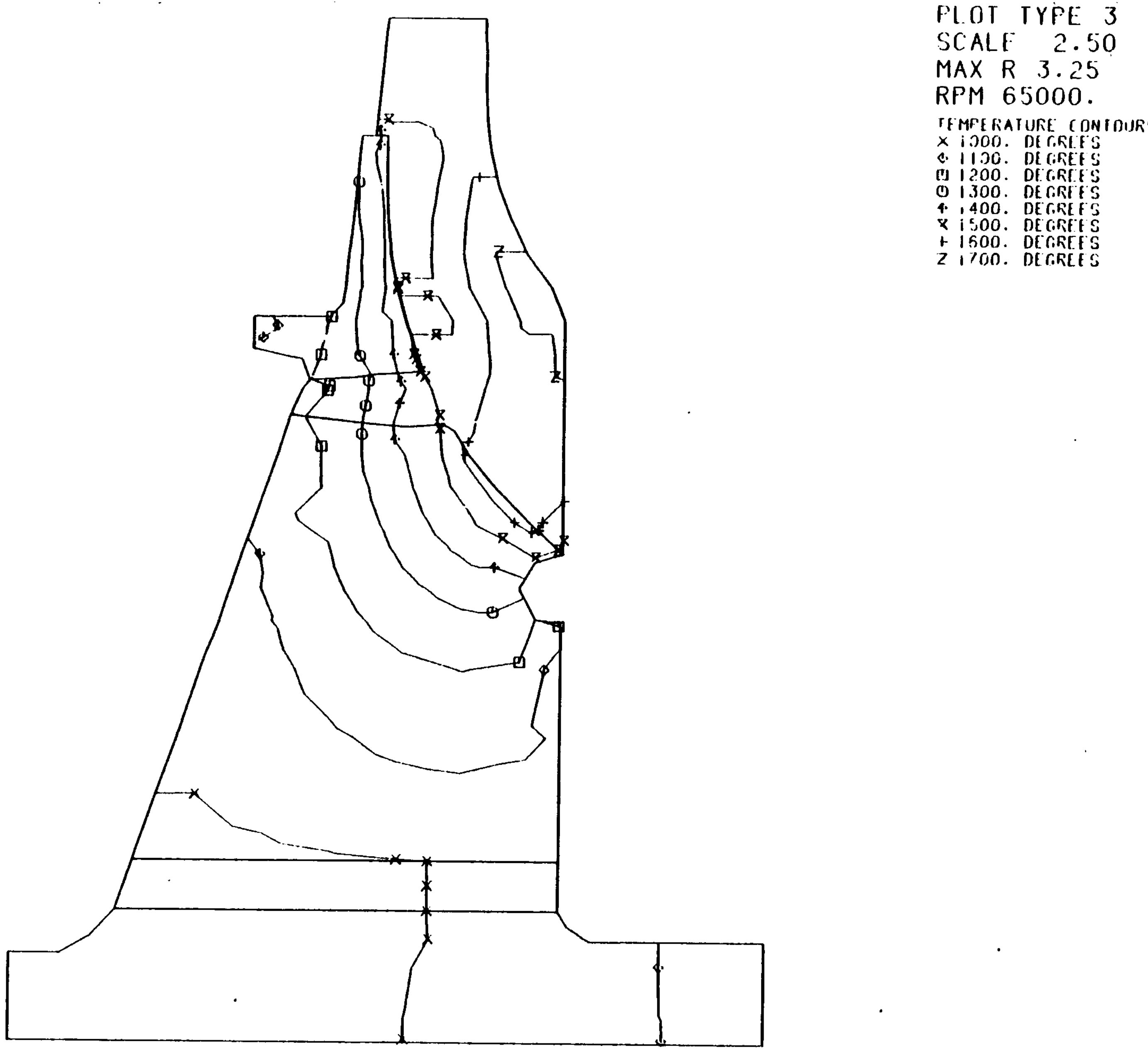

PLOT TYPE 3
SCALE 2.50
MAX R 3.25
RPM 65000.
TEMPERATURE CONTOURS
X 1000. DEGREES
◇ 1100. DEGREES
□ 1200. DEGREES
O 1300. DEGREES
+ 1400. DEGREES
X 1500. DEGREES
+ 1600. DEGREES
Z 1700. DEGREES

FIGURE 9

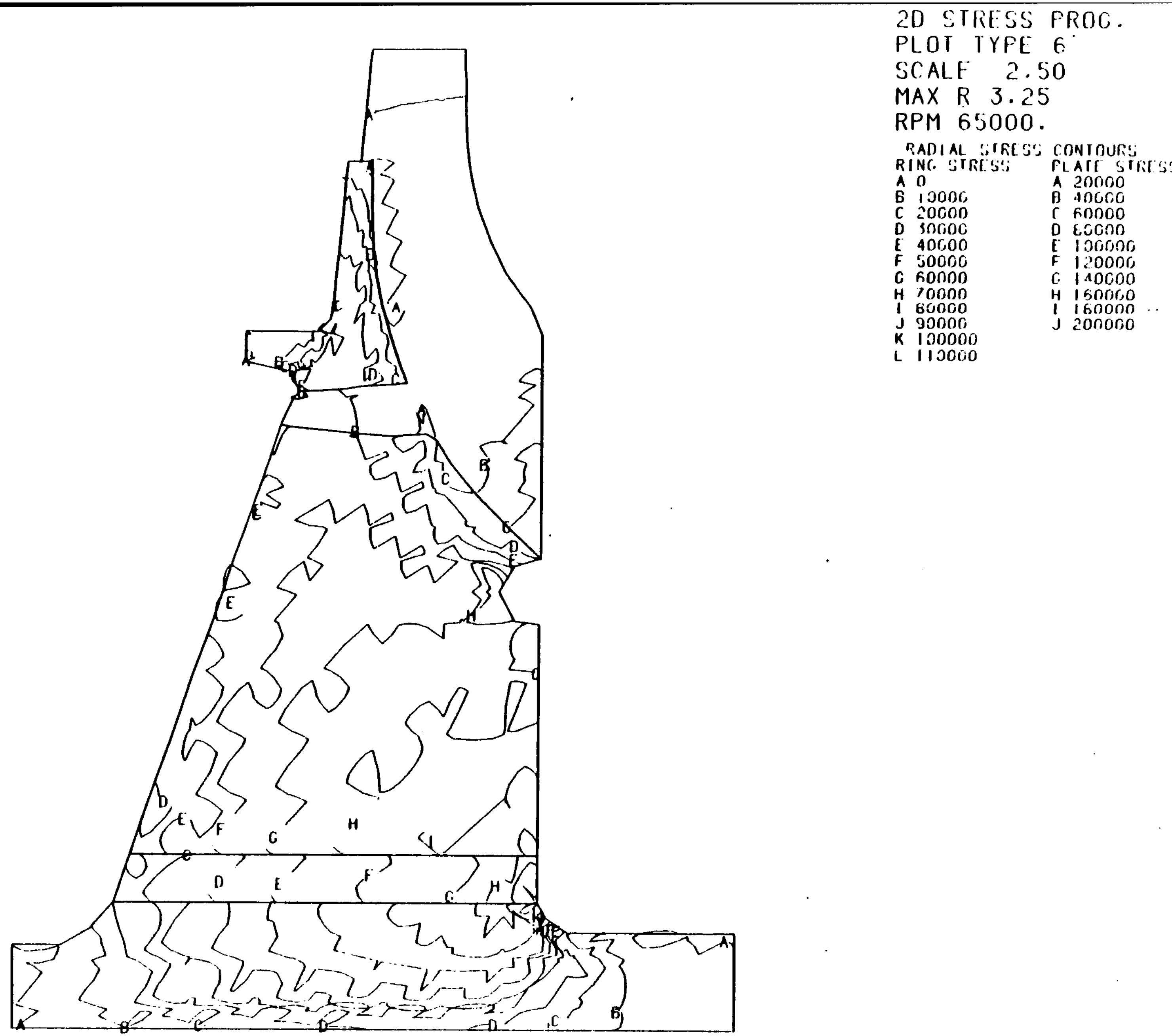

2D STRESS PROG.
PLOT TYPE 6
SCALE 2.50
MAX R 3.25
RPM 65000.
RADIAL STRESS CONTOURS
RING STRESS
A 0
B 10000
C 20000
D 30000
E 40000
F 50000
G 60000
H 70000
I 80000
J 90000
K 100000
L 110000
PLATE STRESS
A 20000
B 40000
C 60000
D 80000
E 100000
F 120000
G 140000
H 160000
I 160000
J 200000

FIGURE 10

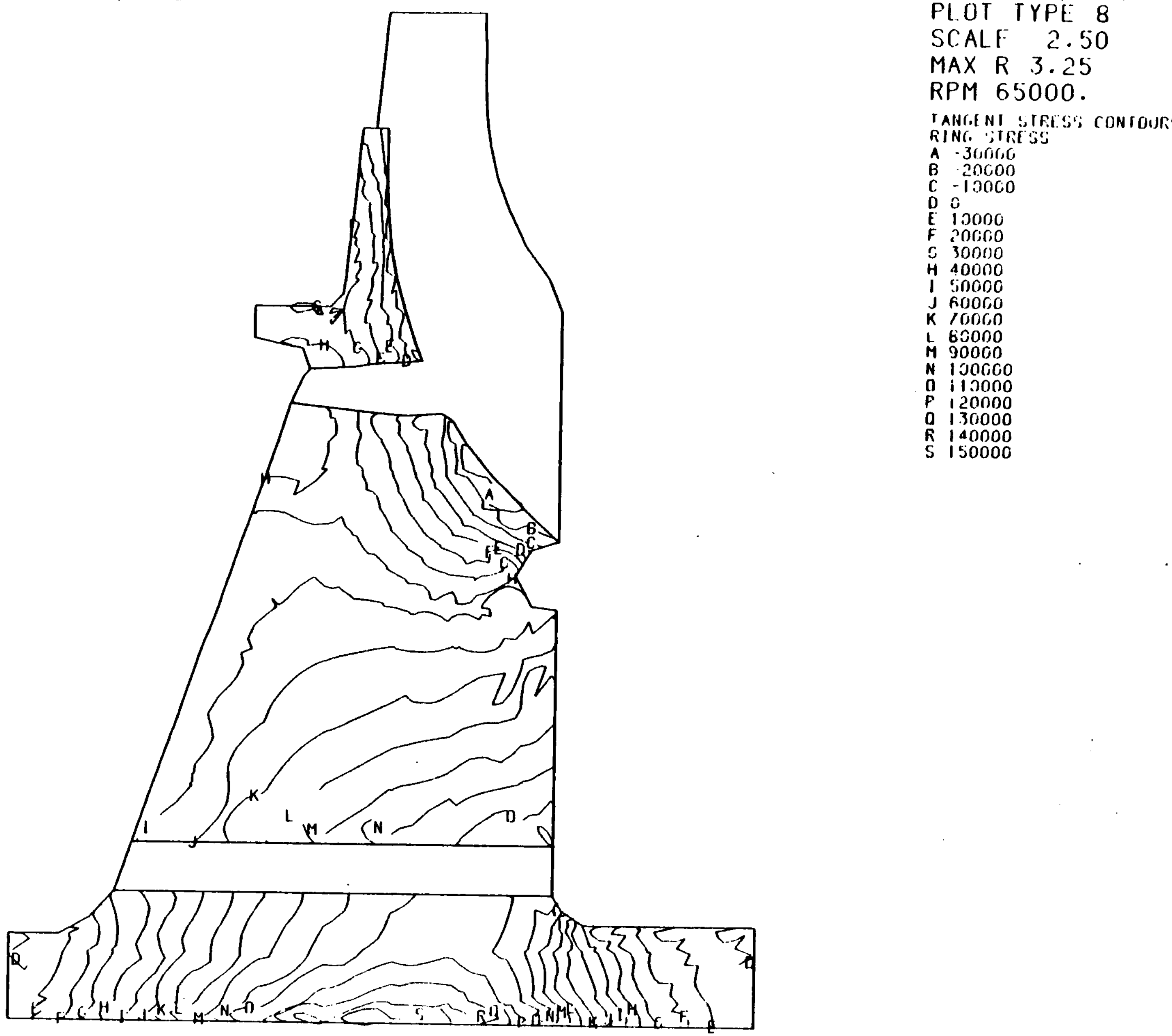

PLOT TYPE 8
SCALF 2.50
MAX R 3.25
RPM 65000.
TANGENT STRESS CONTOURS
RING STRESS
A -30000
B -20000
C -10000
D 0
E 10000
F 20000
G 30000
H 40000
I 50000
J 60000
K 70000
L 80000
M 90000
N 100000
O 110000
P 120000
Q 130000
R 140000
S 150000

FIGURE 11

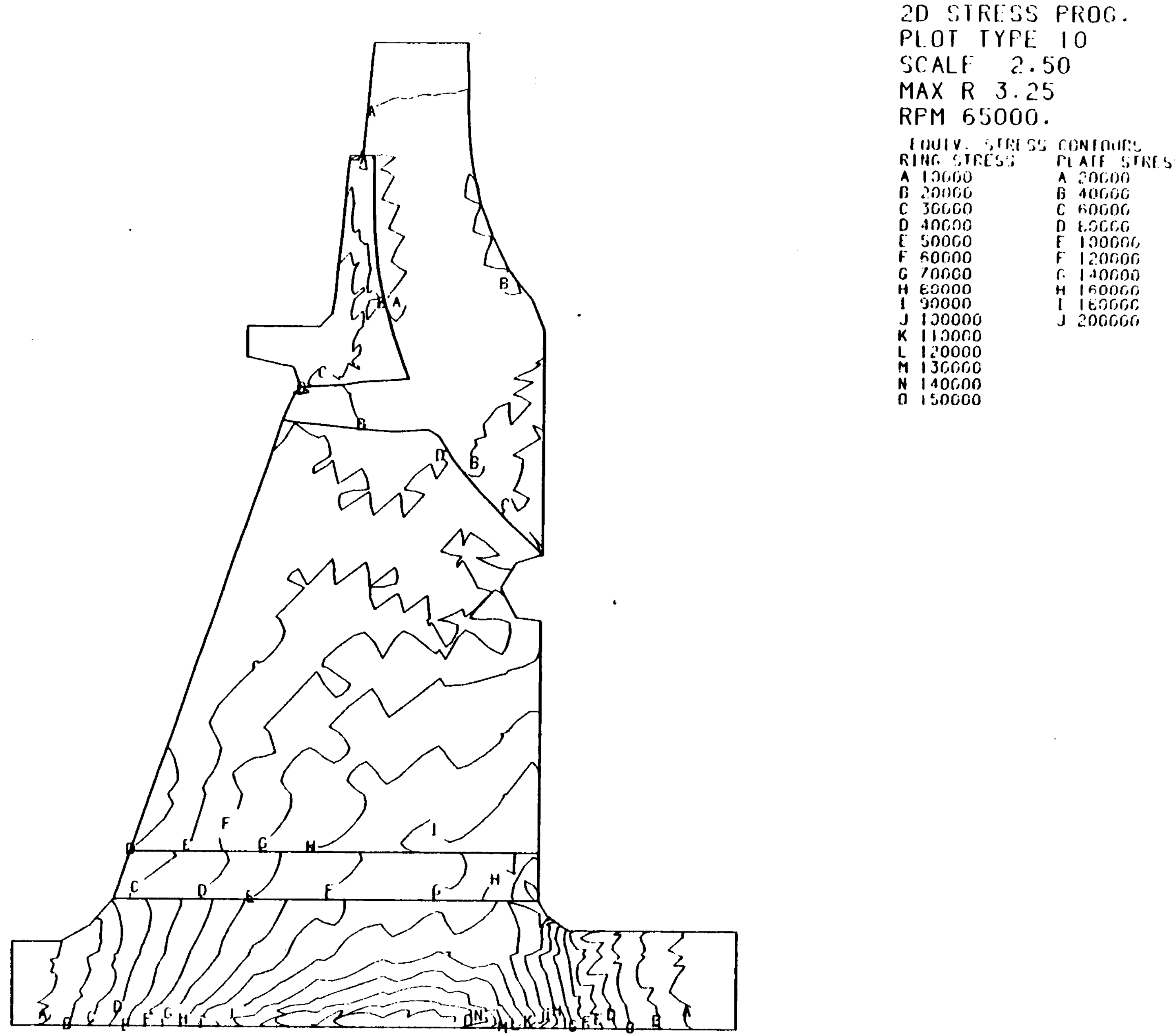

2D STRESS PROG.
PLOT TYPE 10
SCALE 2.50
MAX R 3.25
RPM 65000.
EQUIV. STRESS CONTOURS
RING STRESS
A 10000
B 20000
C 30000
D 40000
E 50000
F 60000
G 70000
H 80000
I 90000
J 100000
K 110000
L 120000
M 130000
N 140000
O 150000
PLATE STRESS
A 20000
B 40000
C 60000
D 80000
E 100000
F 120000
G 140000
H 160000
I 180000
J 200000

FIGURE 12

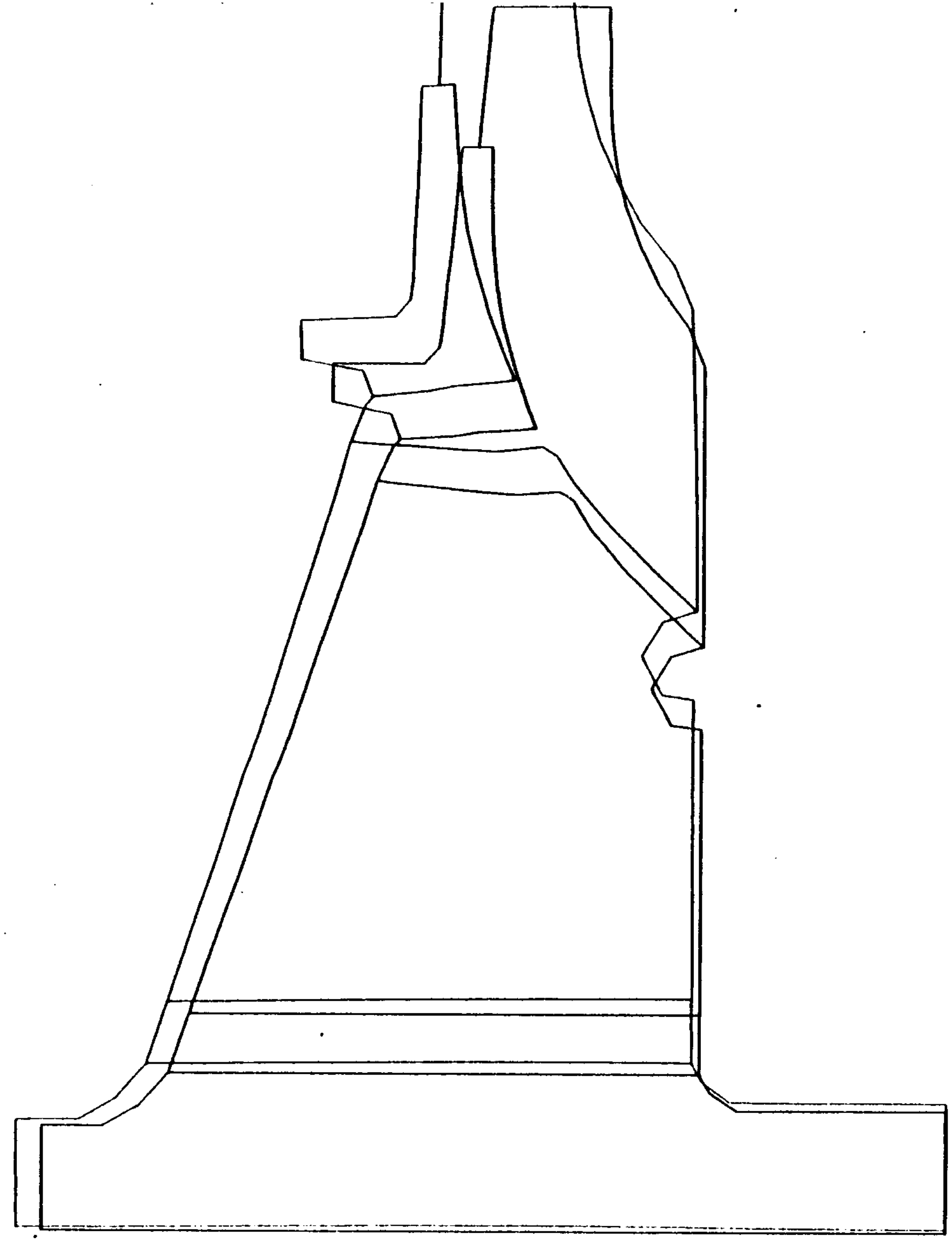

SCALE 2.50
MAX R 3.25
RPM 65000.
DISPLACEMENT MAGNIFICATION
FACTOR - 5.06

FIGURE 13

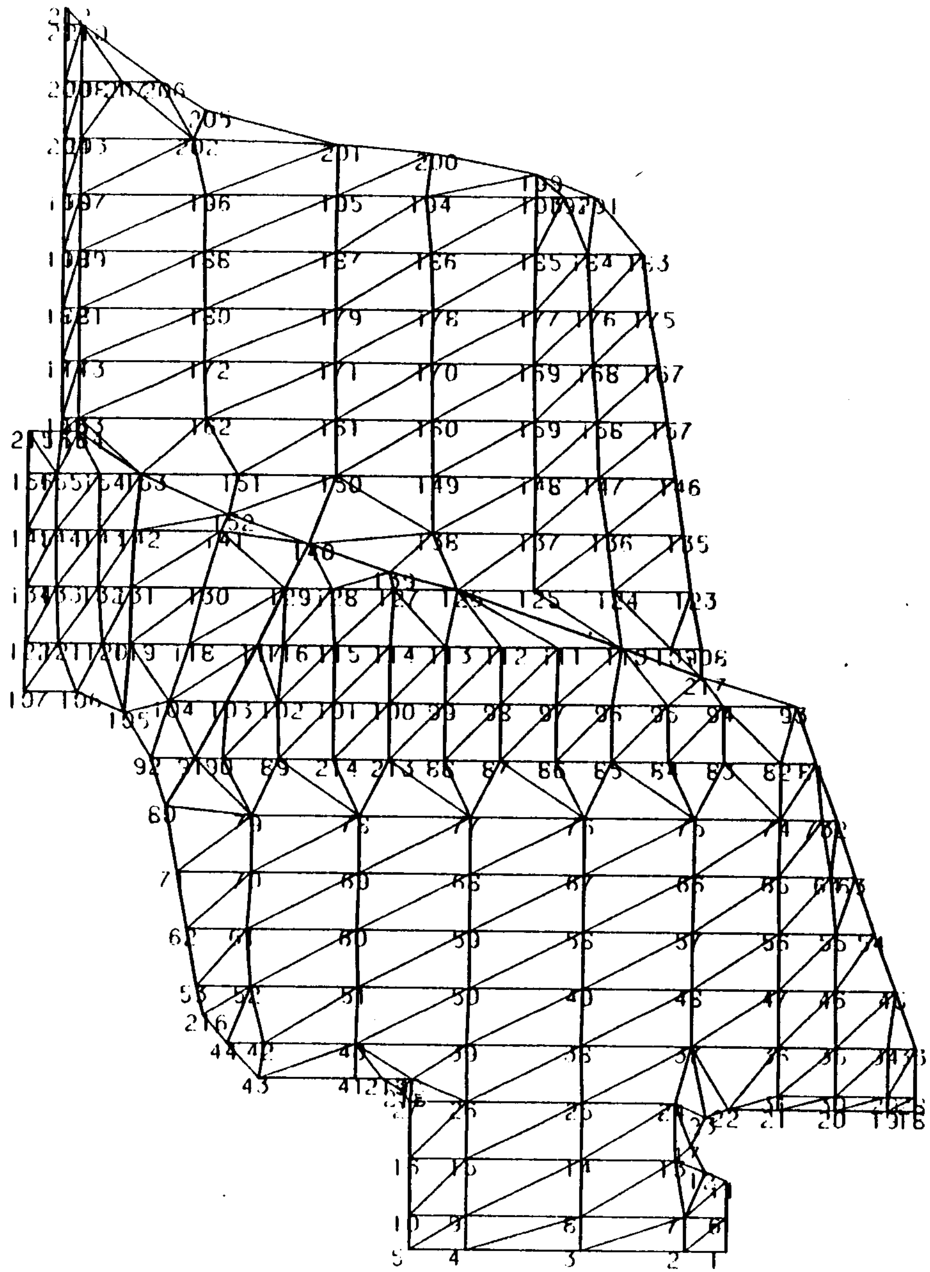

2D STRESS PROG.
PLOT TYPE 1
SCALE 3.50
MAX R 2.38
RPM 65000.
ORIG. NODE NOS.

FIGURE 14

PLOT TYPE 2
SCALE 3.50
MAX R 2.38
RPM 65000.
ELEMENT NOS.

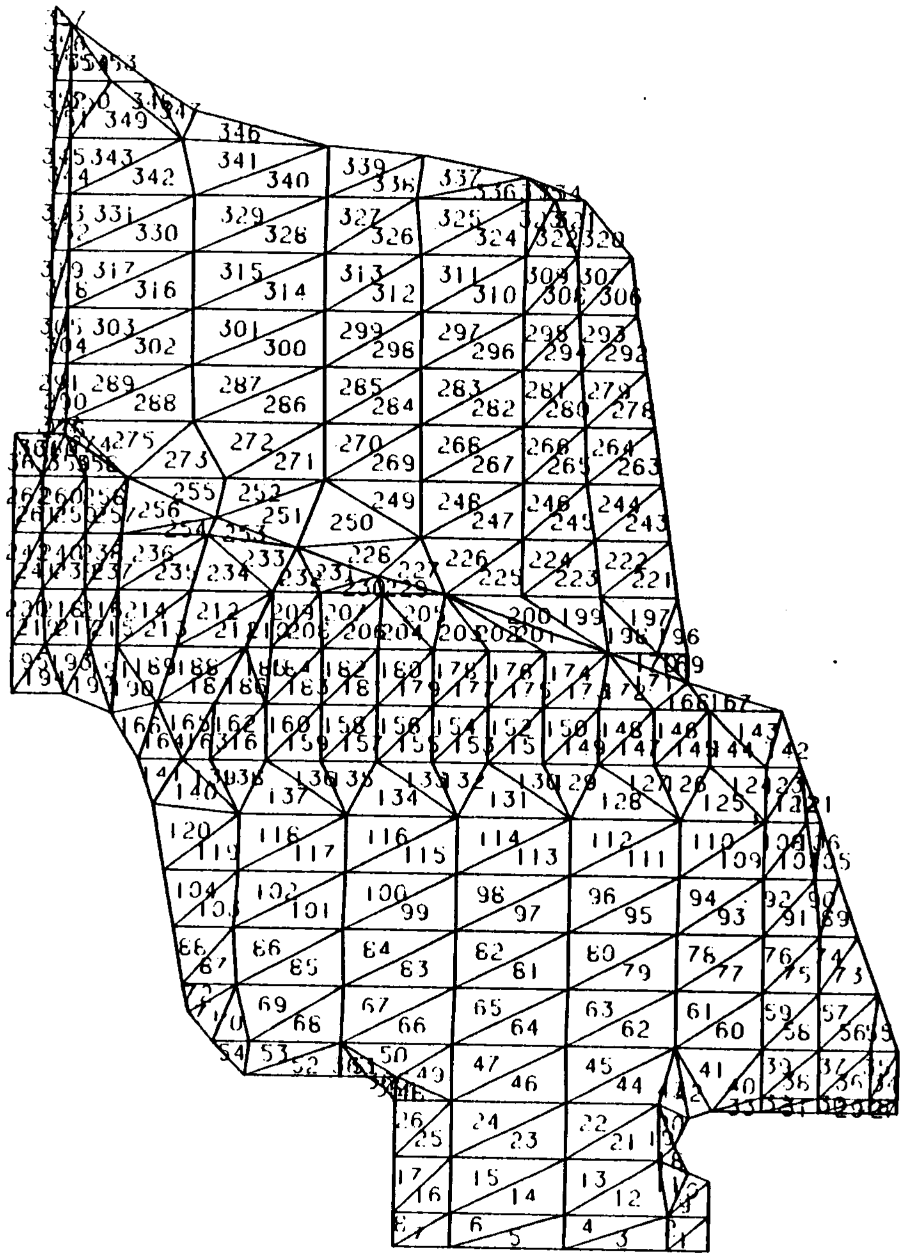
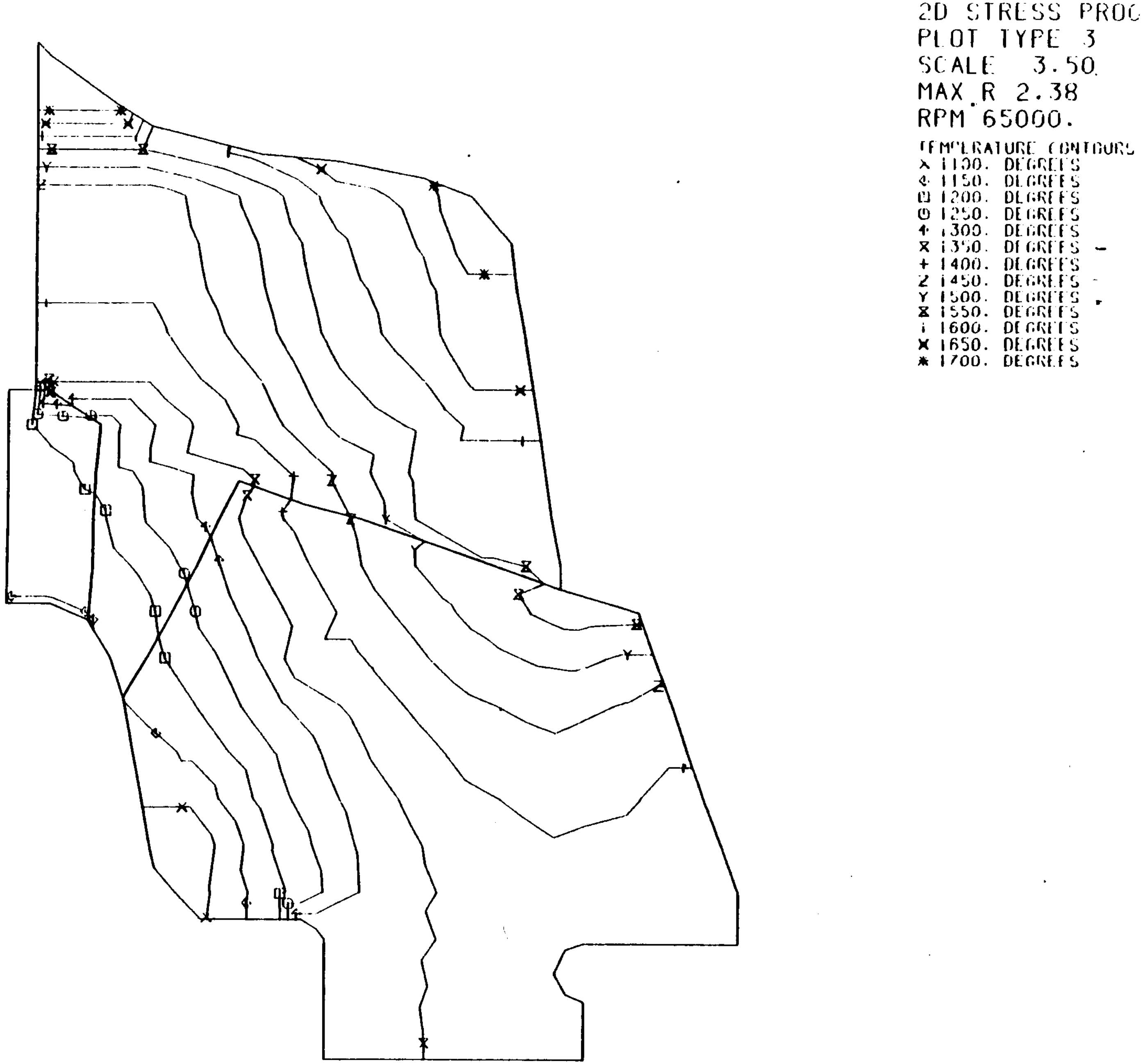


FIGURE 15



2D STRESS PROC.
PLOT TYPE 3
SCALE 3.50
MAX R 2.38
RPM 65000.
TEMPERATURE CONTOURS
1100. DEGREES
1150. DEGREES
1200. DEGREES
1250. DEGREES
1300. DEGREES
1350. DEGREES
1400. DEGREES
1450. DEGREES
1500. DEGREES
1550. DEGREES
1600. DEGREES
1650. DEGREES
1700. DEGREES

FIGURE 16

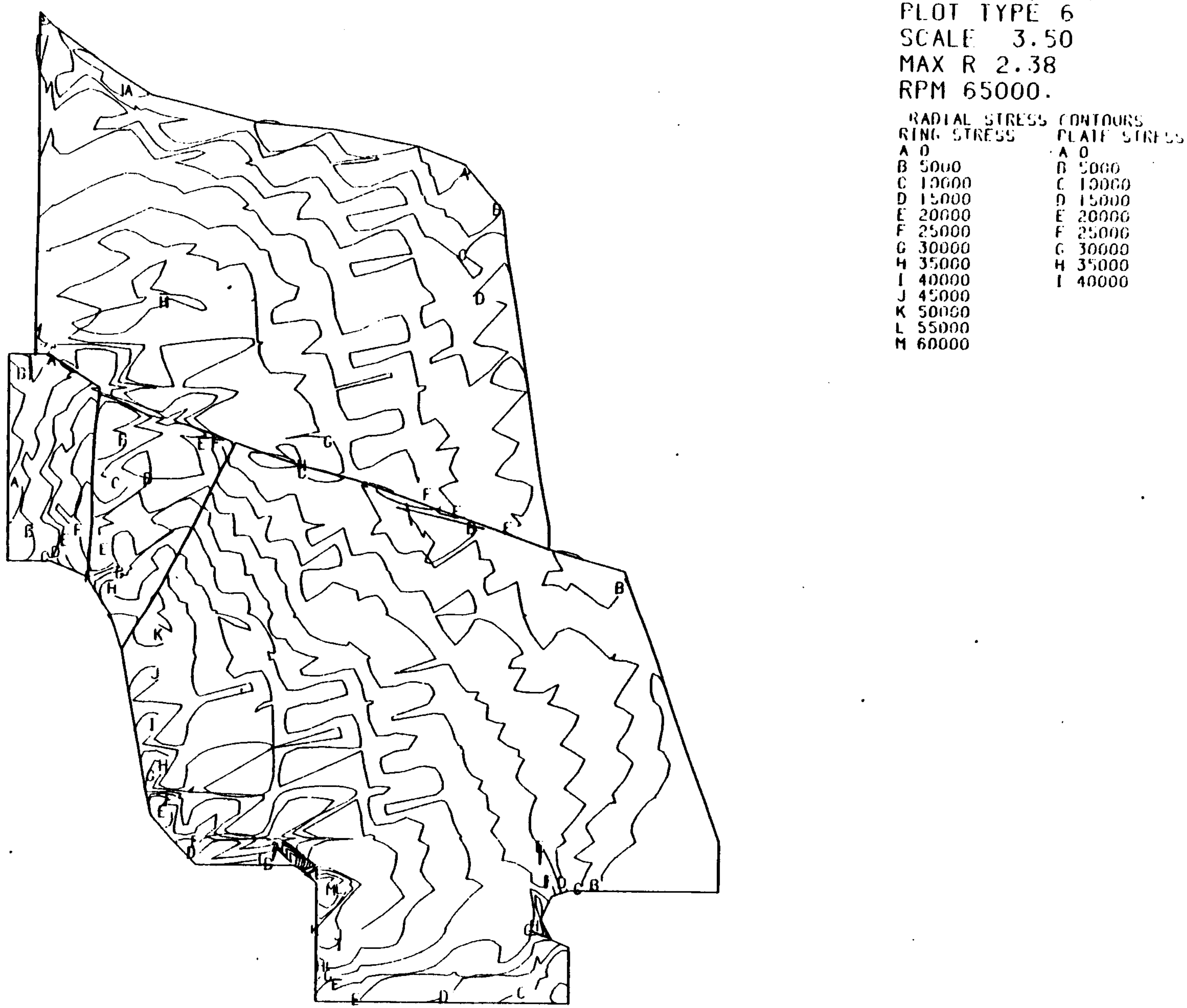

PLOT TYPE 6
SCALE 3.50
MAX R 2.38
RPM 65000.
RADIAL STRESS CONTOURS
RING STRESS
A 0
B 5000
C 10000
D 15000
E 20000
F 25000
G 30000
H 35000
I 40000
J 45000
K 50000
L 55000
M 60000
PLATE STRESS
A 0
B 5000
C 10000
D 15000
E 20000
F 25000
G 30000
H 35000
I 40000

FIGURE 17

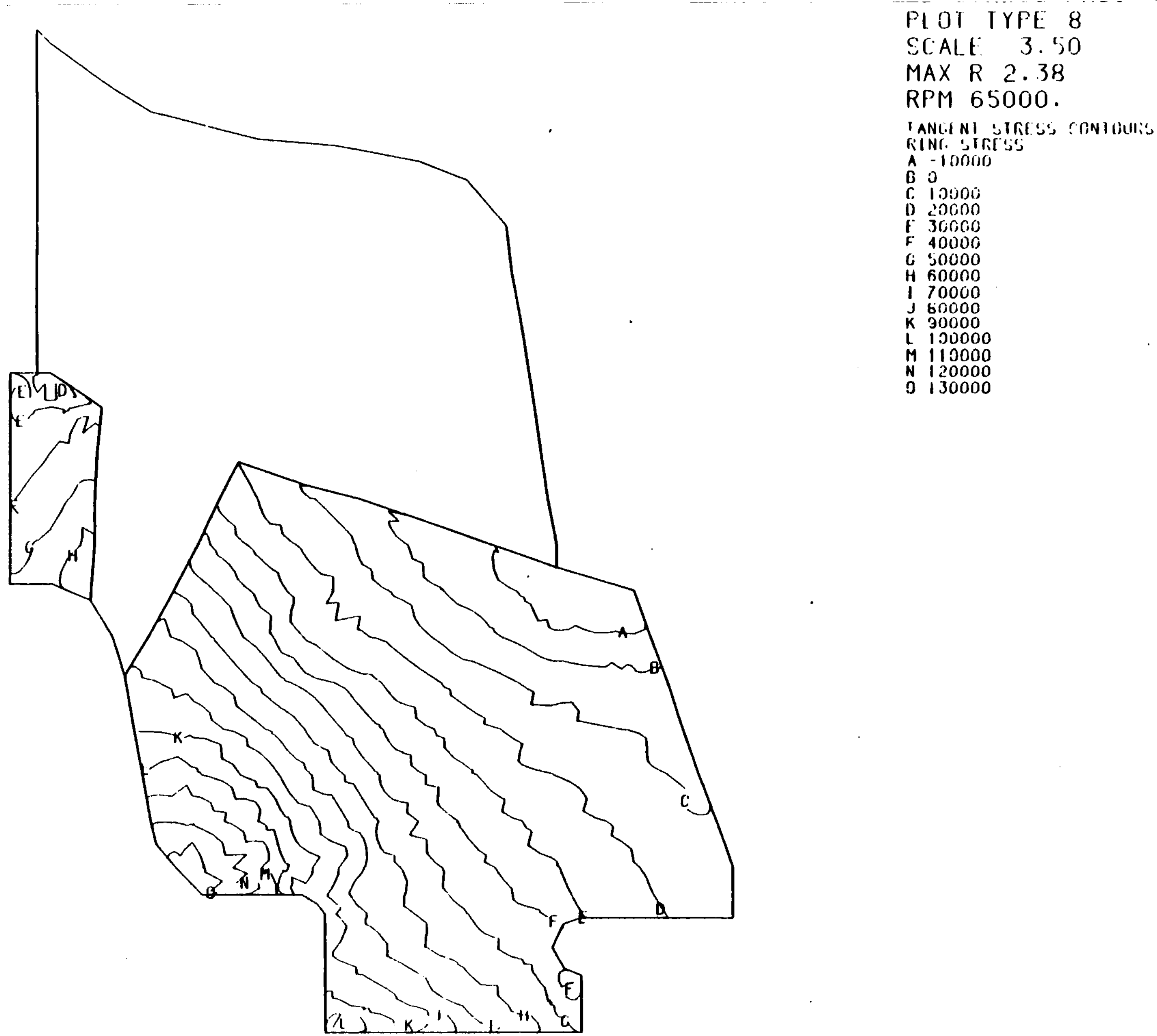

PLOT TYPE 8
SCALE 3.50
MAX R 2.38
RPM 65000.
TANGENT STRESS CONTOURS
RING STRESS
A -10000
B 0
C 10000
D 20000
E 30000
F 40000
G 50000
H 60000
I 70000
J 80000
K 90000
L 100000
M 110000
N 120000
O 130000

FIGURE 18

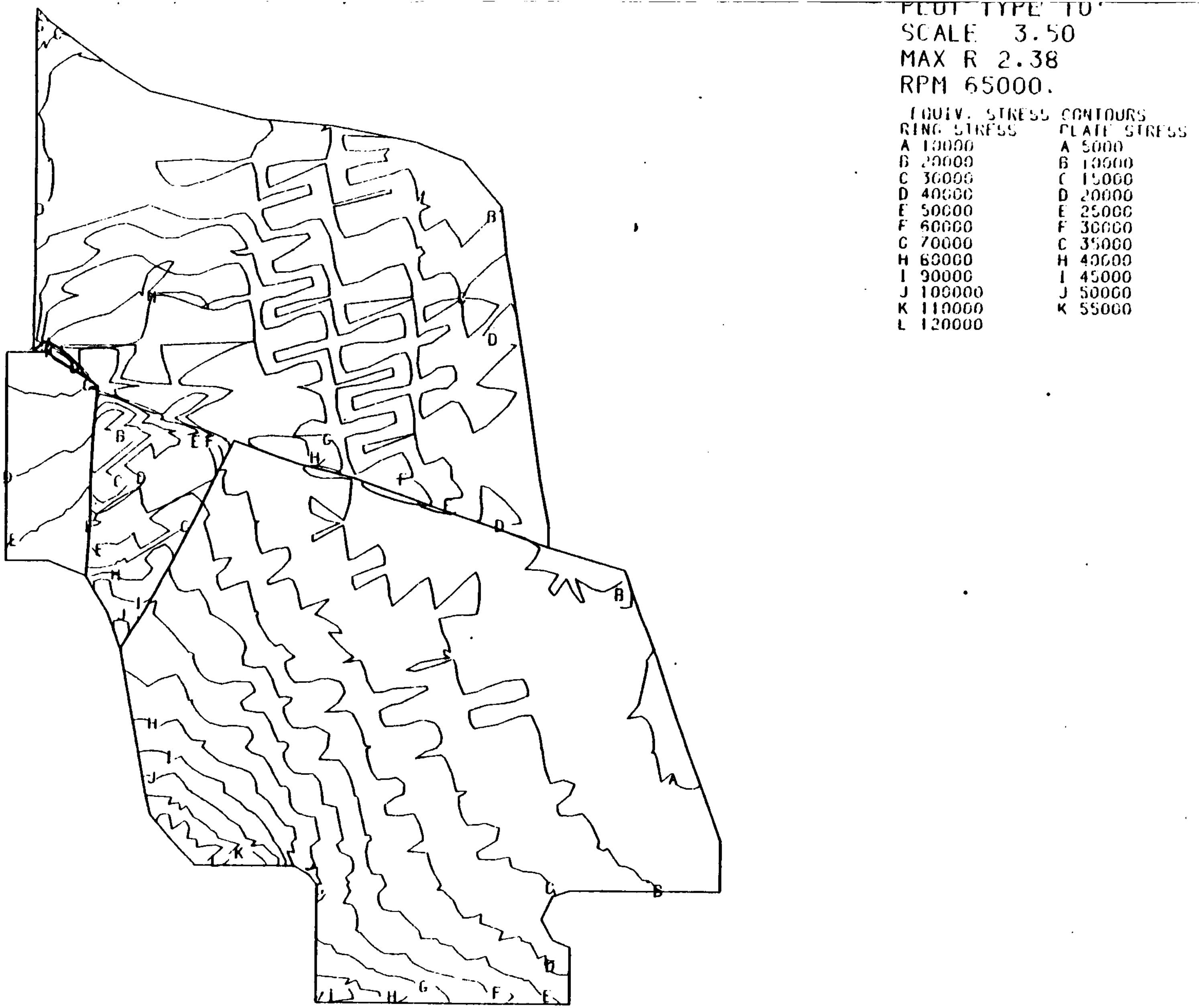

PLOT TYPE 10
SCALE 3.50
MAX R 2.38
RPM 65000.
EQUIV. STRESS CONTOURS
RING STRESS
A 10000
B 20000
C 30000
D 40000
E 50000
F 60000
G 70000
H 80000
I 90000
J 100000
K 110000
L 120000
PLATE STRESS
A 5000
B 10000
C 15000
D 20000
E 25000
F 30000
G 35000
H 40000
I 45000
J 50000
K 55000

FIGURE 19

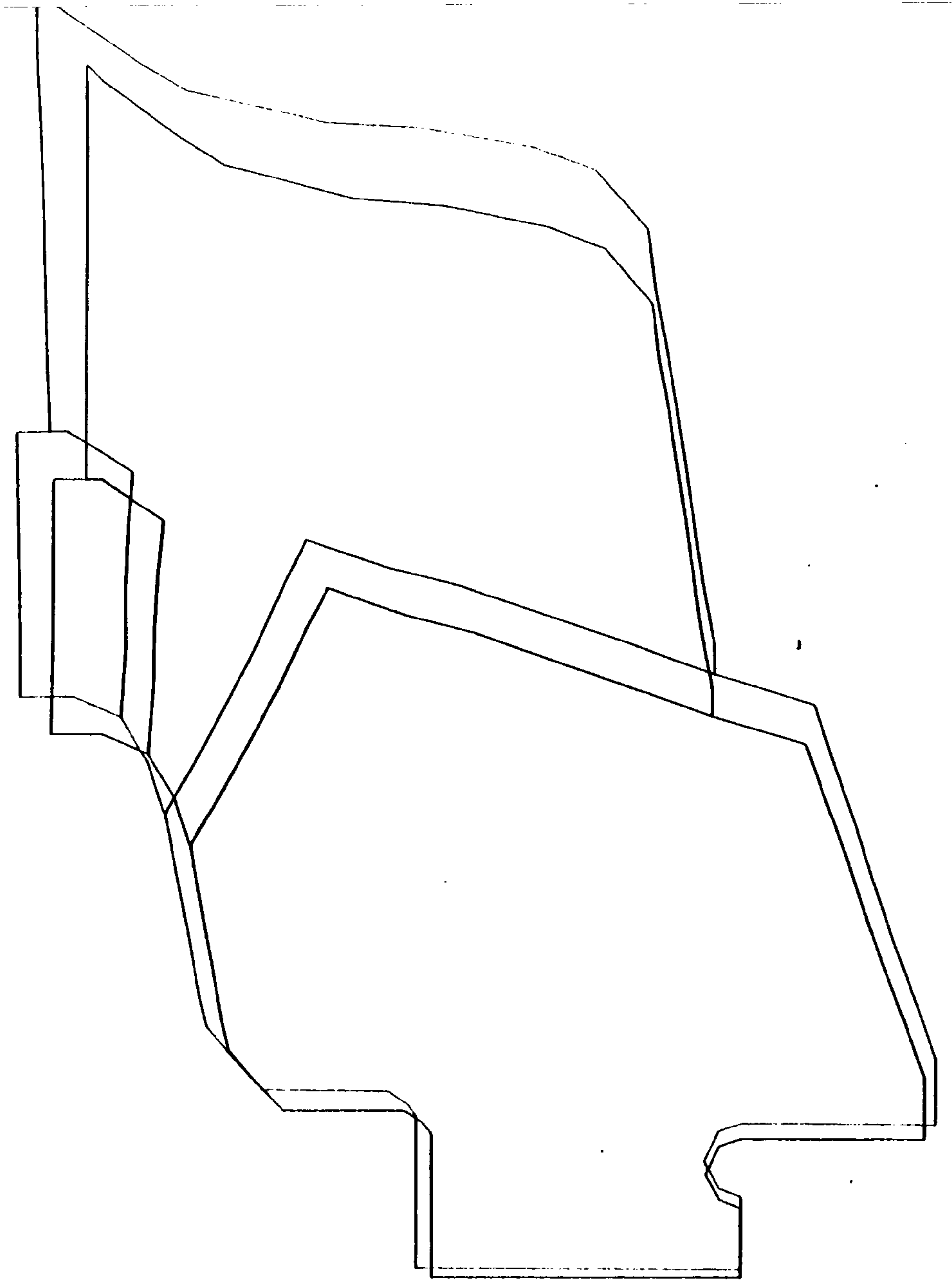

2D STRESS PROG.
PLOT TYPE 5
SCALE 3.50
MAX R 2.38
RPM 65000.
DISPLACEMENT MAGNIFICATION
FACTOR - 5.60

FIGURE 20

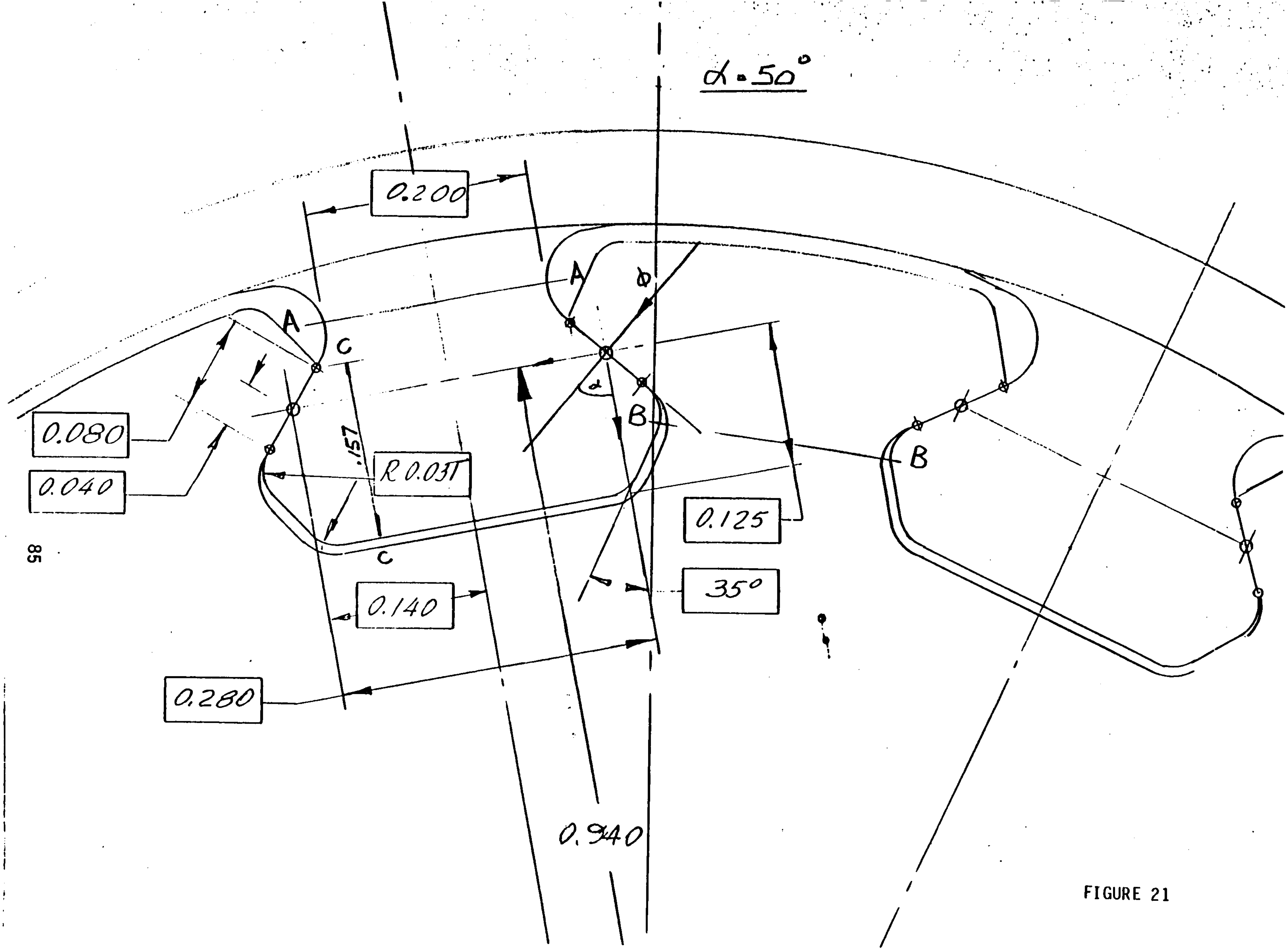


FIGURE 21

INSERTED BLADE ROOT FIXING ANALYSIS 7-13 81 CRT6PLOT.RJE 07/13/81 01.24.06 F.BARROW

2D STRESS PROC.
PLOT TYPE 1
SCALE 20.00
MAX R 0.34
RPM 0.
ORIG. NODE NOS.

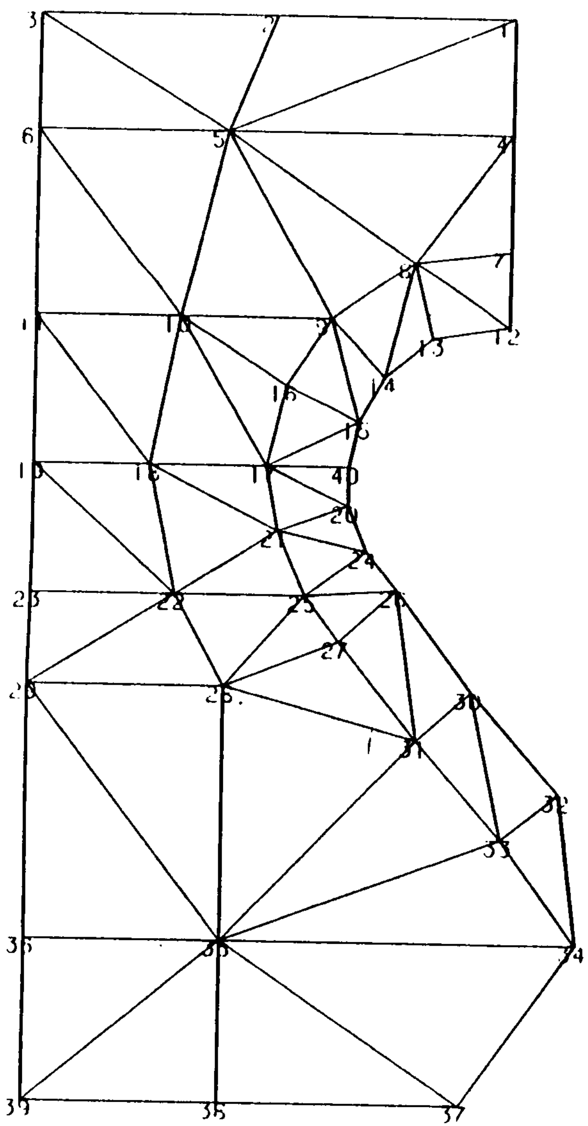


FIGURE 22

INSERTED BLADE ROOT FIXING ANALYSIS 7-13 81 CRT6PLOT.RJE P.BARROW

2D STRESS PROC.
PLOT TYPE 2
SCALE 20.00
MAX R 0.34
RPM 0.
ELEMENT NOS.

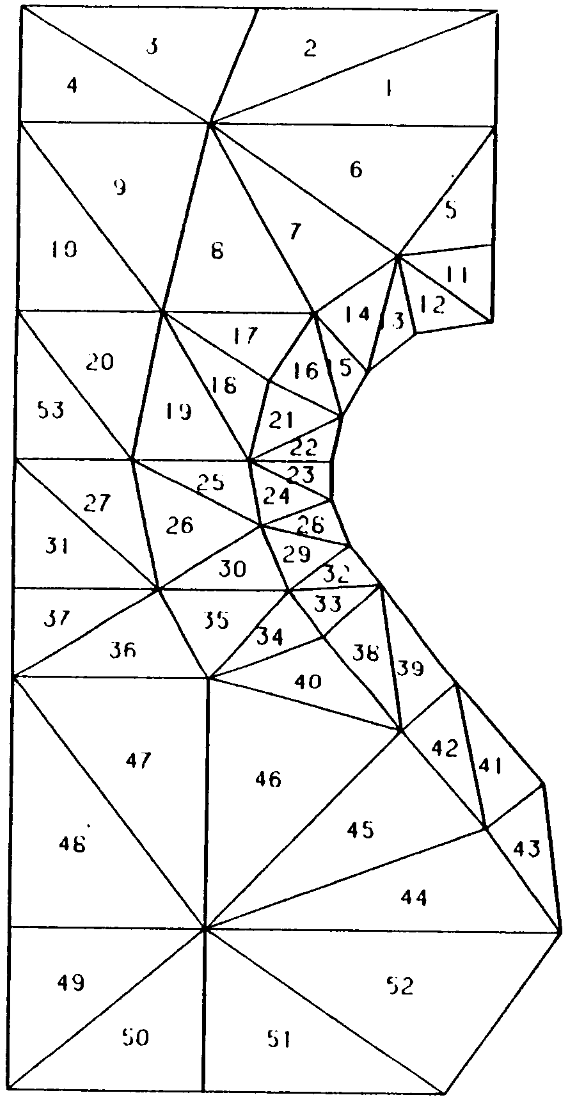
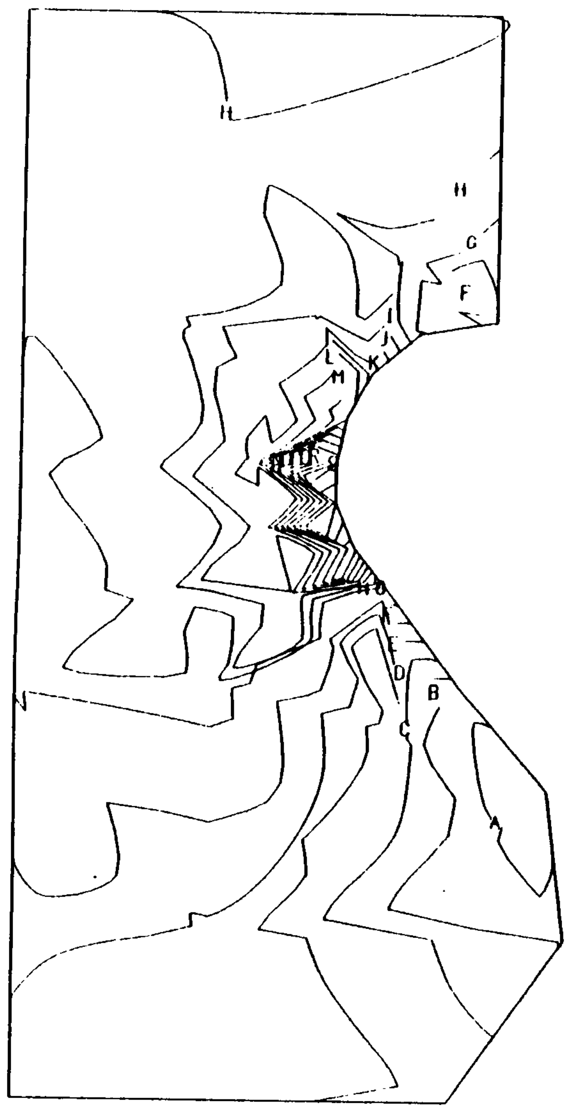


FIGURE 23

INSERTED BLADE ROOT FIXING ANALYSIS . 7-13 81 CR16PLOT.RJE 07/13/81 09.26.24 P.BARROW



2D STRESS PROC.
PLOT TYPE 6
SCALE 20.00
MAX R 0.34
RPM 0.

RADIAL STRESS CONTOURS
PLATE STRESS
A -30000
B 20000
C -10000
D 0
E 10000
F 20000
G 30000
H 40000
I 50000
J 60000
K 70000
L 80000
M 90000
N 100000
O 110000
P 120000
Q 130000
R 140000
S 150000

FIGURE 24

2D STRESS PROC.
PLOT TYPE 7
SCALE 20.00
MAX R 0.34
RPM 0.

AXIAL STRESS CONTOURS
PLATE STRESS
A -60000
B -55000
C -50000
D -45000
E -40000
F -35000
G -30000
H -25000
I -20000
J -15000
K -10000
L -5000
M 0
N 5000
O 10000
P 15000

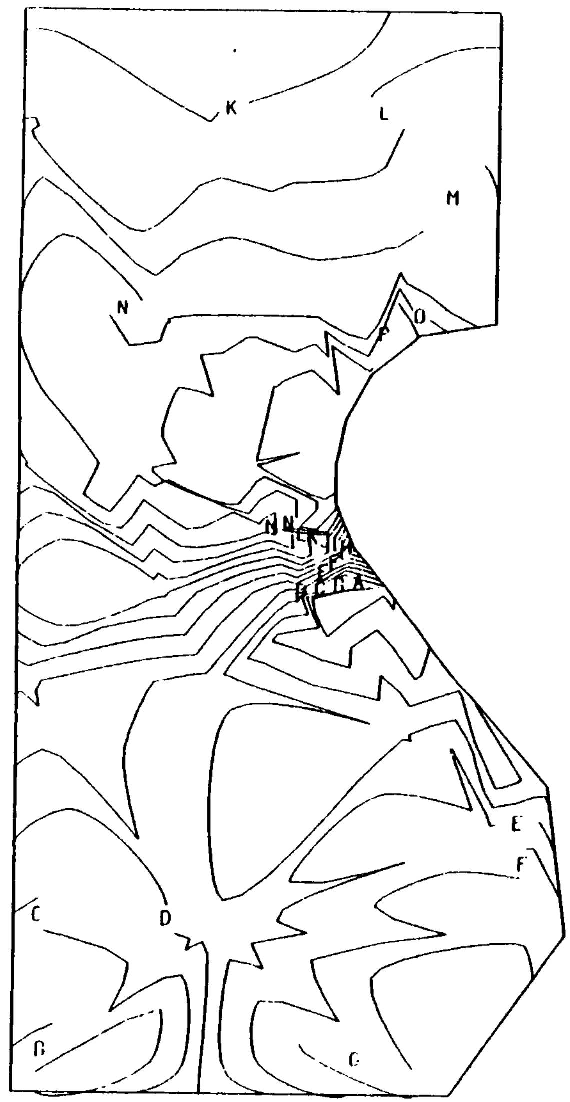


FIGURE 25

INSERTED BLADE ROOT FIXING ANALYSIS 7-13 81 CRT6PLOT.RJE 07/13/81 09.27.18 P.BARROW

2D STRESS PROG.
PLOT TYPE 10
SCALE 20.00
MAX R 0.34
RPM 0.

EQUIV. STRESS CONTOURS
PLATE STRESS
A 30000
B 40000
C 50000
D 60000
E 70000
F 80000
G 90000
H 100000
I 110000
J 120000
K 130000
L 140000

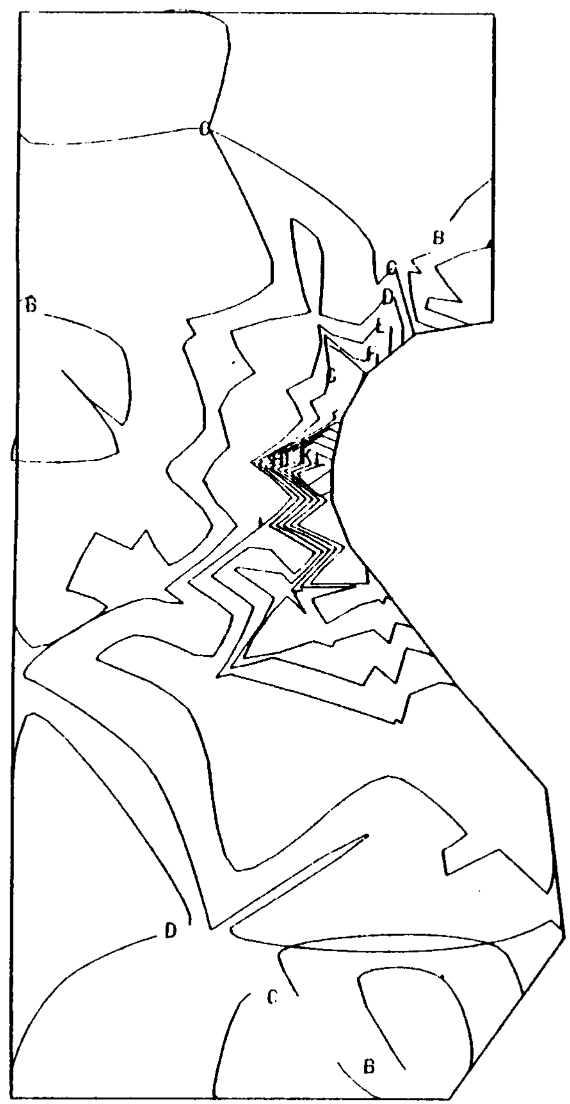
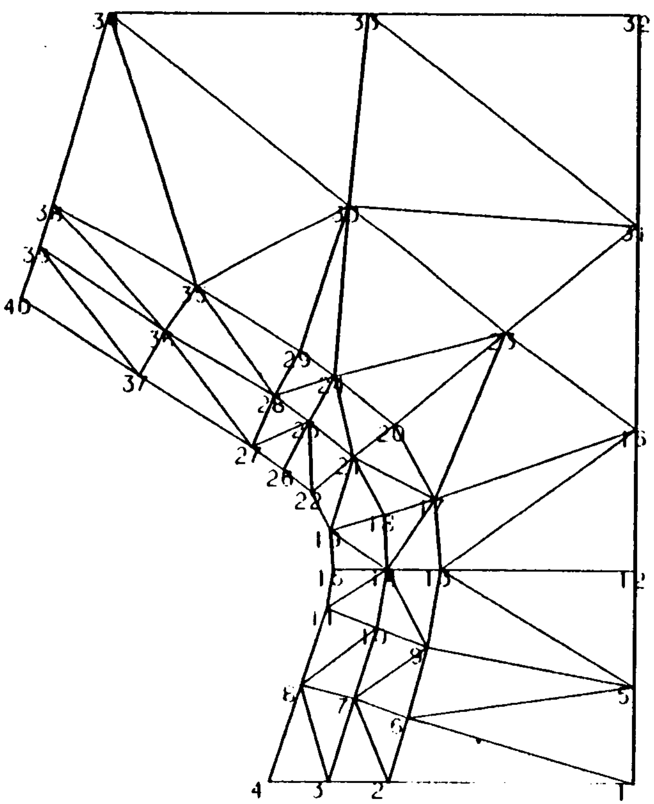


FIGURE 26



ORIG. NODE NOS.

FIGURE 27

INSERTED BLADE DISC FIXING ANALYSIS 7-16-81 CRTSPLOT.RJE P.BARROW 07/16/81 14.11.41

2D STRESS PROC
PLOT TYPE 2
SCALE 20.00
MAX R 0.24
RPM 0
ELEMENT NOS.

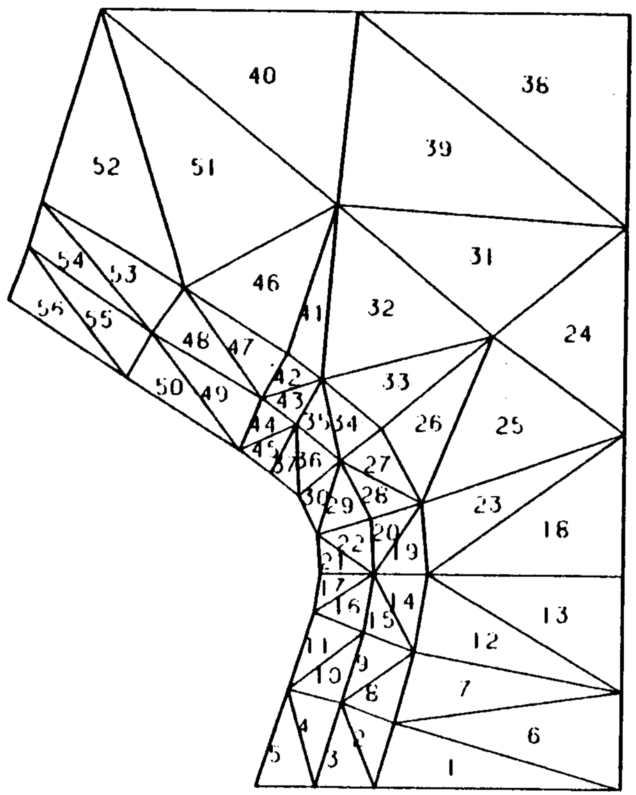


FIGURE 28

INSERTED BLADE DISC FIXING ANALYSIS 7-16-61 CRT6PLOT.RJE 07/16/61 14.42.22 P.BARROW

2D STRESS PROG
PLOT TYPE 6
SCALE 20.00
MAX R 0.24
RPM 0.

RADIAL STRESS CONTOURS
PLATE STRESS
A -60000
B -40000
C -20000
D 0
E 20000
F 40000
G 60000
H 80000
I 100000
J 120000
K 140000

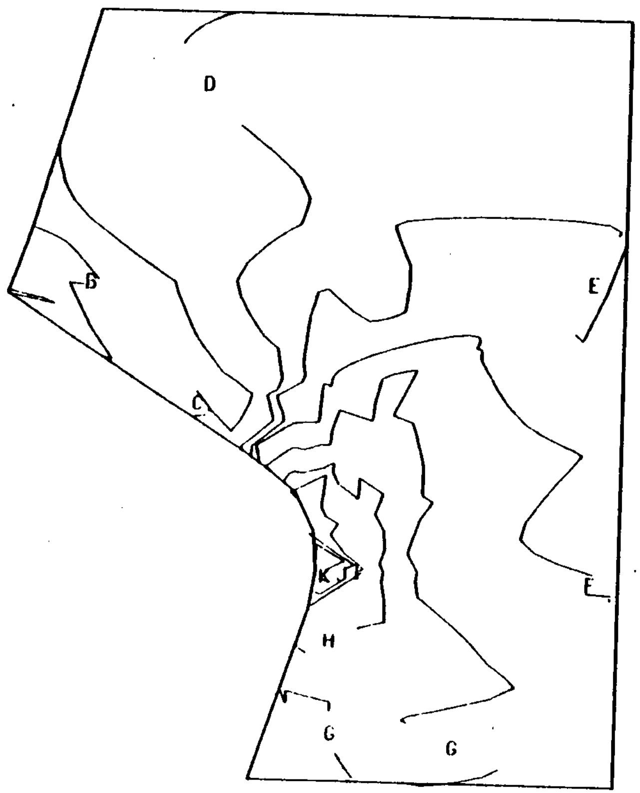


FIGURE 29

INSERTED BLADE DISC FIXING ANALYSIS 7-16-81 CRT6PLOT.RJE 07/16/81 14.42.24 P.BARROW

2D STRESS PROC.
PLOT TYPE 7
SCALE 20.00
MAX R 0.24
RPM 0.

AXIAL STRESS CONTOURS
PLATE STRESS

A -60000
B 70000
C -60000
D 50000
E -40000
F -30000
G -20000
H -10000
I 0
J 10000

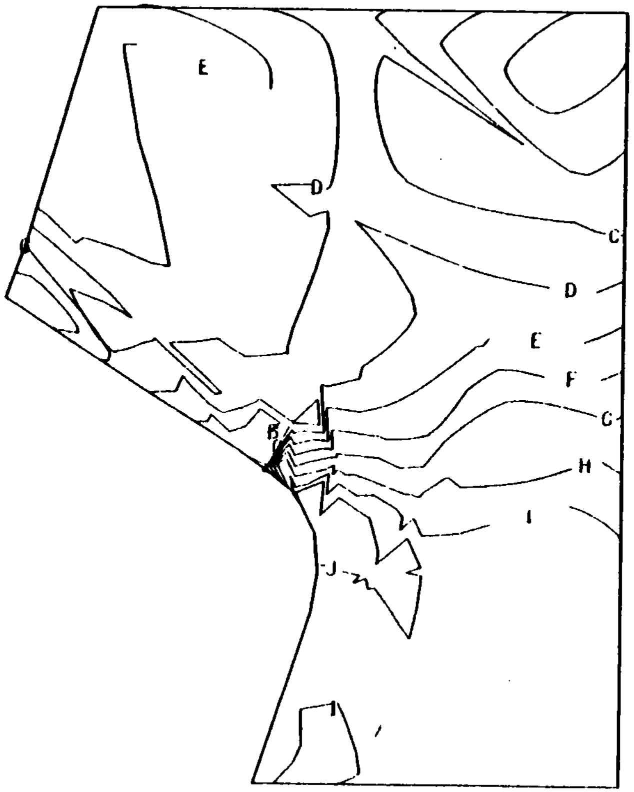


FIGURE 30

INSERTED BLADE DISC FIXING ANALYSIS 7-16-81 CRT8PLOT.RJE 07/16/81 14.42.26 P.BARROW

2D STRESS PROG.
PLOT TYPE 10
SCALE 20.00
MAX R 0.24
RPM 0.

EQUIV. STRESS CONTOURS

PLATE	STRESS
A	40000
B	50000
C	60000
D	70000
E	60000
F	90000
G	100000
H	110000
I	120000
J	130000
K	140000

FIGURE 31

INSERTED BLADE DISC ANALYSIS 7-14-81 CRT4PLOT.RJE P.BARROW 07/14/81 10.14.49

2D STRESS PROG.
PLOT TYPE 1
SCALE 8.50
MAX R 0.81
RPM 65000.
ORIG. NODE NOS.

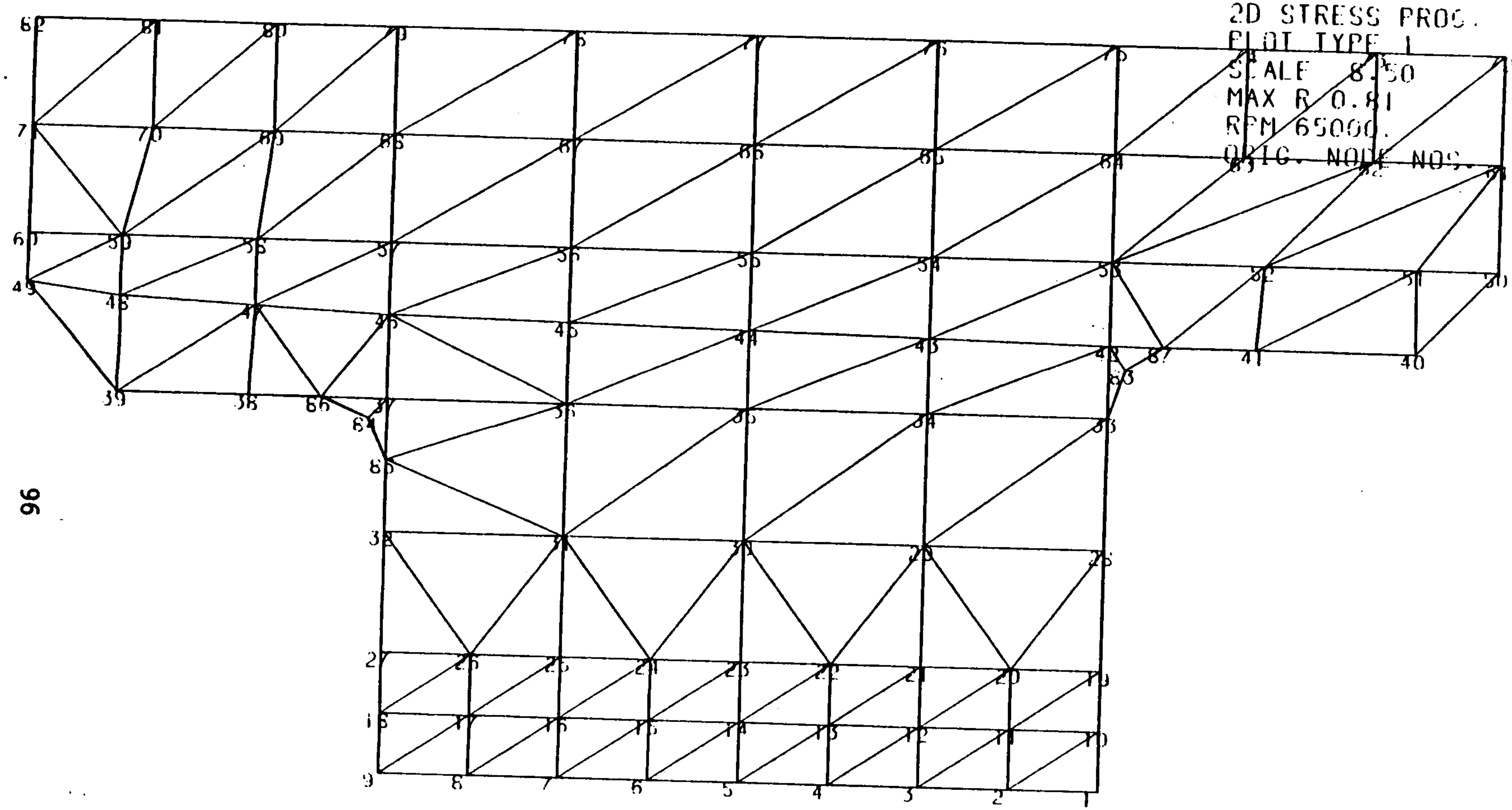


FIGURE 32

INSERTED BLADE DISC ANALYSIS 7-14-81 CRT4PLOT.RJE P.BARROW

07/14/81 10.14.49

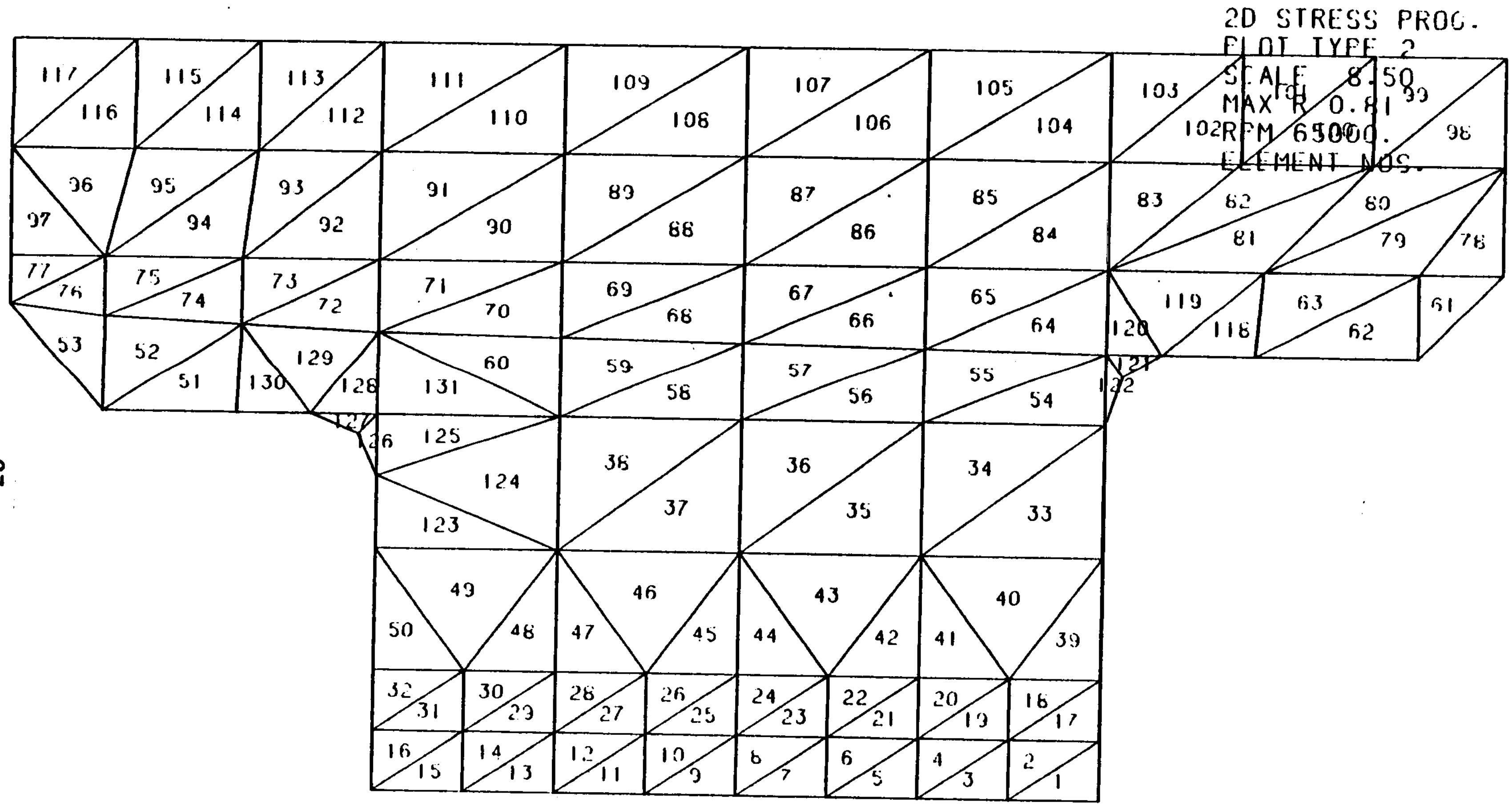


FIGURE 33

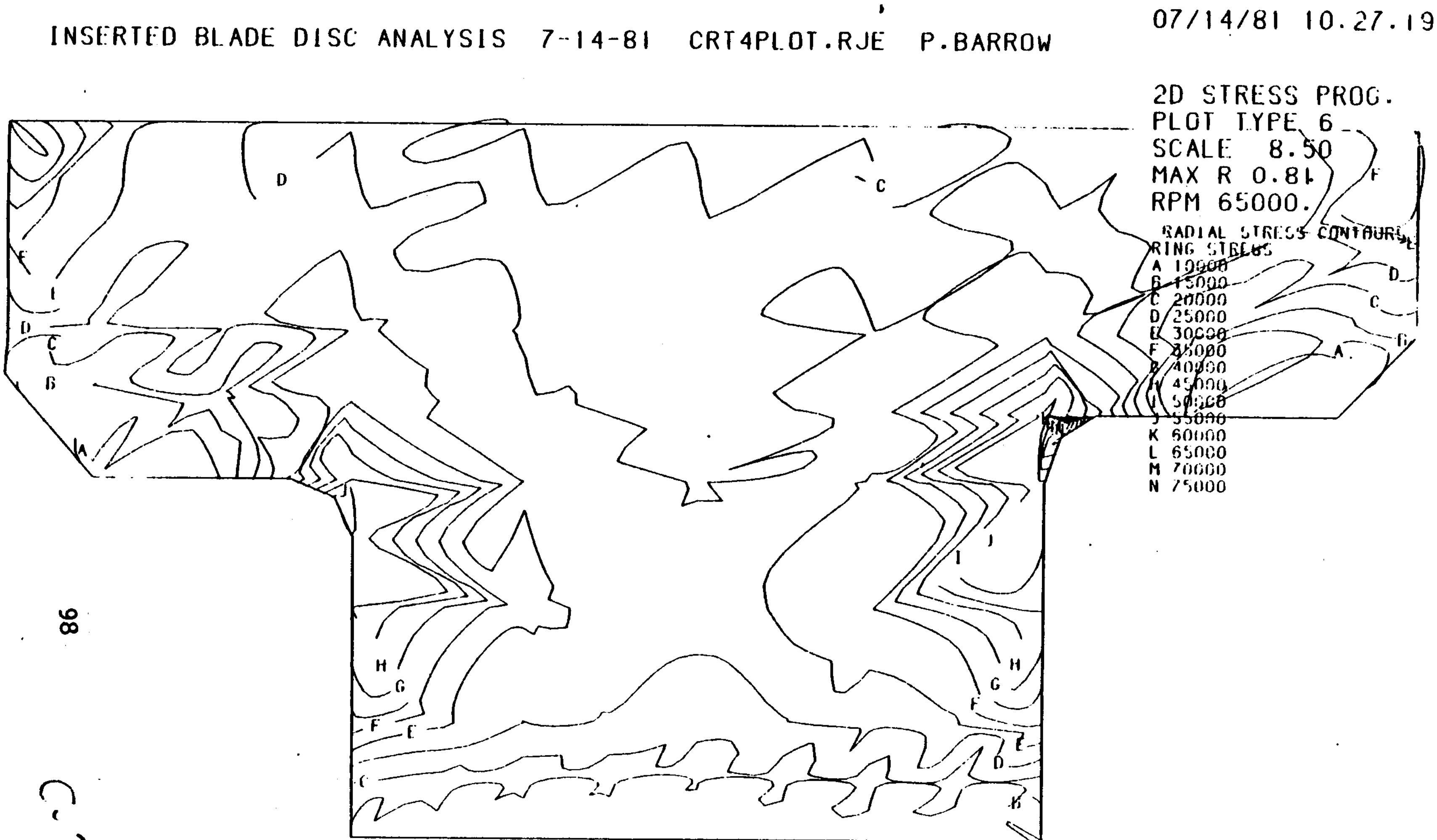

INSERTED BLADE DISC ANALYSIS 7-14-81 CRT4PLOT.RJE P.BARROW
07/14/81 10.27.19
2D STRESS PROG.
PLOT TYPE 6
SCALE 8.50
MAX R 0.81
RPM 65000.
RADIAL STRESS CONTOURS
RING STRESS
A 10000
B 15000
C 20000
D 25000
E 30000
F 35000
G 40000
H 45000
I 50000
J 55000
K 60000
L 65000
M 70000
N 75000

FIGURE 34

C-2

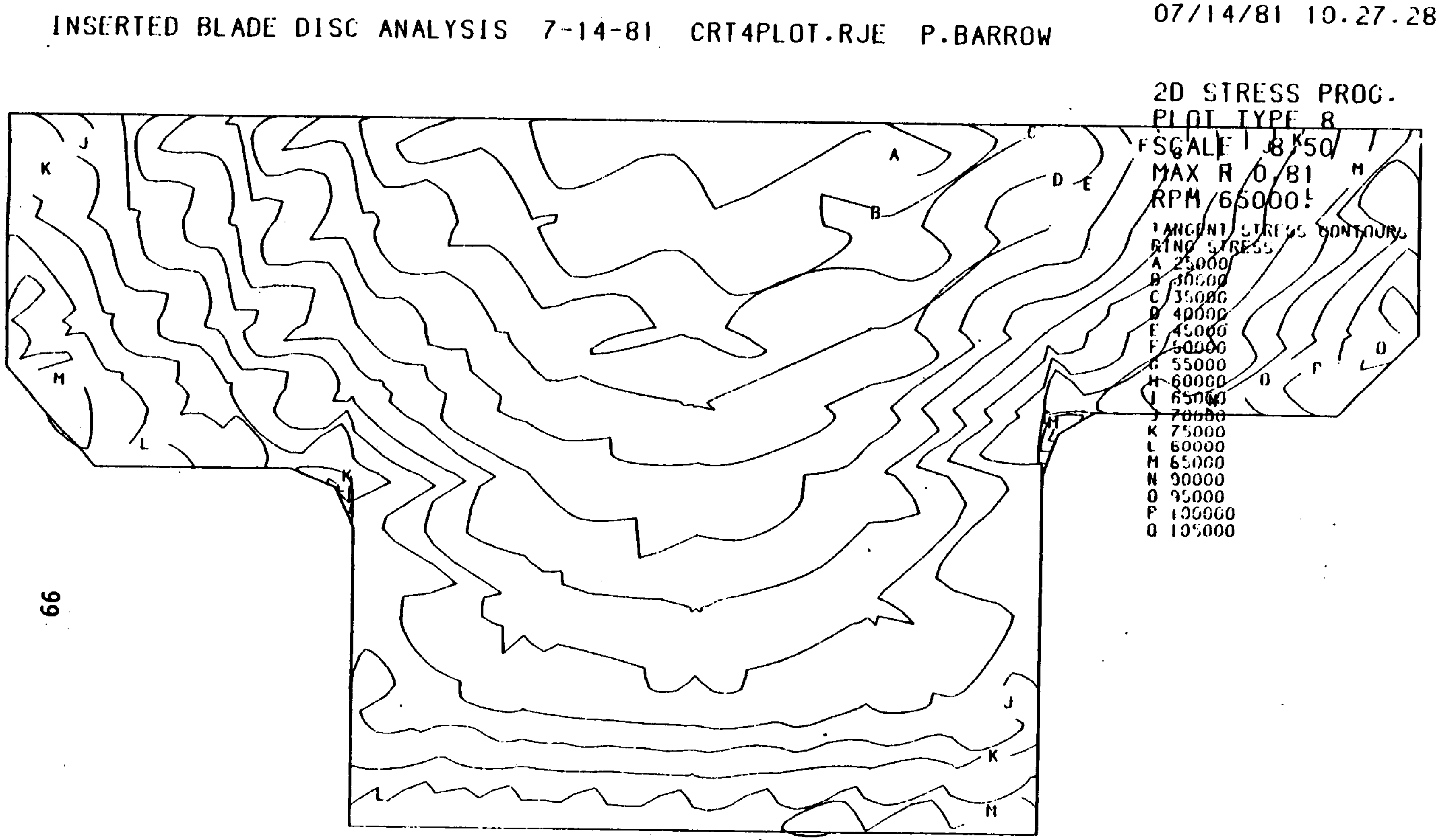

INSERTED BLADE DISC ANALYSIS 7-14-81 CRT4PLOT.RJE P.BARROW
07/14/81 10.27.28
2D STRESS PROG.
PLOT TYPE 8
SCALE 1.8 50
MAX R 0.81
RPM 65000!
TANGENT STRESS CONTOURS
RING STRESS
A 25000
B 30000
C 35000
D 40000
E 45000
F 50000
G 55000
H 60000
I 65000
J 70000
K 75000
L 60000
M 65000
N 90000
O 95000
P 100000
Q 105000

FIGURE 35

INSERTED BLADE DISC ANALYSIS 7-14-81 CRT4PLOT.RJE P.BARROW

07/14/81 10.27.36

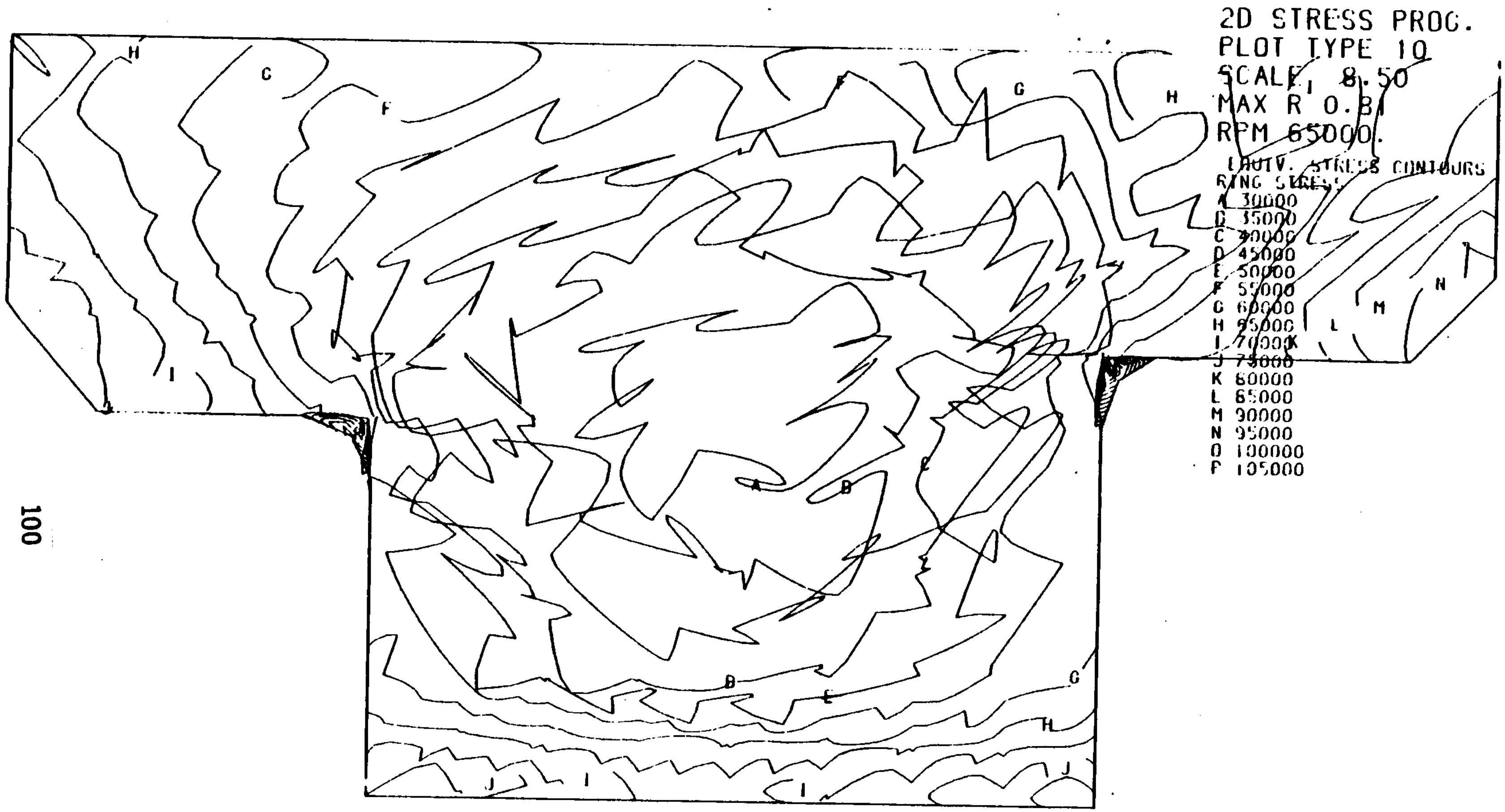
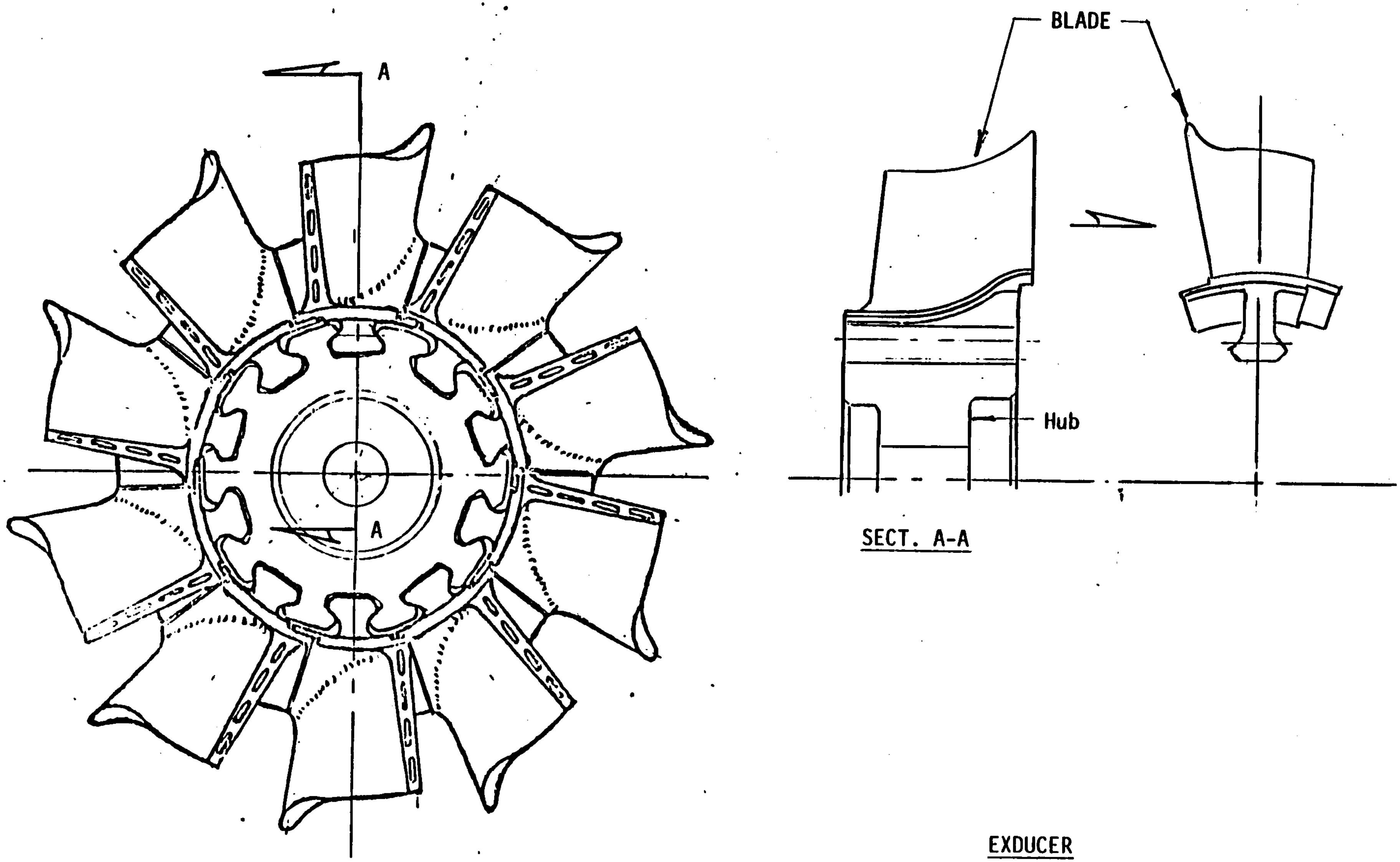


FIGURE 36



EXDUCER

BLADE-HUB ASSEMBLY

FIGURE 38

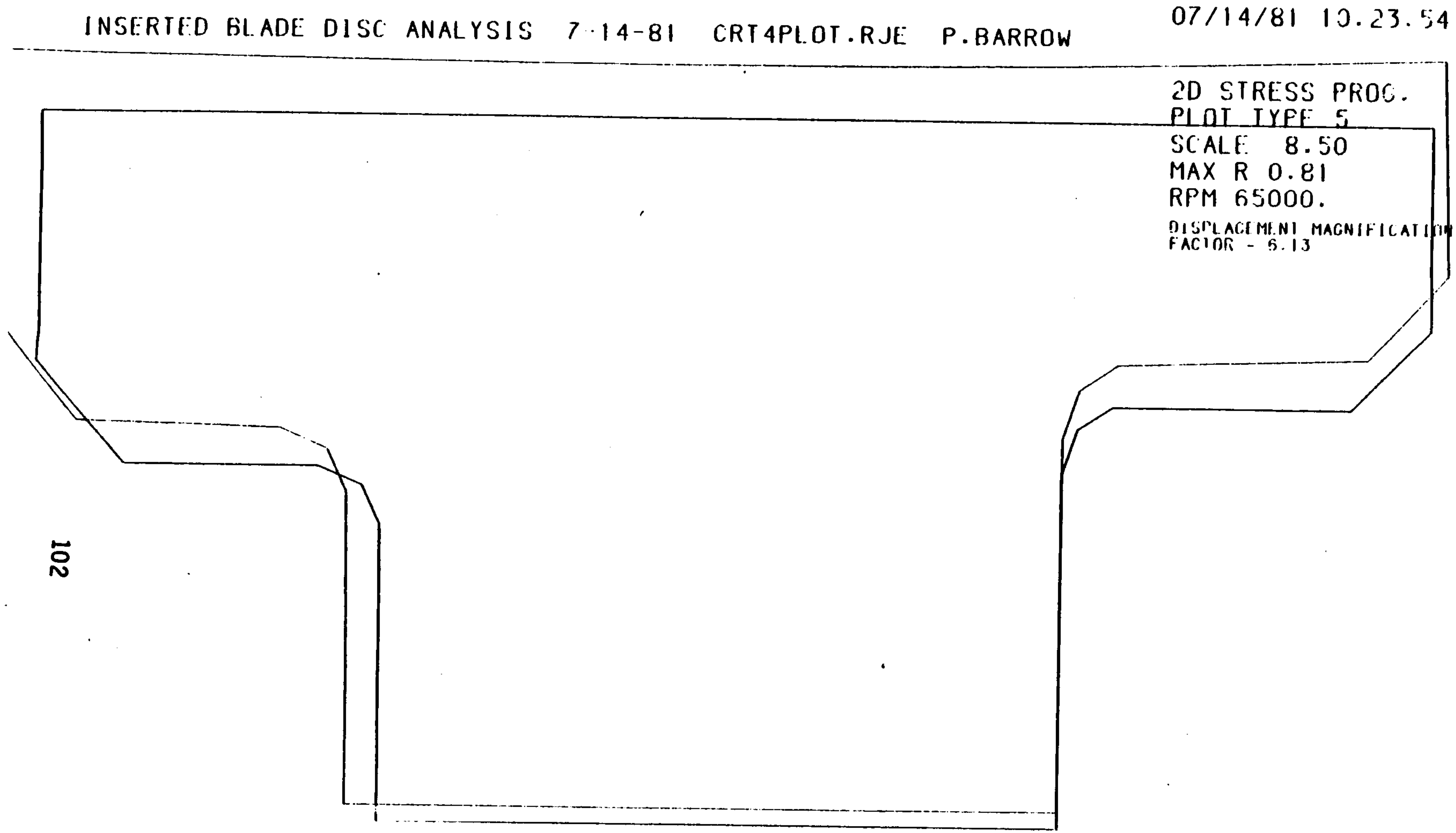

INSERTED BLADE DISC ANALYSIS 7-14-81 CRT4PLOT.RJE P.BARROW
07/14/81 10.23.54
2D STRESS PROC.
PLOT TYPE 5
SCALE 8.50
MAX R 0.81
RPM 65000.
DISPLACEMENT MAGNIFICATION FACTOR - 6.13

FIGURE 37

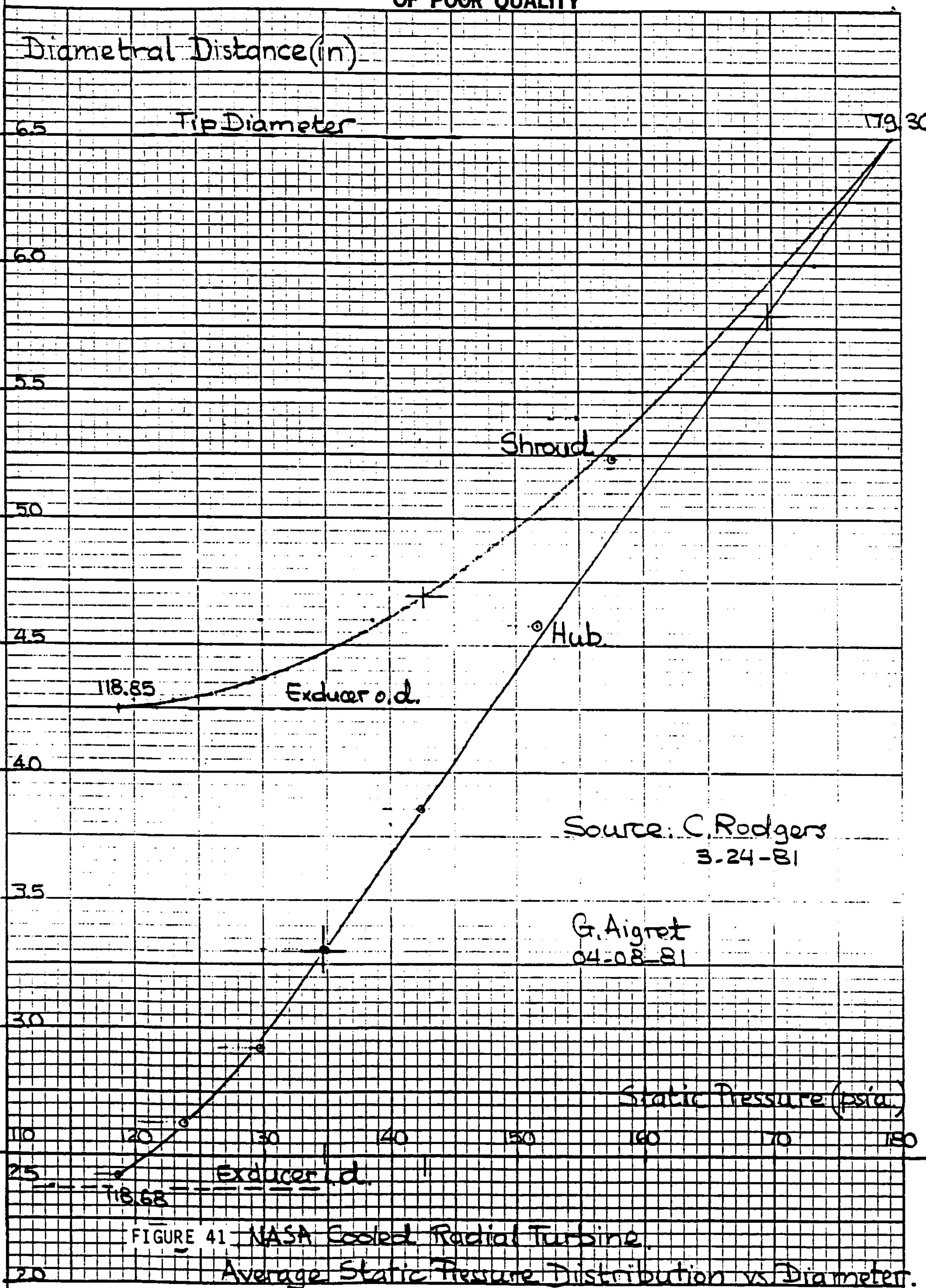


FIGURE 41 NASA Cooled Radial Turbine.
Average Static Pressure Distribution vs Diameter.

FIG 41

ADDENDUM

These data are copies of the computer printout sheets showing:

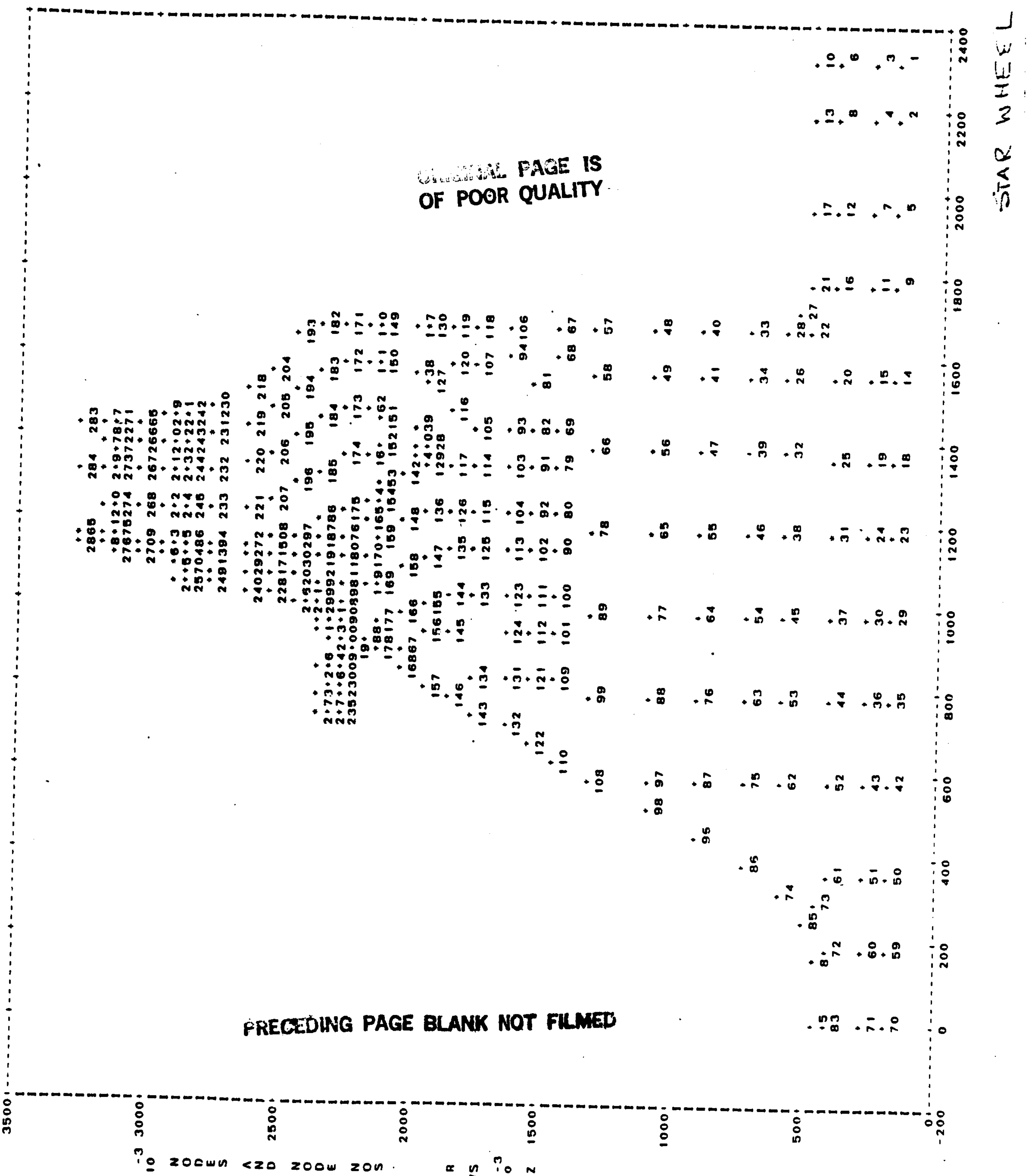
a) Radial and axial displacement at each node point.

b) Stresses (radial, axial, tangential, shear and effective) at each element made up of three adjacent nodes.

Both a) and b) above are under operating conditions listed in para 3.0.4.1.

NOTE: The program performs node re-numbering (optimized wave front) to minimize computation time. Each output group has a re-numbered node diagram as a front sheet. This (re-numbered node) sheet should be used in determining the values of a and b above for each design.

ORIGINAL PAGE IS
OF POOR QUALITY



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PAGE 106 INTENTIONALLY BLANK

DISPLACEMENTS AND REDUNDANT LOADS

NODE	RADIAL DISP.	AXIAL DISP.	RADIAL LOAD	AXIAL LOAD
1	0.150926E-02	0.0	0.115267D+02	-0.108336D-02
2	0.158488E-02	-0.102642E-02		
3	0.206931E-02	0.476131E-04		
4	0.213094E-02	-0.978606E-03		
5	0.170772E-02	-0.272347E-02		
6	0.329984E-02	0.148603E-03		
7	0.222625E-02	-0.265090E-02		
8	0.335095E-02	-0.880460E-03		
9	0.205017E-02	-0.408848E-02		
10	0.395260E-02	0.186212E-03		
11	0.254643E-02	-0.398409E-02		
12	0.340474E-02	-0.253259E-02		
13	0.399463E-02	-0.846174E-03		
14	0.249518E-02	-0.516281E-02		
15	0.298652E-02	-0.507360E-02		
16	0.374614E-02	-0.384756E-02		
17	0.402047E-02	-0.245577E-02		
18	0.267170E-02	-0.589468E-02		
19	0.315062E-02	-0.585729E-02		
20	0.429590E-02	-0.489814E-02		
21	0.434880E-02	-0.370384E-02		
22	0.474034E-02	-0.428668E-02		
23	0.266278E-02	-0.656401E-02		
24	0.312674E-02	-0.658202E-02		
25	0.443568E-02	-0.577371E-02		
26	0.587372E-02	-0.472381E-02		
27	0.500286E-02	-0.408142E-02		
28	0.563870E-02	-0.419637E-02		
29	0.251493E-02	-0.739704E-02		
30	0.297465E-02	-0.745231E-02		
31	0.437738E-02	-0.660248E-02		
32	0.595465E-02	-0.572146E-02		
33	0.782261E-02	-0.429971E-02		
34	0.780942E-02	-0.482649E-02		
35	0.230137E-02	-0.827216E-02		
36	0.275960E-02	-0.835181E-02		
37	0.419710E-02	-0.755654E-02		
38	0.586070E-02	-0.672074E-02		
39	0.776815E-02	-0.584260E-02		
40	0.945251E-02	-0.438447E-02		
41	0.941962E-02	-0.494235E-02		
42	0.202540E 02	-0.925815E-02		
43	0.248446E-02	-0.935432E-02		
44	0.394420E-02	-0.851173E-02		
45	0.564794E-02	-0.772272E-02		
46	0.760823E-02	-0.687871E-02		
47	0.936016E-02	-0.602567E-02		
48	0.112924E-01	-0.445765E-02		
49	0.112710E-01	-0.505899E-02		
50	0.169747E-02	-0 103835E-01		
51	0.215696E-02	-0.104817E-01		
52	0.362439E-02	-0.954801E-02		
53	0.534107E-02	-0.874071E-02		
54	0.731306E-02	-0.792407E-02		
55	0.917477E-02	-0.713963E-02		
56	0.112162E-01	-0.626010E-02		
57	0.131204E-01	-0.451015E-02		
58	0.132171E-01	-0.517161E-02		
59	0.142004E-02	-0.116381E-01		
60	0.188406E-02	-0.117280E-01		
61	0.323159E-02	-0.106865E-01		
62	0.495278E-02	-0.981669E-02		
63	0.689013E-02	-0.897771E-02		
64	0.893689E-02	-0.826087E-02		
65	0.110062E-01	-0.747173E-02		
66	0.132601E-01	-0.648931E-02		
67	0.144938E-01	-0.436082E-02		
68	0.147674E-01	-0.489720E-02		
69	0.148945E-01	-0.619771E-02		
70	0.123311E-02	-0 127736E-01		
71	0.170065E-02	-0.128607E-01		
72	0.277316E-02	-0.119232E-01		
73	0.334432E-02	-0.113003E-01		
74	0.435846E-02	-0.112662E-01		
75	0.633880E-02	-0.100850E-01		
76	0.834759E-02	-0.938124E-02		
77	0.105956E-01	[illegible]		

78	0.130019E-01	-0.785734E-02
79	0.147982E-01	-0.702528E-02
80	0.146669E-01	-0.778322E-02
81	0.159836E-01	-0.518345E-02
82	0.160082E-01	-0.630878E-02
83	0.258725E-02	-0.130491E-01
84	0.314459E-02	-0.120926E-01
85	0.362339E-02	-0.115953E-01
86	0.573531E-02	-0.112437E-01
87	0.770804E-02	-0.105380E-01
88	0.100043E-01	-0.988436E-02
89	0.124938E-01	-0.919576E-02
90	0.144417E-01	-0.852152E-02
91	0.159189E-01	-0.720808E-02
92	0.157503E-01	-0.804274E-02
93	0.172143E-01	-0.647191E-02
94	0.170900E-01	-0.468069E-02
95	0.298151E-02	-0.131180E-01
96	0.725233E-02	-0.113549E-01
97	0.925171E-02	-0.111031E-01
98	0.899699E-02	-0.114772E-01
99	0.117696E-01	-0.104781E-01
100	0.141054E-01	-0.932307E-02
101	0.137837E-01	-0.993255E-02
102	0.154955E-01	-0.882690E-02
103	0.170935E-01	-0.745248E-02
104	0.168796E-01	-0.835066E-02
105	0.185373E-01	-0.569790E-02
106	0.174869E-01	-0.369161E-02
107	0.186907E-01	-0.490279E-02
108	0.109211E-01	-0.117254E-01
109	0.133126E-01	-0.106977E-01
110	0.124283E-01	-0.119100E-01
111	0.151124E-01	-0.966944E-02
112	0.147486E-01	-0.102991E-01
113	0.165798E-01	-0.918052E-02
114	0.183301E-01	-0.776752E-02
115	0.180538E-01	-0.872029E-02
116	0.200382E-01	-0.631776E-02
117	0.196231E-01	-0.813559E-02
118	0.189686E-01	-0.370369E-02
119	0.205632E-01	-0.387688E-02
120	0.202856E-01	-0.511974E-02
121	0.142188E-01	-0.110909E-01
122	0.134513E-01	-0.120874E-01
123	0.161414E-01	-0.100590E-01
124	0.157183E-01	-0.107062E-01
125	0.176938E-01	-0.959123E-02
126	0.192603E-01	-0.915169E-02
127	0.217571E-01	-0.596108E-02
128	0.212109E-01	-0.778843E-02
129	0.209460E-01	-0.856250E-02
130	0.222485E-01	-0.422131E-02
131	0.151273E-01	-0.115302E-01
132	0.144868E-01	-0.123076E-01
133	0.171948E-01	-0.105012E-01
134	0.160705E-01	-0.120137E-01
135	0.188253E-01	-0.100628E-01
136	0.204765E-01	-0.964668E-02
137	0.234278E-01	-0.453217E-02
138	0.229042E-01	-0.614293E-02
139	0.223405E-01	-0.781005E-02
140	0.221497E-01	-0.828235E-02
141	0.219650E-01	-0.870531E-02
142	0.220598E-01	-0.925100E-02
143	0.155849E-01	-0.125608E-01
144	0.182488E-01	-0.110083E-01
145	0.177196E-01	-0.117020E-01
146	0.167238E-01	-0.128375E-01
147	0.198846E-01	-0.107293E-01
148	0.213683E-01	-0.103872E-01
149	0.255688E-01	-0.527841E-02
150	0.249989E-01	-0.670243E-02
151	0.243781E-01	-0.818496E-02
152	0.239087E-01	-0.912773E-02
153	0.233107E-01	-0.101754E-01
154	0.230921E-01	-0.105806E-01
155	0.192746E-01	-0.116158E-01
156	0.186948E-01	-0.122891E-01
157	0.178537E-01	-0.131329E-01
158	0.207631E-01	-0.118487E-01
159	0.224542E-01	-0.116113E-01
160	0.263859E-01	-0.561688E-02
161	0.257923E-01	-0.698837E-02

*

162	0.251689E-01	-0.839444E-02
163	0.244501E-01	-0.972803E-02
164	0.236595E-01	-0.109906E-01
165	0.233590E-01	-0.113884E-01
166	0.201653E-01	-0.124777E-01
167	0.195042E-01	-0.133055E-01
168	0.192125E-01	-0.136696E-01
169	0.217309E-01	-0.125613E-01
170	0.225308E-01	-0.124103E-01
171	0.272165E-01	-0.598373E-02
172	0.265634E-01	-0.736812E-02
173	0.258865E-01	-0.878806E-02
174	0.250401E-01	-0.102476E-01
175	0.241440E-01	-0.115815E-01
176	0.235895E-01	-0.123643E-01
177	0.209408E-01	-0.134213E-01
178	0.203640E-01	-0.139737E-01
179	0.219331E-01	-0.129111E-01
180	0.231789E-01	-0.128681E-01
181	0.227550E-01	-0.133224E-01
182	0.288033E-01	-0.673926E-02
183	0.280070E-01	-0.834325E-02
184	0.271378E-01	-0.993514E-02
185	0.261698E-01	-0.113746E-01
186	0.250833E-01	-0.127868E-01
187	0.247820E-01	-0.131539E-01
188	0.207756E-01	-0.139794E-01
189	0.223213E-01	-0.137486E-01
190	0.218805E-01	-0.141685E-01
191	0.242678E-01	-0.137308E-01
192	0.239165E-01	-0.141648E-01
193	0.301076E-01	-0.814008E-02
194	0.291912E-01	-0.987017E-02
195	0.281813E-01	-0.114167E-01
196	0.271025E-01	-0.127893E-01
197	0.260254E-01	-0.140462E-01
198	0.212215E-01	-0.145992E-01
199	0.233274E-01	-0.145806E-01
200	0.216644E-01	-0.147019E-01
201	0.225928E-01	-0.148465E-01
202	0.255453E-01	-0.145574E-01
203	0.250298E-01	-0.150180E-01
204	0.311466E-01	-0.102024E-01
205	0.303209E-01	-0.115148E-01
206	0.292598E-01	-0.128902E-01
207	0.281298E-01	-0.141361E-01
208	0.269790E-01	-0.153290E-01
209	0.213405E-01	-0.151302E-01
210	0.208336E-01	-0.153256E-01
211	0.237998E-01	-0.150988E-01
212	0.229911E-01	-0.150109E-01
213	0.221796E-01	-0.152097E-01
214	0.226359E-01	-0.152696E-01
215	0.266624E-01	-0.156244E-01
216	0.244068E-01	-0.155104E-01
217	0.260800E-01	-0.160965E-01
218	0.322960E-01	-0.120609E-01
219	0.313922E-01	-0.131915E-01
220	0.303439E-01	-0.143486E-01
221	0.291115E-01	-0.155507E-01
222	0.279900E-01	-0.166111E-01
223	0.208516E-01	-0.157595E-01
224	0.217788E-01	-0.155756E-01
225	0.204434E-01	-0.159762E-01
226	0.220163E-01	-0.158143E-01
227	0.277576E-01	-0.168113E-01
228	0.255177E-01	-0.165084E-01
229	0.268205E-01	-0.169206E-01
230	0.334024E-01	-0.139123E-01
231	0.324403E-01	-0.148922E-01
232	0.314454E-01	-0.158310E-01
233	0.302395E-01	-0.168790E-01
234	0.290364E-01	-0.179074E-01
235	0.205672E-01	-0.160835E-01
236	0.214043E-01	-0.159565E-01
237	0.209160E-01	-0.164370E-01
238	0.214489E-01	-0.163545E-01
239	0.287983E-01	-0.180982E-01
240	0.266606E-01	-0.176183E-01
241	0.281772E-01	-0.185565E-01
242	0.345779E-01	-0.156323E-01
243	0.336161E-01	-0.164834E-01
244	0.327036E-01	-0.172480E-01
245	0.314246E-01	[illegible]

246	0.301380E-01	-0.192649E-01
247	0.211320E-01	-0.166611E-01
248	0.298861E-01	-0.194601E-01
249	0.278130E-01	-0.188003E-01
250	0.292158E-01	-0.199316E-01
251	0.351798E-01	-0.164771E-01
252	0.342195E-01	-0.172793E-01
253	0.333554E-01	-0.179740E-01
254	0.320527E-01	-0.189785E-01
255	0.306940E-01	-0.199921E-01
256	0.301494E-01	-0.203748E-01
257	0.289429E-01	-0.201128E-01
258	0.295281E-01	-0.207830E-01
259	0.357893E-01	-0.172938E-01
260	0.348963E-01	-0.180122E-01
261	0.340182E-01	-0.187029E-01
262	0.327049E-01	-0.197088E-01
263	0.313013E-01	-0.207456E-01
264	0.308206E-01	-0.210850E-01
265	0.370657E-01	-0.188219E-01
266	0.361522E-01	-0.195396E-01
267	0.352898E-01	-0.202096E-01
268	0.339685E-01	-0.212223E-01
269	0.326834E-01	-0.221864E-01
270	0.322483E-01	-0.225120E-01
271	0.383561E-01	-0.202973E-01
272	0.374058E-01	-0.210499E-01
273	0.365675E-01	-0.217073E-01
274	0.353613E-01	-0.226454E-01
275	0.341099E-01	-0.236070E-01
276	0.336780E-01	-0.239401E-01
277	0.389407E-01	-0.210827E-01
278	0.380462E-01	-0.217890E-01
279	0.371909E-01	-0.224602E-01
280	0.360129E-01	-0.233794E-01
281	0.347901E-01	-0.243222E-01
282	0.343608E-01	-0.246520E-01
283	0.395420E-01	-0.218303E-01
284	0.377925E-01	-0.232132E-01
285	0.355143E-01	-0.249919E-01
286	0.350512E-01	-0.253465E-01

REDUNDANT LOAD CALC. TIME (MIN.)= 0.0167

ELEMENT STRESSES

	ELEMENT	STRESS-R	STRESS-Z	STRESS-Q	STRESS-RZ	EFF. STRESS
1	1- 2- 3	9.	1587.	1315.	821.	2039.
2	2- 4- 3	-4839.	582.	1894.	1917.	7017.
3	2- 5- 4	5990.	9224.	19074.	1033.	11939.
4	5- 7- 4	-1143.	7490.	20941.	5735.	21686.
5	5- 9- 7	14436.	8609.	52406.	-7299.	43092.
6	9- 11- 7	12574.	9720.	61935.	-1726.	50939.
7	9- 14- 11	20476.	-16346.	98000.	-6571.	102588.
8	14- 15- 11	26505.	-7526.	110845.	-8478.	106575.
9	14- 18- 15	30823.	-33897.	143522.	3680.	155649.
10	18- 19- 15	25786.	-30261.	135486.	-2987.	146125.
11	18- 23- 19	36013.	-27977.	162609.	5743.	168297.
12	23- 24- 19	24377.	-29399.	142218.	-1246.	152060.
13	23- 29- 24	34017.	-18409.	159534.	4412.	158569.
14	29- 30- 24	23809.	-24077.	133831.	-669.	140248.
15	29- 35- 30	30558.	-12789.	141420.	2751.	137838.
16	35- 36- 30	20232.	-20296.	114627.	-620.	119922.
17	35- 42- 36	24712.	-8248.	114312.	2259.	109928.
18	42- 43- 36	15083.	-16500.	87968.	-116.	92804.
19	42- 50- 43	18037.	-1519.	80266.	2473.	74099.
20	50- 51- 43	7758.	-11721.	54600.	2156.	59163.
21	50- 59- 51	9749.	5239.	42993.	-25.	35715.
22	59- 60- 51	3355.	-3270.	24423.	927.	25098.
23	59- 70- 60	1462.	4036.	10693.	-1706.	8674.
24	70- 71- 60	-1559.	-317.	553.	-1513.	3201.
25	3- 4- 6	1645.	1353.	711.	1735.	3117.
26	4- 8- 6	-1167.	315.	284.	2355.	4335.
27	4- 7- 8	6621.	3220.	11363.	1924.	7829.
28	7- 12- 8	2975.	3039.	13338.	5114.	13609.
29	7- 11- 12	15221.	-600.	35173.	-8689.	34505.
30	11- 16- 12	30249.	9795.	50880.	-8620.	38588.
31	11- 15- 16	34064.	-17115.	74619.	-12168.	82367.
32	15- 20- 16	64177.	-4986.	94874.	-14902.	92282.
33	15- 19- 20	67700.	-23256.	118539.	3124.	124549.
34	19- 25- 20	68116.	-10502.	117551.	-1610.	111893.
35	19- 24- 25	70329.	-19610.	130312.	6718.	131220.
36	24- 31- 25	65429.	-9102.	120367.	1765.	112597.
37	24- 30- 31	66814.	-13921.	126306.	5800.	122323.
38	30- 37- 31	58944.	-10208.	110558.	1707.	105000.
39	30- 36- 37	60905.	-9199.	112591.	3852.	106089.
40	36- 44- 37	48986.	-10710.	93752.	2101.	90852.
41	36- 43- 44	51274.	-4760.	92158.	3069.	84446.
42	43- 52- 44	36195.	-10727.	71335.	3059.	71512.
43	43- 51- 52	38666.	658.	65796.	3437.	56987.
44	51- 61- 52	17321.	-11092.	41986.	5917.	47135.
45	51- 60- 61	20318.	4948.	34853.	306.	25908.
46	60- 72- 61	4594.	-2153.	18048.	1551.	18015.
47	60- 71- 72	3161.	3284.	7834.	-3834.	8086.
48	71- 83- 72	-1177.	-1468.	-250.	-3185.	5625.
49	72- 73- 61	5514.	-1730.	19508.	2643.	19253.
50	72- 84- 73	2765.	-3696.	10711.	1453.	12751.
51	72- 83- 84	-1504.	-515.	3256.	-3096.	6905.
52	83- 95- 84	62.	-3561.	-1008.	-1337.	3964.
53	6- 8- 10	664.	-435.	-1318.	655.	2060.
54	8- 13- 10	-2596.	-990.	-1684.	945.	2151.
55	8- 12- 13	1905.	-3713.	4285.	1707.	7704.
56	12- 17- 13	-3562.	-6284.	5842.	8159.	17921.
57	12- 16- 17	8990.	-7586.	24479.	-7994.	31036.
58	16- 21- 17	10312.	-9933.	32762.	848.	37022.
59	16- 22- 21	24548.	-2942.	57211.	-22856.	65484.
60	16- 20- 22	79717.	-2125.	88668.	-20680.	93779.
61	21- 22- 27	52206.	9508.	71053.	-31866.	77654.
62	22- 28- 27	112564.	32131.	105510.	-56316.	124369.
63	22- 26- 28	111524.	13279.	108709.	-11425.	98874.
64	20- 26- 22	89528.	953.	103092.	-17940.	100983.
65	20- 25- 26	89734.	-5546.	111227.	2043.	107711.
66	25- 32- 26	88043.	11969.	115179.	-2223.	92756.
67	25- 31- 32	81437.	-6832.	112537.	5092.	107623.
68	31- 38- 32	81329.	7155.	111372.	672.	92925.
69	31- 37- 38	77257.	-6362.	106711.	4248.	101870.
70	37- 45- 38	72199.	1326.	100736.	1325.	88330.
71	37- 44- 45	69989.	-4632.	94870.	3393.	89885.
72	44- 53- 45	60150.	-2065.	84689.	2446.	77577.
73	44- 52- 53	59186.	-2292.	77921.	2936.	72860.
74	52- 62- 53	44883.	-3330.	65031.	3575.	61160.
75	52- 61- 62	44381.	1221.	55970.	3607.	50364.
76	61- 74- 62	24001.	-2997.	37973.	5266.	37211.

77	61- 73- 74	17200.	-554.	26773.	-260.	24022.
78	73- 85- 74	12158.	-421.	20680.	3049.	19130.
79	73- 84- 85	-1539.	-5080.	10402.	-1540.	14302.
94	33- 34- 40	91716.	9213.	120025.	-3465.	99903.
95	34- 41- 40	80092.	5757.	108269.	-3346.	91916.
96	34- 39- 41	86585.	10568.	116305.	-4334.	94753.
97	39- 47- 41	74310.	7270.	103413.	-7114.	86284.
98	39- 46- 47	80573.	6514.	110141.	-2252.	92546.
99	46- 55- 47	68017.	4617.	96818.	-5288.	82216.
100	46- 54- 55	74504.	3097.	101582.	-45.	88128.
101	54- 64- 55	60109.	956.	87344.	-2156.	76592.
102	54- 63- 64	66890.	1940.	89946.	2195.	79136.
103	63- 76- 64	49541.	-1398.	74515.	1768.	67086.
104	63- 75- 76	56325.	3915.	74582.	4839.	64090.
105	75- 87- 76	35410.	-2286.	57207.	6447.	53317.
106	75- 86- 87	41730.	7683.	54832.	5603.	43258.
107	86- 96- 87	23864.	2992.	40425.	6398.	34329.
108	40- 41- 48	82567.	-1897.	97585.	-694.	92937.
109	41- 49- 48	77599.	147.	90245.	-3958.	84770.
110	41- 47- 49	77625.	-2716.	90567.	-2969.	87687.
111	47- 56- 49	75709.	6825.	86999.	-9163.	76829.
112	47- 55- 56	74988.	-4938.	85445.	-2868.	85782.
113	55- 65- 56	69008.	1247.	79983.	-6614.	74749.
114	55- 64- 65	72786.	-5139.	80850.	-557.	82263.
115	64- 77- 65	61008	-321.	73374.	-1853.	68434.
116	64- 76- 77	66503.	-3257.	73690.	2200.	73719.
117	76- 88- 77	50604.	-1241.	64033.	3296.	59978.
118	76- 87- 88	56831.	833.	62894.	5682.	60077.
119	87- 97- 88	38079.	-233.	50595.	8067.	47953.
120	87- 98- 97	40393.	4814.	46536.	12832.	44904.
121	87- 96- 98	33530.	2668.	41727.	5283.	36831.
122	48- 49- 57	66637.	-1150.	87273.	-593.	80133.
123	49- 58- 57	78632.	10687.	87083.	-14359.	76689.
124	49- 56- 58	59364.	-10416.	68488.	-2746.	74915.
125	56- 66- 58	70819.	3346.	70199.	-13177.	70940.
126	56- 65- 66	71032.	-9503.	69442.	-927.	79771.
127	65- 78- 66	65908.	5292.	67711.	-6151.	62456.
128	65- 77- 78	69490.	-7386.	67705.	1011.	76023.
129	77- 89- 78	58226.	2630.	63339.	-252.	58325.
130	77- 88- 89	65078.	-3351.	64382.	4053.	68448.
131	88- 99- 89	48379.	1223.	56872.	6369.	53087.
132	88- 97- 99	55787.	2164.	56531.	7793.	55662.
133	97-108- 99	37408.	5661.	46947.	10183.	41388.
134	97- 98-108	37667.	-135.	41173.	8398.	42256.
135	57- 58- 67	44522.	-12030.	62473.	809.	67364.
136	58- 68- 67	57116.	-3238.	57338.	-16505.	66885.
137	58- 69- 68	48082.	5228	53052.	-9203.	48255.
138	58- 66- 69	69585.	-11373.	55101.	-7051.	75770.
139	66- 79- 69	60114.	15782.	54099.	-1012.	41690.
140	66- 80- 79	63665.	8181.	54349.	1308.	51515.
141	66- 78- 80	65963.	-6305.	56164.	-7350.	69087.
142	78- 90- 80	59336.	7625.	55216.	-191.	49782.
143	78- 89- 90	66235.	-4613.	57726.	-552.	67009.
144	89-100- 90	54914.	4321.	54714.	-1308.	50546.
145	89-101-100	54243.	2994.	55037.	5715.	52593.
146	89- 99-101	60220.	-1091.	56910.	4073.	60143.
147	99-109-101	48142.	3219.	52703.	5941.	48475.
148	99-110-109	47124.	5420.	49756.	13208.	48780.
149	99-108-110	39077.	2082.	44026.	8002.	42053.
150	68- 69- 81	106815.	12697.	61228.	-4124.	81838.
151	69- 82- 81	52129.	19998.	36942.	-11173.	33907.
152	69- 79- 82	51198.	-3371.	34977.	-700.	48553.
153	79- 91- 82	55282.	14630.	38052.	-8581.	38341.
154	79- 80- 91	57278.	-7393.	38520.	-4548.	58167.
155	80- 92- 91	52200.	9166.	40145.	-8125.	40947.
156	80- 90- 92	58596.	-3607.	44406.	-2797.	56671.
157	90-102- 92	54506.	6707.	45141.	-4279.	44497.
158	90-100-102	61396.	-3145.	49146.	-484.	59380.
159	100-111-102	52420.	3721.	47767.	-408.	46551.
160	100-101-111	59759.	-875.	51927.	1849.	57214.
161	101-112-111	50861.	2714.	49769.	4521.	48252.
162	101-109-112	57816.	845.	53049.	4531.	55305.
163	109-121-112	44292.	3208.	48773.	6948.	45134.
164	109-122-121	50799.	5410.	49733.	12218.	49608.
165	109-110-122	37685.	247.	42158.	8011.	42211.
166	81- 93- 94	79273.	30039.	28407.	4863.	50776.
167	81- 82- 93	52016.	4002.	21567.	-16436.	50805.
168	82- 91- 93	51273.	-3804.	20485.	-6624.	49169.
169	91-103- 93	45053.	10407.	20240.	-11032.	36355.
170	91- 92-103	54874.	-3967.	27903.	-6593.	52281.
171	92-104-103	47310.	8577.	28360.	-8163.	36406.
[illegible]2	92-102-104	57012.	-4042.	35[illegible]	-4447.	54184.
[illegible]3	102-113-104	49968	5864.	36[illegible]	-4429.	39801.
[illegible]4	102-111-113	60347.	-2402.	43172.	-1088.	56200.

175	111-123-113	49817.	3444.	41713.	186.	42902.
176	111-112-123	59748.	-412.	48122.	2287.	55416.
177	112-124-123	46576.	1566.	44887.	7067.	45856.
178	112-121-124	56355.	3092.	50749.	5575.	51607.
179	121-131-124	43945.	7918.	47937.	7667.	40425.
180	121-132-131	49491.	5364.	48571.	11929.	48327.
181	121-122-132	36975.	591.	42402.	6775.	41055.
182	106- 94-107	28774.	2582.	-18910.	7090.	43150.
183	94-105-107	23858.	-1505.	-24192.	9588.	44826.
184	94- 93-105	41008.	-9633.	-5618.	-12275.	53194.
185	93-103-105	53718.	-5733.	5708.	-9126.	56879.
186	103-114-105	36869.	7930.	4147.	-9340.	34972.
187	103-104-114	51655.	-5340.	15882.	-8620.	52081.
188	104-115-114	41641.	5614.	16674.	-7823.	34722.
189	104-113-115	55214.	-4538.	27080.	-5813.	52748.
190	113-125-115	46170.	4916.	28235.	-3967.	36483.
191	113-123-125	58672.	-2934.	37070.	-1797.	54232.
192	123-133-125	48805.	3562.	37071.	310.	40671.
193	123-124-133	60867.	237.	45208.	3669.	54886.
194	124-134-133	45478.	-93.	38672.	9840.	45865.
195	124-131-134	44953.	2358.	42233.	3381.	41717.
196	131-143-134	48155.	3109.	41426.	14253.	48795.
197	131-132-143	40648.	103.	41673.	5480.	42102.
202	107-105-116	16078.	-24188.	-44293.	-9230.	55596.
203	105-117-116	29355.	6106.	-18888.	4006.	42363.
204	105-114-117	33603.	-4145.	-6501.	-14629.	46494.
205	114-115-117	48041.	-7387.	5626.	-8359.	52251.
206	115-126-117	36379.	4805.	8039.	-5684.	31659.
207	115-125-126	51905.	-5250.	19839.	-5750.	50612.
208	125-135-126	41965.	5461.	22409.	-2510.	31939.
209	125-133-135	55514.	-3550.	31908.	-2410.	51664.
210	133-144-135	43659.	4534.	32795.	714.	35005.
211	133-134-144	54027.	-3931.	36730.	4703.	52177.
212	134-145-144	48611.	2518.	39309.	4505.	42934.
213	134-146-145	39182.	3543.	39229.	13401.	42553.
214	134-143-146	38753.	-1449.	36046.	10191.	42737.
219	116-117-128	16897.	-13895.	-36749.	-11443.	50668.
220	117-129-128	22042.	10506.	-18140.	-1017.	35880.
221	117-126-129	42313.	-7881.	-2300.	-6059.	48794.
222	126-136-129	30486.	7666.	2685.	-2208.	25960.
223	126-135-136	46578.	-4387.	14597.	-4559.	45309.
224	135-147-136	37368.	7430.	18690.	-248.	26196.
225	135-144-147	50967.	-1873.	28287.	-3091.	46226.
226	144-155-147	40573.	4426.	29985.	2577.	32497.
227	144-145-155	53774.	-1622.	39134.	1151.	49778.
228	145-156-155	41964.	5248.	40708.	8312.	38870.
229	145-157-156	53883.	4837.	47796.	12717.	51278.
230	145-146-157	37708.	7980.	43496.	8540.	36170.
237	128-129-141	9177.	-5554.	-32221.	-9357.	39797.
238	129 142-141	23869.	9973.	-13549.	1192.	32827.
239	129-136-142	33239.	-2137.	-4826.	-7673.	39122.
240	136-148-142	25957.	1759.	-2178.	-1290.	26484.
241	136-147-148	41057.	-3559.	9433.	-5777.	40987.
242	147-158-148	31471.	4057.	14340.	1889.	24210.
243	147-155-158	48883.	1809.	28977.	-3577.	41397.
244	155-166-158	40559.	7771.	33553.	6117.	31730.
245	155-156-166	51618.	5005.	41767.	2604.	42792.
246	156-167-166	44662.	8284.	42222.	11107.	40134.
247	156-157-167	46545.	424.	42688.	4789.	45090.
248	157-168-167	32399.	9137.	40791.	11551.	34744.
293	164 165-175	14364.	-4152.	-13150.	-6044.	26459.
294	165-176-175	21385.	2471.	-1910.	4313.	22707.
295	165-170-176	32732.	8916.	15593.	-7223.	24685.
296	170-180-176	25514.	5476.	17516.	2411.	17964.
297	170-181-180	34704.	3392.	24432.	7754.	30737.
298	170-179-181	36213.	14566.	36564.	624.	21358.
299	179-189-181	33749.	6020.	34178.	10242.	33102.
300	179-190-189	40911.	6266.	40898.	6313.	36326.
301	179-188-190	32807.	14360.	42709.	4157.	25940.
302	188-198-190	53830.	12723.	49642.	-769.	39205.
303	198-200-190	14637.	2401.	36100.	-4707.	30653.
304	198-209-200	19782.	4968.	40609.	-2426.	31296.
305	198-210-209	11670.	12727.	42253.	-8900.	33791.
306	210-223-209	-3436.	2998.	34956.	-1769.	35747.
307	210-225-223	3244.	2774.	36367.	-2180.	33575.
308	225-235-223	-1807.	-314.	32613.	-469.	33710.
317	175-176-186	16222.	-3311.	-7445.	-5616.	23959.
318	176-187-186	23381.	9885.	5906.	4651.	17793.
319	176-180-187	34465.	309.	13785.	-3441.	30390.
320	180-191-187	28140.	8124.	16074.	3914.	18727.
321	180-181-191	34807.	-918.	20152.	296.	31175.
322	181-192-191	27160.	-1579.	19434.	8910.	30030.
323	181-189-192	38676.	-60.	28378.	2315.	34973.
324	189-199-192	23556.	-3896.	24182.	14679.	37653.

325	189-190-199	36433.	571.	34184.	707.	34815.
326	190-201-199	17363.	-7569.	29345.	16632.	43520.
327	190-200-201	28511.	1462.	39375.	-6602.	35699.
328	200-213-201	10099.	-4240.	34765.	4038.	34882.
329	200-209-213	17483.	3417.	40194.	-6912.	34301.
330	209-224-213	860.	-8992.	31679.	618.	36766.
331	209-223-224	8481.	3175.	36962.	-9645.	35631.
332	223-236-224	-1541.	-3983.	33011.	-3911.	36472.
333	223-237-236	3283.	-1342.	36274.	-2320.	35758.
334	223-235-237	-240.	1677.	34453.	-2414.	34034.
343	186-187-197	13775.	-5215.	-8363.	-6090.	23273.
344	187-191-197	25372.	-8826.	858.	-5713.	32096.
345	191-202-197	20711.	10969.	7619.	278.	11307.
346	191-192-202	37350.	-3014.	19723.	-2820.	35389.
347	192-203-202	31016.	4092.	23211.	4452.	25203.
348	192-199-203	39905.	-1657.	28059.	2424.	37325.
349	199-211-203	30400.	3873.	28773.	10563.	31591.
350	211-216-203	41338.	5316.	34083.	10725.	37869.
351	199-212-211	41898.	4060.	37608.	7388.	38101.
352	199-201-212	3766.	-1243.	28551.	9083.	31799.
353	201-214-212	11603.	-17033.	30866.	9959.	45171.
354	201-213-214	-7603.	-11121.	28306.	518.	37803.
355	213-224-214	11886.	-6374.	35594.	-3112.	36846.
356	224-226-214	2690.	-17223.	26446.	1895.	38657.
357	224-236-226	9231.	-2249.	35734.	-7323.	36048.
358	236-238-226	-1689.	-8518.	32222.	-1098.	37840.
359	236-237-238	3118.	267.	37622.	-2344.	36244.
360	237-247-238	-85.	-1481.	35068.	-992.	35914.
369	197-202-208	8278.	-7038.	-8860.	-6023.	19356.
370	202-215-208	21050.	10088.	9021.	5632.	15105.
371	202-203-215	36242.	837.	21724.	-3249.	31338.
372	203-217-215	29040.	4285.	23270.	6617.	25193.
373	203-216-217	39848.	576.	31061.	376.	35707.
374	216-228-217	35926	2606.	33642.	7680.	34876.
383	208-215-222	4601.	-7420.	-7691.	-3972.	13971.
384	215-227-222	18809.	9316.	8619.	4143.	12195.
385	215-217-227	30054.	-2553.	17826.	-3224.	29074.
386	217-229-227	24365.	220.	19571.	5650.	24208.
387	217-228-229	36809.	-3384.	29043.	-2750.	37235.
388	228-240-229	29363.	11541.	32267.	1917.	19720.
397	222-227-234	458.	-6827.	-6923.	-2690.	8689.
398	227-239-234	9054.	5410.	3797.	5999.	11390.
399	227-229-239	21102.	2379.	14289.	-2699.	17067.
400	229-241-239	19876.	7488.	17771.	5688.	15130.
401	229-240-241	26050.	-6717.	21379.	1830.	30864.
402	240-249-241	26775.	5646.	26135.	7072.	24154.
411	234-239-246	3003.	-4309.	-5416.	-2978.	9455.
412	239-248-246	4483.	3956.	-1976.	3283.	8422.
413	239-241-248	11629.	-8414.	3188.	-3611.	18519.
414	241-250-248	8690.	2334.	7705.	4590.	9915.
415	241-249-250	21180.	-3593.	17860.	-2382.	23655.
416	249-257-250	16503	5359.	16905.	4293.	13570.
425	246-248-255	-2737.	-7420.	-12736.	-4745.	11944.
426	248-256-255	425.	-1019.	-3527.	5801.	10628.
427	248-250-256	6115.	-500.	5698.	-3736.	9114.
428	250-257-258	645.	-7352.	4691.	-1719.	11025.
429	250-258-256	7636.	887.	10944.	2629.	9977.

ELEMENT STRESSES

	ELEMENT	STRESS-Y	STRESS-X	STRESS-XY	EFF. STRESS
80	28- 26- 33	201951.	8904.	-28774.	203836.
81	26--34- 33	154606.	-5459.	-5619	157707.
82	26- 32- 34	155623.	-2067.	-10922.	157805.
83	32- 39- 34	133140.	-6395.	-6000.	136845.
84	32- 38- 39	131942.	-11325.	-3442.	138082.
85	38- 46- 39	121317.	-9537.	-2644.	126439.
86	38- 45- 46	120518.	-14750.	-140.	128579.
87	45- 54- 46	107294.	-12766.	996.	114227.
88	45- 53- 54	108116.	-13709.	1719.	115621.
89	53- 63- 54	88432.	-14408.	5077.	96846.
90	53- 62- 63	91390.	-9331.	3367.	96571.
91	62- 75- 63	67692.	-13159.	9350.	72046.
92	62- 74- 75	67423.	-1430.	5980.	68931.
93	74- 86- 75	36145.	-8222.	11541.	45506.
198	106-107-118	78771.	13931.	21077.	81451.
199	118-107-119	63280.	-4967.	7659.	67226.
200	107-120-119	50203.	-9881.	4067.	56247.
201	107-116-120	49629.	-11797.	2354.	56606.
215	119-120-130	71681.	-2573.	-5811.	73692.
216	120-127-130	56873.	-2404.	-1364.	58160.
217	120-116-127	45096.	-12296.	-9830.	55039.
218	116-128-127	32678.	-6045.	-2329.	36307.
231	130-127-137	71432.	301.	-7584.	72482.
232	127-138-137	40513.	-2870.	-9173.	44925.
233	127-139-138	45086.	979.	-8020.	46718.
234	127-128-139	27210.	-5821.	-14992.	40087.
235	128-140-139	22346.	-2293.	-4870.	25040.
236	128-141-140	26859.	-3991.	-3165.	29570.
249	137-138-149	53680.	-3831.	-12284.	59621.
250	138-150-149	31827.	1694.	-7780.	33816.
251	138-151-150	37705.	-967.	-7074.	40115.
252	138-139-151	24982.	-3979.	-16421.	39349.
253	139-152-151	27002.	2154.	-1143.	26068.
254	139-140-152	25097.	6127.	-10398.	28948.
255	140-141-152	29034.	4225.	-8428.	30843.
256	152-141-153	22560.	965.	4279.	23303.
257	141-142-153	8805.	-7397.	-10248.	22637.
258	142-154-153	25426.	994.	-3384.	25623.
259	142-148-154	26980.	1955.	-10445.	31722.
260	148-159-154	29037.	5165.	324.	26836.
261	148-158-159	35687.	-2304.	-5054.	37917.
262	158-169-159	38657.	6072.	4669.	36904.
263	158-166-169	45452.	-3553.	972.	47369.
264	166-177-169	45581.	3919.	8394.	46106.
265	166-167-177	49382.	-4699.	6188.	52986.
266	167-178-177	46552.	5238.	10894.	48029.
267	167-168-178	47160.	-1421.	11085.	51610.
268	149-150-160	46760.	1282.	-10816.	49791.
269	150-161-160	27898.	172.	-9368.	32199.
270	150-151-161	37828.	-1465.	-12657.	44375.
271	151-162-161	23272.	3110.	-14006.	32672.
272	151-152-162	33048.	4236.	-9881.	35539.
273	152-163-162	28472.	8432.	-4211.	26361.
274	152-153-163	37687.	10586.	-3707.	34273.
275	153-164-163	25960.	457.	4358.	26819.
276	153-154-164	9308	-4488.	-6530.	16628.
277	154-165-164	22364.	6085.	-1962.	20313.
278	154-159-165	32639.	6259.	-8669.	33604.
279	159-170-165	25030.	3382.	2186.	23825.
280	159-169-170	39694.	6302.	-5365.	38070.
281	169-179-170	34004.	3522.	4647.	33372.
282	169-177-179	45121.	3774.	2846.	43637.
283	177-188-179	39450.	3953.	9134.	40819.
284	177-178-188	72924.	13151.	7947.	68712.
285	160-161-171	49024.	1898.	-11293.	51928.
286	161-172-171	31198.	3367.	-8970.	33481.
287	161-162-172	41194.	4228.	-14021.	46156.
288	162-173-172	25186.	6464.	-12479.	31313.
289	162-163-173	39294.	5316.	-10265.	40974.
290	163-174-173	31509.	8285.	-4114.	29175.
291	163-164-174	42116.	7879.	-3762.	39325.
292	164-175-174	21821.	-1980.	2485.	23277.
309	171-172-182	33049.	-1064.	-8561.	36720.
310	172-183-182	23201.	2604.	-7519.	25579.
311	172-173-183	30532.	-1426.	-13480.	39024.
312	173-184-183	19522.	3211.	-7020.	21830.

313	173-174-184	37897.	2482.	-11757.	41987.
314	174-185-184	32843.	7163.	-2144.	30142.
315	174-175-185	38978.	6059.	-6197.	37882.
316	175-186-185	20016.	1163.	3157.	20214.
335	182-183-193	27671.	-689.	-10006.	32948.
336	183-194-193	20569.	1985.	-6971.	23065.
337	183-184-194	27418.	-3502.	-12491.	36443.
338	184-195-194	20725.	1182.	-1761.	20389.
339	184-185-195	37163.	25.	-11717.	42332.
340	185-196-195	28503.	2927.	-984.	27212.
341	185-186-196	37453.	7784.	-6986.	36313.
342	186-197-196	14904.	-187.	1403.	15195.
361	193-194-204	36824.	8564.	-17197.	44735.
362	194-205-204	25150.	2190.	-7105.	27086.
363	194-195-205	29760.	-4964.	-12057.	38654.
364	195-206-205	23511.	1572.	-416.	22777.
365	195-196-206	34703.	-4887.	-11380.	42265.
366	196-207-206	25837.	1624.	-48.	25065.
367	196-197-207	30851.	4595.	-7898.	31910.
368	197-208-207	7523.	-179.	2367.	8648.
375	204-205-218	40903.	12058.	-21134.	51625.
376	205-219-218	24761.	1204.	-4722.	25527.
377	205-206-219	24060.	-2680.	-12032.	32938.
378	206-220-219	19086.	3171.	898.	17783.
379	206-207-220	28573.	-2950.	-10163.	34917.
380	207-221-220	19785.	3788.	923.	18259.
381	207-208-221	24097.	7850.	-6951.	24456.
382	208-222-221	4464.	4089.	2039.	5556.
389	218-219-230	42802.	14996.	-19343.	50373.
390	219-231-230	27557.	179.	-3433.	28104.
391	219-220-231	26966.	4065.	-11190.	31776.
392	220-232-231	22517.	3886.	2367.	21247.
393	220-221-232	31485.	3462.	-8559.	33378.
394	221-233-232	18952.	5512.	3059.	17696.
395	221-222-233	26492.	13171.	-5821.	24273.
396	222-234-233	1666.	4964.	4842.	9460.
403	230-231-242	43498.	13197.	-14153.	45751.
404	231-243-242	29871.	1014.	-1824.	29547.
405	231-232-243	32789.	6323.	-8431.	33481.
406	232-244-243	27895.	5039.	2809.	26204.
407	232-233-244	30985.	8008.	-6367.	37328.
408	233-245-244	24244.	6936.	3997.	22708.
409	233-234-245	31244.	15076.	-4418.	28125.
410	234-246-245	4026.	6582.	6242.	12244.
417	242-243-251	44079.	10315.	-9841.	43419.
418	243-252-251	32609.	584.	-3082.	32758.
419	243-244-252	38568.	5845.	-3839.	36631.
420	244-253-252	34762.	5731.	939.	32321.
421	244-245-253	44983.	7777.	-2067.	41796.
422	245-254-253	30852.	6981.	912.	28066.
423	245-246-254	38989.	14905.	-621.	34093.
424	246-255-254	1159.	3606.	4730.	8791.
430	251-252-259	39660.	5446.	-6530.	38923.
431	252-260-259	32126.	64.	-2095.	32298.
432	252-253-260	35439.	3086.	-2120.	34199.
433	253-261-260	32984.	3941.	468.	31211.
434	253-254-261	38744.	3449.	-875.	37171.
435	254-262-261	29242.	4809.	-650.	27182.
436	254-255-262	34506.	9311.	2246.	31164.
437	255-263-262	24310.	4276.	3484.	23275.
438	255-256-263	37303.	5740.	2344.	35026.
439	256-264-263	29893.	8549.	3681.	27418.
440	259-260-265	31421.	2415.	-3421.	30860.
441	260-266-265	28645.	2544.	-649.	27484.
442	260-261-266	28789.	1667.	-1487.	28111.
443	261-267-266	28462.	4095.	277.	26656.
444	261-262-267	29830.	1207.	-712.	29271.
445	262-268-267	26479.	5049.	-43.	24350.
446	262-263-268	27320.	1756.	1965.	26703.
447	263-269-268	25932.	4583.	737.	24005.
448	263-264-269	23711.	-6355.	2796.	27870.
449	264-270-269	21952.	3719.	883.	20406.
450	265-266-271	21464.	-532.	-180.	21737.
451	266-272-271	17917.	222.	-164.	17809.
452	266-267-272	20302.	-935.	-24.	20786.
453	267-273-272	17136.	19.	-52.	17127.
454	267-268-273	19885.	-1179.	316.	20507.
455	268-274-273	16290.	-133.	-755.	16409.
456	268-269-274	18482.	-1898.	1245.	19619.
457	269-275-274	16696.	-6.	-970.	16783.
458	269-270-275	15348.	-2508.	1395.	16917.
[illegible]	270-276-275	13914.	-168.	[illegible]	14015.
[illegible]	271-272-277	11777.	-1808.	-1[illegible].	12963.
461	272-278-277	13001.	801.	-913.	12718.

462	272-273-278	9879.	-2809	389.	11562.
463	273-279-278	12030.	551.	-438.	11789.
464	273-274-279	8847.	-3379.	154.	10939.
465	274-280-279	11149.	510.	-412.	10927.
466	274-275-280	7741.	-3709.	913.	10242.
467	275-281-280	10024.	173.	309.	9953.
468	275-276-281	7720.	-82.	1364.	8113.
469	276-282-281	11122.	313.	1233.	11175.
470	277-278-283	4372.	160.	-372.	4342.
471	278-284-283	3419.	896.	-465.	3174.
472	278-279-284	4508.	245.	-457.	4462.
473	279-280-284	4582.	490.	348.	4400.
474	280-285-284	1958.	1266.	116.	1731.
475	280-281-285	4782.	549.	64.	4534.
476	281-282-285	4539.	270.	438.	4475.
477	282-286-285	3029.	768.	1070.	3298.

STRESS CALCULATION TIME (MIN.)= 0.0833

MAXIMUM EFFECTIVE STRESS OCCURS AT ELEMENT 80 -28- -26- -33 AND IS EQUAL TO 2.0384E+05 PSI

MAXIMUM RADIAL DISPLACEMENT OCCURS AT NODE 283 AND IS EQUAL TO 3.9542E-02 INS.

MAXIMUM AXIAL DISPLACEMENT OCCURS AT NODE 286 AND IS EQUAL TO -2.5346E-02 INS.

AVERAGE STRESSES OF DISK - VOL. AVG. TANG. IS 47856.227 PSI
AREA AVG. TANG. IS 59368.332 PSI
AREA AVG. EQUIV. IS 61271.520 PSI

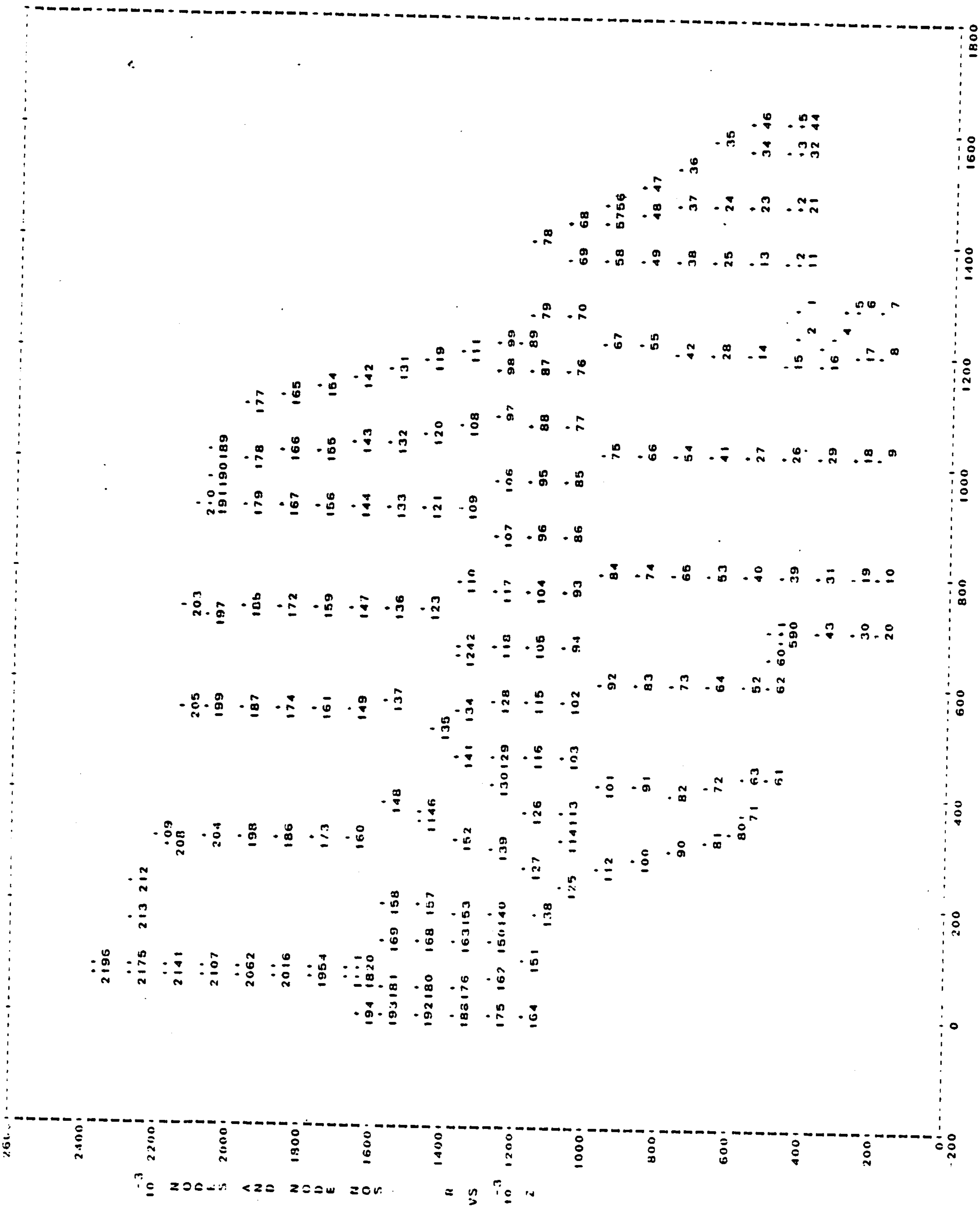
TOTAL WEIGHT OF BODY IS 4.804 LBS

DIAMETRAL INERTIA ABOUT ORIGIN IS 12.800 LB-IN**2

DIAMETRAL INERTIA ABOUT CENTROID IS 6.825 LB-IN**2

POLAR INERTIA OF BODY IS 12.563 LB-IN**2

CENTROID OF BODY FROM ORIGIN IS 1.1153 IN.



DISPLACEMENTS AND REDUNDANT LOADS

NODE	RADIAL DISP.	AXIAL DISP.	RADIAL LOAD	AXIAL LOAD
1	0.501715E-02	0.328833E-03		
2	0.487303E-02	-0.858138E-04		
3	0.436575E-02	-0.383274E-03		
4	0.376611E-02	-0.198481E-03		
5	0.355173E-02	0.150909E-03		
6	0.290577E-02	0.714402E-04		
7	0.232815E-02	0.0	0.583516D+01	-0.205454D-02
8	0.242933E-02	-0.699132E-03		
9	0.258060E-02	-0.239649E-02		
10	0.273165E-02	-0.422214E-02		
11	0.497826E-02	0.121940E-02		
12	0.522558E-02	0.124078E-02		
13	0.608482E-02	0.133559E-02		
14	0.619077E-02	-0.224540E-03		
15	0.513235E-02	-0.592222E-03		
16	0.406398E-02	-0.678215E-03		
17	0.300789E-02	-0.637725E-03		
18	0.314931E-02	-0.234637E-02		
19	0.329421E-02	-0.418045E-02		
20	0.281453E-02	-0.507526E-02		
21	-0.486985E-02	0.223163E-02		
22	0.511833E-02	0.226087E-02		
23	0.597069E-02	0.236390E-02		
24	0.699043E-02	0.248212E-02		
25	0.712593E-02	0.145766E-02		
26	0.522579E-02	-0.218205E-02		
27	0.629482E-02	-0.212575E-02		
28	0.726623E-02	-0.999804E-04		
29	0.417098E-02	-0.226199E-02		
30	0.333613E-02	-0.503471E-02		
31	0.432600E-02	-0.411396E-02		
32	0.474663E-02	0.315729E-02		
33	0.499441E-02	0.318986E-02		
34	0.584096E-02	0.330074E-02		
35	0.687288E-02	0.357580E-02		
36	0.790306E-02	0.335858E-02		
37	0.802800E-02	0.264649E-02		
38	0.819059E-02	0.161371E-02		
39	0.538798E-02	-0.404984E-02		
40	0.644398E-02	-0.398102E-02		
41	0.736827E-02	-0.200988E-02		
42	0.835952E-02	0.309748E-04		
43	0.445133E-02	-0.496647E-02		
44	0.467953E-02	0.365265E-02		
45	0.492750E-02	0.368602E-02		
46	0.577208E-02	0.379774E-02		
47	0.900785E-02	0.319323E-02		
48	0.910261E-02	0.273924E-02		
49	0.928113E-02	0.177172E-02		
50	0.558015E-02	-0.489168E-02		
51	0.601982E-02	-0.482895E-02		
52	0.677885E-02	0.558797E-02		
53	0.745920E-02	0.388110E-02		
54	0.845589E-02	-0.192253E-02		
55	0.947146E-02	0.187240E-03		
56	0.101411E-01	0.307842E-02		
57	0.102117E-01	0.280365E-02		
58	0.103890E-01	0.199379E-02		
59	0.587279E-02	-0.501356E-02		
60	0.615691E-02	-0.528516E-02		
61	0.661419E-02	-0.681163E-02		
62	0.634180E-02	-0.569177E-02		
63	0.700081E-02	-0.667705E-02		
64	0.763636E-02	-0.550771E-02		
65	0.849413E-02	-0.383309E-02		
66	0.956101E-02	-0.184527E-02		
67	0.106100E-01	0.324313E-03		
68	0.113738E-01	0.296234E-02		
69	0.115331E-01	0.223371E-02		
70	0.117152E-01	0.106192E-02		
71	0.709196E-02	-0.705861E-02		
72	0.775360E-02	-0.679938E-02		
73	0.855022E-02	-0.552962E-02		
74	0.954828E-02	-0.381354E-02		
75	0.106891E-01	-0.177840E-02		
76	0.118146E-01	-0.860909E-04		
77	0.118477E-01	-0.120600E-02		

78	0.127106E-01	0.281104E-02
79	0.129639E-01	0.118035E-02
80	0.744295E-02	-0.730384E-02
81	0.777867E-02	-0.736340E-02
82	0.855579E-02	-0.690001E-02
83	0.950717E-02	-0.554820E-02
84	0.106220E-01	-0.381214E-02
85	0.116132E-01	-0.228164E-02
86	0.117625E-01	-0.331036E-02
87	0.130702E-01	-0.803464E-05
88	0.130658E-01	-0.116698E-02
89	0.136657E-01	0.760148E-03
90	0.852181E-02	-0.757113E-02
91	0.943309E-02	-0.696962E-02
92	0.105012E-01	-0.562787E-02
93	0.116866E-01	-0.429400E-02
94	0.115992E-01	-0.524013E-02
95	0.129896E-01	-0.228086E-02
96	0.129057E-01	-0.335230E-02
97	0.143353E-01	-0.987020E-03
98	0.143272E-01	0.828529E-04
99	0.143274E-01	0.734342E-03
100	0.933997E-02	-0.785050E-02
101	0.103620E-01	-0.712773E-02
102	0.114751E-01	-0.613762E-02
103	0.113709E-01	-0.693524E-02
104	0.128063E-01	-0.436916E-02
105	0.126733E-01	-0.534555E-02
106	0.141927E-01	-0.229024E-02
107	0.140718E-01	-0.342339E-02
108	0.156068E-01	-0.120889E-02
109	0.153760E-01	-0.287761E-02
110	0.151314E-01	-0.441273E-02
111	0.156431E-01	0.461394E-03
112	0.103323E-01	-0.823877E-02
113	0.112459E-01	-0.770042E-02
114	0.111855E-01	-0.806247E-02
115	0.125088E-01	-0.626153E-02
116	0.123574E-01	-0.711654E-02
117	0.139373E-01	-0.446953E-02
118	0.137525E-01	-0.546979E-02
119	0.169815E-01	0.218715E-03
120	0.169152E-01	-0.144413E-02
121	0.167024E-01	-0.301287E-02
122	0.148653E-01	-0.556823E-02
123	0.162603E-01	-0.507497E-02
124	0.151789E-01	-0.570488E-02
125	0.111535E-01	-0.871288E-02
126	0.122231E-01	-0.783520E-02
127	0.121180E-01	0.869065E-02
128	0.135545E-01	-0.641098E-02
129	0.133805E-01	-0.721979E-02
130	0.132991E-01	-0.759891E-02
131	0.183364E-01	-0.274764E-04
132	0.182401E-01	-0.176075E-02
133	0.180221E-01	-0.317745E-02
134	0.146096E-01	-0.663508E-02
135	0.153364E-01	-0.721096E-02
136	0.175113E-01	-0.529240E-02
137	0.169253E-01	-0.710232E-02
138	0.119012E-01	-0.930635E-02
139	0.131144E-01	-0.864334E-02
140	0.129280E-01	-0.951431E-02
141	0.144126E-01	-0.739714E-02
142	0.197580E-01	-0.306911E-03
143	0.196174E-01	-0.196481E-02
144	0.193662E-01	-0.339973E-02
145	0.151732E-01	-0.869251E-02
146	0.155056E-01	-0.865694E-02
147	0.188007E-01	-0.558507E-02
148	0.163356E-01	-0.878164E-02
149	0.161578E-01	-0.745538E-02
150	0.128340E-01	-0.987152E-02
151	0.120821E-01	-0.999818E-02
152	0.141293E-01	-0.869020E-02
153	0.138104E-01	-0.979758E-02
154	0.212196E-01	-0.658824E-03
155	0.210298E-01	-0.226573E-02
156	0.207471E-01	-0.366532E-02
157	0.147134E-01	-0.100664E-01
158	0.156359E-01	-0.103273E-01
159	0.201120E-01	-0.592351E-02
160	0.172194E-01	-0.974261E-02
161	0.194012E-01	-0.786646E-02

162	0.126416E-01	-0.104691E-01
163	0.136412E-01	-0.102421E-01
164	0.118391E-01	-0.107039E-01
165	0.226906E-01	-0.112370E-02
166	0.224587E-01	-0.259652E-02
167	0.221483E-01	-0.395106E-02
168	0.144898E-01	-0.105742E-01
169	0.153283E-01	-0.109580E-01
170	0.158533E-01	-0.116273E-01
171	0.161292E-01	-0.117872E-01
172	0.214420E-01	-0.627786E-02
173	0.184039E-01	-0.102461E-01
174	0.206727E-01	-0.829040E-02
175	0.124718E-01	-0.109254E-01
176	0.134140E-01	-0.108202E-01
177	0.241383E-01	-0.154574E-02
178	0.238785E-01	-0.297684E-02
179	0.235495E-01	-0.427752E-02
180	0.142136E-01	-0.111917E-01
181	0.150251E-01	-0.116067E-01
182	0.157009E-01	-0.118938E-01
183	0.159494E-01	-0.120764E-01
184	0.172778E-01	-0.124244E-01
185	0.227457E-01	-0.671994E-02
186	0.196168E-01	-0.107460E-01
187	0.219195E-01	-0.874908E-02
188	0.132356E-01	-0.112416E-01
189	0.253601E-01	-0.314162E-02
190	0.251459E-01	-0.393951E-02
191	0.249461E-01	-0.463555E-02
192	0.140150E-01	-0.116073E-01
193	0.148094E-01	-0.120283E-01
194	0.154174E-01	-0.123654E-01
195	0.170934E-01	-0.127224E-01
196	0.184360E-01	-0.130241E-01
197	0.240186E-01	-0.726919E-02
198	0.207980E-01	-0.112927E-01
199	0.231561E-01	0.921288E-02
200	0.255014E-01	-0.480805E-02
201	0.182543E-01	-0.133284E-01
202	0.195857E-01	-0.136256E-01
203	0.250956E-01	-0.749158E-02
204	0.219633E-01	-0.118378E-01
205	0.242953E-01	-0.963543E-02
206	0.193966E-01	-0.139349E-01
207	0.207129E-01	-0.142669E-01
208	0.230536E-01	-0.126312E-01
209	0.238145E-01	-0.125863E-01
210	0.205035E-01	-0.145904E-01
211	0.219123E-01	-0.149935E-01
212	0.240893E-01	0.138124E-01
213	0.237158E-01	-0.147460E-01
214	0.216850E-01	-0.153658E-01
215	0.232882E-01	-0.157453E-01
216	0.247980E-01	-0.163208E-01
217	0.230938E-01	-0.161685E-01
218	0.246108E-01	-0.167538E-01
219	0.250484E-01	-0.169410E-01

REDUNDANT LOAD CALC. TIME (MIN.)= 0.0167

*

ELEMENT STRESSES

	ELEMENT	STRESS-R	STRESS-Z	STRESS-Q	STRESS-RZ	EFF. STRESS
1	7- 8- 6	3716.	-1765.	49264.	-1422.	48565.
2	8- 17- 6	5027.	1670.	48992.	-3036.	46039.
3	8- 9- 17	10431.	258.	65883.	1929.	61271.
4	9- 18- 17	7171.	1025.	64518.	712.	60669.
5	9- 10- 18	17944.	6040.	89354.	954.	78066.
6	10- 19- 18	16181.	6846.	87168.	-47.	76088.
7	10- 20- 19	22174.	3818.	106636.	-1068.	95002.
8	20- 30- 19	23417.	2528.	100216.	-2044.	89173.
9	6- 17- 5	7292.	-1361.	37377.	-1247.	35286.
10	17- 4- 5	13285.	-184.	37484.	-3002.	33468.
11	17- 16- 4	15776.	-252.	40933.	-3945.	36603.
12	17- 18- 16	25803.	2661.	54561.	4345.	45660.
13	18- 29- 16	23623.	8412.	55416.	1896.	41674.
14	18- 19- 29	28855.	4354.	69878.	1299.	57391.
15	19- 31- 29	35569.	10741.	73485.	-760.	54749.
16	19- 30- 31	38077.	2823.	85815.	-2144.	72242.
17	30- 43- 31	47346.	6058.	86408.	-5140	70164.
18	4- 16 3	43118.	10227.	48517.	-550.	35910.
19	16- 15- 3	27815.	8623.	42599.	1462.	29617.
20	3- 15- 2	39475.	14683.	46139.	10745.	34216.
21	16- 29- 15	29126.	5805.	46221.	3716.	35726.
22	29- 26- 15	29228.	10751.	48548.	2155.	32949.
23	29- 31- 26	32985.	4058.	57999.	456.	46764.
24	31- 39- 26	42121.	13164.	66277.	-1291.	46116.
25	31- 43- 39	42307.	1527.	73188.	-5343.	62944.
26	43- 50- 39	64158	8884.	83235.	-10164.	69166.
27	44- 32- 45	83.	-118.	13597.	-63.	13617.
28	32- 33- 45	537.	757.	14813.	-316.	14179.
29	32- 21- 33	87.	-1057.	17155.	-72.	17669.
30	21- 22- 33	871.	-139	18726.	-1328.	18524.
31	21- 11- 22	180.	-1819.	21415.	1049.	22377.
32	11- 12- 22	-457.	-260.	22603.	-1661.	23143.
33	11- 1- 12	2504.	4535.	27940.	3733.	25324.
34	45- 33- 46	-55.	-287.	11929.	-214.	12108.
35	33- 34- 46	1092.	653.	12710.	-654.	11941.
36	33- 22- 34	943.	-430.	15645.	-123.	15437.
37	22- 23- 34	2791	1692.	16934.	-1504.	14953.
38	22- 12- 23	2194	-22.	19984.	1526.	19179.
39	12- 13- 23	4495	2261.	21156.	66.	17894.
40	12- 1- 13	6416.	3284.	26280.	5513.	23618.
41	1- 14- 13	10072	4455	27497.	3901.	21881.
42	1- 2- 14	21982	6973.	35313.	8059.	28246.
43	2- 15- 14	20239.	2859.	33623.	7972.	30076.
44	15- 25- 14	26925	5073.	38957.	4043.	30567.
45	26- 27- 14	26499.	9272.	41985.	2918.	28922.
46	26- 39- 27	34685	4933.	52655.	453.	41709.
47	39- 40- 27	40844	13516	61614.	465.	41792.
48	39- 50- 51	6116.	7789.	80160.	-10406.	67446.
49	39- 51- 40	40553.	-1004.	66918.	-12565.	63180.
50	51- 52- 40	41637	9219.	84937.	-4948.	66358.
51	51- 60- 52	-296.	7094.	77350.	-4277.	74600.
52	62- 61- 52	14627	-1055.	123203.	1505.	117240.
53	61- 63- 52	8654	8216.	129139.	171.	120710.
54	61- 71- 63	15441.	-1078.	140201.	888.	133801.
55	46- 34- 35	805.	-242.	10437.	725.	10273.
56	34- 23- 35	757.	179.	12391.	671.	11990.
57	23- 24- 35	4631	2257.	14053.	-1379.	11068.
58	23- 13- 24	4059.	640	16696.	2444.	15248.
59	13- 25- 24	9380.	3079.	18670.	-65.	13586.
60	13 14- 25	9804.	1491	21944.	5740.	20404
61	14- 28- 25	19133.	5464.	25727.	3074.	18678.
62	14- 27- 28	21654	1103.	31142.	6420.	28828.
63	27- 41- 28	25573.	7706.	35719.	3957.	25504.
64	27- 40- 41	35132.	4432.	48515.	2259.	39343.
65	40- 53- 41	27317	9260.	51548.	2530.	37014.
66	40- 52- 53	53579.	13170.	83699.	-8539.	63058.
67	52- 64- 53	22663	13906.	83565.	-3092.	65999.
68	52- 63- 64	47893.	9011.	117794.	-7147.	96281.
69	63- 72- 64	25614.	12551.	117557.	-1529.	99083.
70	63- 71- 72	31277.	3901.	134821.	-1319.	121207.
71	71- 80- 72	17982.	-257.	128193.	-1009.	120390.
72	80- 81- 72	15398.	-999.	121876.	-530.	115561.
73	35- 24- 36	1693.	-1314.	8676.	1818.	9419.
4	24- 37- 36	5593.	1981.	[illegible]	-1256.	7851.
5	24- 25- 37	5578.	-324	[illegible]	2803.	12683.
6	25- 38- 37	11555.	2312.	15306.	-297.	11595.

*

77	25- 28- 38	10615.	-1106.	17150.	5854.	18361.
78	28- 42- 38	18135.	4240.	20681.	2001.	15715.
79	28- 41- 42	20328.	-742.	25358.	6993.	26870.
80	41- 54- 42	23122.	6988.	29725.	3387.	21092.
81	41- 53- 54	32669.	2023.	41332.	3847.	36385.
82	53- 65- 54	26885.	9084.	45060.	2647.	31485.
83	53- 64- 65	47530.	6417.	69011.	-3763.	65476.
84	64- 73- 65	26667.	12166.	70734.	-2295.	52983.
85	64- 72- 73	53830.	7174.	102985.	-6013.	83639.
86	72- 82- 73	35939.	15382.	104417.	-5292.	81266.
87	72- 81- 82	51182.	8397.	124405.	-8382.	102648.
88	81- 90- 82	29105.	4260.	108549.	-6283.	94982.
89	36 37- 47	1641.	-2483.	5336.	1984.	7597.
90	37- 48- 47	5687	1927.	8142.	-1720.	6186.
91	37- 38- 48	6258.	-1906.	9583.	3060.	11531.
92	38- 49- 48	12084.	1962.	11707	-998.	10089.
93	38- 42- 49	10636.	-2343.	12545.	6157.	17626.
94	42- 55- 49	16874.	4266.	15509.	893.	12084.
95	42- 54- 55	17999.	-2440.	18996.	7664.	24808.
96	54- 66- 55	20172.	6348.	23132.	2817.	16267.
97	54- 65- 66	29445.	-651.	33552.	5223.	33589.
98	65- 74- 66	24368.	8339.	37385.	2314.	25518.
99	65- 73- 74	42170.	1997.	56420.	-743.	48910.
100	73- 83- 74	29377.	12828.	61062.	-2236.	42630.
101	73- 82- 83	51269.	1431.	84714.	-4030.	72928.
102	82- 91- 83	42221.	15526.	89589.	-7990.	66429.
103	82- 90- 91	52516.	3075.	101480.	-7929.	86325.
104	90- 100- 91	38824.	5028.	93682.	-8181.	78784.
105	47- 48- 56	2674.	-2294.	3719.	1820.	6396.
106	48- 57- 56	5870.	4316.	6809.	-3368.	6228.
107	48- 49- 57	6374.	-2323.	6442.	3445.	10576.
108	49- 58- 57	14375.	6175.	9841.	-2840.	8650.
109	49- 55- 58	8515.	-3329.	6645.	6621.	15911.
110	55- 67- 58	14667.	5250.	9392.	-553.	8231.
111	55- 66- 67	14955.	-4516.	11496.	7986.	22696.
112	66- 75- 67	16299.	4809.	15278.	2337.	11736.
113	66- 74- 75	26090.	-2762.	25451.	6460.	30654.
114	74- 84- 75	19352.	6215.	28458.	3046.	20131.
115	74- 83- 84	38194.	570.	46616.	2001.	42609.
116	83- 92- 84	29138.	13294.	51155.	-1774.	33079.
117	83- 91- 92	46634.	-1981.	68711.	-3941.	63016.
118	91- 101- 92	40931.	12241.	73984.	-8174.	55359.
119	91- 100- 101	55209.	2894.	88369.	-8501.	76082.
120	100- 112- 101	44824.	8939.	84332.	-10248.	67689.
121	56- 57- 68	9159.	-3456.	-233.	1188.	11537.
122	57- 58- 68	7221.	-4617.	-1458.	4609.	13284.
123	58- 69- 68	6410.	5459.	-2545.	-765.	8623.
124	58- 70- 69	5071.	5883.	-1961.	5234.	11748.
125	58- 67- 70	12677.	-3702.	554.	2603.	15396.
126	67- 76- 70	3900.	2292.	-2566.	3495.	8358.
127	67- 77- 76	13160.	-2356.	2035.	7169.	18605.
128	67- 75- 77	17931.	-1985.	8621.	1951.	17588.
129	75- 85- 77	10804.	-644.	8093.	7804.	17033.
130	75- 86- 85	18732.	-2407.	14023.	7173.	22889.
131	84- 86- 75	21781.	-459.	21335.	1431.	22185.
132	84- 93- 86	22371.	1571.	25211.	5857.	24550.
133	84- 94- 93	24670.	-3893.	25579.	5313.	30453.
134	84- 92- 94	25333.	-3301.	33027.	-2163.	33371.
135	92- 102- 94	27461.	2662.	39750.	4115.	33491.
136	92- 103- 102	40796	1519.	53517.	-1179.	46995.
137	101- 103- 92	39997	2556.	62103.	-9491.	54655.
138	101- 113- 103	46410.	11072	71450.	-4027.	53005.
139	101- 114- 113	51015	7956.	75487.	-6554.	60299.
140	101- 112- 114	51738.	5261.	78466.	-10455.	66671.
142	68- 69 78	11109	-7090.	-14207.	811.	22659
143	69- 79- 78	1528	2202	-18329.	3251.	20974.
144	69- 70- 79	8855	-7209.	-12961.	-3093.	20305.
145	70 76- 79	7389.	-9033.	-13222.	3488.	19813.
146	76- 87- 79	5376.	-5362.	-15009.	-369.	17675.
147	76- 77- 87	15013	-11330.	-5924.	5668.	26023.
148	77- 88- 87	8298.	-1592.	-5802.	3634.	14029.
149	77- 85- 88	17278.	-6953	2316.	6245.	23780.
150	85- 95- 88	8470.	-2153.	656.	6522.	14792.
151	85- 86- 95	17133.	-8336.	8279.	4431.	23675.
152	86- 96- 95	13855.	1452.	10554.	3621.	12773.
153	86- 93- 96	21118.	-6856.	16798.	2970.	26587.
154	93- 104- 96	19520.	1477.	18936.	2126.	18137.
155	93- 94- 104	21711.	-9023.	20089.	1085.	30016.
156	94- 105- 104	14983.	-2360.	20805.	2455.	21302.
157	94- 102- 105	25418.	-6443.	30089.	1683.	34560.
158	102- 115- 105	27185.	5748.	38213.	3690.	29300.
159	102- 103- 115	36365	-3863.	45901.	-1623.	46651.
160	103- 116- 115	32828.	7620	49976.	-1094.	36952.
161	103- 113- 116	43377.	1054.	59854.	-3784.	52946.

162	113-126-116	42862.	7535.	62022.	-3393.	48236.
163	113-114-126	52365.	5218.	70840.	-5510.	59386.
167	78- 79- 89	-5048.	-7408.	-25513.	-3583.	20362.
168	79- 87- 89	13695.	-7624.	-16386.	326.	26781.
171	87- 97- 89	2082.	1836.	-13294.	1669.	15627.
172	87- 88- 97	9538.	-8604.	-11704.	-82.	19875.
173	88- 95- 97	14456.	-9526.	-5550.	6510.	24956.
174	95-106- 97	1501.	-8090.	-9025.	7763.	16812.
175	95- 96-106	11672.	-10411.	-579.	4510.	20695.
176	96-107-106	6998.	-2382.	510.	4030.	10861.
177	96-104-107	15751.	-10070.	7889.	2449.	23315.
178	104-117-107	11107.	-3600.	8993.	2960.	14661.
179	104-105-117	23307.	-3947.	19669.	2683.	26113.
180	105-118-117	13411.	-656.	18108.	5350.	19200.
181	105-115-118	23424.	-5921.	26566.	3611.	31661.
182	115-128-118	19190.	355.	27322.	4374.	25129.
183	115-116-128	30202.	-4942.	36907.	185.	38935.
184	116-129-128	26096.	2384.	38703.	1344.	32025.
185	116-130-129	33909.	-490.	43173.	687.	41216.
186	116-126-130	39052.	-1411.	52144.	-3777.	48800.
191	138-150-140	26260.	1378.	63862.	-3183.	54766.
192	138-151-150	21798.	1289.	63994.	-9417.	57731.
193	151-162-150	2288.	-246.	53491.	264.	52520.
194	151-164-162	3960.	-1916.	53468.	1016.	52728.
195	164-175-162	-3148.	-20.	47907.	2179.	49711.
201	97-106-110	-2688.	-6597.	-8148.	6990.	13051.
202	106-107-110	2642.	-4732.	-1963.	1521.	6969.
203	107-117-110	14042.	-6804.	6017.	-1542.	18407.
204	117-118-122	10525.	-7265.	11168.	2309.	18557.
205	117-122-110	15328.	-7937.	9208.	7610.	24701.
206	118-128-122	18468.	-9913.	17500.	3829.	28688.
207	126-134-122	12781.	-6012.	16833.	4832.	22713.
208	128-129-134	23599.	-10016.	26234.	819.	35037.
209	129-141-134	19525.	-4323.	27899.	3322.	29525.
210	129-130-141	30812.	-6992.	37972.	-1604.	41941.
215	140-150-153	32452.	21.	60534.	-9195.	54818.
216	150-163-153	17672.	-580.	53272.	-1398.	47500.
217	150-162-163	20537.	4253.	56231.	-5358.	46977.
218	162-176-163	4561.	-1147.	46011.	-633.	44594.
219	162-175-176	6424.	856.	47263.	-2166.	44051.
220	175-188-176	-3663.	-476.	40088.	1370.	42316.
229	110-122-124	6434.	-9956.	6404.	4206.	17923.
230	122-134-124	12483.	-13204.	10316.	2743.	25127.
231	134-135-124	8810.	-5523.	16383.	4143.	20563.
232	134-141-135	15100.	-9653.	22530.	-560.	29203.
237	153-163-157	26037.	-2439.	50468.	-2300.	46039.
238	163-168-157	15410.	2457.	46063.	1147.	38840.
239	163-176-168	18019.	1081.	47410.	-3200.	40981.
240	176-180-168	5501.	2617.	41009.	-160.	37037.
241	176-188-180	5592.	592.	39997.	-2465.	37404.
242	188-192-180	-3435.	384.	34399.	1559.	36169.
257	157-168-158	20646.	176.	43515.	483.	37563.
258	168-169-158	12125.	12477.	42754.	2464.	30754.
259	168-180-169	10210.	1120.	39121.	-2857.	34726.
260	180-181-169	4504.	8370.	36773.	-2464.	30819.
261	180-192-181	3278.	903.	34173.	-3176.	32617.
262	192-193-181	-2633.	506.	29955.	-590.	31156.
358	158-169-170	4896.	-9513.	18587.	-3222.	24971.
359	169-181-170	2541.	-11609.	15871.	-5593.	25700.
360	181-182-170	-7975.	-170.	15273.	2857.	21082.
361	181-194-182	10201.	-2228.	31490.	572.	29553.
362	181-193-194	1317.	1344.	29631.	-3340.	28887.
363	60- 62- 52	-7956.	8089.	92588.	-18609.	98960.
364	50- 59- 51	73960.	21398.	92136.	-30345.	82540.
365	59- 60- 51	29485.	5216.	75260.	-17912.	68979.

ELEMENT STRESSES

	ELEMENT	STRESS-Y	STRESS-X	STRESS-XY	EFF. STRESS
141	112-125-114	43314.	11175.	-24152.	57157.
164	114-125-127	34698.	7899.	-18151.	44498.
165	114-127-126	36269	3964.	-12201.	40423.
166	125-138-127	39036.	12871	-19175.	47854.
169	99- 98- 99	24776.	2004.	-4214.	24929.
170	89- 97- 98	24159.	5940.	-3395.	24929.
187	126-127-130	37586.	-2127.	-9673.	22584.
188	127-139-130	20701.	995.	-9525.	42164.
189	127-140-139	26576.	1294.	-6187.	26098.
190	127-138-140	9756.	3334.	-16653.	28078.
196	99- 98-111	21211.	-257.	-2929.	29930.
197	98-108-111	17928.	-621.	-1071.	21936.
198	98- 97-108	12297.	1178.	-3164.	18341.
199	97-109-108	15056.	-4917.	10505.	12967.
200	97-110-109	29719.	-4979.	3687.	25612.
211	130-139-141	29519.	-7816	-5000.	33117.
212	139-152-141	13702.	-4152.	-6101.	35187.
213	139-140-152	26119.	-5742.	-6463.	19327.
214	140-153-152	6511.	-1801.	-3980.	31472.
221	111-108-119	23591.	-662.	-3073.	10242.
222	108-120-119	17664.	1375.	-3336.	24514.
223	108-109-120	18974.	-6831.	5551.	17973.
224	109-121-120	20017.	599.	2304.	24436.
225	109-110-121	27858.	-7614.	3482.	20124.
226	110-123-121	21030.	2308.	7301.	32901.
227	110-124-123	34071.	-7873.	5171.	23643.
228	124-135-123	35739.	-5825.	11953.	39639.
233	141-145-135	16505.	-8701.	609.	44136.
234	141-152-145	10253.	-10685.	-6772.	22200.
235	152-153-145	18450.	-6570.	-1167.	21597.
236	153-157-145	4004.	1480.	-1874.	22559.
243	119-120-131	22028.	-1802.	-1258.	4777.
244	120-132-131	13126.	376.	-3648.	23085.
245	120-121-132	19019.	-4172.	3221.	14402.
246	121-133-132	15644.	3255.	2144.	22127.
247	121-123-133	27516.	-4466.	6385.	14772.
248	123-136-133	21185.	3677.	6011.	31974.
249	123-137-136	30183.	-6600.	11141.	22199.
250	123-135-137	34306.	-3892.	268.	39066.
251	135-146-137	43030.	-12135.	2522.	36412.
252	146-148-137	21334.	-8560.	-5610.	50399.
253	135-145-146	5877.	-14946.	-6331.	28381.
254	145-157-146	9592.	-8330.	284.	21505.
255	146-158-148	35343.	-5678.	1620.	15542.
256	157-158-146	4104.	-5284.	-4005.	38600.
263	131-132-142	22619.	-4929.	-677.	8437.
264	132-143-142	8969.	-1202.	-3079.	25501.
265	132-133-143	16270.	-4183.	2910.	11022.
266	133-144-143	14408.	3747.	2192.	21287.
267	133-136-144	25542.	-7141.	6394.	13493.
268	136-147-144	17925.	256.	3147.	31756.
269	136-137-147	29778.	-13525.	5494.	18614.
270	137-149-147	26268.	-1944.	3241.	39534.
271	137-148-149	41131.	-11103.	-256.	27863.
272	148-160-149	20938.	-6382.	1619.	47664.
273	148-158-160	39321.	-6293.	-3842.	24912.
274	158-170-171	19405.	-52287.	-10007.	43330.
275	158-171-160	14276.	-13691.	2156.	66520.
276	170-182-171	35745.	-3902.	-12142.	24507.
277	182-183-171	12742.	7244.	-12031.	43298.
278	142-143-154	20293.	-4564.	-2264.	23596.
279	143-155-154	7814.	-1765.	-2351.	23251.
280	143-144-155	15393.	-7568.	1994.	9724.
281	144-156-155	12426.	2210.	2134.	20558.
282	144-147-156	23340.	-8552.	5236.	12062.
283	147-159-156	14360.	-270.	2519.	29996.
284	147-149-159	27053.	-13569.	4377.	15139.
285	149-161-159	22204.	-555.	1662.	36614.
286	149-160-161	37014.	-12270.	518.	22671.
287	160-173-161	34017.	-1489.	-3918.	44447.
288	160-171-173	39361.	-18386.	147.	35441.
289	171-184-173	27915.	-6577.	-12794.	51098.
290	171-183-184	31652.	-1476.	-3368.	38693.
291	183-195-184	29667.	2711.	-2812.	32936.
292	154-155-165	19985.	-721.	4418.	28823.
293	155-166-165	9221.	1350.	2146.	21746.
					9393.

294	155-156-166	13348.	-5565.	1152.	16953.
295	156-167-166	13143.	5974.	1896.	11662.
296	156-159-167	20739.	-6702.	4692.	26077.
297	159-172-167	13550.	3107.	2350.	12951.
298	159-161-172	23947.	-11172.	4451.	32020.
299	161-174-172	23828.	2801.	2270.	22899.
300	161-173-174	37146.	-10510.	440.	43376.
301	173-186-174	32760.	1881.	-4751.	32906.
302	173-184-186	38988	-6694.	-530.	42740.
303	184-196-186	26286.	-1852.	-7232.	30000.
304	184-195-196	27995.	-1287.	1318.	28751.
305	195-201-196	28116.	2211.	-37.	27079.
306	165-166-177	11804.	-768.	-2718.	13082.
307	166-178-177	2224.	1585.	-2564.	4864.
308	166-167-178	9129.	-3514.	854.	11400.
309	167-179-178	7336.	4679.	1789.	7141.
310	167-172-179	17955.	-3426.	4489.	21357.
311	172-185-179	8006.	4697.	2958.	8642.
312	172-174-185	19628.	-8349.	3557.	25628.
313	174-187-185	16234.	4348.	2780.	15377.
314	174-186-187	29079.	-7861.	-240.	33707.
315	186-198-187	25834.	4651.	-4701.	25202.
316	186-196-198	31851.	-2069.	-772.	32962.
317	196-202-198	23142.	2446.	-5731.	24156.
318	196-201-202	22474	-1383.	366.	23205.
319	201-206-202	21174.	1569.	2113.	20760.
320	177-178-189	1597.	-1227.	-5632.	10059.
321	178-190-189	-182.	2156.	3728.	6839.
322	178-179-190	7.	-5063.	-1312.	5553.
323	179-191-190	1684.	1605.	2060.	3929.
324	179-185-191	12224.	-2214.	4381.	15458.
325	185-197-191	2457.	3066.	3840.	7221.
326	185-187-197	15514.	-7349.	3971.	21355.
327	187-199-197	6263.	2324.	4920.	10133.
328	187-198-199	22598.	-5256.	-280.	25638.
329	198-204-199	17685.	6108.	-3979.	17016.
330	198-202-204	25454.	2073.	-764.	24519.
331	202-207-204	18197.	9003.	-7729.	20678.
332	202-206-207	15797.	-1111.	-954.	16464.
333	206-210-207	13371.	8370.	3746.	13380.
334	189-190-200	-8409.	2615.	2340.	10769.
335	190-191-200	-3415.	-2833.	-2389.	5210.
336	191-197-200	4930.	-4970.	2663.	9735.
337	197-203-200	-4209.	-7878.	386.	6861.
338	197-199-203	7878.	-14134.	6657.	22498.
339	199-205-203	-10925.	-16859.	7219.	19371.
340	199-204-205	14477.	-12502.	1444.	23519.
341	204-208-205	686.	-15764.	-788.	16176.
342	204-207-208	25140.	-311.	1526.	25434.
343	207-211-208	10458.	5432.	-13559.	25172.
344	207-210-211	19583.	-1179.	-2437.	20635.
345	210-214-211	11353.	21378.	-1496.	18706.
346	205-208-209	1741.	-24861.	7615.	28954.
347	208-212-209	-993.	-18664.	-246.	18193.
348	208-213-212	-3326.	-4461.	13066.	22985.
349	208-211-213	15083.	-19918.	-3256.	30926.
350	211-215-213	1029.	42.	-12613.	21871.
351	211-214-215	16542.	-4732.	455.	19363.
352	214-217-215	10887.	11183.	-11746.	23146.
353	212-213-216	-1760.	-19866.	-3317.	19894.
354	213-215-216	5942	-14572.	742.	18327.
355	215-217-216	8563.	-5847.	5278.	15528.
356	217-218-216	12095.	1381.	2819.	12463.
357	216-218-219	-19.	-2272.	0.	2263.

STRESS CALCULATION TIME (MIN.)= 0.0667

MAXIMUM EFFECTIVE STRESS OCCURS AT ELEMENT 54 61- 71- 63 AND IS EQUAL TO 1.3380E+05 PSI

MAXIMUM RADIAL DISPLACEMENT OCCURS AT NODE 200 AND IS EQUAL TO 2.5501E-02 INS.

MAXIMUM AXIAL DISPLACEMENT OCCURS AT NODE 219 AND IS EQUAL TO -1.6941E-02 INS.

AVERAGE STRESSES OF DISK - VOL. AVG. TANG. IS 35625.488 PSI
AREA AVG. TANG. IS 1248.711 PSI
AREA AVG. EQUIV. IS 1334.590 PSI

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TOTAL WEIGHT OF BODY IS        2.388  LBS

DIAMETRAL  INERTIA ABOUT ORIGIN IS          3.257  LB-IN**2

DIAMETRAL  INERTIA ABOUT CENTROID IS          2.006  LB-IN**2

POLAR INERTIA OF BODY IS          3.255  LB IN**2

CENTROID OF BODY FROM ORIGIN IS     0.7235  IN.
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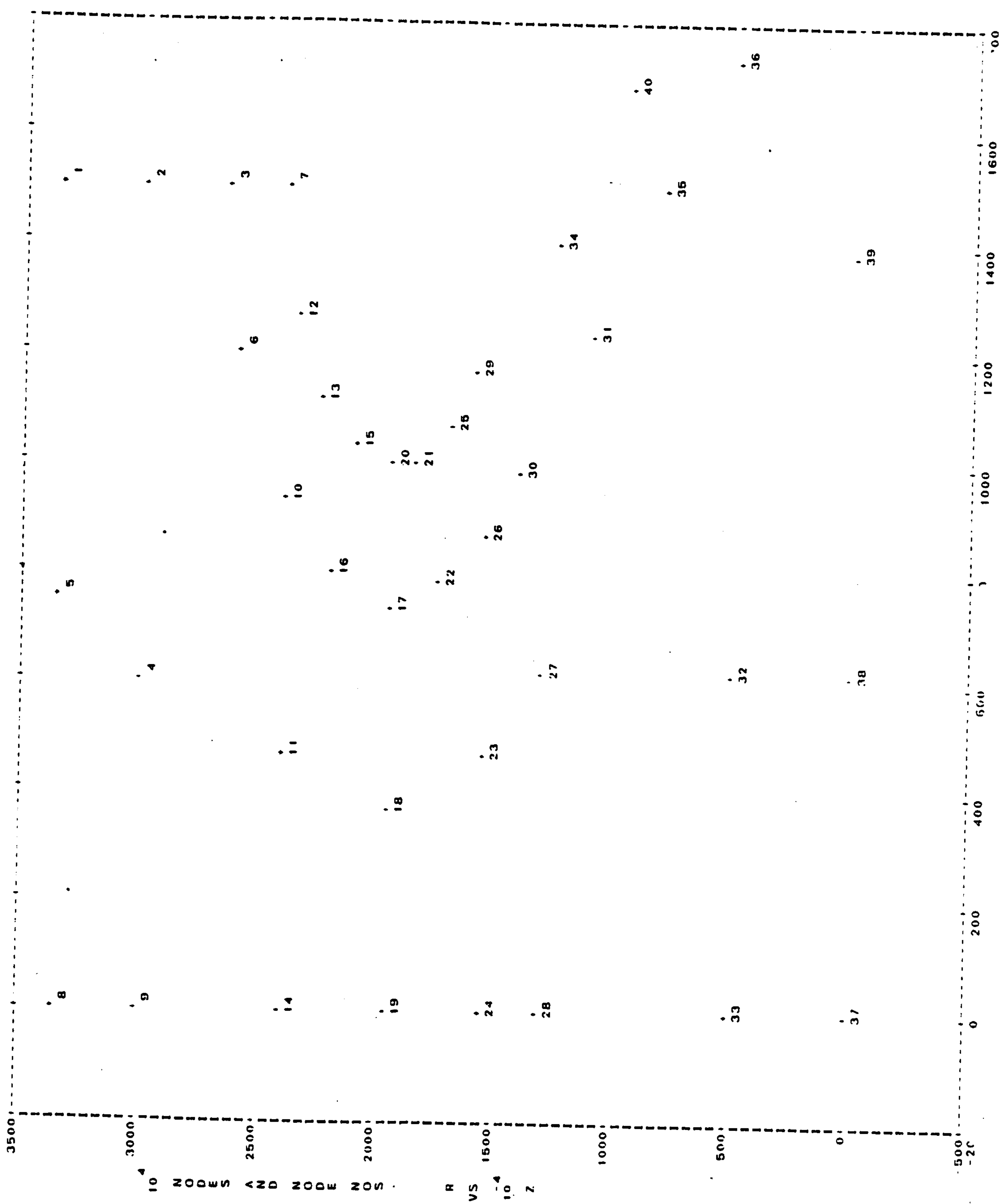
10^4 NODES AND NODE NOS. R VS 10^-4 Z

DISPLACEMENTS AND REDUNDANT LOADS

NODE	RADIAL DISP.	AXIAL DISP.	RADIAL LOAD	AXIAL LOAD
1	0.506701E-02	0.172288E 02		
2	0.452590E-02	0.177064E-02		
3	0.400837E-02	0.181706E-02		
4	0.433535E 02	0.700942E 03		
5	0.487913E-02	0.834167E-03		
6	0.386804E-02	0.144954E-02		
7	0.368560E-02	0.186439E-02		
8	0.490382E-02	0.0	0.258700D+04	0.275196D+03
9	0.435152E-02	0.0	-0.225780D-01	0.425275D+03
10	0.352166E-02	0.115990E-02		
11	0.347484E-02	0.571636E 03		
12	0.355783E-02	0.156491E-02		
13	0.329874E-02	0.138485E-02		
14	0.349318E-02	0.0	0.208128D-01	-0.434457D+03
15	0.301413E 02	0.129577E-02		
16	0.317374E 02	0.100133E-02		
17	0.277719E-02	0.930718E 03		
18	0.280631E-02	0.460714E-03		
19	0.282910E 02	0.0	0.168209D 02	-0.362173D+03
20	0.274507E 02	0.122696E-02		
21	0.250384E-02	0.122128E-02		
22	0.245899E-02	0.938858E-03		
23	0.221006E-02	0.525005E-03		
24	0.223817E-02	0.0	-0.137290D-02	0.742165D+03
25	0.219662E-02	0.123343E-02		
26	0.209980E-02	0.956461E-03		
27	0.174655E-02	0.645045E-03		
28	0.183337E 02	0.0	0.154304D-02	0.232650D+04
29	0.187924E-02	0.121129E-02		
30	0.179685E-02	0.100957E-02		
31	0.125344E-02	0.124979E-02		
32	0.613755E 03	0.623410E-03		
33	0.689326E-03	0.0	-0.258191D 02	0.403891D+04
34	0.135313E 02	0.143497E-02		
35	0.787013E 03	0.157122E-02		
36	0.344704E-03	0.191513E-02		
37	0.0	0.0	0.239958D-02	0.223464D+04
38	-0.616953E-04	0.613888E-03		
39	-0.210753E 03	0.146454E-02		
40	0.888009E-03	0.175262E-02		

REDUNDANT LOAD CALC. TIME (MIN.)= 0.0

ELEMENT STRESSES

	ELEMENT	STRESS-Y	STRESS-X	STRESS-XY	EFF. STRESS
1	1- 2- 4	45907.	-4092.	6282.	49300.
2	1- 4- 5	23681.	-11507.	10078.	35642.
3	4- 8- 5	45533.	-19980.	-10032.	50697.
4	4- 9- 8	51585.	-6589.	-2142.	55300.
5	3- 6- 2	34696.	3640.	11698.	38747.
6	6- 4- 2	42002.	-5264.	9783.	47959.
7	6- 10- 4	56901.	-2132.	12590.	61960.
8	10- 11- 4	38665.	1381.	1960.	38146.
9	11- 9- 4	41586.	-9589.	-6835.	48582.
10	11- 14- 9	44332.	6621.	-3168.	41782.
11	7- 6- 3	14261.	-608.	7252.	19240.
12	7- 12- 6	21242.	6340.	11308.	27210.
13	12- 13- 6	39901.	21436.	33959.	68234.
14	13- 10- 6	47947.	-1797.	13323.	54044.
15	13- 15- 10	102014.	24232.	35723.	111133.
16	15- 16- 10	73329.	15693	6.	66878.
17	16- 11- 10	68570.	10352.	2829.	64212.
18	16- 17- 11	64682.	14775.	5071.	59359.
19	17- 18- 11	43675.	12128.	-6846.	40811.
20	18- 14- 11	40067.	5342.	-3327.	38120.
21	15- 17- 16	67138.	19008.	2845.	60141.
22	20- 17- 15	143674.	15081.	9840.	137816.
23	20- 21- 17	157740.	19298.	-6051.	149399.
24	21- 22- 17	51497.	2116.	-11754.	54423.
25	22- 18- 17	67858.	19381.	10702.	63314.
26	22- 23- 18	38465.	568.	-1636.	38289.
27	23- 19- 18	43790.	6973.	4598.	41524.
28	25- 22- 21	149442.	16507.	-8989.	142762.
29	25- 26- 22	46902.	-13121.	-14672.	60275.
30	26- 23- 22	75664.	-23319.	9267.	91054.
31	23- 24- 19	36842.	-16575.	-4857.	48099.
32	29- 26- 25	111271.	-60876.	-1969.	151237.
33	29- 30- 26	19498.	-80257.	-45143.	120416.
34	30- 27- 26	73631.	-55972.	-17397.	121811.
35	27- 23- 26	36321.	-35123.	-7657.	63280.
36	27- 28- 23	52237.	-32814.	2047.	74378.
37	28- 24- 23	29661.	-18730.	-4857.	43092.
38	31- 30- 29	-18624.	-51535.	-46539.	92415.
39	34- 31- 29	-16309.	-56468.	-37277.	81869.
40	31- 27- 30	22348	-50146.	-31316.	84122.
41	40- 35- 34	-36456.	-55354.	-33630.	75947.
42	35- 31- 34	-35549.	-39792.	-38835.	77182.
43	36- 35- 40	-38475.	-34392.	-41810.	81142.
44	36- 32- 35	-24858.	-32605.	-35765.	68614.
45	32- 31- 35	-4788.	-36565.	-28181.	59727.
46	32- 27- 31	21439.	-50677.	-31771.	84513.
47	32- 28- 27	24282.	-41200.	-8927.	59385.
48	32- 33- 28	25181.	-48142.	-9689.	66676.
49	32- 37- 33	5179.	-54143.	-9689.	59332.
50	32- 38- 37	-2080	-59494.	-6422.	59530.
51	32- 39- 38	6715	-30168.	-14055.	41839.
52	32- 36- 39	-62[illegible]4	-27030.	-13468.	33831.
53	19- 14- 18	36268.	4716.	-4896.	35192.

STRESS CALCULATION TIME (MIN.)= 0.0167

MAXIMUM EFFECTIVE STRESS OCCURS AT ELEMENT 32 -29- -26- -25 AND IS EQUAL TO 1.5124E+05 PSI

MAXIMUM RADIAL DISPLACEMENT OCCURS AT NODE 1 AND IS EQUAL TO 5.0670E-03 INS.

MAXIMUM AXIAL DISPLACEMENT OCCURS AT NODE 36 AND IS EQUAL TO 1.9151E-03 INS.

AVERAGE STRESSES OF DISK - VOL. AVG. TANG. IS 0.0 PSI
AREA AVG. TANG. IS 0.0 PSI
AREA AVG EQUIV. IS 0.0 PSI

TOTAL WEIGHT OF BODY IS 0.0 LBS

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DIAMETRAL  INERTIA ABOUT ORIGIN IS        0.0    LB-IN**2

DIAMETRAL  INERTIA ABOUT CENTROID IS        0.0    LB-IN**2

POLAR INERTIA OF BODY IS        0.0    LB-IN**2

CENTROID OF BODY FROM ORIGIN IS    0.0     IN.
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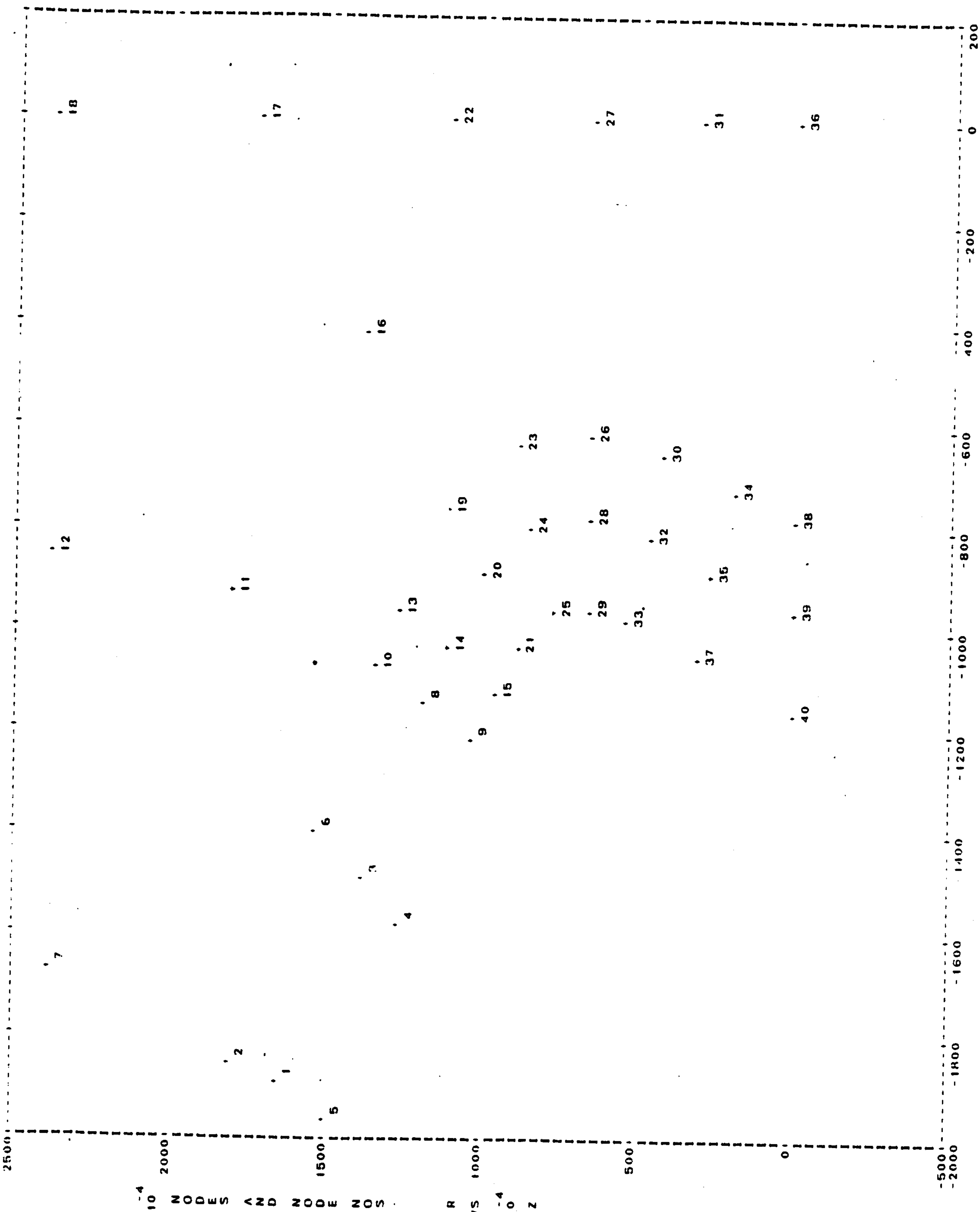

10 -4 NODES AND NODE NOS.
R VS 10 -4 Z

DISPLACEMENTS AND REDUNDANT LOADS

NODE	RADIAL DISP.	AXIAL DISP.	RADIAL LOAD	AXIAL LOAD
1	0.363918E-02	-0.180495E-02		
2	0.375987E-02	-0.176792E-02		
3	0.303641E-02	-0.141004E-02		
4	0.293816E 02	-0.151000E-02		
5	0.352771E 02	-0.185141E-02		
6	0.311960E-02	-0.129276E-02		
7	0.438254E 02	-0.142179E-02		
8	0.246973E-02	-0.109007E-02		
9	0.237355E-02	-0.120281E-02		
10	0.256835E 02	-0.989872E-03		
11	0.309889E-02	-0.768886E-03		
12	0.390440E-02	-0.595313E-03		
13	0.231816E 02	-0.909023E-03		
14	0.218463E-02	-0.103504E-02		
15	0.206263E-02	-0.123778E-02		
16	0.223633E-02	-0.401968E-03		
17	0.263415E-02	0.0	-0.968993D-03	-0.446177D+04
18	0.364459E-02	0.0	-0.235628D-03	-0.446503D+04
19	0.193043E-02	-0.809506E-03		
20	0.183378F 02	-0.978270E-03		
21	0.178779E-02	0.119037E-02		
22	0.168465E-02	0.0	-0.289813D-02	-0.131531D+04
23	0.146135E-02	-0.752714E-03		
24	0.145211E-02	-0.951689E-03		
25	0.145783E-02	-0.118083E-02		
26	0.109368F-02	-0.767001E-03		
27	0.102905E-02	0.0	0.336791D-02	0.276415D+03
28	0.114442E-02	-0.980117E-03		
29	0.117701E-02	-0.115556E-02		
30	0.702476E-03	-0.809016E-03		
31	0.475702E-03	0.0	-0.414839D-02	0.528143D+03
32	0.820862E-03	-0.998649E-03		
33	0.919713E-03	-0.118471E-02		
34	0.335248E-03	-0.867327E-03		
35	0.435081E 03	-0.106480E-02		
36	0.0	0.0	-0.246017D+04	0.181536D+03
37	0.472501E-03	-0.126434E-02		
38	0.0	-0.931408E-03	-0.379063D+04	0.663900D-04
39	0.0	-0.114809E-02	-0.128577D+04	0.118188D-02
40	0.0	-0.137386E-02	-0.224424D+03	-0.654497D 03

REDUNDANT LOAD CALC TIME (MIN.)= 0.0

ELEMENT STRESSES

	ELEMENT	STRESS Y	STRESS-X	STRESS-XY	EFF. STRESS
1	36- 38- 34	63244.	6624.	-2221.	60328.
2	38- 35- 34	60959	-390.	-1260.	61194.
3	38- 39- 35	60065.	-2520.	-1794.	61443.
4	39- 37- 35	52931.	-948.	7273.	54877.
5	39- 40- 37	45964	546.	-1820.	45802.
6	36- 34- 31	48578.	3829.	-1477.	46851.
7	31- 34- 30	64803.	10096.	-6118.	61314.
8	34- 35- 30	59512	-2000.	-2672.	60714.
9	35- 32- 30	78403.	5903.	-8328.	76987.
10	35- 37- 32	64826.	1556.	6540.	65057.
11	37- 33- 32	88106.	6470.	1312.	85086.
12	31- 30- 26	58102.	9129.	-4358.	54642.
13	31- 26- 27	42060.	6832.	-6121.	40506.
14	30- 28- 26	66327	16785.	-19516.	69055.
15	30- 32- 28	83198.	6154.	-8865.	81752.
16	32- 33- 28	79926.	1661.	-1912.	78178.
17	33- 29- 28	138949.	4589.	-7095.	137263.
18	27- 26- 22	34161.	4462.	-6121.	33865.
19	26- 28- 23	60849.	14991.	-7022.	56241.
20	28- 24- 23	79534	7804.	-15425.	80497.
21	28- 29- 25	163781.	12038.	-18575.	161346.
22	28- 25- 24	84342.	25551.	-18438.	81432.
23	22- 26- 23	55280.	-7258.	-3059.	59480.
24	22- 16- 17	18993.	-42840.	-14904.	60631.
25	22- 23- 16	41142.	-13619.	929.	49407.
26	23- 19- 16	58320	-34815.	-16181.	86193.
27	23- 20- 19	61736.	-17786.	-13854.	76168.
28	23- 24- 20	84922.	-1400.	-3086.	85797.
29	24- 25- 20	85185.	13483.	-2831.	79459.
30	25- 21- 20	127019	25707.	-51023.	146081.
31	17- 16- 11	42985.	-52783.	-15159.	87132.
32	16- 13- 11	15881.	-54199.	-20140.	72576.
33	16- 19- 13	66228.	-47100.	-13072.	101176.
34	19- 20- 13	67695.	-34497.	-7851.	91065.
35	20- 14- 13	36813.	-66370.	-44104.	118486.
36	20- 21- 14	66061	-22803.	-22184.	88695.
37	21- 15- 14	67632.	-4093.	-56051.	119553.
38	17- 12- 18	13614.	-84886.	-17739.	97420.
39	17- 11- 12	-3145.	-65968.	-12360.	67915.
40	11- 7- 12	7670.	-38477.	-23170.	58694.
41	11- 13- 10	23016.	-53931.	-56715.	119705.
42	13- 8- 10	4082.	-58022.	-60827.	121326.
43	13- 14- 8	51542	-54631.	-53258.	130254.
44	14- 9- 8	-18590	-82934.	-74341.	149204.
45	14- 15- 9	45713.	-114633.	-42833.	161166.
46	11- 10- 6	10600	-37352.	-38751.	80052.
47	10- 8- 6	-20818.	-47628.	-45895.	89607.
48	8- 3- 6	-19711.	-49554.	-45653.	90112.
49	8- 9- 3	-49308.	-48615.	-45611.	92944.
50	9- 4- 3	-31276.	-58106.	-39743.	85298.
51	11- 6- 7	-20469	-48601.	-31612.	69168.
52	6- 2- 7	-12170	-24971.	-27535.	52367.
53	6- 3- 2	-34999.	-43678.	-39347.	79048.
54	3- 1- 2	-44605.	-52621.	-44209.	90847.
55	3- 4- 1	-33636	-43173.	-38577.	77509.
56	4- 5- 1	-60636	-79303.	-54971.	119258.

STRESS CALCULATION TIME (MIN.)= 0.0167

MAXIMUM EFFECTIVE STRESS OCCURS AT ELEMENT 21 -28- -29- -25 AND IS EQUAL TO 1.6135E+05 PSI

MAXIMUM RADIAL DISPLACEMENT OCCURS AT NODE 7 AND IS EQUAL TO 4.3825E-03 INS.

MAXIMUM AXIAL DISPLACEMENT OCCURS AT NODE 5 AND IS EQUAL TO -1.8514E-03 INS.

AVERAGE STRESSES OF DISK - VOL. AVG. TANG. IS 0.0 PSI
AREA AVG. TANG. IS 0.0 PSI
AREA AVG. EQUIV. IS 0.0 PSI

```
TOTAL WEIGHT OF BODY IS        0.0    LBS

DIAMETRAL  INERTIA ABOUT ORIGIN IS        0.0    LB-IN**2

DIAMETRAL  INERTIA ABOUT CENTROID IS        0.0    LB-IN**2

POLAR INERTIA OF BODY IS        0.0    LB-IN**2

CENTROID OF BODY FROM ORIGIN IS    0.0     IN.
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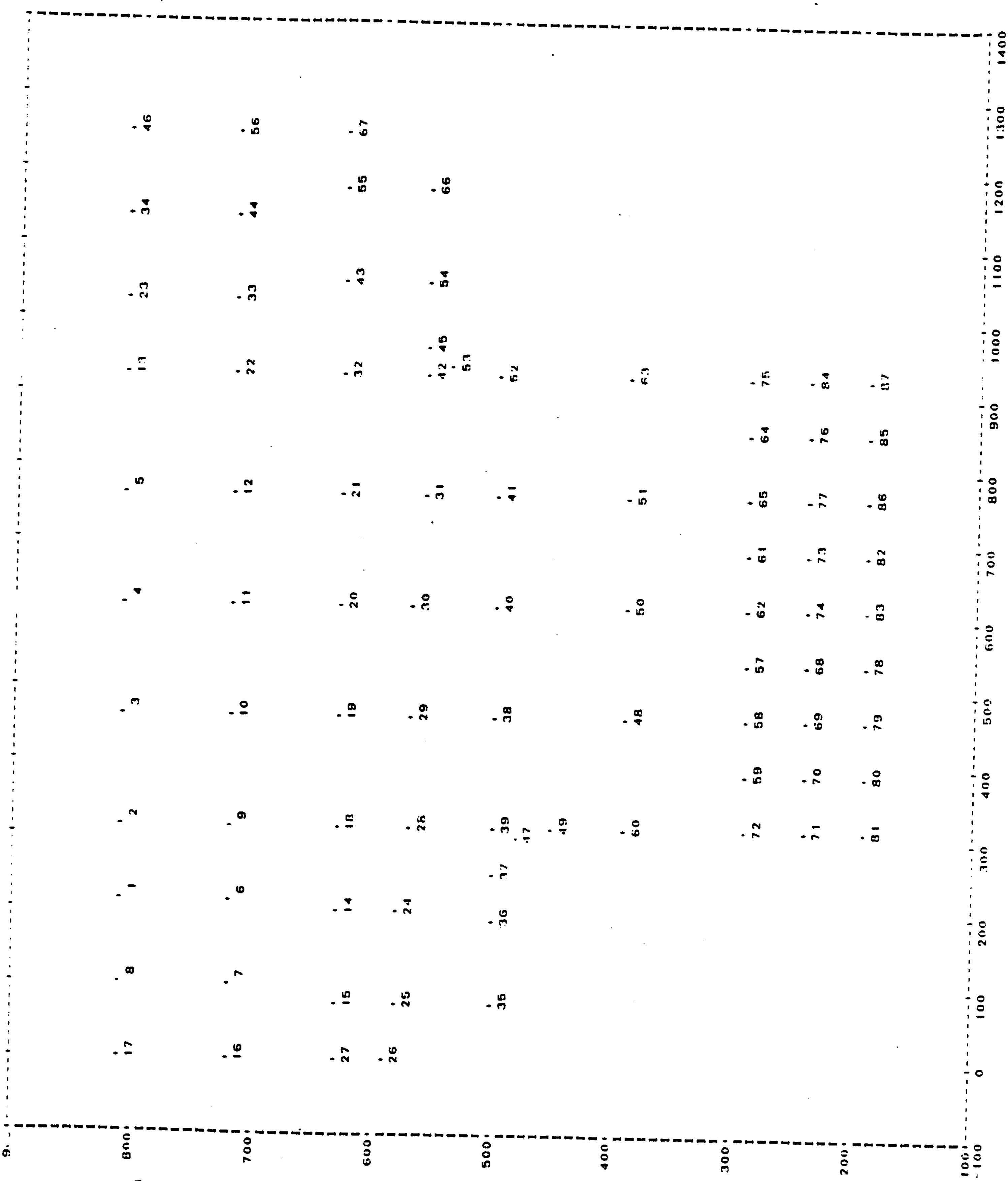

10^{-3} NODES AND NODE NOS R VS 10^{-3} Z

DISPLACEMENTS AND REDUNDANT LOADS

NODE	RADIAL DISP.	AXIAL DISP.	RADIAL LOAD	AXIAL LOAD
1	0.829528E-02	-0.506498E-02		
2	0.799572E-02	-0.438197E-02		
3	0.773715E-02	-0.338895E-02		
4	0.766766E-02	-0.239389E-02		
5	0.775704E-02	-0.141234E-02		
6	0.746743E-02	-0.629993E-02		
7	0.782124E-02	-0.604085E-02		
8	0.862833E-02	-0.577583E-02		
9	0.715493E-02	-0.455966E-02		
10	0.689947E-02	-0.347351E-02		
11	0.682688E-02	-0.238008E-02		
12	0.691670E-02	-0.128776E-02		
13	0.806913E-02	-0.451767E-03		
14	0.670838E-02	-0.558130E-02		
15	0.711579E-02	-0.644054E-02		
16	0.818817E-02	-0.678131E-02		
17	0.905501E-02	-0.646516E-02		
18	0.632850E-02	-0.471034E-02		
19	0.607955E-02	-0.354446E-02		
20	0.600918E-02	-0.236269E-02		
21	0.609940E-02	-0.117047E-02		
22	0.723272E-02	-0.204956E-03		
23	0.851816E-02	0.238614E-03		
24	0.623991E-02	-0.569892E-02		
25	0.670427E-02	-0.657361E-02		
26	0.707302E-02	-0.713512E-02		
27	0.739986E-02	-0.701598E-02		
28	0.578337E-02	-0.480143E-02		
29	0.552207E-02	-0.358526E-02		
30	0.543243E-02	-0.235667E-02		
31	0.550146E-02	-0.110806E-02		
32	0.640660E-02	0.251844E-04		
33	0.771109E-02	0.566738E-03		
34	0.901291E-02	0.974406E-03		
35	0.608151E-02	-0.692455E-02		
36	0.568167E-02	-0.593219E-02		
37	0.538924E-02	-0.537924E-02		
38	0.492183E-02	-0.362480E-02		
39	0.515568E-02	-0.428068E-02		
40	0.486583E-02	-0.235736E-02		
41	0.495714E-02	-0.108835E-02		
42	0.577562E-02	0.163931E-03		
43	0.704921E-02	0.103407E-02		
44	0.824173E-02	0.137193E-02		
45	0.602116E-02	0.580681E-03		
46	0.959238E-02	0.174443E-02		
47	0.508228E-02	-0.501512E-02		
48	0.395593E-02	-0.361935E-02		
49	0.467922E-02	-0.486361E-02		
50	0.390944E-02	-0.235584E-02		
51	0.397820E-02	-0.111122E-02		
52	0.518333E-02	0.125578E-03		
53	0.565719E-02	0.270252E-03		
54	0.648921E-02	0.129317E-02		
55	0.772131E-02	0.202076E-02		
56	0.879015E-02	0.215288E-02		
57	0.306589E-02	-0.297931E-02		
58	0.308658E-02	-0.358576E-02		
59	0.311888E-02	-0.418154E-02		
60	0.409189E-02	-0.478842E-02		
61	0.307126E-02	-0.174596E-02		
62	0.305462E-02	-0.236211E-02		
63	0.409185E-02	0.207286E-04		
64	0.312495E-02	-0.561263E-03		
65	0.309761E-02	-0.114793E-02		
66	0.720458E-02	0.234766E-02		
67	0.807055E-02	0.252305E-02		
68	0.264977E-02	-0.297455E-02		
69	0.266800E-02	-0.357774E-02		
70	0.269332E-02	-0.416548E-02		
71	0.270092E-02	-0.473041E-02		
72	0.314206E-02	-0.473305E-02		
73	0.265364E-02	-0.176070E-02		
74	0.264120E-02	-0.236128E-02		
75	0.315231E-02	-0.731810E-05		
76	0.269860E-02	-0.571469E-03		
77	0.267675E-02	-0.115286E-02		

78	0.226228E-02	-0.297554E-02		
79	0.227780E-02	-0.357934E-02		
80	0.229855E-02	-0.416308E-02		
81	0.229678E-02	-0.472704E-02		
82	0.226592E-02	-0.174656E-02		
83	0.225509E-02	-0.235977E-02		
84	0.272415E-02	-0.795899E-05		
85	0.230528E-02	-0.566844E-03		
86	0.228587E-02	-0.114809E-02		
87	0.233650E-02	0.0	0.494406D+01	-0.137622D-02

REDUNDANT LOAD CALC. TIME (MIN.)= 0.0

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ELEMENT STRESSES

	ELEMENT	STRESS R	STRESS-Z	STRESS-Q	STRESS-RZ	EFF. STRESS
1	87- 85- 84	9812.	3680.	89190.	2406.	82723.
2	84- 85- 76	8004.	-1149.	78544.	2333.	75644.
3	35- 86- 76	14581.	9902.	89416.	1559.	77331.
4	76- 86- 77	8310..	4603.	77867.	1838.	71557.
5	86- 82- 77	14777.	15374.	88652.	1599.	73634.
6	77- 82- 73	7906.	9557.	76815.	2116.	68201.
7	82- 83- 73	14192.	19724.	87604.	568.	70818.
8	73- 83- 74	8225.	13715.	76424.	1279.	65667.
9	83- 78- 74	13207.	20006.	86741.	-1197.	70415.
10	74- 78- 68	9728.	16367.	77490.	-889.	65147.
11	78- 79- 68	12599.	15849.	86577.	-1766.	72476.
12	68- 79- 69	10562.	12615.	78498.	-1992.	67025.
13	79- 80- 69	11899.	9047.	86524.	-2308.	76199.
14	69- 80- 70	17103.	8501.	80124.	-3656.	70181.
15	80- 81- 70	12269.	2667.	86512.	-240.	79485.
16	70- 81- 71	14768.	1809.	80085.	-1609.	72725.
17	84- 76- 75	25724.	3166.	75207.	3345.	64091.
18	75- 76- 64	19952.	-4322.	66471.	5413.	63014.
19	76- 77- 64	26498.	9136.	74800.	4718.	59502.
20	64- 77- 65	21095.	7187.	67933.	4396.	55650.
21	77- 73- 65	24545.	13454.	73165.	3862.	55419.
22	65- 73- 61	19713.	9918.	65996.	4233.	52397.
23	73- 74- 61	23615.	16986.	71937.	2480.	52134.
24	61- 74- 62	19337.	15727.	65936.	1939.	48623.
25	74- 68- 62	20914.	16579.	70343.	-1240.	51779.
26	62- 68- 57	21421.	17033.	67056.	-2338.	48152.
27	68- 69- 57	21544.	13623.	70876.	-3215.	54023.
28	57- 69- 58	21915.	13875.	67782.	-4150.	50883.
29	69- 70- 58	21473.	8715.	71468.	-4735.	58032.
30	58- 70- 59	25972.	12556.	70990.	-7161.	54450.
31	70- 71- 59	23078.	1882.	72018.	-4047.	62699.
32	59- 71- 72	29190.	-1380.	69697.	-3431.	62043.
33	63- 51- 52	60811.	12648.	69032.	16331.	59863.
34	52- 51- 41	31139.	13077.	55336.	16292.	46317.
35	51- 50- 41	32272.	18080.	54110.	6335.	33297.
36	41- 50- 40	25437.	18263.	48225.	5624.	28796.
37	50- 48- 40	25881.	18013.	49954.	-3064.	29309.
38	40- 48- 38	28313.	19278.	49593.	-4006.	27838.
39	75- 64- 63	45475.	4504.	70368.	6147.	58582.
40	63- 64- 51	34558.	2287.	60748.	8706.	52916.
41	64- 65- 51	29325.	7941.	62215.	6977.	48874.
42	65- 61- 51	30676.	12159.	62502.	6852.	45674.
43	51- 61- 50	29407.	18558.	58568.	5530.	37099.
44	61- 62- 50	23770.	14777.	58336.	2702.	40107.
45	62- 57- 50	23888.	15161.	68348.	-820.	39580.
46	50- 57- 48	28879.	21572.	58653.	-3728.	34662.
47	57- 58- 48	27910.	13678.	61132.	-5838.	43376.
48	58- 59- 48	26681.	9759.	60955.	-7303.	46918.
49	48- 59- 60	35991.	9370.	62641.	-10721.	49734.
50	59- 72- 60	48239.	4674.	70828.	-8247.	59972.
51	36- 35- 24	5406.	12743.	79339.	-7485.	71736.
52	24- 35- 25	9781.	8972.	81152.	-5411.	72392.
53	35- 26- 25	10705.	3521.	89685.	-4803.	83227.
54	52- 41- 42	64222.	27627.	70757.	20439.	53615.
55	42- 41- 31	27958.	20778.	52891.	15626.	39811.
56	41- 40- 31	24894.	17438.	46019.	2724.	26110.
57	31- 40- 30	21791.	11617.	40851.	5828.	27617.
58	40- 38- 30	23819.	16015.	43211.	-3429.	24973.
59	30- 38- 29	26192.	10297.	42206.	1382.	27739.
60	38- 28- 29	27630.	10218.	47243.	-9441.	36010.
61	66- 55- 67	4486.	520.	105511.	3069.	103208.
62	66- 54- 55	7079.	14226.	100448.	5674.	90548.
63	55- 54- 43	2537.	3223.	81896.	7864.	80163.
64	42- 31- 32	39048.	25480.	59751.	-352.	29901.
65	32- 31- 21	24028.	4453.	43686.	10479.	38523.
66	31- 30- 21	26093.	12904.	42120.	-3142.	25920.
67	21- 30- 20	20321.	27.	34522.	4797.	31158.
68	30- 29- 20	23934.	8196.	33389.	-5144.	27633.
69	20- 29- 19	21260.	-1248.	35046.	1840.	31893.
70	29- 28- 19	27546.	9582.	45165.	-8793.	34375.
71	19- 28- 18	29727.	2027.	46171.	-1100.	38691.
72	28- 24- 18	38716.	15345.	62823.	-19777.	53520.
73	18- 24- 14	17727.	-430.	55945.	-11201.	53487.
74	24- 25- 14	26812.	11068.	74737.	-14704.	62834.
75	14- 25- 15	15980.	1390.	72257.	-8473.	66459.
76	25- 26- 15	20748.	3851.	85691.	-8839.	76389.

77	15- 26- 27	17367.	-1444.	84644.	-5504.	78975.
78	67- 55- 56	21970.	6200.	106962.	8423.	95007.
79	55- 43- 56	15768.	10673.	93543.	7064.	81373.
80	56- 43- 44	18681.	-3747.	83440.	15767.	83040.
81	43- 32- 44	19895.	9373.	70866.	9006.	59065.
82	44- 32- 33	21042.	-3534.	63422.	18223.	66621.
83	32- 22- 33	29184.	-12428.	51009.	17229.	63300.
84	32- 21- 22	36103.	10357.	51292.	-5217.	36964.
85	22- 21- 12	19435.	-18657.	32912.	7396.	48066.
86	21- 20- 12	27281.	2987.	37426.	-6841.	32865.
87	12- 20- 11	17026.	-19951.	25810.	3806.	42578.
88	20- 19- 11	25640.	-57.	34635.	-6294.	33035.
89	11- 19- 10	18331.	-18977.	27140.	3004.	42725.
90	19- 18- 10	27826.	-348.	40156.	-8116.	38612.
91	10- 18- 9	24093.	-15520.	36873.	-9.	47319.
92	18- 14- 9	35672.	4731.	55198.	-15664.	51761.
93	9- 14- 6	19294.	-12667.	47734.	-7946.	54120.
94	14- 15- 6	32470.	6135.	68245.	-13315.	59473.
95	6- 15- 7	23511.	-6410.	63845.	-8095.	62656.
96	15- 16- 7	29574.	-1064.	75968.	-9304.	69084.
97	15- 27- 16	34222.	4108.	86292.	-9072.	73713.
98	56- 44- 46	43358.	8473.	99496.	4296.	79893.
99	46- 44- 34	25107.	-5045.	80966.	8181.	76909.
100	44- 33- 34	24283.	280.	72894.	3918.	64440.
101	34- 33- 23	24168.	-19646.	59164.	8191.	69864.
102	33- 22- 23	23690.	-13848.	51770.	6759.	58215.
103	23- 22- 13	20421.	-37602.	37458.	12881.	71720.
104	22- 12- 13	27919.	-14254.	39100.	-6443.	50000.
105	13- 12- 5	15581.	-42846.	22927.	6368.	63395.
106	12- 11- 5	25625.	-16129.	29891.	-7647.	46018.
107	5- 11- 4	14700.	-41176.	17917.	4160.	58004.
108	11- 10- 4	25270.	-16497.	28471.	-6052.	44705.
109	4- 10- 3	15145.	-38366.	19455.	4652.	56372.
110	10- 9- 3	25974.	-16050.	33234.	-7074.	47687.
111	3- 9- 2	19710.	-34721.	28164.	2682.	59292.
112	9- 6- 2	33034.	-8658.	46692.	-10094.	53099.
113	2- 6- 1	21659.	-28122.	40020.	-2774.	61260.
114	6- 7- 1	34479.	-4526.	59158.	-7922.	57244.
115	1- 7- 8	23362.	-16302.	54764.	-2678.	61896.
116	7- 16- 8	33405.	-1247.	71527.	-5829.	63854.
117	8- 16- 17	50145.	-6791.	77542.	-5926.	75220.
118	54- 45- 43	15195.	46904.	86176.	14577.	66565.
119	45- 32- 43	31223.	12114.	68670.	20263.	60950.
120	45- 42- 32	54372.	55254.	81063.	32266.	61751.
121	53- 42- 45	77666.	66165.	94136.	61188.	108748.
122	52- 42- 53	74753.	48684.	84798.	60204.	109314.
123	48- 60- 49	59561.	18738.	70300.	-20622.	59130.
124	48- 49- 38	29151.	16821.	54853.	-12862.	40322.
125	49- 39- 38	56580.	31693.	69041.	-18026.	45382.
126	49- 47- 39	67155.	52055.	83939.	-50796.	92221.
127	47- 37- 39	45367.	48149.	79458.	-44913.	84423.
128	39- 37- 28	50509.	49277.	78072.	-29217.	57934.
129	37- 24- 28	23180.	11225.	63079.	-15928.	54527.
130	37- 36- 24	14323.	39064.	78920.	-18876.	65238.
131	38- 39- 28	36583.	22511.	58418.	-3859.	32044.

STRESS CALCULATION TIME (MIN.)= 0.0333

MAXIMUM EFFECTIVE STRESS OCCURS AT ELEMENT 122 52- 42- 53 AND IS EQUAL TO 1.0931E+05 PSI

MAXIMUM RADIAL DISPLACEMENT OCCURS AT NODE 46 AND IS EQUAL TO 9.5924E-03 INS.

MAXIMUM AXIAL DISPLACEMENT OCCURS AT NODE 26 AND IS EQUAL TO -7.1351E-03 INS.

AVERAGE STRESSES OF DISK - VOL. AVG. TANG. IS 54967.168 PSI
AREA AVG. TANG. IS 57492.172 PSI
AREA AVG. EQUIV. IS 52473.430 PSI

TOTAL WEIGHT OF BODY IS 0.650 LBS

DIAMETRAL INERTIA ABOUT ORIGIN IS 0.372 LB-IN**2

DIAMETRAL INERTIA ABOUT CENTROID IS 0.168 B-IN**2

```
POLAR INERTIA OF BODY IS         0.219  LB-IN**2

CENTROID OF BODY FROM ORIGIN IS    0.6092  IN.
```

APPENDIX B

ENGINEERING REPORT

2800 F R.T.I. NASA COOLED RADIAL TURBINE ROTOR HEAT TRANSFER AND AERODYNAMICS DESIGN STATUS REPORT

Engineering Report

2800^{0}F R.I.T. NASA COOLED RADIAL TURBINE ROTOR
HEAT TRANSFER AND AERODYNAMICS DESIGN STATUS REPORT

REPORT T-5500 ISSUED 5/8/81

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Research & Advanced Development

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NOTE: There is no Figure 20

NOMENCLATURE

SYMBOLS	UNITS	DEFINITIONS
Stations		
0		Stator entrance
1		Stator exit
2		Rotor entrance
3		Rotor exit
4		Exhaust diffuser exit
T, p	°F, psia	Static values of gas temperature and pressure
T_o, p_o	°F, psia	Total values of gas temperature and pressure
To, rel	°F	Relative total gas temperature
b	in.	Flow path width
c	ft/s	Absolute velocity
c_p	Btu/lb°F	Constant pressure specific heat
C	-	Film turbulence factor (J.M.)
C_D	-	Discharge coefficient
d	in.	Leading edge diameter
D	in.	Diameter
D_H	in.	Hydraulic diameter
e	in.	Wall thickness
g_c	$\frac{ft.lb_m}{lb_f.s^2}$	Conversion factor
h	Btu/hft^{2}F	Heat transfer coefficient
h	Btu/lb	Enthalpy
J	$\frac{ft.lb_f}{Btu}$	Energy conversion factor (778.161)
k	Btu/hftF	Thermal conductivity

NOMENCLATURE (Cont.)

SYMBOLS	UNITS	DEFINITIONS
K	-	Total pressure loss factor
L	in.	Flow path length
l	in.	Meridional length
$\dot{m}$	lb/s	Mass flow rate
m	-	Film blowing parameter
M	lb/lb mole	Molecular mass
N	RPM	Rotation, speed
Nu	-	Nusselt number
N_s	$\left(\frac{ft\ lb_m}{lb_f}\right)^{3/4} \frac{1}{min.\ s^{1/2}}$	Specific speed
P	hp	Shaft power
Pr	-	Prandtl number
q"	Btu/hft^2	Heat flux
Q	Btu/s	Heat load
R_n	$\frac{ft \cdot lb_f}{lb_m \cdot R}$	Gas constant
r	in , ft	Current radius
R_p, R_T	-	Ratios defined on page 13
Re	-	Reynolds number
R_2	in.	Rotor tip radius
R.I.T.	°F	Rotor inlet total temperature
s	in.	Film slot height
t	in.	Airfoil normal thickness
u, U_2	ft/s	Tangential wheel speed

NOMENCLATURE (Cont)

SYMBOLS	UNITS	DEFINITIONS
U	$\frac{Btu}{h.ft^2.F}$	Overall heat transfer coefficient
W	ft/s	Relative velocity
x	in.	Distance from film injection point
z	-	Number of blades (z_2) or vanes (z_1)

Greek Symbols

α_2	degree	Rotor flow inlet angle (w.r.t. tang.)
β_3	degree	Blade exit angle (w.r.t. axial)
γ	-	Ratio of specific heats
Δ	-	Difference
η_c	-	Metal cooling effectiveness
η_f	-	Film cooling effectiveness
η	-	Isentr. efficiency
θ	degree	Angular position
λ	-	Work factor
μ	lb/ft.h	Dynamic viscosity
ν	ft^2/h	Kinematic viscosity
ρ	lb/ft^3	Density
ϕ	-	Coolant flow ratio
ω	rad/s	Angular speed

Subscripts

r	Rotor
c	Coolant
f	Film
g	Gas

NOMENCLATURE (Cont)

SYMBOLS	UNITS	DEFINITION
e		External
m		Metal
i		Internal
tt		Total-to-total
ts		Total-to-static
b		Blading
d		Disc
h		Hub
s		Shroud
R.M.S		Root mean square value
o		Outer
i		Inner
-		Average

I. INTRODUCTION

NASA-Lewis awarded Manufacturing Contract NAS3-22513 (Solar S.O. 6-4938-7) to Solar Turbines International to design and manufacture a high-temperature cooled radial inflow turbine rotor characterized by (Figs. 1-a, 1-b and 2).

- Shaft power: $P = 1000$ hp
- Stator inlet total pressure; $p_{OO} = 280$ psia
- Rotor inlet total gas temperature selected: $T_{02} = 2800°F$ (2420°F is the lowest acceptable to NASA)
- Rotor inlet gas flow: $\dot{m}_{g2} \simeq 5$ lb/s
- Cooling air available at 280 psia and 950°F
- Primary flow total-total isentropic efficiency: $\eta_{tt_{0-3}} \geq 0.85$
- Heat transfer promoters in the internal cooling passages for more effective use of the coolant expenditure that should not exceed 1 lb/s for the rotor and the stationary rotor shroud. The stator vanes and associated shrouds are assumed to be made out of ceramic material, i.e., are uncooled.
- Parts designed to be castable
- 1500 hours life.

II. CONTRIBUTORS

NASA Program Manager - H. E. Rohlik

Solar Project Director - A. G. Metcalfe

Solar Project Manager - A. N. Hammer

External Aerodynamic Design - C. Rodgers

Heat Transfer Design and Internal Aerodynamics - G. Aigret and N. Anderson

Configuration and Stress Design - T. P. Psichogios and R. P. Barrow

Mechanical Design - A. W. August and T. P. Psichogios

Manufacturing Engineers - J. R. Woodward and A. N. Hammer

III. FLUID PROPERTIES

The products of combustion at 2800°F of air at 950°F with a liquid fuel such as ASTM-A-1 (H/C = 0.168; L.H.V. = 18,700 Btu/lb_m) result from a fuel-air ratio of f/a = 0.0315. Per NASA TN D-7488 (see App. B for references), the transport properties at 20 atmospheres pressure are:

	γ_g	C_{pg} (Btu/lbF)	μ_g (lb/ft.h)	k_g (Btu/hftF)	Pr_g	M_g (lb/lb mole)
At rotor entrance	1.2699	0.3232	0.1485	0.06870	0.699	28.966
At rotor exit	1.2828	0.3113	0.1345	0.05975	0.702	28.968
Average	1.2751	0.3182	0.1430	0.06483	0.701	28.967

Likewise, per the same source, the coolant properties at pressure are:

	γ_c	C_{pc}	μ_c	k_c	Pr_c
At 950°F (fresh)	1.3537	0.2626	0.0876	0.03266	0.706
At 1500°F (spent)	1.3288	0.2773	0.1076	0.04233	0.705
Average	1.3413	0.2700	0.0976	0.03750	0.705

IV. FLOW PATH DESCRIPTION

After several iterations involving the aerodynamics, heat transfer, applied mechanics, manufacturing and design disciplines, the flow path of Figures 1-a, 1-b, and 2 and shown on the drawings listed in Appendix E was found to satisfy the design requirements. Main features are:

Stator:
- O.D.: D_0 = 9 inches
- I.D.: D_1 = 7.4 inches
- Width: $b_0 = b_1$ = 0.29 inch
- z_1 = 17 vanes

Rotor:
- Tip diameter: D_2 = 6.5 inches (R_2 = 3.25 inches)
- Inlet blade width: b_2 = 0.30 inch
- Exducer O.D.: D_{3s} = 4.25 inches
- Exducer I.D.: D_{3h} = 2.40 inches
- Exducer $D_{3,RMS}$ = 3.45 inches
- $D_2/D_{3,RMS}$ = 1.88

z_2 = 10 full blades
N = 65,000 RPM
Tip speed: U_2 = 1844 ft/s
Rotor flow inlet angle: α_2 = 22.31° (w.r.t. tang.)
Exducer R.M.S. blade exit angle: β_3 = 55° (w.r.t. axial)
Rotor tip leading edge thickness: t_2 = 0.110 inch
Exducer R.M.S. trailing edge thickness: t_3 = 0.15 inch
Mean meridian flow path length: ℓ_2 = 2.366 inch
Solidity factor: $z_2\ell_2/D_2$ = 3.64
Nozzle hot throat area: 2.2 inch^2

Figure 2 also shows the main aerothermodynamic parameters such as pressures and temperatures. These are for an uncooled turbine:

Rotor inlet total temperature: T_{o2} = 2800°F
Rotor inlet static temperature: T_2 = 2510°F
Rotor inlet pressure: total: P_{o2} = 276.1 psia
static: p_2 = 179.3 psia
Exhaust gas temperature: T_{o3} = 2363°F
Enthalpy drop: Δh_o = 139.0 Btu/lb
Exit total pressure: p_{03} = 126.1 psia
Exit static pressure: p_3 = 118.8 psia
Total-to-total rotor pressure ratio: p_{o2}/p_{o3} = 2.19
Overall total-to-static pressure ratio: p_{oo}/p_3 = 2.36
Gas flow rate: $\dot{m}_{g2}$ = 4.98 lb/s

$$\text{Velocity ratio: } \frac{U_2}{C_{\text{spouting, isentrop (0-4)}}} \simeq 0.65$$

$$\frac{U_2}{\sqrt{T_{o2}}} = 32.3 \text{ ft/s.R}^{1/2}$$

$$\text{Work factor: } \lambda = \frac{\Delta h_0}{U_2^2} = 1.023$$

$$\text{Rotor Reynolds number: } Re = \frac{\dot{m}_{g2}}{\mu_g R_2} = 4.63\ 10^5$$

$$\text{Flow function: } \frac{\dot{m}_{g2}\sqrt{T_{o2}}}{p_{o2}} = 1.03 \frac{\text{lb.R}^{1/2}}{\text{S. psia}}$$

Shaft power: P = 980. hp (uncooled; no mechanical losses)

$$\text{Specific speed (02-03): } N_s \simeq 64.2 \left(\frac{\text{ft.lb}_m}{\text{lb}_f}\right)^{3/4} \frac{1}{\text{min. s}^{1/2}}$$

Reaction: ≃ 0.44

Expected primary flow (uncooled) efficiency (0-3): $\eta_{tt} \simeq 0.848$

V. DISCUSSION OF THE AERODYNAMIC DESIGN

The turbine rotor was designed for a low solidity ($z_2 \ell_2/D_2$) and a small inlet relative width ($b_2/D_2 = 0.046$) to minimize the blading area to be cooled. The results of initial geometry optimizations at the design conditions are listed below:

Effect of Blade Height b_2 (inch)

b2	0.25	0.30●	0.35
$\%\Delta\eta_{tt}$	-1.1	0	+0.2
%P	0	0	+0.8

Effect of Blade Number z_2

z2	8	10 ●	12	14
$\%\Delta\eta_{tt}$	-1.4	0	0.75	1.3
%P	-0.2	0	0.4	1.0

Effect of Blade Exit Angle β_3 (deg)

β_3	55.0●	60.0	65.0
$\%\Delta\eta_{tt}$	-0.9	0	+0.8
%P	+2.0	0	-3.3

Effect of Hub Diameter D_{3h} (inch)

D_{3h}	2.2	2.4●	2.6
$\%\Delta\eta_{tt}$	-0.3	0	+0.1
%P	+1.0	0	-1.4

Effect of Trailing Edge Thickness t_3 (inch)

t_3	0.06	0.08	0.10	0.15●
$\%\Delta\eta_{tt}$	+0.2	0	-0.2	-0.6
%P	+0.1	0	-0.1	-0.5

● indicates selected parameters

From manufacturing and cooling constraints, the final geometry selected is shown in Figures 1-a and 1-b (see App. E for drawing numbers) and employs ten blades with a relatively large exducer hub diameter to minimize exit blade height. A relatively thick exducer trailing edge (RMS) blade thickness of 0.15 inch is needed to permit trailing edge ejection of the largest rotor cooling flow fraction. Estimated total-to-total primary flow (uncooled) adiabatic efficiency from stator inlet to exducer outlet (i.e., 0-3) is 84.8 percent compared to the design goal of 85 percent.

Design rotational speed is 65,000 RPM; reducing this to 60,000 RPM would reduce the blade stresses by approximately 15 percent at the expense of a 2 percent points reduction in total-to-total efficiency.

Figure 3 shows the velocity triangles. Note a 10-degree positive incidence at the entrance and nearly axial leaving velocities. Figures 4, 5 and 6 give the surface velocity distributions on the blades near the shroud, at mid-passage and near the hub, respectively. The flow path was modified several times to obtain the desirable zero or negative surface pressure gradients at the expected airfoil and hub film injection points. The flow path was further assumed continuous without any flow ejection at the star/exducer blade interface (see Fig. 1-b).

Figure 7 provides the average static pressure distributions necessary to find the sink pressures for coolant ejection. A smooth acceleration is shown along both the shroud and hub. The velocity distribution output listing from external flow program P-229 is included in Appendix A.

VI. COOLING SCHEME SELECTION

Using the formula proposed by J. W. Gauntner in NASA TM 81453, the allowable bulk metal temperature for the blades of an axial turbine using a 1970 material such as Inconel 792 (Mod. 5A) and a 1500-hour life would be 1582°F.

The average blade metal cooling effectiveness, based on a relative total gas temperature of 2600°F and a target bulk average metal temperature of 1500°F, is:

$$\bar{\eta}_c = \frac{2600-1500}{2600-950} = 0.667$$

From the axial turbine cooling experience of Solar, with a blading coolant-to-gas flow ratio of $\phi_{gb} = 0.10$, we expect to achieve for the blading;

$$\bar{\eta}_{cb} = \frac{1}{1 + 0.0641\ \phi_{gb}^{-0.8296}} = 0.698$$

This approximation and more detailed calculations (presented later), based on the heat loads on the blading and the hub exposed area lead to the following cooling airflow requirements for the rotor:

For the blading: $\phi_{gb} = 0.10$ or 0.50 lb/s

For the disc hub: $\phi_{gd} = 0.03$ or 0.15 lb/s

Corresponding quantities per blade are 0.05 and 0.015 lb/s, respectively, for a total of $\phi_g = 0.13$ or 0.065 lb/s per blade (Fig. 10).

A double-pass convective scheme in the blade tip region is required to avoid massive tip ejection with resulting poor aerodynamic performances and to achieve the proper cooling effectiveness; Figure 1-a shows that the net coolant flow area near the blade tip is quite reduced (see also Fig. 11 and Table 1): for a passage gap of 0.050 inch between walls, we have the following passage widths: 0.160 inch for the outflow (Sec. S_6) and 0.070 inch for the inflow (Sec. S_9) channels! Likewise, the feed holes S_2 (Fig. 11) are rapidly choked. Obviously then, the coolant to the exducer portion has to be introduced through the feed holes E_1 near the bore. The limited amount of spent air from the radial blade portion has to be ejected in the form of films on the exducer surfaces (see Fig. 1-b). Disc cooling can be achieved by impingement cooling on the back side of the rim (holes A_1) and subsequent veil cooling from A_2 along the hub surface. Such a film will quickly lose its effectiveness; hence, it is necessary to supply another film on the hub between the blades in the exducer region through slots E_{32}. The advantages of a two-piece rotor now become apparent, both from the aerothermodynamic and manufacturing viewpoints. The bore holes E_1 feed air to the exducer blades through holes E_4 and to the exducer hub through metering slots E_{31}. The spent air from the star portion blades is ejected to film cool the leading edges of the exducer blades (Fig. 1-b). The effect of a possible misalignment of the exducer blades with respect to the star blades is discussed next.

An uncooled two-piece radial inflow turbine of similar construction and dimensions has been tested at Solar (Ref. 27, Fig. 3 of pg. 7) with the following characteristics:

- Tip diameter: 6.25 inches
- Exducer maximum O.D.: 4.16 inches
- Exducer minimum I.D.: 1.00 inch
- Speed: 56,700 RPM
- Number of blades: 12

The effect of an exducer blading misalignment with respect to the star blading was systematically investigated for this simplified tandem arrangement (see pgs. 5 and 6 of Ref. 27).

The effects of exducer position on overall turbine efficiency indicated maximum overall turbine efficiency with direct alignment to the star blades and minimum efficiency with maximum misalignment. The efficiency variation from maximum to minimum was almost four percentage points. When the exducer was misaligned a quarter of a pitch against the direction of rotation, the efficiency penalty was less than one percentage point (see Fig. 3 of Ref. 27).

<u>Preferred misalignment</u> is also <u>against the direction of rotation</u> for the cooled turbine presented here, as it will result in more film cooling flow to the suction side of the exducer blades where the heat load is the highest.

Heat transfer promotion is logically obtained by staggered trip strips in the passages of the star blades and by a variable density array of pin fins in the triple-pass convectively cooled passages of the exducer blades. The gap between the internal blade walls is kept everywhere at a constant value of 0.050 inch to ease the casting process. The final flow split is shown in Figure 10. Note that a small percentage of air (1%) is bled at the rotor tip (radius R_2) to protect it by convection in the holes and by some external filming from the impinging external flow. Special attention has been paid to the thick blade roots cooling: this is achieved by flowing fresh coolant in the root passages (e.g., through orifices S_4 and E_6 [Fig. 11] and outflow along the hub passages S_5 of the star blades) and by cooling the blades by conduction to the impingement - (jets A_1 and E_2) and film-cooled (films A_2 and E_{32}) hub surfaces.

The cooling flow usage can be summarized as follows on a per blade basis (see Fig. 10):

	Area To Be Cooled (in.^{2})	Coolant Flow (lb/s)	Specific Coolant Flow (lb/s. in.^{2})	Percentage of Gas Flow
Star portion				
Blade (with edges)	1.343	0.015	0.0112	3.0
Hub (net)	1.458	0.010	0.0069	2.0
Exducer portion				
Blade (with edges)	2.310	0.035	0.0152	7.0
Hub (net)	0.930	0.005	0.0054	1.0
Total for Rotor	6.041	0.065	(0.0108)	13.0

It is seen that the largest portion of the spent coolant is ejected at the exducer blade trailing edges (≃5.46%): the next most important portion (≃2%) is ejected as films on the exducer blade leading edges (Fig. 1-b) in a region of favorable external pressure gradients, as can be seen from Figures 4, 5 and 6.

Some coolant (≃1.54%) is ejected in the exducer blade-shroud gap for several reasons:

- To reduce the blade-tip clearance losses where they are most detrimental.
- To partly cool the shroud: as a total of one lb/s was assigned for the rotor and its shroud cooling, there remains 0.35 lb/s for further back cooling of this shroud.
- To completely flow-fill the blade internal cavities (corners).
- To provide core support locations.

The last two reasons also justify the tip leading edge film cooling holes.

The cooling flow ratios mentioned here are referred to the radial turbine total inlet flow of 5 lb/s. The engine inlet flow would be of the order of

6.6 lb/s as the downstream turbine would require about 0.75 lb/s of cooling air. (The mass balance is: 6.6−1.0−0.75+0.15 fuel flow = 5 lb/s gas flow.) Using the engine inlet air flow as a reference, we get the following ratios for this project:

Rotor cooling: $\phi_{c,r} = \frac{0.65}{6.6} \times 100 = 9.85\%$

Rotor and shroud cooling: $\phi_{c,t} = \frac{1.00}{6.6} \times 100 = 15.15\%$

Again, it is assumed that a ceramic distributor is used.

VII. INTERNAL AERODYNAMICS OF COOLING CIRCUITS

7.1 ANALYTICAL COOLANT FLOW MODELS

7.1.1 Purpose

An analytical model (Fig. 12) of the blade cooling circuits was developed in order to gain a better understanding of the stationary flow models, to predict flow distribution within the rotating cooling circuits, and to predict internal heat transfer coefficients for the heat transfer analysis.

7.1.2 Major Assumptions

The analysis assumed that pre-swirl nozzles would not be used and that the star blade cooling air would be pumped radially outward between the rotor and a stationary shroud from near the exducer inlet port (E_1) to the star blade inlet port (S_2) (see Fig. 11). The analysis superimposed the effects of heat transfer and forced vortex pumping on a conventional compressible flow network of orifices, frictional passages, and turning losses. It was assumed that the cooling air will be available at a total temperature of 950°F and a total pressure of 280 psia.

7.1.3 Methods of Analysis

A block diagram of the cooling circuit model is illustrated in Figure 12.

7.1.3.1 Star Internal Cooling Circuit

The flow characteristics between the turbine wheel and shroud were modeled from graphical data in Reference 34. The analysis assumed a 0.030-inch gap between the shroud and turbine wheel. This small gap was sized to prevent inflow near the stationary shroud. It was found that a total pressure rise of 10 psi occurred between the inlet to the shroud and the inlet to the star cooling circuit. The core velocity of the fluid was found to be approximately one-half of the turbine wheel velocity when the throughflow effects are included. It was then assumed that the total pressure in the star blade entry port was equal to the static pressure in the gap between the turbine wheel and the shroud.

The frictional effects of the star circuit trip strips were estimated from graphical data presented in Reference 35. The pressure loss at the star tip turn is estimated by applying a loss coefficient of 2.1 to the maximum dynamic head.

The holes (S_4) near the bottom of the partition between the star blade cooling passages and the star blade tip holes (S_{81} through S_{84}) were sized using a discharge coefficient of 0.80 applied to the isentropic orifice equation.

Effects of forced vortex pumping were estimated from the following equations:

$$R_P = \left[1 + \frac{\omega^2(r_0^2 - r_i^2)}{2g_c J c_p T_0}\right]^{\frac{\gamma}{\gamma-1}}$$

$$R_T = \left[1 + \frac{\omega^2(r_0^2 - r_i^2)}{2g_c J c_p T_0}\right]$$

7.1.3.2 Exducer Internal Cooling Circuit

The exducer cooling circuit analytical model combines the traditional compressible flow elements, the forced vortex pumping, and the heat transfer effects as in the star cooling circuit. A discharge coefficient of 0.8 was applied to the orifice elements (E_6, E_{24}, E_{15}). The pressure drop due to the pin fin array was estimated from experimental data in reference one (pg 10) expressed as:

$$\Delta P_c = \frac{1}{2} K \cdot \gamma \cdot p \cdot M^2 \quad \text{with } K = 0.605$$

where the Mach number and static pressure are defined at the minimum flow area.

7.1.4 Results

The results of the analytical flow model are illustrated and tabulated in Figure 10 and Table 1, respectively. In summary, cooling passages were sized to provide the following flows <u>per</u> turbine <u>wheel</u>:

Star internal cooling circuit: 0.15 lb/sec
Star hub film cooling: 0.10 lb/sec
Star blade film cooling: 0.05 lb/sec
Exducer blade internal cooling circuit: 0.35 lb/sec
Exducer hub film cooling: 0.05 lb/sec
Exducer shroud cooling: 0.077 lb/sec
Exducer blade film cooling: 0.10 lb/sec

The total flow used for cooling the turbine wheel, neglecting seal leakage, is 0.65 lb/sec which is approximately 10 percent of the total compressor mass flow. This leaves 0.35 lb/sec for additional shroud cooling.

7.2 EXPERIMENTAL STATIC COLD FLOW MODELS

7.2.1 Purpose

One-to-one scale models of the star blade and exducer blade internal cooling passages were fabricated from brass, aluminum and clear plastic. Pieces of steel wire (Ø 0.013 in.) were glued with lacquer to form the trip strips. The curvature of the exducer flow passage was removed in order to ease the fabrication. Static cold airflow tests were performed with various combinations of turbulence promoters, tip holes, and internal division schemes until a satisfactory design was achieved.

The flow tests provided a flow function which must be corrected for inlet losses and the effects of forced vortex pumping before applying the results to a design calculation. These flow tests were then used to verify portions of the analytical model of the internal flow network.

Cold air flow tests will also provide a basis for determining the extent of plugging or voidage in the castings.

7.2.2 Test Apparatus

A block diagram of the flow bench is illustrated in Figure 13-a. Figure 13-b is a sample data sheet with the accuracies of each gauge shown. The sonic orifice was not operating under choked conditions for all but the highest flows; consequently, it was disconnected for the tests.

The flow bench as well as each test model was checked for leaks before the tests.

7.2.3 Static Flow Models

Photographs of the flow models are provided in Figures 14, 15, 16 and 17. Upon completion of flow testing, several measurements were made in order to determine differences between the models and the design drawings. These differences are tabulated in Figure 19 for the final flow models. The lack of dimensional accuracy is due to the fact that the models were fabricated before the final design was completed.

Analysis indicates that the star piece flow function is most sensitive to dimension "F" and dimension "C" in Figure 18. Analysis also indicates that the exducer flow function is sensitive to dimension "K" and to the pin density. The results of the flow tests were corrected for dimensional inaccuracies before they were applied to design calculations.

7.2.4 Test Results

7.2.4.1 Final Test Results, Exducer Blade Model

The results of the final test of the exducer passage is illustrated in Figure 21. Results of the analytical model indicate a flow of 0.035 lb/sec per blade at an upstream pressure of 234 psia, a downstream pressure of 120 psia, an upstream temperature of 960°C and a speed of 65,000 RPM (6807 rad/sec). The pressure rise due to forced vortex pumping is calculated from an inlet radius of 1.05 inches and an outlet radius of 1.477 inches by the expression:

$$\Delta P_B = \frac{p_i \cdot \omega^2 \cdot (r_0^2 - r_i^2)}{2 g_c \, R_n \, T_o} .$$

The resulting pressure rise due to pumping through the exducer is 16 psi. In order to relate the analytical results to the experimental results obtained with a stationary passage, the pressure rise due to pumping is subtracted from the inlet pressure to obtain an equivalent pressure of 218 psia. The resulting analytical flow function per blade is 0.0061 lb_m $°R_{1/2}$ (sec.psia) at a pressure ratio of 1.82. Since the endwall spacing was 0.05 inch in this analytical model and the test piece endwall spacing was measured to be 0.06 inch, the analytical model should yield a flow function that is 0.05/0.06 or 0.833 times the experimental results.

The experimental results from Figure 21 indicate a flow function of 0.0076 lb_m $°R^{1/2}$ (s.piai) at a pressure ratio of 1.82. Multiplying 0.0076 by 0.833 gives a flow function that is 3 percent higher than the analytical model. This is a fortunate occurrence since the discrepancy between the methods is well within the uncertainties of the measurements and the analytical model.

7.2.4.4 Final Test Results, Star Blade Model

The results of the final test of the star passage are illustrated in Figure 21. Results of the analytical model indicate a flow of 0.015 lb/sec/blade at an inlet pressure of 270 psia, an exit pressure of 140 psia, and an inlet temperature of 1410°R. Forced vortex pumping effects are not considered in the star piece since most of the flow exits at the same radius as it enters.

The flow function per blade at design point from the analytical model is 0.0021 $°R^{1/2}$ lb_m/sec/psia at a pressure ratio of 1.93. The results of the experimental hardware model indicate a flow function of 0.0027 $°R^{1/2}$ lb_m/(s.psia) at the same pressure ratio. Correcting the experimental hardware results for dimensional inaccuracies, we obtain a flow function of 0.0025 $°R^{1/2}$ lb_m/sec/psia at a pressure ratio of 1.93. Consequently, the corrected hardware model results are 19 percent larger than the analytical model results. This is considered quite satisfactory considering the uncertainty in the loss coefficients used in the analytical models.

7.3 PROTOTYPE HARDWARE COLD FLOW TESTING (See Fig. 11)

Number the blades 1 through 10.

a) Flow with water: to make sure all holes are open

Part	Feedpoint	Plug	Observe
Star	S_2; each hole		S_{81}-S_{84}, S_{11}-S_{14}
Exducer	E_4; each hole		E_{91}-E_{94}, E_{16}-E_{20}
Assembly	E_1; all holes	E_4	Flow at E_{32} in each passage
Assembly	S_2; each hole		Flow around exducer leading edge

b) Flow with air: at a pressure ratio of 1.4083 or 6 psig plenum

Part	Feedpoint	Plug	Acceptable flow function limits $\left(\frac{lb\ °R^{1/2}}{s.psia}\right)$
Star	S_2; each hole		0.0022 ± 0.0002
Exducer	E_4; each hole		0.0055 ± 0.0005
Assembly	E_1; all holes together	E_4	To calibrate slots E_{31}
Assembly	S_2; each hole		0.0022 ± 0.0002

VIII. DETAILED HEAT TRANSFER ANALYSIS

8.1 GAS SIDE HEAT TRANSFER COEFFICIENTS

The primary aim of this project being to prove the feasibility of manufacturing a highly cooled, high pressure radial inflow turbine rotor, and the literature (see App. B) being relatively sparse on the subject of heat loading of such a turbine, it has been decided to not distinguish between the blading suction and pressure side heat transfer coefficient distributions, but rather to use an average distribution, variable along the mean line, but constant from hub to shroud (see Figs. 9-1, 9-2, 9-3). Likewise, the film cooling heat transfer coefficients were assumed to be those calculated for gas flow only.

a) Flow field in the rotor

The surface velocities were nevertheless duly calculated (see App. A) in five streamsheets during the course of the aerodynamic design and the results are used here to properly assess the static pressure distributions near the film and trailing edge ejection ports. Figures 4, 5 and 6 show the surface velocities in the shroud, mid, and hub streamsheets, respectively. The exducer leading edge and the aft hub film cooling air flows are seen to be injected in regions of constant or accelerating external flow, as they should be.

b) Blading heat transfer coefficients

All the available literature resources (see App. B) and a boundary layer analysis were utilized to generate the distributions of Figures 9-1, 9-2 and 9-3.

Important numbers are listed here:

- Exit Reynolds number based on rotor throat area and mean flow length of L_2 = 2.8 inch; $Re_{g,L_2} = 1.814\ 10^6$
- Reynolds number based on mean relative velocity of $\bar{W}_{2-3}$ = 1009 ft/s and L_2 = 2.8 inch; $\overline{Re}_g = 0.871\ 10^6$
- Leading edge Reynolds number based on a diameter of
- $d = t_2 = 0.10$ inch; $Re_{g,t_2} = 23{,}425$
- Leading edge stagnation h.t.c: $h_{g2} = 1246$ Btu/h.ft^2.F
- Exit h.t.c.
  - Per Swartwout: $h_{g3} = 743$ Btu/h.ft^2.F
  - Per Hamed-Baskharone-Tabakoff: $h_{g3} = 647$ Btu/h.ft^2.F

- Average h.t.c.
  - Per flat plate formula: $\bar{h}_{g2-3}$ = 903 Btu/h.ft^2.F
  - Per Halls plot (axial): 611 Btu/h.ft^2.F
  - Per Russian method 1 (mean velocity; factor of 2 for turbulence): 626 Btu/h.ft^2.F
  - Per Russian method 2 (accounts for RPM): 657 Btu/h.ft^2.F

The boundary layer analysis (per NASA TND-5681), together with the leading edge classical formula, gives a blading distribution (Fig. 9-1) whose average is 611 Btu/hft^2°F as obtained from the Halls plot. Figure 9-2 provides the detailed external h.t.c. distribution used on the star blade.

c) Hub surface heat transfer coefficient

The following Russian formula was used:

$\overline{Nu_{g,L_2}} = 0.1\ Re_{g,L_2}^{0.65}$ which yields $\bar{h}_{g,h}$ = 325 Btu/hft^{2}F

This low value is well justified considering the lower and more constant surface velocities prevailing near the hub (see Fig. 6). Figure 9-3 shows the actual distribution of the star disc hug h.t.c. that has been used.

8.2 RELATIVE TOTAL GAS TEMPERATURE

For an uncooled purely radial inflow turbine, this temperature can be calculated from:

$$T_{o,rel}(r) = R.I.T. -3.0416\ 10^{-9} \frac{N^2}{\bar{c}_{pg}} \left[R_2^{\,2} - \frac{r^2}{2}\right] \quad (°F)$$

In our design, however, the flow enters with a 10^0 positive incidence (see Fig. 3), and it is thus necessary near the tip to use the results of the external flow analysis to calculate:

$$T_{o,rel}(r) = T + 1.997\ 10^{-5} \frac{W^2}{\bar{c}_{pg}} \quad (°F)$$

For the 2800°F R.I.T., we find (see Figs. 2 and 8-a):

at the tip (6.5 inch diameter): $T_{o,rel,2}$ = 2553°F

at the exducer O.D. (4.25 inch diameter): 2455°F

I.D. (2.419 inch diameter): 2395°F

for a rotor average relative total gas temperature of 2490°F (i.e., 310°F below the R.I.T.). To be conservative, we used the full total relative gas temperature distribution of Figure 8-a for the source temperatures to calculate the heat loads at non-film cooled locations, and the adiabatic wall film temperatures (see Figs. 8-b and 8-c) on the film-cooled portions.

8.3 APPROXIMATE HEAT LOAD ON TURBINE WHEEL (See Also Page 11)

Exposed Portion	Net Total Area (in.^{2})	Average Gas-Side h.t.c. (Btu/ hft^{2}F)	$\left[\overline{T}_{o,rel}-\overline{T}_m\right]^*$ (°F)	Q(Btu/s)	Total Coolant Flow (lb/s)	Coolant Temp. Rise (°F)
Blading	36.53	611.0	900.0	38.750	0.50	287.0
Hub Surface (net)	23.88	325.0	900.0	13.474	0.15	333.0
	60.41			52.224	0.65	

* $T_{o,rel}$ = 2490°F
$\overline{T}_m$ = 1590°F (surface)

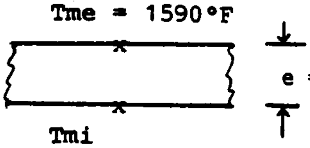
<u>Typical Blading Heat Flux</u>

x $\overline{T}_{o,rel}$ = 2490°F

$\overline{h}_g$ = 611 Btu/h.ft^2.F

IN-792 blade wall Tme = 1590°F

$k_m = 13.5 \dfrac{Btu}{hftF}$



e = 0.025 to 0.040 inch

Tmi

h_c

Cooling air x T_c

To achieve a wall external temperature of 1590°F with a local gas total relative temperature of 2490°F, the cooling flow must remove a heat flux of:

$q'' = (2490-1590)611 = 549{,}900$ Btu/h.ft^2 and a wall gradient of

$$\frac{\Delta T_m}{\Delta e} = \frac{549{,}900}{13.5 \quad 12} = 3{,}394 \text{ °F/in. results}$$

The wall thermal differential (Tme-Tmi) amounts to 102, 136, 170 and 204°F for a 0.030, 0.040, 0.050 and 0.060 inch thick wall, respectively! It is thus mandatory to cast the walls as thin as feasible. For example, with the 0.060-inch wall, the internal surface would be at Tmi = 1386°F and with a coolant-side h.t.c. of h_c = 2000 Btu/hft^{2}F, the local coolant temperature T_c must not be higher than 1111°F, i.e., 161°F above the supply temperature. This explains the moderate global coolant temperature rises shown in the last column of the table above.

For the 0.060-inch thick wall, the resistances to heat flow are:

- Gas side: $\frac{1}{h_g} = 0.001637 \frac{hft^2F}{Btu}$
- Wall: $\frac{e}{k_m} = 0.000370 \frac{hft^2F}{Btu}$
- Coolant side: $\frac{1}{h_c} = 0.000500 \frac{hft^2F}{Btu}$.

for a total of $\frac{1}{U} = 0.002507 \frac{hft^2F}{Btu}$ or $U = 398.883 \frac{Btu}{hft^2F}$.

The wall resistance for a thin 0.060-inch wall is clearly of the same order of magnitude as the coolant side resistance. For a thicker wall (say 0.18"), the wall resistance approaches the gas-side one.

8.4 FILM COOLING

This technique is used at four locations (see Figs. 10, 11), namely to protect the hub by injections at points A_2 and E_{32}, to evacuate the spent air out of the star blades through slots S_{11} to S_{14}, thereby film cooling the leading edge of the exducer blades (see Fig. 1-b) and at the blade tip leading edges (holes S_{81} to S_{84}). Figures 8-b and 8-c show the adiabatic wall film temperatures versus the distance from the injection points used in the two analytical heat transfer models.

IX. HEAT TRANSFER MODELS AND RESULTS

Two steady-state analytical thermal models were devised: one for a 1/10 pie-shaped segment of the assembled disc (see Fig. 22), and one for the two components (star and exducer) of half a blade (see Fig. 23). The disc model has boundary nodes that simulate one full blade, and the half blade model has boundary nodes that simulate the disc; the two models were run several times until agreement was found at the blade-disc interfaces where the heat leaving the blade walls must equal the heat entering the disc.

9.1 DISC MODEL (Fig. 22; Appendix C)

Characterized as follows:

- Axisymmetric pie-shaped ($\Delta\theta = 360°/10 = 36°$) per Figure 22.
- 359 nodes total, of which 267 are metal nodes
- 632 conductances per network of Appendix C
- Material conductivity of IN-792 per Figure 24.
- Cooling heat transfer coefficients:
  - on back face per Figure 25
  - in holes A (Fig. 22); $\bar{h}_c$ = 765 Btu/hft^{2}F
    - B 808 " "
    - C 449 " "
    - D 701 " "
  - no contact resistance between the two disc parts
  - adiabatic wall film temperatures per Figure 8-b
  - the heat exchange with the blade takes place between each disc surface node and a blade boundary node

9.2 BLADE MODEL (Fig. 23; Appendix D)

Only <u>half a blade</u> was modeled using the external streamwise h.t.c. distribution of Figures 9-1 and 9-2 for both suction and pressure sides, and from hub to shroud. This is realistic as the cooling air, the blade cavity end caps, the webs, the pin fins and the disc altoghether tend to equalize the leading and trailing wall metal temperatures. A three-layer model (see Fig. 23) was used for each wall (star and exducer) including the associated edges with the nodes placed on the external and internal surfaces and at mid-wall thickness, thereby accounting for the full wall resistance to heat flow. In the vicinity of the disc hub, each layer is connected to a single local disc node whose temperature has been iteratively calculated with the disc model. The disc model ($\Delta\theta$ = 360°/10 = 36°) concerns one full blade, and each of the hub surface nodes is connected to a single equivalent local blade node (in fact, the mid-wall layer node) through a conductance equivalent to six conductances of the blade model (three layers and two half blades).

Each half blade region is cooled by half of the local cooling air flow. The effect of rotation on the coolant temperature has been neglected.

Figures 26 and 27 show the internal heat transfer coefficients used inside the star and exducer blade passages, respectively. Figure 28 gives the several coolant flow networks used to simulate coolant temperature rise, to calculate mixed flow temperatures,.....

The blade model is characterized by a total of 271 nodes, of which 159 are metal nodes.

9.3 CALCULATED TEMPERATURES

These can be consulted in Appendices C and D for the disc and blading models of Figures 22 and 23, respectively.

A few predicted temperatures are shown in Figure 29 for the two-piece disc and in Figures 30, 31-a and 31-b for the two-piece blade.

Maximum disc temperature has been estimated at 1592°F at node 74 (Fig. 29). The star disc rim is well cooled by backide impingement and film-cooled on the gas-side ($T_2 \simeq$ 1400°F).

Maximum blade temperature occurs at node 76 (Fig. 30) where the external wall is at 1825°F and the internal at 1529°F, i.e., a differential of 296°F exists across a wall 0.170 inch thick. The star blade temperature in this attachment region could be reduced by changing the star blade flow split, i.e., by opening the S_4 orifices (see Fig. 11). It is also conceivable to add a radial row of film cooling holes where needed in the attachment region of the star blade.

X. FINAL DIMENSIONS (Figs. 11 and 1-a)

S_2	10 holes	dia. 0.110	E_8		0.430 x 0.050
S_3	10 holes	0.160 x 0.050	E_{10}		0.275 x 0.050
S_4	2 holes	dia. 0.026	E_{12}		0.430 x 0.050
S_5		0.220 x 0.050	E_{13}		0.360 x 0.050
S_6		0.150 x 0.050	E_6		0.050 x 0.050
S_7		0.063 x 0.050	E_{14}		0.260 x 0.050
S_9		0.070 x 0.050	E_{24}		dia. 0.050
S_{81}-S_{84}	4 holes	dia. 0.0235	E_{15}		dia. 0.050
S_{10}		0.160 x 0.050	E_{20}		0.15 x 0.050
S_{11}		0.080 x 0.050	E_{19}		0.14 x 0.050
S_{12}		0.125 x 0.050	E_{18}		0.15 x 0.050
S_{13}		0.100 x 0.050	E_{17}		0.14 x 0.050
S_{14}		0.095 x 0.050	E_{16}		0.125 x 0.050
E_1-E_2	10 holes	dia. 0.160	E_{91}-E_{94}	2 holes	dia. 0.050
E_{31}	10 slots	0.037 x 0.0625	Trip strips:		height 0.010
E_{32}		gap 0.025			spacing 0.100
E_4		dia. 0.160	88 pin fins:		dia. 0.025
E_5		0.325 x 0.050	Tip thickness:		t_2 = 0.110

XI. CLOSING REMARKS

Every attempt has been made in this design to flow fresh cooling air in the highly stressed attachment region of the blades. This is the case (Fig. 11) for the passages S_5-S_6, S_4-S_{14}, and E_6. Highest calculated metal temperatures occur in the star piece in the S_{14} region where the blade roots are quite thick; note that the S_4 holes could be opened and that a larger number of the the E_{31} slots could be used to improve the cooling effectiveness in that region. Airfoil film-cooling could also be considered by means of a radial row of film holes drilled in the S_4-S_{14} region.

The present design achieves a minimum blading external wall cooling effectiveness (Fig. 30) based on the entrance relative total gas temperature of;

$$\eta_{b,e} = \frac{2553-1825}{2553-950} = 0.454$$

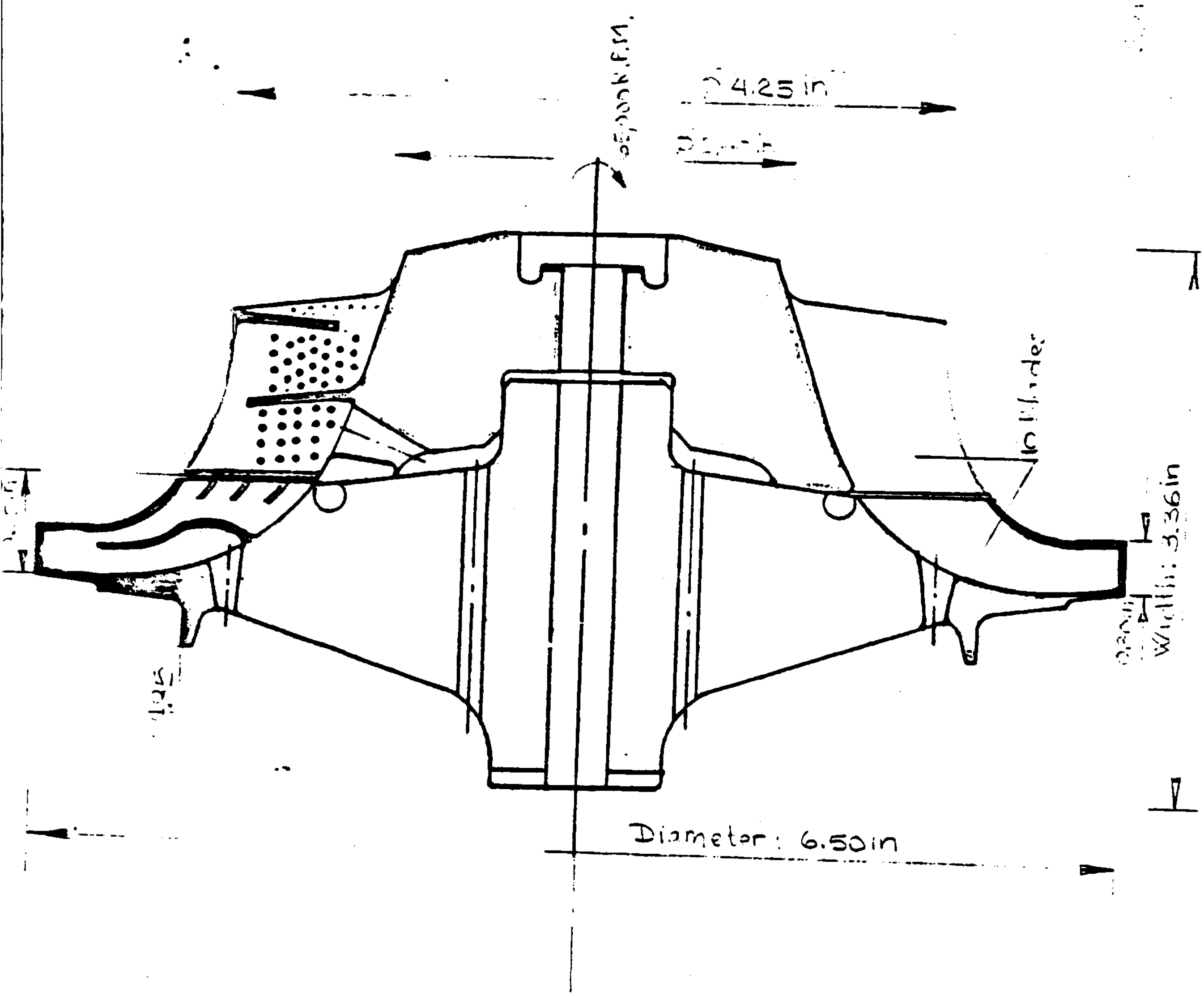
which could be improved, as explained above.

Another approach would be to run the rotor at 2200°F relative total temperature, i.e., at 2450°F R.I.T. (minimum NASA goal being 2420°F), with the maximum blading temperature left below 1630°F for longer life; the minimum cooling effectivensss would still be:

$$\eta_{b,e} = \frac{2200-1630}{2200-950} = 0.456$$

The aerodynamic penalties associated with coolant flow reinjection have been estimated to be 3.4 percentage points which would reduce the total-total isentropic efficiency ηtt_{0-3} from 0.848 for the uncooled turbine to 0.814 for the cooled turbine.

A logical extension of this program would, of course, be to measure the performances of this cooled rotor and to compare them to those of the uncooled version.



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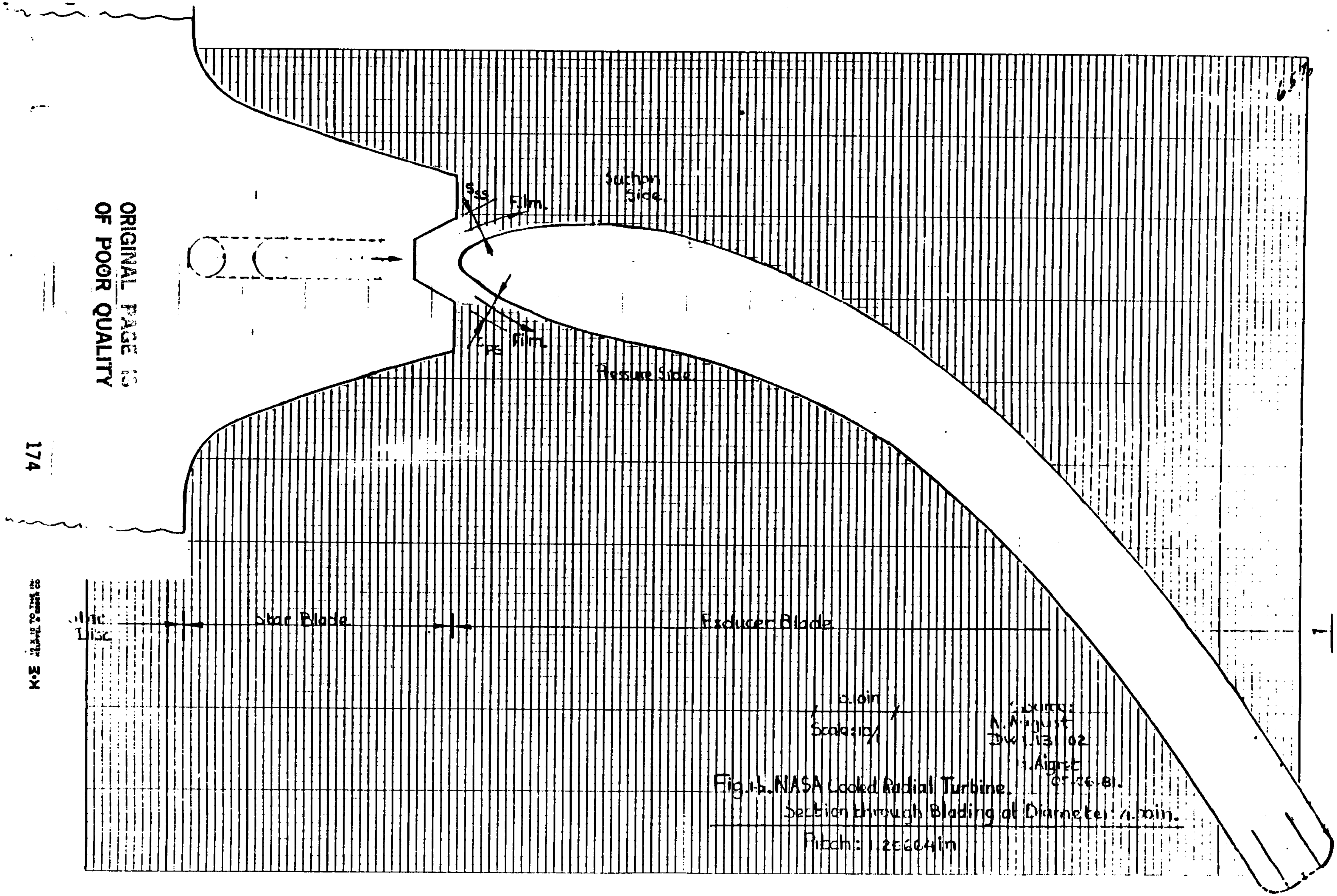

Fig. 1-b. NASA Cooled Radial Turbine.
Section through Blading at Diameter

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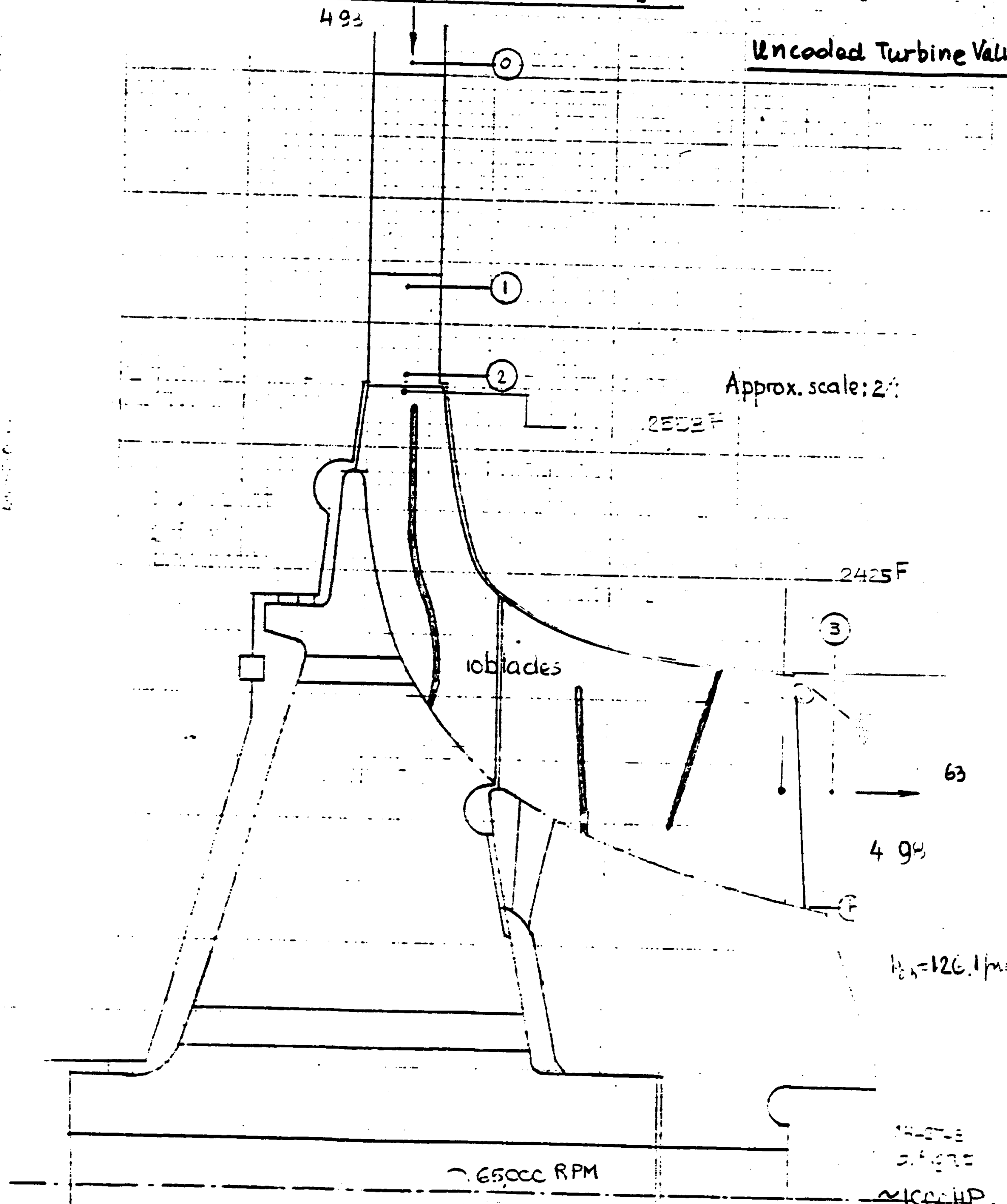
Fig.2 . NASA Cooled Radial Turbine Project.



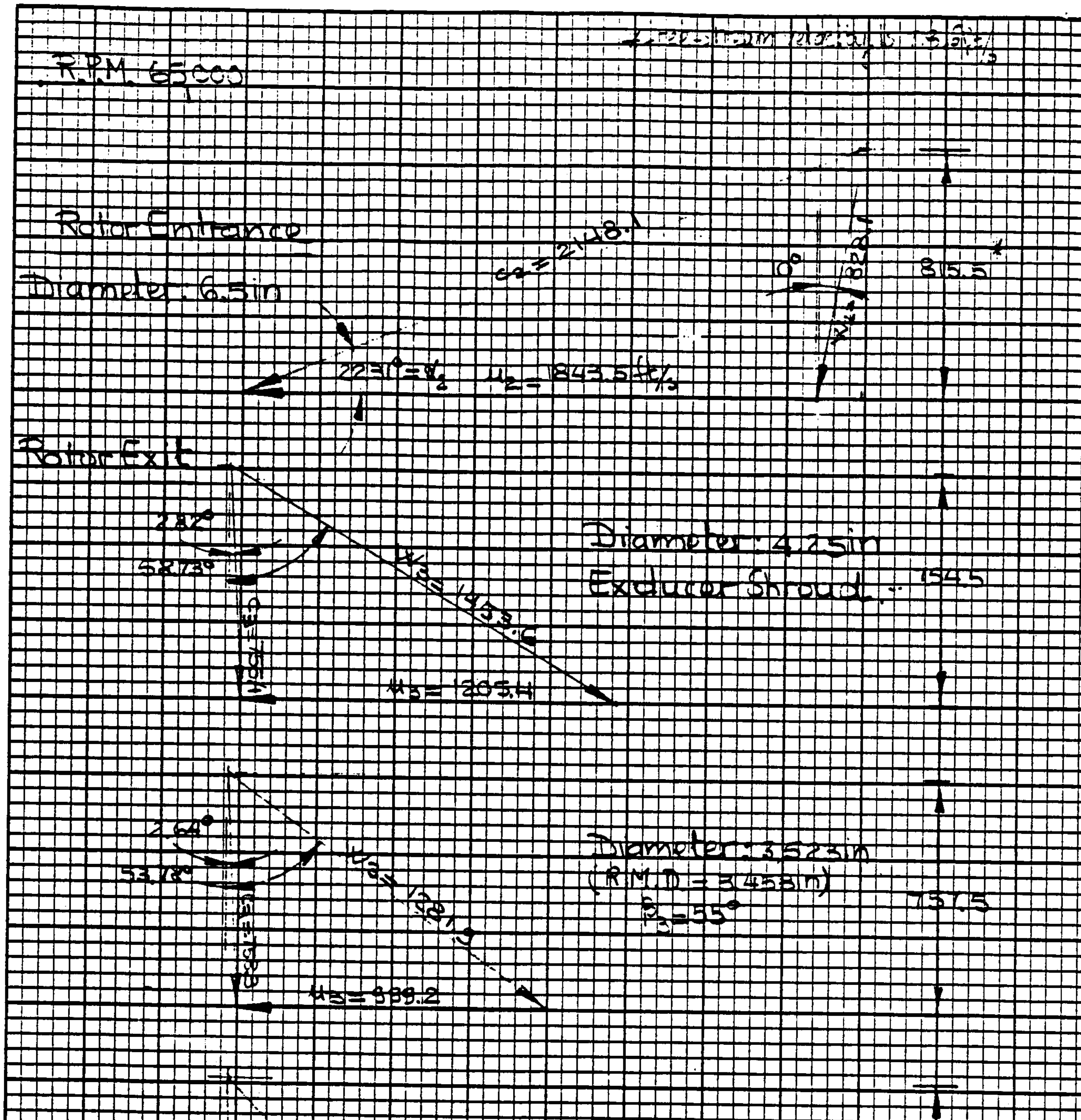


Fig 3 NASA Cooled Radial Turbine
Blocked Velocity Triangles
Source: C. Rodgers 03-24-81

Uncooled Turbine Analysis.

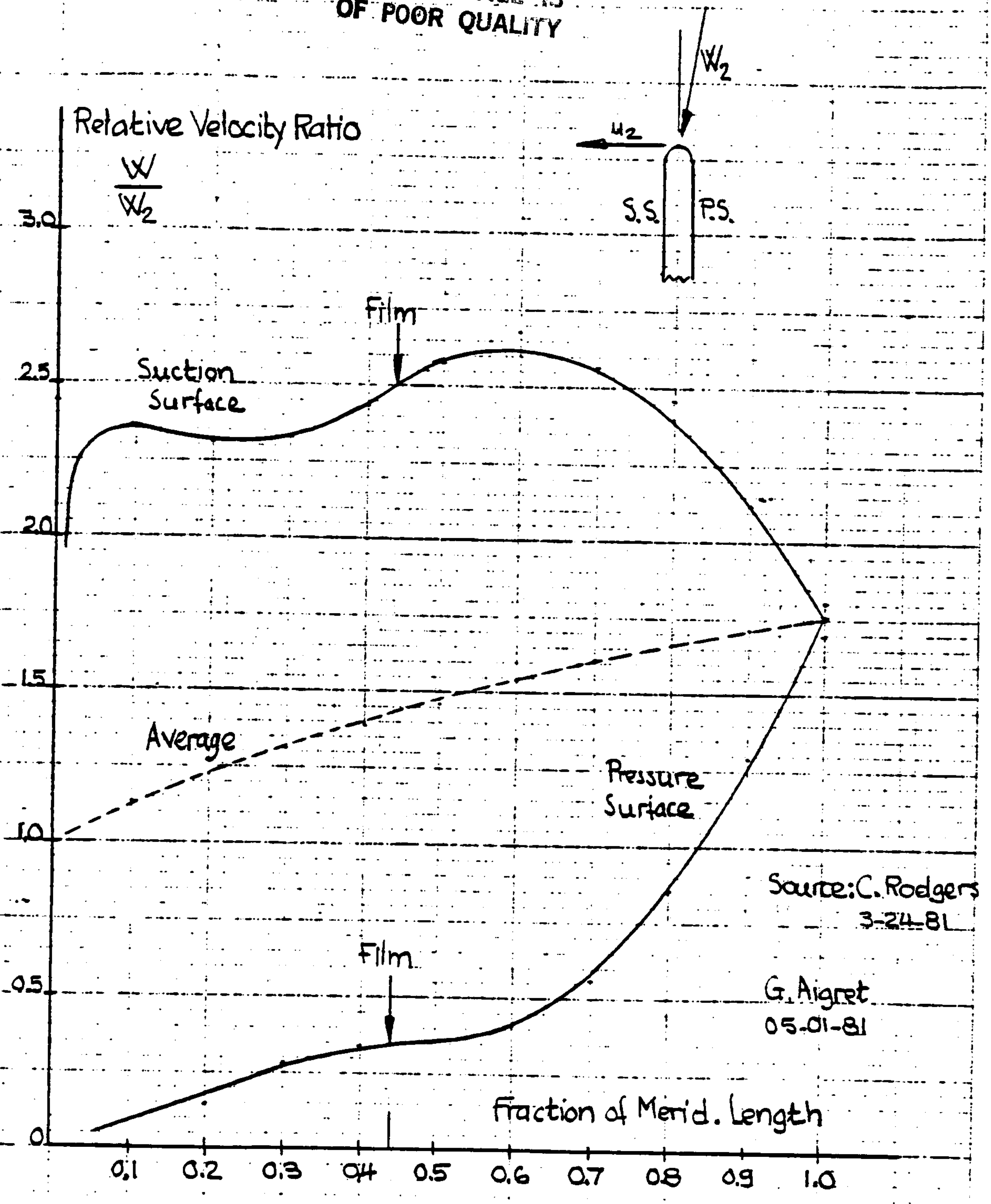


Fig. 4. NASA Cooled Radial Turbine,
Blade Relative Velocity Distribution near Shroud.

- Meridional Line Length: 2.059 in.
- Actual Length:
- Entrance Relative Velocity: $W_2 = 828.1$ ft/s (blocked)

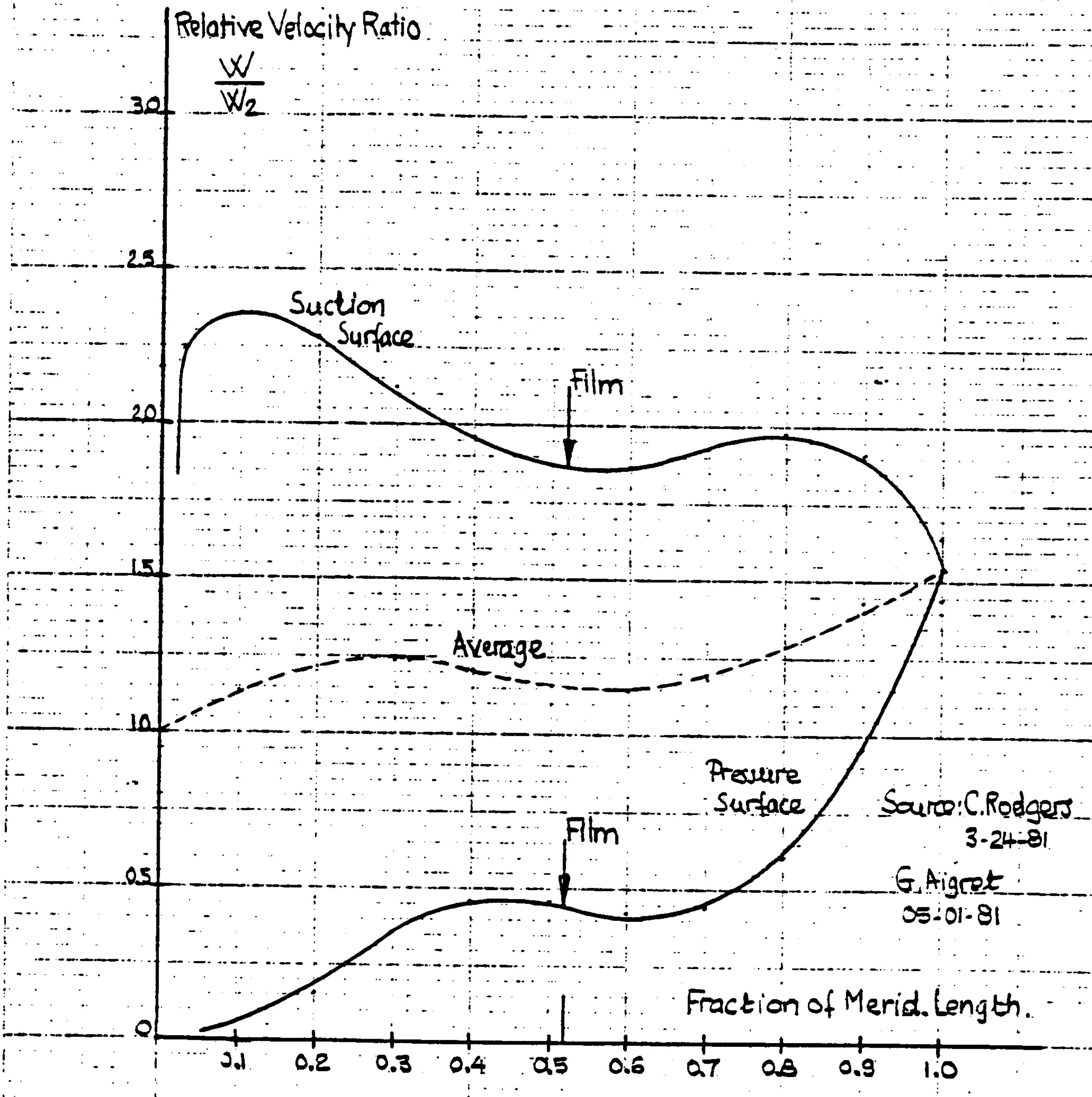


Fig.5. NASA Coded Radial Turbine.

Blade Relative Velocity Distribution near Mid. Passage.

- Merid. Line Length: 2.366 in
- Actual Length:
- Entrance Relative Velocity: $W_2 = 228.1$ ft/s (blocked)

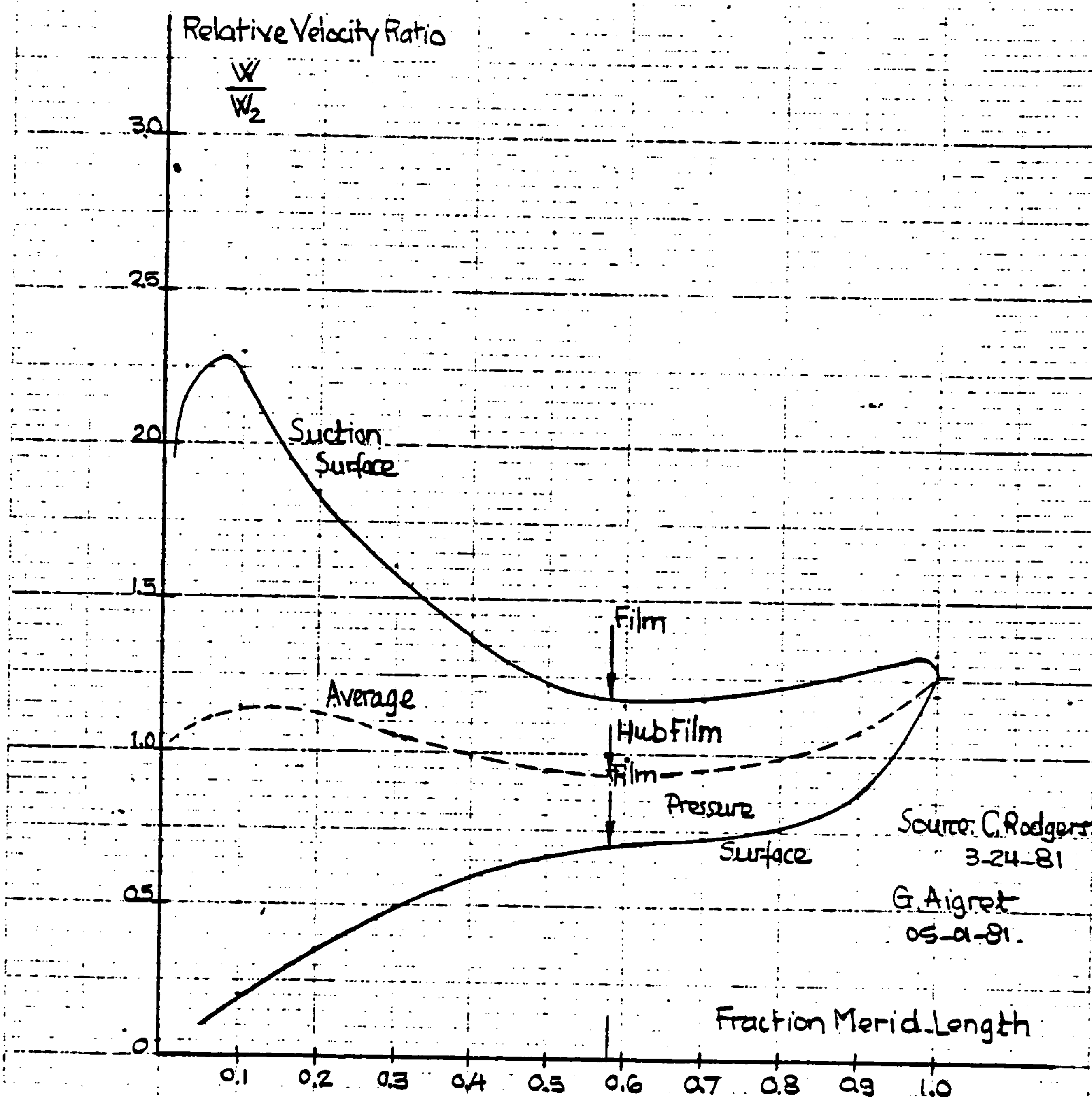


Fig. 6, NASA Cooled Radial Turbine
Blade Relative Velocity Distribution near Hub.

- Merid. Line Length: 2.918 in.
- Actual Length:
- Entrance Relative Velocity: W2 = 828.1 ft/s (blocked)

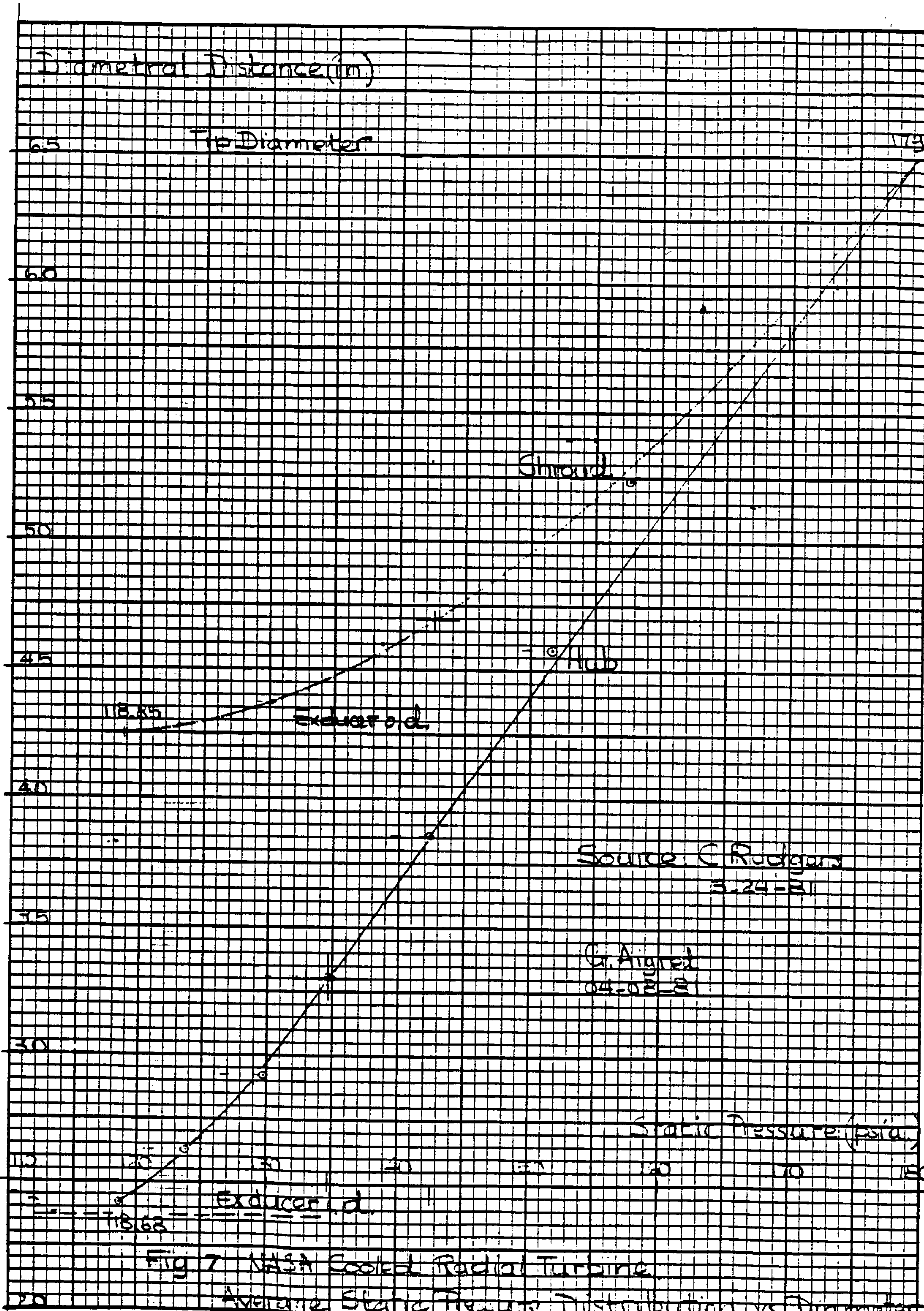


Fig 7 NASA Cooled Radial Turbine
Average Static Pressure Distribution vs Diameter

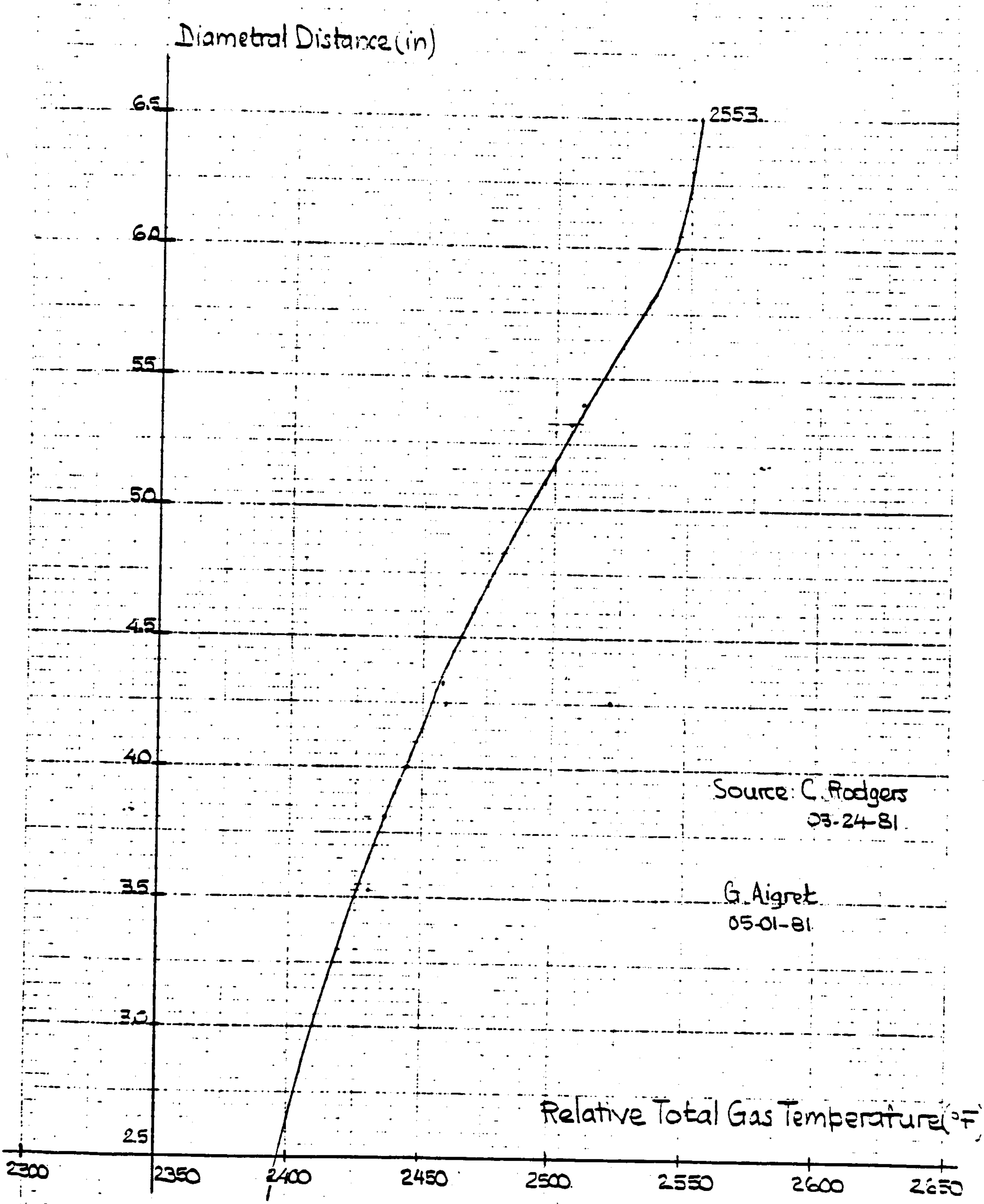


Fig. 8-a NASA Cooled Radial Turbine.
Relative Total Gas Temperatures (without cooling)

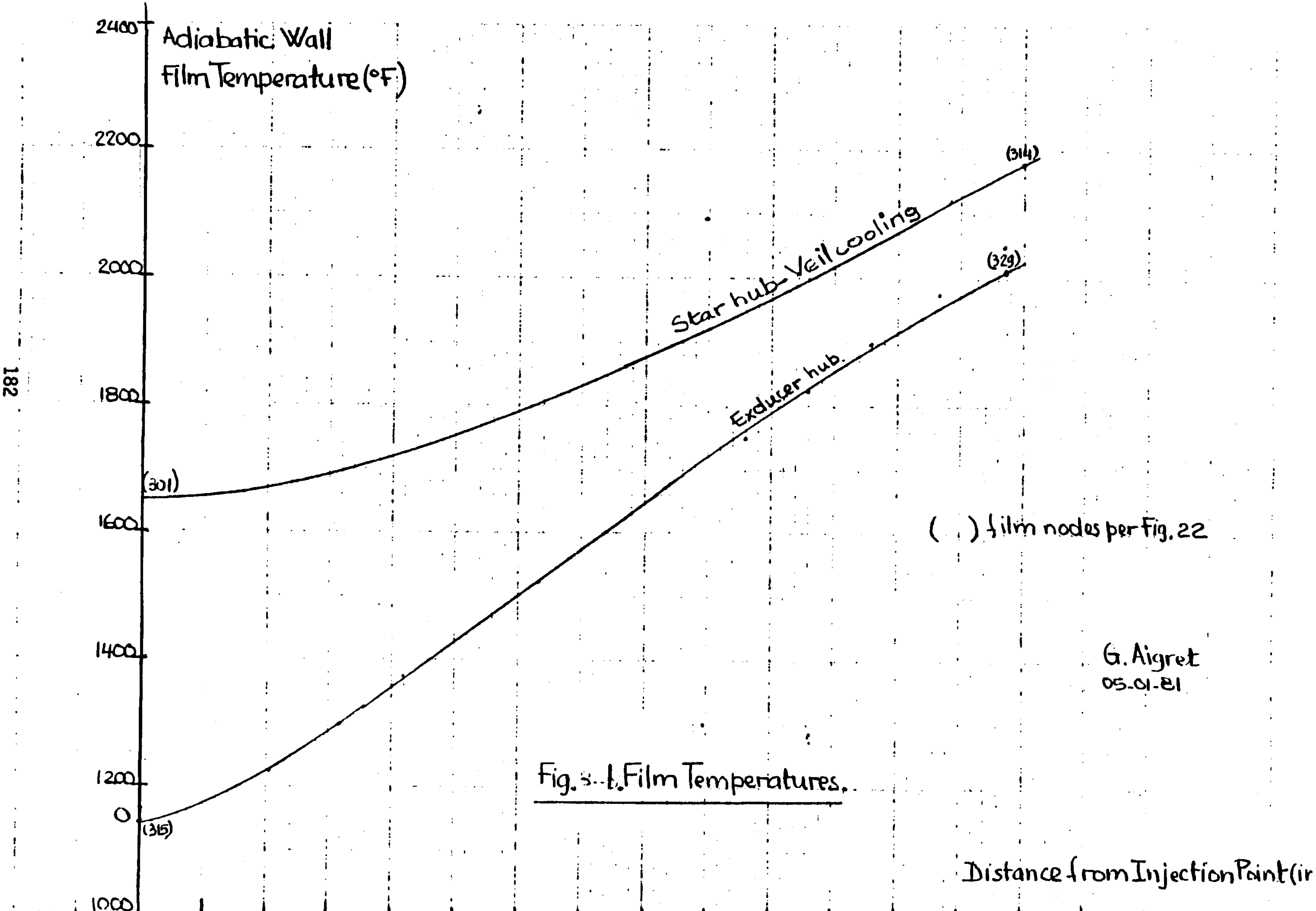


Fig. 5.1. Film Temperatures.

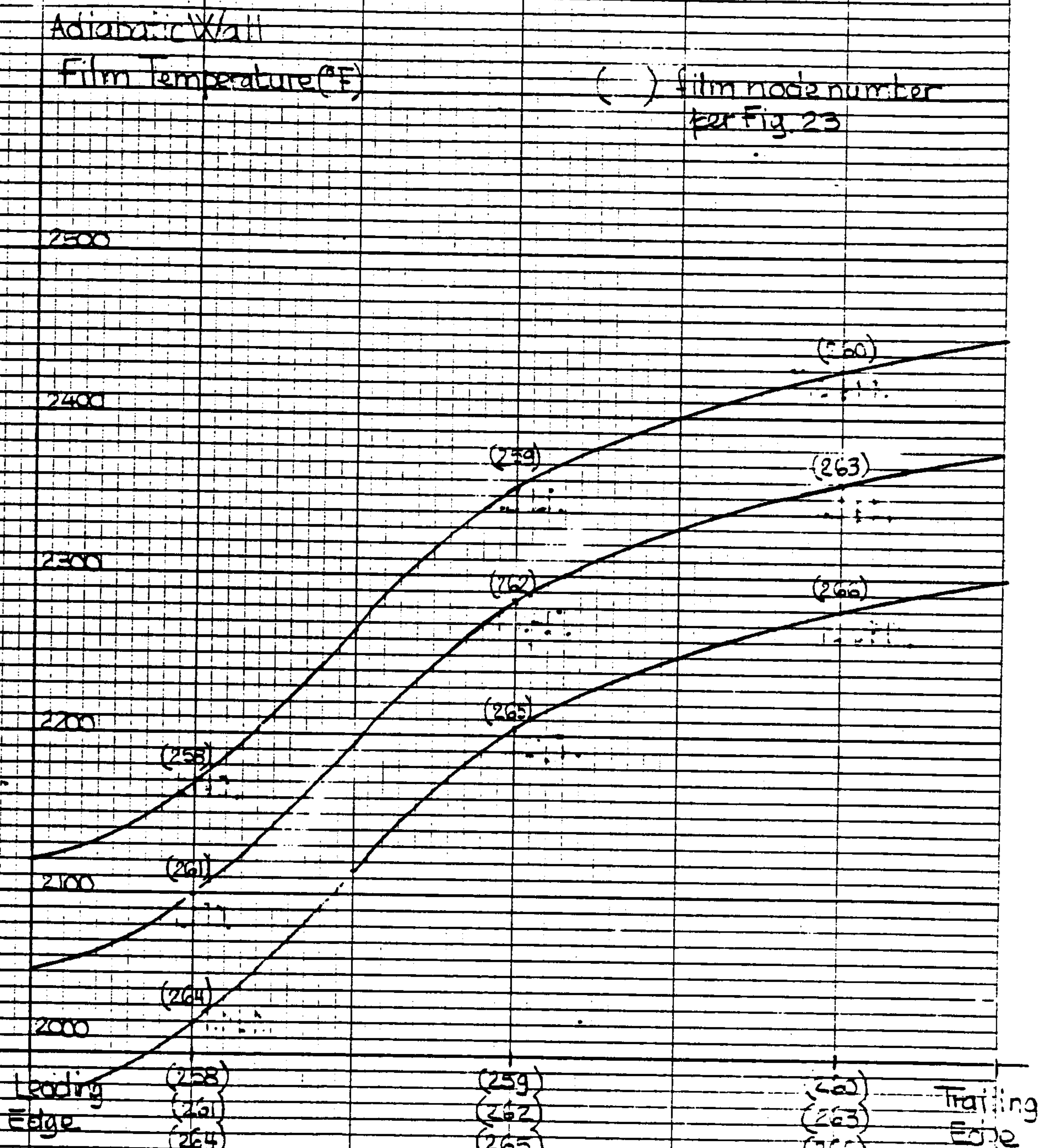


Fig. 3-?, Exducer Blade Film Temperatures.

Aigret
05-22-81

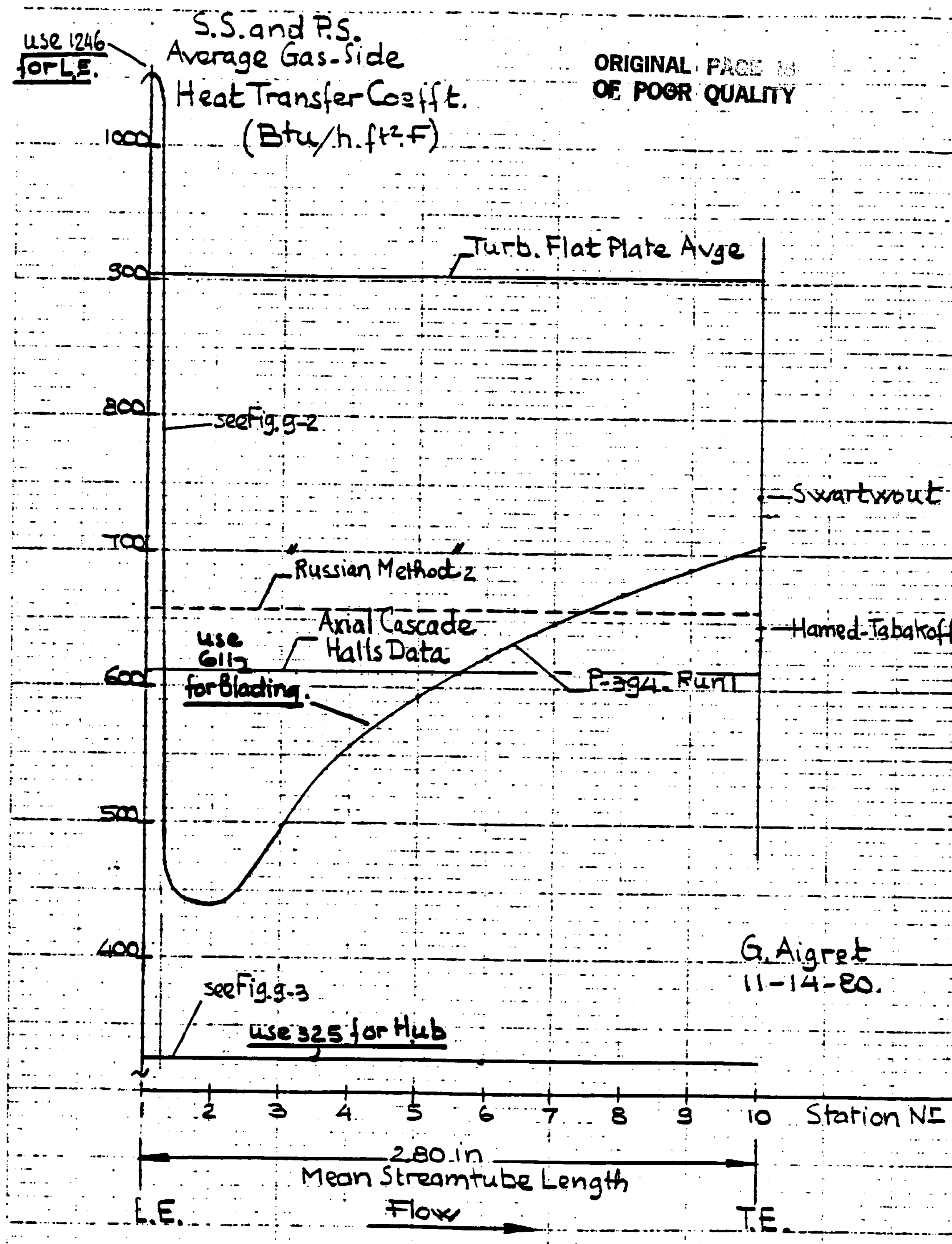


Fig. 9-1. NASA Cooled Radial Turbine. Gas-Side Heat Transfer Coefficient.

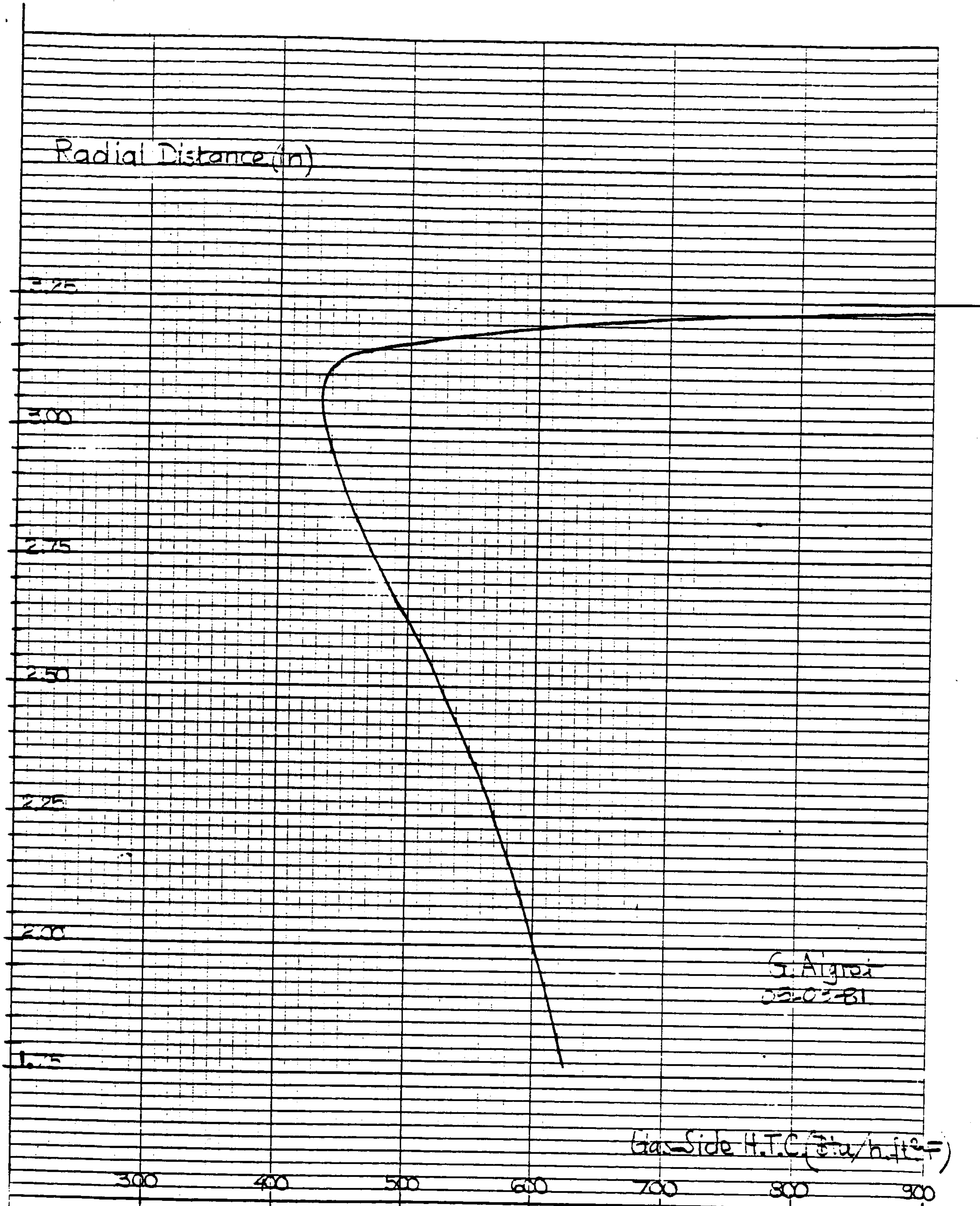


Fig. 32. NASA Cooled Radial Turbine.
Star Blade External Heat Transfer Coefficient.

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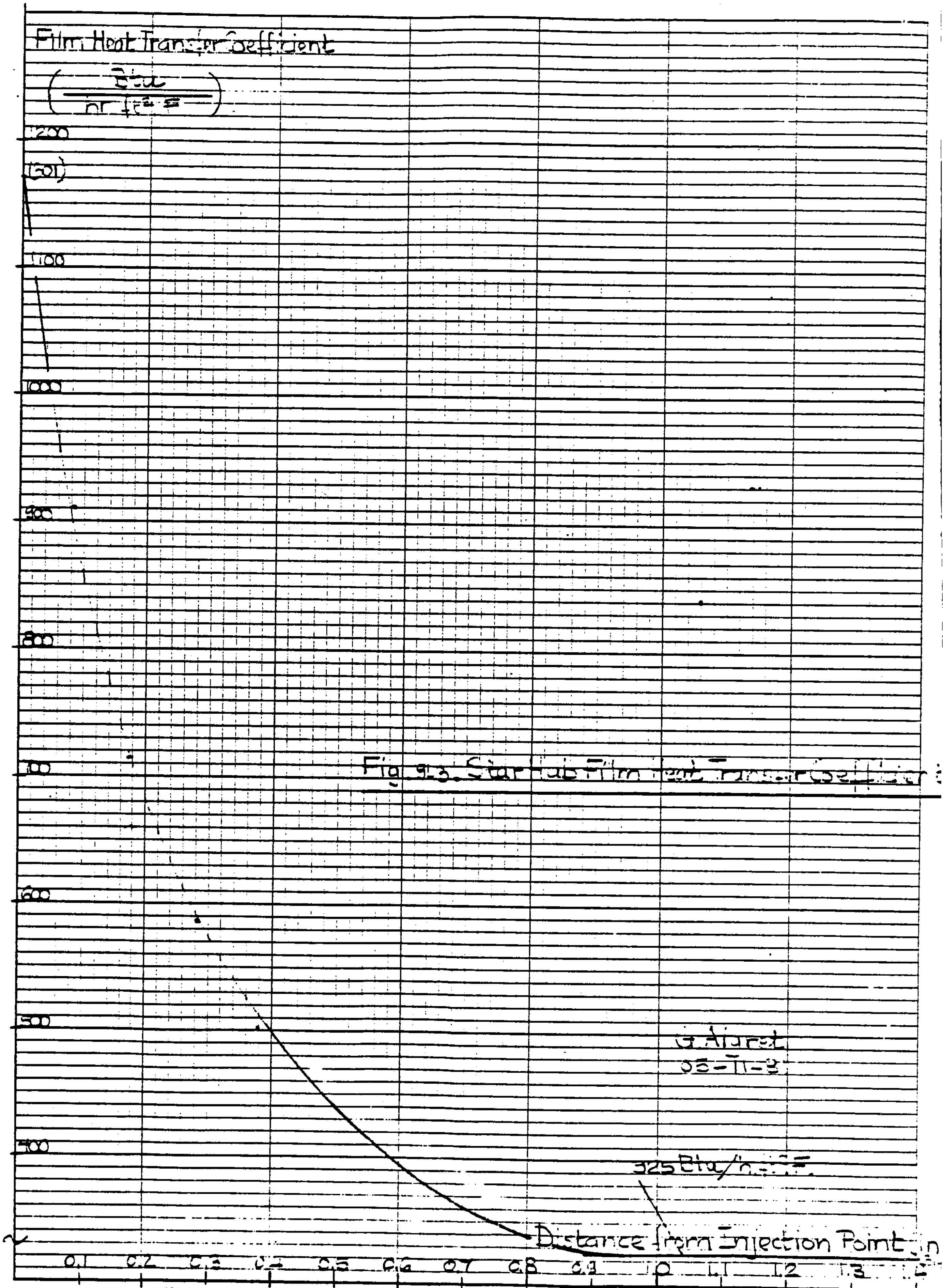
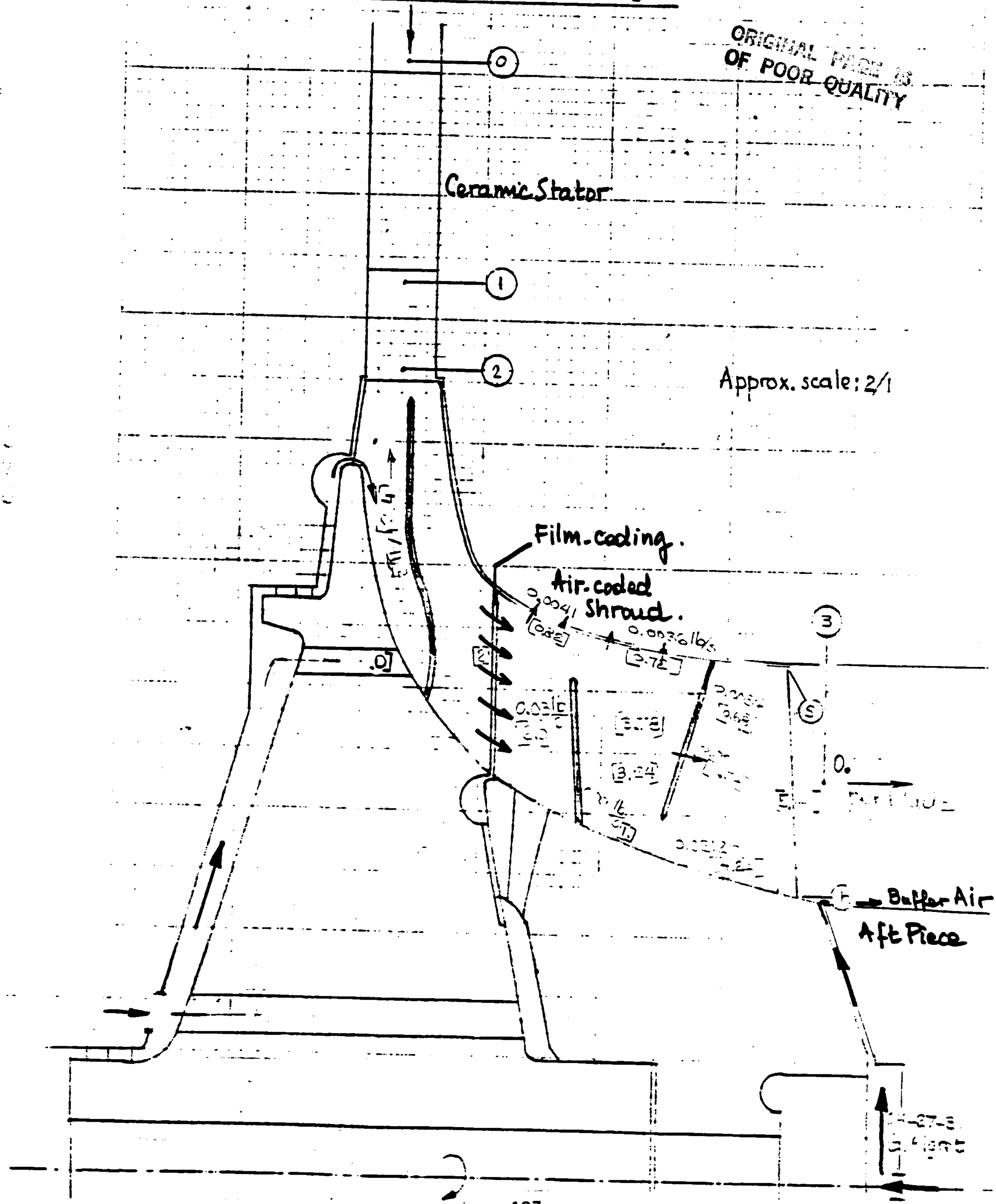


Fig. 9.3 Star Tub Film Heat Transfer Coefficient

Fig. 10. NASA Cooled Radial Turbine Project.



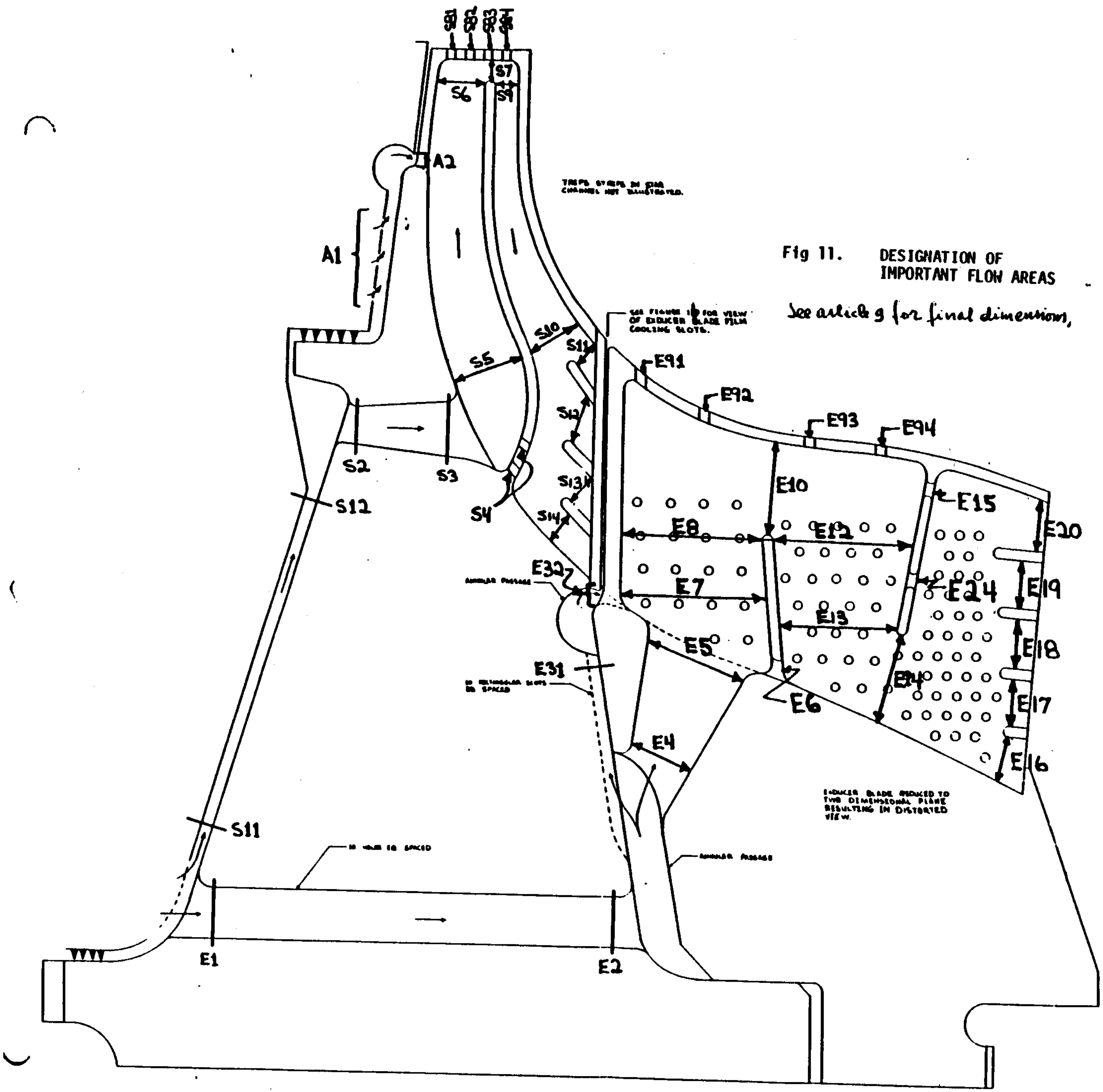


Fig 11. DESIGNATION OF IMPORTANT FLOW AREAS

See article 9 for final dimensions,

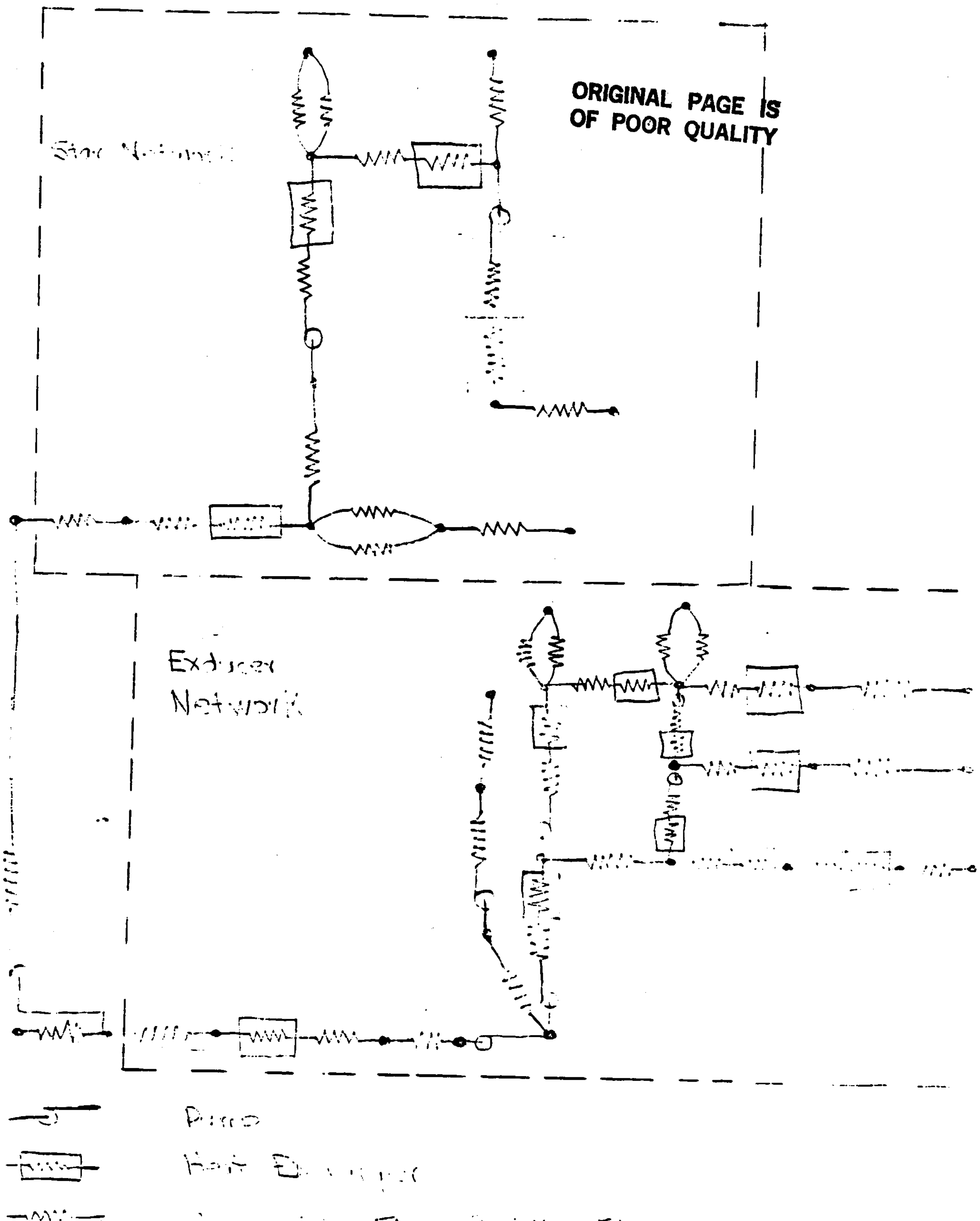


Figure 1 [illegible] Network [illegible]

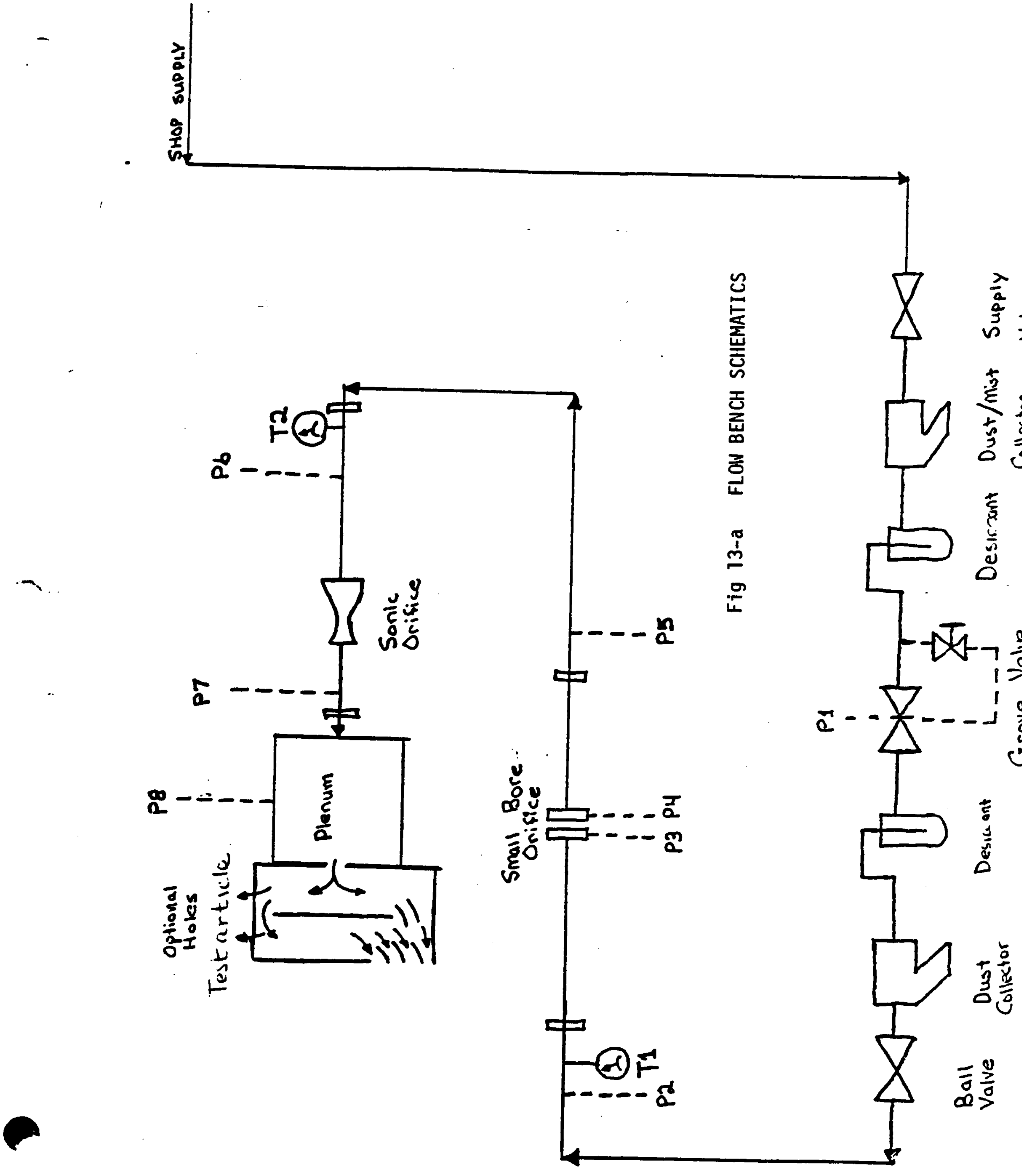


Fig 13-a FLOW BENCH SCHEMATICS

TEST:

DATE: **TIME:**

Bench Temps			Bench Gauges				Bench Manometers				Barometer		
Bench Amb. (°F)	S.B. Upst. (°F) T1	Sonic Upst. (°F) T2	Grove Press. (PSIG) P1	S. Bore Downstr. (PSIG) P5	S. Bore Upstream (PSIG) P2	S.B. Inlet Flange (PSIG) P3	Test Plenum (in Hg) P8	Sonic Orifice ΔP (in Hg) P6-P7	Sonic Upstr. (in Hg) P6	S. B. ΔP (in H_2O) P3-P4	Press (in Hg)	Temp. (°F)	Corrected Press. (in Hg)
±1°F	±1°F	±1°F	±1 psi	±1 psi	±1 psi	±1/2 psi	±1 in	±1 in	±1 in	±1 in			

COMMENTS:

Fig 13-b COLD FLOW DATA SHEET

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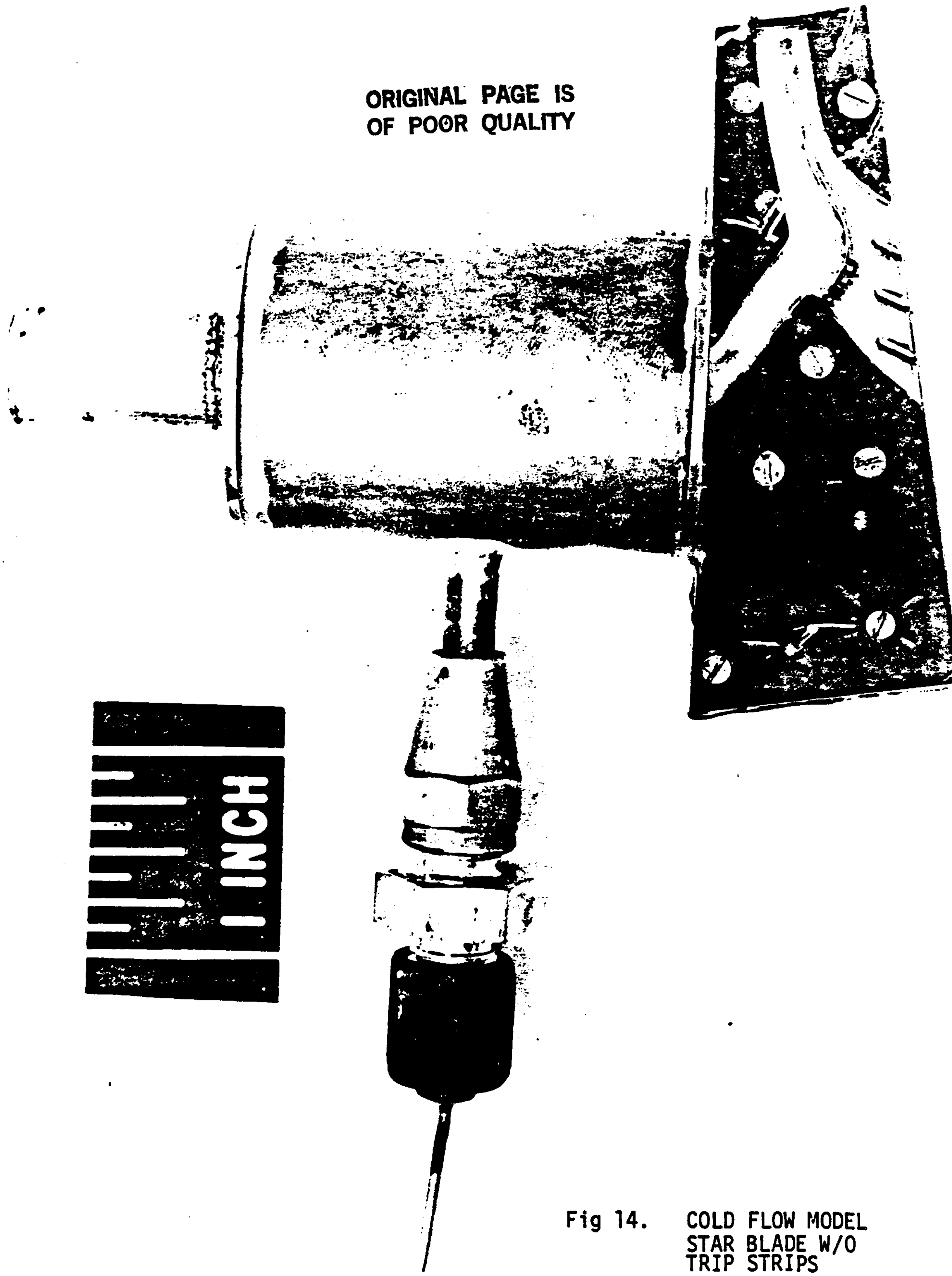

Fig 14. COLD FLOW MODEL
STAR BLADE W/O
TRIP STRIPS

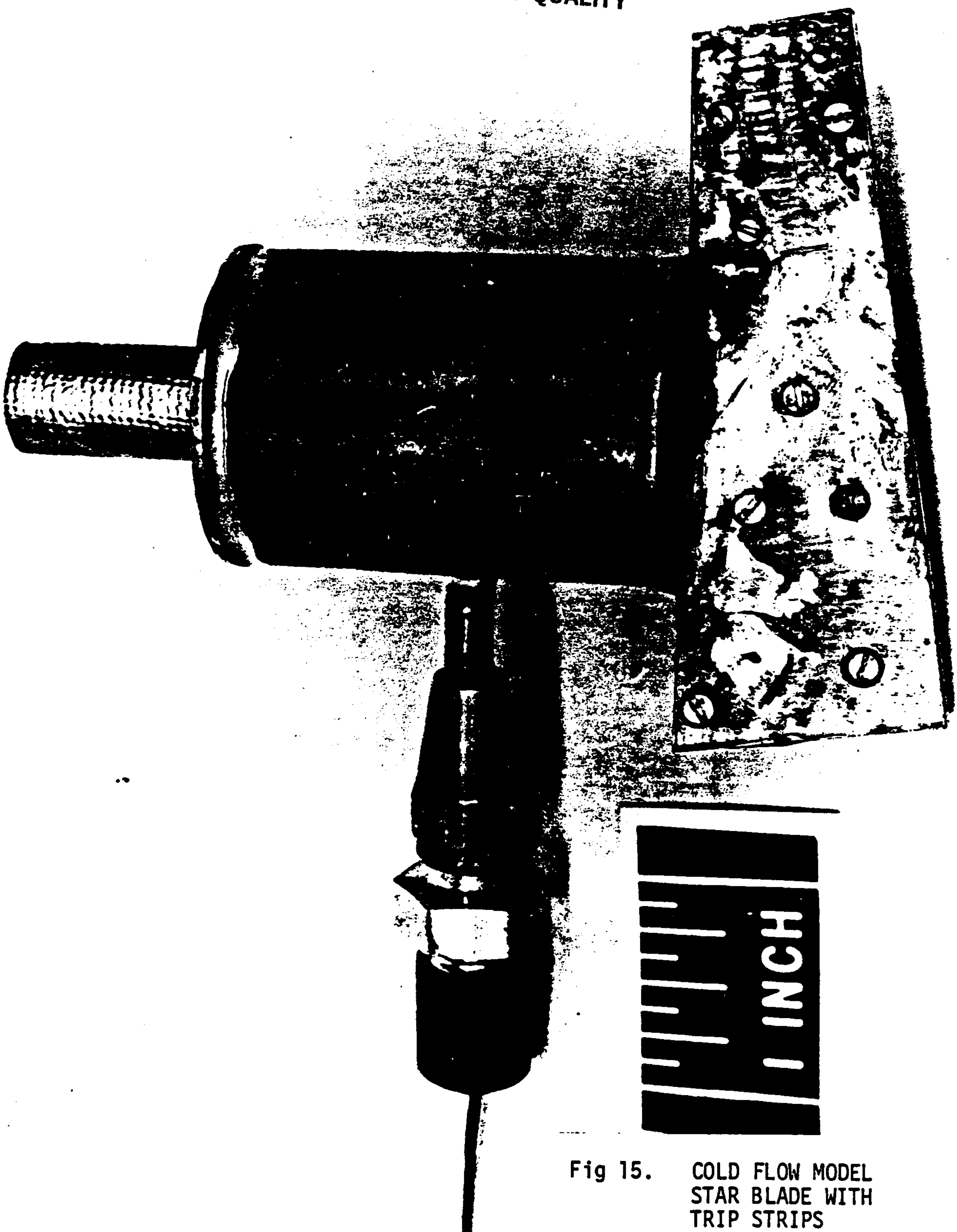

Fig 15. COLD FLOW MODEL STAR BLADE WITH TRIP STRIPS

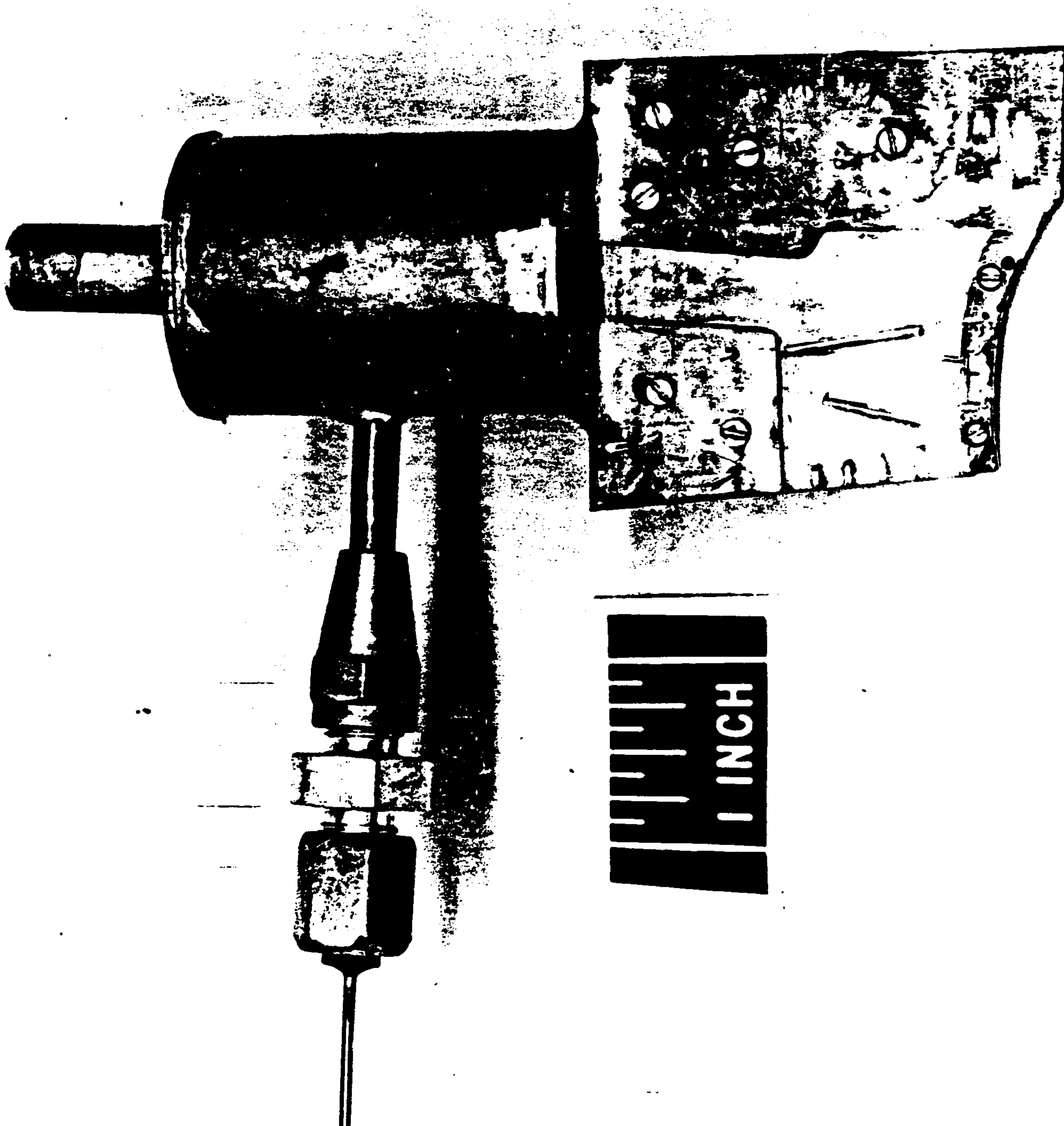

Fig 16. COLD FLOW MODEL EXDUCER BLADE W/O PIN FINS

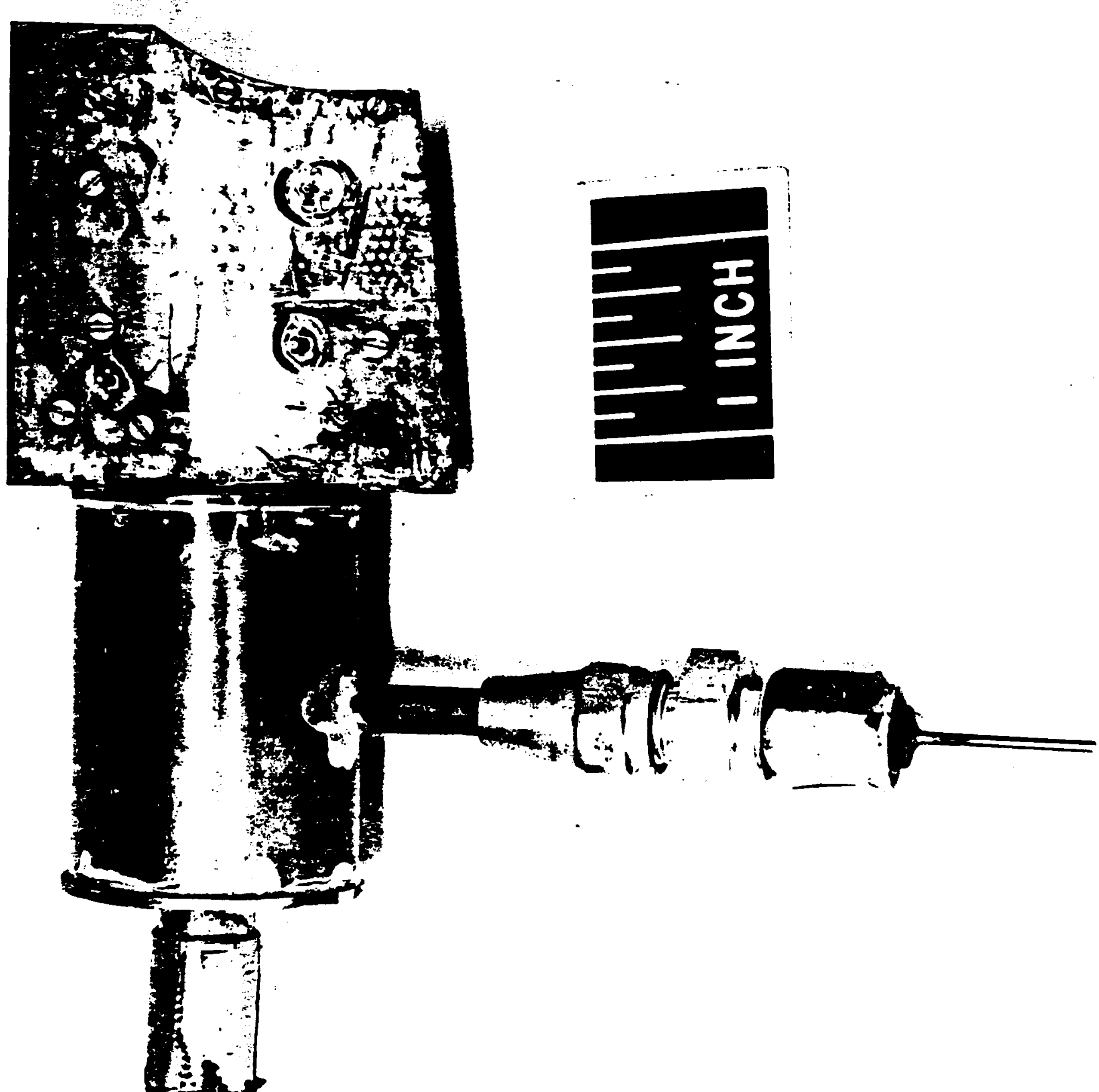

Fig 17. COLD FLOW MODEL EXDUCER BLADE WITH PIN FINS

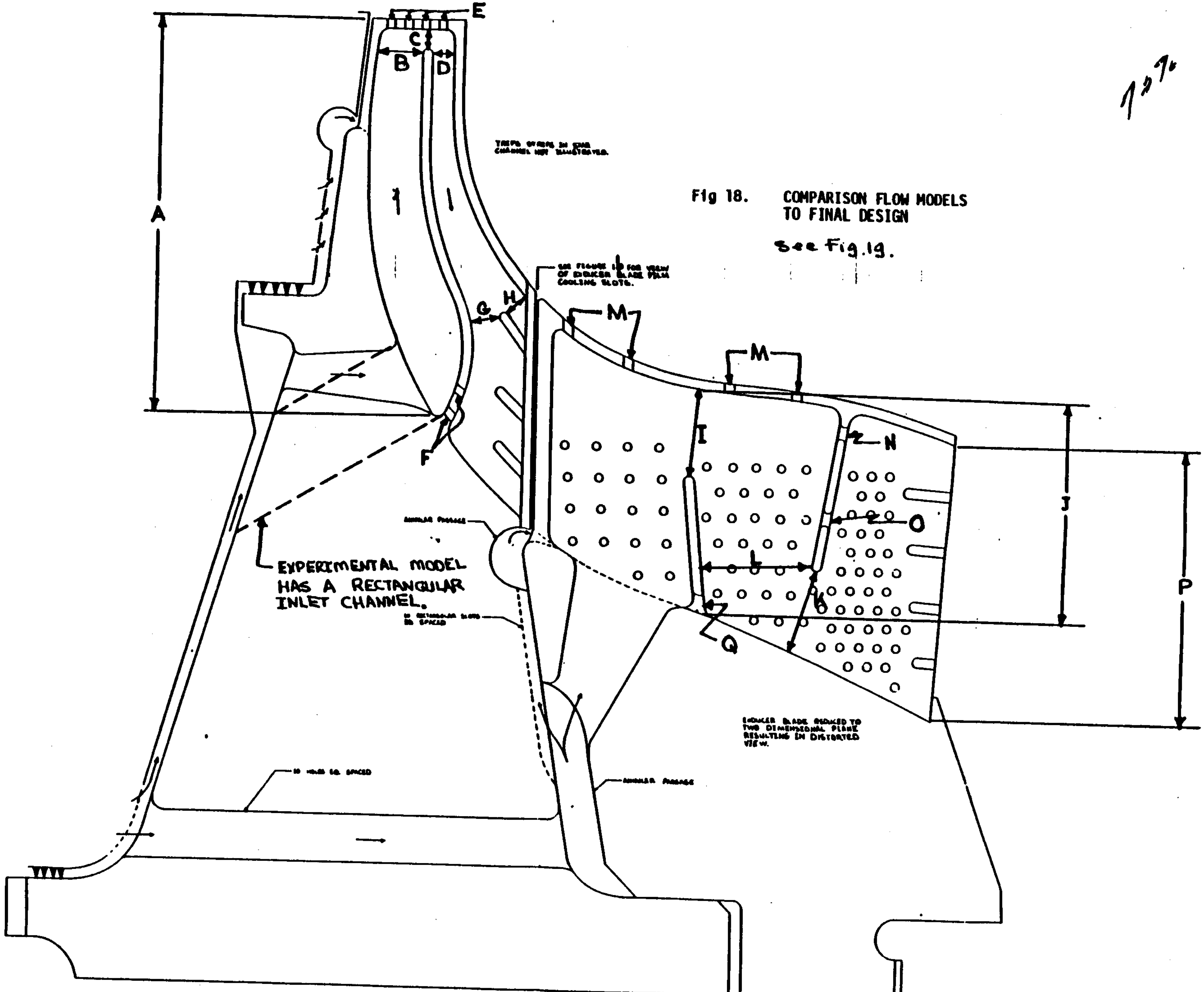

Fig 18. COMPARISON FLOW MODELS TO FINAL DESIGN

See Fig. 19.

COMPARISON OF DIMENSIONAL ACCURACIES BETWEEN EXPERIMENTAL FLOW MODELS AND THE [EARLY] DESIGN DRAWINGS.

LOCATION	EXPERIMENTAL FLOW MODELS				DESIGN DRAWINGS			
	DIMENSION (in)	AREA (in^2)	C_D	$A \cdot C_D$ (in^2)	DIMENSION (in)	AREA (in^2)	C_D	$A \cdot C_D$ (in^2)
A	1.35	—			1.22	—		
B	.135 x .060	.00810			.144 x .050	.00666		
C	.044 x .060	.00264			.0[illegible] x .050			
D	.070 x .060	.00420			.069 x .050	.00345 ~~.00297~~		
E	3Ø .030	.00212 ~~.00071~~	.8	.00170	4Ø .024	.00181	.8	.00145
F	.032 x .060	.00192	.6	.00115	2Ø .026 ~~.050~~	.00106 ~~.00393~~	.8	.00085
G	.093 x .060	.00558			.094 x .050	.00416		
H	.125 x .060	.00750			.081 x .050	.00351		
I	.270 x .060	.01620			.278 x .050	.01336		
J	[illegible]	—			.7[illegible]	—		
K	.265 x .060	.01590			.269 x .050	.01291		
L	.265 x .060	.01590			.363 x .050	.0176		
M	4Ø .030	.00283	.8	.00226	4Ø .030	.00283	.8	.00226
N	.032 x .060	.00192	.6	.00115	Ø .040	.00126	.8	.00101
O	.030 x .060	.00180	.6	.00108	Ø .040	.00126	.8	.00101
P	.906	—			.870			
Q	.054 x .060	.00324	.6	.00194	Ø .050	.00196	.8	.00157

FOR FINAL DIMENSIONS; REFER TO THE DRAWINGS LISTED IN APPENDIX E. A SUMMARY APPEARS IN SECTION [illegible] OF THE REPORT. 49

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OF POOR QUALITY

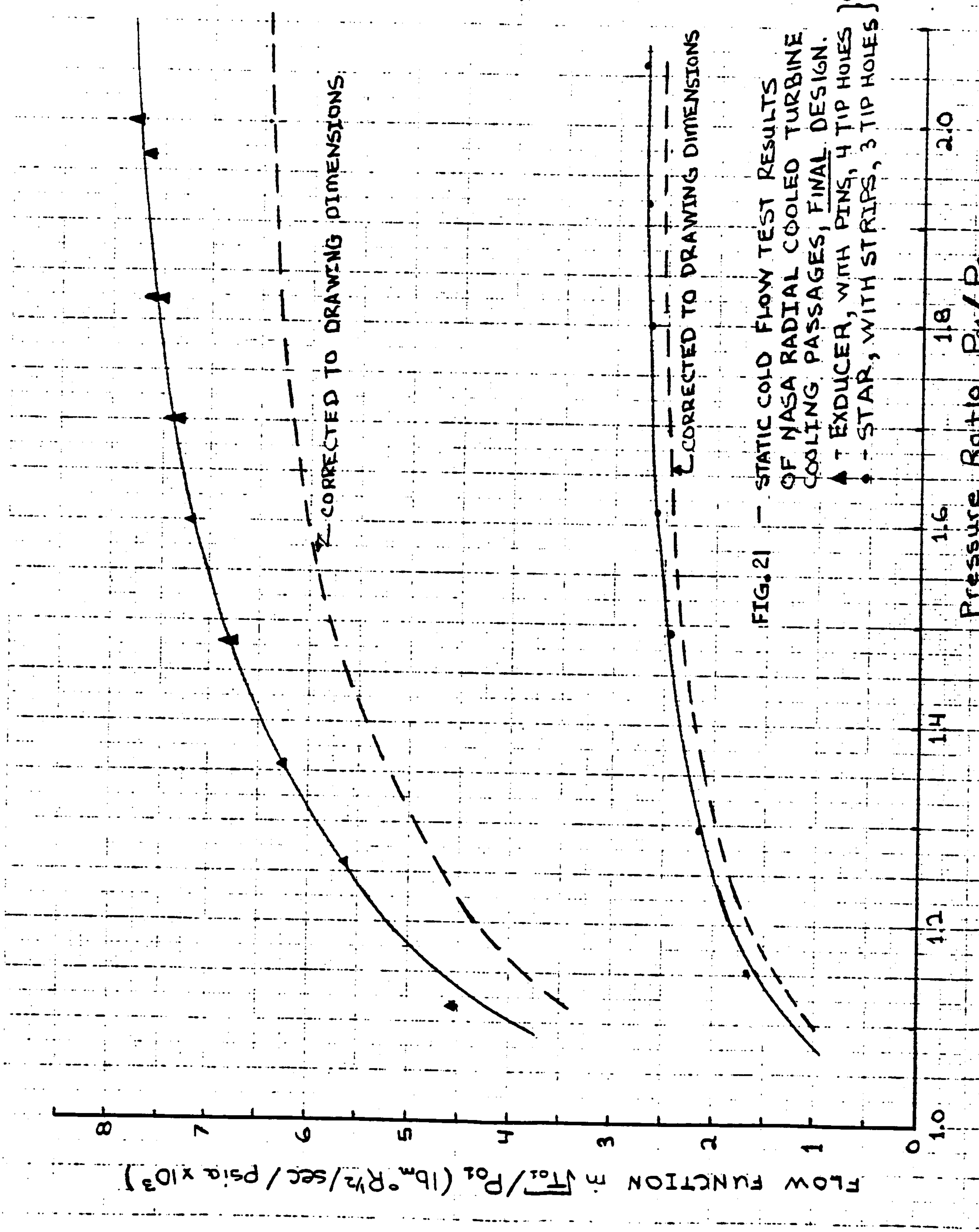

FIG. 21 — STATIC COLD FLOW TEST RESULTS OF NASA RADIAL COOLED TURBINE COOLING PASSAGES, FINAL DESIGN.
▲ - EXDUCER, WITH PINS, 4 TIP HOLES } OPEN.
● - STAR, WITH STRIPS, 3 TIP HOLES }

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OF POOR QUALITY

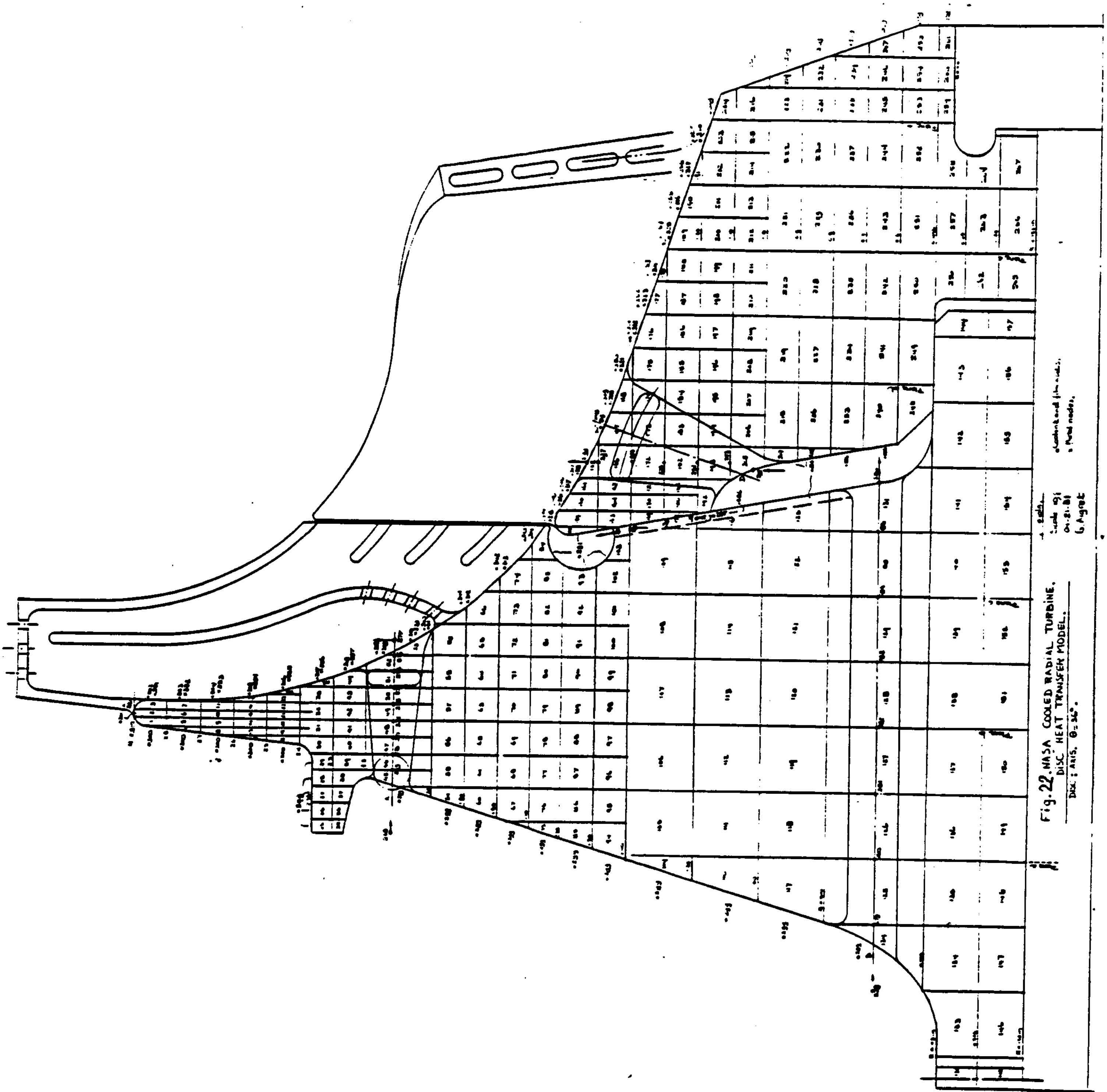

Fig. 22. NASA COOLED RADIAL TURBINE. DISC HEAT TRANSFER MODEL.

DISC ; AXIS. θ = 36°.

C-3

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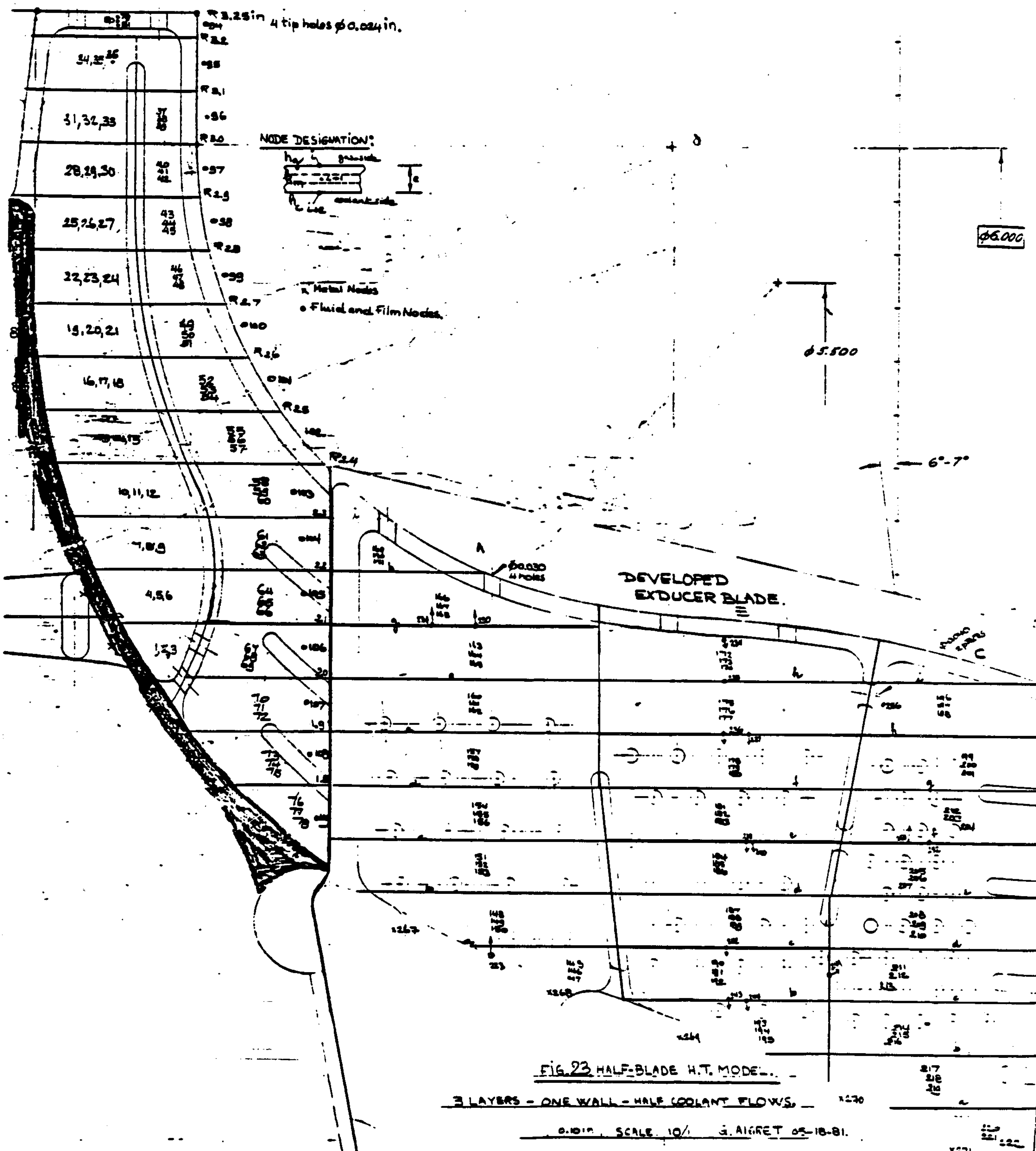


FIG. 23 HALF-BLADE H.T. MODEL.
3 LAYERS - ONE WALL - HALF COOLANT FLOWS.
0.010 in. SCALE 10/1 G. AIGRET 05-18-81.

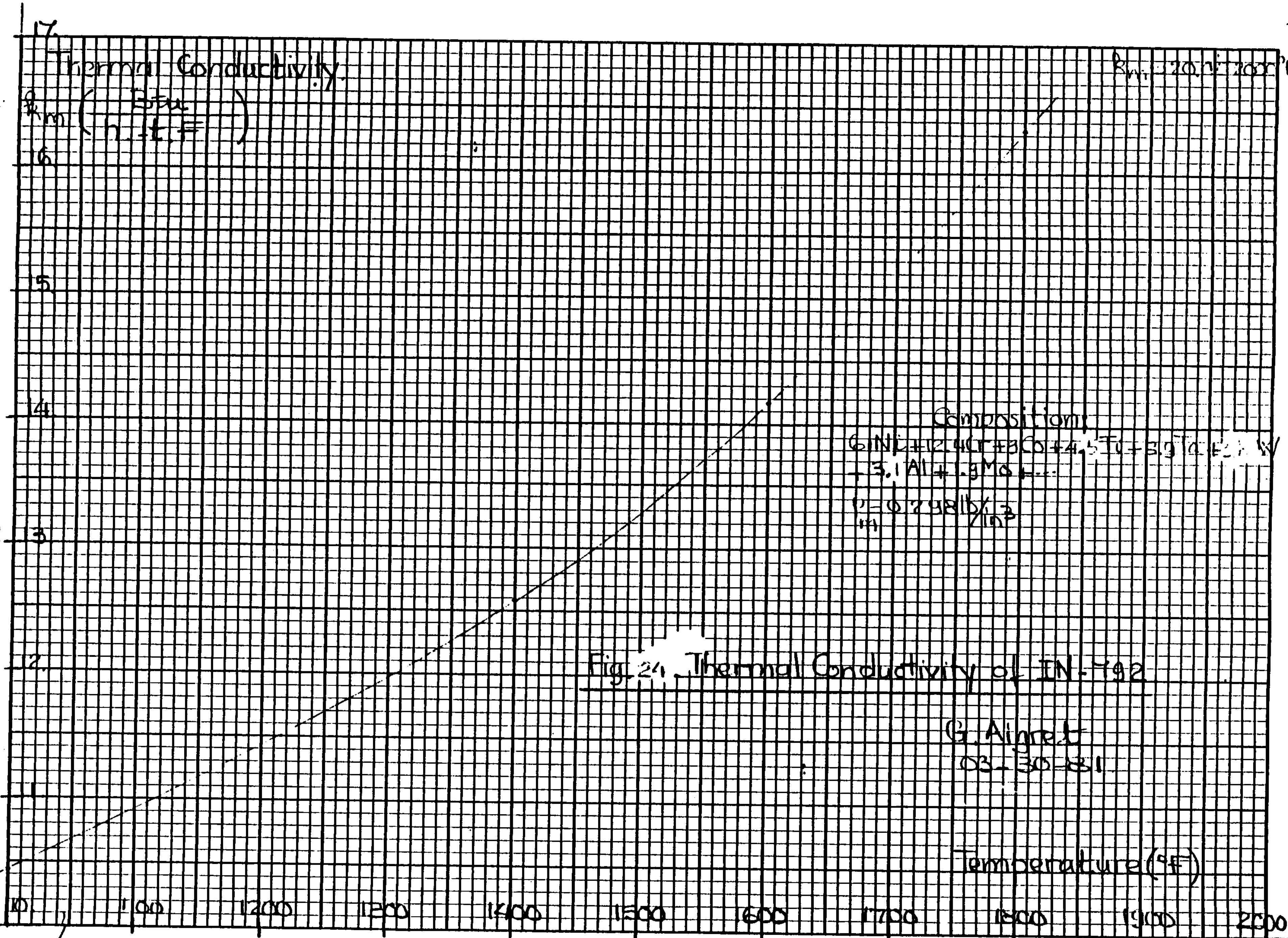
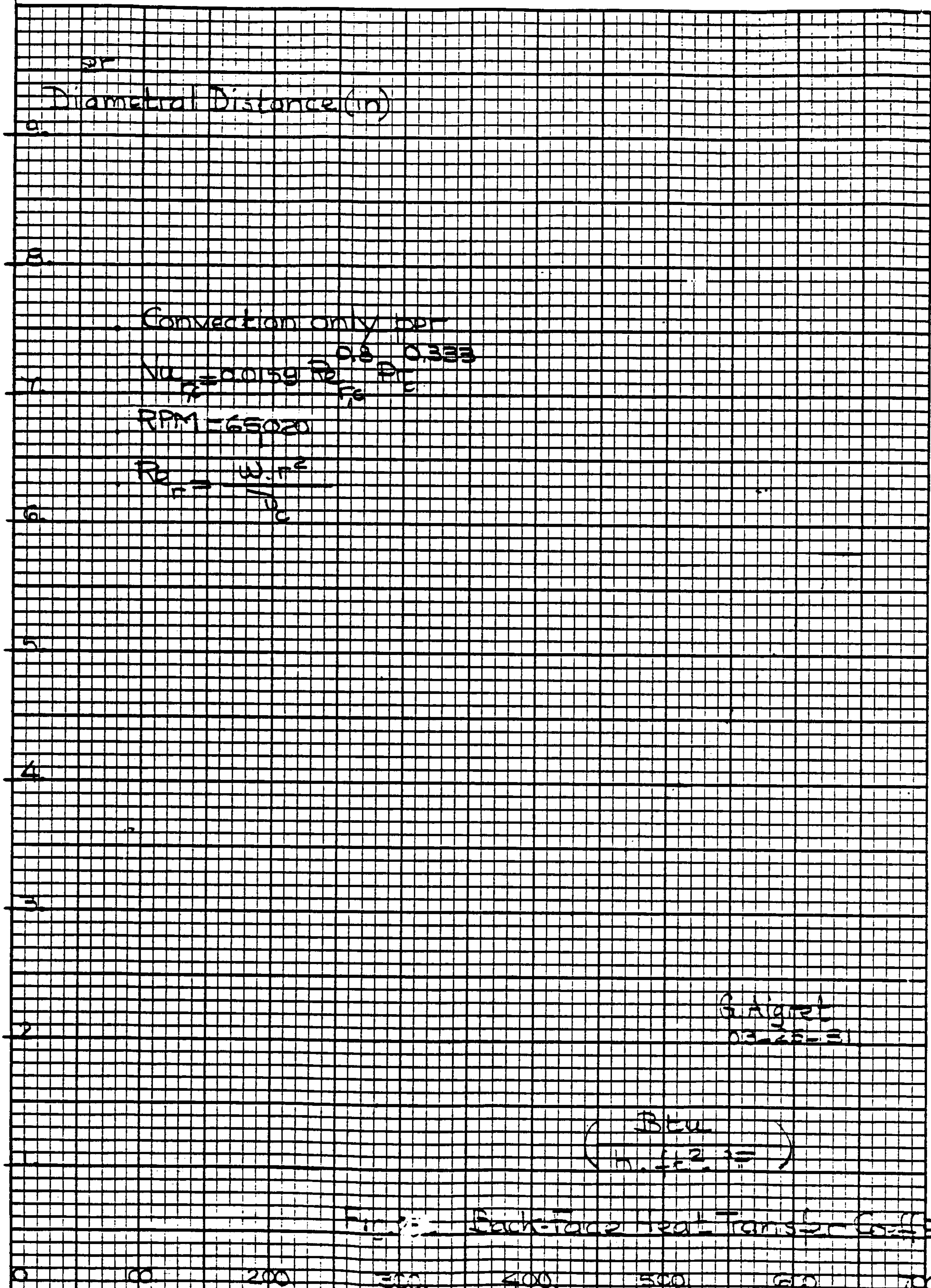


Fig. 24 Thermal Conductivity of IN-792


Diametral Distance (in)
Convection only per
$Nu_r = 0.0159\ Re_r^{0.8}\ Pr^{0.333}$
RPM = 65020
$Re_r = \frac{\omega \cdot r^2}{\nu}$
Btu
Back-Face Heat Trans
0
200
400
500

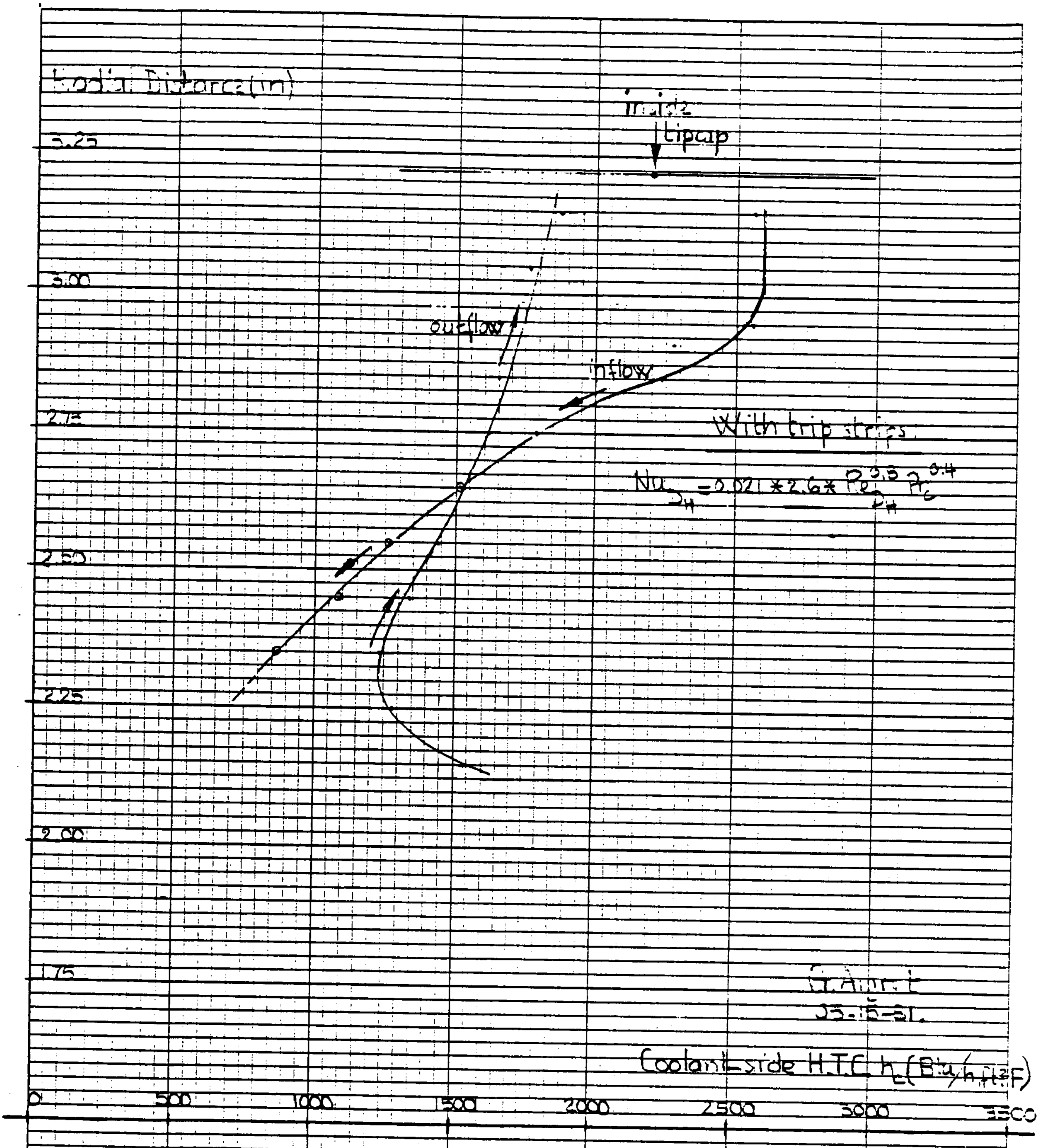


Fig 26. [illegible] Internal Heat Transfer [illegible]

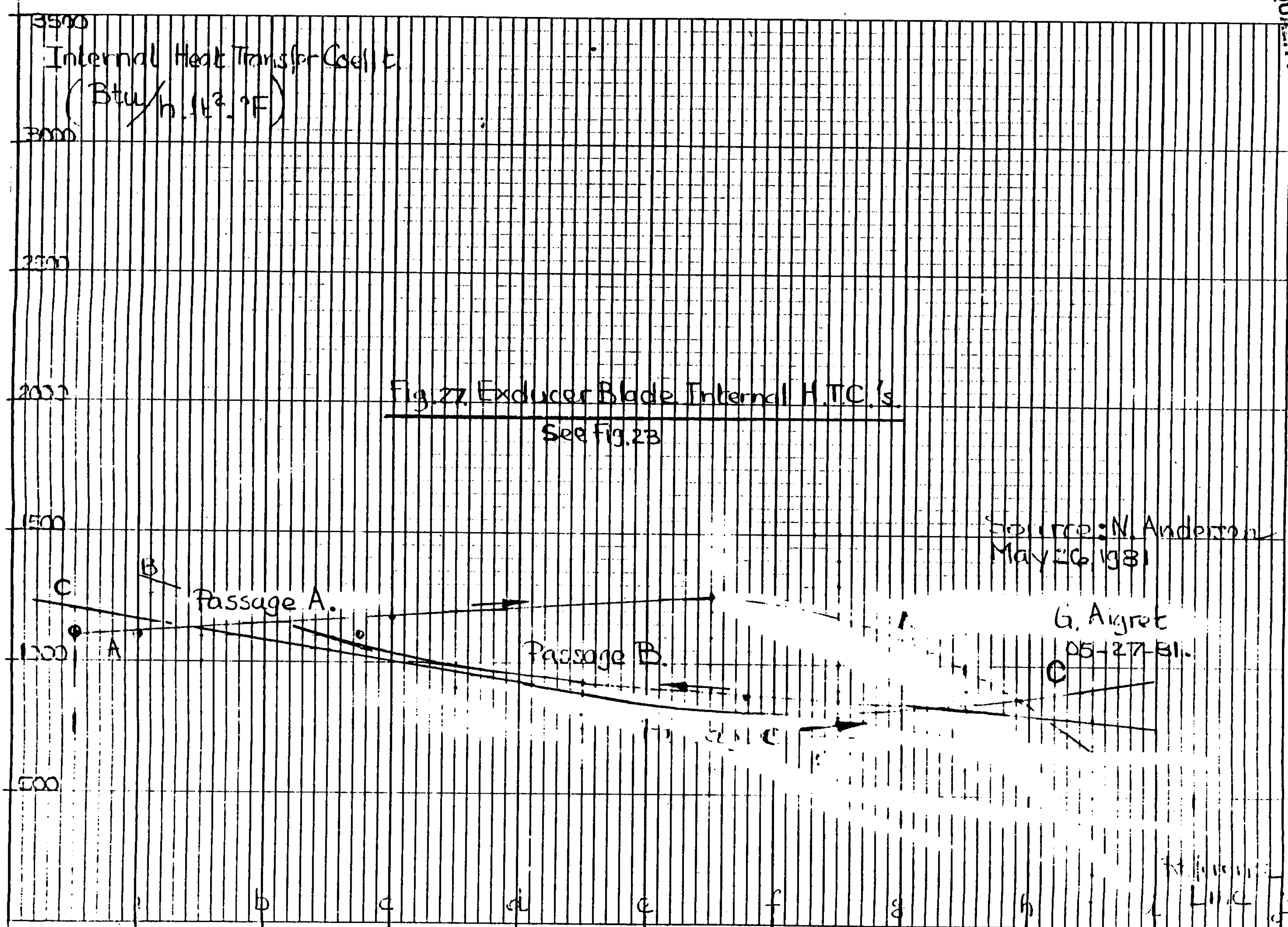


Fig. 27 Exducer Blade Internal H.T.C.'s
See Fig. 23

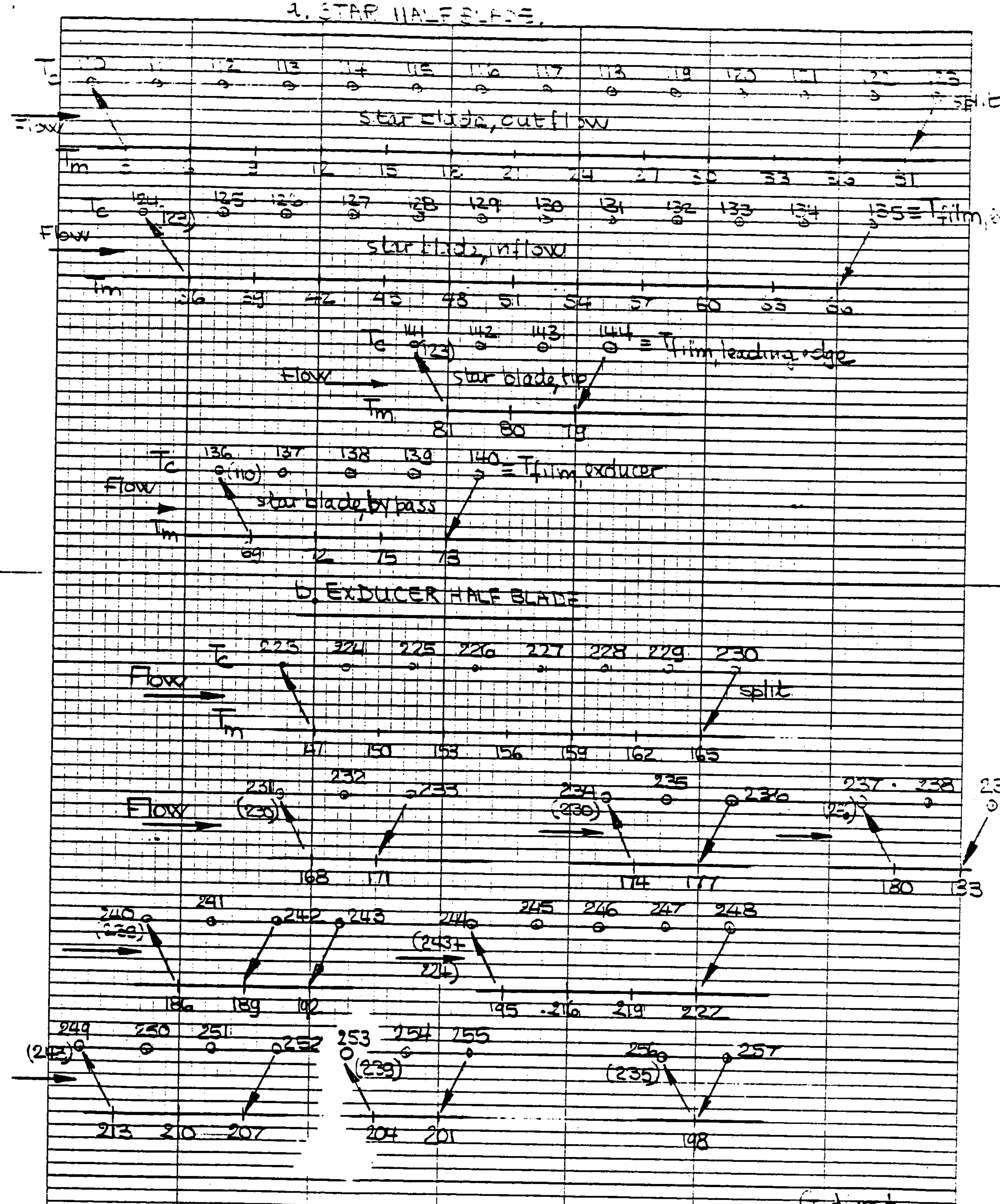


Fig. 28. Blade Heat Transfer Model: Coolant Flow Network.

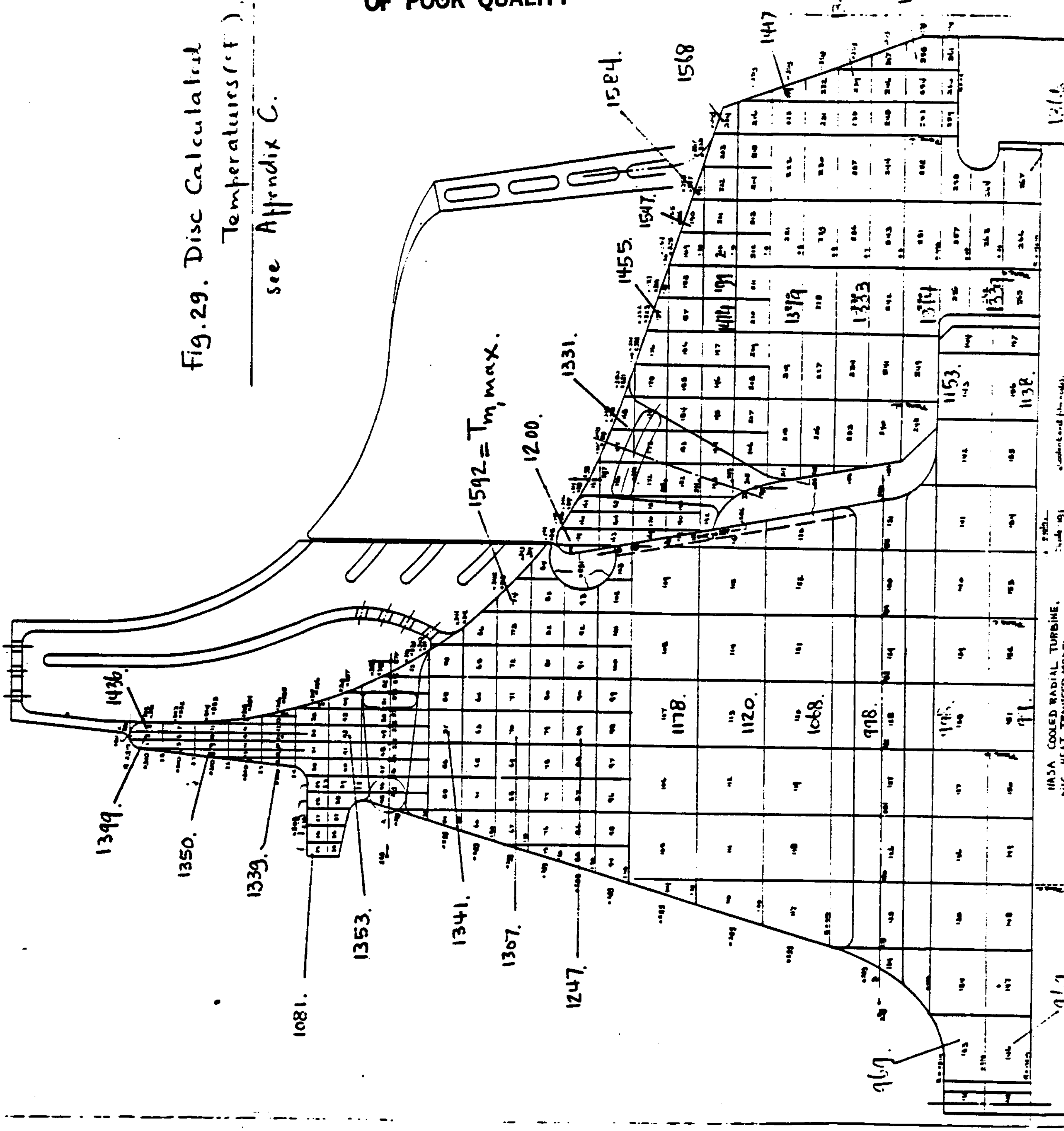


Fig. 29. Disc Calculated Temperatures (°F).
see Appendix C.

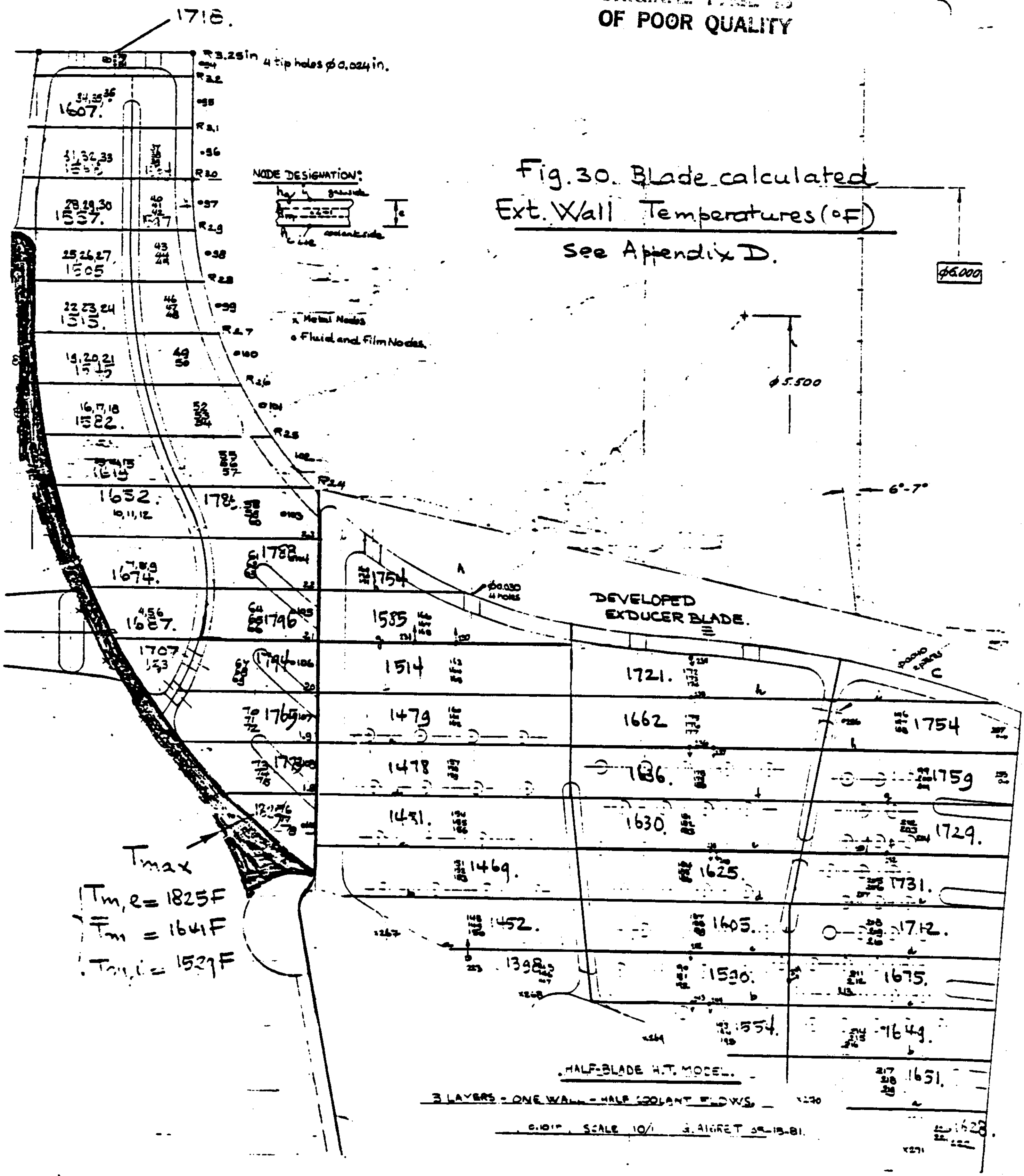
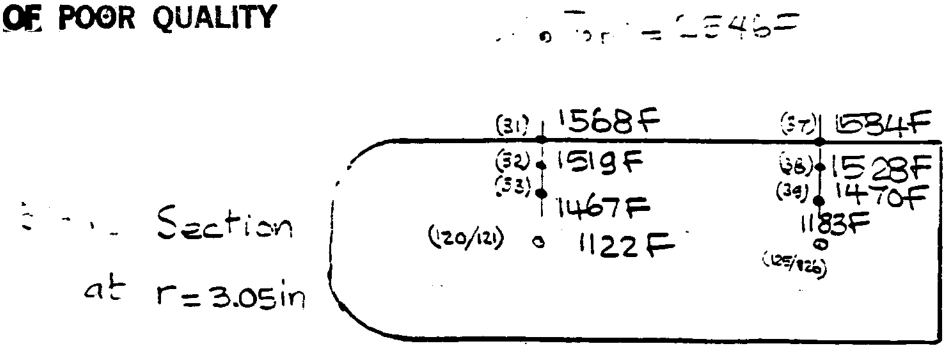
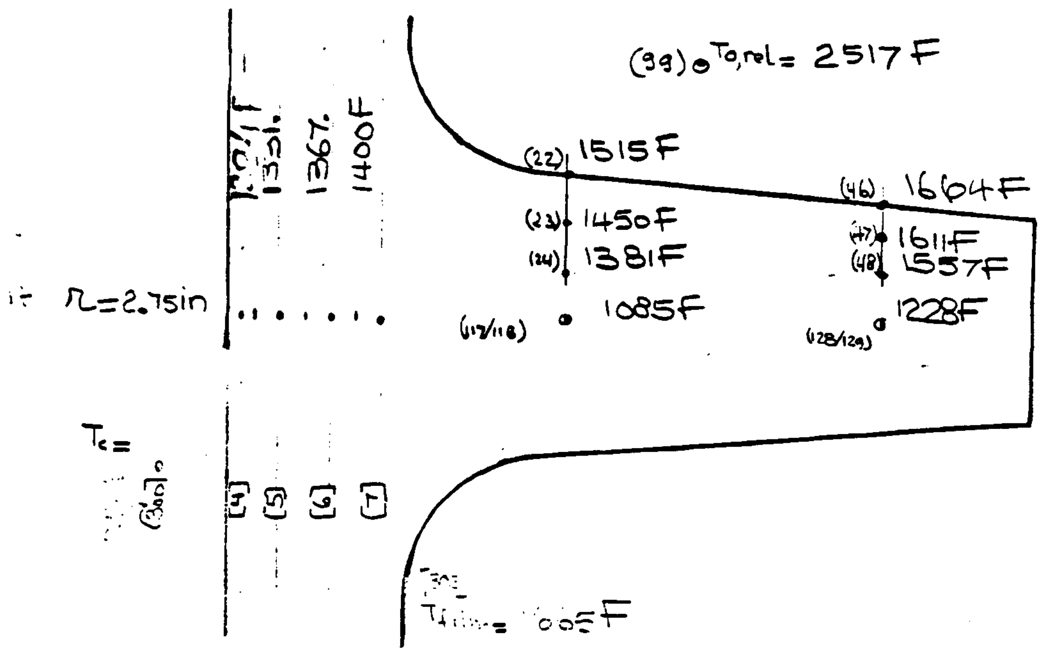
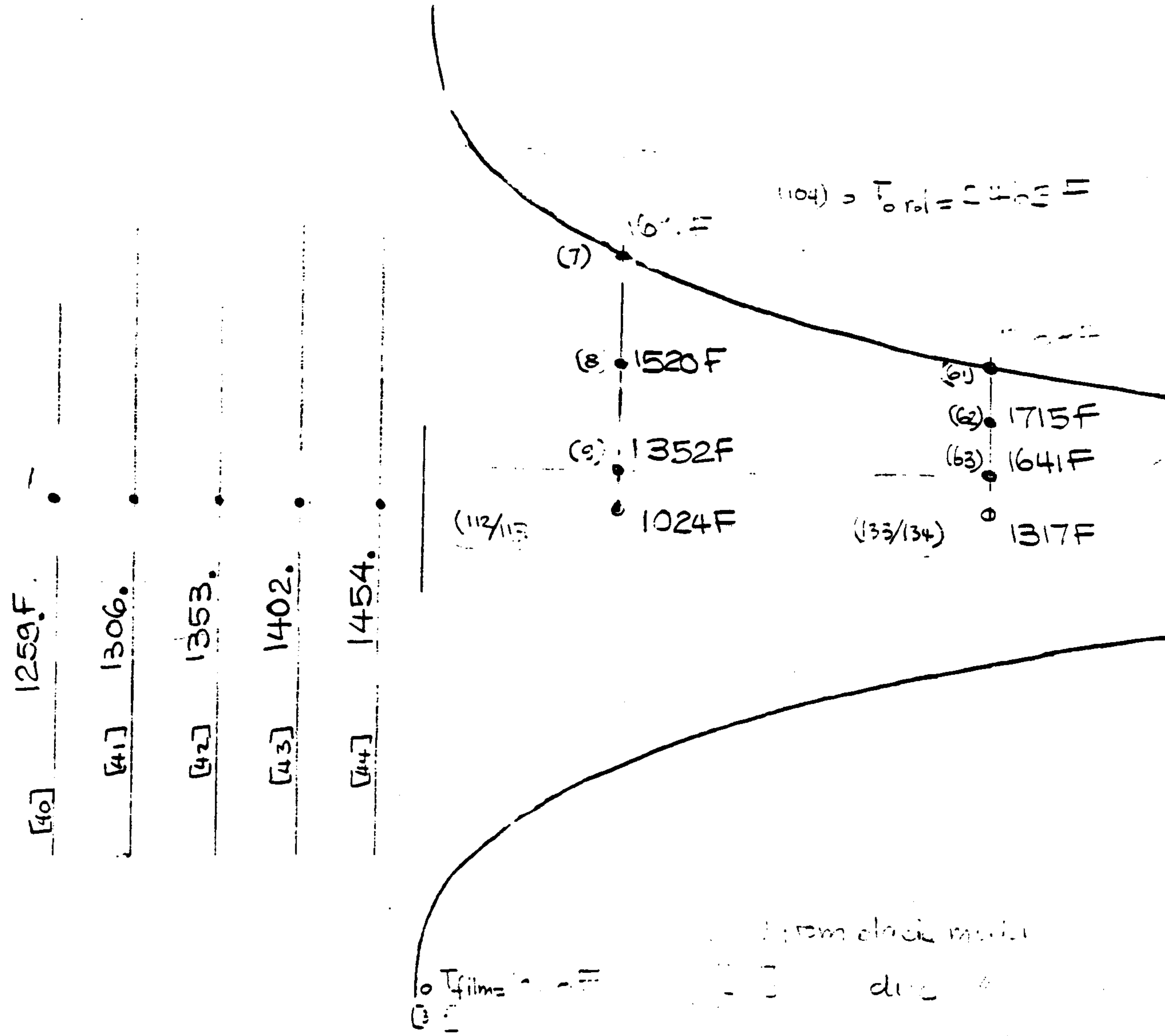


Fig. 30. Blade calculated Ext. Wall Temperatures (°F)
See Appendix D.


Section
at r=3.05in
(31) 1568F
(32) 1519F
(33) 1467F
(120/121) 1122F
(37) 1534F
(38) 1528F
(39) 1470F
1183F
(125/126)


(99) $T_{0,rel}$= 2517F
(22) 1515F
(23) 1450F
(24) 1381F
(117/118) 1085F
(46) 1664F
(47) 1611F
(48) 1557F
(128/129) 1228F
1400F
1367.
R=2.75in
T_c=
[4] [5] [6] [7]

disc model


(7)
(8) 1520F
(9) 1352F
1024F
(61)
(62) 1715F
(63) 1641F
(133/134)
1317F
1259F
1306.
1353.
1402.
1454.
[40]
[41]
[42]
[43]
[44]

Plane	Profile	Area in^2	Perimeter in	Hyd. Diam in	Mass Flow (lb/sec)	Mass Flux lb/sec/in^2	Temp °F	Press psia	Dyn Hd. psi	Comments
S1	.030 gap				.15	.40	750	270	20	[illegible]
S2	ø .11	.0095	.346	.11	.015	1.6	760	260	10	
S3	1.161 .25	.0077	.3746	.08	.015	1.9	780	255	13	
S4	2ø.026	.0010			.003	2.0	970			K_f = 1.7, C_D = .3
S5	[illegible] .25	.0104	.495	.084	.012	1.2	1020	243	9	
S6	1 .16 1 .25	.0015	.377	.080	[illegible]	1.6	1260	235	10	
S7	.0625 .25	[illegible]	.182	.057	.0036	3.3	1260	290	45	
S31	ø.0275	.0006	.086	.0275	.0018	3.0	1260			K_f = 1.72, C_D = .3
S32	ø.0275	.0006	.086	.0275	.0016	2.7	1260			K_f = 1.67, C_D = .3
S33	ø.0275	.0006	.086	.0275	.0015	2.5	1260			K_f = 1.67, C_D = .3
S9	1.071 .25	.0?3	.1971	.061	.0071	[illegible]	1260	237	32	
S10	1.1631 .25	.0076	.384	.077	.0071	.12	1270	149	9	
S[illegible]	.61x .040	.0?3			.010	.36				
Sps	.61x .022	.022			.010	.45				
A1	70x .030	.047			.10	2.0				ṁ = .01/blade
A[illegible]	[illegible] .05	.173			.10	.58				ṁ = .01/blade

Plane	Profile	Area in²	Perimeter in	Hyd. Diam. in	Mass Flow (lb/sec)	Mass Flux lb/sec/in²	Temp °F	Press psia	Ovr Hd. psi	Comments
E1	Ø.15	.0177	.471	.15	.010	2.26	950	247	25	
E2	Ø.15	[illegible]		.15	.040	2.26	953	242	25	
E:1	1.041 [illegible]	.00102	.160	.0255	.005	4.90	970	135	87	Mach = .80 !?
E:2	Δr = .025	.457			.005	.011	754	237	0	
E4	Ø.16	.0201	.503	.16	.035	1.74	980	226	16	
E5	[illegible] .25	.016	.717	.01	.035	2.19	1005	229	28	
E6	Ø.050	.00177	.1575	.05	.005	2.54	1005			R_p = 1.57
E7	[illegible]	.02176	.957	.01[illegible]	.030	1.37	1010	243	11	WITH FINS A = .017 P = .757, d_H = .091
E8	.71 .050	.01996	877	.091	.030	1.50	1070	2[illegible]7	13	WITH FINS A = .015 P = .677 d_H = .091
E11	Ø.030	.00071	.0094	.030	.0021	2.96	1110			R_p = [illegible]5, C_p = .3
E1[illegible]	Ø.030	.00071	.0094	.030	.0020	2.82	1110			R_p = 1.90, C_p = .8
E[illegible]	Ø.030	.00071	.0094	.030	.0018	2.54	1110			R_p = 1.77 C_p = .3
E[illegible]	Ø.030	.00071	.0094	.030	.0018	2.54	1110			R_p = 1.77, C_p = .8
E1[illegible]	1.275 .050	.01321	.607	.037	.026	1.97	1100	219	18	
E12	1.430 [illegible]	.0235	1.017	.092	.0187	.80	1120	216	4	WITH PINS, A = .013 P = .[illegible]92, d_H = .071
E13	1.24 [illegible]	[illegible]46	[illegible]	.087	.016	.77	1150	155	10	WITH PINS, A = .012 P = .527, d_H = .091
E14	1.28 .25	.01346	.617	.037	.021	1.56	1155	127	28	WITH [illegible]NS, A = .0[illegible]0 P = .317, d_H = .076
E15	Ø.010	.00126	.126	.040	.0034	2.70	1160			R_p = 1.80, [illegible].3
E16	1.15 [illegible]	.00[illegible]16	.357	.078	.0105	1.51	1180	120	24	
E17	"	↓	↓	↓	.0010	1.01	1200	120	14	
E18	"				.00[illegible]	.50	1220	120	3	
E1[illegible]	"				.0027	.39	1230	120		

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Plane	Profile	Area in^2	Perimeter in	Hyd. Diam in	Mass Flow (lb/sec)	Mass Flux lb/sec/in^2	Temp °F	Press psia	Dyn Hd. psi	Comments
[illegible]	.15 [illegible]	[illegible]	.357	.073	.0024	.49	1320	120		
E-1	[illegible]	.0075	.457	.083	0.0					
E-2	[illegible]	.0115	.537	.085	0.0					
E-4	3 .040	.00126	.126	[illegible]	.0027	2.14	1100			R_{p} = 1.55

APPENDIX A

ROTOR EXTERNAL FLOW ANALYSIS

FROM PROGRAM P-229 PER C. RODGERS (03-24-81)

NASA CRT 55   2-13-81   'NASACRT.RJE'   03/24/81 16:00:31

3-24-81

SPEED	ZTIP	NP	NE	L	W	S	TIN	PIN	GAM	R	CP	VA	NPR	NER
65000.	10.	12	4	1.600	1.660	0.0	3260.0	276.0	1.275	53.30	0.318	500.0	5	1

A/L	0.0	0.1000	0.2000	0.3000	0.4000	0.5000	0.6000	0.7000	0.8000	0.9000	1.0000	1.1000
TA	0.0	0.0	0.0	0.0	0.0	0.0170	0.0500	0.0970	0.1680	0.2560	0.3700	0.5050

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A/L	A	THETA	THETA'(A)
0.0	0.0	-0.0006	0.0461
0.0500	0.0800	0.0017	0.0137
0.1000	0.1600	0.0019	-0.0077
0.1500	0.2400	0.0008	-0.0187
0.2000	0.3200	-0.0008	-0.0200
0.2500	0.4000	-0.0022	-0.0121
0.3000	0.4800	-0.0026	0.0043
0.3500	0.5600	-0.0013	0.0285
0.4000	0.6400	0.0022	0.0600
0.4500	0.7200	0.0085	0.0981
0.5000	0.8000	0.0180	0.1421
0.5500	0.8800	0.0314	0.1916
0.6000	0.9600	0.0488	0.2458
0.6500	1.0400	0.0708	0.3041
0.7000	1.1200	0.0976	0.3659
0.7500	1.2000	0.1294	0.4306
0.8000	1.2800	0.1665	0.4975
0.8500	1.3600	0.2091	0.5660
0.9000	1.4400	0.2571	0.6355
0.9500	1.5200	0.3107	0.7053
1.0000	1.6000	0.3700	0.7749

ID	DS	TS	A	DELTA	GAMMA	UM	UH	LAM	ETA	NS	NM	N	Q	Z
1	6.50	0.100	0.300	-10.00	90.00	1.0000	1.0000	0.990	1.030	0.100	0.100	0.300	0.95	10.

AS	D	N	ALPHA	BETA	TT	TS	PT	PS	RO	VR	VW	U	VA	M REL
0.0	6.500	0.0	-10.00	-0.00	3260.0	2970.4	276.00	179.29	0.163	828.2	1987.3	1843.5	815.6	0.3249
1.770	6.500	0.093	-10.00	-0.00	3260.0	2970.4	276.00	179.29	0.163	828.2	1987.3	1843.5	815.6	0.3249
1.770	6.500	0.095	-10.00	-0.00	3260.0	2970.4	276.00	179.30	0.163	828.1	1987.3	1843.5	815.5	0.3248
1.770	6.500	0.109	-10.00	0.00	3260.0	2970.4	276.00	179.30	0.163	828.1	1987.3	1843.5	815.5	0.3248
0.0	6.500	0.0	-10.00	0.00	3260.0	2970.4	276.00	179.30	0.163	828.1	1987.3	1843.5	815.5	0.3248

ID	DS	TS	A	DELTA	GAMMA	UM	UH	LAM	ETA	NS	NM	N	Q	Z
2	6.00	0.100	0.300	-3.00	90.00	1.0000	1.0000	0.990	1.060	0.100	0.100	0.300	1.00	10.

AS	D	N	ALPHA	BETA	TT	TS	PT	PS	RO	VR	VW	U	VA	M REL
0.0	6.000	0.0	-3.00	-0.00	3196.9	2951.7	250.71	173.18	0.159	920.2	1749.9	1701.7	919.0	0.3621
1.639	6.000	0.092	-3.00	-0.00	3196.9	2951.7	250.71	173.18	0.159	920.2	1749.9	1701.7	919.0	0.3621
1.639	6.000	0.095	-3.00	-0.00	3196.9	2951.7	250.71	173.19	0.159	920.0	1749.8	1701.7	918.7	0.3620
1.638	6.000	0.110	-3.00	0.00	3196.9	2951.7	250.71	173.16	0.158	920.8	1749.9	1701.7	919.5	0.3623
0.0	6.000	0.0	-3.00	0.00	3196.9	2951.7	250.71	173.16	0.158	920.8	1749.9	1701.7	919.5	0.3623

ID	DS	TS	A	DELTA	GAMMA	UM	UH	LAM	ETA	NS	NM	N	Q	Z
3	5.40	0.100	0.330	0.0	75.00	0.9500	0.8500	0.990	1.090	0.100	0.110	0.330	1.00	10.

AS	D	N	ALPHA	BETA	TT	TS	PT	PS	RO	VR	VW	U	VA	M REL
0.0	5.400	0.0	-0.78	-0.78	3120.5	2889.9	221.17	154.93	0.145	1132.2	1546.9	1531.5	1132.1	0.4502
1.461	5.376	0.092	-0.82	-0.82	3118.1	2888.6	220.29	154.55	0.145	1132.2	1541.0	1524.8	1132.1	0.4503
1.529	5.326	0.100	-0.53	-0.53	3111.5	2893.8	217.94	155.70	0.145	1075.4	1520.6	1510.7	1075.3	0.4274
1.685	5.266	0.134	-0.54	-0.54	3101.4	2904.8	214.30	158.25	0.143	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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ID	DS	TS	A	DELTA	GAMMA	UM	UH	LAM	ETA	NS	NM	N	Q	Z
4	5.00	0.100	0.430	0.0	60.00	0.9000	0.7500	0.990	1.100	0.110	0.150	0.430	1.00	10.

AS	D	N	ALPHA	BETA	TT	TS	PT	PS	RO	VR	VW	U	VA	M REL
0.0	5.000	0.0	-0.50	-0.50	3077.2	2875.3	205.46	150.00	0.141	1085.8	1427.5	1410.1	1085.8	0.4329
1.568	4.946	0.108	-1.03	-1.03	3073.5	2872.6	204.21	149.25	0.140	1086.0	1422.2	1402.8	1085.8	0.4331
1.720	4.829	0.126	-1.42	-1.42	3062.8	2880.3	200.56	150.86	0.142	982.0	1394.0	1369.6	981.7	0.3911
2.049	4.670	0.192	-0.29	-0.29	3044.0	2891.5	194.34	153.12	0.143	815.6	1328.7	1324.6	815.6	0.3242
0.0	4.574	0.0	1.33	1.33	3031.3	2887.0	190.20	151.70	0.142	815.8	1278.5	1297.3	815.6	0.3246

ID	DS	TS	A	DELTA	GAMMA	UM	UH	LAM	ETA	NS	NM	N	Q	Z
5	4.60	0.100	0.640	0.0	45.00	0.7800	0.6500	0.990	1.120	0.130	0.220	0.530	1.00	10.

AS	D	N	ALPHA	BETA	TT	TS	PT	PS	RO	VR	VW	U	VA	M REL
0.0	4.600	0.0	5.57	5.57	3017.4	2837.2	184.38	138.57	0.132	1215.8	1186.6	1304.6	1210.1	0.4880
1.500	4.519	0.114	3.95	3.95	3015.9	2833.9	183.88	137.78	0.131	1213.0	1198.2	1281.8	1210.1	0.4871
1.863	4.330	0.154	0.97	0.97	3010.0	2861.9	182.00	144.03	0.136	943.8	1212.2	1228.1	943.7	0.3772
2.231	4.040	0.257	-1.40	-1.40	2990.7	2866.7	175.95	144.60	0.136	786.1	1164.9	1145.7	785.8	0.3139
0.0	3.858	0.0	-1.58	-1.58	2976.4	2859.5	171.59	142.49	0.135	786.1	1115.9	1094.2	785.8	0.3143

ID	DS	TS	A	DELTA	GAMMA	UM	UH	LAM	ETA	NS	NM	N	Q	Z
6	4.37	0.100	0.860	0.0	30.00	0.7800	0.6500	0.990	1.140	0.150	0.280	0.620	1.00	10.

AS	D	N	ALPHA	BETA	TT	TS	PT	PS	RO	VR	VW	U	VA	M REL
0.0	4.370	0.0	18.69	18.69	2951.1	2813.2	162.45	130.14	0.125	1301.3	822.4	1239.4	1232.6	0.5245
1.493	4.261	0.126	16.37	16.37	2951.5	2811.2	162.58	129.71	0.125	1284.7	846.4	1208.6	1232.6	0.5180
1.873	4.003	0.172	11.38	11.38	2957.3	2863.7	164.31	137.01	0.130	980.5	941.8	1135.3	961.2	0.3930
2.279	3.580	0.316	5.01	5.01	2943.6	2847.2	160.25	137.32	0.130	804.8	945.2	1015.4	801.7	0.3224
0.0	3.307	0.0	2.14	2.14	2930.0	2837.9	156.32	134.81	0.128	802.2	907.9	937.9	801.7	0.3219

ID	DS	TS	A	DELTA	GAMMA	UM	UH	LAM	ETA	NS	NM	N	Q	Z
7	4.28	0.080	1.070	0.0	15.00	0.7800	0.6500	0.990	1.160	0.160	0.320	0.710	1.00	10.

AS	D	N	ALPHA	BETA	TT	TS	PT	PS	RO	VR	VW	U	VA	M REL
0.0	4.280	0.0	34.05	34.05	2890.2	2795.7	143.48	122.99	0.119	1382.1	440.0	1213.9	1145.2	0.5588
1.490	4.141	0.144	32.02	32.02	2890.7	2795.2	143.62	122.91	0.119	1350.7	458.3	1174.4	1145.2	0.5461
1.898	3.811	0.198	27.23	27.23	2907.4	2833.1	148.23	131.47	0.125	1004.6	621.0	1080.7	893.3	0.4035
2.401	3.271	0.361	19.82	19.82	2899.9	2837.9	146.15	132.21	0.126	790.8	659.4	927.6	744.0	0.3174
0.0	2.922	0.0	15.53	15.53	2887.8	2828.8	142.85	129.80	0.124	772.1	622.1	828.8	744.0	0.3103

ID	DS	TS	A	DELTA	GAMMA	UM	UH	LAM	ETA	NS	NM	N	Q	Z
8	4.25	0.070	1.300	0.0	0.0	0.9000	0.8000	0.990	1.160	0.200	0.330	0.820	1.00	10.

AS	D	N	ALPHA	BETA	TT	TS	PT	PS	RO	VR	VW	U	VA	M REL
0.0	4.250	0.0	47.55	47.55	2852.2	2796.0	133.42	121.66	0.118	1373.0	192.3	1205.4	926.7	0.5551
1.522	4.068	0.182	46.30	46.30	2849.8	2793.7	132.79	121.12	0.117	1341.3	184.0	1153.7	926.7	0.5425
1.746	3.656	0.230	43.24	43.24	2856.0	2808.4	134.40	124.32	0.120	1144.6	252.7	1036.8	833.8	0.4617
2.116	3.026	0.400	37.90	37.90	2853.5	2814.1	133.75	125.40	0.120	938.5	281.8	858.3	740.6	0.3782
0.0	2.626	0.0	34.04	34.04	2846.0	2807.8	131.83	123.83	0.119	893.7	244.6	744.9	740.6	0.3606

ID	DS	TS	A	DELTA	GAMMA	UM	UH	LAM	ETA	NS	NM	N	Q	Z
9	4.25	0.060	1.600	0.0	0.0	1.0000	1.0000	0.990	1.160	0.240	0.340	0.925	1.00	10.

AS	D	N	ALPHA	BETA	TT	TS	PT	PS	RO	VR	VW	U	VA	M REL
0.0	4.250	0.0	58.73	58.73	2823.1	2787.3	126.10	118.85	0.115	1453.6	-37.1	1205.4	754.5	0.5886
1.485	4.021	0.229	57.31	57.31	2823.1	2787.3	126.10	118.85	0.115	1396.9	-35.1	1140.6	754.5	0.5656
1.619	3.523	0.269	53.78	53.78	2823.1	2787.0	126.10	118.79	0.115	1281.9	-34.9	999.3	757.5	0.5191
1.831	2.836	0.418	47.70	47.70	2823.1	2786.4	126.10	118.68	0.115	1134.9	-35.0	804.4	763.8	0.4596
0.0	2.419	0.0	43.14	43.14	2823.1	2786.4	126.10	118.68	0.115	1046.7	-29.8	685.9	763.8	0.4239

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shroud

F. M. L.	M. L.	D	VRθ	VRM	VRφ	VRθ/VRI	VRM/VRI	VRφ/VRI	ALPHA	PS/P1	DF
0.0	0.0	6.500	2021.3	820.0	-381.4	2.441	0.990	-0.460	10.14✓	0.651	0.0
0.10	0.206	6.089	1956.9	935.7	-85.5	2.363	1.130	-0.103	0.0	0.628	0.0
0.20	0.412	5.673	1910.4	1016.4	122.3	2.307	1.227	0.148	5.05	0.596	0.0
0.30	0.618	5.276	1931.4	1083.8	236.2	2.332	1.309	0.285	4.37	0.561	0.0
0.40	0.823	4.924	2017.5	1148.6	279.8	2.436	1.387	0.338	0.0	0.530	0.0
0.50	1.029	4.638	2133.3	1213.5	293.7	2.576	1.465	0.355	0.0	0.503	0.0
0.60	1.235	4.431	2218.3	1275.9	333.4	2.678	1.541	0.403	14.93	0.480	0.0
0570	5441	45307	220256	133155	46053	25660	15608	05556	27597	05460	050
0.80	1.647	4.256	2041.1	1377.0	712.8	2.465	1.663	0.861	41.07	0.443	0.0
0.90	1.853	4.252	1755.4	1413.4	1071.4	2.120	1.707	1.294	52.49	0.432	0.0
1.00	2.059	4.250	1406.2	1449.0	1491.8	1.698	1.750	1.801	58.73✓	0.432	0.0

F. M. L.	M. L.	D	VRθ	VRM	VRφ	VRθ/VRI	VRM/VRI	VRφ/VRI	ALPHA	PS/P1	DF
0.0	0.0	6.500	1987.0	819.7	-347.5	2.399	0.990	-0.420	10.22	0.651	0.0
0.10	0.215	6.073	1967.8	939.0	-89.7	2.376	1.134	-0.108	0.0	0.627	0.0
0.20	0.430	5.636	1914.3	1022.1	130.0	2.311	1.234	0.157	5.06	0.593	0.0
0.30	0.645	5.220	1905.0	1089.4	273.7	2.300	1.315	0.331	4.88	0.558	0.0
0.40	0.860	4.853	1958.4	1150.9	343.4	2.365	1.390	0.415	0.0	0.526	0.0
0.50	1.075	4.551	2053.9	1209.7	365.5	2.480	1.461	0.441	0.0	0.500	0.0
0.60	1.290	4.327	2139.2	1264.0	388.8	2.583	1.526	0.469	13.04	0.478	0.0
0.70	1.505	4.179	2141.6	1310.2	478.8	2.586	1.582	0.578	26.04	0.458	0.0
0.80	1.719	4.097	2000.5	1345.5	690.6	2.415	1.625	0.834	39.06	0.442	0.0
0.90	1.934	4.057	1714.0	1370.7	1027.4	2.069	1.655	1.241	50.56	0.431	0.0
1.00	2.149	4.021	1328.4	1392.7	1457.0	1.604	1.682	1.759	57.32	0.431	0.0

mean

F. M. L.	M. L.	D	VRθ	VRM	VRφ	VRθ/VRI	VRM/VRI	VRφ/VRI	ALPHA	PS/P1	DF
0.0	0.0	6.499	1807.7	820.5	-166.8	2.183	0.991	-0.201	10.41	0.651	0.0
0.10	0.237	6.031	1951.2	942.5	-66.2	2.356	1.138	-0.080	0.0	0.624	0.0
0.20	0.473	5.549	1892.6	1012.5	132.4	2.285	1.222	0.160	4.81	0.589	0.0
0.30	0.710	5.089	1755.5	1025.5	295.5	2.120	1.238	0.357	5.61	0.557	0.0
0.40	0.946	4.678	1623.5	998.9	374.3	1.960	1.206	0.452	0.0	0.534	0.0
0.50	1.183	4.335	1547.9	962.5	377.1	1.869	1.162	0.455	0.0	0.518	0.0
0.60	1.420	4.066	1547.1	948.4	349.6	1.868	1.145	0.422	9.06	0.504	0.0
0.70	1.656	3.870	1597.5	980.9	364.2	1.929	1.184	0.440	22.03	0.487	0.0
0.80	1.893	3.733	1634.5	1067.0	499.5	1.974	1.288	0.603	34.72	0.465	0.0
0.90	2.129	3.629	1579.5	1186.1	792.6	1.907	1.432	0.957	46.21	0.442	0.0
1.00	2.366	3.523	1364.0	1280.0	1196.0	1.647	1.546	1.444	53.82	0.431	0.0

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F. M. L.	M. L.	D	VRB	VRM	VRØ	VRB/VRI	VRM/VRI	VRØ/VRI	ALPHA	PS/PI	DF
0.0	0.0	6.499	1594.4	822.3	50.1	1.925	0.993	0.061	10.60	0.651	0.0
0.10	0.270	5.963	1718.1	945.1	172.0	2.075	1.141	0.208	0.0	0.620	0.0
0.20	0.540	5.415	1579.9	935.9	291.9	1.908	1.130	0.352	3.82	0.589	0.0
0.30	0.810	4.885	1362.1	878.0	393.8	1.645	1.060	0.476	5.99	0.561	0.0
0.40	1.080	4.396	1172.5	819.6	466.6	1.416	0.990	0.563	0.0	0.538	0.0
0.50	1.350	3.972	1056.5	783.3	510.1	1.276	0.946	0.616	0.0	0.519	0.0
0.60	1.620	3.625	1019.3	775.8	532.2	1.231	0.937	0.643	0.93	0.502	0.0
0.70	1.890	3.358	1045.9	797.2	548.4	1.263	0.963	0.662	16.12	0.486	0.0
0.80	2.160	3.160	1109.5	850.4	591.3	1.340	1.027	0.714	27.99	0.469	0.0
0.90	2.430	3.002	1177.7	951.0	724.3	1.422	1.148	0.875	39.13	0.450	0.0
1.00	2.700	2.836	1243.5	1136.4	1029.4	1.501	1.372	1.243	47.81	0.430	0.0

F. M. L.	M. L.	D	VRB	VRM	VRØ	VRB/VRI	VRM/VRI	VRØ/VRI	ALPHA	PS/PI	DF
0.0	0.0	6.499	1604.5	822.1	39.8	1.937	0.993	0.048	10.59	0.651	0.0
0.10	0.292	5.918	1727.3	948.0	168.8	2.086	1.145	0.204	0.0	0.617	0.0
0.20	0.584	5.329	1571.3	932.8	294.3	1.897	1.126	0.355	3.18	0.584	0.0
0.30	0.875	4.752	1334.3	871.0	407.6	1.611	1.052	0.492	5.94	0.554	0.0
0.40	1.167	4.213	1132.0	813.7	495.3	1.367	0.982	0.598	1.96	0.529	0.0
0.50	1.459	3.735	1008.6	780.9	553.2	1.218	0.943	0.668	0.0	0.509	0.0
0.60	1.751	3.337	962.6	773.9	585.2	1.162	0.934	0.707	0.0	0.492	0.0
0.70	2.042	3.027	972.3	787.0	601.7	1.174	0.950	0.727	12.61	0.477	0.0
0.80	2.334	2.794	1011.4	820.3	629.2	1.221	0.990	0.760	23.74	0.462	0.0
0.90	2.626	2.611	1055.2	891.8	728.4	1.274	1.077	0.879	34.35	0.446	0.0
1.00	2.918	2.419	1104.4	1049.3	994.1	1.333	1.267	1.200	43.28	0.430	0.0

hub

APPENDIX B

COOLED RADIAL TURBINES LITERATURE CONSULTED

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NASA COOLED RADIAL TURB.DISC HEAT TRANSFER.THETA=36DEGR.AXISYM.G.AIGRET.

DUMP CODE	MAX. COUNT	PRINT INTER.	STAB. CRIT.	VAR. EVALUATION CRIT. TIME	TEMP.	PROBLEM START	PRINT START		DUMMY	INCREMENTS		TIME LIMIT	PUNCH CODE	READ CODE
1	300		-1.1000E+00	1.0000E+00	2.0000E+01	0.0	6.0000E+00	0.0	-1	0	0.0	10	0	0

TEMPERATURE NODES AND CAPACITANCES

NODE	INC	CAP	CURV	RCX	EVX	NO.	TEMP	CAP. VAL.
1	1	1	0	0	0	99	1.5000E+03	0.0
100	1	1	0	0	0	99	1.5000E+03	0.0
199	1	1	0	0	0	69	1.5000E+03	0.0
268	1	-2	0	1	0	9	9.6500E+02	0.0
277	0	0	0	0	0	0	9.5000E+02	0.0
278	1	-2	0	1	0	8	9.5000E+02	0.0
286	0	0	0	0	0	0	9.5000E+02	0.0
287	1	-2	0	1	1	4	9.5000E+02	0.0
291	0	0	0	0	0	0	9.5000E+02	0.0
292	1	-2	0	1	1	6	9.5000E+02	0.0
298	0	0	0	0	0	0	9.5000E+02	0.0
299	0	0	0	0	0	0	9.5800E+02	0.0
300	0	0	0	0	0	0	9.5000E+02	0.0
301	0	0	0	0	0	0	1.6500E+03	0.0
302	0	0	0	0	0	0	1.6530E+03	0.0
303	0	0	0	0	0	0	1.6650E+03	0.0
304	0	0	0	0	0	0	1.6860E+03	0.0
305	0	0	0	0	0	0	1.7140E+03	0.0
306	0	0	0	0	0	0	1.7470E+03	0.0
307	0	0	0	0	0	0	1.7840E+03	0.0
308	0	0	0	0	0	0	1.8280E+03	0.0
309	0	0	0	0	0	0	1.8750E+03	0.0
310	0	0	0	0	0	0	1.9240E+03	0.0
311	0	0	0	0	0	0	1.9800E+03	0.0
312	0	0	0	0	0	0	2.0390E+03	0.0
313	0	0	0	0	0	0	2.1030E+03	0.0
314	0	0	0	0	0	0	2.1720E+03	0.0
315	0	0	0	0	0	0	1.1400E+03	0.0
316	0	0	0	0	0	0	1.1600E+03	0.0
317	0	0	0	0	0	0	1.1800E+03	0.0
318	0	0	0	0	0	0	1.2250E+03	0.0
319	0	0	0	0	0	0	1.3000E+03	0.0
320	0	0	0	0	0	0	1.3700E+03	0.0
321	0	0	0	0	0	0	1.4500E+03	0.0
322	0	0	0	0	0	0	1.5250E+03	0.0
323	0	0	0	0	0	0	1.6000E+03	0.0
324	0	0	0	0	0	0	1.6800E+03	0.0
325	0	0	0	0	0	0	1.7600E+03	0.0
326	0	0	0	0	0	0	1.8250E+03	0.0
327	0	0	0	0	0	0	1.8900E+03	0.0
328	0	0	0	0	0	0	1.9500E+03	0.0
329	0	0	0	0	0	0	2.0100E+03	0.0
330	0	0	0	0	0	0	1.4900E+03	0.0
331	0	0	0	0	0	0	1.4670E+03	0.0
332	0	0	0	0	0	0	1.4640E+03	0.0
333	0	0	0	0	0	0	1.4750E+03	0.0
334	0	0	0	0	0	0	1.4900E+03	0.0
335	0	0	0	0	0	0	1.5080E+03	0.0
336	0	0	0	0	0	0	1.5180E+03	0.0
337	0	0	0	0	0	0	1.5240E+03	0.0
338	0	0	0	0	0	0	1.5220E+03	0.0
339	0	0	0	0	0	0	1.5280E+03	0.0
340	0	0	0	0	0	0	1.6000E+03	0.0
341	0	0	0	0	0	0	1.6200E+03	0.0
342	0	0	0	0	0	0	1.6400E+03	0.0
343	0	0	0	0	0	0	1.6500E+03	0.0
344	0	0	0	0	0	0	1.3300E+03	0.0
345	0	0	0	0	0	0	1.3490E+03	0.0
346	0	0	0	0	0	0	1.3680E+03	0.0
347	0	0	0	0	0	0	1.3870E+03	0.0
348	0	0	0	0	0	0	1.4050E+03	0.0
349	0	0	0	0	0	0	1.4240E+03	0.0
350	0	0	0	0	0	0	1.4430E+03	0.0
351	0	0	0	0	0	0	1.4620E+03	0.0
352	0	0	0	0	0	0	1.4810E+03	0.0
353	0	0	0	0	0	0	1.5000E+03	0.0
354	0	0	0	0	0	0	1.5180E+03	0.0
355	0	0	0	0	0	0	1.5370E+03	0.0
356	0	0	0	0	0	0	1.5560E+03	0.0
357	0	0	0	0	0	0	1.5750E+03	0.0
358	0	0	0	0	0	0	9.5000E+02	0.0
359	0	0	0	0	0	0	1.3000E+03	0.0

PRECEDING PAGE BLANK NOT FILMED

PAGE 222 INTENTIONALLY BLANK

CONDUCTANCES

COND	INC	NODE	INC	NODE	INC	CURV	EVX	NO.	COND. VAL.
1	1	1	1	2	1	41	0	2	5.9690E-01
3	1	4	1	5	1	41	0	3	5.7596E-01
6	1	8	1	9	1	41	0	3	5.5502E-01
9	1	12	1	13	1	41	0	5	5.3407E-01
14	1	18	1	19	1	41	0	6	5.1313E-01
20	1	25	1	26	1	41	0	4	1.4640E-01
24	0	29	0	30	0	41	0	0	1.4640E-01
25	1	30	1	31	1	41	0	4	2.4609E-01
29	0	35	0	36	0	41	0	0	1.0381E-01
30	0	36	0	37	0	41	0	0	1.3089E-01
31	0	37	0	38	0	41	0	0	1.6136E-01
32	1	38	1	39	1	41	0	6	2.3562E-01
38	1	45	1	46	1	41	0	8	4.2639E-01
46	1	54	1	55	1	41	0	5	1.0210E-01
51	1	60	1	61	1	41	0	6	9.6866E-02
57	1	67	1	68	1	41	0	7	9.1630E-02
64	1	75	1	76	1	41	0	8	8.6394E-02
72	0	83	0	84	0	41	0	0	6.9534E-02
73	1	85	1	86	1	41	0	8	8.1158E-02
81	1	94	1	95	1	41	0	8	7.5922E-02
89	0	102	0	103	0	41	0	0	5.7223E-02
90	0	104	0	105	0	41	0	0	1.1345E-01
91	1	105	1	106	1	41	0	4	6.8068E-02
95	0	110	0	111	0	41	0	0	7.6794E-02
96	1	111	1	112	1	41	0	4	5.7596E-02
100	0	115	0	116	0	41	0	0	8.8609E-02
101	1	117	1	118	1	41	0	6	4.7124E-02
107	0	124	0	125	0	41	0	0	6.8015E-02
108	1	125	1	126	1	41	0	6	4.4210E 02
114	0	132	0	133	0	41	0	0	2.1608E-02
115	1	133	1	134	1	41	0	10	1.8121E-02
125	0	143	0	144	0	41	0	0	2.5887E-02
126	0	145	0	146	0	41	0	0	1.5429E-02
127	1	146	1	147	1	41	0	10	9.2570E-03
137	0	156	0	157	0	41	0	0	1.3225E-02
138	0	12	0	18	0	41	0	0	6.0000E-04
139	0	4	0	8	0	41	0	0	2.5444E-02
140	0	8	0	13	0	41	0	0	3.4030E-02
142	1	1	1	5	1	41	0	3	4.2023E-02
145	1	9	1	14	1	41	0	3	3.4030E-02
148	1	13	1	19	1	41	0	5	1.0000E-03
153	0	18	0	30	0	41	0	0	3.1411E-02
154	0	19	0	31	0	41	0	0	1.0420E-03
155	0	20	0	31	0	41	0	0	1.0420E-03
156	0	21	0	32	0	41	0	0	1.0420E-03
157	0	22	0	32	0	41	0	0	1.0420E-03
158	0	23	0	33	0	41	0	0	1.0420E-03
159	0	24	0	33	0	41	0	0	1.0420E-03
160	1	25	1	35	1	41	0	5	9.6337E-02
165	1	30	1	40	1	41	0	4	6.0204E-02
169	0	34	0	44	0	41	0	0	3.6123E-02
170	0	38	0	45	0	41	0	0	1.8973E-02
171	1	39	1	46	1	41	0	6	3.7946E 02
177	0	45	0	55	0	41	0	0	3.5327E-02
178	0	46	0	55	0	41	0	0	3.5327E-02
179	0	47	0	56	0	41	0	0	3.5327E-02
180	0	48	0	56	0	41	0	0	3.5327E-02
181	0	49	0	57	0	41	0	0	3.5327E-02
182	0	50	0	57	0	41	0	0	3.5327E-02
183	0	51	0	58	0	41	0	0	3.5327E-02
184	0	52	0	58	0	41	0	0	3.5327E-02
185	0	53	0	59	0	41	0	0	3.4725E-02
186	0	54	0	60	0	41	0	0	6.0325E-02
187	1	55	1	61	1	41	0	5	9.9461E-02
192	1	60	1	67	1	41	0	7	9.4224E-02
199	1	67	1	76	1	41	0	8	8.8986E-02
207	0	75	0	85	0	41	0	0	4.1874E-02
208	1	76	1	86	1	41	0	8	8.3749E-02
216	1	85	1	94	1	41	0	9	7.8511E-02
225	0	94	0	105	0	41	0	0	4.7949E-02
226	0	95	0	105	0	41	0	0	4.7949E-02
227	0	96	0	106	0	41	0	0	4.7949E-02
228	0	97	0	106	0	41	0	0	4.7949E-02
229	0	98	0	107	0	41	0	0	4.7949E-02
230	C	99	0	107	0	41	0	0	4.7949E-02
231	[illegible]	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

COND	INC	NODE	INC	NODE	INC	CURV	EVX	NO.	COND. VAL.
232	0	101	0	108	0	41	0	0	4.7949E-02
233	0	102	0	109	0	41	0	0	4.7949E-02
234	0	103	0	109	0	41	0	0	5.3000E-02
235	0	104	0	110	0	41	0	0	2.3507E-02
236	1	105	1	111	1	41	0	5	6.2686E-02
241	0	110	0	117	0	41	0	0	3.5226E-02
242	1	111	1	118	1	41	0	5	5.2185E-02
247	0	116	0	123	0	41	0	0	2.2179E-02
248	1	117	1	125	1	41	0	6	3.1878E-02
254	0	123	0	131	0	41	0	0	1.9127E-02
255	0	124	0	134	0	41	0	0	2.3124E-02
256	1	125	1	135	1	41	0	7	2.3124E-02
263	0	132	0	145	0	41	0	0	8.4470E-03
264	0	133	0	146	0	41	0	0	2.5992E-02
265	1	134	1	147	1	41	0	10	2.2748E-02
275	0	144	0	157	0	41	0	0	9.1000E-03
276	0	158	0	159	0	41	0	0	2.9219E-01
277	0	159	0	160	0	41	0	0	1.9095E-01
278	0	160	0	161	0	41	0	0	1.3896E-01
279	0	161	0	162	0	41	0	0	8.5126E-02
280	1	163	1	164	1	41	0	2	1.5184E-01
282	0	165	0	166	0	41	0	0	9.4143E-02
283	0	166	0	167	0	41	0	0	7.0607E-02
284	0	167	0	168	0	41	0	0	4.7483E-02
285	0	169	0	170	0	41	0	0	1.6439E-01
286	0	170	0	171	0	41	0	0	1.4137E-01
287	0	171	0	172	0	41	0	0	8.7650E 02
288	0	172	0	173	0	41	0	0	6.5738E-02
289	0	173	0	174	0	41	0	0	6.5738E-02
290	0	174	0	175	0	41	0	0	6.5738E-02
291	0	175	0	176	0	41	0	0	7.0686E-02
292	0	176	0	177	0	41	0	0	4.1783E-02
294	0	179	0	180	0	41	0	0	1.9833E-01
295	0	180	0	181	0	41	0	0	1.4544E-01
296	0	181	0	182	0	41	0	0	8.1158E-02
297	0	182	0	183	0	41	0	0	6.0868E-02
298	0	183	0	184	0	41	0	0	6.0868E-02
299	1	184	1	185	1	41	0	5	6.5450E-02
304	0	189	0	190	0	41	0	0	4.5265E-02
306	0	192	0	193	0	41	0	0	5.6000E-02
307	0	193	0	194	0	41	0	0	5.6000E-02
308	1	194	1	195	1	41	0	9	6.0214E-02
317	0	203	0	204	0	41	0	0	4.3789E-02
318	0	205	0	206	0	41	0	0	5.9453E-02
319	1	206	1	207	1	41	0	10	5.4978E-02
329	0	217	0	218	0	41	0	0	4.1452E-02
330	1	218	1	219	1	41	0	4	2.4871E-02
334	0	222	0	223	0	41	0	0	3.3161E-02
335	0	223	0	224	0	41	0	0	6.6323E-02
336	0	225	0	226	0	41	0	0	3.8701E-02
337	1	226	1	227	1	41	0	4	2.2253E-02
341	0	230	0	231	0	41	0	0	2.9671E-02
342	0	231	0	232	0	41	0	0	4.8114E-02
343	1	233	1	234	1	41	0	4	1.9635E-02
347	0	237	0	238	0	41	0	0	2.6180E-02
348	0	238	0	239	0	41	0	0	3.9270E-02
349	1	240	1	241	1	41	0	4	1.7017E-02
353	0	244	0	245	0	41	0	0	2.2689E-02
354	0	245	0	246	0	41	0	0	3.4034E-02
355	0	246	0	247	0	41	0	0	4.2542E-02
356	0	248	0	249	0	41	0	0	1.7762E-02
357	1	249	1	250	1	41	0	3	1.4920E-02
360	0	252	0	253	0	41	0	0	1.9894E-02
361	1	253	1	254	1	41	0	2	2.9841E-02
363	1	256	1	257	1	41	0	2	1.3246E-02
365	0	258	0	259	0	41	0	0	9.1480E-03
366	1	259	1	260	1	41	0	2	1.3722E-02
368	1	262	1	263	1	41	0	2	1.0780E-02
370	1	265	1	266	1	41	0	2	8.1830E-03
372	1	159	1	163	1	41	0	3	3.9255E-02
375	0	162	0	166	0	41	0	0	9.8841E-02
376	1	163	1	169	1	41	0	3	2.9309E-02
379	0	166	0	172	0	41	0	0	6.5213E-02
380	0	167	0	173	0	41	0	0	7.2205E-02
381	0	168	0	174	0	41	0	0	1.1638E-01
382	0	169	0	179	0	41	0	0	1.7009E-02
383	1	170	1	180	1	41	0	2	3.4017E-02
385	1	172	1	182	1	41	0	2	6.0550E-02

NASA COOLED RADIAL TURB.DISC .HEAT TRANSFER.THETA=36DEGR.AXISYM.G.AIGRET.

COND	INC	NODE	INC	NODE	INC	CURV	EVX	NO.	COND. VAL.
387	0	174	0	184	0	41	0	0	6.4633E-02
388	1	175	1	185	1	41	0	2	6.8034E-02
391	0	177	0	187	0	41	0	0	9.6094E-02
392	0	178	0	188	0	41	0	0	1.1168E-01
393	0	180	0	192	0	41	0	0	3.9583E-02
394	0	181	0	192	0	41	0	0	3.7604E-02
395	0	182	0	193	0	41	0	0	5.5888E-02
396	0	183	0	194	0	41	0	0	5.5888E-02
397	1	184	1	195	1	41	0	6	6.2795E-02
403	0	190	0	201	0	41	0	0	8.8612E-02
404	0	191	0	202	0	41	0	0	1.0295E-01
405	0	193	0	205	0	41	0	0	5.1225E-02
406	0	194	0	206	0	41	0	0	5.4391E-02
407	1	195	1	207	1	41	0	10	5.7556E-02
417	0	205	0	217	0	41	0	0	3.1390E-02
418	0	206	0	218	0	41	0	0	5.2316E-02
628	0	207	0	218	0	41	0	0	5.2316E-02
419	0	208	0	219	0	41	0	0	5.2316E-02
420	0	209	0	219	0	41	0	0	5.2316E-02
421	0	210	0	220	0	41	0	0	5.2316E-02
422	0	211	0	220	0	41	0	0	5.2316E-02
423	0	212	0	221	0	41	0	0	5.2316E-02
424	0	213	0	221	0	41	0	0	5.2316E-02
425	0	214	0	222	0	41	0	0	5.2316E-02
426	0	215	0	222	0	41	0	0	5.2316E-02
427	0	216	0	223	0	41	0	0	5.2316E-02
428	0	217	0	225	0	41	0	0	1.8830E-02
429	1	218	1	226	1	41	0	5	9.4151E-02
434	1	223	1	231	1	41	0	2	4.7075E-02
436	1	226	1	233	1	41	0	5	8.3667E-02
441	1	231	1	238	1	41	0	2	4.1833E-02
443	1	233	1	240	1	41	0	5	7.3179E-02
448	1	238	1	245	1	41	0	2	3.6589E-02
450	1	240	1	248	1	41	0	5	6.1348E-02
455	1	245	1	253	1	41	0	3	3.0674E-02
458	1	250	1	256	1	41	0	3	4.6777E-02
461	1	253	1	259	1	41	0	3	3.3180E-02
464	1	256	1	262	1	41	0	3	3.1108E-02
467	1	262	1	265	1	41	0	3	2.5739E-02
470	0	103	0	163	0	41	0	0	3.3270E-02
471	0	109	0	169	0	41	0	0	3.4278E-02
472	0	109	0	179	0	41	0	0	3.4278E-02
473	0	115	0	192	0	41	0	0	1.0283E-02
474	0	249	0	143	0	41	0	0	3.6711E-02
629	1	5	1	9	1	41	0	3	3.6752E-02
476	1	268	1	45	1	0	0	9	3.8020E-02
485	0	-269	0	45	0	0	0	0	3.8020E-02
486	0	-270	0	46	0	0	0	0	3.8020E-02
487	0	-271	0	47	0	0	0	0	3.8020E-02
488	0	-272	0	48	0	0	0	0	3.8020E-02
489	0	-273	0	49	0	0	0	0	3.8020E-02
490	0	-274	0	50	0	0	0	0	3.8020E-02
491	0	-275	0	51	0	0	0	0	3.8020E-02
492	0	-276	0	52	0	0	0	0	3.8020E-02
493	0	-277	0	53	0	0	0	0	3.8020E-02
494	1	278	1	124	1	0	0	8	2.3302E-01
502	0	-279	0	124	0	0	0	0	2.3302E-01
503	0	-280	0	125	0	0	0	0	2.3302E-01
504	0	-281	0	126	0	0	0	0	2.3302E-01
505	0	-282	0	127	0	0	0	0	2.3302E-01
506	0	-283	0	128	0	0	0	0	2.3302E-01
507	0	-284	0	129	0	0	0	0	2.3302E-01
508	0	-285	0	130	0	0	0	0	2.3302E-01
509	0	-286	0	131	0	0	0	0	2.3302E-01
510	0	287	0	192	0	0	0	0	5.3790E-02
511	0	288	0	179	0	0	0	0	5.3790E-02
512	0	289	0	169	0	0	0	0	5.3790E-02
513	0	290	0	163	0	0	0	0	5.3790E-02
514	0	-288	0	192	0	0	0	0	5.3790E-02
515	0	-289	0	179	0	0	0	0	5.3790E-02
516	0	-290	0	169	0	0	0	0	5.3790E-02
517	0	-291	0	163	0	0	0	0	5.3790E-02
518	0	292	0	205	0	0	0	0	8.5790E-02
519	0	293	0	193	0	0	0	0	8.5790E-02
520	0	294	0	182	0	0	0	0	8.5790E-02
521	0	295	0	172	0	0	0	0	8.5790E-02
522	[illegible]	296	0	166	0	0	0	0	8.5790E-02
523	[illegible]	297	0	162	0	0	0	0	[illegible]

COND	INC	NODE	INC	NODE	INC	CURV	EVX	NO.	COND. VAL.
524	0	-293	0	205	0	0	0	0	8.5790E-02
525	0	-294	0	193	0	0	0	0	8.5790E-02
526	0	-295	0	182	0	0	0	0	8.5790E-02
527	0	-296	0	172	0	0	0	0	8.5790E-02
528	0	-297	0	166	0	0	0	0	8.5790E-02
529	0	-298	0	162	0	0	0	0	8.5790E-02
530	0	299	0	124	0	0	0	0	2.6550E-01
531	0	299	0	117	0	0	0	0	2.6390E-01
532	0	299	0	110	0	0	0	0	3.6290E-01
533	0	299	0	104	0	0	0	0	4.7050E-01
534	0	299	0	94	0	0	0	0	2.7640E-01
535	0	299	0	85	0	0	0	0	3.1250E-01
536	0	299	0	75	0	0	0	0	3.3340E-01
537	0	299	0	67	0	0	0	0	3.6610E-01
538	0	299	0	60	0	0	0	0	4.0720E-01
539	0	299	0	54	0	0	0	0	4.4670E-01
540	0	299	0	45	0	0	0	0	9.8620E-01
541	0	300	0	18	0	0	0	0	6.1470E-01
542	0	300	0	12	0	0	0	0	6.5650E-01
543	0	300	0	8	0	0	0	0	6.9610E-01
544	0	300	0	4	0	0	0	0	7.4150E-01
545	0	300	0	1	0	0	0	0	8.6180E-01
546	0	301	0	2	0	0	0	0	3.7010E-01
547	0	302	0	3	0	0	0	0	1.3580E+00
548	0	303	0	7	0	0	0	0	8.5600E-01
549	0	304	0	11	0	0	0	0	6.7600E-01
550	0	305	0	17	0	0	0	0	5.5800E-01
551	0	306	0	24	0	0	0	0	5.0100E-01
552	0	307	0	34	0	0	0	0	4.5400E-01
553	0	308	0	44	0	0	0	0	4.1700E-01
554	0	309	0	52	0	0	0	0	2.3400E-01
555	0	310	0	53	0	0	0	0	4.3930E-01
556	0	311	0	59	0	0	0	0	3.3180E-01
557	0	312	0	66	0	0	0	0	3.6730E-01
558	0	313	0	74	0	0	0	0	3.6000E-01
559	0	314	0	84	0	0	0	0	1.9000E-01
560	0	315	0	159	0	0	0	0	1.1560E-01
561	0	316	0	160	0	0	0	0	1.3610E-01
562	0	317	0	161	0	0	0	0	1.2910E-01
563	0	318	0	162	0	0	0	0	2.4950E-01
564	0	319	0	167	0	0	0	0	2.1960E-01
565	0	320	0	168	0	0	0	0	2.1440E-01
566	0	321	0	175	0	0	0	0	2.0640E-01
567	0	322	0	176	0	0	0	0	2.0980E-01
568	0	323	0	177	0	0	0	0	1.9570E-01
569	0	324	0	178	0	0	0	0	1.9280E-01
570	0	325	0	189	0	0	0	0	1.8980E-01
571	0	326	0	190	0	0	0	0	1.8010E-01
572	0	327	0	191	0	0	0	0	1.8500E-01
573	0	328	0	203	0	0	0	0	1.7900E-01
574	0	329	0	204	0	0	0	0	1.3050E-01
575	0	330	0	2	0	41	0	0	2.0000E-03
576	0	331	0	3	0	41	0	0	6.1200E-03
577	0	332	0	7	0	41	0	0	7.5420E-03
578	0	333	0	11	0	41	0	0	9.6480E-03
579	0	334	0	17	0	41	0	0	1.0794E-02
580	0	335	0	24	0	41	0	0	1.1808E-02
581	0	336	0	34	0	41	0	0	1.4136E-02
582	0	337	0	44	0	41	0	0	1.7334E-02
583	0	338	0	52	0	41	0	0	2.6664E-02
584	0	339	0	53	0	41	0	0	5.5458E-02
585	0	340	0	59	0	41	0	0	2.4732E-02
586	0	341	0	66	0	41	0	0	6.2520E-02
587	0	342	0	74	0	41	0	0	1.0031E-01
588	0	343	0	84	0	41	0	0	8.0000E-03
589	0	344	0	159	0	41	0	0	1.3780E-02
590	0	345	0	160	0	41	0	0	1.6536E-02
591	0	346	0	161	0	41	0	0	1.4610E-02
592	0	347	0	162	0	41	0	0	3.1690E-02
593	0	348	0	167	0	41	0	0	2.9210E-02
594	0	349	0	168	0	41	0	0	2.9210E-02
595	0	350	0	175	0	41	0	0	2.8110E-02
596	0	351	0	176	0	41	0	0	2.9770E-02
597	0	352	0	177	0	41	0	0	2.8390E-02
598	0	353	0	178	0	41	0	0	2.8110E-02
599	0	354	0	189	0	41	0	0	2.8390E-02
600	0	355	0	190	0	41	0	0	2.8110E-02
601	0	356	0	191	0	41	0	0	2.8390E-02

COND	INC	NODE	INC	NODE	INC	CURV	EVX	NO.	COND. VAL.
602	0	357	0	203	0	41	0	0	2.8940E-02
603	1	358	0	25	1	0	0	5	2.7190E-01
612	0	291	0	103	0	0	0	0	1.2650E-01
613	0	291	0	93	0	0	0	0	1.3530E-01
614	0	291	0	84	0	0	0	0	2.7950E-01
615	0	286	0	240	0	0	0	0	7.8540E-01
616	0	286	0	233	0	0	0	0	2.6180E-01
617	0	286	0	225	0	0	0	0	1.4840E-01
618	0	286	0	217	0	0	0	0	8.2900E-02
619	0	286	0	123	0	0	0	0	1.5710E-01
620	0	286	0	116	0	0	0	0	1.5010E-01
621	0	359	0	261	0	0	0	0	2.1800E-02
622	0	359	0	255	0	0	0	0	6.7700E-02
623	0	359	0	247	0	0	0	0	8.6400E-02
624	0	359	0	239	0	0	0	0	1.0070E-01
625	0	359	0	232	0	0	0	0	1.2070E-01
626	0	359	0	224	0	0	0	0	1.4640E-01
627	0	359	0	216	0	0	0	0	2.3250E-01
632	0	158	0	291	0	0	0	0	1.6232E-01

OTHER VALUES

LOC. INC NO. VALUE

VARIABLE LINES

ANS	INC	PRMA	INC	PRMB	INC	PRMC	INC	CODE	CURV	EVX	NO.	PARAM. A	PARAM. B	PARAM. C
20268	1	41003	0	0	0	0	0	6	0	1	9	0.0	1.4580E+01	0.0
20278	1	41003	0	0	0	0	0	6	0	1	8	0.0	3.8880E+01	0.0
20287	1	41003	0	0	0	0	0	6	0	1	4	0.0	4.8600E+00	0.0
20292	1	41003	0	0	0	0	0	6	0	1	6	0.0	3.4020E+01	0.0
10292	0	10286	0	0	0	0	0	4	0	1	0	0.0	5.0000E+00	0.0
10287	0	10286	0	0	0	0	0	4	0	1	0	0.0	5.0000E+00	0.0

CURVE NO. 41 IN-792 THER.CON

0.0	7.9200E+00
8.0000E+02	1.0000E+01
1.0000E+03	1.0420E+01
1.2000E+03	1.1420E+01
1.4000E+03	1.2580E+01
1.6000E+03	1.4170E+01
1.8000E+03	1.6330E+01
2.0000E+03	2.0000E+01
0.0	0.0

OUTPUT CODES

I.D.	INC	NO.
10001	1	359
0	0	0

PSEUDO SE

CAP.	COND.	NODE	RCX	STU	DCND
1			0	0	0
	1	2			
	142	5			
	545	300			
2			0	0	0
	1	1			
	2	3			
	143	6			
	546	301			
	575	330			
3			0	0	0
	2	2			
	144	7			
	547	302			
	576	331			
4			0	0	0
	3	5			
	139	8			
	544	300			
5			0	0	0
	3	4			
	4	6			
	142	1			
	629	9			
6			0	0	0
	4	5			
	5	7			
	143	2			
	630	10			
7			0	0	0
	5	6			
	144	3			
	548	303			
	577	332			
	631	11			
8			0	0	0
	6	9			
	139	4			
	140	13			
	543	300			
9			0	0	0
	6	8			
	7	10			
	145	14			
	629	5			
10			0	0	0
	7	9			
	8	11			
	146	15			
	630	6			
11			0	0	0
	8	10			
	147	16			
	549	304			
	578	333			
	631	7			
12			0	0	0
	9	13			
	138	18			
	542	300			
13			0	0	0
	9	12			
	10	14			
	140	8			

CAP.	COND.	NODE	RCX	STU	DCND
	148	19			
14			0	0	0
	10	13			
	11	15			
	145	9			
	149	20			
15			0	0	0
	11	14			
	12	16			
	146	10			
	150	21			
16			0	0	0
	12	15			
	13	17			
	147	11			
	151	22			
17			0	0	0
	13	16			
	152	23			
	550	305			
	579	334			
18			0	0	0
	14	19			
	138	12			
	153	30			
	541	300			
19			0	0	0
	14	18			
	15	20			
	148	13			
	154	31			
20			0	0	0
	15	19			
	16	21			
	149	14			
	155	31			
21			0	0	0
	16	20			
	17	22			
	150	15			
	156	32			
22			0	0	0
	17	21			
	18	23			
	151	16			
	157	32			
23			0	0	0
	18	22			
	19	24			
	152	17			
	158	33			
24			0	0	0
	19	23			
	159	33			
	551	306			
	580	335			
25			0	0	0
	20	26			
	160	35			
	603	358			
26			0	0	0
	20	25			
	21	27			
	[illegible]	36			
	[illegible]	358			

CAP.	COND.	NODE	RCX	STU	DCND
27			0	0	0
	21	26			
	22	28			
	162	37			
	605	358			
28			0	0	0
	22	27			
	23	29			
	163	38			
	606	358			
29			0	0	0
	23	28			
	24	30			
	164	39			
	607	358			
30			0	0	0
	24	29			
	25	31			
	153	18			
	165	40			
31			0	0	0
	25	30			
	26	32			
	154	19			
	155	20			
	166	41			
32			0	0	0
	26	31			
	27	33			
	156	21			
	157	22			
	167	42			
33			0	0	0
	27	32			
	28	34			
	158	23			
	159	24			
	168	43			
34			0	0	0
	28	33			
	169	44			
	552	307			
	581	336			
35			0	0	0
	29	36			
	160	25			
36			0	0	0
	29	35			
	30	37			
	161	26			
37			0	0	0
	30	36			
	31	38			
	162	27			
38			0	0	0
	31	37			
	32	39			
	163	28			
	170	45			
39			0	0	0
	32	38			
	33	40			
	164	29			
	171	46			

ORIGINAL PAGE IS
OF POOR QUALITY

P-315 THERMAL TRANSIENT ANALY
NASA COOLED

CAP.	COND.	NODE	RCX	STU	DCND
40			0	0	0
	33	39			
	34	41			
	165	30			
	172	47			
41			0	0	0
	34	40			
	35	42			
	166	31			
	173	48			
42			0	0	0
	35	41			
	36	43			
	167	32			
	174	49			
43			0	0	0
	36	42			
	37	44			
	168	33			
	175	50			
44			0	0	0
	37	43			
	169	34			
	176	51			
	553	308			
	582	337			
45			0	0	0
	38	46			
	170	38			
	177	55			
	476	268			
	485	269			
	540	299			
46			0	0	0
	38	45			
	39	47			
	171	39			
	178	55			
	477	269			
	486	270			
47			0	0	0
	39	46			
	40	48			
	172	40			
	179	56			
	478	270			
	487	271			
48			0	0	0
	40	47			
	41	49			
	173	41			
	180	56			
	479	271			
	488	272			
49			0	0	0
	41	48			
	42	50			
	174	42			
	181	67			
	480	272			
	489	273			
50			0	0	0
	42	49			
	43	51			
		43			
		57			
		273			

P-315 THERMAL TRANSIENT ANALYSER REVISION
NASA COOLED RADIAL TURB.

CAP.	COND.	NODE	RCX	STU	DCND
	490	274			
51			0	0	0
	43	50			
	44	52			
	176	44			
	183	58			
	482	274			
	491	275			
52			0	0	0
	44	51			
	45	53			
	184	58			
	483	275			
	492	276			
	554	309			
	583	338			
53			0	0	0
	45	52			
	185	59			
	484	276			
	493	277			
	555	310			
	584	339			
54			0	0	0
	46	55			
	186	60			
	539	299			
55			0	0	0
	46	54			
	47	56			
	177	45			
	178	46			
	187	61			
56			0	0	0
	47	55			
	48	57			
	179	47			
	180	48			
	188	62			
57			0	0	0
	48	56			
	49	58			
	181	49			
	182	50			
	189	63			
58			0	0	0
	49	57			
	50	59			
	183	51			
	184	52			
	190	64			
59			0	0	0
	50	58			
	185	53			
	191	65			
	556	311			
	585	340			
60			0	0	0
	51	61			
	186	54			
	192	67			
	538	299			
61			0	0	0
	51	60			
	52	62			
	187	56			

P-315 THERMAL TRANSIENT ANALYSER REVISION NC
NASA COOLED RADIAL TURB.DI

CAP.	COND.	NODE	RCX	STU	DCND
62			0	0	0
	52	61			
	53	63			
	188	56			
	194	69			
63			0	0	0
	53	62			
	54	64			
	189	57			
	195	70			
64			0	0	0
	54	63			
	55	65			
	190	58			
	196	71			
65			0	0	0
	55	64			
	56	66			
	191	59			
	197	72			
66			0	0	0
	56	65			
	198	73			
	557	312			
	586	341			
67			0	0	0
	57	68			
	192	60			
	199	76			
	537	299			
68			0	0	0
	57	67			
	58	69			
	193	61			
	200	77			
69			0	0	0
	58	68			
	59	70			
	194	62			
	201	78			
70			0	0	0
	59	69			
	60	71			
	195	63			
	202	79			
71			0	0	0
	60	70			
	61	72			
	196	64			
	203	80			
72			0	0	0
	61	71			
	62	73			
	197	65			
	204	81			
73			0	0	0
	62	72			
	63	74			
	198	66			
	205	82			
74			0	0	0
	63	73			
	206	83			

PAGE 230-199 INTENTIONALLY BLANK

CAP.	COND.	NODE	RCX	STU	DCND
75			0	0	0
	64	76			
	207	85			
	536	299			
76			0	0	0
	64	75			
	65	77			
	199	67			
	208	86			
77			0	0	0
	65	76			
	66	78			
	200	68			
	209	87			
78			0	0	0
	66	77			
	67	79			
	201	69			
	210	88			
79			0	0	0
	67	78			
	68	80			
	202	70			
	211	89			
80			0	0	0
	68	79			
	69	81			
	203	71			
	212	90			
81			0	0	0
	69	80			
	70	82			
	204	72			
	213	91			
82			0	0	0
	70	81			
	71	83			
	205	73			
	214	92			
83			0	0	0
	71	82			
	72	84			
	206	74			
	215	93			
84			0	0	0
	72	83			
	559	314			
	588	343			
	614	291			
85			0	0	0
	73	86			
	207	75			
	216	94			
	535	299			
86			0	0	0
	73	85			
	74	87			
	208	76			
	217	95			
87			0	0	0
	74	86			
	75	88			
	209	77			
	218	96			

CAP.	COND.	NODE	RCX	STU	DCND
88			0	0	0
	75	87			
	76	89			
	210	78			
	219	97			
89			0	0	0
	76	88			
	77	90			
	211	79			
	220	98			
90			0	0	0
	77	89			
	78	91			
	212	80			
	221	99			
91			0	0	0
	78	90			
	79	92			
	213	81			
	222	100			
92			0	0	0
	79	91			
	80	93			
	214	82			
	223	101			
93			0	0	0
	80	92			
	215	83			
	224	102			
	613	291			
94			0	0	0
	81	95			
	216	85			
	225	105			
	534	299			
95			0	0	0
	81	94			
	82	96			
	217	86			
	226	105			
96			0	0	0
	82	95			
	83	97			
	218	87			
	227	106			
97			0	0	0
	83	96			
	84	98			
	219	88			
	228	106			
98			0	0	0
	84	97			
	85	99			
	220	89			
	229	107			
99			0	0	0
	85	98			
	86	100			
	221	90			
	230	107			
100			0	0	0
	86	99			
	87	101			
	[illegible]	91			
		108			

CAP.	COND.	NODE	RCX	STU	DCND
101			0	0	0
	87	100			
	88	102			
	223	92			
	232	108			
102			0	0	0
	88	101			
	89	103			
	224	93			
	233	109			
103			0	0	0
	89	102			
	234	109			
	470	163			
	612	291			
104			0	0	0
	90	105			
	235	110			
	533	299			
105			0	0	0
	90	104			
	91	106			
	225	94			
	226	95			
	236	111			
106			0	0	0
	91	105			
	92	107			
	227	96			
	228	97			
	237	112			
107			0	0	0
	92	106			
	93	108			
	229	98			
	230	99			
	238	113			
108			0	0	0
	93	107			
	94	109			
	231	100			
	232	101			
	239	114			
109			0	0	0
	94	108			
	233	102			
	234	103			
	240	115			
	471	169			
	472	179			
110			0	0	0
	95	111			
	235	104			
	241	117			
	532	299			
111			0	0	0
	95	110			
	96	112			
	236	105			
	242	118			
112			0	0	0
	96	111			
	97	113			
	237	106			
	243	119			

P-315 RMAL TRANSIENT ANALYSER REVISION
NASA COOLED RADIAL TURB

CAP.	COND.	NODE	RCX	STU	DCND
113			0	0	0
	97	112			
	98	114			
	238	107			
	244	120			
114			0	0	0
	98	113			
	99	115			
	239	108			
	245	121			
115			0	0	0
	99	114			
	100	116			
	240	109			
	246	122			
	473	192			
116			0	0	0
	100	115			
	247	123			
	620	286			
117			0	0	0
	101	118			
	241	110			
	248	125			
	531	299			
118			0	0	0
	101	117			
	102	119			
	242	111			
	249	126			
119			0	0	0
	102	118			
	103	120			
	243	112			
	250	127			
120			0	0	0
	103	119			
	104	121			
	244	113			
	251	128			
121			0	0	0
	104	120			
	105	122			
	245	114			
	252	129			
122			0	0	0
	105	121			
	106	123			
	246	115			
	253	130			
123			0	0	0
	106	122			
	247	116			
	254	131			
	619	286			
124			0	0	0
	107	125			
	255	134			
	494	278			
	502	279			
	530	299			
125			0	0	0
	107	124			
	[illegible]	126			

P-315 RMAL TRANSIENT ANALYSER REVI
NASA COOLED RADIAL

CAP.	COND.	NODE	RCX	STU	DCND
	256	135			
	495	279			
	501	280			
126			0	0	0
	108	125			
	109	127			
	249	118			
	257	136			
	496	280			
	504	281			
127			0	0	0
	109	126			
	110	128			
	250	119			
	258	137			
	497	281			
	505	282			
128			0	0	0
	110	127			
	111	129			
	251	120			
	259	138			
	498	282			
	506	283			
129			0	0	0
	111	128			
	112	130			
	252	121			
	260	139			
	499	293			
	507	284			
130			0	0	0
	112	129			
	113	131			
	253	122			
	261	140			
	500	284			
	508	285			
131			0	0	0
	113	130			
	254	123			
	262	141			
	501	285			
	509	286			
132			0	0	0
	114	133			
	263	145			
133			0	0	0
	114	132			
	115	134			
	264	146			
134			0	0	0
	115	133			
	116	135			
	255	124			
	265	147			
135			0	0	0
	116	134			
	117	136			
	256	125			
	266	148			
136			0	0	0
	117	135			
	118	137			
	257	126			
	267	149			

P-315 THERMAL TRANSIENT ANALYSER REVISION
NASA COOLED RADIAL TURB

CAP.	COND.	NODE	RCX	STU	DCND
137			0	0	0
	118	136			
	119	138			
	258	127			
	268	150			
138			0	0	0
	119	137			
	120	139			
	259	128			
	269	151			
139			0	0	0
	120	138			
	121	140			
	260	129			
	270	152			
140			0	0	0
	121	139			
	122	141			
	261	130			
	271	153			
141			0	0	0
	122	140			
	123	142			
	262	131			
	272	154			
142			0	0	0
	123	141			
	124	143			
	273	155			
143			0	0	0
	124	142			
	125	144			
	274	156			
	474	249			
144			0	0	0
	125	143			
	275	157			
145			0	0	0
	126	146			
	263	132			
146			0	0	0
	126	145			
	127	147			
	264	133			
147			0	0	0
	127	146			
	128	148			
	265	134			
148			0	0	0
	128	147			
	129	149			
	266	135			
149			0	0	0
	129	148			
	130	150			
	267	136			
150			0	0	0
	130	149			
	131	151			
	268	137			
151			0	0	0
	1	150			

ORIGINAL PAGE IS
OF POOR QUALITY

CAP.	COND.	NODE	RCX	STU	DCND
	269	138			
152			0	0	0
	132	151			
	133	153			
	270	139			
153			0	0	0
	133	152			
	134	154			
	271	140			
154			0	0	0
	134	153			
	135	155			
	272	141			
155			0	0	0
	135	154			
	136	156			
	273	142			
156			0	0	0
	136	155			
	137	157			
	274	143			
157			0	0	0
	137	156			
	275	144			
158			0	0	0
	276	159			
	632	291			
159			0	0	0
	276	158			
	277	160			
	372	163			
	560	315			
	589	344			
160			0	0	0
	277	159			
	278	161			
	373	164			
	561	316			
	590	345			
161			0	0	0
	278	160			
	279	162			
	374	165			
	562	317			
	591	346			
162			0	0	0
	279	161			
	375	166			
	523	297			
	529	298			
	563	318			
	592	347			
163			0	0	0
	280	164			
	372	159			
	376	169			
	470	103			
	513	290			
	517	291			
164			0	0	0
	280	163			
	281	165			
	373	160			
	377	170			

CAP.	COND.	NODE	RCX	STU	DCND
165			0	0	0
	281	164			
	282	166			
	374	161			
	378	171			
166			0	0	0
	282	165			
	283	167			
	375	162			
	379	172			
	522	296			
	528	297			
167			0	0	0
	283	166			
	284	168			
	380	173			
	564	319			
	593	348			
168			0	0	0
	284	167			
	381	174			
	565	320			
	594	349			
169			0	0	0
	285	170			
	376	163			
	382	179			
	471	109			
	512	289			
	516	290			
170			0	0	0
	285	169			
	286	171			
	377	164			
	383	180			
171			0	0	0
	286	170			
	287	172			
	378	165			
	384	181			
172			0	0	0
	287	171			
	288	173			
	379	166			
	385	182			
	521	295			
	527	296			
173			0	0	0
	288	172			
	289	174			
	380	167			
	386	183			
174			0	0	0
	289	173			
	290	175			
	381	168			
	387	184			
175			0	0	0
	290	174			
	291	176			
	388	185			
	566	321			
	595	350			
176			0	0	0
		175			
		177			

CAP.	COND.	NODE	RCX	STU	DCND
	389	186			
	567	322			
	596	351			
177			0	0	0
	292	176			
	391	187			
	568	323			
	597	352			
178			0	0	0
	392	188			
	569	324			
	598	353			
179			0	0	0
	294	180			
	382	169			
	472	109			
	511	288			
	515	289			
180			0	0	0
	294	179			
	295	181			
	383	170			
	393	192			
181			0	0	0
	295	180			
	296	182			
	384	171			
	394	192			
182			0	0	0
	296	181			
	297	183			
	385	172			
	395	193			
	520	294			
	526	295			
183			0	0	0
	297	182			
	298	184			
	386	173			
	396	194			
184			0	0	0
	298	183			
	299	185			
	387	174			
	397	195			
185			0	0	0
	299	184			
	300	186			
	388	175			
	398	196			
186			0	0	0
	300	185			
	301	187			
	389	176			
	399	197			
187			0	0	0
	301	186			
	302	188			
	391	177			
	400	198			
188			0	0	0
	302	187			
	303	189			
	392	178			
	401	199			

P-315 THERMAL TRANSIENT ANALYSER REVISI
NASA COOLED RADIAL TL

CAP.	COND.	NODE	RCX	STU	DCND
189			0	0	0
	303	188			
	304	190			
	402	200			
	570	325			
	599	354			
190			0	0	0
	304	189			
	403	201			
	571	326			
	600	355			
191			0	0	0
	404	202			
	572	327			
	601	356			
192			0	0	0
	306	193			
	393	180			
	394	181			
	473	115			
	510	287			
	514	288			
193			0	0	0
	306	192			
	307	194			
	395	182			
	405	205			
	519	293			
	525	294			
194			0	0	0
	307	193			
	308	195			
	396	183			
	406	206			
195			0	0	0
	308	194			
	309	196			
	397	184			
	407	207			
196			0	0	0
	309	195			
	310	197			
	398	185			
	408	208			
197			0	0	0
	310	196			
	311	198			
	399	186			
	409	209			
198			0	0	0
	311	197			
	312	199			
	400	187			
	410	210			
199			0	0	0
	312	198			
	313	200			
	401	188			
	411	211			
200			0	0	0
	313	199			
	314	201			
	402	189			
	2	212			

P-315 THERMAL TRANSIENT ANALYSER REV
NASA COOLED RADIAL

CAP.	COND.	NODE	RCX	STU	DCND
201			0	0	0
	314	200			
	315	202			
	403	190			
	413	213			
202			0	0	0
	315	201			
	316	203			
	404	191			
	414	214			
203			0	0	0
	316	202			
	317	204			
	415	215			
	573	328			
	602	357			
204			0	0	0
	317	203			
	416	216			
	574	329			
205			0	0	0
	318	206			
	405	193			
	417	217			
	518	292			
	524	293			
206			0	0	0
	318	205			
	319	207			
	406	194			
	418	218			
207			0	0	0
	319	206			
	320	208			
	407	195			
	628	218			
208			0	0	0
	320	207			
	321	209			
	408	196			
	419	219			
209			0	0	0
	321	208			
	322	210			
	409	197			
	420	219			
210			0	0	0
	322	209			
	323	211			
	410	198			
	421	220			
211			0	0	0
	323	210			
	324	212			
	411	199			
	422	220			
212			0	0	0
	324	211			
	325	213			
	412	200			
	423	221			
213			0	0	0
	325	21			

P-315 THERMAL TRANSIENT ANALYSER REVISION N
NASA COOLED R AL TURB.D

CAP.	COND.	NODE	RCX	STU	DCND
	424	221			
214			0	0	0
	326	213			
	327	215			
	414	202			
	425	222			
215			0	0	0
	327	214			
	328	216			
	415	203			
	426	222			
216			0	0	0
	328	215			
	416	204			
	427	223			
	627	359			
217			0	0	0
	329	218			
	417	205			
	428	225			
	618	286			
218			0	0	0
	329	217			
	330	219			
	418	206			
	429	226			
	628	207			
219			0	0	0
	330	218			
	331	220			
	419	208			
	420	209			
	430	227			
220			0	0	0
	331	219			
	332	221			
	421	210			
	422	211			
	431	228			
221			0	0	0
	332	220			
	333	222			
	423	212			
	424	213			
	432	229			
222			0	0	0
	333	221			
	334	223			
	425	214			
	426	215			
	433	230			
223			0	0	0
	334	222			
	335	224			
	427	216			
	434	231			
224			0	0	0
	335	223			
	435	232			
	626	359			
225			0	0	0
	336	226			
	428	217			
	617	286			

P-315 ERMAL TRANSIENT ANALYSER REVI
NASA COOLED RA IAL

CAP.	COND.	NODE	RCX	STU	DCND
226			0	0	0
	336	225			
	337	227			
	429	218			
	436	233			
227			0	0	0
	337	226			
	338	228			
	430	219			
	437	234			
228			0	0	0
	338	227			
	339	229			
	431	220			
	438	235			
229			0	0	0
	339	228			
	340	230			
	432	221			
	439	236			
230			0	0	0
	340	229			
	341	231			
	433	222			
	440	237			
231			0	0	0
	341	230			
	342	232			
	434	223			
	441	238			
232			0	0	0
	342	231			
	435	224			
	442	239			
	625	359			
233			0	0	0
	343	234			
	436	226			
	443	240			
	616	286			
234			0	0	0
	343	233			
	344	235			
	437	227			
	444	241			
235			0	0	0
	344	234			
	345	236			
	438	228			
	445	242			
236			0	0	0
	345	235			
	346	237			
	439	229			
	446	243			
237			0	0	0
	346	236			
	347	238			
	440	230			
	447	244			
238			0	0	0
	347	237			
	348	239			
	441	231			
	448	245			

P-315 THERMAL TR IENT ANALYSER REVIS
NASA COOLED RADIAL T

CAP.	COND.	NODE	RCX	STU	DCND
239			0	0	0
	348	238			
	442	232			
	449	246			
	624	359			
240			0	0	0
	349	241			
	443	233			
	450	248			
	615	286			
241			0	0	0
	349	240			
	350	242			
	444	234			
	451	249			
242			0	0	0
	350	241			
	351	243			
	445	235			
	452	250			
243			0	0	0
	351	242			
	352	244			
	446	236			
	453	251			
244			0	0	0
	352	243			
	353	245			
	447	237			
	454	252			
245			0	0	0
	353	244			
	354	246			
	448	238			
	455	253			
246			0	0	0
	354	245			
	355	247			
	449	239			
	456	254			
247			0	0	0
	355	246			
	457	255			
	623	359			
248			0	0	0
	356	249			
	450	240			
249			0	0	0
	356	248			
	357	250			
	451	241			
	474	143			
250			0	0	0
	357	249			
	358	251			
	452	242			
	458	256			
251			0	0	0
	358	250			
	359	252			
	453	243			
	459	257			
252			0	0	0
		251			

P-315 THERMAL TRANSIENT A YSER REVISION N
NASA COOLED RADIAL TURB.D

CAP.	COND.	NODE	RCX	STU	DCND
	360	253			
	454	244			
	460	258			
253			0	0	0
	360	252			
	361	254			
	455	245			
	461	259			
254			0	0	0
	361	253			
	362	255			
	456	246			
	462	260			
255			0	0	0
	362	254			
	457	247			
	463	261			
	622	359			
256			0	0	0
	363	257			
	458	250			
	464	262			
257			0	0	0
	363	256			
	364	258			
	459	251			
	465	263			
258			0	0	0
	364	257			
	365	259			
	460	252			
	466	264			
259			0	0	0
	365	258			
	366	260			
	461	253			
260			0	0	0
	366	259			
	367	261			
	462	254			
261			0	0	0
	367	260			
	463	255			
	621	359			
262			0	0	0
	368	263			
	464	256			
	467	265			
263			0	0	0
	368	262			
	369	264			
	465	257			
	468	266			
264			0	0	0
	369	263			
	466	258			
	469	267			
265			0	0	0
	370	266			
	467	262			
266			0	0	0
	370	265			
	371	267			

P-315 HERMAL TRANSIENT ANALYSER REV
NASA COOLED RADIAL

CAP	COND.	NODE	RCX	STU	DCND
267			0	0	0
	171	266			
	469	264			
268			1	1	1
	476	45			
269			1	1	1
	477	46			
270			1	1	1
	478	47			
271			1	1	1
	479	48			
272			1	1	1
	480	49			
273			1	1	1
	481	50			
274			1	1	1
	482	51			
275			1	1	1
	483	52			
276			1	1	1
	484	53			
278			1	1	1
	494	124			
279			1	1	1
	495	125			
280			1	1	1
	496	126			
281			1	1	1
	497	127			
282			1	1	1
	498	128			
283			1	1	1
	499	129			
284			1	1	1
	500	130			
285			1	1	1
	501	131			
287			1	1	1
	510	192			
288			1	1	1
	511	179			
289			1	1	1
	512	169			
290			1	1	1
	513	163			
292			1	1	1
	518	205			
293			1	1	1
	519	193			
294			1	1	1
	[illegible]	[illegible]			

P 315 HERMAL TR ENT ANALYSER REVISION N
ASA COOLED R AL TURB D

CAP	COND	NODE	RCX	STU	DCND
295			1	1	1
	521	[illegible]			
296			1	1	1
	522	166			
297			1	1	1
	523	162			

ORIGINAL PAGE IS
OF POOR QUALITY

NASA COOLED RADIAL TURB.DISC .HEAT TRANSFER.THETA=36DEGR.AXISYM.G.AIGRET.

COUNT	PREV INC	NEXT INC	MIN RC
300	3.7500E-01	3.7500E-01	1.5000E+00

STEADY TEMPERATURES (°F)

1	2	3	4	5	6	7	8	9	10
1.3512E+03	1.3992E+03	1.4359E+03	1.2935E+03	1.3306E+03	1.3665E+03	1.4003E+03	1.2829E+03	1.3172E+03	1.3504E+03
11	12	13	14	15	16	17	18	19	20
1.3825E+03	1.2507E+03	1.2820E+03	1.3128E+03	1.3428E+03	1.3720E+03	1.4001E+03	1.2515E+03	1.2810E+03	1.3101E+03
21	22	23	24	25	26	27	28	29	30
1.3386E+03	1.3667E+03	1.3944E+03	1.4216E+03	1.0811E+03	1.0925E+03	1.1147E+03	1.1479E+03	1.1948E+03	1.2678E+03
31	32	33	34	35	36	37	38	39	40
1.3141E+03	1.3616E+03	1.4102E+03	1.4594E+03	1.0976E+03	1.1129E+03	1.1397E+03	1.1757E+03	1.2128E+03	1.2591E+03
41	42	43	44	45	46	47	48	49	50
1.3055E+03	1.3530E+03	1.4021E+03	1.4535E+03	1.1560E+03	1.1959E+03	1.2375E+03	1.2784E+03	1.3219E+03	1.3654E+03
51	52	53	54	55	56	57	58	59	60
1.4123E+03	1.4591E+03	1.4928E+03	1.1249E+03	1.1898E+03	1.2624E+03	1.3407E+03	1.4258E+03	1.5195E+03	1.1253E+03
61	62	63	64	65	66	67	68	69	70
1.1893E+03	1.2566E+03	1.3282E+03	1.4049E+03	1.4880E+03	1.5789E+03	1.1242E+03	1.1832E+03	1.2438E+03	1.3067E+03
71	72	73	74	75	76	77	78	79	80
1.3723E+03	1.4409E+03	1.5130E+03	1.5918E+03	1.0786E+03	1.1234E+03	1.1735E+03	1.2256E+03	1.2787E+03	1.3316E+03
81	82	83	84	85	86	87	88	89	90
1.3828E+03	1.4293E+03	1.4647E+03	1.4770E+03	1.0742E+03	1.1159E+03	1.1600E+03	1.2036E+03	1.2474E+03	1.2878E+03
91	92	93	94	95	96	97	98	99	100
1.3230E+03	1.3463E+03	1.3461E+03	1.0710E+03	1.1044E+03	1.1450E+03	1.1787E+03	1.2162E+03	1.2447E+03	1.2693E+03
101	102	103	104	105	106	107	108	109	110
1.2792E+03	1.2662E+03	1.2013E+03	1.0382E+03	1.0731E+03	1.1301E+03	1.1778E+03	1.2022E+03	1.1866E+03	1.0194E+03
111	112	113	114	115	116	117	118	119	120
1.0504E+03	1.0896E+03	1.1198E+03	1.1323E+03	1.1183E+03	1.0867E+03	9.9883E+02	1.0243E+03	1.0493E+03	1.0681E+03
121	122	123	124	125	126	127	128	129	130
1.0751E+03	1.0664E+03	1.0421E+03	9.6255E+02	9.7049E+02	9.8106E+02	9.9081E+02	9.9843E+02	1.0025E+03	1.0022E+03
131	132	133	134	135	136	137	138	139	140
9.9758E+02	9.6906E+02	9.6900E+02	9.6856E+02	9.7378E+02	9.8184E+02	9.9042E+02	9.9843E+02	1.0060E+03	1.0160E+03
141	142	143	144	145	146	147	148	149	150
1.0370E+03	1.0952E+03	1.1531E+03	1.1505E+03	9.6919E+02	9.6927E+02	9.7013E+02	9.7485E+02	9.8221E+02	9.9045E+02
151	152	153	154	155	156	157	158	159	160
9.9875E+02	1.0078E+03	1.0210E+03	1.0464E+03	1.0941E+03	1.1383E+03	1.1433E+03	1.1899E+03	1.2003E+03	1.2126E+03
161	162	163	164	165	166	167	168	169	170
1.2221E+03	1.2258E+03	1.1860E+03	1.1951E+03	1.2033E+03	1.2145E+03	1.2828E+03	1.3306E+03	1.1701E+03	1.1766E+03
171	172	173	174	175	176	177	178	179	180
1.1839E+03	1.1956E+03	1.2612E+03	1.3200E+03	1.3798E+03	1.4203E+03	1.4554E+03	1.5059E+03	1.1585E+03	1.1619E+03
181	182	183	184	185	186	187	188	189	190
1.1670E+03	1.1776E+03	1.2405E+03	1.2978E+03	1.3506E+03	1.3961E+03	1.4401E+03	1.4849E+03	1.5220E+03	1.5472E+03
191	192	193	194	195	196	197	198	199	200
1.5842E+03	1.1479E+03	1.1627E+03	1.2221E+03	1.2738E+03	1.3250E+03	1.3699E+03	1.4143E+03	1.4539E+03	1.4904E+03
201	202	203	204	205	206	207	208	209	210
1.5220E+03	1.5524E+03	1.5727E+03	1.5681E+03	1.1571E+03	1.2053E+03	1.2463E+03	1.3023E+03	1.3404E+03	1.3895E+03
211	212	213	214	215	216	217	218	219	220
1.4218E+03	1.4596E+03	1.4829E+03	1.5048E+03	1.5108E+03	1.4910E+03	1.1522E+03	1.1983E+03	1.2946E+03	1.3790E+03
221	222	223	224	225	226	227	228	229	230
1.4400E+03	1.4678E+03	1.4464E+03	1.4170E+03	1.1197E+03	1.1611E+03	1.2666E+03	1.3544E+03	1.4130E+03	1.4373E+03
231	232	233	234	235	236	237	238	239	240
1.4220E+03	1.4036E+03	1.1085E+03	1.2380E+03	1.3334E+03	1.3910E+03	1.4142E+03	1.4044E+03	1.3909E+03	1.0620E+03
241	242	243	244	245	246	247	248	249	250
1.2125E+03	1.3186E+03	1.3746E+03	1.3971E+03	1.3916E+03	1.3815E+03	1.3688E+03	1.0918E+03	1.1919E+03	1.3138E+03

251	252	253	254	255	256	257	258	259	260
1.3639E+03	1.3849E+03	1.3832E+03	1.3766E+03	1.3667E+03	1.3289E+03	1.3589E+03	1.3762E+03	1.3801E+03	1.3752E+03
261	262	263	264	265	266	267	268	269	270
1.3667E+03	1.3386E+03	1.3565E+03	1.3692E+03	1.3428E+03	1.3557E+03	1.3660E+03	9.6500E+02	9.6599E+02	9.6719E+02
271	272	273	274	275	276	277	278	279	280
9.6859E+02	9.7021E+02	9.7204E+02	9.7408E+02	9.7636E+02	9.7887E+02	9.8155E+02	9.5000E+02	9.5015E+02	9.5039E+02
281	282	283	284	285	286	287	288	289	290
9.5076E+02	9.5123E+02	9.5180E+02	9.5240E+02	9.5299E+02	9.5352E+02	9.5852E+02	9.6267E+02	9.6696E+02	9.7140E+02
291	292	293	294	295	296	297	298	299	300
9.7610E+02	9.5852E+02	9.5952E+02	9.6054E+02	9.6164E+02	9.6281E+02	9.6408E+02	9.6540E+02	9.5800E+02	9.5000E+02
301	302	303	304	305	306	307	308	309	310
1.6500E+03	1.6530E+03	1.6650E+03	1.6860E+03	1.7140E+03	1.7470E+03	1.7840E+03	1.8280E+03	1.8750E+03	1.9240E+03
311	312	313	314	315	316	317	318	319	320
1.9800E+03	2.0390E+03	2.1030E+03	2.1720E+03	1.1400E+03	1.1600E+03	1.1800E+03	1.2250E+03	1.3000E+03	1.3700E+03
321	322	323	324	325	326	327	328	329	330
1.4500E+03	1.5250E+03	1.6000E+03	1.6800E+03	1.7600E+03	1.8250E+03	1.8900E+03	1.9500E+03	2.0100E+03	1.4900E+03
331	332	333	334	335	336	337	338	339	340
1.4670E+03	1.4640E+03	1.4750E+03	1.4900E+03	1.5080E+03	1.5180E+03	1.5240E+03	1.5220E+03	1.5280E+03	1.6000E+03
341	342	343	344	345	346	347	348	349	350
1.6200E+03	1.6400E+03	1.6500E+03	1.3300E+03	1.3490E+03	1.3680E+03	1.3870E+03	1.4050E+03	1.4240E+03	1.4430E+03
351	352	353	354	355	356	357	358	359	
1.4620E+03	1.4810E+03	1.5000E+03	1.5180E+03	1.5370E+03	1.5560E+03	1.5750E+03	9.5000E+02	1.3000E+03	

CAPACITANCES

	...	...					268	269	270
							5.4675E+00	5.4675E+00	5.4675E+00
271	272	273	274	275	276	278	279	280	281
5.4675E+00	5.4675E+00	5.4675E+00	5.4675E+00	5.4675E+00	5.4675E+00	1.4580E+01	1.4580E+01	1.4580E+01	1.4580E+01
282	283	284	285	287	288	289	290	292	293
1.4580E+01	1.4580E+01	1.4580E+01	1.4580E+01	1.8225E+00	1.8225E+00	1.8225E+00	1.8225E+00	1.2758E+01	1.2758E+01
294	295	296	297						
1.2758E+01	1.2758E+01	1.2758E+01	1.2758E+01						

CONDUCTANCES

1	2	3	4	5	6	7	8	9	10
7.423: +0	7.5922E+00	6.9519E+00	7.0737E+00	7.1901E+00	6.66 +00	6.7690E+00	6.8740E+00	6.3046E+00	6.4008E+00

11	12	13	14	15	16	17	18	19	20
6.4950E+00	6.5867E+00	6.6754E+00	6.0570E+00	6.1442E+00	6.2299E+00	6.3143E+00	6.3972E+00	6.4876E+00	1.5890E+00
21	22	23	24	25	26	27	28	29	30
1.6013E+00	1.6216E+00	1.6509E+00	1.6984E+00	2.9402E+00	3.0071E+00	3.0757E+00	3.1639E+00	1.1363E+00	1.4465E+00
31	32	33	34	35	36	37	38	39	40
1.8086E+00	2.6840E+00	2.7399E+00	2.8032E+00	2.8674E+00	2.9333E+00	3.0161E+00	4.8180E+00	4.9106E+00	5.0126E+00
41	42	43	44	45	46	47	48	49	50
5.1171E+00	5.2246E+00	5.3363E+00	5.4849E+00	5.6214E+00	1.1442E+00	1.1814E+00	1.2261E+00	1.2745E+00	1.3434E+00
51	52	53	54	55	56	57	58	59	60
1.0855E+00	1.1191E+00	1.1581E+00	1.1998E+00	1.2543E+00	1.3213E+00	1.0252E+00	1.0536E+00	1.0864E+00	1.1205E+00
61	62	63	64	65	66	67	68	69	70
1.1575E+00	1.2088E+00	1.2637E+00	9.4386E-01	9.6436E-01	9.8644E-01	1.0128E+00	1.0393E+00	1.0654E+00	1.0910E+00
71	72	73	74	75	76	77	78	79	80
1.1191E+00	9.1391E-01	8.8422E-01	9.0163E-01	9.1943E-01	9.3884E-01	9.5865E-01	9.7642E-01	9.9020E-01	9.9564E-01
81	82	83	84	85	86	87	88	89	90
8.2441E-01	8.3845E-01	8.5254E-01	8.6606E-01	8.8044E-01	8.9213E-01	8.9973E-01	8.9903E-01	6.6467E-01	1.2137E+00
91	92	93	94	95	96	97	98	99	100
7.4385E-01	7.6166E-01	7.7393E-01	7.7544E-01	8.1359E-01	6.2030E-01	6.3030E-01	6.3645E-01	6.3623E-01	9.6873E-01
101	102	103	104	105	106	107	108	109	110
4.9375E-01	4.9970E-01	5.0486E-01	5.0791E-01	5.0771E-01	5.0382E-01	7.0393E-01	4.5842E-01	4.5936E-01	4.6017E-01
111	112	113	114	115	116	117	118	119	120
4.6077E-01	4.6118E-01	4.6066E-01	2.2375E-01	1.8763E-01	1.8772E-01	1.8798E-01	1.8829E-01	1.8861E-01	1.8902E-01
121	122	123	124	125	126	127	128	129	130
1.8982E-01	1.9122E-01	1.9481E-01	2.0007E-01	2.8939E-01	1.5977E-01	9.5869E-02	9.5923E-02	9.6041E 02	9.6192E-02
131	132	133	134	135	136	137	138	139	140
9.6353E-02	9.6609E-02	9.7124E-02	9.8018E-02	9.9710E-02	1.0184E-01	1.4711E-01	7.0297E-03	3.0359E-01	4.0489E-01
142	143	144	145	146	147	148	149	150	151
5.1425E-01	5.2447E-01	5.3470E-01	4.1132E-01	4.1756E-01	4.2360E-01	1.1893E-02	1.2066E-02	1.2236E-02	1.2402E-02
152	153	154	155	156	157	158	159	160	161
1.2564E-02	3.6958E-01	1.2489E-02	1.2577E-02	1.2807E-02	1.2892E-02	1.3127E-02	1.3240E-02	1.0469E+00	1.0533E+00
162	163	164	165	166	167	168	169	170	171
1.0651E+00	1.0818E+00	1.1023E+00	7.0968E-01	7.2587E-01	7.4245E-01	7.6030E-01	4.7063E-01	2.1343E-01	4.3430E-01
172	173	174	175	176	177	178	179	180	181
4.4397E-01	4.5358E-01	4.6359E-01	4.7378E-01	4.8727E-01	3.9864E-01	4.0216E-01	4.1366E-01	4.1785E-01	4.3034E-01
182	183	184	185	186	187	188	189	190	191
4.3479E-01	4.4976E-01	4.5634E-01	4.6614E-01	6.6631E-01	1.1306E+00	1.1702E+00	1.2134E+00	1.2634E+00	1.3332E+00
192	193	194	195	196	197	198	199	200	201
1.0406E+00	1.0696E+00	1.1035E+00	1.1402E+00	1.1791E+00	1.2336E+00	1.2946E+00	9.8231E-01	1.0066E+00	1.0341E+00
202	203	204	205	206	207	208	209	210	211
1.0641E+00	1.0946E+00	1.1278E+00	1.1697E+00	1.2102E+00	4.5232E-01	9.2276E-01	9.4249E-01	9.6351E-01	9.8705E-01
212	213	214	215	216	217	218	219	220	221
1.0097E+00	1.0307E+00	1.0476E+00	1.0572E+00	8.4658E-01	8.6132E-01	8.7794E-01	8.9312E-01	9.1109E-01	9.2675E-01
222	223	224	225	226	227	228	229	230	231
9.4037E-01	9.4794E-01	9.4492E-01	5.1691E-01	5.2091E-01	5.3261E-01	5.3664E-01	5.4686E-01	5.5070E-01	5.5753E-01
232	233	234	235	236	237	238	239	240	241
5.5890E-01	5.5491E-01	6.0365E-01	2.4833E-01	6.7254E-01	6.8762E-01	6.9983E-01	7.0561E-01	7.0097E-01	3.6865E-01
242	243	244	245	246	247	248	249	250	251
5.5351E-01	5.6189E-01	5.6828E-01	5.7083E-01	5.6787E-01	2.3825E-01	3.3114E-01	3.3259E-01	3.3537E-01	3.3747E-01
252	253	254	255	256	257	258	259	260	261
3.3835E-01	3.3763E-01	2.0120E-01	2.3928E-01	2.3960E-01	2.4005E-01	2.4050E-01	2.4088E-01	2.4144E-01	2.4200E-01
262	263	264	265	266	267	268	269	270	271
2.4295E-01	8.7470E-02	2.6915E-01	2.3557E-01	2.3581E-01	2.3618E-01	2.3658E-01	2.3697E-01	2.3782E-01	2.3914E-01

ORIGINAL PAGE IS
OF POOR QUALITY

272	273	274	275	276	277	278	279	280	281
2.4178E-01	2.4780E-01	2.5360E-01	1.0151E-01	3.3296E+00	2.1878E+00	1.6009E+00	9.8397E-01	1.7269E+00	1.7335E+00
282	283	284	285	286	287	288	289	290	291
1.0800E+00	8.2626E-01	5.7165E-01	1.8554E+00	1.6005E+00	9.9647E-01	7.6156E-01	7.8527E-01	8.0789E-01	8.8927E-01
292	294	295	296	297	298	299	300	301	302
5.3820E-01	2.2255E+00	1.6351E+00	9.1558E-01	6.9832E-01	7.1954E-01	7.9459E-01	8.1324E-01	8.3277E-01	8.5587E-01
303	304	306	307	308	309	310	311	312	313
8.7719E-01	6.1787E-01	6.2700E-01	6.3739E-01	7.0438E-01	7.2236E-01	7.3913E-01	7.5472E-01	7.7381E-01	7.9202E-01
314	315	316	317	318	319	320	321	322	323
8.0831E-01	8.2317E-01	8.3530E-01	6.1019E-01	6.7336E-01	6.3607E-01	6.5153E-01	6.6653E-01	6.8045E-01	6.9411E-01
324	325	326	327	328	329	330	331	332	333
7.0942E-01	7.2277E-01	7.3264E-01	7.3873E-01	7.3572E-01	4.6825E-01	2.9073E-01	3.0376E-01	3.1475E-01	3.2353E-01
334	335	336	337	338	339	340	341	342	343
4.3222E-01	8.5106E-01	4.3043E-01	2.5591E-01	2.6839E-01	2.7783E-01	2.8439E-01	3.8025E-01	6.1018E-01	2.2161E-01
344	345	346	347	348	349	350	351	352	353
2.3399E-01	2.4270E-01	2.4741E-01	3.3128E-01	4.9348E-01	1.8899E-01	2.0080E-01	2.0880E-01	2.1268E-01	2.8468E-01
354	355	356	357	358	359	360	361	362	363
4.2549E-01	5.2904E-01	1.9768E-01	1.7496E-01	1.8240E-01	1.8548E-01	2.4842E-01	3.7192E-01	3.7049E-01	1.6232E-01
364	365	366	367	368	369	370	371	372	373
1.6414E-01	1.1392E-01	1.7084E-01	1.7031E-01	1.3233E-01	1.3329E-01	1.0053E-01	1.0108E-01	4.4694E-01	4.4918E-01
374	375	376	377	378	379	380	381	382	383
4.5119E-01	1.1403E+00	3.3149E-01	3.3264E-01	3.3377E-01	7.4665E-01	8.5474E-01	1.4136E+00	1.9120E-01	3.8325E-01
384	385	386	387	388	389	391	392	393	394
3.8430E-01	6.8743E-01	7.0935E-01	7.7893E-01	8.4215E-01	8.6030E-01	1.2453E+00	1.4897E+00	4.4311E-01	4.2143E-01
395	396	397	398	399	400	401	402	403	404
6.2990E-01	6.4839E-01	7.4837E-01	7.6731E-01	7.8376E-01	8.0352E-01	8.2460E-01	8.4297E-01	1.2095E+00	1.4329E+00
405	406	407	408	409	410	411	412	413	414
5.7472E-01	6.2546E-01	6.7733E-01	6.9522E-01	7.0907E-01	7.2492E-01	7.4138E-01	7.5837E-01	7.7092E-01	7.8290E-01
415	416	417	418	419	420	421	422	423	424
7.8890E-01	7.8334E-01	3.5136E-01	5.9799E-01	6.2732E-01	6.3310E-01	6.5336E-01	6.5830E-01	6.7885E-01	6.8369E-01
425	426	427	428	429	430	431	432	433	434
6.9403E-01	6.9527E-01	6.8672E-01	2.0901E-01	1.0656E+00	1.1192E+00	1.1662E+00	1.2042E+00	1.2237E+00	6.0502E-01
435	436	437	438	439	440	441	442	443	444
5.9606E-01	9.2820E-01	9.8086E-01	1.0253E+00	1.0538E+00	1.0696E+00	5.3066E-01	5.2559E-01	7.9372E-01	8.4643E-01
445	446	447	448	449	450	451	452	453	454
8.8918E-01	9.1328E-01	9.2388E-01	4.5986E-01	4.5735E-01	6.6283E-01	7.0137E-01	7.4193E-01	7.6081E-01	7.6856E-01
455	456	457	458	459	460	461	462	463	464
3.8363E-01	3.8215E-01	3.8014E-01	5.6710E-01	5.7797E-01	5.8318E-01	4.1387E-01	4.1277E-01	4.1099E-01	3.7938E-01
465	466	467	468	469	470	471	472	473	474
3.8370E-01	3.8641E-01	3.1494E-01	3.1724E-01	3.1895E-01	3.7888E-01	3.8774E-01	3.8675E-01	1.1399E-01	4.1418E-01
476	477	478	479	480	481	482	483	484	485
3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02
486	487	488	489	490	491	492	493	494	495
3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	3.8020E-02	2.3302E-01	2.3302E-01
496	497	498	499	500	501	502	503	504	505
2.3302E-01	2.3302E-01	2.3302E-01	2.3302E-01	2.3302E-01	2.3302E-01	2.3302E-01	2.3302E-01	2.3302E-01	2.3302E-01
506	507	508	509	510	511	512	513	514	515
2.3302E-01	2.3302E-01	2.3302E-01	2.3302E-01	5.3790E-02	5.3790E-02	5.3790E-02	5.3790E-02	5.3790E-02	5.3790E-02
516	517	518	519	520	521	522	523	524	525
5.3790E-02	5.3790E-02	8.5790E-02	8.5790E-02	8.5790E-02	8.5790E-02	8.5790E-02	8.5790E-02	8.5790E-02	8.5790E-02
526	527	528	529	530	531				

536	537	538	539	540	541	542	543	544	545
3.3340E-01	3.6610E-01	4.0720E-01	4.4670E-01	9.8620E-01	6.1470E-01	6.5650E-01	6.9610E-01	7.4150E-01	8.6180E-01
546	547	548	549	550	551	552	553	554	555
3.7010E-01	1.3580E+00	8.5600E-01	6.7600E-01	5.5800E-01	5.0100E-01	4.5400E-01	4.1700E-01	2.3400E-01	4.3930E-01
556	557	558	559	560	561	562	563	564	565
3.3180E-01	3.6730E-01	3.6000E-01	1.9000E-01	1.1560E-01	1.3610E-01	1.2910E-01	2.4950E-01	2.1960E-01	2.1440E-01
566	567	568	569	570	571	572	573	574	575
2.0640E-01	2.0980E-01	1.9570E-01	1.9280E-01	1.8980E-01	1.8010E-01	1.8500E-01	1.7900E-01	1.3050E-01	2.5869E-02
576	577	578	579	580	581	582	583	584	585
7.9492E-02	9.6807E-02	1.2358E-01	1.3965E-01	1.5463E-01	1.8780E-01	2.3029E-01	3.5463E-01	7.4533E-01	3.4254E-01
586	587	588	589	590	591	592	593	594	595
8.8563E-01	1.4386E+00	1.1104E-01	1.6257E-01	1.9659E-01	1.7490E-01	3.8146E-01	3.5796E-01	3.6362E-01	3.5618E-01
596	597	598	599	600	601	602	603	604	605
3.8425E-01	3.7253E-01	3.7663E-01	3.8423E-01	3.8538E-01	3.9553E-01	4.0406E-01	2.7190E-01	2.7190E-01	2.7190E-01
606	607	612	613	614	615	616	617	618	619
2.7190E-01	2.7190E-01	1.2650E-01	1.3530E-01	2.7950E-01	7.8540E-01	2.6180E-01	1.4840E-01	8.2900E-02	1.5710E-01
620	621	622	623	624	625	626	627	628	629
1.5010E-01	2.1800E-02	6.7700E-02	8.6400E-02	1.0070E-01	1.2070E-01	1.4640E-01	2.3250E-01	6.0421E-01	4.4612E-01
630	631	632							
4.5348E-01	4.6051E-01	1.6232E-01							

MISCELLANEOUS VALUES

1003	
3.7500E-01	

TIME CONSTANTS

HEAT BALANCE

1	2	3	4	5	6	7	8	9	10
7.0801E-03	-3.3741E-03	9.2010E-03	-1.8463E-03	-6.5374E-03	-3.1090E-03	-3.7384E-03	-1.6586E-02	-1.1907E-02	-3.1063E-02
11	12	13	14	15	16	17	18	19	20
-2.2669E-03	-1.7136E-02	-3.7586E-02	-4.3732E-02	-3.4350E-02	-4.4359E-02	-1.4257E-02	-1.5234E-01	-2.9772E-01	-3.1251E-01
21	22	23	24	25	26	27	28	29	30
-3.2229E-01	-3.2216E-01	-3.1000E-01	-1.5111E-01	-2.0157E-02	-3.1189E-02	-3.4561E-02	-3.7338E-02	-4.3427E-02	-6.2030E-02
31	32	33	34	35	36	37	38	39	40
-6.0890E-02	-6.0066E-02	-5.1167E-02	-2.6338E-02	-1.7838E-02	-2.8732E-02	-3.6896E-02	-4.7573E-02	-6.1202E-02	-6.4763E-02
41	42	43	44	45	46	47	48	49	50
-6.2327E-02	-5.6000E-02	-4.9133E-02	-2.0874E-02	-2.7039E-02	-7.5004E-02	-7.4653E-02	-7.0731E-02	-9.2831E-02	-4.9105E-02
51	52	53	54	55	56	57	58	59	60
-7.4081E-02	-4.2877E-02	-2.2141E-02	-1.2802E-02	-2.4619E-02	-3.1979E-02	-2.6187E-02	-2.3834E-02	-6.1493E-03	-1.3763E-02
61	62	63	64	65	66	67	68	69	70
-2.9287E-02	-2.5639E-02	-2.9251E-02	-1.9501E-02	-2.0172E-02	-5.4016E-03	-1.9897E-02	-2.2824E-02	-3.0182E-02	-2.2171E-02
71	72	73	74	75	76	77	78	79	80
-2.9602E-02	-1.7044E-02	-1.3794E-02	-6.5002E-03	-8.5144E-03	-1.7612E-02	-2.6551E-02	-2.8152E-02	-2.8305E-02	-1.9608E-02
81	82	83	84	85	86	87	88	89	90
-2.0172E-02	-1.6373E-02	-5.9509E-03	-3.3417E-03	-1.0666E-02	-2.1303E-02	-2.1935E-02	-2.5818E-02	-2.6001E-02	-2.6520E-02
91	92	93	94	95	96	97	98	99	100
-2.3865E-02	-1.6220E-02	-1.5839E-02	-1.1169E-02	-1.8356E-02	-2.0734E-02	-2.1652E-02	-2.3758E-02	-2.2720E-02	-1.9882E-02
101	102	103	104	105	106	107	108	109	110
-1.6312E-02	-1.5884E-02	-8.6670E-03	-6.1340E-03	-1.5921E-02	-2.0020E-02	-2.0538E-02	-2.0370E-02	-1.7201E-02	-5.5847E-03
111	112	113	114	115	116	117	118	119	120
-9.1496E-03	-1.2756E-02	-1.4008E-02	-1.1108E-02	-1.4163E-02	-5.2338E-03	-2.3966E-03	-4.7226E-03	-7.1411E-03	-8.0719E-03
121	122	123	124	125	126	127	128	129	130
-8.0414E-03	-7.6141E-03	-2.5816E-03	-1.8263E-03	-1.4772E-03	-3.2349E-03	-2.6760E-03	-3.9368E-03	-3.9253E-03	-4.0236E-03

131	132	133	134	135	136	137	138	139	140
-2.5425E-03	-2.2291E-04	-5.0932E-04	1.5974E-05	-4.0740E-04	-6.4570E-04	-6.6707E-04	-1.5892E-03	-1.4439E-03	-2.0933E-03
141	142	143	144	145	146	147	148	149	150
-2.9650E-03	-4.4522E-03	-1.1780E-02	-3.4751E-03	-2.1764E-04	-3.0363E-04	-2.8336E-04	-3.7867E-04	-3.7760E-04	-7.1356E-04
151	152	153	154	155	156	157	158	159	160
-5.9479E-04	-9.4557E-04	-1.3170E-03	-2.2678E-03	-2.8987E-03	-4.2696E-03	-2.1926E-03	-4.4556E-03	-4.5471E-03	6.5613E-04
161	162	163	164	165	166	167	168	169	170
-5.9052E-03	-5.9662E-03	-1.3134E-02	-1.2550E-03	-1.3072E-02	-2.2888E-04	-7.6294E-03	-4.0283E-03	-1.3495E-02	-1.2578E-02
171	172	173	174	175	176	177	178	179	180
-1.0783E-02	-1.1505E-02	-9.9316E-03	-1.1368E-02	-6.4392E-03	-1.0025E-02	-5.1517E-03	-8.0748E-03	-1.6349E-02	-1.0275E-02
181	182	183	184	185	186	187	188	189	190
-1.6246E-02	-1.3504E-02	-1.0697E-02	-1.3519E-02	-1.3138E-02	-1.3474E-02	-1.4603E-02	-1.1124E-02	-1.0005E-02	-8.9855E-03
191	192	193	194	195	196	197	198	199	200
-8.0338E-03	-9.3498E-03	-1.3321E-02	-1.3108E-02	-1.6464E-02	-1.7245E-02	-1.6907E-02	-1.7426E-02	-1.5167E-02	-1.7838E-02
201	202	203	204	205	206	207	208	209	210
-1.7944E-02	-1.5137E-02	-9.8032E-03	-7.7057E-03	-8.9722E-03	-1.3587E-02	-1.8082E-02	-1.7499E-02	-2.1744E-02	-2.1550E-02
211	212	213	214	215	216	217	218	219	220
-2.5375E-02	-1.9459E-02	-2.0035E-02	-1.8951E-02	-2.0828E-02	-1.5762E-02	-6.4697E-03	-1.9028E-02	-2.5101E-02	-2.5406E-02
221	222	223	224	225	226	227	228	229	230
-3.0334E-02	-2.7863E-02	-2.2824E-02	-1.3245E-02	-3.2349E-03	-1.5930E-02	-2.2171E-02	-3.0029E-02	-2.9739E-02	-3.1723E-02
231	232	233	234	235	236	237	238	239	240
-2.1823E-02	-1.8654E-02	-1.1856E-02	-2.1835E-02	-2.9392E-02	-3.4387E-02	-3.1406E-02	-2.4281E-02	-1.7263E-02	-9.8267E-03
241	242	243	244	245	246	247	248	249	250
-1.9426E-02	-2.6354E-02	-3.0034E-02	-3.3031E-02	-2.0407E-02	-2.3385E-02	-1.1040E-02	-4.9438E-03	-1.4359E-02	-2.6662E-02
251	252	253	254	255	256	257	258	259	260
-2.8503E-02	-2.9336E-02	-2.3236E-02	-2.0513E-02	-1.5855E-02	-1.8187E-02	-2.2296E-02	-2.1052E-02	-9.6827E-03	-1.0752E-02
261	262	263	264	265	266	267			
-7.2231E-03	-1.4597E-02	-1.7529E-02	-1.5173E-02	-7.5312E-03	-9.6571E-03	-7.8430E-03			

RELATIVE HEAT BALANCE

1	2	3	4	5	6	7	8	9	10
9.9347E-06	4.5168E-06	1.5472E-05	3.5785E-06	1.2383E-05	5.9634E-06	7.4256E-06	3.5741E-05	2.5817E-05	6.8199E-05
11	12	13	14	15	16	17	18	19	20
5.0406E-06	4.3403E-05	9.5212E-05	1.1098E-04	8.7975E-05	1.1646E-04	3.7977E-05	4.1123E-04	8.3181E-04	8.7671E-04
21	22	23	24	25	26	27	28	29	30
9.0617E-04	9.0889E-04	8.7647E-04	4.2811E-04	2.8293E-04	2.7360E-04	2.1513E-04	1.7359E-04	1.5085E-04	2.2770E-04
31	32	33	34	35	36	37	38	39	40
2.1310E-04	2.0086E-04	1.6420E-04	8.3139E-05	5.1417E-04	3.7072E-04	2.8265E-04	2.3890E-04	2.4136E-04	2.3755E-04
41	42	43	44	45	46	47	48	49	50
2.1889E-04	1.8612E-04	1.5226E-04	5.9571E-05	6.4462E-05	1.7699E-04	1.6594E-04	1.5038E-04	1.8605E-04	9.1776E-05
51	52	53	54	55	56	57	58	59	60
1.3074E-04	6.9411E-05	4.8513E-05	8.5888E-05	1.3950E-04	1.5561E-04	1.0976E-04	8.4486E-05	1.7047E-05	9.9039E-05
61	62	63	64	65	66	67	68	69	70
1.9286E-04	1.4315E-04	1.3627E-04	7.4654E-05	6.2193E-05	1.3147E-05	1.6142E-04	1.6244E-04	1.8286E-04	1.1308E-04
71	72	73	74	75	76	77	78	79	80
1.2540E-04	5.8745E-05	3.7291E-05	1.2826E-05	1.0078E-04	1.7908E-04	2.1715E-04	1.9398E-04	1.6718E-04	9.8894E-05
81	82	83	84	85	86	87	88	89	90
8.6756E-05	5.9502E-05	1.8028E-05	1.1046E-05	1.3702E-04	2.2799E-04	2.0726E-04	2.0699E-04	1.8686E-04	1.6872E-04
91	92	93	94	95	96	97	98	99	100
1.4071E-04	9.3308E-05	6.3055E-05	1.7878E-04	2.0933E-04	2.4742E-04	1.9763E-04	2.2195E-04	1.8349E-04	1.6748E-04
101	102	103	104	105	106	107	108	109	110
1.2819E-04	9.1006E-05	1.0046E-04	7.2357E-05	1.3552E-04	1.4243E-04	1.3367E-04	1.2665E-04	1.3204E-04	9.3510E-05

121	122	123	124	125	125	127	128	129	130
1.2330E-04	1.1221E-04	5.6432E-05	1.2999E-04	4.9203E-05	8.4925E-05	5.7856E-05	7.7591E-05	7.7089E-05	7.9936E-05
131	132	133	134	135	136	137	138	139	140
6.1549E-05	9.2339E-03	3.0437E-03	5.5634E-06	1.1521E-04	1.8967E-04	2.0657E-04	5.2540E-04	3.1370E-04	2.0020E-04
141	142	143	144	145	146	147	148	149	150
1.0899E-04	1.9213E-04	3.6665E-04	2.3664E-03	9.1833E-03	1.8330E-03	3.1251E-04	2.6807E-04	2.3812E-04	4.4604E-04
151	152	153	154	155	156	157	158	159	160
3.4062E-04	3.6760E-04	2.6451E-04	2.3827E-04	3.0472E-04	4.7508E-04	1.4873E-03	6.4206E-05	4.7291E-05	7.8090E-06
161	162	163	164	165	166	167	168	169	170
1.0134E-04	4.8512E-05	2.3385E-04	2.8508E-05	3.1703E-04	1.6514E-06	5.0951E-05	4.7512E-05	2.8316E-04	3.5339E-04
171	172	173	174	175	176	177	178	179	180
2.9717E-04	8.9782E-05	7.6853E-05	8.9634E-05	4.4123E-05	8.8188E-05	6.8023E-05	1.2028E-04	3.9256E-04	3.6944E-04
181	182	183	184	185	186	187	188	189	190
4.9892E-04	1.1991E-04	9.5699E-05	1.1416E-04	1.0666E-04	1.1715E-04	1.2725E-04	8.7041E-05	8.2348E-05	8.9791E-05
191	192	193	194	195	196	197	198	199	200
7.0987E-05	1.9879E-04	1.4091E-04	1.3549E-04	1.4964E-04	1.6326E-04	1.5638E-04	1.6943E-04	1.3929E-04	1.7087E-04
201	202	203	204	205	206	207	208	209	210
1.6129E-04	1.2135E-04	7.1566E-05	6.3759E-05	1.2572E-04	1.8552E-04	1.6412E-04	2.1216E-04	1.9996E-04	2.6707E-04
211	212	213	214	215	216	217	218	219	220
2.5069E-04	2.4232E-04	2.1700E-04	2.2715E-04	2.1323E-04	1.0509E-04	1.3897E-04	1.5547E-04	2.1132E-04	2.3381E-04
221	222	223	224	225	226	227	228	229	230
2.9331E-04	2.5066E-04	2.8649E-04	2.6402E-04	6.5613E-05	1.1953E-04	2.0168E-04	3.3349E-04	3.7692E-04	4.2434E-04
231	232	233	234	235	236	237	238	239	240
5.3039E-04	4.8555E-04	7.6479E-05	2.1702E-04	4.1435E-04	5.9412E-04	6.3555E-04	9.6400E-04	6.4335E-04	5.7687E-05
241	242	243	244	245	246	247	248	249	250
2.2627E-04	5.2979E-04	7.5850E-04	1.0476E-03	1.3596E-03	1.3636E-03	8.1943E-04	1.2500E-04	2.0040E-04	6.2542E-04
251	252	253	254	255	256	257	258	259	260
1.1838E-03	1.5587E-03	3.1580E-03	2.3931E-03	1.7596E-03	1.0617E-03	1.9337E-03	1.8994E-03	3.7967E-03	3.7241E-03
261	262	263	264	265	266	267			
2.4864E-03	1.9822E-03	3.3567E-03	2.7945E-03	2.8874E-03	3.7271E-03	3.7932E-03			

DUMP CODE	MAX. COUNT	PRINT INTER.	STAB. CRIT.	VAR. EVALUATION CRIT. TIME	VAR. EVALUATION CRIT. TEMP.	PROBLEM START	PRINT START	DUMMY	INCREMENTS	TIME LIMIT	PUNCH CODE	READ CODE
1	200	9.0000E+00	-1.1000E+00	0.0	2.0000E+01	0.0	9.0000E+00	0.0 -1	0.0 0	10	0	0

TEMPERATURE NODES AND CAPACITANCES

NODE	INC	CAP	CURV	RCX	EVX	NO.	TEMP.	CAP. VAL.
1	1	1	0	0	0	81	1.5000E+03	0.0
82	0	0	0	0	0	0	1.4350E+03	0.0
83	0	0	0	0	0	0	1.4050E+03	0.0
84	0	0	0	0	0	0	1.3880E+03	0.0
85	0	0	0	0	0	0	1.4000E+03	0.0
86	0	0	0	0	0	0	1.4150E+03	0.0
87	0	0	0	0	0	0	1.4470E+03	0.0
88	0	0	0	0	0	0	1.4550E+03	0.0
89	0	0	0	0	0	0	1.4650E+03	0.0
90	0	0	0	0	0	0	1.4800E+03	0.0
91	0	0	0	0	0	0	1.5050E+03	0.0
92	0	0	0	0	0	0	1.5530E+03	0.0
93	0	0	0	0	0	0	1.5700E+03	0.0
94	0	0	0	0	0	0	2.4740E+03	0.0
95	0	0	0	0	0	0	2.5500E+03	0.0
96	0	0	0	0	0	0	2.5460E+03	0.0
97	0	0	0	0	0	0	2.5380E+03	0.0
98	0	0	0	0	0	0	2.5290E+03	0.0
99	0	0	0	0	0	0	2.5170E+03	0.0
100	0	0	0	0	0	0	2.5060E+03	0.0
101	0	0	0	0	0	0	2.4950E+03	0.0
102	0	0	0	0	0	0	2.4850E+03	0.0
103	0	0	0	0	0	0	2.4740E+03	0.0
104	0	0	0	0	0	0	2.4650E+03	0.0
105	0	0	0	0	0	0	2.4560E+03	0.0
106	0	0	0	0	0	0	2.4480E+03	0.0
107	0	0	0	0	0	0	2.4390E+03	0.0
108	0	0	0	0	0	0	2.4320E+03	0.0
109	0	0	0	0	0	0	2.4240E+03	0.0
110	1	-2	0	1	0	13	9.8100E+02	0.0
123	0	0	0	0	0	0	9.6700E+02	0.0
124	1	-2	0	1	0	11	1.2000E+03	0.0
135	0	0	0	0	0	0	1.2000E+03	0.0
136	1	-2	0	1	0	4	9.6000E+02	0.0
140	0	0	0	0	0	0	9.6000E+02	0.0
141	1	-2	0	1	0	3	1.2000E+03	0.0
144	0	0	0	0	0	0	1.2000E+03	0.0
145	1	1	0	0	0	78	1.5000E+03	0.0
223	1	-2	0	1	0	7	9.6500E+02	0.0
230	0	0	0	0	0	0	9.6000E+02	0.0
231	1	-2	0	1	0	2	9.6000E+02	0.0
233	0	0	0	0	0	0	9.6000E+02	0.0
234	1	-2	0	1	0	2	9.6000E+02	0.0
236	0	0	0	0	0	0	9.6000E+02	0.0
237	1	-2	0	1	0	2	9.6000E+02	0.0
239	0	0	0	0	0	0	9.6000E+02	0.0
240	1	-2	0	1	0	3	9.6000E+02	0.0
243	0	0	0	0	0	0	9.6000E+02	0.0
244	1	-2	0	1	0	4	9.6000E+02	0.0
248	0	0	0	0	0	0	9.6000E+02	0.0
249	1	-2	0	1	0	3	9.6000E+02	0.0
252	0	0	0	0	0	0	9.6000E+02	0.0
253	1	-2	0	1	0	2	9.6000E+02	0.0
255	0	0	0	0	0	0	9.6000E+02	0.0
256	0	-2	0	1	0	0	9.6000E+02	0.0
257	0	0	0	0	0	0	9.6000E+02	0.0
258	0	0	0	0	0	0	2.1400E+03	0.0
259	0	0	0	0	0	0	2.3250E+03	0.0
260	0	0	0	0	0	0	2.4000E+03	0.0
261	0	0	0	0	0	0	2.0800E+03	0.0
262	0	0	0	0	0	0	2.2650E+03	0.0
263	0	0	0	0	0	0	2.3400E+03	0.0
264	0	0	0	0	0	0	2.0200E+03	0.0
265	0	0	0	0	0	0	2.2050E+03	0.0
266	0	0	0	0	0	0	2.2800E+03	0.0
267	0	0	0	0	0	0	1.2200E+03	0.0
268	0	0	0	0	0	0	1.3190E+03	0.0
269	0	0	0	0	0	0	1.4300E+03	0.0
270	0	0	0	0	0	0	1.5200E+03	0.0
271	0	0	0	0	0	0	1.5600E+03	0.0

Appendix D

PRECEDING PAGE BLANK NOT FILMED

PAGE 314 INTENTIONALLY BLANK

CONDUCTANCES

COND	INC	NODE	INC	NODE	INC	CURV	EVX	NO.	COND. VAL.
1	1	1	1	2	1	41	0	2	6.9440E-03
291	1	79	1	80	1	41	0	2	9.1667E-02
293	1	79	1	34	1	41	0	3	3.5900E-03
3	1	4	1	5	1	41	0	2	2.0964E-02
5	1	7	1	8	1	41	0	2	3.0769E-02
7	1	10	1	11	1	41	0	2	3.8993E-02
9	1	13	1	14	1	41	0	2	4.5098E-02
11	1	16	1	17	1	41	0	2	5.1961E-02
13	1	19	1	20	1	41	0	2	6.1728E-02
15	1	22	1	23	1	41	0	2	7.2868E-02
17	1	25	1	26	1	41	0	2	8.4259E-02
19	1	28	1	29	1	41	0	2	1.1217E-01
21	1	31	1	32	1	41	0	2	1.1222E-01
23	1	34	1	35	1	41	0	2	1.7111E-01
25	1	37	1	38	1	41	0	2	6.4444E-02
27	1	40	1	41	1	41	0	2	6.4516E-02
29	1	43	1	44	1	41	0	2	6.6667E-02
31	1	46	1	47	1	41	0	2	7.0476E-02
33	1	49	1	50	1	41	0	2	7.4561E-02
35	1	52	1	53	1	41	0	2	7.5000E-02
37	1	55	1	56	1	41	0	2	8.0208E-02
39	1	58	1	59	1	41	0	2	7.2620E-02
41	1	61	1	62	1	41	0	2	5.6771E-02
43	1	64	1	65	1	41	0	2	4.7587E-02
45	1	67	1	68	1	41	0	2	4.5185E-02
47	1	70	1	71	1	41	0	2	4.4753E-02
49	1	73	1	74	1	41	0	2	2.8205E-02
51	1	76	1	77	1	41	0	2	1.3084E-02
53	1	1	1	4	1	41	0	3	7.0710E-03
56	1	4	1	7	1	41	0	3	8.8800E-03
59	1	7	1	10	1	41	0	3	8.1600E-03
62	1	10	1	13	1	41	0	3	6.2810E-03
65	1	13	1	16	1	41	0	3	4.6660E-03
68	1	16	1	19	1	41	0	3	3.5080E-03
71	1	19	1	22	1	41	0	3	2.6130E-03
74	1	22	1	25	1	41	0	3	2.0670E-03
77	1	25	1	28	1	41	0	3	2.0170E-03
80	1	28	1	31	1	41	0	3	1.7420E-03
83	1	31	1	34	1	41	0	3	1.6670E-03
86	1	34	1	37	1	41	0	3	9.6700E-04
89	1	37	1	40	1	41	0	3	9.6700E-04
92	1	40	1	43	1	41	0	3	1.1020E-03
95	1	43	1	46	1	41	0	3	1.5170E-03
98	1	46	1	49	1	41	0	3	1.6440E-03
101	1	49	1	52	1	41	0	3	2.0840E-03
104	1	52	1	55	1	41	0	3	2.7340E-03
107	1	55	1	58	1	41	0	3	3.6690E-03
110	1	58	1	61	1	41	0	3	3.7670E-03
113	1	61	1	64	1	41	0	3	4.1420E-03
116	1	64	1	67	1	41	0	3	5.2020E-03
119	1	67	1	70	1	41	0	3	7.4250E-03
122	1	70	1	73	1	41	0	3	7.7400E-03
125	1	73	1	76	1	41	0	3	6.7530E-03
128	1	1	1	67	1	41	0	3	1.9650E-03
131	1	4	1	64	1	41	0	3	1.4570E-03
134	1	7	1	61	1	41	0	3	1.0780E-03
137	1	10	1	58	1	41	0	3	8.4900E-04
140	1	13	1	55	1	41	0	3	7.7000E-04
143	1	16	1	52	1	41	0	3	7.1700E-04
146	1	19	1	49	1	41	0	3	6.7300E-04
149	1	22	1	46	1	41	0	3	6.3700E-04
152	1	25	1	43	1	41	0	3	6.0800E-04
155	1	28	1	40	1	41	0	3	5.0700E-04
158	1	31	1	37	1	41	0	3	5.2100E-04
161	1	1	1	90	0	41	0	3	8.7730E-03
164	1	4	1	89	0	41	0	3	4.4440E-03
167	1	7	1	88	0	41	0	3	3.0870E-03
170	1	10	1	87	0	41	0	3	2.3560E-03
173	1	13	1	86	0	41	0	3	1.9680E-03
176	1	16	1	85	0	41	0	3	1.6260E-03
179	1	19	1	84	0	41	0	3	1.3690E-03
182	1	22	1	83	0	41	0	3	1.2570E-03
185	1	25	1	82	0	41	0	3	1.1600E-03
188	1	70	1	91	0	41	0	3	4.1220E-03
191	1	73	1	92	0	41	0	3	1.0420E-02
194	1	76	1	93	0	41	0	3	1.6718E-02

ORIGINAL PAGE IS
OF POOR QUALITY

COND	INC	NODE	INC	NODE	INC	CURV	EVX	NO	COND. VAL.
296	1	1	1	70	1	41	0	3	2.3330E-03
300	1	28	1	82	0	41	0	3	2.2900E-04
299	0	72	0	110	0	0	0	0	8.1600E-02
197	0	94	0	79	0	0	0	0	2.1420E-01
198	0	95	0	34	0	0	0	0	1.3708E-01
199	0	96	0	31	0	0	0	0	7.7400E-02
200	0	96	0	37	0	0	0	0	5.1300E-02
201	0	97	0	28	0	0	0	0	8.1769E-02
202	0	97	0	40	0	0	0	0	5.2981E-02
203	0	98	0	25	0	0	0	0	5.7507E-02
204	0	98	0	43	0	0	0	0	5.8455E-02
205	0	99	0	22	0	0	0	0	6.2081E-02
206	0	99	0	46	0	0	0	0	6.5366E-02
207	0	100	0	19	0	0	0	0	6.8611E-02
208	0	100	0	49	0	0	0	0	7.7874E-02
209	0	101	0	16	0	0	0	0	7.5967E-02
210	0	101	0	52	0	0	0	0	9.1733E-02
211	0	102	0	13	0	0	0	0	8.5611E-02
212	0	102	0	55	0	0	0	0	1.0906E-01
213	0	103	0	10	0	0	0	0	9.4855E-02
214	0	103	0	58	0	0	0	0	1.0753E-01
215	0	104	0	7	0	0	0	0	9.4833E-02
216	0	104	0	61	0	0	0	0	9.9180E-02
217	0	105	0	4	0	0	0	0	8.0972E-02
218	0	105	0	64	0	0	0	0	1.0526E-01
219	0	106	0	1	0	0	0	0	5.9500E-02
220	0	106	0	67	0	0	0	0	1.2892E-01
221	0	107	0	70	0	0	0	0	1.5571E-01
223	0	108	0	73	0	0	0	0	1.3218E-01
225	0	109	0	76	0	0	0	0	1.8108E-01
227	0	110	0	3	0	0	0	0	1.1685E-01
228	0	111	0	6	0	0	0	0	1.1108E-01
229	0	112	0	9	0	0	0	0	1.1039E-01
230	0	113	0	12	0	0	0	0	1.1105E-01
231	0	114	0	15	0	0	0	0	1.1090E-01
232	0	115	0	18	0	0	0	0	1.1092E-01
233	0	116	0	21	0	0	0	0	1.1105E-01
234	0	117	0	24	0	0	0	0	1.1133E-01
235	0	118	0	27	0	0	0	0	1.1146E-01
236	0	119	0	30	0	0	0	0	1.1146E-01
237	0	120	0	33	0	0	0	0	1.1187E-01
238	0	121	0	36	0	0	0	0	1.1239E-01
239	0	122	0	81	0	0	0	0	1.2604E-01
240	0	3	0	-111	0	0	0	0	1.1685E-01
241	0	6	0	-112	0	0	0	0	1.1108E-01
242	0	9	0	-113	0	0	0	0	1.1089E-01
243	0	12	0	-114	0	0	0	0	1.1105E-01
244	0	15	0	-115	0	0	0	0	1.1090E-01
245	0	18	0	-116	0	0	0	0	1.1092E-01
246	0	21	0	-117	0	0	0	0	1.1105E-01
247	0	24	0	-118	0	0	0	0	1.1133E-01
248	0	27	0	-119	0	0	0	0	1.1146E-01
249	0	30	0	-120	0	0	0	0	1.1146E-01
250	0	33	0	-121	0	0	0	0	1.1187E-01
251	0	36	0	-122	0	0	0	0	1.1239E-01
252	0	81	0	-123	0	0	0	0	1.2604E-01
253	0	124	0	36	0	0	0	0	8.7560E-02
254	0	125	0	39	0	0	0	0	8.7990E-02
255	0	126	0	42	0	0	0	0	8.7560E-02
256	0	127	0	45	0	0	0	0	8.4120E-02
257	0	128	0	48	0	0	0	0	7.9980E-02
258	0	129	0	51	0	0	0	0	7.7730E-02
259	0	130	0	54	0	0	0	0	7.6230E-02
260	0	131	0	57	0	0	0	0	9.0300E-02
261	0	132	0	60	0	0	0	0	9.0300E-02
262	0	133	0	63	0	0	0	0	9.0300E-02
263	0	134	0	66	0	0	0	0	9.0300E-02
264	0	36	0	-125	0	0	0	0	8.7560E-02
265	0	39	0	-126	0	0	0	0	8.7990E-02
266	0	42	0	-127	0	0	0	0	8.7560E-02
267	0	45	0	-128	0	0	0	0	8.4120E-02
268	0	48	0	-129	0	0	0	0	7.9980E-02
269	0	51	0	-130	0	0	0	0	7.7730E-02
270	0	54	0	-131	0	0	0	0	7.6230E-02
271	0	57	0	-132	0	0	0	0	9.0300E-02
272	0	60	0	-133	0	0	0	0	9.0300E-02
273		63	0	-134	0	0	0	0	9.0300E-02
274		66	0	-135	0	0	0	0	9.0300E-02

COND	INC	NODE	INC	NODE	INC	CURV	EVX	NO.	COND. VAL.
275	0	136	0	69	0	0	0	0	4.9340E-02
276	0	137	0	72	0	0	0	0	5.8940E-02
277	0	138	0	75	0	0	0	0	4.7590E-02
278	0	139	0	78	0	0	0	0	3.4820E-02
279	0	69	0	-137	0	0	0	0	4.9340E-02
280	0	72	0	-138	0	0	0	0	5.8940E-02
281	0	75	0	-139	0	0	0	0	4.7590E-02
282	0	78	0	-140	0	0	0	0	3.4820E-02
285	0	141	0	81	0	0	0	0	2.0169E-02
286	0	142	0	80	0	0	0	0	2.0169E-02
287	0	143	0	79	0	0	0	0	2.0169E-02
288	0	81	0	-142	0	0	0	0	2.0169E-02
289	0	80	0	-143	0	0	0	0	2.0169E-02
290	0	79	0	-144	0	0	0	0	2.0169E-02
303	1	145	1	146	1	41	0	2	2.7778E-02
305	1	148	1	149	1	41	0	2	6.8571E-02
307	1	151	1	152	1	41	0	2	1.1644E-01
309	1	154	1	155	1	41	0	2	1.3333E-01
311	1	157	1	158	1	41	0	2	1.5123E-01
313	1	160	1	161	1	41	0	2	1.7563E-01
315	1	163	1	164	1	41	0	2	2.0417E-01
317	1	166	1	167	1	41	0	2	2.0476E-01
319	1	169	1	170	1	41	0	2	1.3095E-01
321	1	172	1	173	1	41	0	2	3.1532E-01
323	1	175	1	176	1	41	0	2	2.5000E-01
325	1	178	1	179	1	41	0	2	2.2394E-01
327	1	181	1	182	1	41	0	2	1.8987E-01
329	1	184	1	185	1	41	0	2	1.5556E-01
331	1	187	1	188	1	41	0	2	1.2635E-01
333	1	190	1	191	1	41	0	2	9.9740E-02
335	1	193	1	194	1	41	0	2	5.0955E-02
337	1	196	1	197	1	41	0	2	2.9918E-01
339	1	199	1	200	1	41	0	2	1.9792E-01
341	1	202	1	203	1	41	0	2	1.8841E-01
343	1	205	1	206	1	41	0	2	1.7316E-01
345	1	208	1	209	1	41	0	2	1.5168E-01
347	1	211	1	212	1	41	0	2	1.2821E-01
349	1	214	1	215	1	41	0	2	1.0732E-01
351	1	217	1	218	1	41	0	2	8.3900E-02
353	1	220	1	221	1	41	0	2	3.5765E-02
355	1	145	1	148	1	41	0	3	7.2530E-03
358	1	148	1	151	1	41	0	3	1.0270E-02
361	1	151	1	154	1	41	0	3	9.4170E-03
364	1	154	1	157	1	41	0	3	7.9750E-03
367	1	157	1	160	1	41	0	3	6.8330E-03
370	1	160	1	163	1	41	0	3	5.8770E-03
373	1	163	1	166	1	41	0	3	5.0360E-03
376	1	166	1	169	1	41	0	3	2.1390E-03
379	1	172	1	175	1	41	0	3	3.9030E-03
382	1	175	1	178	1	41	0	3	4.5810E-03
385	1	178	1	181	1	41	0	3	4.7480E-03
388	1	181	1	184	1	41	0	3	5.0630E-03
391	1	184	1	187	1	41	0	3	5.4000E-03
394	1	187	1	190	1	41	0	3	6.1910E-03
397	1	190	1	193	1	41	0	3	7.4940E-03
400	1	196	1	199	1	41	0	3	2.6840E-03
406	1	202	1	205	1	41	0	3	3.9800E-03
403	1	199	1	202	1	41	0	3	3.5480E-03
409	1	205	1	208	1	41	0	3	4.6690E-03
412	1	208	1	211	1	41	0	3	5.3870E-03
415	1	211	1	214	1	41	0	3	6.1910E-03
418	1	214	1	217	1	41	0	3	7.2770E-03
421	1	217	1	220	1	41	0	3	6.0220E-03
424	1	145	1	190	1	41	0	3	6.2100E-04
427	1	148	1	187	1	41	0	3	4.4700E-04
430	1	151	1	184	1	41	0	3	3.4500E-04
433	1	154	1	181	1	41	0	3	2.8300E-04
436	1	157	1	178	1	41	0	3	2.3700E-04
439	1	160	1	175	1	41	0	3	2.0100E-04
442	1	163	1	172	1	41	0	3	1.7900E-04
445	1	175	1	196	1	41	0	3	1.9600E-04
448	1	178	1	199	1	41	0	3	2.0800E-04
451	1	181	1	202	1	41	0	3	2.3400E-04
454	1	184	1	205	1	41	0	3	2.7600E-04
457	1	187	1	208	1	41	0	3	3.2100E-04
460	1	190	1	211	1	41	0	3	3.9300E-04
463	1	193	1	214	1	41	0	3	5.6400E-04
466	0	147	0	-224	0	0	0	0	5.1560E-02

COND	INC	NODE	INC	NODE	INC	CURV	EVX	NO.	COND. VAL.
467	0	150	0	-225	0	0	0	0	1.4089E 01
468	0	153	0	-226	0	0	0	0	1.8608E-01
469	0	156	0	-227	0	0	0	0	1.8672E-01
470	0	159	0	-228	0	0	0	0	1.8800E-01
471	0	162	0	-229	0	0	0	0	1.9184E-01
472	0	165	0	-230	0	0	0	0	1.8110E-01
473	0	147	0	223	0	0	0	0	5.1560E-02
474	0	150	0	224	0	0	0	0	1.4089E-01
475	0	153	0	225	0	0	0	0	1.8608E-01
476	0	156	0	226	0	0	0	0	1.8672E-01
477	0	159	0	227	0	0	0	0	1.8800E-01
478	0	162	0	228	0	0	0	0	1.9184E-01
479	0	165	0	229	0	0	0	0	1.8110E-01
480	0	168	0	-232	0	0	0	0	1.0157E 01
481	0	171	0	-233	0	0	0	0	1.5050E-02
482	0	168	0	231	0	0	0	0	1.0157E-01
483	0	171	0	232	0	0	0	0	1.5050E-02
484	0	174	0	-235	0	0	0	0	1.1816E-01
485	0	177	0	-236	0	0	0	0	1.4337E 01
486	0	174	0	234	0	0	0	0	1.1816E 01
487	0	177	0	235	0	0	0	0	1.4337E-01
488	0	180	0	-238	0	0	0	0	1.4169E-01
489	0	183	0	-239	0	0	0	0	1.3844E-01
490	0	180	0	237	0	0	0	0	1.4169E-01
491	0	183	0	238	0	0	0	0	1.3844E-01
492	0	186	0	-241	0	0	0	0	1.3546E-01
493	0	189	0	-242	0	0	0	0	1.3655E-01
494	0	192	0	243	0	0	0	0	1.4686E-01
495	0	186	0	240	0	0	0	0	1.3546E-01
496	0	189	0	241	0	0	0	0	1.3655E-01
497	0	192	0	242	0	0	0	0	1.4686E 01
498	0	195	0	-245	0	0	0	0	1.2569E 01
499	0	216	0	-246	0	0	0	0	1.4328E 01
500	0	219	0	-247	0	0	0	0	1.2?94E 01
501	0	222	0	248	0	0	0	0	8.0400E 02
502	0	195	0	244	0	0	0	0	1.2569E-01
503	0	216	0	245	0	0	0	0	1.4328E-01
504	0	219	0	246	0	0	0	0	1.2794E-01
505	0	222	0	247	0	0	0	0	8.0400E-02
506	0	213	0	-250	0	0	0	0	1.3369E 01
507	0	210	0	-251	0	0	0	0	1.2554E-01
508	0	207	0	-252	0	0	0	0	1.1481E-01
509	0	213	0	249	0	0	0	0	1.3369E-01
510	0	210	0	250	0	0	0	0	1.2554E-01
511	0	207	0	251	0	0	0	0	1.1481E-01
512	0	204	0	-254	0	0	0	0	1.1119E-01
513	0	201	0	-255	0	0	0	0	1.1348E-01
514	0	204	0	253	0	0	0	0	1.1119E-01
515	0	201	0	254	0	0	0	0	1.1348E 01
516	0	198	0	-257	0	0	0	0	1.4048E-01
517	0	198	0	256	0	0	0	0	1.4048E-01
518	0	253	0	169	0	0	0	0	9.7533E 02
519	0	258	0	166	0	0	0	0	1.7417E 01
520	0	258	0	163	0	0	0	0	2.1335E-01
521	0	261	0	160	0	0	0	0	2.1335E 01
522	0	261	0	157	0	0	0	0	2.1335E-01
523	0	261	0	154	0	0	0	0	2.1771E-01
524	0	264	0	151	0	0	0	0	2.2206E-01
525	0	264	0	148	0	0	0	0	1.6110E 01
526	0	264	0	145	0	0	0	0	6.5313E 02
527	0	259	0	172	0	0	0	0	2.6957E 01
528	0	259	0	175	0	0	0	0	2.2619E-01
529	0	262	0	178	0	0	0	0	2.1933E-01
530	0	262	0	181	0	0	0	0	2.0567E 01
531	0	262	0	184	0	0	0	0	1.9192E 01
532	0	265	0	187	0	0	0	0	1.8049E-01
533	0	265	0	190	0	0	0	0	1.7638E-01
534	0	265	0	193	0	0	0	0	1.3023E-01
535	0	260	0	196	0	0	0	0	2.6196E 01
536	0	260	0	199	0	0	0	0	1.8182E-01
537	0	263	0	202	0	0	0	0	1.8660E 01
538	0	263	0	205	0	0	0	0	1.9187E-01
539	0	263	0	208	0	0	0	0	1.9426E-01
540	0	266	0	211	0	0	0	0	1.9139E-01
541	0	266	0	214	0	0	0	0	1.8852E-01
542	0	266	0	217	0	0	0	0	1.?225E-01
543		266	0	220	0	0	0	0	7.7513E-02
544		148	1	267	0	41	0	3	3.2080E-03

COND	INC	NODE	INC	NODE	INC	CURV	EVX	NO.	COND. VAL.
547	1	145	1	268	0	41	0	3	2.6667E-02
550	1	193	1	269	0	41	0	3	1.5758E-02
553	1	217	1	270	0	41	0	3	1.4710E-03
556	1	220	1	271	0	41	0	3	1.4679E-02

OTHER VALUES

LOC. INC NO. VALUE

VARIABLE LINES

ANS	INC	PRMA	INC	PRMB	INC	PRMC	INC	CODE	CURV	EVX	NO.	PARAM. A	PARAM. B	PARAM. C
20110	1	41003	0	0	0	0	0	6	0	1	13	0.0	5.8320E+00	0.0
10124	0	10123	0	0	0	0	0	6	0	1	0	0.0	1.0000E+00	0.0
20124	1	41003	0	0	0	0	0	6	0	1	11	0.0	3.4020E+00	0.0
10136	0	10110	0	0	0	0	0	6	0	1	0	0.0	1.0000E+00	0.0
20136	1	41003	0	0	0	0	0	6	0	1	4	0.0	1.4580E+00	0.0
10141	0	10123	0	0	0	0	0	6	0	1	0	0.0	1.0000E+00	0.0
20141	1	41003	0	0	0	0	0	6	0	1	3	0.0	2.4300E+00	0.0
20223	1	41003	0	0	0	0	0	6	0	1	7	0.0	1.4580E+01	0.0
20231	1	41003	0	0	0	0	0	6	0	1	2	0.0	1.9976E+00	0.0
20234	1	41003	0	0	0	0	0	6	0	1	2	0.0	1.2587E+01	0.0
20237	1	41003	0	0	0	0	0	6	0	1	2	0.0	9.1854E+00	0.0
20240	1	41003	0	0	0	0	0	6	0	1	3	0.0	7.8732E+00	0.0
20244	1	41003	0	0	0	0	0	6	0	1	4	0.0	5.1516E+00	0.0
20249	1	41003	0	0	0	0	0	6	0	1	3	0.0	5.1516E+00	0.0
20253	1	41003	0	0	0	0	0	6	0	1	2	0.0	1.3122E+00	0.0
20256	0	41003	0	0	0	0	0	6	0	1	0	0.0	1.6524E+00	0.0
10234	0	10230	0	0	0	0	0	6	0	1	0	0.0	1.0000E+00	0.0
10237	0	10236	0	0	0	0	0	6	0	1	0	0.0	1.0000E+00	0.0
10249	0	10243	0	0	0	0	0	6	0	1	0	0.0	1.0000E+00	0.0
10256	0	10235	0	0	0	0	0	6	0	1	0	0.0	1.0000E+00	0.0
10231	0	10230	0	0	0	0	0	6	0	1	0	0.0	1.0000E+00	0.0
10240	0	10239	0	0	0	0	0	6	0	1	0	0.0	1.0000E+00	0.0
10253	0	10239	0	0	0	0	0	6	0	1	0	0.0	1.0000E+00	0.0
40243	0	10243	0	0	0	0	0	6	0	1	0	0.0	7.8732E+00	0.0
40224	0	10224	0	0	0	0	0	6	0	1	0	0.0	1.4580E+01	0.0
40244	0	40243	0	40224	0	0	0	4	0	1	0	0.0	0.0	0.0
10244	0	40244	0	0	0	0	0	7	0	1	0	0.0	2.2453E+01	0.0

CURVE NO. 41 IN-792 THER.CON

0.0	7.9200E+00
8.0000E+02	1.0000E+01
1.0000E+03	1.0420E+01
1.2000E+03	1.1420E+01
1.4000E+03	1.2580E+01
1.6000E+03	1.4170E+01
1.8000E+03	1.6330E+01
2.0000E+03	2.0000E+01
0.0	0.0

OUTPUT CODES

I.D.	INC	NO.
10001	1	271
0	0	0

P-315 THERMAL TRANSIENT ANALY[illegible]
NASA COOLED

PSEUDO SEQU[illegible]

CAP.	COND	NODE	RCX	STU	DCND
1			0	0	0
	1	2			
	53	4			
	128	67			
	161	90			
	219	106			
	296	70			
2			0	0	0
	1	1			
	2	3			
	54	5			
	129	68			
	162	90			
	297	71			
3			0	0	0
	2	2			
	55	6			
	130	69			
	163	90			
	227	110			
	240	111			
	298	72			
4			0	0	0
	3	5			
	53	1			
	56	7			
	131	64			
	164	89			
	217	105			
5			0	0	0
	3	4			
	4	6			
	54	2			
	57	8			
	132	65			
	165	89			
6			0	0	0
	4	5			
	55	3			
	58	9			
	133	66			
	166	89			
	228	111			
	241	112			
7			0	0	0
	5	8			
	56	4			
	59	10			
	134	61			
	167	88			
	215	104			
8			0	0	0
	5	7			
	6	9			
	57	5			
	60	11			
	135	62			
	168	88			
9			0	0	0
	6	8			
	58	6			
	61	12			
	136	63			
	169	88			
	[illegible]	112			
	[illegible]	113			

P-315 THERMAL TRANSIENT ANALYSER RE
NASA COOLED RADIA

CAP.	COND.	NODE	RCX	STU	DCND
10			0	0	0
	7	11			
	59	7			
	62	13			
	137	58			
	170	87			
	213	103			
11			0	0	0
	7	10			
	8	12			
	60	8			
	63	14			
	138	59			
	171	87			
12			0	0	0
	8	11			
	61	9			
	64	15			
	139	60			
	172	87			
	230	113			
	243	114			
13			0	0	0
	9	14			
	62	10			
	65	16			
	140	55			
	173	86			
	211	102			
14			0	0	0
	9	13			
	10	15			
	63	11			
	66	17			
	141	56			
	174	86			
15			0	0	0
	10	14			
	64	12			
	67	18			
	142	57			
	175	86			
	231	114			
	244	115			
16			0	0	0
	11	17			
	65	13			
	68	19			
	143	52			
	176	85			
	209	101			
17			0	0	0
	11	16			
	12	18			
	66	14			
	69	20			
	144	53			
	177	85			
18			0	0	0
	12	17			
	67	15			
	70	21			
	145	54			
	178	85			
	232	115			
	245	116			
19			0	0	
	13	20			

P-315 THERMAL TRANSIENT ANALYSER REVISI[illegible]
NASA COOLED RADIAL TUR[illegible]

CAP.	COND.	NODE	RCX	STU	DCND
	68	16			
	71	22			
	146	49			
	179	84			
	207	100			
20			0	0	0
	13	19			
	14	21			
	69	17			
	72	23			
	147	50			
	180	84			
21			0	0	0
	14	20			
	70	18			
	73	24			
	148	51			
	181	84			
	233	116			
	246	117			
22			0	0	0
	15	23			
	71	19			
	74	25			
	149	46			
	182	83			
	205	99			
23			0	0	0
	15	22			
	16	24			
	72	20			
	75	26			
	150	47			
	183	83			
24			0	0	0
	16	23			
	73	21			
	76	27			
	151	48			
	184	83			
	234	117			
	247	118			
25			0	0	0
	17	26			
	74	22			
	77	28			
	152	43			
	185	82			
	203	98			
26			0	0	0
	17	25			
	18	27			
	75	23			
	78	29			
	153	44			
	186	82			
27			0	0	0
	18	26			
	76	24			
	79	30			
	154	45			
	187	82			
	235	118			
	248	119			
28			0	0	0
	19	29			
	77	25			
	8	31			
	11	40			

P-315 RMAL TRANSIENT ANALYSER REVIS
NASA COOLED RADIAL T

CAP.	COND.	NODE	RCX	STU	DCND
	201	97			
	300	82			
29			0	0	0
	19	28			
	20	30			
	78	26			
	81	32			
	156	41			
	301	82			
30			0	0	0
	20	29			
	79	27			
	82	33			
	157	42			
	236	119			
	249	120			
	302	82			
31			0	0	0
	21	32			
	80	28			
	83	34			
	158	37			
	199	96			
32			0	0	0
	21	31			
	22	33			
	81	29			
	84	35			
	159	38			
33			0	0	0
	22	32			
	82	30			
	85	36			
	160	39			
	237	120			
	250	121			
34			0	0	0
	23	35			
	83	31			
	86	37			
	198	95			
	293	79			
35			0	0	0
	23	34			
	24	36			
	84	32			
	87	38			
	294	80			
36			0	0	0
	24	35			
	85	33			
	88	39			
	238	121			
	251	122			
	253	124			
	264	125			
	295	81			
37			0	0	0
	25	38			
	86	34			
	89	40			
	158	31			
	200	96			
38			0	0	0
	25	37			
	26	39			
	87	35			
	90	41			

P-315 THERMAL TF IENT ANALYSER REVISI(
NASA COOLED RA.IAL TUI

CAP.	COND.	NODE	RCX	STU	DCND
	159	32			
39			0	0	0
	26	38			
	88	36			
	91	42			
	160	33			
	254	125			
	265	126			
40			0	0	0
	27	41			
	89	37			
	92	43			
	155	28			
	202	97			
41			0	0	0
	27	40			
	28	42			
	90	38			
	93	44			
	156	29			
42			0	0	0
	28	41			
	91	39			
	94	45			
	157	30			
	255	126			
	266	127			
43			0	0	0
	29	44			
	92	40			
	95	46			
	152	25			
	204	98			
44			0	0	0
	29	43			
	30	45			
	93	41			
	96	47			
	153	26			
45			0	0	0
	30	44			
	94	42			
	97	48			
	154	27			
	256	127			
	267	128			
46			0	0	0
	31	47			
	95	43			
	98	49			
	149	22			
	206	99			
47			0	0	0
	31	46			
	32	48			
	96	44			
	99	50			
	150	23			
48			0	0	0
	32	47			
	97	45			
	100	51			
	151	24			
	257	128			
	268	129			
49			0	0	0
		50			

P-315 THERMAL TRANSIENT ALYSER REVI
NASA COOLED RADIAL

CAP.	COND.	NODE	RCX	STU	DCND
	98	46			
	101	52			
	146	19			
	208	100			
50			0	0	0
	33	49			
	34	51			
	99	47			
	102	53			
	147	20			
51			0	0	0
	34	50			
	100	48			
	103	54			
	148	21			
	258	129			
	269	130			
52			0	0	0
	35	53			
	101	49			
	104	55			
	143	16			
	210	101			
53			0	0	0
	35	52			
	36	54			
	102	50			
	105	56			
	144	17			
54			0	0	0
	36	53			
	103	51			
	106	57			
	145	18			
	259	130			
	270	131			
55			0	0	0
	37	56			
	104	52			
	107	58			
	140	13			
	212	102			
56			0	0	0
	37	55			
	38	57			
	105	53			
	108	59			
	141	14			
57			0	0	0
	38	56			
	106	54			
	109	60			
	142	15			
	260	131			
	271	132			
58			0	0	0
	39	59			
	107	55			
	110	61			
	137	10			
	214	103			
59			0	0	0
	39	58			
	40	60			
	108	56			
	111	62			

P-315 ERMAL TRANSIENT ANALYSER REVI
NASA COOLED RA[illegible]IAL

CAP.	COND.	NODE	RCX	STU	DCND
60			0	0	0
	40	59			
	109	57			
	112	63			
	139	12			
	261	132			
	272	133			
61			0	0	0
	41	62			
	110	58			
	113	64			
	134	7			
	216	104			
62			0	0	0
	41	61			
	42	63			
	111	59			
	114	65			
	135	8			
63			0	0	0
	42	62			
	112	60			
	115	66			
	136	9			
	262	133			
	273	134			
64			0	0	0
	43	65			
	113	61			
	116	67			
	131	4			
	218	105			
65			0	0	0
	43	64			
	44	66			
	114	62			
	117	68			
	132	5			
66			0	0	0
	44	65			
	115	63			
	118	69			
	133	6			
	263	134			
	274	135			
67			0	0	0
	45	68			
	116	64			
	119	70			
	128	1			
	220	106			
68			0	0	0
	45	67			
	46	69			
	117	65			
	120	71			
	129	2			
69			0	0	0
	46	68			
	118	66			
	121	72			
	130	3			
	275	136			
	279	137			
70			0	0	0
	7	71			
		67			

P-315 THERMAL T [illegible]SIENT ANALYSER REVI[illegible]
NASA COOLED RADIAL T

CAP.	COND.	NODE	RCX	STU	DCND
	122	73			
	188	91			
	221	107			
	296	1			
71			0	0	0
	47	70			
	48	72			
	120	68			
	123	74			
	189	91			
	297	2			
72			0	0	0
	48	71			
	121	69			
	124	75			
	190	91			
	276	137			
	280	138			
	298	3			
	299	110			
73			0	0	0
	49	74			
	122	70			
	125	76			
	191	92			
	223	108			
74			0	0	0
	49	73			
	50	75			
	123	71			
	126	77			
	192	92			
75			0	0	0
	50	74			
	124	72			
	127	78			
	193	92			
	277	138			
	281	139			
76			0	0	0
	51	77			
	125	73			
	194	93			
	225	109			
77			0	0	0
	51	76			
	52	78			
	126	74			
	195	93			
78			0	0	0
	52	77			
	127	75			
	196	93			
	278	139			
	282	140			
79			0	0	0
	197	94			
	287	143			
	290	144			
	291	80			
	293	34			
80			0	0	0
	286	142			
	289	143			
	291	79			
	292	81			
	294	35			

P-315 THERMAL TRANSIEN [illegible]ALYSER REVISI[illegible]
NASA [illegible]LED RADIAL TUR

CAP.	COND.	NODE	RCX	STU	DCND
81			0	0	0
	239	122			
	257	123			
	281	141			
	288	142			
	292	80			
	295	36			
110			1	1	1
	227	3			
	299	72			
111			1	1	1
	228	6			
112			1	1	1
	229	9			
113			1	1	1
	230	12			
114			1	1	1
	231	15			
115			1	1	1
	232	18			
116			1	1	1
	233	21			
117			1	1	1
	234	24			
118			1	1	1
	235	27			
119			1	1	1
	236	30			
120			1	1	1
	237	33			
121			1	1	1
	238	36			
122			1	1	1
	239	81			
124			1	1	1
	253	36			
125			1	1	1
	254	39			
126			1	1	1
	255	42			
127			1	1	1
	256	45			
128			1	1	1
	257	48			
129			1	1	1
	258	51			
130			1	1	1
	259	54			
131			1	1	1
	260	57			
132			1	1	1
	261	60			
133			1	1	1
	2[illegible]	63			

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P-315 'RMAL TRANSIENT ANALYSER REV
NASA COOLED RADIAL

CAP.	COND.	NODE	RCX	STU	DCND
134			1	1	1
	263	66			
136			1	1	1
	275	69			
137			1	1	1
	276	72			
138			1	1	1
	277	75			
139			1	1	1
	278	78			
141			1	1	1
	285	81			
142			1	1	1
	286	80			
143			1	1	1
	287	79			
145			0	0	0
	303	146			
	355	148			
	424	190			
	526	264			
	547	268			
146			0	0	0
	303	145			
	304	147			
	356	149			
	425	191			
	548	268			
147			0	0	0
	304	146			
	357	150			
	426	192			
	466	224			
	473	223			
	549	268			
148			0	0	0
	305	149			
	355	145			
	358	151			
	427	187			
	525	264			
	544	267			
149			0	0	0
	305	148			
	306	150			
	356	146			
	359	152			
	428	188			
	545	267			
150			0	0	0
	306	149			
	357	147			
	360	153			
	429	189			
	467	225			
	474	224			
	546	267			
151			0	0	0
	307	152			
	358	148			
	361	154			
	430	184			
	524	264			

P-315 THERMAL TRA ENT ANALYSER REVI
SA COOLED RADIAL

CAP.	COND.	NODE	RCX	STU	DCND
152			0	0	0
	307	151			
	308	153			
	359	149			
	362	155			
	431	185			
153			0	0	0
	308	152			
	360	150			
	363	156			
	432	186			
	468	226			
	475	225			
154			0	0	0
	309	155			
	361	151			
	364	157			
	433	181			
	523	261			
155			0	0	0
	309	154			
	310	156			
	362	152			
	365	158			
	434	182			
156			0	0	0
	310	155			
	363	153			
	366	159			
	435	183			
	469	227			
	476	226			
157			0	0	0
	311	158			
	364	154			
	367	160			
	436	178			
	522	261			
158			0	0	0
	311	157			
	312	159			
	365	155			
	368	161			
	437	179			
159			0	0	0
	312	158			
	366	156			
	369	162			
	438	180			
	470	228			
	477	227			
160			0	0	0
	313	161			
	367	157			
	370	163			
	439	175			
	521	261			
161			0	0	0
	313	160			
	314	162			
	368	158			
	371	164			
	440	176			
162			0	0	0
	314	161			
	369	159			
	[illegible]	165			

P-315 .ERMAL TRANSIENT AN SER REVI
NASA COO RADIAL

CAP.	COND.	NODE	RCX	STU	DCND
	441	177			
	471	229			
	478	228			
163			0	0	0
	315	164			
	370	160			
	373	166			
	442	172			
	520	258			
164			0	0	0
	315	163			
	316	165			
	371	161			
	374	167			
	443	173			
165			0	0	0
	316	164			
	372	162			
	375	168			
	444	174			
	472	230			
	479	229			
166			0	0	0
	317	167			
	373	163			
	376	169			
	519	258			
167			0	0	0
	317	166			
	318	168			
	374	164			
	377	170			
168			0	0	0
	318	167			
	375	165			
	378	171			
	480	232			
	482	231			
169			0	0	0
	319	170			
	376	166			
	518	258			
170			0	0	0
	319	169			
	320	171			
	377	167			
171			0	0	0
	320	170			
	378	168			
	481	233			
	483	232			
172			0	0	0
	321	173			
	379	175			
	442	163			
	527	259			
173			0	0	0
	321	172			
	322	174			
	380	176			
	443	164			
174			0	0	0
	322	173			
	381	177			
	444	165			

CAP.	COND.	NODE	RCX	STU	DCND
	486	234			
175			0	0	0
	323	176			
	379	172			
	382	178			
	439	160			
	445	196			
	528	259			
176			0	0	0
	323	175			
	324	177			
	380	173			
	383	179			
	440	161			
	446	197			
177			0	0	0
	324	176			
	381	174			
	384	180			
	441	162			
	447	198			
	485	236			
	487	235			
178			0	0	0
	325	179			
	382	175			
	385	181			
	436	157			
	448	199			
	529	262			
179			0	0	0
	325	178			
	326	180			
	383	176			
	386	182			
	437	158			
	449	200			
180			0	0	0
	326	179			
	384	177			
	387	183			
	438	159			
	450	201			
	488	238			
	490	237			
181			0	0	0
	327	182			
	385	178			
	388	184			
	433	154			
	451	202			
	530	262			
182			0	0	0
	327	181			
	328	183			
	386	179			
	389	185			
	434	155			
	452	203			
183			0	0	0
	328	182			
	387	180			
	390	186			
	435	156			
	453	204			
	489	239			
	491	238			

CAP.	COND.	NODE	RCX	STU	DCND
184			0	0	0
	329	185			
	388	181			
	391	187			
	430	151			
	454	205			
	531	262			
185			0	0	0
	329	184			
	330	186			
	389	182			
	392	188			
	431	152			
	455	206			
186			0	0	0
	330	185			
	390	183			
	393	189			
	432	153			
	456	207			
	492	241			
	495	240			
187			0	0	0
	331	188			
	391	184			
	394	190			
	427	148			
	457	208			
	532	265			
188			0	0	0
	331	187			
	332	189			
	392	185			
	395	191			
	428	149			
	458	209			
189			0	0	0
	332	188			
	393	186			
	396	192			
	429	150			
	459	210			
	493	242			
	496	241			
190			0	0	0
	333	191			
	394	187			
	397	193			
	424	145			
	460	211			
	533	265			
191			0	0	0
	333	190			
	334	192			
	395	188			
	398	194			
	425	146			
	461	212			
192			0	0	0
	334	191			
	396	189			
	399	195			
	426	147			
	462	213			
	494	243			
	497	242			
193			0	0	0
	335	194			

CAP.	COND.	NODE	RCX	STU	DCND
	397	190			
	463	214			
	534	265			
	550	269			
194			0	0	0
	335	193			
	336	195			
	398	191			
	464	215			
	551	269			
195			0	0	0
	336	194			
	399	192			
	465	216			
	498	245			
	502	244			
	552	269			
196			0	0	0
	337	197			
	400	199			
	445	175			
	535	260			
197			0	0	0
	337	196			
	338	198			
	401	200			
	446	176			
198			0	0	0
	338	197			
	402	201			
	447	177			
	516	257			
	517	256			
199			0	0	0
	339	200			
	400	196			
	403	202			
	448	178			
	536	260			
200			0	0	0
	339	199			
	340	201			
	401	197			
	404	203			
	449	179			
201			0	0	0
	340	200			
	402	198			
	405	204			
	450	180			
	513	255			
	515	254			
202			0	0	0
	341	203			
	403	199			
	406	205			
	451	181			
	537	263			
203			0	0	0
	341	202			
	342	204			
	404	200			
	407	206			
	452	182			
204			0	0	0
	342	203			
	4	201			

CAP.	COND.	NODE	RCX	STU	DCND
	408	207			
	453	183			
	512	254			
	514	253			
205			0	0	0
	343	206			
	406	202			
	409	208			
	454	184			
	538	263			
206			0	0	0
	343	205			
	344	207			
	407	203			
	410	209			
	455	185			
207			0	0	0
	344	206			
	408	204			
	411	210			
	456	186			
	508	252			
	511	251			
208			0	0	0
	345	209			
	409	205			
	412	211			
	457	187			
	539	263			
209			0	0	0
	345	208			
	346	210			
	410	206			
	413	212			
	458	188			
210			0	0	0
	346	209			
	411	207			
	414	213			
	459	189			
	507	251			
	510	250			
211			0	0	0
	347	212			
	412	208			
	415	214			
	460	190			
	540	266			
212			0	0	0
	347	211			
	348	213			
	413	209			
	416	215			
	461	191			
213			0	0	0
	348	212			
	414	210			
	417	216			
	462	192			
	506	250			
	509	249			
214			0	0	0
	349	215			
	415	211			
	418	217			
	463	193			
	541	266			

CAP.	COND.	NODE	RCX	STU	DCND
215			0	0	0
	349	214			
	350	216			
	416	212			
	419	218			
	464	194			
216			0	0	0
	350	215			
	417	213			
	420	219			
	465	195			
	499	246			
	503	245			
217			0	0	0
	351	218			
	418	214			
	421	220			
	542	266			
	553	270			
218			0	0	0
	351	217			
	352	219			
	419	215			
	422	221			
	554	270			
219			0	0	0
	352	218			
	420	216			
	423	222			
	500	247			
	504	246			
	555	270			
220			0	0	0
	353	221			
	421	217			
	543	266			
	556	271			
221			0	0	0
	353	220			
	354	222			
	422	218			
	557	271			
222			0	0	0
	354	221			
	423	219			
	501	248			
	505	247			
	558	271			
223			1	1	1
	473	147			
224			1	1	1
	474	150			
225			1	1	1
	475	153			
226			1	1	1
	476	156			
227			1	1	1
	477	159			
228			1	1	1
	478	162			
229			1	1	1
	[illegible]	165			

CAP.	COND.	NODE	RCX	STU	DCND
231			1	1	1
	482	168			
232			1	1	1
	483	171			
234			1	1	1
	486	174			
235			1	1	1
	487	177			
237			1	1	1
	490	180			
238			1	1	1
	491	183			
240			1	1	1
	495	186			
241			1	1	1
	496	189			
242			1	1	1
	497	192			
244			1	1	1
	502	195			
245			1	1	1
	503	216			
246			1	1	1
	504	219			
247			1	1	1
	505	222			
249			1	1	1
	509	213			
250			1	1	1
	510	210			
251			1	1	1
	511	207			
253			1	1	1
	514	204			
254			1	1	1
	515	201			
256			1	1	1
	517	198			

[illegible]
TIME = TEMPERATURES (°F)

1	2	3	4	5	6	7	8	9	10
1.7070E+03	1.5188E+03	1.2661E+03	1.6873E+03	1.5150E+03	1.3150E+03	1.6735E+03	1.5201E+03	1.3524E+03	1.6517E+03
11	12	13	14	15	16	17	18	19	20
1.5188E+03	1.3763E+03	1.6191E+03	1.5054E+03	1.3835E+03	1.5821E+03	1.4862E+03	1.3836E+03	1.5452E+03	1.4661E+03
21	22	23	24	25	26	27	28	29	30
1.3820E+03	1.5149E+03	1.4500E+03	1.3812E+03	1.5046E+03	1.4501E+03	1.3915E+03	1.5570E+03	1.5053E+03	1.4528E+03
31	32	33	34	35	36	37	38	39	40
1.5682E+03	1.5185E+03	1.4670E+03	1.6072E+03	1.5513E+03	1.4925E+03	1.5841E+03	1.5283E+03	1.4701E+03	1.5965E+03
41	42	43	44	45	46	47	48	49	50
1.5410E+03	1.4835E+03	1.6265E+03	1.5714E+03	1.5151E+03	1.6643E+03	1.6110E+03	1.5566E+03	1.7145E+03	1.6611E+03
51	52	53	54	55	56	57	58	59	60
1.6072E+03	1.7595E+03	1.7028E+03	1.6474E+03	1.7778E+03	1.7186E+03	1.6593E+03	1.7845E+03	1.7216E+03	1.6587E+03
61	62	63	64	65	66	67	68	69	70
1.7876E+03	1.7145E+03	1.6409E+03	1.7964E+03	1.7085E+03	1.6230E+03	1.7940E+03	1.6834E+03	1.5765E+03	1.7652E+03
71	72	73	74	75	76	77	78	79	80
1.6308E+03	1.4896E+03	1.7733E+03	1.6398E+03	1.5285E+03	1.8254E+03	1.6410E+03	1.5288E+03	1.7175E+03	1.6192E+03
81	82	83	84	85	86	87	88	89	90
1.5312E+03	1.4350E+03	1.4050E+03	1.3880E+03	1.4000E+03	1.4150E+03	1.4470E+03	1.4550E+03	1.4650E+03	1.4800E+03
91	92	93	94	95	96	97	98	99	100
1.5050E+03	1.5530E+03	1.5700E+03	2.4740E+03	2.5500E+03	2.5460E+03	2.5380E+03	2.5290E+03	2.5170E+03	2.5060E+03
101	102	103	104	105	106	107	108	109	110
2.4950E+03	2.4850E+03	2.4740E+03	2.4650E+03	2.4560E+03	2.4480E+03	2.4390E+03	2.4320E+03	2.4240E+03	9.8100E+02
111	112	113	114	115	116	117	118	119	120
1.0058E+03	1.0174E+03	1.0299E+03	1.0428E+03	1.0555E+03	1.0678E+03	1.0795E+03	1.0908E+03	1.1021E+03	1.1152E+03
121	122	123	124	125	126	127	128	129	130
1.1285E+03	1.1422E+03	1.1587E+03	1.1587E+03	1.1754E+03	1.1903E+03	1.2050E+03	1.2200E+03	1.2354E+03	1.2520E+03
131	132	133	134	135	136	137	138	139	140
1.2694E+03	1.2895E+03	1.3086E+03	1.3258E+03	1.3412E+03	9.8100E+02	1.0200E+03	1.0564E+03	1.0863E+03	1.1069E+03
141	142	143	144	145	146	147	148	149	150
1.1587E+03	1.1648E+03	1.1723E+03	1.1813E+03	1.3979E+03	1.3360E+03	1.2785E+03	1.4521E+03	1.3590E+03	1.2649E+03
151	152	153	154	155	156	157	158	159	160
1.4691E+03	1.3872E+03	1.3020E+03	1.4806E+03	1.4055E+03	1.3277E+03	1.4778E+03	1.4117E+03	1.3425E+03	1.4790E+03
161	162	163	164	165	166	167	168	169	170
1.4214E+03	1.3604E+03	1.5135E+03	1.4632E+03	1.4100E+03	1.5850E+03	1.5509E+03	1.5163E+03	1.7536E+03	1.7380E+03
171	172	173	174	175	176	177	178	179	180
1.7252E+03	1.7210E+03	1.6881E+03	1.6554E+03	1.6621E+03	1.6207E+03	1.5775E+03	1.6357E+03	1.5922E+03	1.5473E+03
181	182	183	184	185	186	187	188	189	190
1.6299E+03	1.5816E+03	1.5321E+03	1.6254E+03	1.5704E+03	1.5144E+03	1.6046E+03	1.5432E+03	1.4802E+03	1.5900E+03
191	192	193	194	195	196	197	198	199	200
1.5138E+03	1.4368E+03	1.5535E+03	1.4608E+03	1.3627E+03	1.7541E+03	1.7179E+03	1.6809E+03	1.7587E+03	1.7219E+03
201	202	203	204	205	206	207	208	209	210
1.6849E+03	1.7291E+03	1.6892E+03	1.6476E+03	1.7312E+03	1.6880E+03	1.6444E+03	1.7117E+03	1.6594E+03	1.6059E+03
211	212	213	214	215	216	217	218	219	220
1.6750E+03	1.6132E+03	1.5490E+03	1.6493E+03	1.5706E+03	1.4864E+03	1.6507E+03	1.5640E+03	1.4740E+03	1.6276E+03
221	222	223	224	225	226	227	228	229	230
1.5510E+03	1.4647E+03	9.6500E+02	9.6721E+02	9.7291E+02	9.8120E+02	9.8996E+02	9.9894E+02	1.0083E+03	1.0182E+03
231	232	233	234	235	236	237	238	239	240
1.0182E+03	1.0665E+03	1.0763E+03	1.0182E+03	1.0300E+03	1.0424E+03	1.0424E+03	1.0577E+03	1.0718E+03	1.0718E+03
241	242	243	244	245	246	247	248	249	250
1.0868E+03	1.1002E+03	1.1125E+03	1.0182E+03	1.0346E+03	1.0590E+03	1.0791E+03	1.0910E+03	1.1125E+03	1.1346E+03

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251 1.1570E+03	252 1.1782E+03	253 1.0718E+03	254 1.1616E+03	255 1.2447E+03	256 1.0300E+03	257 1.1318E+03	258 2.1400E+03	259 2.3250E+03	260 2.4000E+03
261 2.0800E+03	262 2.2650E+03	263 2.3400E+03	264 2.0200E+03	265 2.2050E+03	266 2.2800E+03	267 1.2200E+03	268 1.3190E+03	269 1.4300E+03	270 1.5200E+03
271 1.5600E+03									

CURRENT TEMPERATURES

1 1.7070E+03	2 1.5188E+03	3 1.2661E+03	4 1.6873E+03	5 1.5150E+03	6 1.3150E+03	7 1.6735E+03	8 1.5201E+03	9 1.3524E+03	10 1.6517E+03
11 1.5188E+03	12 1.3763E+03	13 1.6191E+03	14 1.5054E+03	15 1.3835E+03	16 1.5821E+03	17 1.4862E+03	18 1.3836E+03	19 1.5452E+03	20 1.4661E+03
21 1.3820E+03	22 1.5149E+03	23 1.4500E+03	24 1.3812E+03	25 1.5046E+03	26 1.4501E+03	27 1.3915E+03	28 1.5570E+03	29 1.5053E+03	30 1.4528E+03
31 1.5682E+03	32 1.5185E+03	33 1.4670E+03	34 1.6072E+03	35 1.5513E+03	36 1.4925E+03	37 1.5841E+03	38 1.5283E+03	39 1.4701E+03	40 1.5965E+03
41 1.5410E+03	42 1.4835E+03	43 1.6265E+03	44 1.5714E+03	45 1.5151E+03	46 1.6643E+03	47 1.6110E+03	48 1.5566E+03	49 1.7145E+03	50 1.6611E+03
51 1.6072E+03	52 1.7585E+03	53 1.7028E+03	54 1.6474E+03	55 1.7778E+03	56 1.7186E+03	57 1.6593E+03	58 1.7845E+03	59 1.7216E+03	60 1.6582E+03
61 1.7876E+03	62 1.7145E+03	63 1.6409E+03	64 1.7964E+03	65 1.7085E+03	66 1.6230E+03	67 1.7940E+03	68 1.6834E+03	69 1.5765E+03	70 1.7652E+03
71 1.6308E+03	72 1.4896E+03	73 1.7733E+03	74 1.6398E+03	75 1.5285E+03	76 1.8254E+03	77 1.6410E+03	78 1.5288E+03	79 1.7175E+03	80 1.6192E+03
81 1.5312E+03	82 1.4350E+03	83 1.4050E+03	84 1.3880E+03	85 1.4000E+03	86 1.4150E+03	87 1.4470E+03	88 1.4550E+03	89 1.4650E+03	90 1.4900E+03
91 1.5050E+03	92 1.5530E+03	93 1.5700E+03	94 2.4740E+03	95 2.5500E+03	96 2.5460E+03	97 2.5380E+03	98 2.5290E+03	99 2.5170E+03	100 2.5060E+03
101 2.4950E+03	102 2.4850E+03	103 2.4740E+03	104 2.4650E+03	105 2.4560E+03	106 2.4480E+03	107 2.4390E+03	108 2.4320E+03	109 2.4240E+03	110 9.8100E+02
111 1.0058E+03	112 1.0174E+03	113 1.0299E+03	114 1.0428E+03	115 1.0555E+03	116 1.0678E+03	117 1.0795E+03	118 1.0908E+03	119 1.1021E+03	120 1.1152E+03
121 1.1285E+03	122 1.1422E+03	123 1.1587E+03	124 1.1587E+03	125 1.1754E+03	126 1.1903E+03	127 1.2050E+03	128 1.2200E+03	129 1.2354E+03	130 1.2520E+03
131 1.2694E+03	132 1.2895E+03	133 1.3086E+03	134 1.3258E+03	135 1.3412E+03	136 9.8100E+02	137 1.0200E+03	138 1.0564E+03	139 1.0863E+03	140 1.1069E+03
141 1.1587E+03	142 1.1648E+03	143 1.1723E+03	144 1.1813E+03	145 1.3979E+03	146 1.3360E+03	147 1.2785E+03	148 1.4521E+03	149 1.3590E+03	150 1.2649E+03
151 1.4691E+03	152 1.3872E+03	153 1.3020E+03	154 1.4806E+03	155 1.4055E+03	156 1.3277E+03	157 1.4778E+03	158 1.4117E+03	159 1.3425E+03	160 1.4790E+03
161 1.4214E+03	162 1.3604E+03	163 1.5135E+03	164 1.4632E+03	165 1.4100E+03	166 1.5850E+03	167 1.5509E+03	168 1.5163E+03	169 1.7536E+03	170 1.7380E+03
171 1.7252E+03	172 1.7210E+03	173 1.6881E+03	174 1.6554E+03	175 1.6621E+03	176 1.6207E+03	177 1.5775E+03	178 1.6357E+03	179 1.5922E+03	180 1.5473E+03
181 1.6299E+03	182 1.5816E+03	183 1.5321E+03	184 1.6254E+03	185 1.5704E+03	186 1.5144E+03	187 1.6046E+03	188 1.5432E+03	189 1.4802E+03	190 1.5900E+03
191 1.5138E+03	192 1.4368E+03	193 1.5535E+03	194 1.4608E+03	195 1.3627E+03	196 1.7541E+03	197 1.7179E+03	198 1.6809E+03	199 1.7587E+03	200 1.7219E+03
201 1.6849E+03	202 1.7291E+03	203 1.6892E+03	204 1.6476E+03	205 1.7312E+03	206 1.6880E+03	207 1.6444E+03	208 1.7117E+03	209 1.6594E+03	210 1.6059E+03
211 1.6750E+03	212 1.6132E+03	213 1.5490E+03	214 1.6493E+03	215 1.5706E+03	216 1.4864E+03	217 1.6507E+03	218 1.5640E+03	219 1.4740E+03	220 1.6276E+03
221 1.5510 [illegible]	222 1.4647E+03	223 9.6500E+02	224 [illegible]	225 [illegible]	226	227	228	229	230

231	232	233	234	235	236	237	238	239	240
1.0182E+03	1.0665E+03	1.0763E+03	1.0182E+03	1.0300E+03	1.0424E+03	1.0424E+03	1.0577E+03	1.0718E+03	1.0718E+03
241	242	243	244	245	246	247	248	249	250
1.0868E+03	1.1002E+03	1.1125E+03	1.0182E+03	1.0346E+03	1.0590E+03	1.0791E+03	1.0910E+03	1.1125E+03	1.1346E+03
251	252	253	254	255	256	257	258	259	260
1.1570E+03	1.1782E+03	1.0718E+03	1.1616E+03	1.2447E+03	1.0300E+03	1.1318E+03	2.1400E+03	2.3250E+03	2.4000E+03
261	262	263	264	265	266	267	268	269	270
2.0800E+03	2.2650E+03	2.3400E+03	2.0200E+03	2.2050E+03	2.2800E+03	1.2200E+03	1.3190E+03	1.4300E+03	1.5200E+03
271									
1.5600E+03									

CAPACITANCES

1	2	3	4	5	6	7	8	9	10
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	12	13	14	15	16	17	18	19	20
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	22	23	24	25	26	27	28	29	30
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	32	33	34	35	36	37	38	39	40
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	42	43	44	45	46	47	48	49	50
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	52	53	54	55	56	57	58	59	60
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
61	62	63	64	65	66	67	68	69	70
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	72	73	74	75	76	77	78	79	80
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
81	110	111	112	113	114	115	116	117	118
0.0	6.5610E+00	6.5610E+00	6.5610E+00	6.5610E+00	6.5610E+00	6.5610E+00	6.5610E+00	6.5610E+00	6.5610E+00
119	120	121	122	124	125	126	127	128	129
6.5610E+00	6.5610E+00	6.5610E+00	6.5610E+00	3.8273E+00	3.8273E+00	3.8273E+00	3.8273E+00	3.8273E+00	3.8273E+00
130	131	132	133	134	136	137	138	139	141
3.8273E+00	3.8273E+00	3.8273E+00	3.8273E+00	3.8273E+00	1.6403E+00	1.6403E+00	1.6403E+00	1.6403E+00	2.7338E+00
142	143	145	146	147	148	149	150	151	152
2.7338E+00	2.7338E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
153	154	155	156	157	158	159	160	161	162
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
163	164	165	166	167	168	169	170	171	172
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
173	174	175	176	177	178	179	180	181	182
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
183	184	185	186	187	188	189	190	191	192
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
193	194	195	196	197	198	199	200	201	202
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
203	204	205	206	207	208	209	210	211	212
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
213	214	215	216	217	218	219	220	221	222
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
223	224	225	226	227	228	229	231	232	234
1.6402E+01	1.6402E+01	1.6402E+01	1.6402E+01	1.6402E+01	1.6402E+01	1.6402E+01	2.2417E+00	2.2417E+00	1.4161E+01
235	237	238	240	241	242	244	245	246	247
1.4161E+01	1.0334E+01	1.0334E+01	8.8574E+00	8.8574E+00	8.8574E+00	5.7955E+00	5.7955E+00	5.7955E+00	5.7955E+00

249	250	251	253	254	256
5.7955E+00	5.7955E+00	5.7955E+00	1.4762E+00	1.4762E+00	1.8589E+00

CONDUCTANCES

1	2	3	4	5	6	7	8	9	10
9.9164E-02	8.7052E-02	2.9732E-01	2.6623E-01	4.3521E-01	3.9593E-01	5.4796E-01	5.0528E-01	6.2550E-01	6.[illegible]E-01
11	12	13	14	15	16	17	18	19	20
7.0909E-01	6.6809E-01	8.2837E-01	7.8834E-01	9.6445E-01	9.2571E-01	1.1118E+00	1.0739E+00	1.5281E+00	1.4[illegible]E+00
21	22	23	24	25	26	27	28	29	30
1.5196E+00	1.4945E+00	2.3964E+00	2.3184E+00	8.9074E-01	8.6155E-01	8.9816E-01	8.6917E-01	9.4412E-01	9.1[illegible]E-01
31	32	33	34	35	36	37	38	39	40
1.0273E+00	9.8956E-01	1.1272E+00	1.0840E+00	1.1686E+00	1.1236E+00	1.2649E+00	1.2136E+00	1.1490E+00	1.0[illegible]E+00
41	42	43	44	45	46	47	48	49	50
8.9706E-01	8.5206E-01	7.5264E-01	7.0809E-01	7.0796E-01	6.5488E-01	6.8153E-01	6.2000E-01	4.3212E-01	3.9611E-01
51	52	53	54	55	56	57	58	59	60
2.0422E-01	1.8383E-01	1.0761E-01	9.5527E-02	8.4464E-02	1.3354E-01	1.2001E-01	1.0829E-01	1.2114E-01	1.1040E-01
61	62	63	64	65	66	67	68	69	70
1.0097E-01	9.1400E-02	8.4613E-02	7.8284E-02	6.6146E-02	6.2253E-02	5.8253E-02	4.8694E-02	4.6255E-02	4.[illegible]E-02
71	72	73	74	75	76	77	78	79	80
3.5572E-02	3.4078E-02	3.2592E-02	2.7806E-02	2.6825E-02	2.5539E-02	2.7471E-02	2.6620E-02	2.5729E-02	2.4166E-02
81	82	83	84	85	86	87	88	89	90
2.3464E-02	2.2744E-02	2.3458E-02	2.2759E-02	2.2028E-02	1.3669E-02	1.3240E-02	1.2790E-02	1.3628E-02	1.3200E-02
91	92	93	94	95	96	97	98	99	100
1.2755E-02	1.5754E-02	1.5231E-02	1.4733E-02	2.2240E-02	2.1389E-02	2.0722E-02	2.4883E-02	2.3935E-02	2.3059E-02
101	102	103	104	105	106	107	108	109	110
3.2603E-02	3.1375E-02	3.0145E-02	4.3706E-02	4.2010E-02	4.0317E-02	5.9167E-02	5.6750E-02	5.4329E-02	6.0942E-02
111	112	113	114	115	116	117	118	119	120
5.8180E-02	5.5405E-02	6.7281E-02	6.3678E-02	6.0121E-02	8.4679E-02	7.9101E-02	7.3702E-02	1.1962E-01	1.0979E-01
121	122	123	124	125	126	127	128	129	130
1.0126E-01	1.2383E-01	1.1263E-01	1.0408E-01	1.1023E-01	9.8635E-02	9.1860E-02	3.1038E-02	2.7868E-02	2.5052E-02
131	132	133	134	135	136	137	138	139	140
2.2877E-02	2.0831E-02	1.9128E-02	1.6796E-02	1.5476E-02	1.4389E-02	1.3113E-02	1.2216E-02	1.1474E-02	1.1729E-02
141	142	143	144	145	146	147	148	149	150
1.1011E-02	1.0430E-02	1.0704E-02	1.0129E-02	9.6783E-03	9.7532E-03	9.3417E-03	8.9724E-03	8.9736E-03	8.6[illegible]E-03
151	152	153	154	155	156	157	158	159	160
8.3623E-03	8.4489E-03	8.1838E-03	7.9063E-03	7.0905E-03	6.8744E-03	6.6527E-03	7.2838E-03	7.0653E-03	6.9[illegible]E-03
161	162	163	164	165	166	167	168	169	170
1.2386E-01	1.1730E-01	1.0899E-01	6.2128E-02	5.9086E-02	5.5648E-02	4.2866E-02	4.0983E-02	3.8925E-02	3.2435E-02
171	172	173	174	175	176	177	178	179	180
3.1192E-02	2.9857E-02	2.6589E-02	2.5699E-02	2.4749E-02	2.1632E-02	2.1012E-02	2.0378E-02	1.7947E-02	1.7516E-02
181	182	183	184	185	186	187	188	189	190
1.7103E-02	1.6412E-02	1.6088E-02	1.5763E-02	1.5236E-02	1.4985E-02	1.4715E-02	5.9972E-02	5.7357E-02	5.5044E-02
191	192	193	194	195	196	197	198	199	200
1.5476E-01	1.4735E-01	1.4274E-01	2.5453E-01	2.3789E-01	2.3017E-01	2.1420E-01	1.3708E-01	7.7400E-02	5.1300E-02
201	202	203	204	205	206	207	208	209	210
8.1769E-02	5.2981E-02	5.7507E-02	5.8455E-02	6.2081E-02	6.5366E-02	6.8611E-02	7.7874E-02	7.5967E-02	9.1733E-02
211	212	213	214	215	216	217	218	219	220
8.5611E-02	1.0906E-01	9.4855E-02	1.0753E-01	9.4833E-02	9.9180E-02	8.0972E-02	1.0526E-01	5.9500E-02	1.2992E-01
221	223	225	227	228	229	230	231	232	233
1.5571E-01	1.3218E-01	1.8108E-01	1.1685E-01	1.1108E-01	1.1089E-01	1.1105E-01	1.1090E-01	1.1092E-01	1.1105E-01
234	235	236	237	238	239	240	241	242	243
1.1133E-01	1.1146E-01	1.1146E-01	1.1187E-01	1.1239E-01	1.2604E-01	1.1685E-01	1.1108E-01	1.1089E-01	1.1105E-01

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254 8.7990E-02	255 8.7560E-02	256 8.4120E-02	257 7.9980E-02	258 7.7730E-02	259 7.6230E-02	260 9.0300E-02	261 9.0300E-02	262 9.0300E-02	263 9.0300E-02
264 8.7560E-02	265 8.7990E-02	266 8.7560E-02	267 8.4120E-02	268 7.9980E-02	269 7.7730E-02	270 7.6230E-02	271 9.0300E-02	272 9.0300E-02	273 9.0300E-02
274 9.0300E-02	275 4.9340E-02	276 5.8940E-02	277 4.7590E-02	278 3.4820E-02	279 4.9340E-02	280 5.8940E-02	281 4.7590E-02	282 3.4820E-02	285 2.0169E-02
286 2.0169E-02	287 2.0169E-02	288 2.0169E-02	289 2.0169E-02	290 2.0169E-02	291 1.3666E+00	292 1.2809E+00	293 5.3288E-02	294 5.0450E-02	295 4.8355E-02
296 3.6488E-02	297 3.2592E-02	298 2.9050E-02	299 8.1600E-02	300 3.0556E-03	301 3.0086E-03	302 2.9608E-03	303 3.4412E-01	304 3.3451E-01	305 8.6566E-01
306 8.2761E-01	307 1.4909E+00	308 1.4274E+00	309 1.7229E+00	310 1.6515E+00	311 1.9563E+00	312 1.8824E+00	313 2.2795E+00	314 2.2001E+00	315 2.7118E+00
316 2.6278E+00	317 2.8493E+00	318 2.7934E+00	319 2.0618E+00	320 2.0417E+00	321 4.8242E+00	322 4.7125E+00	323 3.6544E+00	324 3.5407E+00	325 3.2071E+00
326 3.1195E+00	327 2.7023E+00	328 2.6264E+00	329 2.2016E+00	330 2.1330E+00	331 1.7642E+00	332 1.7017E+00	333 1.3752E+00	334 1.3144E+00	335 6.8442E-01
336 6.4576E-01	337 4.6788E+00	338 4.5606E+00	339 3.1043E+00	340 3.0254E+00	341 2.8918E+00	342 2.8089E+00	343 2.6586E+00	344 2.5775E+00	345 2.2895E+00
346 2.2028E+00	347 1.8777E+00	348 1.7974E+00	349 1.5322E+00	350 1.4597E+00	351 1.1956E+00	352 1.1348E+00	353 5.0375E-01	354 4.8060E-01	355 9.2684E-02
356 8.9035E-02	357 8.5847E-02	358 1.3415E-01	359 1.2759E-01	360 1.2225E-01	361 1.2407E-01	362 1.1827E-01	363 1.1381E-01	364 1.0535E-01	365 1.0087E-01
366 9.7323E-02	367 9.0219E-02	368 8.6857E-02	369 8.4036E-02	370 7.8429E-02	371 7.5908E-02	372 7.3428E-02	373 6.9328E-02	374 6.7639E-02	375 6.5880E-02
376 3.1911E-02	377 3.1337E-02	378 3.0788E-02	379 5.9166E-02	380 5.7599E-02	381 5.5999E-02	382 6.7333E-02	383 6.5234E-02	384 6.3543E-02	385 6.8960E-02
386 6.6786E-02	387 6.5003E-02	388 7.3255E-02	389 7.0777E-02	390 6.8653E-02	391 7.7394E-02	392 7.4664E-02	393 7.2107E-02	394 8.7594E-02	395 8.4207E-02
396 8.0761E-02	397 1.0451E-01	398 9.9473E-02	399 9.4263E-02	400 4.2565E-02	401 4.1508E-02	402 4.0435E-02	403 5.5789E-02	404 5.4319E-02	405 5.2814E-02
406 6.1991E-02	407 6.0205E-02	408 5.8374E-02	409 7.2285E-02	410 6.9875E-02	411 6.7427E-02	412 8.1765E-02	413 7.8444E-02	414 7.5369E-02	415 9.1881E-02
416 8.7328E-02	417 8.3678E-02	418 1.0704E-01	419 1.0122E-01	420 9.6184E-02	421 8.7877E-02	422 8.3299E-02	423 7.9076E-02	424 8.2760E-03	425 7.9351E-03
426 7.6597E-03	427 6.0794E-03	428 5.8049E-03	429 5.5521E-03	430 4.7441E-03	431 4.5562E-03	432 4.3625E-03	433 3.9094E-03	434 3.7706E-03	435 3.6274E-03
436 3.2768E-03	437 3.1736E-03	438 3.0661E-03	439 2.8012E-03	440 2.7220E-03	441 2.6388E-03	442 2.5698E-03	443 2.5018E-03	444 2.4406E-03	445 3.0062E-03
446 2.9241E-03	447 2.8391E-03	448 3.1657E-03	449 3.0755E-03	450 2.9835E-03	451 3.5167E-03	452 3.4053E-03	453 3.2969E-03	454 4.1443E-03	455 3.9980E-03
456 3.8657E-03	457 4.7502E-03	458 4.5530E-03	459 4.4032E-03	460 5.7067E-03	461 5.4547E-03	462 5.2342E-03	463 8.0006E-03	464 7.6138E-03	465 7.2052E-03
466 5.1560E-02	467 1.4089E-01	468 1.8608E-01	469 1.8672E-01	470 1.8800E-01	471 1.9184E-01	472 1.8110E-01	473 5.1560E-02	474 1.4089E-01	475 1.8608E-01
476 1.8672E-01	477 1.8800E-01	478 1.9184E-01	479 1.8110E-01	480 1.0157E-01	481 1.5050E-02	482 1.0157E-01	483 1.5050E-02	484 1.1816E-01	485 1.4337E-01
486 1.1816E-01	487 1.4337E-01	488 1.4169E-01	489 1.3844E-01	490 1.4169E-01	491 1.3844E-01	492 1.3546E-01	493 1.3655E-01	494 1.4686E-01	495 1.3546E-01
496 1.3655E-01	497 1.4686E-01	498 1.2569E-01	499 1.4328E-01	500 1.2794E-01	501 8.0400E-02	502 1.2569E-01	503 1.4328E-01	504 1.2794E-01	505 8.0400E-02
506 1.3369E-01	507 1.2554E-01	508 1.1481E-01	509 1.3369E-01	510 1.2554E-01	511 1.1481E-01	512 1.1119E-01	513 1.1348E-01	514 1.1119E-01	515 1.1348E-01

516	517	518	519	520	521	522	523	524	525
1.4048E-01	1.4048E-01	9.7533E 02	1.7417E-01	2.1335E-01	2.1335E-01	2.1335E-01	2.1771E-01	2.2206E-01	1.6110E-01
526	527	528	529	530	531	532	533	534	535
6.5313E 02	2.6957E-01	2.2619E-01	2.1933E 01	2.0562E-01	1.9192E-01	1.8049E 01	1.7638E-01	1.3021E-01	2.6196E-01
536	537	538	539	540	541	542	543	544	545
1.8182E 01	1.8660E-01	1.9187E-01	1.9426E-01	1.9139E 01	1.8852E-01	1.7225E-01	7.7513E 02	3.9167E 02	3.8301E 02
546	547	548	549	550	551	552	553	554	555
3.7425E-02	3.2904E-01	3.2426E 01	3.1981E-01	2.0973E-01	2.0392E-01	1.9790E 01	2.0672E 02	2.0166E-02	1.9639E 02
556	557	558							
2.0728E 01	2.0281E-01	1.9777E-01							

MISCELLANEOUS VALUES

224	243	244	1003
1.4102E+04	8.7589E+03	2.2861E+04	1.1250E+00

TIME CONSTANTS

HEAT BALANCE

1	2	3	4	5	6	7	8	9	10
8.3542E-04	6.5613E 04	9.7370E 04	1.0529E 03	5.7793E 04	4.2725E 04	7.4768E 04	-1.6832E 03	9.6130E 04	9.2656E 04
11	12	13	14	15	16	17	18	19	20
-3.1652E-03	5.1880E 04	7.9346E-04	-4.0417E 03	1.2207E-03	8.2397E 04	-3.2682E-03	2.2888E 04	2.5940E 04	2.7390E 03
21	22	23	24	25	26	27	28	29	30
-5.7983E 04	-3.9673E 03	-1.6307E-03	-2.9602E-03	-3.3875E-03	-3.7853E-03	-2.8687E-03	-3.5132E 03	5.7476E-03	4.4204E 03
31	32	33	34	35	36	37	38	39	40
-5.8441E-03	3.8466E-03	-4.2114E 03	4.2706E 03	-8.3065E-03	3.5982E 03	-6.4087E-04	-3.6703E-03	9.9182E-04	-6.1035E 04
41	42	43	44	45	46	47	48	49	50
-3.3804E-03	-1.4038E-03	-2.6703E-03	-3.1139E-03	-2.2278E-03	-4.1351E-03	-5.9404E-03	-3.1586E-03	-6.4087E-03	-4.6616E 03
51	52	53	54	55	56	57	58	59	60
-5.0507E-03	-3.2501E-03	-6.0682E-03	-6.4392E-03	-4.9286E-03	3.1061E-03	-6.9427E-03	-3.7384E 03	5.4140E-03	-3.1281E 03
61	62	63	64	65	66	67	68	69	70
-4.1504E-03	-2.4137E-03	-3.0365E 03	1.0834E-03	-2.8820E-03	-3.5095E-04	-4.5776E-05	-1.7843E-03	8.3923E-04	2.4033E 04
71	72	73	74	75	76	77	78	79	80
-1.3571E-03	-1.5411E 03	1.0681E-03	-1.2217E 03	8.6975E-04	6.8665E-04	9.6130E-04	5.7220E-04	1.6460E-03	3.0146E-03
81	145	146	147	148	149	150	151	152	153
-2.3012E 03	6.5613E 04	1.0185E-03	6.6948E-04	-1.8482E-03	1.2741E-03	-2.4853E 03	-5.9509E 04	4.5257E 03	1.8311E 04
154	155	156	157	158	159	160	161	162	163
-1.0376E-03	8.1415E 03	-1.2054E-03	2.3193E 03	7.7468E-03	6.5613E-04	3.0518E-03	1.1232E 02	1.5259E 05	1.5167E 02
164	165	166	167	168	169	170	171	172	173
3.0655E-02	1.3489E-02	4.5517E-02	7.2548E-02	4.4708E-02	7.9117E-02	1.6554E-01	8.1361E-02	5.2048E-02	1.0157E-01
174	175	176	177	178	179	180	181	182	183
5.5740E-02	2.4170E 02	5.5399E-02	3.2684E-02	1.3962E-02	2.8077E 02	1.9714E-02	1.3748E-02	1.9235E-02	1.5076E 02
184	185	186	187	188	189	190	191	192	193
1.0681E-04	1.5397E-02	2.8992E-04	2.9907E-03	7.1997E 03	5.7983E-04	-5.8289E 03	1.0960E-02	-3.8300E-03	3.2397E 04
194	195	196	197	198	199	200	201	202	203
9.4032E 04	7.6580E-04	7.9010E-02	1.3930E-01	8.2962E-02	3.7674E 02	6.9436E 02	3.9856E-02	1.7839E-02	4.4596E 02
204	205	206	207	208	209	210	211	212	213
2.6016E 02	1.3474E-02	2.1087E-02	1.7838E-02	2.8687E-03	1.1626E 02	4.5624E-03	-1.9226E 03	1.2502E 02	-4.5776E 05
214	215	216	217	218	219	220	221	222	
-2.5940E 04	7.2563E-03	-6.1035E 05	5.3120E 04	-5.8657E 04	2.5408E-03	-6.5804E-05	1.4353E 03	2.5940E-04	

RELATIVE HEAT BALANCE

1	2	3	4	5	6	7	8	9	10
8.5384E 06	1.2184E-05	7.6400E-06	7.8738E-06	5.1407E 06	2.9861E-06	4.7436E-06	1.2057E-05	6.2455E-06	5.9261E-06
11	12	13	14	15	16	17	18	19	20
2.0992 [illegible]	3.3287E-06	5.0236E-06	2.7093E-05	8.1674E-06	5.59 [illegible] 06	2.2906E-05	1.6009E-06	1.8696E 05	2.0071E 05

ORIGINAL PAGE IS
OF POOR QUALITY

21	22	23	24	25	26	27	28	29	30
4.2317E-06	3.0691E-05	1.2643E-05	2.2458E-05	2.7464E-05	3.0004E-05	2.1716E-05	2.1749E-05	3.6146E-05	2.8210E-05
31	32	33	34	35	36	37	38	39	40
3.8087E-05	2.4891E-05	2.7155E-05	1.5803E-05	3.0246E-05	1.3024E-05	6.4308E-06	3.6568E-05	9.8054E-06	6.0606E-06
41	42	43	44	45	46	47	48	49	50
3.3555E-05	1.3919E-05	2.4912E-05	2.9410E-05	2.1279E-05	3.6281E-05	5.3028E-05	2.8746E-05	5.0802E-05	3.7906E-05
51	52	53	54	55	56	57	58	59	60
4.2311E-05	2.3758E-05	4.6150E-05	5.1328E-05	3.1786E-05	2.0709E-05	4.8223E-05	2.5143E-05	3.7488E-05	2.2607E-05
61	62	63	64	65	66	67	68	69	70
3.0622E-05	1.8265E-05	2.3842E-05	7.8012E-06	2.1656E-05	2.8485E-06	2.7086E-07	1.1105E-05	5.7158E-06	1.0989E-06
71	72	73	74	75	76	77	78	79	80
6.8962E-06	7.6131E-06	5.7545E-06	1.0561E-05	9.1432E-06	3.1673E-06	1.2766E-05	9.4991E-06	5.0792E-06	1.1219E-05
81	145	146	147	148	149	150	151	152	153
1.0206E-05	6.9435E-06	2.0577E-05	1.0027E-05	9.7582E-06	7.4731E-06	1.4659E-05	2.3902E-06	1.8074E-05	7.2977E-07
154	155	156	157	158	159	160	161	162	163
3.9578E-06	3.1155E-05	4.6123E-06	8.9622E-06	2.9611E-05	2.4794E-06	1.1609E-05	4.1589E-05	5.5128E-08	5.4497E-05
164	165	166	167	168	169	170	171	172	173
1.0724E-04	4.5774E-05	2.2308E-04	3.5264E-04	2.1640E-04	1.0509E-03	2.5755E-03	1.5555E-03	1.5986E-04	3.2000E-04
174	175	176	177	178	179	180	181	182	183
1.8077E-04	7.8639E-05	1.7812E-04	1.0362E-04	4.9794E-05	9.9022E-05	6.9154E-05	5.2340E-05	7.3147E-05	5.7377E-05
184	185	186	187	188	189	190	191	192	193
4.3240E-07	6.2891E-05	1.1954E-06	1.3534E-05	3.2477E-05	2.6283E-06	2.6437E-05	5.0806E-05	1.8192E-05	4.6076E-06
194	195	196	197	198	199	200	201	202	203
6.7540E-06	4.5290E-06	2.3325E-04	4.1177E-04	2.4558E-04	1.6158E-04	3.0377E-04	1.7809E-04	7.7039E-05	1.9031E-04
204	205	206	207	208	209	210	211	212	213
1.0963E-04	5.7675E-05	9.1774E-05	7.9219E-05	1.1619E-05	4.7675E-05	1.8952E-05	8.0913E-06	5.2272E-05	1.9138E-07
214	215	216	217	218	219	220	221	222	
1.0684E-06	2.9179E-05	2.3827E-07	2.4500E-06	2.8146E-06	1.2176E-05	6.2559E-07	1.7301E-05	2.1244E-06	

APPENDIX E

NASA AIR-COOLED RADIAL TURBINE WHEEL DRAWINGS

131100	Proposal - Engine Assembly, With High Temperature Turbine Wheel (Full Size to Fit T-62)
131102	Layout - Turbine Wheel, Air-Cooled (Two-Piece 10X Size)
131301	Proposal - Air-Cooled Turbine Wheel Assembly (Multi-Piece Construction 10X Size)
131454	Wheel, Turbine - Air Cooled (Cast Star Wheel)
131103	Wheel, Turbine - Air Cooled (Brazed Star Wheel)
131467	Insert, Blade - Air Cooled (Brazed Star Wheel)
131455	Exducer, Turbine - Air Cooled (Cast One-Piece)
131599	Blade, Exducer - Air Cooled (Cast and Machined)
954959C1	Hub, Exducer - Air Cooled (Machined)
954960C1	Ring, Exducer - Air Cooled (Machined)
954961C1	Retainer, Exducer Blade (Machined)
131453-100	Wheel Assembly, Turbine - Air Cooled (Cast Wheel and Exducer)
-200	Wheel Assembly (Brazed Wheel and Cast Exducer)
-300	Wheel Assembly (Cast Wheel and Multi-Piece Exducer) (Includes assembly, balancing and spinning)
DSK 17073	Material Specification

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FABRICATION OF COOLED RADIAL TURBINE ROTOR

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