2(m1X)

NTIS HC 10.75

NASA CR-120,992
LYCOMING 105.22.21

DESIGN STUDY OF AN AIR PUMP AND INTEGRAL LIFT ENGINE ALF-504 USING THE LYCOMING 502 CORE

by

Dale Rauch

Avco Lycoming Division
550 South Main Street
Stratford, Connecticut 06497

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

July 1972

CONTRACT NAS 3-15696

NASA Lewis Research Center
Cleveland, Ohio
Laurence W. Gertsma, Project Manager

169

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-120, 992		

4. Title and Subtitle	5. Report Date
DESIGN STUDY OF AN AIR PUMP AND INTEGRAL LIFT ENGINE ALF-504 USING THE LYCOMING 502 CORE	July 1972
	6. Performing Organization Code
7. Author(s) Dale Rauch	8. Performing Organization Report No. Lycoming Report No. 105.22.21
	10. Work Unit No.
9. Performing Organization Name and Address Avco Lycoming Division Stratford, Connecticut 06497	11. Contract or Grant No. NAS 3-15696
	13. Type of Report and Period Covered Contractor Report
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with Project Manager, Laurence W. Gertsma, NASA Lewis Research Center, Cleveland, Ohio

16. Abstract

Design studies were conducted for an integral lift fan engine (ALF-504) utilizing the Lycoming 502 fan core with the final MQT power turbine. The fan is designed for a 12.5 bypass ratio and 1.25:1 pressure ratio, and provides supercharging for the core. Maximum sea level static thrust is 8370 pounds with a specific fuel consumption of 0.302 lb/hr-lb. The dry engine weight without starter is 1419 pounds including full-length duct and sound-attenuating rings. The engine envelope including duct treatment but not localized accessory protrusion is 53.25 inches in diameter and 59.2 inches long from exhaust nozzle exit to fan inlet flange.

Detailed analysis includes fan aerodynamics, fan and reduction gear mechanical design, fan dynamic analysis, engine noise analysis, engine performance, and weight analysis.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
High bypass ratio fan engine	Unclassified-unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	171	$3.00

* For sale by the National Technical Information Service, Springfield, Virginia 22151

FOREWORD

The work reported herein was conducted at Avco Lycoming Division, Stratford, Connecticut under NASA Contract No. NAS3-15696. The study was conducted under the management of the NASA Lewis Research Center with Mr. Laurence Gertsma as project manager.

ABSTRACT

Design studies were conducted for an integral lift fan engine (ALF-504) utilizing the Lycoming 502 fan core with the final MQT power turbine. The fan is designed for a 12.5 bypass ratio and 1.25:1 pressure ratio, and provides supercharging for the core. Maximum sea level static thrust is 8370 pounds with a specific fuel consumption of 0.302 lb/hr-lb. The dry engine weight without starter is 1419 pounds including full-length duct and sound-attenuating rings. The engine envelope including duct treatment but not localized accessory protrusion is 53.25 inches in diameter and 59.2 inches long from exhaust nozzle exit to fan inlet flange.

Detailed analysis includes fan aerodynamics, fan and reduction gear mechanical design, fan dynamic analysis, engine noise analysis, engine performance, and weight analysis.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SUMMARY

Preliminary studies and final design studies of an integral lift fan engine ALF-504 were conducted using in all cases the Lycoming 502 fan engine core and MQT power turbine. The fan full-speed design pressure ratio is 1.25:1 at sea level standard conditions as specified by NASA. Preliminary studies were conducted to determine the relative engine performance when supercharging with the fan alone and with the addition of two core inlet duct supercharging stages. The results of the preliminary studies show an increase in maximum sea level static thrust of 10 percent for the additional supercharged engine and an increase of approximately 10 percent in velocity leaving the power turbine. Considerations of the small thrust increase and added noise contribution of the hot exhaust jet* resulted in a decision by NASA to base the final design studies on the engine without additional supercharging. Another important decision as a result of the preliminary studies resulted in an increase of fan tip speed from 985 ft/sec to 1100 ft/sec. This tip speed increase reduced the rotor blade hub overturn (turning past axial in the relative system) from 25 degrees to 10 degrees in the final design, and gives reasonable assurance of flow stability into the core compressor. The final design studies includes detail analysis of fan aerodynamics, fan and reduction gear mechanical design, fan dynamic analysis, engine noise analysis, engine performance, and weight analysis.

Aerodynamic design of the fan includes consideration of the splitter shape and location as this affects local streamline curvature and static pressure gradient. A solution is realized when the splitter stagnation streamline static pressure shows the same value for the duct and core flows. Semi-empirical analytical technique making use of test data from the Lycoming 502 fan has been included in the axisymmetric flow solution to account for the effects of part-span shroud pumping, wake profile and higher losses behind the rotor shroud.

Important design parameters of the final fan aerodynamic sea level standard design point condition for the ALF-504 fan engine are:

1. Total fan flow 421.1 lb/sec

2. Bypass ratio 12.5

3. Fan pressure ratio 1.25:1

---

*A diffuser after the power turbine was not used in either case.

4. Fan design efficiency 88 percent polytropic

5. Fan tip speed 1100 ft/sec

6. Fan tip diameter 48.0 inches

7. Fan inlet hub-tip ratio 0.392

8. Rotor hub overturn 10 degrees

9. Rotor inlet relative tip Mach number 1.15

10. Absolute Mach number at inlet of core stator 0.74

Stress and dynamic considerations of the fan rotor blade and disc based on use of titanium material and a part-span shroud located at an 18-inch radius show the steady stresses to be low compared with the material yield stress. The tangential stress at the disc bore is 43 ksi compared with 132 ksi yield, and the hub blade centrifugal stress is 26.5 ksi. First bending frequency is free from first-, second-, and third-order excitation above 80 percent speed, and therefore should provide adequate inlet distortion margin from a mechanical standpoint. Blade flutter analysis shows adequate design margin in torsion and bending when compared with NASA criteria.

Fan noise analysis without inlet treatment based on a modified Smith and House method shows a maximum 500 feet sideline noise of 98.6 PNdB at 70 degrees from the inlet for this component.

The total 500 feet sideline maximum engine noise without any acoustical treatment is 104.5 PNdB at 100 degrees from the inlet. Use of two sound-attenuating rings in the bypass duct in addition to wall treatment of this duct reduced the 500 feet sideline engine noise at 100 degrees from the inlet to 97.0 PNdB. This 7.5 PNdB engine noise reduction requires an increase of 3.8 inches in bypass duct diameter, produces a minimum of 2.5 percent loss in sea level takeoff thrust, and adds 58 pounds in weight to the engine because of the attenuating rings alone.

Sea level maximum static thrust is 8370* pounds with a 0.302 lb/hr per lb specific fuel consumption. Use of a two-position variable duct exhaust nozzle gives 16 percent higher net thrust at 0.4 flight Mach number sea level and 15 percent improved specific fuel consumption

---

*Does not include added pressure loss of sound-attenuating rings in bypass duct.

The nozzle goes to the closed position (12 percent closed) when a flight Mach number of 0.4 is reached, to rematch the fan at the sea level takeoff point. Engine acceleration time from a steady-state condition of 80 percent maximum thrust to 93.2 percent (66 percent of 80 to 100 percent) is estimated to be 2.5 seconds in the sea level flight Mach number range of 0 to 0.4.

The dry engine weight without starter but including bypass duct sound-attenuating rings and wall treatment is 1419 pounds.

INTRODUCTION

The relative simplicity and the advantages and disadvantages of VTOL and STOL aircraft have been studied and debated in this country and in Europe for more than a decade. Indeed, many system concepts have evolved and a large variety of powerplant types and aircraft systems have been built and tested. Since these aircraft have been developed largely for military application, the noise by-product was of little consequence. However with application of VTOL and STOL to commercial aircraft, noise generated during takeoff and landing has become of paramount importance, with maximum effort and considerable funding being expended both to quiet existing engines and to better understand the fundamentals of the interplay between basic aerodynamic design of fans, compressors and turbines, and noise generation.

As an effort to demonstrate the relative quiet of STOL aircraft employing internal or external wing augmentation and aircraft of the same seating capacity with VTOL capability, NASA (Lewis) has sponsored a design and study program for lift cruise fan engines with Lycoming based on the 502 fan core. These engines would provide power for a demonstrator aircraft. It is intended that the outcome of this demonstrator program would lead to the design, development, qualification, and procurement of larger commercial VTOL aircraft and more powerful engines which would be phased into commercial use in such size, range, and cruise speed as to be economically viable.

The Lycoming 502 fan engine core was chosen by NASA for the demonstrator program because of its relatively short length and low weight, the many development and flying hours of the basic core, and the currently intense fan program sponsored by the Air Force for the AX close-support aircraft.

The design studies reported herein have all been based on the 502 fan core, and demonstrate the relative ease of converting the 502 fan core to a high bypass ratio (BR = 12.5) low pressure ratio (P_r = 1.25:1) fan for lift cruise application. The final design studies include detail analysis of fan aerodynamics, fan stress and dynamics, reduction gear design and stress analysis, fan and engine noise analysis, engine performance evaluation, and weight estimation.

PRELIMINARY STUDIES OF SUPERCHARGED AND NONSUPERCHARGED INTEGRAL LIFT ENGINE AND AIR PUMP

General

Prior to the final design phase of the integral lift engine, parallel studies were made to determine the relative size, weight, performance, and fan aerodynamics for the nonsupercharged engine and a design having two supercharging stages following the fan. Reduction gearing design studies for each engine were also conducted to show any significant differences involved. The results of these studies were presented to NASA in February, and the decision was made to continue the final design effort on the nonsupercharged engine. Its greater simplicity, lower development cost, and reduced hot jet velocity after the power turbine* (which may be a major noise contributor) more than offset the 10 percent lower takeoff thrust compared with the supercharged engine.

Engine Thermodynamic Performance

In this phase of study, only design point sea level static maximum power performance was considered. The use of two additional supercharger stages produced a higher cycle pressure ratio and increased mass flow in the core to increase the engine power. The following data summarize the performance results of the two engines studied:

*In each case the MQT T55-L-11 power turbine is used without exhaust diffuser or jet nozzle.

	Fan Alone	Fan Plus Two Supercharging Stages
$W_{a\ tot}$ - lb/sec	406*	449
W_{core} - lb/sec	31.2	34.4
Bypass Ratio	12.02	12.02
P_{rf}	1.25	1.25
Total Supercharging P_r	1.25	1.5
Overall Pressure Ratio	9.73	10.7
F_{tot} - lb	8000	8800
SFC - lb/hr-lb	0.307	0.300

Fan Aerodynamic Design

Two fans were studied, and they reflect the requirements of the supercharged and nonsupercharged engines. These fans were based on tip speeds of 985 ft/sec, which was later increased to 1100 ft/sec with concurrence of NASA to reduce the hub "overturn" (turning past axial in the relative system) with the belief that the added noise contribution would be small and would be as much affected by the blade aerodynamic loading as the increased tip speed. A summary of the more important aerodynamic parameters follows:

	Fan Alone	Fan Plus Two Supercharging Stages
P_{rf}	1.25	1.25
U_t - ft/sec	985	985
N - RPM	4770	4550
D_t - in.	47.244	49.606
Hub/Tip Ratio, Inlet	0.385	0.385
$W_{a\ tot}$ - lb/sec	406.0	449.0
Rotor Tip Rel Mach No.	0.80	0.80
Rotor Hub Overturn - deg	25	25

*Final design based on 421.1 lb/sec

Reduction Gearing

Reduction gearing design studies were made for the supercharged and nonsupercharged fan designs with appropriate reduction ratios. The study included designs utilizing a rotating planet and carrier with fixed ring gear as a possibility to reduce the gear envelope and weight and to allow positioning of the gear further downstream in the inlet housing to reduce the overall engine length. The results indicated the bearing loads of the rotating carrier to be excessively high for the package required for this application, and this approach was, therefore, abandoned. Gearing having fixed planets and a rotating ring gear (the type used in the Lycoming 502 engine) was used as the basis of the final analysis. Resulting design parameters for the appropriate gearing of the nonsupercharged and supercharged fan engines are as follows:

	Fan Alone	Fan Plus Two Supercharging Stages
Reduction Ratio	3.56	3.73
Output Torque-ft/lb	9080	9520
Output Speed - RPM	4770	4550
Number of Planets	5	4
Face Width of Sun and Planets - in.	2.85	3.12

Air Pump

In this study major emphasis has been directed to the integral lift engine powerplant; therefore, only a cursory study has been conducted for the air pump design concept as agreed upon by NASA.

The fan design was based on a pressure ratio of 3.5:1 with the bypass ratio dependent upon the static pressure desired after the power turbine and associated exhaust nozzle configuration. The fan design could be effectively accomplished from an aerodynamic standpoint with either three or four stages.

The optimum number of stages would depend upon design trade-off studies showing the effect of relative tip speed (higher for the 3 stage design) and number of stages on fan noise, gear reduction ratio size and weight, and fan weight.

The fan supercharges the 502 core and, therefore, gives a significant temperature, pressure, and flow increase into the core of the fan engine. The study revealed that because of the temperature increase at the core inlet, the referred speed of the core compressor is 83.5 percent of design value. At this speed the core compressor requires operation with the bleed port open to prevent surge.

Two solutions to this problem are available:

1. Increase of the core rotor speed above the present 19,260 rpm value, which requires reset of the turbine nozzles and a review of the modifications required by the increased stresses.

2. Removal of one or more of the front stages of the core compressor to lower the overall pressure ratio and allow acceptable operation without requiring the bleed port to be open.

Both solutions are practical but require more extensive modifications than compatible with the minimum modification approach of this study. Accordingly, further analysis of the air pump design was not conducted.

FAN AERODYNAMIC DESIGN

Design Point Conditions and Data

A fan with 1.25:1 SLS (sea level static) total pressure ratio has been selected for the present study. This design pressure ratio corresponds to maximum SLS power setting of the 502 core at maximum rating turbine inlet temperature. The corresponding fan mass flow rate and bypass ratio follow from the power delivered by the supercharged engine core, the fan efficiency, and the condition of ambient static pressure level at exit of the power turbine (no turbine exit diffuser). An 88 percent polytropic fan efficiency is assumed as a realistic target value for a low hub tip ratio transonic fan stage with moderate pressure ratio and low supersonic relative tip Mach number. Initially, the fan design tip speed was set at 985 ft/sec. This speed, however, resulted in a specific work input coefficient $\Delta h/U^2$ considerably larger than 1 at the hub section and in a positive slope of the ψ - φ operating characteristics for the entire supercharging section of the fan rotor blade. The tip speed was subsequently increased to 1100 ft/sec in order to minimize the risk of core flow instability.

The final fan SLS design conditions are summarized below:

Total Stage Pressure Ratio P/P = 1.25:1

Total Mass Flow Rate $W_{a_{tot}}$ = 421.1 lb/sec

Cor Engine Mass Flow Rate W_{a_e} = 31.2 lb/sec

Bypass Ratio BR = 12.5:1

Tip Speed U_t = 1100 ft/sec

Target Total Polytropic Efficiency $\eta_{P_{tot}}$ = 0.88

Aerothermodynamic Design Concept

The main aerothermodynamic problem consists of designing the core supercharging fan section and matching its flow path with the existing 502 fan-core transition duct without increasing the engine length. This latter condition limits the rotor exit hub diameter and the hub work input capacity. With the tip speed increased to 1100 ft/sec, the hub ψ - φ characteristics still has a slight positive slope with a specific work input coefficient $(\Delta h/U^2)_{hub}$ = 1.22.

Overturning gradually disappears over the channel height and the flow conditions at the supercharger upper section are conventional with $(\Delta h/U^2)_{tip}$ = 0.8. The aerodynamic conditions in the supercharger flow region are influenced by the meridional curvature of the core flow path and by the location, orientation, and thickness of the core-duct flow splitter. The meridional curvature of the core flow path raises the meridional velocity level near the inner wall. In order to minimize the core stator inlet Mach number, both the tangential and the meridional velocity components at rotor exit should be minimized in the inner wall region. Minimizing the tangential component requires an increase of the hub radius, which, however, results in an increase of the core channel curvature and the hub meridional velocity component. Similarily, the location, orientation, and thickness of the flow splitter determine the annulus area at inlet of the core stator and the average stator inlet velocity. The overall curvature of the core flow channel and the stator hub inlet velocity are also affected by these variables. The channel and splitter configurations thus markedly influence the flow conditions in the critical supercharger fan section, and their interaction must be studied in order to optimize the aerodynamic fan design. The core flow path matches the 502 core at the upstream flange of the fan support casing. Therefore, the present design allows use of the 502 core cast inlet housing and bearing support structure.

The flow conditions are calculated with Lycoming's IBM Program R136, which solves the complete radial equilibrium equation for the axisymmetric flow field of a turbomachine with a bypass flow splitter. The splitter streamline separating the core and the fan duct flows is subject to two conditions at the splitter stagnation point, perpendicularity to the splitter nose and vanishing of the streamline curvature. Both flows domain upstream and downstream of the splitter nose are treated simultaneously in the iterative computation procedure, which usually converges within 50 iterations.

In addition to the fan design data specified above, the following assumptions are made for the calculation of the flow conditions:

> The compression process through the fan rotor blading is characterized by a polytropic efficiency that varies along the blade span according to Figure 1. The stator losses are defined by a total pressure loss coefficient $\omega = 0.05$, which is constant over the radius except in the vicinity of the inner and outer walls, where the stator losses are increased to account for additional wall boundary layer and secondary flow effects. The rotor work input is determined in conjunction with the assumed rotor efficiency and the stator losses in such a way as to produce a constant overall fan total pressure ratio P/P = 1.25:1, except at the wall regions, where the additional stator losses are superimposed and result in a slight total pressure deficit. It will be seen in Figure 1 that the fan rotor polytropic efficiency has been decreased on the part-span-shroud streamline in order to take into account the effect of the shroud wake. The semi-empirical procedure used to simulate that effect is based on published test data [1] and in-house tests by Lycoming and is described in Appendix I. Finally global flow blockage effects of 1 percent at fan rotor exit and 2 percent at both fan duct and core stator exit stations have been assumed.

The fan hub flow conditions are critical because of the low hub rotational speed resulting from the low hub tip ratio and tip speed limitation. However, for a given tip speed and a given rotor exit hub radius, the rotor hub speed can be increased by decreasing the fan annulus area, i. e., by increasing the fan specific flow capacity. The fan inlet Mach

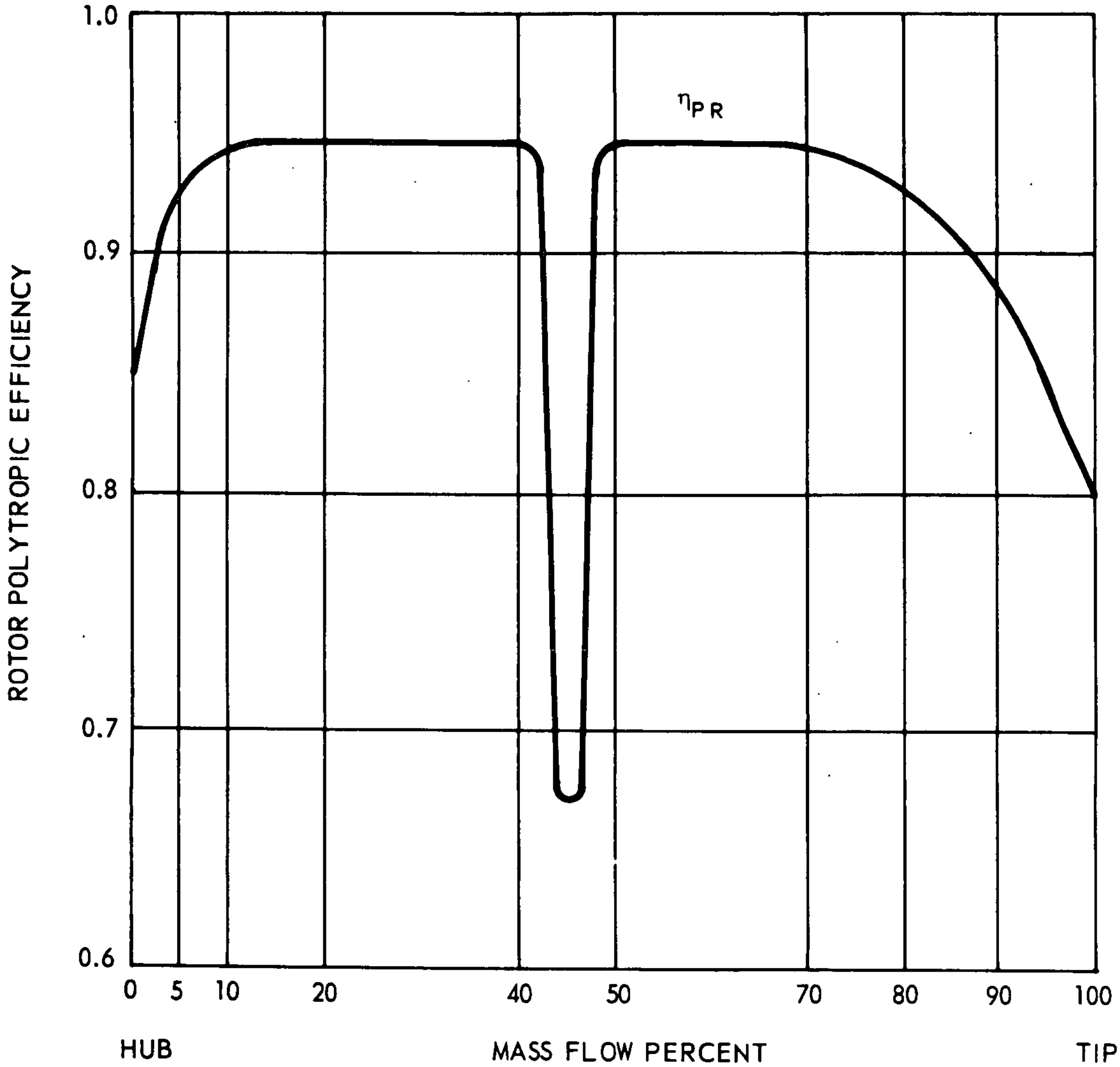


Figure 1. Rotor Polytropic Efficiency.

number consequently has been set at the highest level compatible with a favorable overspeed flow margin potential, namely 0.55 as an average value. For aerothermodynamic and noise reasons, the fan is designed without inlet guide vanes. Moreover, the core-duct flow splitter is located downstream of the rotor blading in order to allow for increased rotor-stator spacing in the duct section without increasing the length of the fan-core transition duct. In addition the fan duct stator tip is leaned in the downstream direction to further minimize wake noise. Figure 2 shows the fan meridional flow path with the stations used in the IBM program R136 calculation and the streamline pattern.

The results of the aerodynamic design optimization are illustrated by the velocity triangles shown in Figure 3. The first three triangles describe the flow conditions in the supercharger section. With the tip speed increased from 985 to 1,100 ft/sec, both the rotor flow overturning and the Mach number at entrance of the stator have been reduced to favorable levels ($\beta_{2_{hub}}$ = 10.4 degrees and $M_{V2_{hub}}$ = 0.715, as compared with 25 degrees and 0.75 to 0.8 with U_{tip} = 985 ft/sec). As a result of the slight relative flow overturning, the highest rotor flow deceleration rate does not occur at the hub section but in the splitter region. The stator hub section, however, is subjected to the highest deceleration rate, which is somewhat above usual practice for stator design. The corresponding velocity ratio $(V_5/V_4)_{hub}$ = 0.712 is accordingly slightly lower than desirable for a shrouded design. (See "Aerodynamic Blading Design.")

The last three triangles describe the flow conditions through the upper fan section, which are typical of conventional transonic design practice.

IBM Program R136 output section given in Appendix II contains a complete set of flow data that substantiate the basic aerodynamic design concept.

Aerodynamic Blading Design

Rotor Blading. - The main blading design problem consists of selectin a favorable compromise between the conflicting aerodynamic, weight, and acoustic design requirements. For the tip section, a profile with thin leading edge and maximum thickness located at 50 to 60 percent chord station is required. A double-circular-arc profile would be adequate.

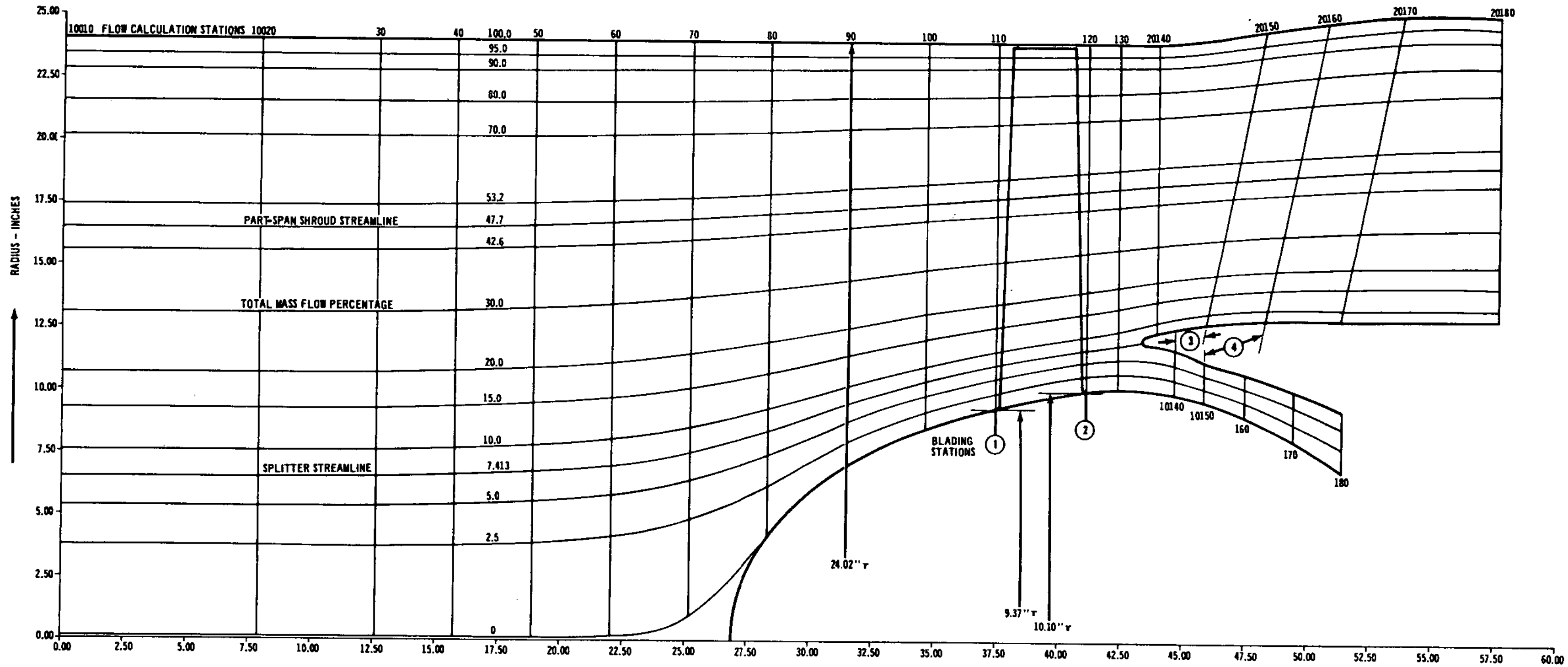


Figure 2. Fan Meridional Flow Path.

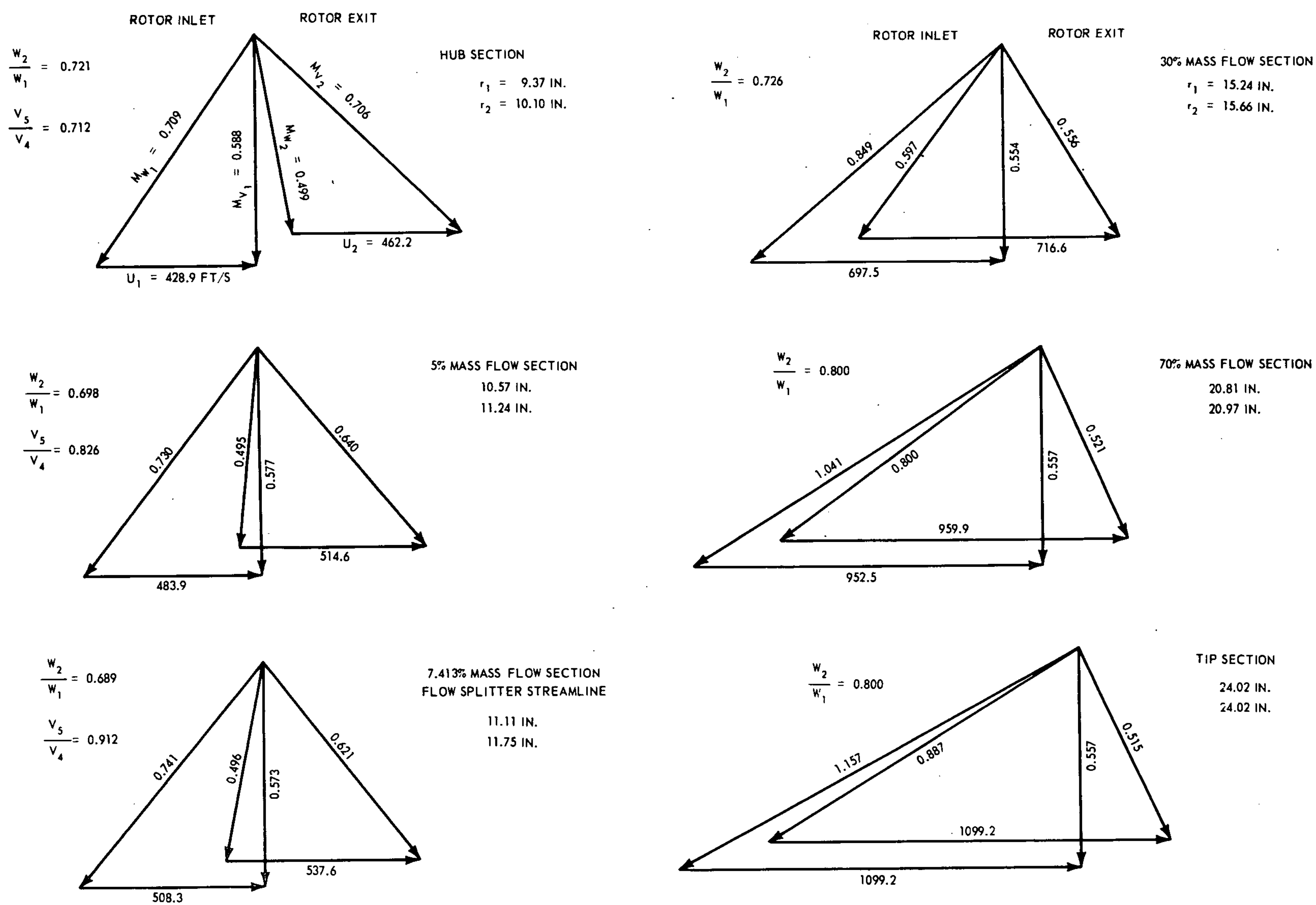
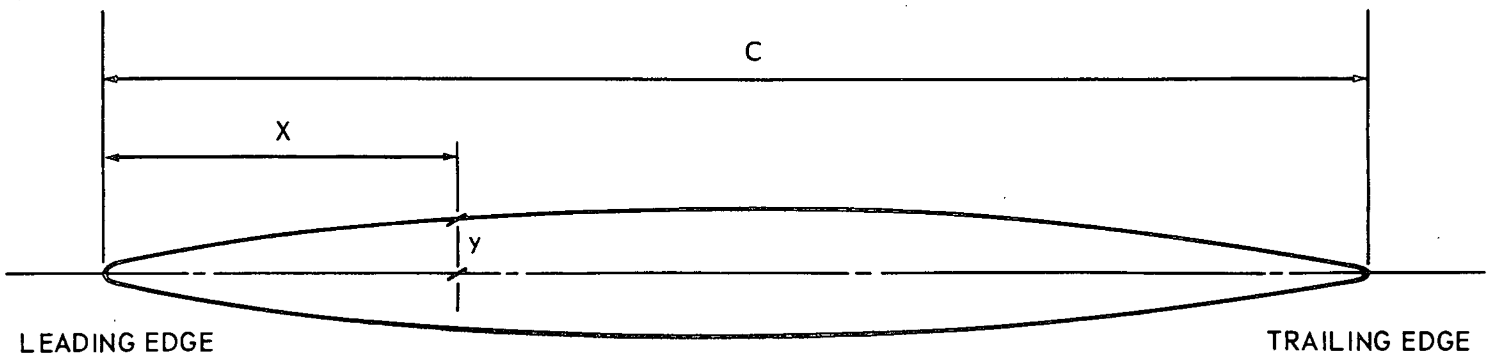


Figure 3. Fan Rotor Velocity Triangles.

A laminar type profile superimposed on a circular mean camber line, however offers better aerodynamic properties for the subsonic blade portion while retaining the favorable characteristics of the double circular type in the transonic region. Such a profile has been used extensively in classical Lycoming transonic rotors with excellent overall performance results, and it is selected here as the best design compromise for all blade sections. The basic 10 percent relative thickness distribution is shown in Table I. Any desired relative thickness value is obtained by multiplying the basic 10 percent profile ordinates by the corresponding thickness factor. For this study the number of blades has been selected so that the blade passing frequency (Z x RPM/60) stays below the lower limit of the critical acoustic range of 2800 to 4500 hertz. Thus Z = 2800 x 60/5245 =32 blades. Two blade aerodynamic loading formulas are currently used to select the blading solidity, namely NACA's diffusion factor D, which is relatively insensitive to solidity, and Zweifel's aerodynamic loading factor ψ_a, which is directly proportional to relative blade spacing. Zweifel's criterion $\psi_{a_{opt}} = 0.9\text{-}1.1$ is often used in conventional blading design, but rotor hub sections have consistently demonstrated a higher loading capability without noticeable performance penalty. From a weight standpoint, it is of course desirable to design for minimum solidity and maximum aspect ratio compatible with good performance and mechanical integrity. On the other hand, it is imperative to insure adequate tolerance of the rotor blading to distorted inlet flow conditions, a requirement which is most efficiently fulfilled by designing for low aerodynamic loadings, i.e., high blading solidities, and low aspect ratios. For the hub section a maximum D value of 0.5 has been set as a compromise between the above conflicting requirements. The selected hub chord length $C_{hub} = 3.38$ inches results in a solidity $\sigma_{hub} = 1.77$, $D_{hub} = 0.486$ and $\psi_{a_{hub}} = 1.27$. For the tip section, $\sigma_{tip} = 1.0$ is an adequate solidity for transonic operation with a normal shock wave in the cascade entrance region. This calls for a tip chord of 4.73 inches, thus a 40 percent blade chord elongation from hub to tip. The tip loading conditions then are $D_{tip} = 0.298$ and $\psi_{a_{tip}} = 0.546$. Based on the mean chord length of 4.05 inches, the rotor blade aspect ratio is approximately 3.5:1.

The next step consists of selecting the design point incidences. In a low pressure-ratio fan discharging through a fixed nozzle, the operating line undergoes a considerable shift between static and flight conditions. At 0.6 flight Mach, for example, the ram compression ratio is of the same order as the fan design pressure ratio, and the fan nozzle expansion

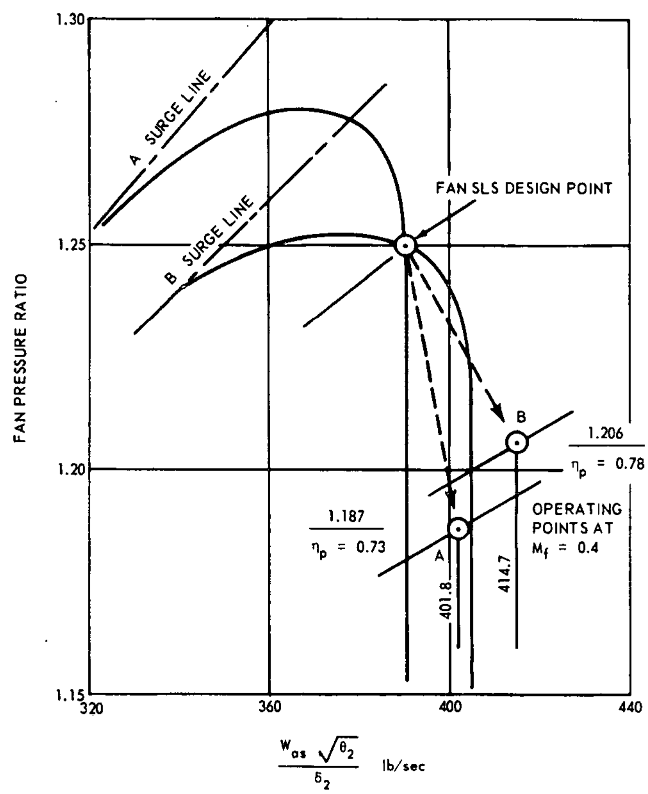
TABLE I. BASIC LAMINAR-TYPE PROFILE, 10 PERCENT THICKNESS



Ratio (pct)

X/C	0	1.25	2.5	5.0	7.5	10.0	15.0	20	30	40
Y/C	0	0.887	1.165	1.650	2.055	2.400	3.000	3.505	4.275	4.778
X/C	50	60	70	80	85	90	95	97.5	100	
Y/C	4.998	4.882	4.250	3.155	2.525	1.829	1.133	0.785	0	

ratio thus would increase from the SLS design value of 1.25:1 to 1.55:1. If the nozzle is sized for SLS conditions, its area will be too large for cruise operation, and the actual fan cruise operating pressure ratio consequently will drop to a substantially lower value than the SLS design value, which would result in lower fan efficiency and thrust performances. Both effects can be minimized by selecting positive angles of incidence at SLS conditions. This relationship is shown schmatically in the following sketch (the performance data quoted on the sketch corresponds to SLS and 0.4 Mach flight conditions and are taken from the performance evaluation presented under "Engine Performance"). The



better cruise performance of fan B is obtained at the expense of operating the blading closer to the surge line at sea level static conditions. The reduced SLS surge margin, however, is critical with regard to operating conditions with inlet flow distortion, and it is advisable to select conventional design incidences for safer VTOL operating conditions.

A variable fan nozzle area will be required to achieve optimum cruise performance.

For the subsonic portion of the blading, a 0-degree incidence relative to the mean camber line constitutes an optimum compromise between efficiency and surge margin. In the transonic region, the profiles are usually designed and set so that the tangent to the suction contour at the midstation of the uncovered segment is aligned with the direction of the relative inlet velocity.

The above ground rules will be followed for final blading design. It must be emphasized that the selection of 32 blades to avoid the critical noise frequency band of 2,800 to 4,500 hertz constitutes a major design constraint, which is reflected by the comparatively large chords necessary to obtain favorable aerodynamic loading conditions. Because of its direct bearing on engine weight, this particular aspect of the noise problem should be critically examined prior to final blading design selection.

Table II presents typical design data for the presently selected 32-blade rotor. Sample conical blade sections are defined corresponding to the velocity triangles shown in Figure 3.

Core Flow Stator. - The core stator flow conditions are illustrated in Figure 4. Although the stator inlet Mach number has been kept down to a very favorable level, the flow turning angles are comparatively large, and the deceleration rate at the hub section is close to the upper limit allowable for a shrouded stator design (V_5/V_4 = 0.70-0.75). In this case, $\psi_{a_{hub}} = 1.0$ must be considered as a maximum value. This consideration requires a solidity $\sigma_{hub} = 2.2$, which results in $D_{hub} = 0.45$ and 105 blades with a chord length $C_{hub} = 1.3$ inches. The blade can be conveniently manufactured from a basic strip stock profile with constant chord, coined to produce the slight twist and camber variation required. The basic profile uses NACA 65 series of 7 percent thickness distribution superimposed on a circular mean camber line. The blade is designed and set for 0-degree incidence over the entire core channel height. Table III presents blading design data for the three sections corresponding to the flow conditions shown in Figure 4.

It will be seen from Figure 4 that for a single row stator, it is necessary to increase the meridional velocity level across the blading in order to achieve favorable aerodynamic blade loading conditions. This

TABLE II. FAN ROTOR BLADING DESIGN DATA, CONICAL SECTIONS (Z = 32 blades)

Radius (in.)	Relative Flow Angles (deg) β_1	β_2	Deviation Angle δ (deg)*	Camber Angle θ (deg)	Setting Angle γ (deg)	Incidence Angle i (deg)	Chord Length C (in.)	Relative Thickness ν (pct)	Cascade Pitch S (in.)	Cascade Solidity $\sigma = C/S$	Aerodynamic Loading ψ_a	D
9.37/10.10	34.0	-10.4	8.3	52.7	7.65	0	3.39	8.0	1.91	1.775	1.265	0.485
10.57/11.24	37.8	6.1	7.4	39.1	18.25	0	3.49	7.25	2.14	1.630	1.172	0.479
11.11/11.75	39.3	11.2	7.1	35.2	21.70	0	3.54	7.00	2.25	1.573	1.178	0.481
15.24/15.66	49.3	36.7	4.6	17.2	40.3	0	3.92	5.25	3.04	1.288	0.868	0.408
20.81/20.97	57.6	53.4	2.0	5.2	54.0	1.0	4.44	3.75	4.10	1.082	0.591	0.394
24.02	61.3	58.2	2.0	4.0	58.2	1.1	4.73	3.0	4.73	1.0	0.546	0.298

* is calculated with Carter's empirical formula $\delta = \frac{m\theta}{\sqrt{\sigma}}$ with $m = 0.230 + 0.1 \frac{\beta_2(\alpha)}{50}$

TABLE III. FAN STATOR BLADING DESIGN DATA, CONICAL SECTIONS

Radius (in.)	Absolute Flow Angles (deg) β_4	β_5	Deviation Angle δ (deg)*	Camber Angle θ (deg)	Setting Angle γ (deg)	Incidence Angle i (deg)	Chord Length C (in.)	Relative Thickness ν (pct)	Cascade Pitch S'(in.)	Cascade Solidity $\sigma = C/S$	Aerodynamic Loading ψ_a	D	Remarks
9.95/9.65	46.1	0	8.5	54.6	18.8	0	1.3	7.0	0.586	2.22	1.01	0.450	Core Stator Sections
11.16/10.78	42.0	0	8.2	50.2	16.9	0	1.3	7.0	0.656	1.97	0.845	0.344	Z = 105 blades
11.73/11.28	43.4	0	8,7	52.1	17.35	0	1.3	7.0	0.689	1.89	0.774	0.250	
12.78/12.95	32.3	0	6.0	38.3	13.15	0	2.5	7.0	1.140	2.19	0.713	0.260	Duct Stator Sections
16.25/16.41	28.5	0	6.0	34.5	11.25	0	2.5	7.0	1.448	1.73	0.705	0.303	Z = 71 blades
21.44/21.67	23.4	0	5.9	29.3	8.75	0	2.5	7.0	1.908	1.31	0.735	0.282	
24.55/24.88	25.4	0	7.0	32.4	9.2	0	2.5	7.0	2.185	1.14	0.924	0.333	

* is calculated with Carter's empirical formula $\delta = \frac{m\theta}{\sqrt{\sigma}}$ with $m = 0.230 + 0.1 \frac{\beta_2(\alpha)}{50}$

C

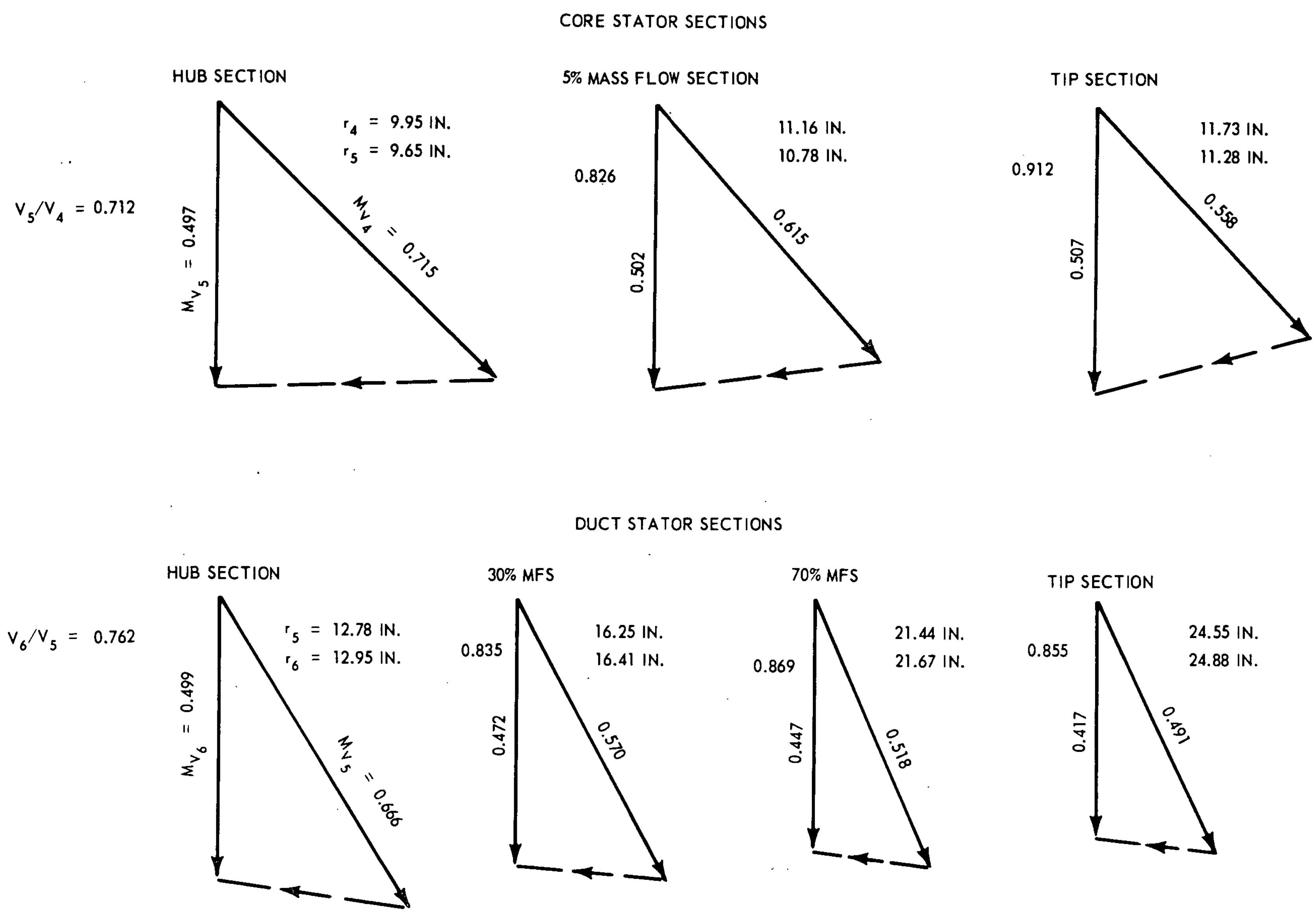


Figure 4. Fan Stator Flow Conditions.

situation generally results as part of the design in highly loaded compressor stages. A lower stator exit velocity level could be realized by using a double-row stator assembly. This alternate solution will be examined prior to final blading design selection.

Fan Duct Flow Stator. - The duct stator flow conditions are illustrated in Figure 4. They do not present any critical problem from a blading design viewpoint. Consequently, design emphasis is put on noise abatement. A stator/rotor blade number ratio of 2.25 is desirable, and this calls for 71 stator blades. The axial distance available between the trailing edge of the fan rotor and the leading edge of the fan support struts allows for an average spacing of approximately 1.5 mean rotor chords between the rotor and the stator blading.

The blades can be manufactured from a basic strip stock profile with constant chord. With the comparatively high aspect ratio of the 71-blade design, it is adviseable to limit the aerodynamic loading to ψ_a values smaller than 1.0 in order to avoid or minimize the loss of surge margin generally observed in higher aspect ratio bladings. With a mean hub tip ratio of 0.52 and a constant chord design, the highest loading occurs at the tip section, where $\psi_{a_{tip}} = 0.95$ has been set as a maximum value. The selected 71-blade design requires a chord length of 2.5 inches resulting in a tip solidity $\sigma_{tip} = 1.142$ and $D_{tip} = 0.333$. At the hub section, $\sigma_{hub} = 2.19$, $\psi_{a_{hub}} = 0.713$ and $D_{hub} = 0.360$. The basic profile again uses an NACA 65 series, 7 percent thickness distribution superimposed on a circular mean camber line. The blade is designed and set for 0 degree incidence over the entire duct channel height. Table III presents blading design data for the four conical sections corresponding to the flow conditions shown in Figure 4.

Fan Performance Evaluation

Performance maps for both the fan duct and the supercharger sections have been established by scaling measured basic performance maps of stages with similar design conditions. The scaling is effected on the basis of prescribed ratios of the design point mass flows, pressure ratios, and efficiencies. The pressure ratios are obtained by assuming a constant effective work input factor $(\Delta h_{scaled}/\Delta h_{basic})_{design}$ and a constant efficiency factor $(\eta_{scaled}/\eta_{basic})_{design}$ for all corresponding off-design points.

The scaled maps predict the actual performance characteristics with an accuracy that depends upon the degree of similarity shown by the basic and the actual designs. Since existing and new designs generally exhibit only limited similarity, it is important to select the basic maps and their representative design points in such a way as to best simulate the most essential characteristics of the new design.

Fan Duct Section. - The measured basic map is shown in Figure 5. It pertains to an experimental transonic stage with the following design-point characteristics:

Total Pressure Ratio $P_t/P_t = 1.404$

Referred Mass Flow Rate $Wa_{ref} = 55.6$ lb/sec

Tip Speed $U_{tip} = 1188$ ft/sec ($M_{u0} = \frac{U_{tip}}{a_{tot}} = 1.064$)

Hub-Tip Ratio $\nu = 0.47$

Adiabatic Efficiency $\eta_{ad} = 0.83$

For scaling, basic design points of fans A and B (with 21 percent and 14 percent surge margin at 100 percent $N/\sqrt{\theta}$ respectively) have been selected on the MU0 = 1.0 speed line, which corresponds to 1115 ft/sec tip speed. This provision insures good aerodynamic similarity for the transonic tip region, and also reflects the requirement for a favorable overspeed flow margin necessary to optimize cruise performance. With $(P/P)_{basic} = 1.37$, point A is representative of the conventional blading design approach adopted for fan A (SM = 21 percent at 100 percent $N/\sqrt{\theta}$). With $(P/P)_{basic} = 1.406$, point B represents a design that compromises surge margin in order to minimize cruise performance degradation with a constant fan nozzle area. The efficiencies have been slightly scaled to the assumed 88 percent target polytropic value for both A and B fans.

Figures 6 and 7 show the resulting estimated maps used for the engine performance evaluation.

Supercharger Section. - The basic tested map is shown in Figure 8. The map represents the supercharger section of the T53-301 fan with the following design-point characteristics:

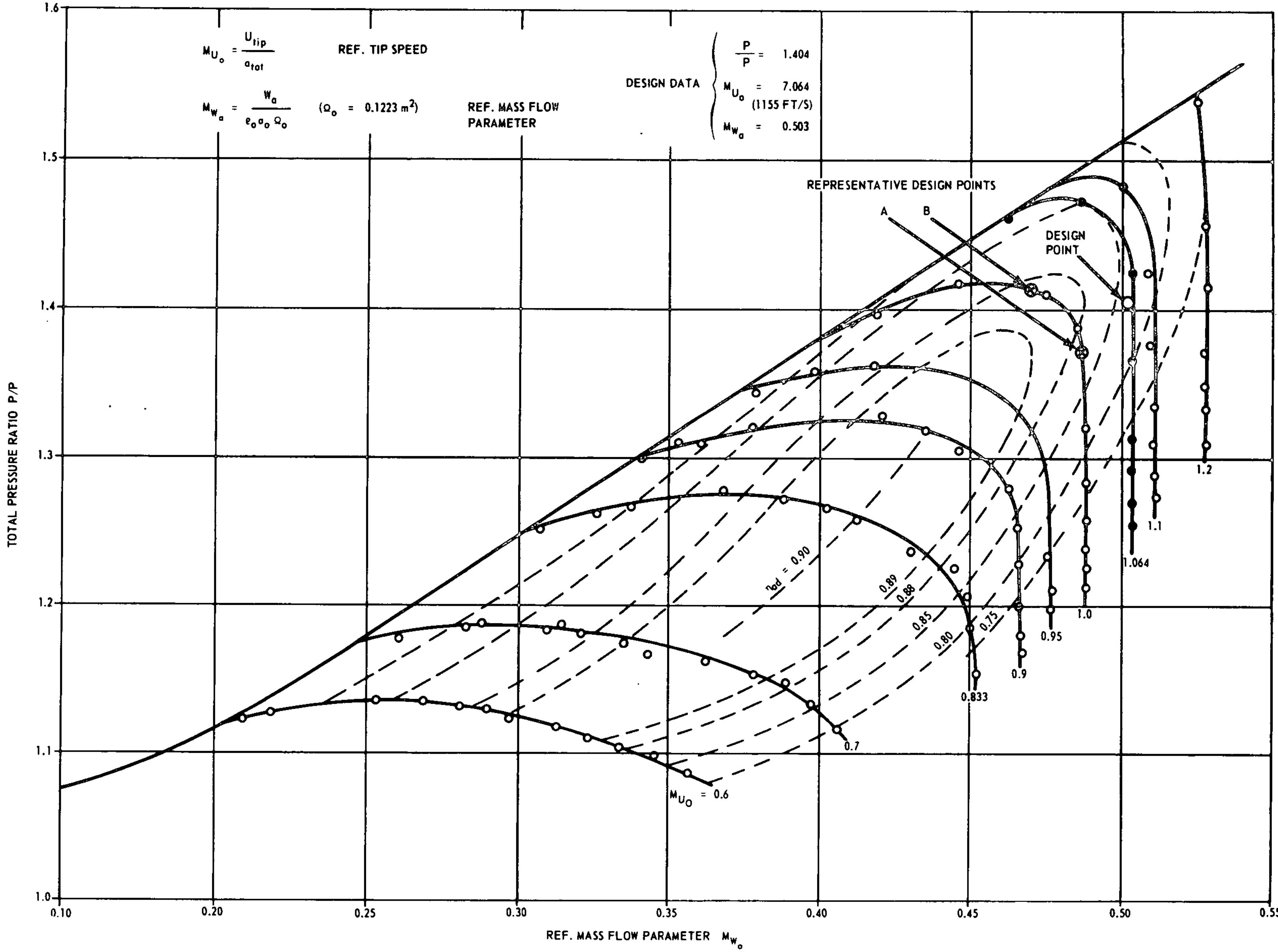


Figure 5. Basic Single Stage Performance Map for Fan Duct Section (Experimental Transonic Stage).

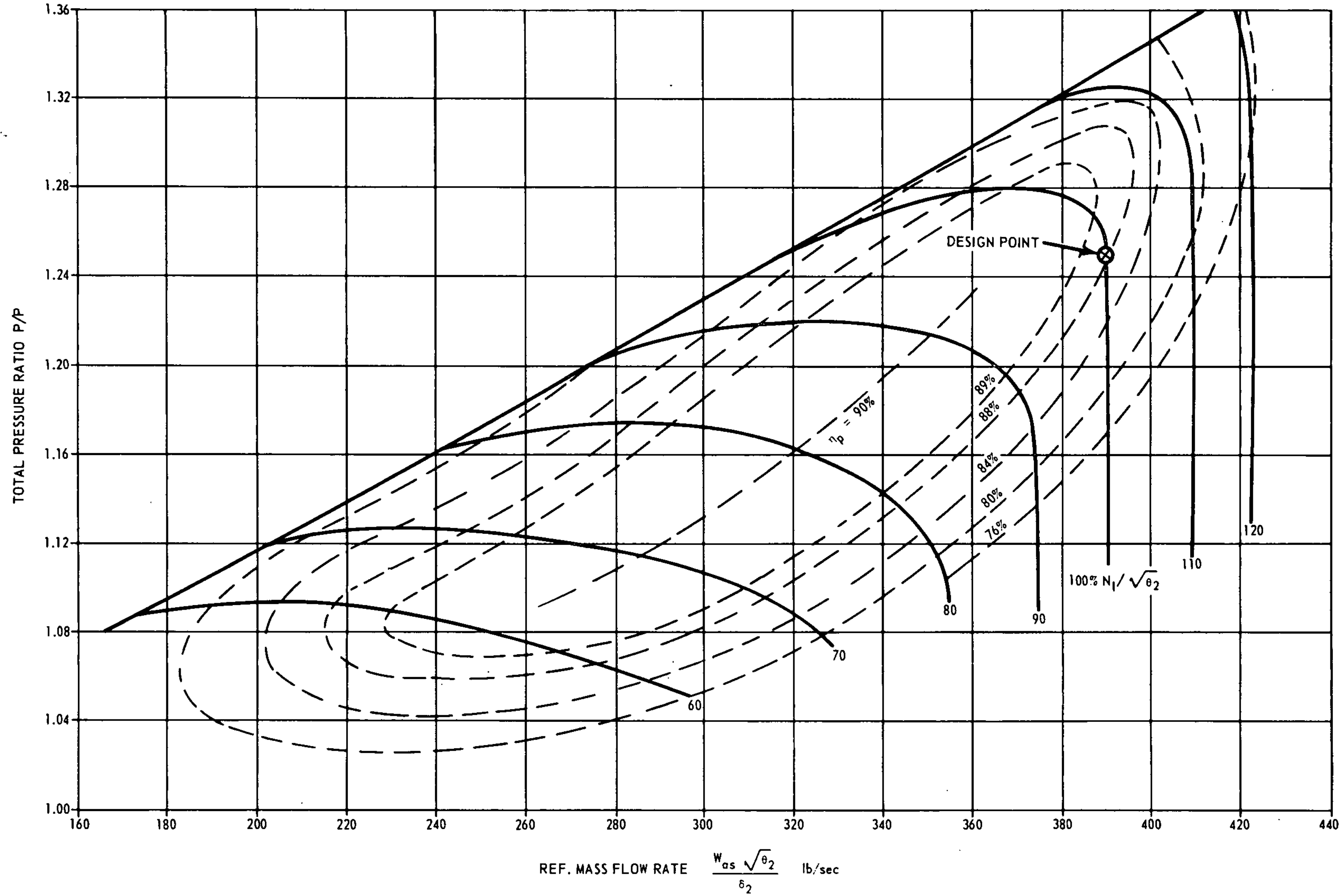


Figure 6. Estimated Performance Map for Duct Flow Fan A (21% Surge Margin at 100% N/√θ).

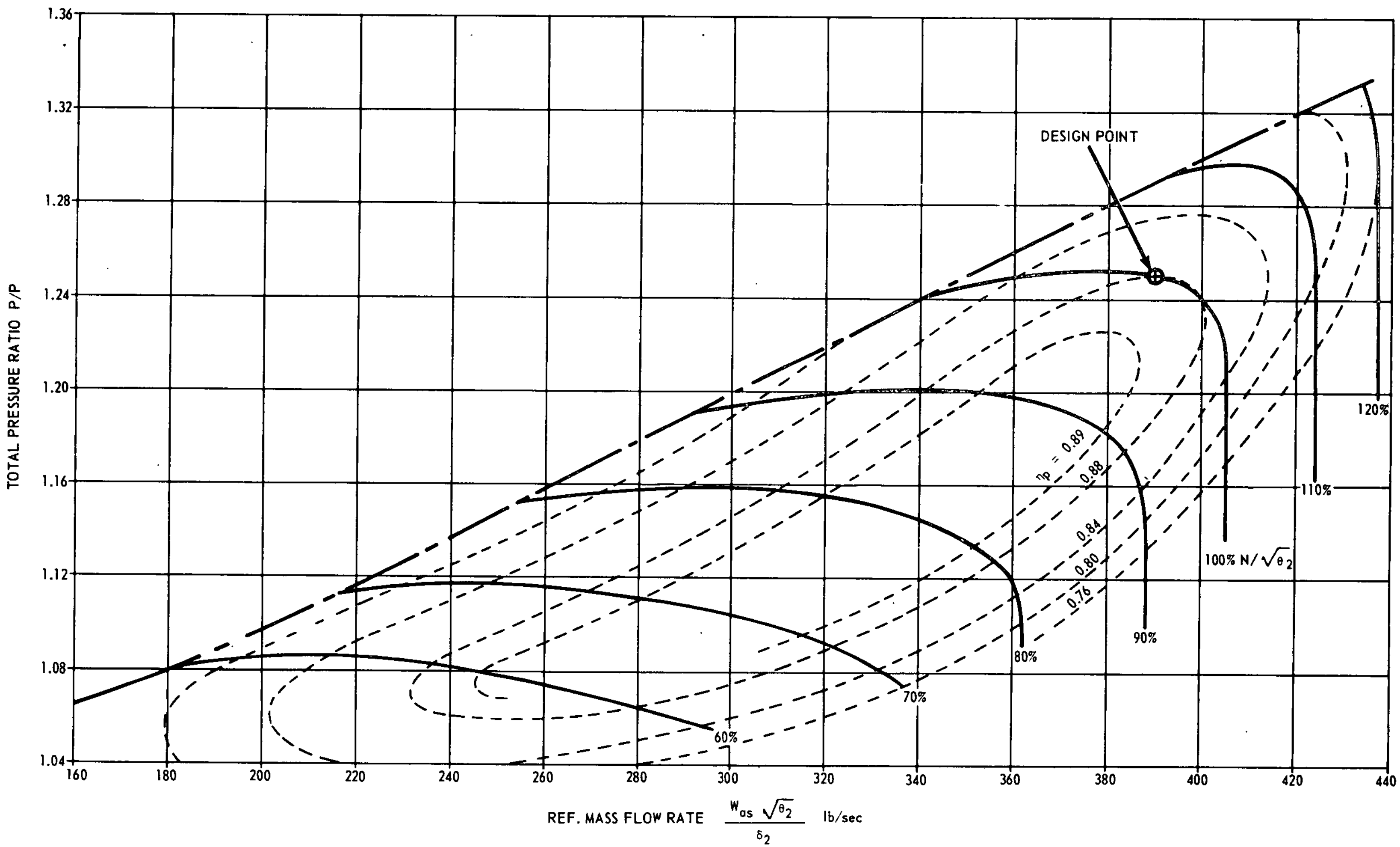


Figure 7. Estimated Performance Map for Duct Flow Fan B (14% Surge Margin at 100% $N/\sqrt{\theta}$).

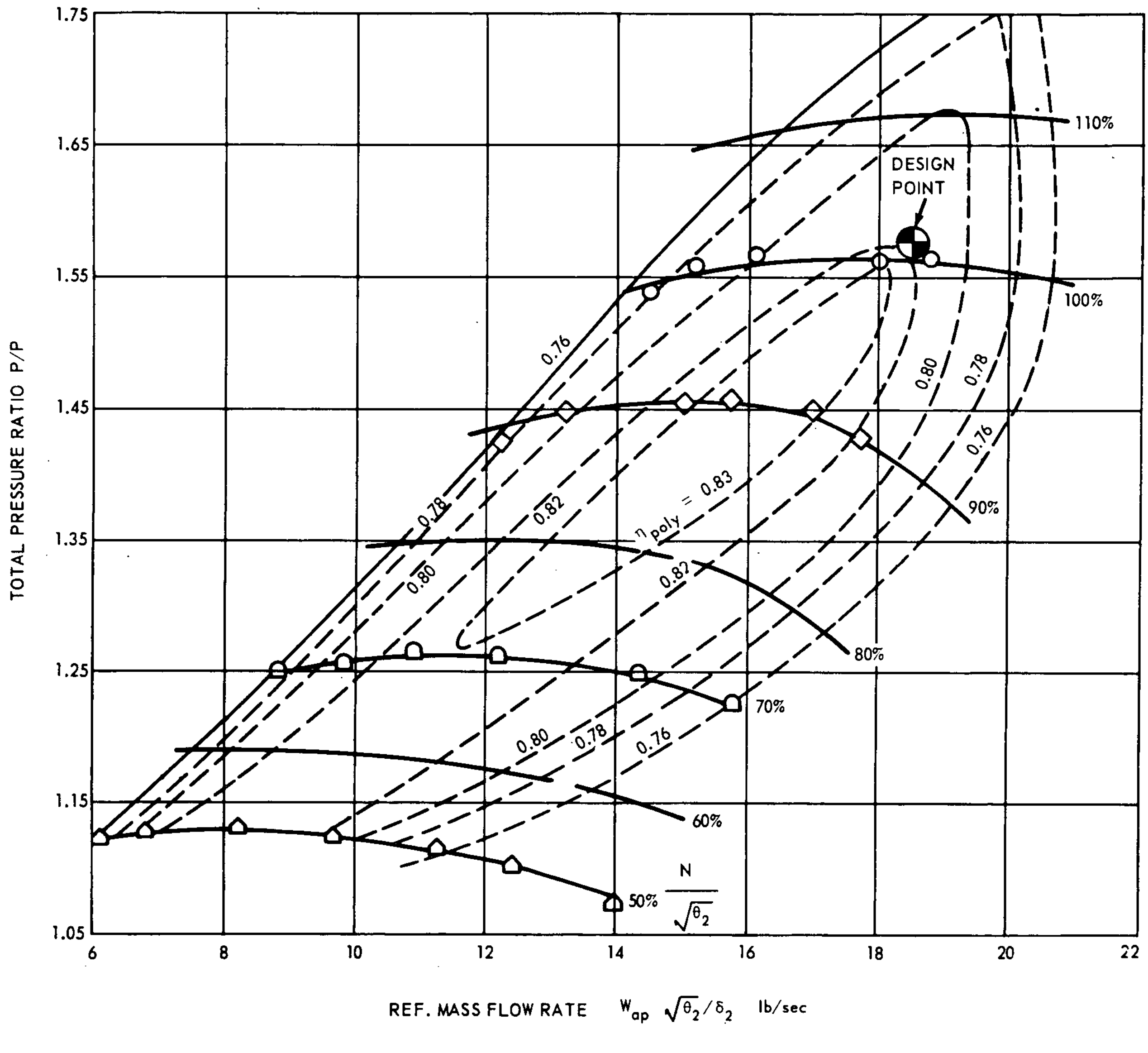


Figure 8. Measured Basic Single Stage Performance Map for Supercharger Fan Section (301 Fan Supercharger).

Total Pressure Ratio (P_t/P_t) = 1.577

Referred Mass Flow Rate $W_{a_{ref}}$ = 18.5 lb/sec

Mean Specific Work Input Coefficient ($\Delta h/U^2$) = 0.82

Polytropic Efficiency η_p = 0.82

Since the flow conditions are subsonic, the essential similarity parameter for scaling is the mean specific work coefficient $\Delta h/U^2$. The 0.82 value of the 301 supercharger section comes reasonably close to the 0.92 value of the present supercharger design. This ensures that the main characteristics of the supercharger section, namely the flat slope of the speed lines, is satisfactorily reproduced by the predicted map. The design-point polytropic efficiency has been sealed up from 82 to 86 percent to account for the favorable effects of the larger size and the lower blading Mach level of the present design.

Figure 9 shows the resulting estimated map used for the engine performance evaluation.

MECHANICAL DESIGN

General

The core engine LTC4B12 is completely compatible with present fan engine and is preceded by considerable work to produce the 502 fan engine. Consequently, the investigations presented in this section are restricted to the new fan component, reduction gear, housing, and exhaust nozzle.

A flow path view of the integral fan engine ALF-504 is shown in Figures 10 and 11. The core engine is identical with the 502 fan engine. The installation drawing of the engine with mounting pad locations is shown in Figure 12. The mounting pad location and engine support method are similar to those of the 502 fan engine. The new fan design is based on the following mechanical data at sea level, standard day, static conditions:

Gas Generator Speed	19,260 rpm
Power Turbine Speed	16,870 rpm
Fan Wheel Speed	5,245 rpm

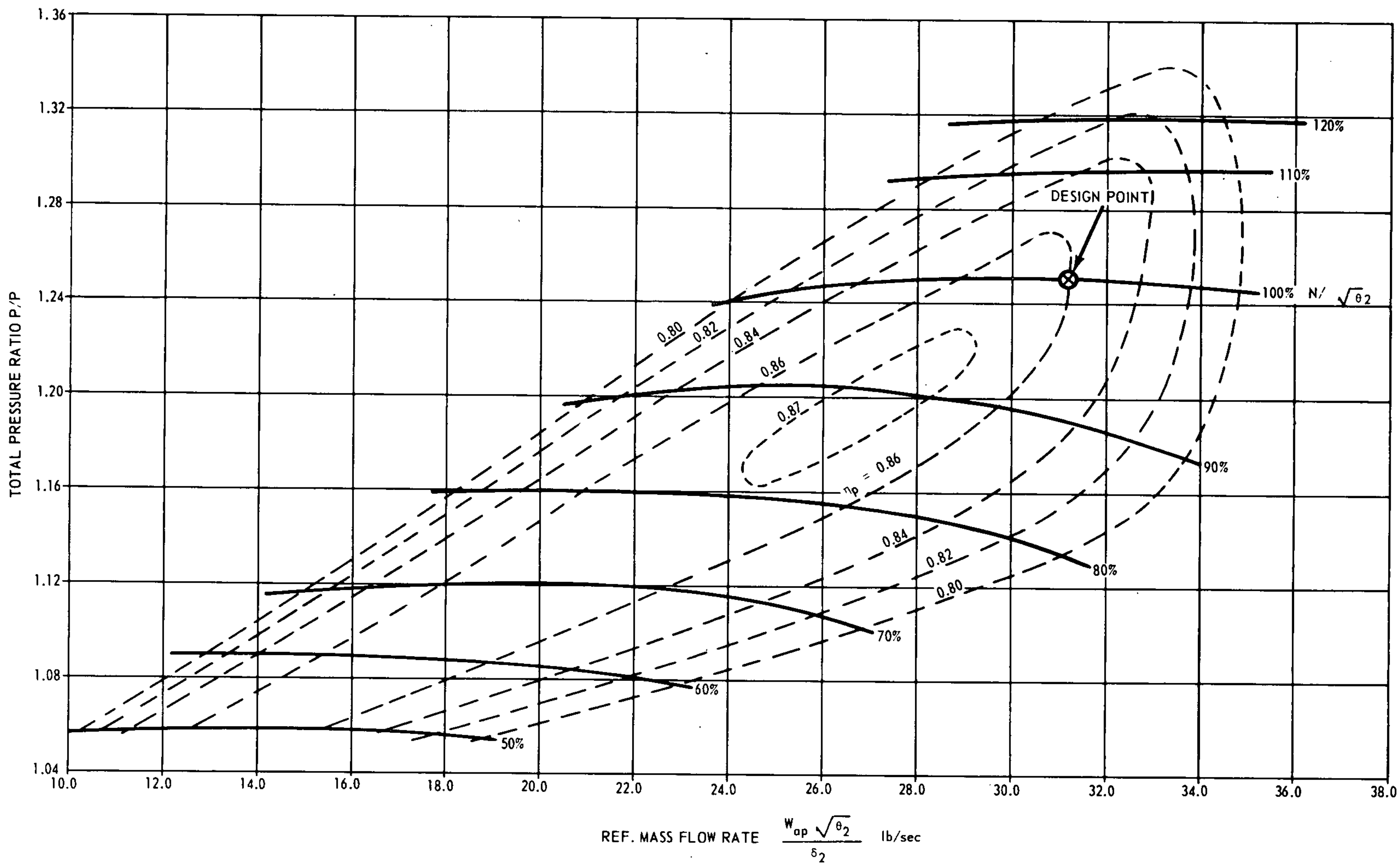


Figure 9. Estimated Performance Map for Fans A and B (Supercharger Section).

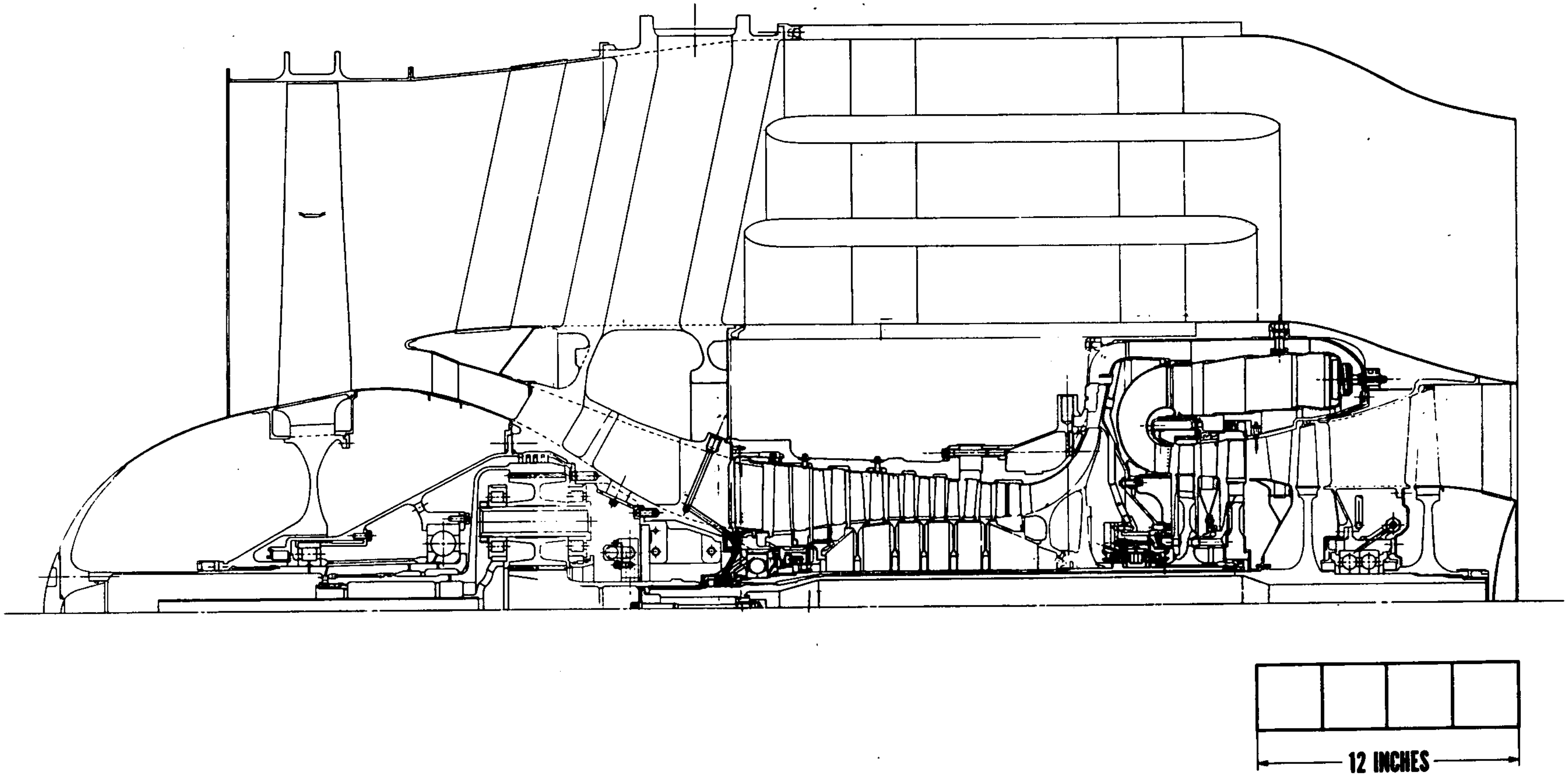


Figure 10. ALF-504 High-Bypass Fan Engine.

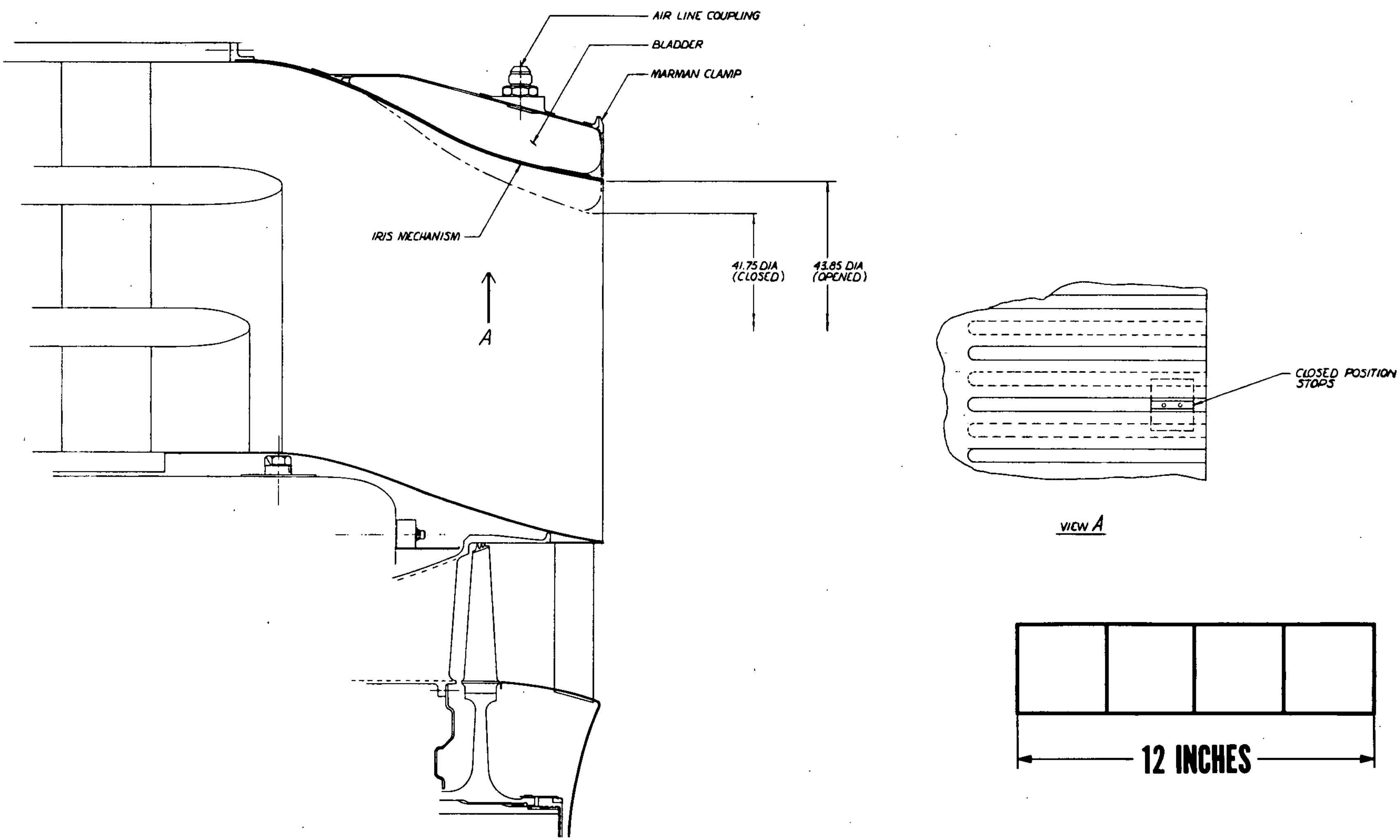


Figure 11. ALF-504 Fan Engine Variable Nozzle.

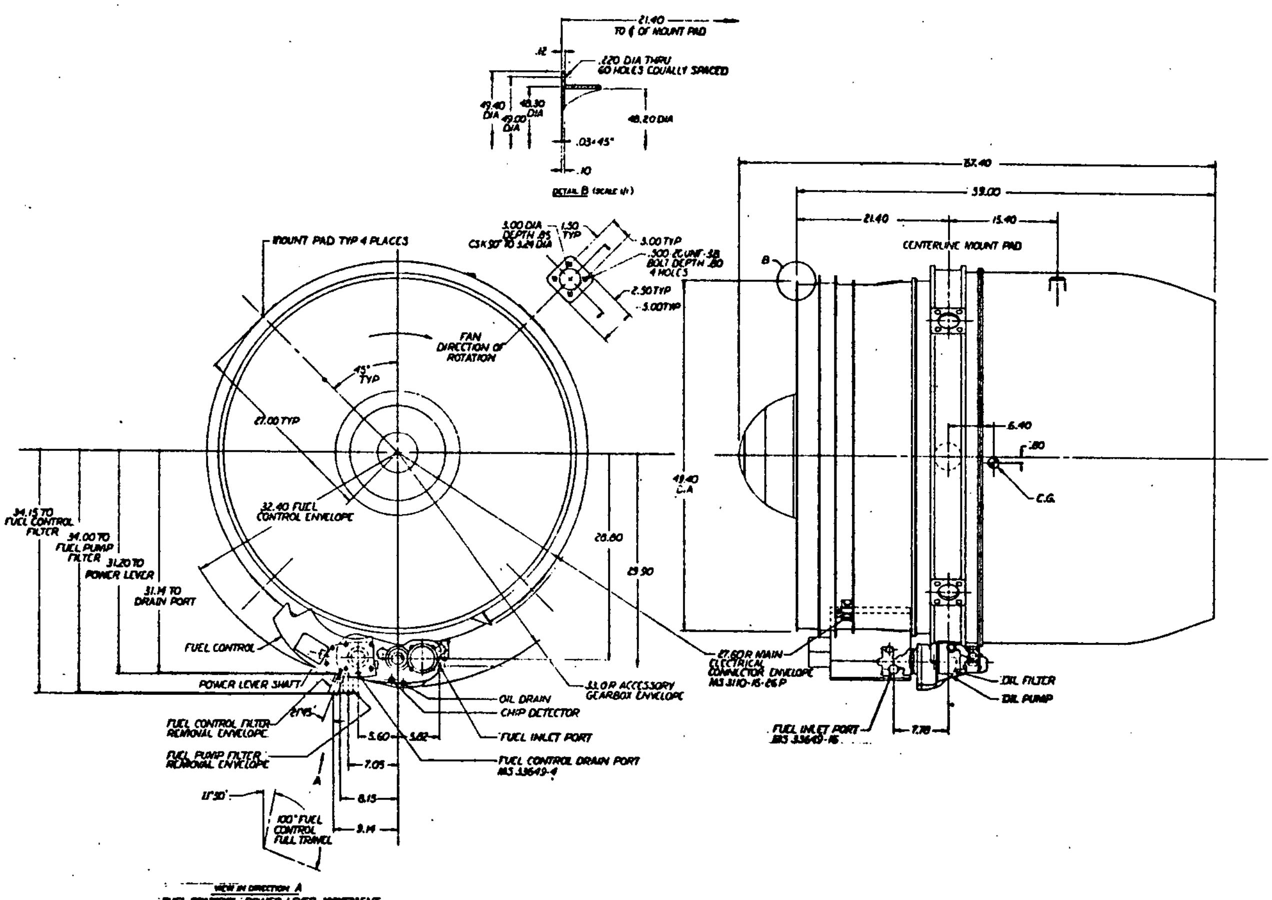


Figure 12. ALF-504 Fan Engine Installation Drawing.

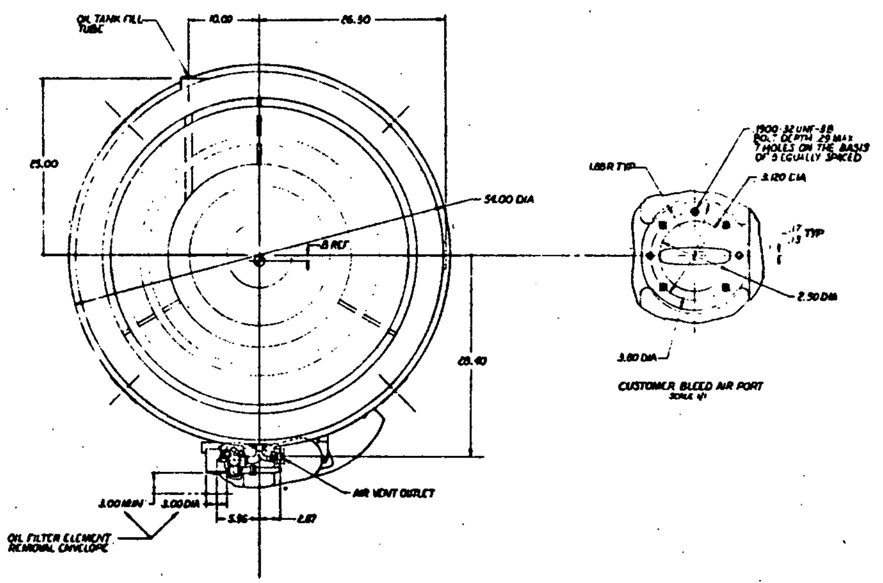


Figure 12. ALF-504 Fan Engine Installation Drawing. (Cont'd)

Fan Wheel Limit Speed	5, 600 rpm
Fan Wheel Maximum Speed	6, 400 rpm (mandatory inspection required)
Power Turbine Power	6, 240 hp (10 percent over SLS cycle value)

The geometry of the fan wheel is shown in Figure 13 with the material strengths and the corresponding stress and strain distributions for the blade and disc. These distributions are based on a constant temperature of 200° F and a speed of 5, 245 rpm.

Disc

It is seen from Figure 13 that the stresses in the disc at the operational speed of 5, 245 rpm are much lower than the allowable stresses and that the low-cycle-fatigue life, resulting from the disc strain distribution, is greater than 10^5 cycles. For the fan overspeed condition of 6, 400 rpm, the low-cycle-fatigue life exceeds the design criterion of 20, 000 cycles.

Rotor Blade

The blade stress distribution that is shown in Figure 13 is a result of the centrifugal loads developed from the fan speed of 5,245 rpm. The bending stresses in the blade due to gas loading have not been included. The anticipated bending stress is in the order of 40 ksi at the base of the blade and will exist only if the blade airfoil sections are stacked on a radial line from the hub to the tip. This blade will not be a stacked blade, but rather a leaned blade, and the centrifugal bending stresses resulting from the lean will be adjusted so that they will cancel the gas bending stresses. The ultimate result will be a blade stress distribution close to the distribution shown in Figure 13. The stacked set of airfoil sections is shown in Figure 14.

Midspan Shroud

The geometry of the midspan shroud is shown in Figure 15. Bending stresses due to centrifugal loads have been calculated at sections x-x and y-y for a radial shroud thickness of 0. 14 inch. The values of these bending stresses are shown in Figure 15 along with the yield and ultimate strengths for the blade material, Ti-6Al-4V.

13

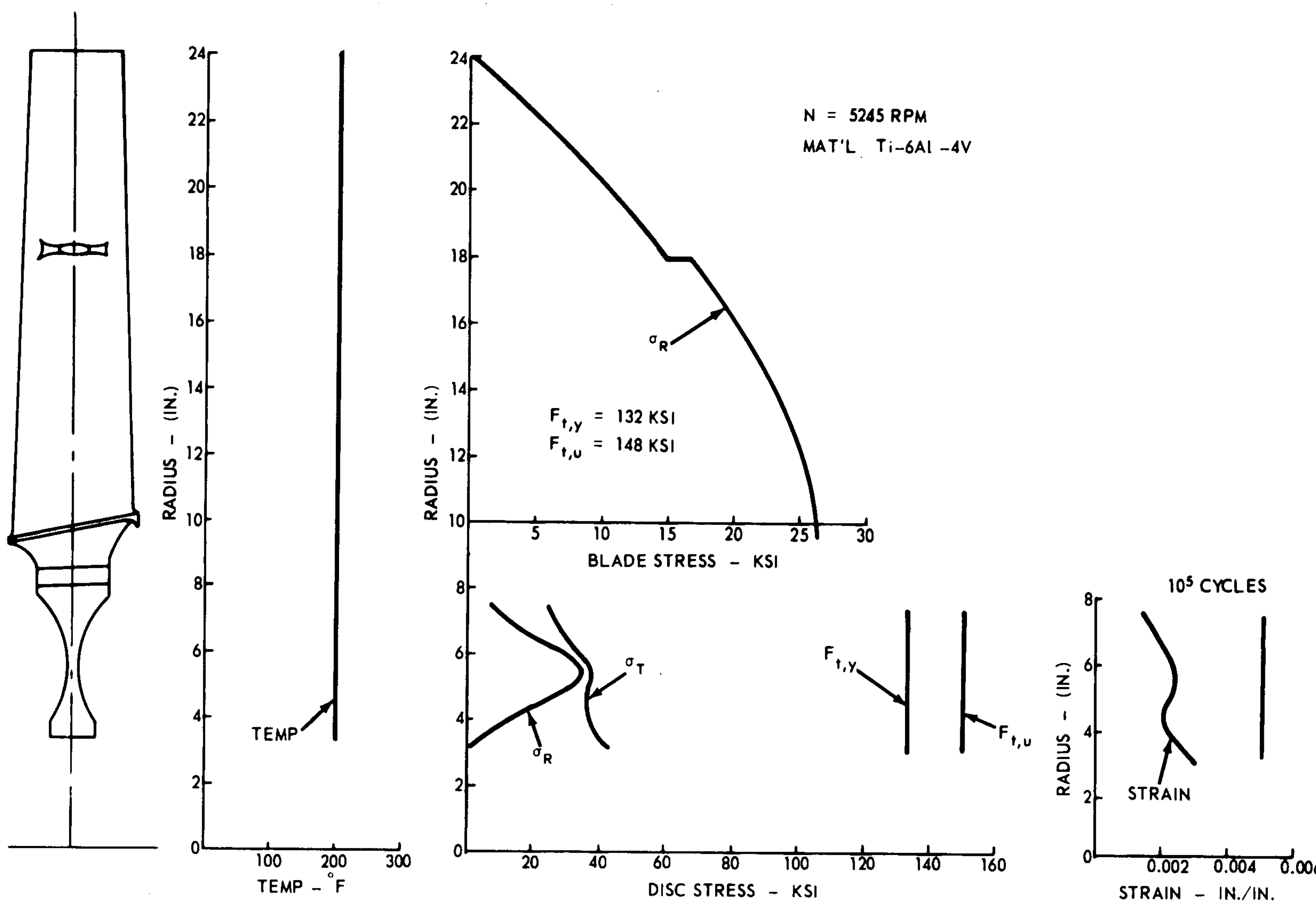


Figure 13. Fan Blade and Disc Stresses. (See Figure 16 for root stresses.).

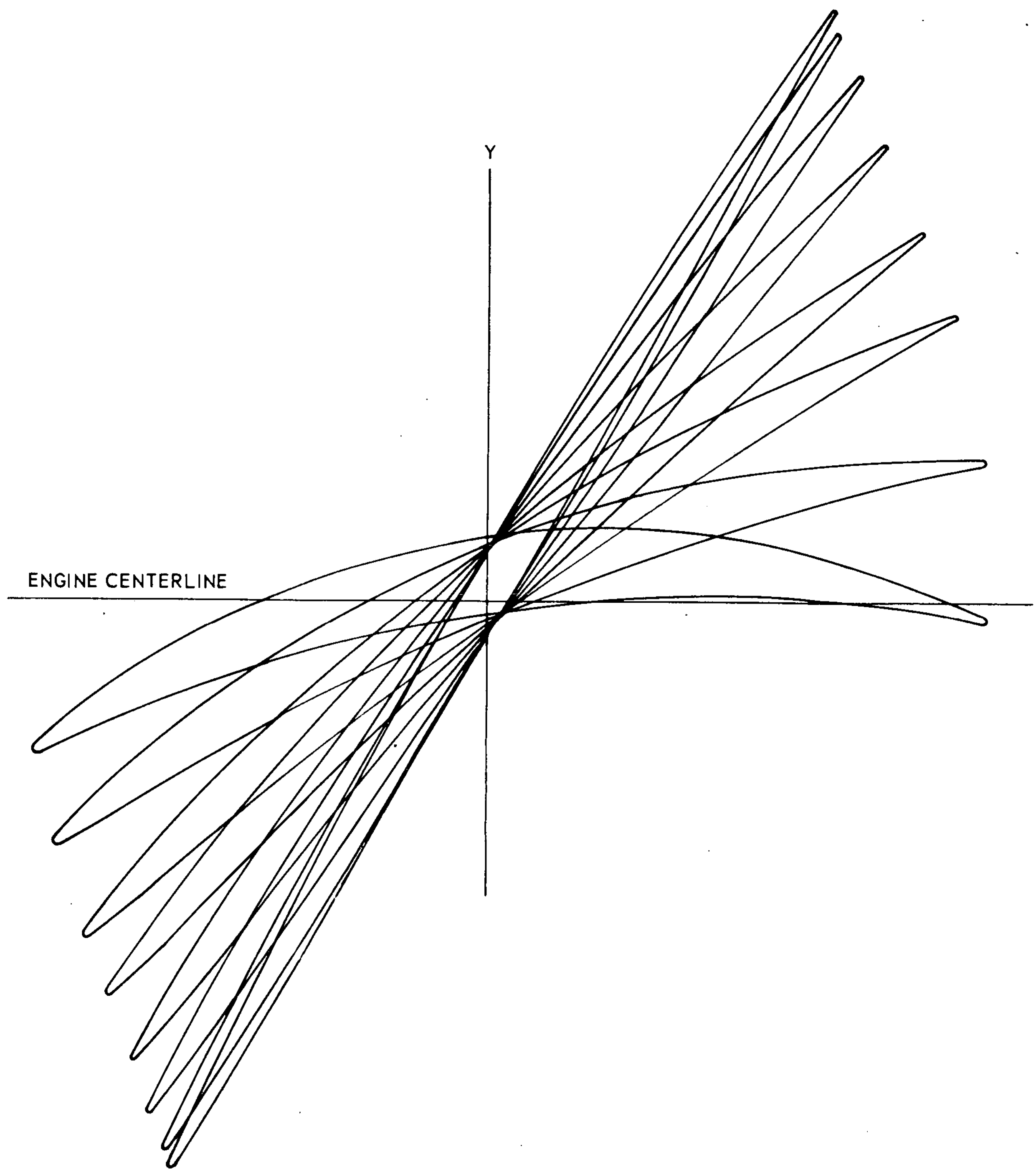
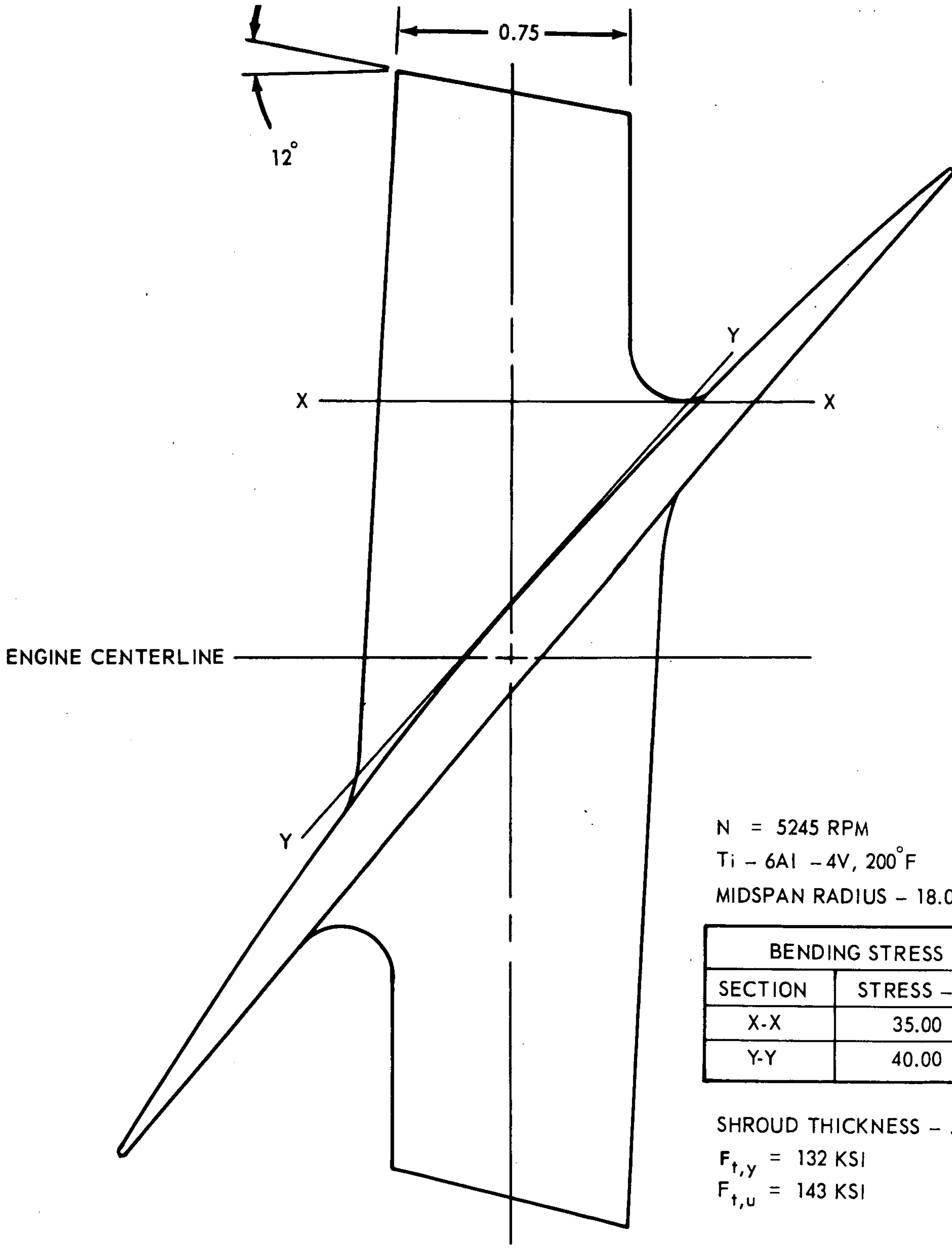


Figure 14. Fan Rotor Blade Airfoil Composite, Scale Approximately 2X.



N = 5245 RPM

Ti – 6Al – 4V, 200°F

MIDSPAN RADIUS – 18.00 IN.

BENDING STRESS	
SECTION	STRESS – KSI
X-X	35.00
Y-Y	40.00

SHROUD THICKNESS – .14 IN.

$F_{t,y}$ = 132 KSI

$F_{t,u}$ = 143 KSI

Figure 15. Midspan Shroud.

Blade and Disc Root

The root and groove geometry shown in Figure 16 is the same as the dovetail that is used in the 502 core engine. The nominal and maximum tenon hoop stress and the nominal and maximum tenon tensile stress have been computed at the base of the root groove. The tenon tensile stress concentration factor is 3. 8, and the tenon hoop concentration factor is 2. 0. The stress values are tabulated in Figure 16, and the groove low-cycle-fatigue life resulting from these stresses is greater than 10^5 cycles.

Gears

The new reduction gear train design (Figure 17) is similar in principle to that of the 502 engine. The reduction ratio has been increased from 2. 30:1 for the 502 to 3. 22:1 for the ALF-504 design. To transmit the additional torque, the gears were made larger in face width to operate within the allowable tooth bending stress required for infinite gear tooth life. The five planet gears are more critical in design than the sun gear since they operate under reversed bending loads; therefore, the maximum tooth bending stress was set at 28 ksi. The resulting planet gear face width is 2. 61 inches, and the corresponding tooth compressive stress is 133 ksi with an allowable stress of 145 ksi.

The ring gear has been analyzed to determine the hoop stresses resulting from the loads applied by the five planet gears. The loads applied by each planet are the radial load W_r, the tangential load W_t, and the bending moment M. A hoop stress also exists because of the rotational speed W of 5, 245 rpm. The hoop stress distributions over that segment of the ring between the planets are shown in Figure 18.for both the inside and outside surfaces. These four distributions are summed to obtain the total hoop stress distribution, and is shown in Figure 18. For the inside surface of the ring, the bending stress of ± 28 ksi at the base of the gear tooth has been added to the total hoop stress distribution, at points on each side of the ring gear tooth, meshed at each planet (see Figure 18). This is a conservative practice because both of these stresses do not occur at an exact point, but it has been done because they occur in the same plane.

Tabulated in Figure 18 are the maximum, minimum, mean, and alternating stresses for the inner and outer surfaces of the ring. Applying the alternating and the mean stresses to the modified Goodman diagram shown in Figure 19 it is seen that the ring gear stresses are well within the safe operating range.

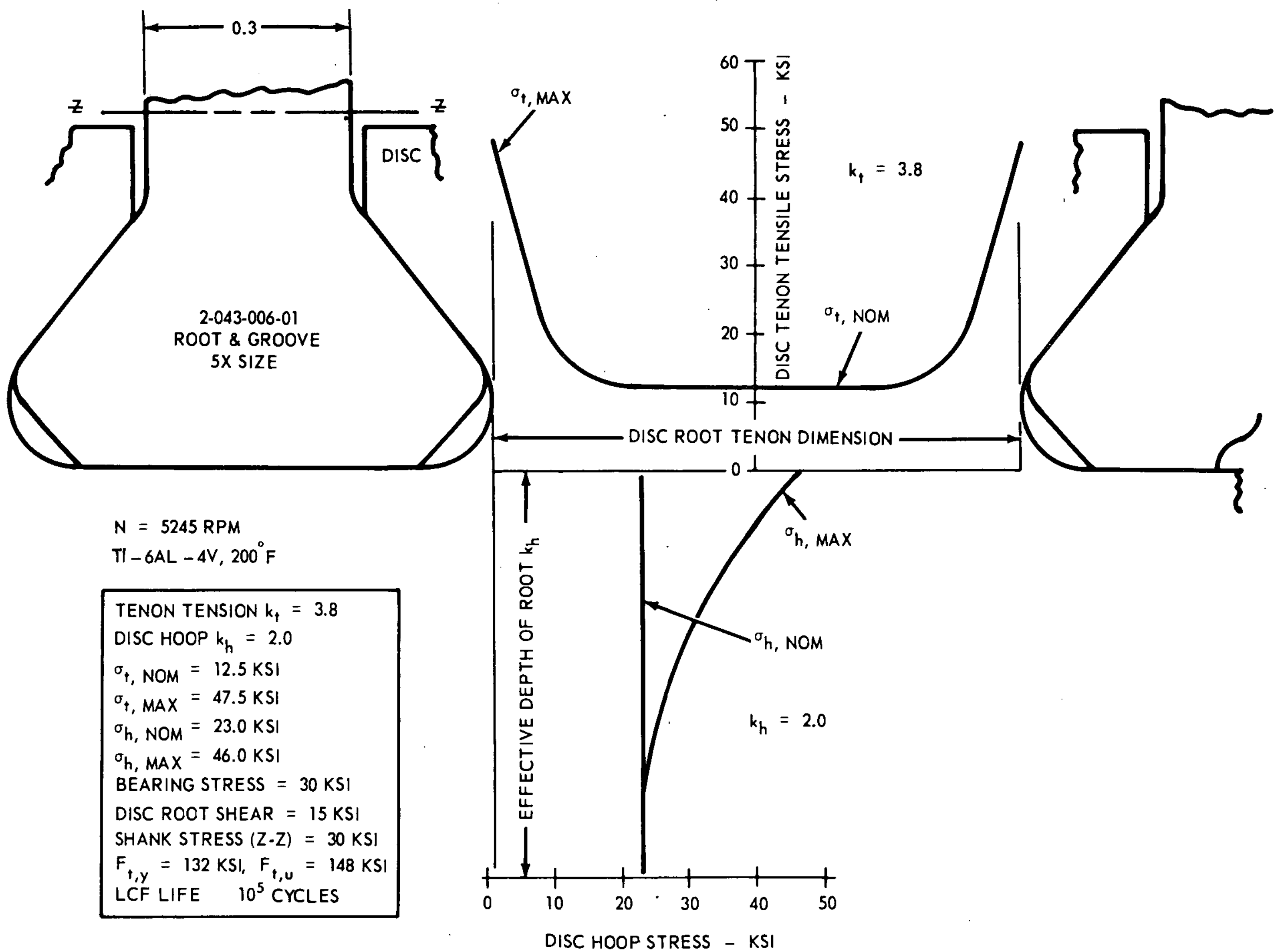


Figure 16. Root and Groove Stresses.

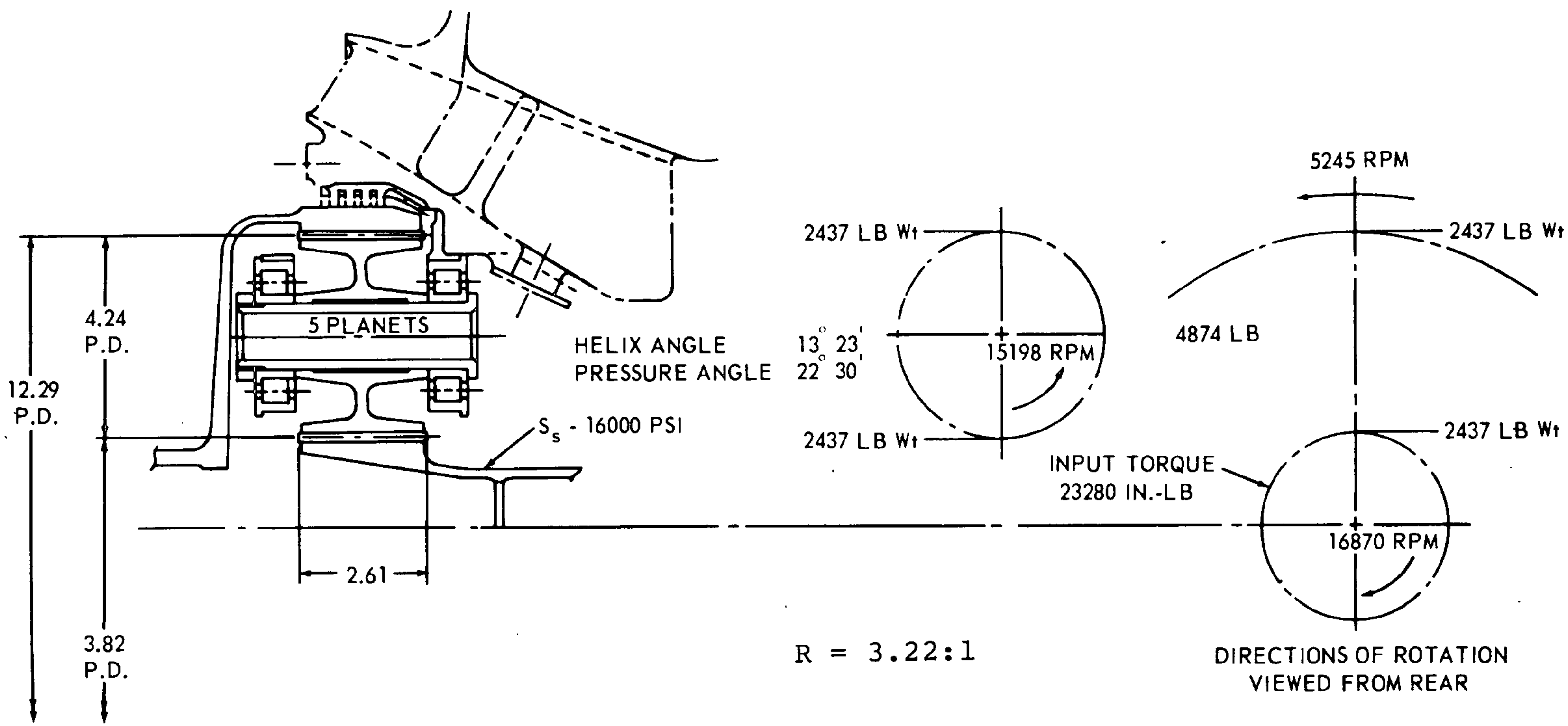


Figure 17. Reduction Gear.

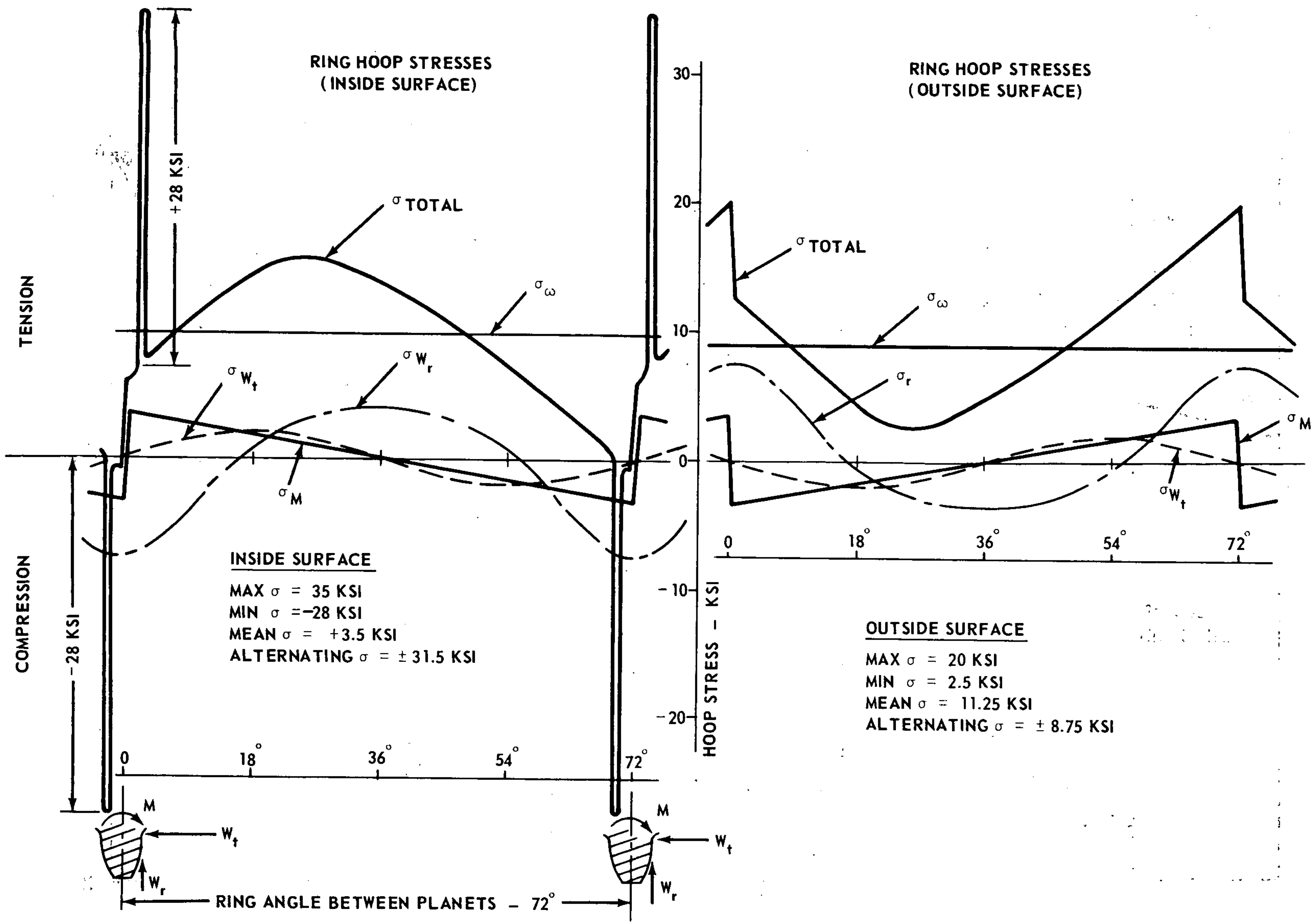


Figure 18. Ring Gear Stresses.

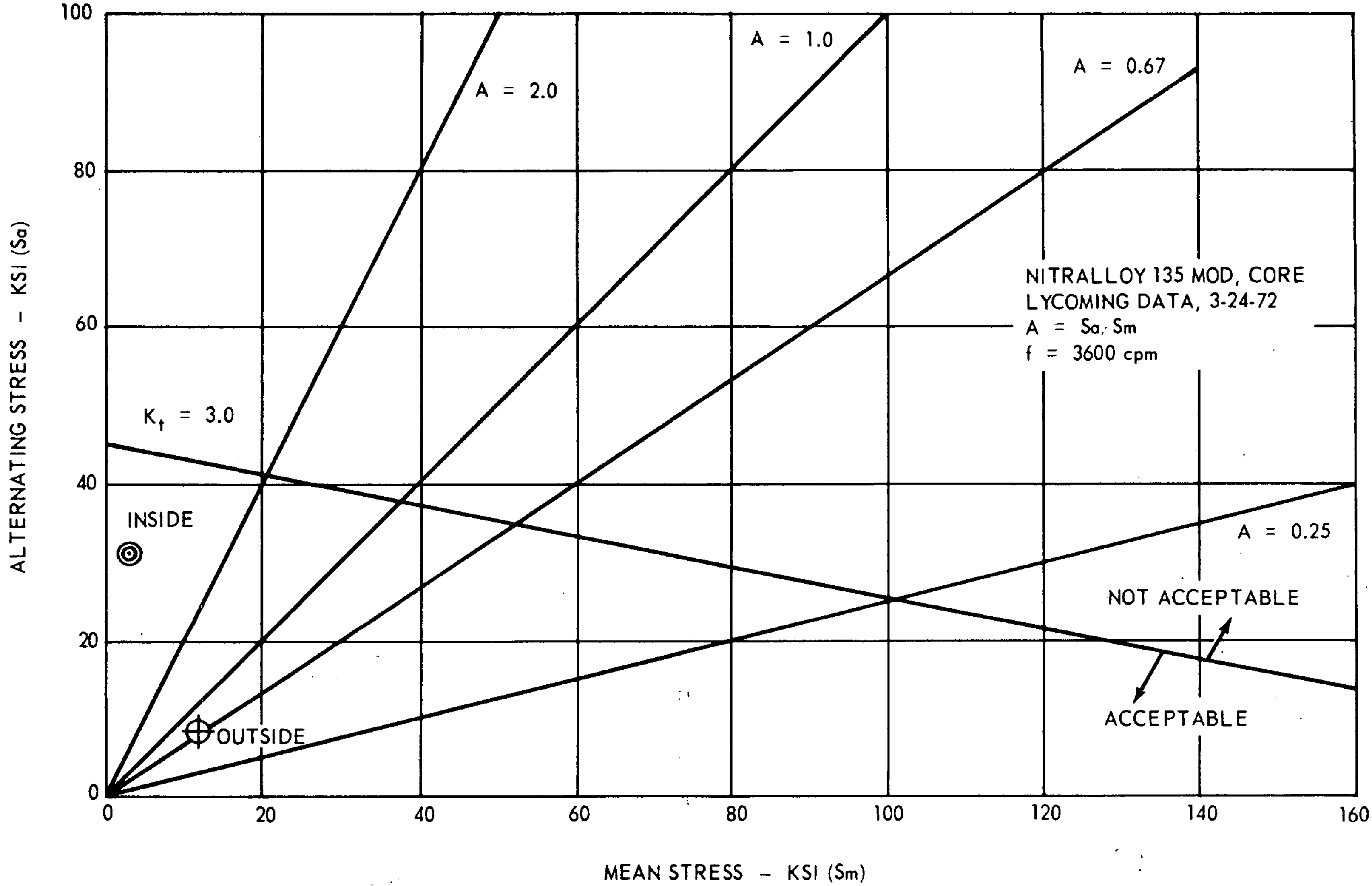


Figure 19. Reduction Gear Stress Analysis.

Fan Housing and Support

The fan housing and front frame will be cast magnesium and includes the same design concepts as the 502 fan inlet housing. There are 12 struts, one of which contains the accessory drive and starter shaft.

Engine mounting is accomplished through three mount pads on the housing. The top two pads support the engine weight and transmit thrust through a yoke, while the third pad gives mounting stability to the system. Similarity of the housing design with that of the 502 fan engine insures an optimal mechanical design.

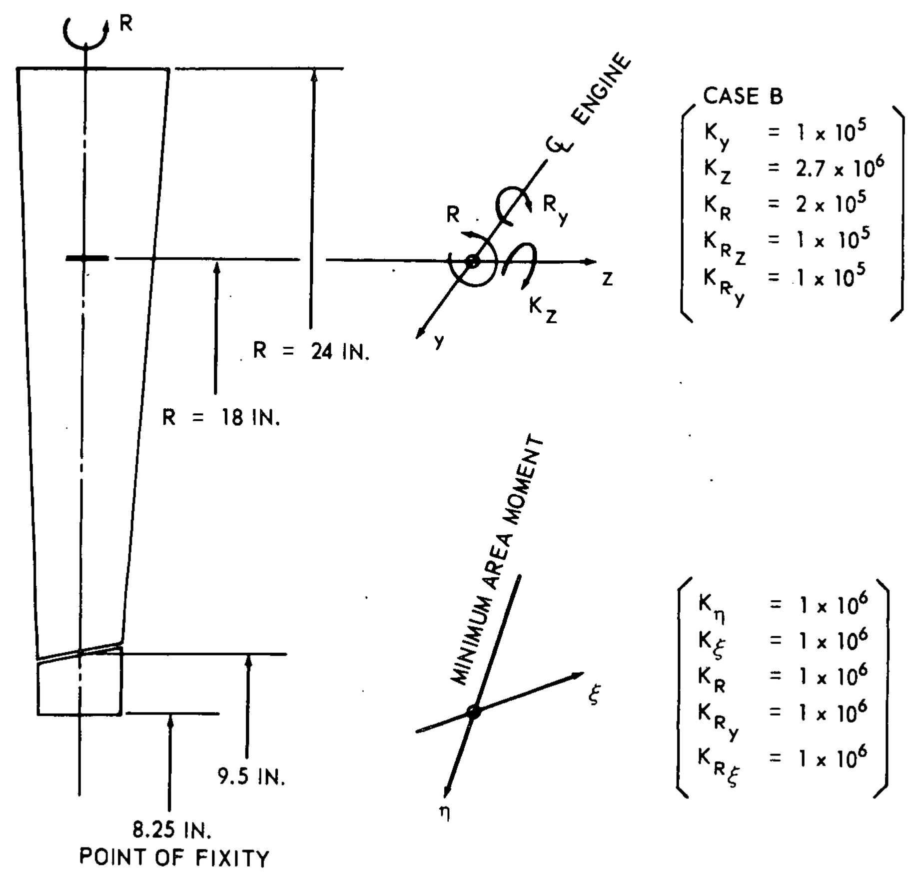
Mechanical Design Study of Fan Duct Variable Area Nozzle

The variable area nozzle type selected is an iris construction made of two conically shaped and slotted members actuated by a contained air bladder mounted around the external circumference. The design concept and mechanical details are shown in Figure 11. The conical members are slotted to form individual fingers which permit the required deflection and necessary area reduction (from 1190 to 1045 square inches). The design of the nozzle is based on a two-position geometry, and "overshoot" is prevented by mechanical stops that are welded to the outer side of the nozzle wall. The bladder was chosen to provide the actuating mechanism because of its simplicity, the low temperature of the bypass duct, and the low force required to oppose the nozzle aerodynamic load (470 pounds radial and 250 pounds axial). Air pressure to inflate the bladder is supplied from the compressor or fan when the flight Mach number exceeds 0.4. The nozzle will automatically go to the open position (the fail-safe position) in the event of bladder failure and prevent fan surge at flight Mach number above 0.4.

DYNAMIC ANALYSIS

Vibration and Flutter Analysis of the Rotor Blade

General. - For the analysis, the fan blade is represented by a lumped mass model that is supported at the base (cantilevered), and partially restrained at a part-span shroud location. The sketch below shows the system of axes used in the analysis:



MATERIAL: TITANIUM

MODULUS OF ELASTICITY = 0.163 LB/IN.^{3}

E = 15×10^6 LB/IN.^{2}

SHEAR MOD. G = 6.5×10^6 LB/IN.^{2}

NUMBER OF BLADES

Z = 32

100% SPEED

N = 5245 RPM

WEIGHT OF BLADE

W = 1.42 LB

A transfer matrix method (Lycoming library program D105) * is used to calculate the natural bending and torsional frequencies (uncoupled). In the analysis, the part-span shroud location was varied in order to find the optimum frequencies for a blade to be free from resonances and flutter. The trend of frequencies is shown in Figure 20. For the selected shroud location R = 18.0 inches, the frequencies are shown in the Campbell diagram in Figure 21. The shroud is 0.75 inch wide and 0.14 inch thick, and is cut at midspan (12 degrees with engine axis) to produce locking and prevent clockwise rotation looking down from tip to hub.

Results of Vibration Analysis. - In Figure 21, a band for the first two frequencies is given to indicate the influence of different spring-restraint conditions at the shroud (case A and B) because of some uncertainty in its prediction.

The first bending frequency is principally free from resonance excitation of low order (first, second, and third engine orders) above 80 percent speed. There is no fixed source of excitation in a fan inlet, but it is known from experience that inlet distortions could contain second or third order sources. The fan has to operate at speed below 80 percent and, therefore, experimental test verification is recommended to determine a tolerable stress limit in the blade.

The first torsion frequency also is free of direct intersection at 100 percent speed. No fifth or sixth order of engine excitation are apparent, and the torsion mode will be free from resonances in its range of operation.

Aeroelastic Analysis of Rotor Blades - The aeroelastic behavior of the blade is judged by the flutter coefficients represented in the form of

$$\lambda = \frac{W}{2\pi f c}$$

where W = relative inlet velocity
f = blade frequency
c = blade chord

* Appendix III gives a more complete engineering development.

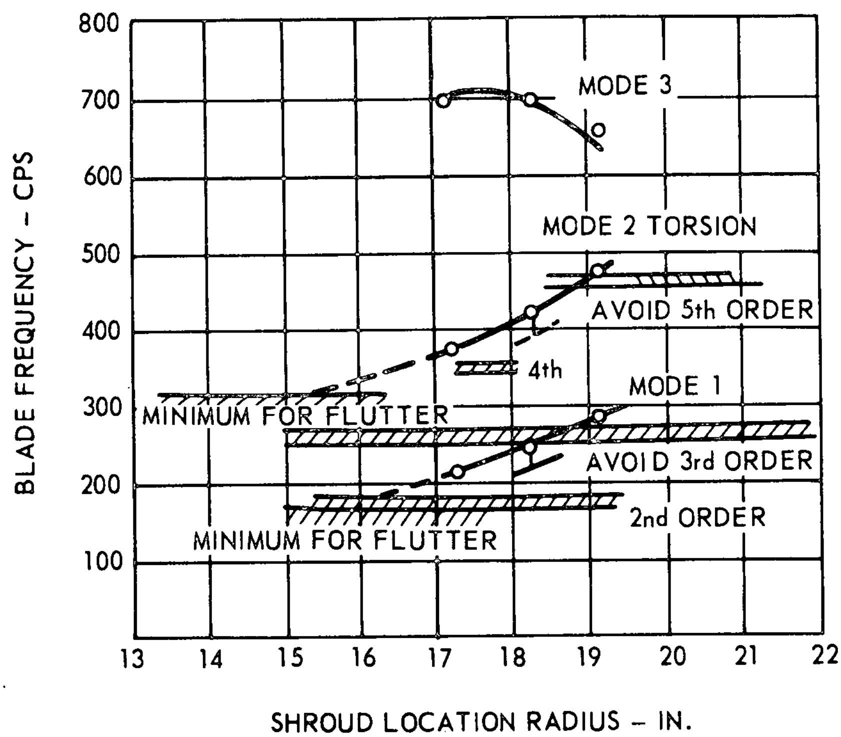


Figure 20. Rotor Blade Frequency Analysis, N = 5245 RPM.

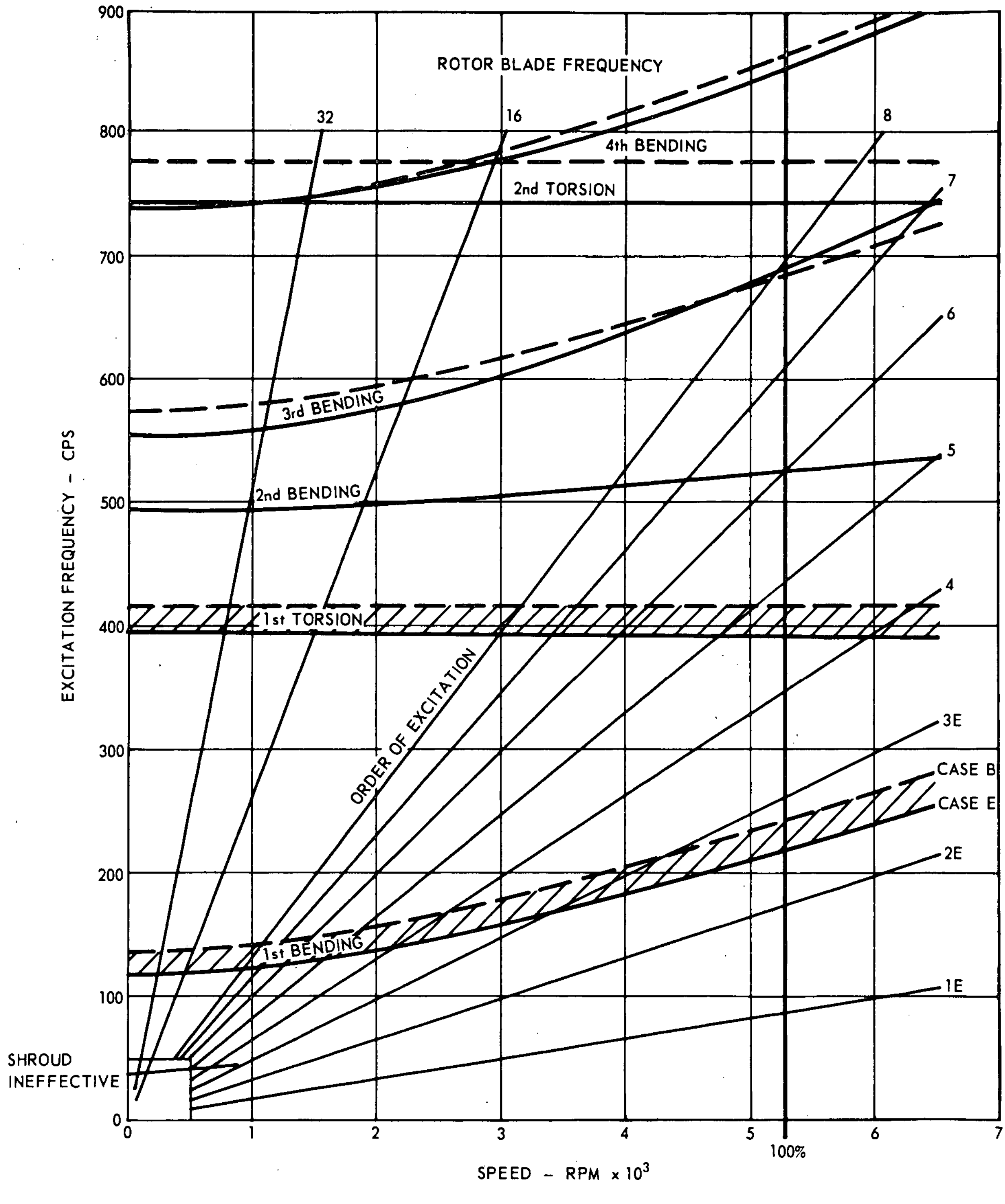


Figure 21. Rotor Blade Vibration Interference Diagram.

Speed (rpm)	%	Relative Flow Vel		Stagger Angle (deg)	Flow Angle (deg)	Frequency		Flutter Coeff.	
						Bend	Tors.	Bending	Tors.
5245	100	Tip	1234	58.6	60.7	240	418	1.93	1.1
		3/4 Span	1127 ft/sec	54	57.5	240	418	1.908	1.04

In Figure 22 the values of the flutter coefficient for the blade 3/4 span are plotted against a limit that is obtained from publications and Lycoming test data. A satisfactory safety margin exists for a shrouded blade even if some uncertainty in the data exists.

Critical Speed Calculation

Power Train Torsion. - The power-train system from the fan to the power turbines is represented by lumped inertias that are connected by flexible elements. By a transfer matrix-type calculation (Lycoming Library program Dl12) * the natural frequencies of the system are determined. There is one natural frequency of N_{T_1} = 6060 cpm for the turbine shaft (36 percent speed) in the operating range where the fan rotor oscillates against the power turbines. The system and its corresponding mode shape are shown in Figure 23. The second mode occurs at N_{T_2} = 31,200 cpm (185 percent design speed).

The sources of excitation originate in the reduction gearing from faulty meshing. Experience has shown that these torsional excitation forces are very small and of no threat to the system.

Fan Module Lateral Vibrations. - A lumped mass model of three levels is employed to calculate the lateral natural frequencies of the fan module and are found by the use of Lycoming program D103 *. It is assumed that the important lateral vibrations of the fan module occur uncoupled from the core engine (Figure 24).

The fan rotor introduces inertial stiffening against the lateral motion. Only one-half of the inertia is used to account for the flexibility of the blades. The support stiffness in the core is calculated as a shell

---

* See Appendix III for more complete analysis.

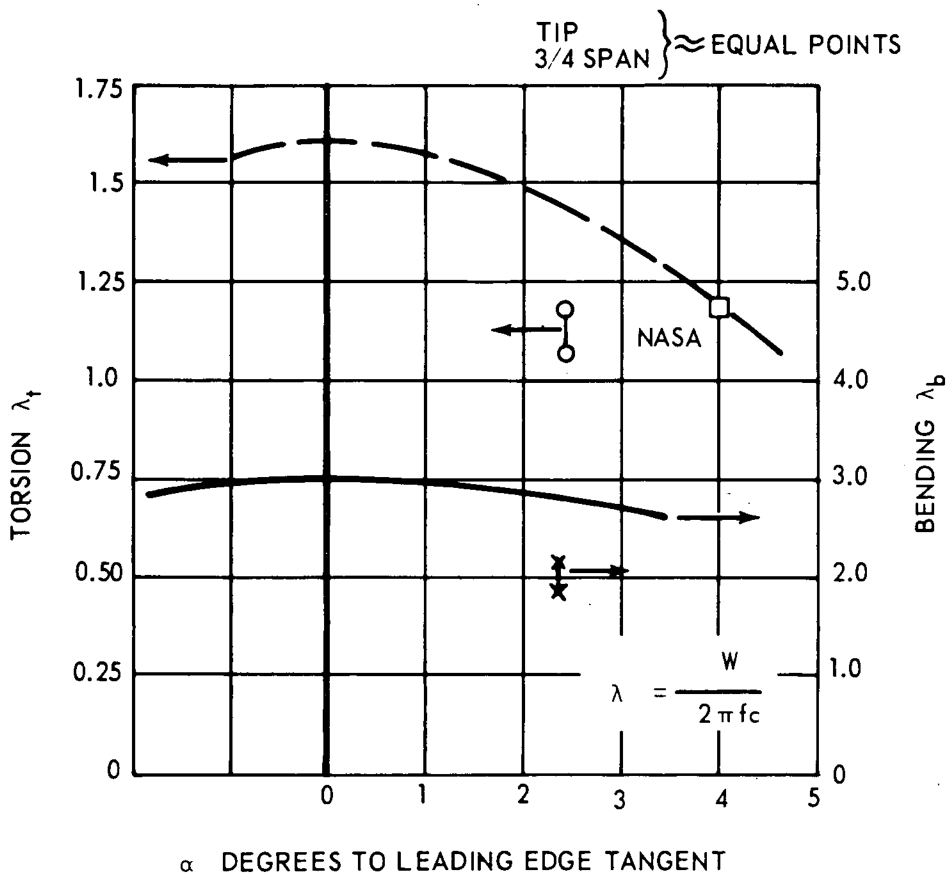


Figure 22. Rotor Blade Flutter Criteria.

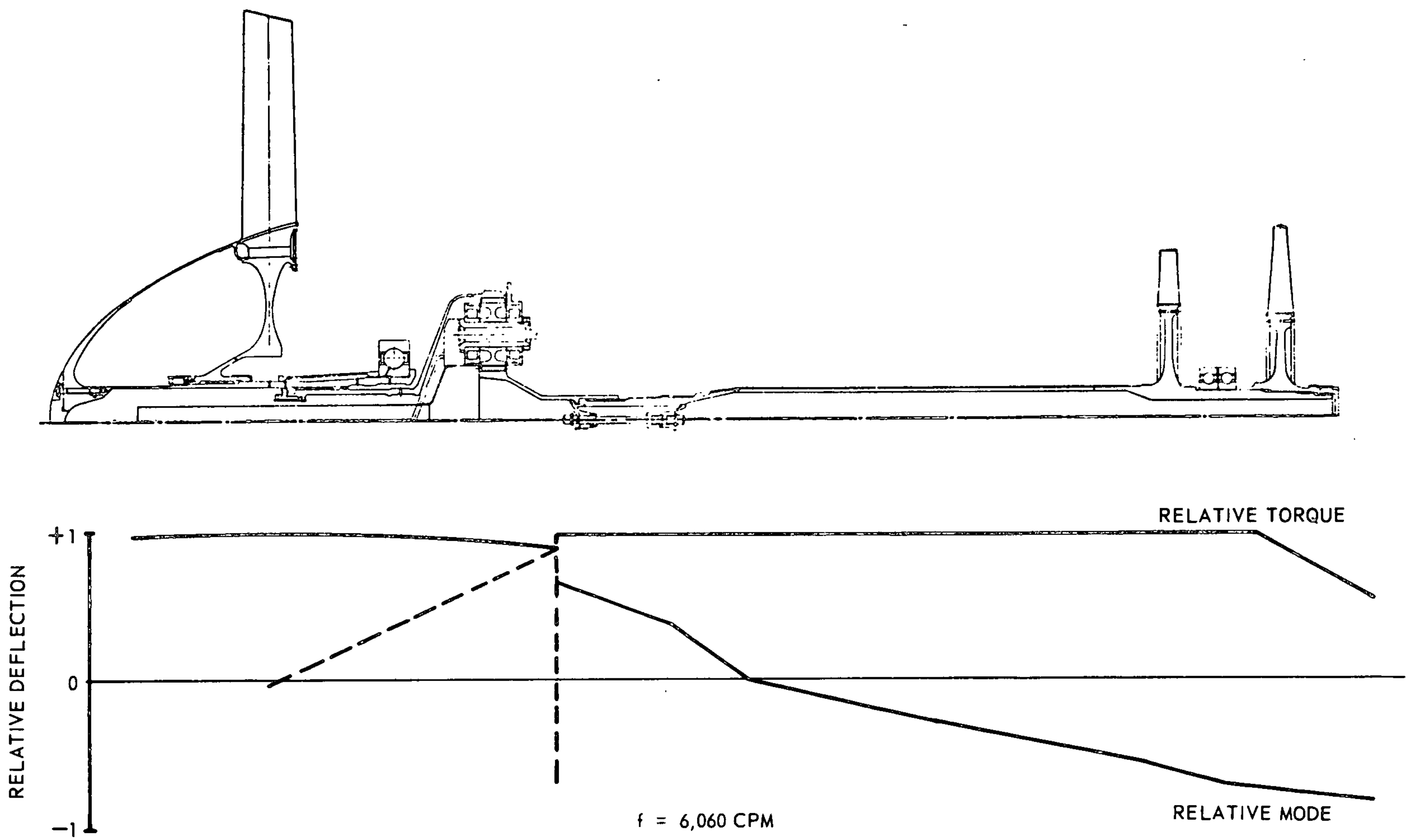


Figure 23. Fan-Power Turbine Torsion Analysis.

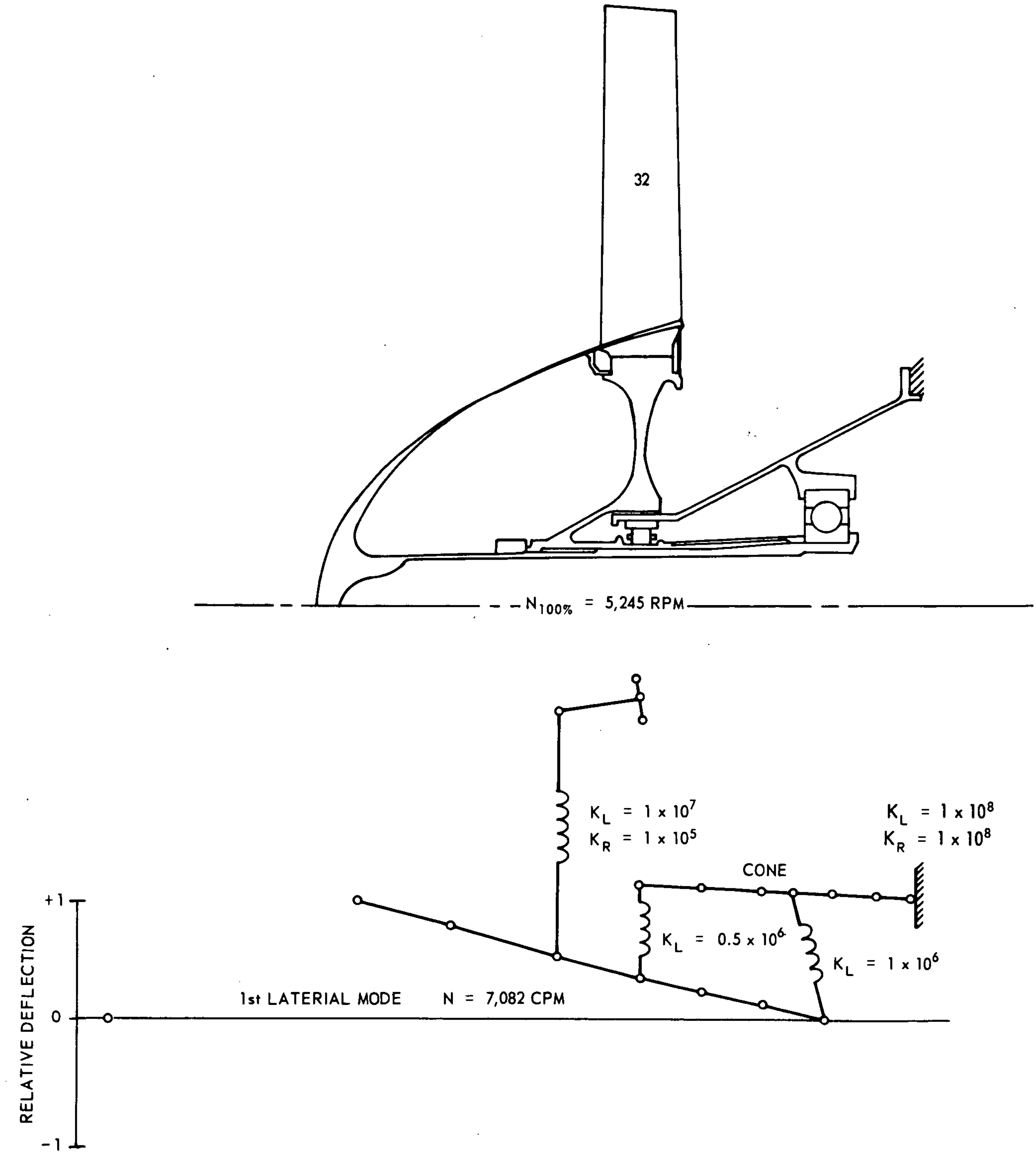


Figure 24. Fan Rotor Deflection.

structure and conservative numbers are used. For the flexibilities of the bearings, represented as lateral springs, conservative values have been taken. The calculated natural frequency, therefore, should represent a lower bound. The mode shape is shown in Figure 24 and it would occur at the first fan shaft critical N_1 = 7,082 rpm = 135 percent operating speed.

There should be no problem from excitation resulting from unbalances, and aerodynamic excitations from the inlet are unlikely to cause resonance problems.

NOISE ANALYSIS

Fan Noise

Noise generated by the fan is governed by the tip speed of the fan, the mass flow, and the spacing of the stator and rotor. The spectrum of the noise is determined by the number of fan blades and their chord length. The noise propagation is governed by the ratio of stator vanes to rotor blades, and the duct aspect ratio.

The noise was estimated by the modified "Smith and House" (2) method, which yields the pure tone and broad band noise for subsonic fans. Analysis for this fan for 500-foot sideline conditions gave a maximum perceived noise level (PNL) of 98.6 PNdB at 70 degrees from the inlet. The method, modified, by Avco Lycoming, is based on the experimental results derived from PLF 1A and 502 fan tests. The correlation with measured data is within ± 2 dB over the spectrum.

Core Engine Noise

The contribution of the compressor to the total noise is based on test data for the T55-L-11A. The turbine noise was computed because this is the new design and test data are not available.

Exhaust Noise

Exhaust noise was computed on the basis of the "Kobrinsky" (3) method. Since the exhaust velocities for the core are high, (above 800 ft/sec) no corrections for combustor noise were made.

Total Noise Without Suppression

The noise generated by the engine was computed for a 500-foot polar and sideline (Tables IV and V). In the extrapolation of the data to 500 feet from 200 feet, only atmospheric attenuation was applied in addition to increase square law attenuation.

The maximum unsuppressed PNL is 106.1 PNdB at 130 degrees from the inlet. The maximum sideline noise is 104.5 PNdB at 100 degrees. The predicted sideline perceived level (SPL) spectrum at 200 feet is shown in Tables VI and VII.

Bypass Duct Acoustical Treatment

Since the maximum engine noise is in the rear quadrant and the maximum contribution to the PNL is by the fan, the treatment of the bypass duct will reduce the noise levels in the rear quadrant.

The analysis of the bypass duct assumed equal spacing between the two splitter rings in the duct. The duct height is 3.5 inches and the flow Mach number is 0.514. In order to maximize the attenuation at the blade passage frequency of 2850 hertz, the backing depth of 0.5 inch was chosen. An attempt was made to optimize the impedance of the treatment with a perforated plate, but sufficient flow resistance could not be achieved for optimum design. Hence, reinforced plastic material was selected. The face material finally selected is fiber-glass cloth impregnated with a polyimid resin with flow resistance required of 3 rayls (MKS). The backing is 0.125 inch, hexcel 0.5 inch deep. The impervious layers are also of the fiber-glass construction.

The assumptions made in the calculations of the attenuation were twofold: (1) the sound pressure is evenly distributed at the inlet to the splitter, and (2) the calculation is made for the least attenuated mode. The results of the duct treatment are shown in Table VIII.

TABLE IV. INTEGRAL LIFT ENGINE SIDELINE PERCEIVED NOISE LEVEL AT 500 FEET

Degrees From Inlet	Treated Bypass Duct (PNL, dB)	Untreated Bypass Duct (PNL, dB)
20	85.0	85.0
30	91.5	91.4
40	94.5	94.4
50	96.8	96.8
60	97.3	97.2
70	97.7	97.8
80	96.6	97.6
90	97.1	100.6
100	95.7	102.6
110	97.0	104.5
120	95.4	104.2
130	96.1	103.1
140	93.1	99.9
150	93.1	96.3
160	86.9	89.0

TABLE V. INTEGRAL LIFT ENGINE POLAR PERCEIVED NOISE LEVEL AT 500 FEET

Degrees From Inlet	Treated Bypass Duct (PNL, dB)	Untreated Bypass Duct (PNL, dB)
0	97.3	97.2
10	98.5	98.5
20	98.9	98.9
30	100.0	99.9
40	99.8	99.7
50	99.9	99.9
60	98.9	98.9
70	98.4	98.5
80	96.7	97.8
90	97.1	100.6
100	95.9	102.8
110	97.7	105.2
120	96.9	105.9
130	99.0	106.1
140	98.0	105.0
150	100.5	104.3
160	98.5	101.8

TABLE VI. POLAR NOISE FIELD, UNTREATED BYPASS DUCT

NASA 1.25 FAN, 8375 LB. THRUST — POLAR FIELD

DEGREES

POLAR COMBINED SOUND LEVELS

FREQ	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0	160.0
20.0	79.3	79.3	68.2	70.2	68.1	68.6	65.3	67.5	65.9	68.4	66.9	69.9	69.0	74.4	75.8	80.7	81.0
25.0	73.1	73.0	70.7	72.4	70.2	70.7	67.6	69.8	69.4	70.9	69.7	72.8	72.2	77.4	79.0	83.1	83.0
31.5	75.6	75.2	72.9	74.4	72.0	72.7	69.7	72.0	70.6	73.3	72.1	75.3	74.7	79.9	81.2	85.1	84.7
40.0	77.4	77.0	74.4	75.9	73.3	74.2	71.3	73.7	72.3	75.1	73.9	77.2	76.6	81.6	82.6	86.5	85.9
50.0	78.4	78.0	75.4	76.8	74.2	75.2	72.5	74.9	73.5	76.4	75.3	78.6	77.9	82.6	83.5	87.3	86.6
63.0	79.9	79.4	76.8	79.1	75.5	76.7	74.2	76.6	75.3	78.2	77.2	80.3	79.7	84.1	84.8	88.6	87.3
80.0	80.7	80.2	77.6	79.0	76.3	77.7	75.3	77.8	76.4	79.4	78.3	81.6	80.8	85.2	85.7	89.5	88.5
100.0	81.0	80.5	77.9	79.2	76.6	78.1	75.9	78.4	77.0	80.0	79.1	82.2	81.5	85.7	86.2	89.9	88.6
125.0	81.4	80.9	79.4	79.7	77.1	78.7	76.8	79.2	77.9	80.9	80.0	83.1	82.4	86.4	86.8	90.4	89.1
160.0	82.2	81.7	79.1	80.6	77.9	79.9	77.8	80.3	79.0	82.1	81.2	84.3	83.5	87.4	87.6	91.2	89.7
200.0	81.7	81.3	78.7	80.1	77.5	79.5	77.7	80.2	78.9	82.0	81.2	84.3	83.4	87.2	87.1	90.7	89.2
250.0	81.6	81.2	78.7	80.1	77.7	79.7	78.1	80.5	79.3	82.4	81.7	84.6	83.9	87.2	87.0	90.5	89.0
315.0	81.6	81.2	78.9	80.3	77.9	80.0	78.5	81.0	79.7	82.9	82.2	85.1	84.3	87.5	86.9	90.4	89.9
400.0	81.2	80.9	78.5	80.1	77.7	80.0	78.6	81.1	79.8	83.0	82.3	85.3	84.5	87.3	86.4	89.9	88.3
500.0	80.2	80.0	77.9	79.5	77.4	79.6	78.4	80.7	79.5	82.7	82.2	85.1	84.4	86.8	85.6	88.9	87.3
630.0	79.8	79.8	78.2	79.7	78.1	79.9	78.9	80.9	79.8	83.0	82.9	85.6	85.2	87.0	85.6	88.4	86.8
800.0	79.4	79.7	78.7	80.1	79.1	80.5	79.5	81.0	80.0	83.2	83.7	86.4	86.2	87.4	85.9	87.9	86.0
1000.0	79.1	79.9	79.9	81.1	80.7	81.4	80.5	81.2	80.3	83.5	84.9	87.4	87.8	88.2	86.7	87.3	85.1
1250.0	79.7	81.0	81.7	82.7	82.7	82.9	82.1	82.0	81.4	84.5	86.7	89.1	89.8	89.5	88.2	87.5	85.0
1600.0	80.9	82.4	83.3	84.3	84.5	84.4	83.6	83.1	82.6	85.7	88.3	90.7	91.5	91.2	89.8	89.3	85.5
2000.0	81.4	83.2	84.4	85.3	85.5	85.3	84.5	83.7	83.2	86.4	89.3	91.6	92.6	92.1	90.7	88.6	85.6
2500.0	81.7	83.5	84.8	85.6	86.0	85.7	84.9	83.9	83.5	86.6	89.7	92.0	93.0	92.4	91.1	88.6	85.6
3150.0	82.5	84.4	85.7	86.5	86.9	86.6	85.8	84.6	83.9	86.7	89.6	91.9	92.9	92.3	91.0	88.4	85.4
4000.0	79.5	81.3	82.7	83.5	83.9	83.6	82.8	81.7	81.3	84.4	87.4	89.7	90.7	90.1	88.8	86.3	83.2
5000.0	77.1	78.9	80.2	81.1	81.5	81.2	80.3	79.3	78.8	81.7	84.6	86.9	87.9	87.4	86.1	83.7	80.6
6300.0	80.1	82.0	83.3	84.2	84.5	84.2	83.4	81.8	80.4	80.8	82.4	84.4	85.2	84.7	83.5	81.2	78.0
8000.0	72.3	74.1	75.4	76.3	76.6	76.4	75.5	74.5	73.7	75.8	78.1	80.2	81.1	80.7	79.6	77.7	74.5
10000.0	71.4	73.3	74.6	75.5	75.8	75.5	74.6	73.5	72.6	74.4	76.7	78.8	79.7	79.2	78.1	75.9	72.9
12500.0	76.8	78.7	80.1	80.9	81.3	80.9	80.1	78.4	76.7	76.0	76.7	78.2	78.9	78.2	77.0	74.7	71.8
16000.0	76.8	78.7	80.1	80.9	81.3	80.9	80.1	78.4	76.8	76.6	77.9	79.6	80.5	79.8	78.5	75.8	73.0
20000.0	67.3	69.2	70.5	71.4	71.8	71.4	70.5	69.3	69.0	71.7	74.7	76.9	78.0	77.3	76.0	73.3	70.5

TABLE VII. SIDELINE NOISE FIELD, UNTREATED BYPASS DUCT

NASA 1.25 FAN, 8375 LB THRUST

SIDELINE FIELD

DEGREES

SIDELINE COMBINED SOUND LEVELS

FREQ	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0	160.0
20.0	58.9	64.1	64.2	66.3	64.0	67.0	65.7	68.4	66.8	69.4	67.7	72.1	72.0	74.6	71.7
25.0	61.4	66.3	66.3	69.4	66.4	69.3	68.2	70.9	69.5	72.2	70.9	75.1	75.1	77.0	73.6
31.5	63.5	68.3	68.1	70.4	68.4	71.4	70.4	73.3	71.9	74.7	73.5	77.6	77.4	79.0	75.3
40.0	65.0	69.8	69.5	71.9	70.1	73.2	72.1	75.1	73.8	76.7	75.3	79.3	78.9	80.4	76.5
50.0	66.0	70.7	70.3	72.9	71.3	74.4	73.4	76.4	75.1	78.0	76.7	80.3	79.6	81.2	77.2
63.0	67.4	72.1	71.7	74.4	72.9	76.0	75.1	78.1	77.0	79.9	78.4	81.8	81.0	82.6	78.4
80.0	68.2	72.9	72.4	75.3	74.0	77.2	76.2	79.3	78.2	81.0	79.5	82.8	81.8	83.5	79.1
100.0	68.4	73.1	72.7	75.7	74.6	77.8	76.8	80.0	78.9	81.6	80.2	83.3	82.3	83.8	79.2
125.0	68.9	73.6	73.2	76.4	75.5	78.6	77.7	80.8	79.9	82.5	81.1	84.0	82.9	84.3	79.6
160.0	69.6	74.4	74.0	77.4	76.5	79.7	78.8	82.0	81.0	83.7	82.2	85.0	83.7	85.1	80.2
200.0	69.1	73.9	73.6	77.1	76.4	79.6	78.7	82.0	80.9	83.6	82.1	84.7	83.2	84.5	79.6
250.0	69.1	73.9	73.7	77.2	76.8	79.9	79.1	82.3	81.4	84.0	82.5	84.8	83.0	84.2	79.4
315.0	69.1	74.0	73.8	77.5	77.2	80.3	79.5	82.8	81.9	84.5	82.9	85.0	82.8	84.1	79.2
400.0	68.7	73.7	73.7	77.5	77.2	80.4	79.5	82.9	82.0	84.6	83.0	84.8	82.3	83.6	78.6
500.0	68.0	73.0	73.3	77.0	76.9	79.9	79.1	82.5	81.9	84.3	82.9	84.2	81.4	82.5	77.4
630.0	68.1	73.1	73.8	77.3	77.3	80.1	79.4	82.7	82.5	84.8	83.5	84.3	81.4	81.9	76.7
800.0	68.4	73.5	74.8	77.7	77.9	80.1	79.5	82.9	83.2	85.5	84.6	84.6	81.6	81.2	75.7
1000.0	69.4	74.2	76.3	78.5	78.8	80.2	79.8	83.1	84.4	86.5	86.1	85.3	82.3	80.5	74.6
1250.0	70.9	75.6	78.1	79.9	80.2	80.9	80.7	84.0	86.0	88.0	87.7	86.7	83.6	80.5	74.2
1600.0	72.1	77.0	79.6	81.3	81.6	81.9	81.8	85.1	87.5	89.5	89.5	88.0	85.0	81.0	74.3
2000.0	72.7	77.6	80.5	82.0	82.4	82.3	82.3	85.6	88.3	90.2	90.4	88.7	85.6	81.0	74.0
2500.0	72.5	77.6	80.6	82.1	82.5	82.3	82.3	85.6	88.5	90.4	90.5	88.9	85.7	80.6	73.4
3150.0	72.7	78.0	81.1	82.6	83.1	82.7	82.5	85.4	88.2	90.0	90.2	88.3	85.2	79.9	72.4
4000.0	68.7	74.3	77.5	79.2	79.7	79.5	79.5	82.8	85.6	87.4	87.6	85.7	82.5	77.1	69.3
5000.0	65.1	71.1	74.5	76.2	76.8	76.6	76.7	79.7	82.5	84.3	84.3	82.5	79.2	73.7	65.4
6300.0	66.6	73.1	76.0	78.6	79.2	78.6	77.7	78.2	79.7	81.2	81.1	79.1	75.7	70.2	61.4
8000.0	56.7	63.9	67.8	69.9	70.6	70.6	70.3	72.6	74.7	76.3	76.1	74.3	70.8	65.3	55.8
10000.0	53.6	61.4	65.8	68.0	68.8	68.7	68.4	70.4	72.5	74.0	73.8	71.7	68.0	61.9	51.9
12500.0	56.2	64.9	69.7	72.1	73.1	72.6	71.5	71.0	71.5	72.3	71.8	69.4	65.4	58.7	47.9
16000.0	52.0	62.1	67.5	70.2	71.4	71.1	70.2	70.2	71.3	72.3	71.9	69.1	64.7	57.0	45.0
20000.0	37.8	49.4	55.5	58.6	60.0	60.3	60.7	63.7	66.5	67.9	67.5	64.5	59.7	51.3	37.8

TABLE VIII. ATTENUATION OF THE BYPASS DUCT TREATMENT

Frequency (Hz)	Attenuation (dB)
500	2.0
630	2.5
800	3.0
1000	5.5
1250	9.0
1600	13.0
2000	17.0
2500	20.0
3150	19.5
4000	17.0
5000	13.0
6300	10.0
8000	8.0
10000	8.0

Total Noise With Treatment

When the computed attenuation for the bypass duct was applied to the bypass radiated noise, the polar and sideline noise changed in amplitude and directivity. The maximum polar PNL is at 150 degrees and is 100.5 PNdB (Table V). The maximum sideline noise is at 70 degrees and is 97.7 PNdB (Table IV). The predicted SPL spectrum at 200 feet is shown in Tables IX and X.

The treatment reduced the sideline noise at 100 degrees from 104.5 PNdB to 97.0 PNdB, a difference of 7.5 PNdB. The reduction is not as large as would be expected from the duct treatment, because the fan noise was suppressed below the jet noise up to 5 kilohertz (Figure 25). Therefore, in order to reduce the noise further, the core exhaust nozzle exit velocity must be lowered to reduct the noise on the sideline. The turbine noise is above 10 kilohertz and does not contribute significantly to the PNL, hence no acoustic treatment is required in the hot exhaust nozzle.

TABLE IX. POLAR NOISE FIELD, TREATED BYPASS DUCT

NASA 1.25 FAN, 8375 LB THRUST — POLAR FIELD

POLAR COMBINED SOUND LEVELS

FREQ	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0	160.0
	DEGREES																
20.0	70.3	70.3	68.2	70.2	68.1	68.6	65.3	67.5	65.9	68.4	66.9	69.9	69.0	74.4	75.8	80.7	81.0
25.0	73.1	73.0	70.7	72.4	70.2	70.7	67.6	69.8	68.4	70.9	69.7	72.8	72.2	77.4	79.0	83.1	83.0
31.5	75.6	75.2	72.9	74.4	72.0	72.7	69.7	72.0	70.6	73.3	72.1	75.3	74.7	79.9	81.2	85.1	84.7
40.0	77.4	77.0	74.4	75.9	73.3	74.2	71.3	73.7	72.3	75.1	73.9	77.2	76.6	81.6	82.6	86.5	85.9
50.0	78.4	78.0	75.4	76.8	74.2	75.2	72.5	74.9	73.5	76.4	75.3	78.6	77.9	82.6	83.5	87.3	86.6
63.0	79.9	79.4	76.8	78.1	75.5	76.7	74.2	76.6	75.3	78.2	77.2	80.3	79.7	84.1	84.8	88.6	87.8
80.0	80.7	80.2	77.6	79.0	76.3	77.7	75.3	77.8	76.4	79.4	78.3	81.6	80.8	85.2	85.7	89.5	88.5
100.0	81.0	80.5	77.9	79.2	76.6	78.1	75.9	78.4	77.0	80.0	79.1	82.2	81.5	85.7	86.2	89.9	88.6
125.0	81.4	80.9	78.4	79.7	77.1	78.7	76.8	79.2	77.9	80.9	80.0	83.1	82.4	86.4	86.8	90.4	89.1
160.0	82.2	81.7	79.1	80.6	77.9	79.8	77.8	80.3	79.0	82.1	81.2	84.3	83.5	87.4	87.6	91.2	89.7
200.0	81.7	81.3	78.7	80.1	77.5	79.5	77.7	80.2	78.9	82.0	81.2	84.3	83.4	87.2	87.1	90.7	89.2
250.0	81.6	81.2	78.7	80.1	77.7	79.7	78.1	80.5	79.3	82.4	81.7	84.6	83.9	87.2	87.0	90.5	89.0
315.0	81.6	81.2	78.8	80.3	77.9	80.0	78.5	81.0	79.7	82.9	82.2	85.1	84.3	87.5	86.9	90.4	88.9
400.0	81.2	80.9	78.5	80.1	77.7	80.0	78.6	81.1	79.8	83.0	82.3	85.3	84.5	87.3	86.4	89.9	88.3
500.0	80.2	80.0	77.9	79.5	77.4	79.6	78.4	80.7	79.4	82.6	82.0	84.9	84.1	86.6	85.5	88.8	87.3
630.0	79.8	79.8	78.2	79.7	78.1	79.9	78.9	80.9	79.7	82.8	82.4	85.2	84.6	86.6	85.3	88.4	86.7
800.0	79.4	79.7	78.7	80.1	79.1	80.5	79.5	81.0	79.8	82.8	82.7	85.4	85.0	96.6	85.1	87.7	95.8
1000.0	79.1	79.9	79.9	81.1	80.7	81.4	80.5	81.1	79.8	82.3	82.3	84.9	84.7	85.9	84.3	86.4	84.4
1250.0	79.7	81.0	81.7	82.7	82.7	82.9	82.1	81.8	80.4	81.9	81.8	84.2	83.9	85.1	83.5	85.3	83.1
1600.0	80.8	82.4	83.3	84.3	84.5	84.4	83.6	82.9	81.2	82.0	81.3	83.5	82.9	84.3	82.7	84.6	82.1
2000.0	81.4	83.2	84.4	85.3	85.5	85.3	84.5	83.4	81.6	81.4	80.0	81.8	81.0	82.6	81.0	82.8	80.1
2500.0	81.7	83.5	84.8	85.6	86.0	85.7	84.9	83.5	81.7	80.9	79.2	80.4	79.4	81.1	79.7	81.3	78.3
3150.0	82.5	84.4	85.7	86.5	86.9	86.6	85.8	84.3	82.4	81.1	79.1	79.9	78.8	80.3	79.0	80.3	77.1
4000.0	79.5	81.3	82.7	83.5	83.9	83.6	82.8	81.4	79.6	78.8	77.2	78.4	77.6	79.2	78.1	79.0	75.5
5000.0	77.1	78.9	80.2	81.1	81.5	81.2	80.3	79.0	77.3	76.8	75.9	77.3	77.0	78.1	77.1	77.4	73.8
6300.0	80.1	82.0	83.3	84.2	84.5	84.2	83.4	81.7	79.9	78.4	76.7	77.1	76.6	77.2	76.4	76.2	72.6
8000.0	72.3	74.1	75.4	76.3	76.6	76.4	75.5	74.4	72.9	72.9	72.6	74.2	74.1	74.9	74.3	74.2	70.7
10000.0	71.4	73.3	74.6	75.5	75.8	75.5	74.6	73.3	71.8	71.4	71.1	72.3	72.3	72.8	72.1	71.9	68.7
12500.0	76.8	78.7	80.1	80.9	81.3	80.9	80.1	78.4	76.7	76.0	76.7	78.2	78.9	78.2	77.0	74.7	71.8
16000.0	76.8	78.7	80.1	80.9	81.3	80.9	80.1	78.4	76.8	76.6	77.9	79.6	80.5	79.8	78.5	75.6	73.0
20000.0	67.3	69.2	70.5	71.4	71.8	71.4	70.5	69.3	69.0	71.7	74.7	76.9	78.0	77.3	76.0	73.3	70.5

TABLE X. SIDELINE NOISE FIELD, TREATED BYPASS DUCT

NASA 1.25 FAN, 8375 LB THRUST — SIDELINE FIELD

SIDELINE COMBINED SOUND LEVELS

FREQ	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0	160.0
	DEGREES														
20.0	58.9	64.1	64.2	66.3	64.0	67.0	65.7	68.4	66.8	69.4	67.7	72.1	72.0	74.6	71.7
25.0	61.4	66.3	66.3	68.4	66.4	69.3	68.2	70.9	69.5	72.2	70.9	75.1	75.1	77.0	73.6
31.5	63.5	68.3	68.1	70.4	68.4	71.4	70.4	73.3	71.9	74.7	73.5	77.6	77.4	79.0	75.3
40.0	65.0	69.8	69.5	71.9	70.1	73.2	72.1	75.1	73.8	76.7	75.3	79.3	78.8	80.4	76.5
50.0	66.0	70.7	70.3	72.9	71.3	74.4	73.4	76.4	75.1	78.0	76.7	80.3	79.6	81.2	77.2
63.0	67.4	72.1	71.7	74.4	72.9	76.0	75.1	78.1	77.0	79.8	78.4	81.8	81.0	82.6	78.4
80.0	68.2	72.9	72.4	75.3	74.0	77.2	76.2	79.3	78.2	81.0	79.5	82.8	81.8	83.5	79.1
100.0	68.4	73.1	72.7	75.7	74.6	77.8	76.8	80.0	78.9	81.6	80.2	83.3	82.3	83.8	79.2
125.0	68.9	73.6	73.2	76.4	75.5	78.6	77.7	80.8	79.9	82.5	81.1	84.0	82.9	84.3	79.6
160.0	69.6	74.4	74.0	77.4	76.5	79.7	78.8	82.0	81.0	83.7	82.2	85.0	83.7	85.1	80.2
200.0	69.1	73.9	73.6	77.1	76.4	79.6	78.7	82.0	80.9	83.6	82.1	84.7	83.2	84.5	79.6
250.0	69.1	73.9	73.7	77.2	76.8	79.9	79.1	82.3	81.4	84.0	82.5	84.8	83.0	84.2	79.4
315.0	69.1	74.0	73.8	77.5	77.2	80.3	79.5	82.8	81.9	84.5	82.9	85.0	82.8	84.1	79.2
400.0	69.7	73.7	73.7	77.5	77.2	80.4	79.5	82.9	82.0	84.6	83.0	84.8	82.3	83.6	78.6
500.0	68.0	73.0	73.3	77.0	76.9	79.9	79.1	82.4	81.7	84.2	82.6	84.1	81.3	82.4	77.4
630.0	68.1	73.1	73.8	77.3	77.3	80.1	79.3	82.5	82.1	84.4	83.0	84.0	81.1	81.8	76.7
800.0	68.4	73.5	74.8	77.7	77.9	80.1	79.3	82.5	82.3	84.6	83.4	83.9	80.7	81.0	75.6
1000.0	69.4	74.2	76.3	78.5	78.8	80.1	79.3	81.9	81.8	84.0	82.9	83.1	79.9	79.6	73.9
1250.0	70.9	75.6	78.1	79.9	80.2	80.7	79.7	81.4	81.2	83.1	82.1	82.1	78.9	78.3	72.4
1600.0	72.1	77.0	79.6	81.3	81.6	81.6	80.5	81.4	80.5	82.3	80.9	81.2	77.9	77.3	71.0
2000.0	72.7	77.6	80.5	82.0	82.4	82.0	80.6	80.6	79.1	80.4	78.8	79.2	75.9	75.2	68.4
2500.0	72.5	77.6	80.6	82.1	82.5	81.9	80.6	79.9	78.0	78.8	77.0	77.5	74.3	73.3	66.1
3150.0	72.7	78.0	81.1	82.6	83.1	82.4	81.0	79.9	77.7	78.0	76.1	76.3	73.2	71.8	64.1
4000.0	68.7	74.3	77.5	79.2	79.7	79.1	77.8	77.2	75.4	76.2	74.5	74.8	71.7	69.8	61.5
5000.0	65.1	71.1	74.5	76.2	76.8	76.3	75.1	74.8	73.7	74.6	73.4	73.2	70.2	67.4	58.7
6300.0	66.6	73.1	76.8	78.6	79.2	78.5	77.2	75.8	74.0	73.9	72.5	71.6	68.6	65.1	56.0
8000.0	56.7	63.9	67.8	69.9	70.6	70.4	69.5	69.7	69.2	70.2	69.2	68.5	65.4	61.8	52.1
10000.0	53.6	61.4	65.8	68.0	68.8	68.5	67.6	67.4	66.9	67.5	66.5	65.2	62.1	57.9	47.7
12500.0	56.2	64.9	69.7	72.1	73.1	72.6	71.5	71.0	71.5	72.3	71.8	69.4	65.4	58.7	47.9
16000.0	52.0	62.1	67.5	70.2	71.4	71.1	70.2	70.2	71.3	72.3	71.9	69.1	64.7	57.0	45.0
20000.0	37.8	49.4	55.5	58.6	60.0	60.3	60.7	63.7	66.5	67.9	67.5	64.5	59.7	51.3	37.8

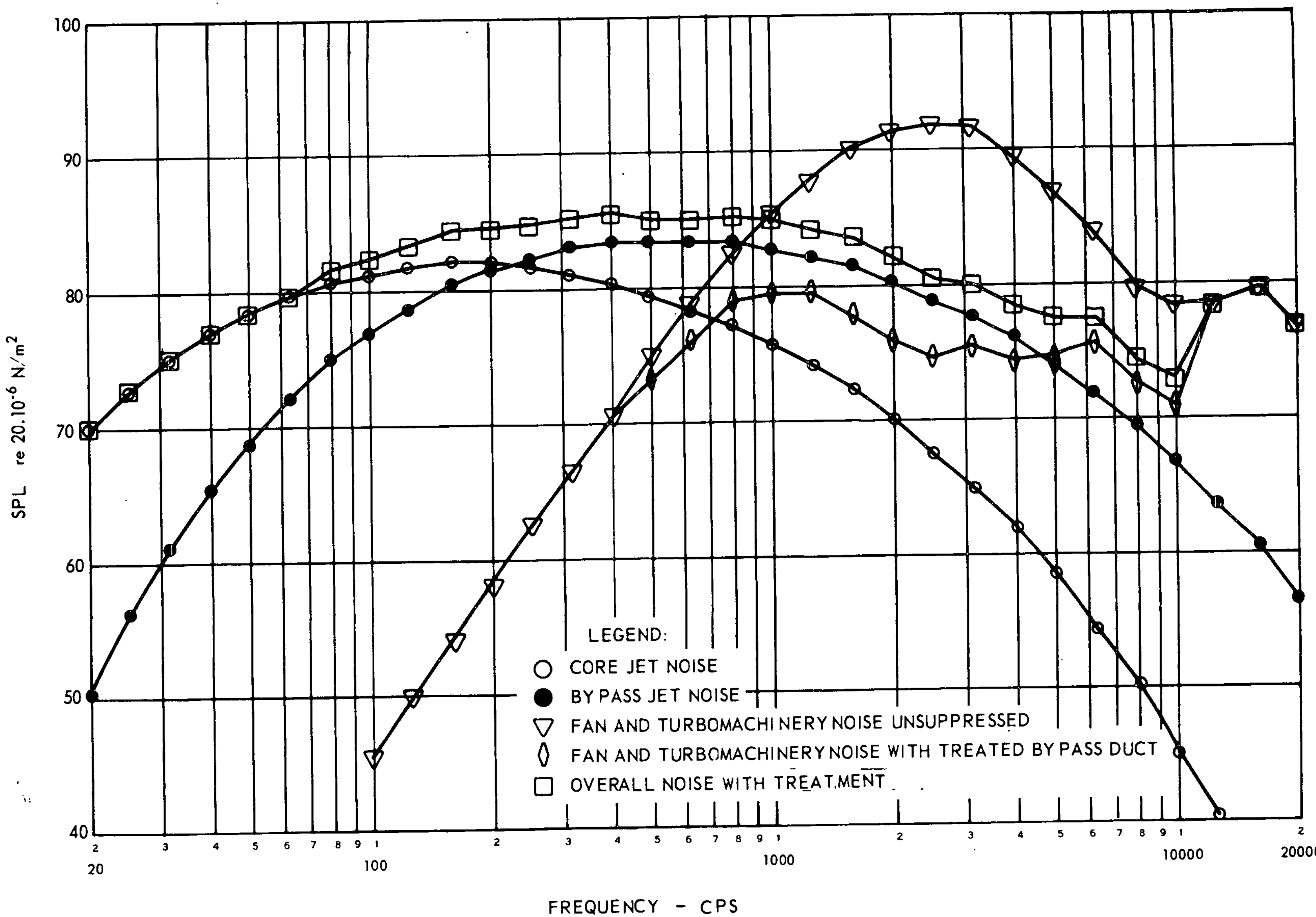


Figure 25. Integral Lift Engine Noise at 200 Feet Radius and 110 Degrees.

ENGINE PERFORMANCE

Design Cycle Considerations

The final turbofan engine design cycle was established at the maximum rating at sea level, static, standard conditions for the Lycoming LTC4B-12 shaft tubine engine. The B-12 engine, with minor modifications, serves as the power producer, and consequently its ratings (i.e. torque and speed limits) are applied to the fan version in addition to limits unique to the fan and reduction gearbox.

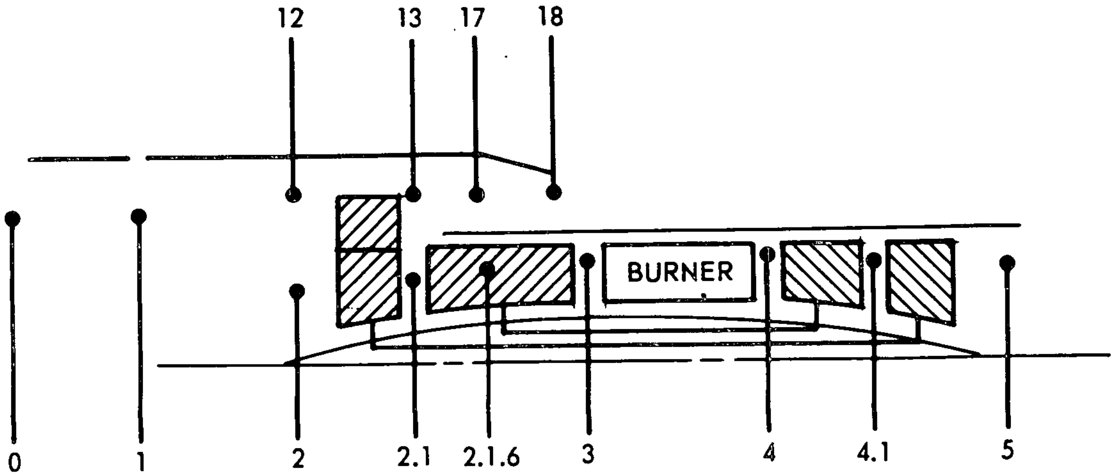
The rematch of the core engine at maximum rating when operating behind a supercharger stage is similar to the shaft engine being rammed at flight velocity. The operating point on the high compressor referred to its inlet reflects the reduction in referred turbine inlet temperature $T_4/\theta_{2.1}$. See the engine station diagram in Figure 26. This is manifested as a reduction in referred gas producer speed $N_G/\sqrt{\theta_{2.1}}$, referred compressor inlet airflow $W_{aP}\sqrt{\theta_{2.1}}/\delta_{2.1}$, and compressor pressure ratio $P_3/P_{2.1}$. Determination of the high compressor referred inlet airflow as a function of supercharger pressure ratio and efficiency allows computation of the actual engine inlet airflow, which is also the referred inlet airflow of the engine supercharging portion of the fan.

With a prescribed fan pressure ratio selection of the design bypass ratio and, therefore, the inlet referred airflow into the bypass stream portion of the fan, is dependent on the available power turbine work resulting from the power turbine gas flow, inlet temperature, and the expansion ratio necessary to diffuse the hot nozzle exit stream to the velocity desired for minimum exhaust noise. Gas flow and power turbine inlet temperature are determined by the compressor and supercharger match, component losses, airbleeds, and the maximum turbine inlet temperature T_4 of the B-12 engine. The resultant turbine power available* to drive the fan and supercharger at their respective pressure ratios and efficiencies establish the fan total inlet airflow and bypass ratio.

Estimated Engine Performance and Fan Matching

Estimated performance data presented herein are based on a lower heating value of 18,400 Btu/lb and are representative of typical average production engines. The standard atmospheric conditions are as given in U.S. Standard Atmosphere, 1962 (ASTIA Document 401813). Tropical atmospheric conditions are as presented in Climatic Extremes for Military Equipment, 1957 (MIL-STD-210A). Thermodynamic and performance data for the engine design point are presented in Tables XI through XIII. Part-load performance data have been generated for both the prime fan A with large design surge margin (SM = 21 ~~percent at 100 percent~~

* There is no exhaust diffuser or exhaust nozzle after the power turbine.



0	FREE STREAM	4	HIGH-PRESSURE TURBINE INLET
1	ENGINE INLET	4.1	LOW-PRESSURE TURBINE INLET
2	LOW-PRESSURE COMPRESSOR INLET	5	LOW-PRESSURE TURBINE EXIT
2.1	HIGH-PRESSURE COMPRESSOR INLET	12	FAN COMPRESSOR INLET
2.1.6	HIGH-PRESSURE COMPRESSOR INTERSTAGE BLEED PORT	13	FAN COMPRESSOR EXIT
3	HIGH-PRESSURE COMPRESSOR EXIT	17	COLD-STREAM EXHAUST NOZZLE INLET
		18	COLD-STREAM EXHAUST NOZZLE EXIT

Figure 26, Engine Stations.

F

TABLE XI. TURBOFAN ENGINE DESIGN CYCLE DATA

Item	Symbol	Unit	
Fan Engine Inlet Conditions			
Altitude		ft	0
Ambient Temperature	T_{am}	°R	518.7
Ambient Pressure	P_{am}	psia	14.7
Flight Mach Number	M_f	-	0
Cycle Temperature *	T_4	°F	2067
Specific Thrust	$F_{NT}/W_{a\ T}$	lb_f-sec/lbm	19.9
Pressure Ratios			
Compressor Overall	P_3/P_2	-	9.8
Fan (and Supercharger)	P_{13}/P_{12}	-	1.25
Gas Generator Compressor	$P_3/P_{2.1}$	-	7.84
Referred Airflows			
Total	$W_{aT}\sqrt{\theta_2}/\delta_2$	lb/sec	421
Gas Generator (Inlet)	$W_{aP}\sqrt{\theta_{2.1}}/\delta_{2.1}$	lb/sec	25.9
Bypass Ratio	BR	-	12.5
Fan Speed	N_F	rpm	5245
Power Turbine Speed	N_{PT}	rpm	16870
Gas Generator Spool	N_G	rpm	19180
Total Net Thrust	F_{NT}	lb	8370
Thrust Specific Fuel Consumption	TSFC	lbm/hr-lb_f	.302
Engine Stream (Primary) Exhaust Velocity	V_{jP}	ft/sec	846
Bypass Stream (Secondary) Exhaust Velocity	V_{jS}	ft/sec	623

*Total temperature at first turbine rotor inlet

TABLE XII. TURBOFAN ENGINE DESIGN EFFICIENCY AND LOSS ASSUMPTIONS

Item		Symbol	Unit	
Pressure Losses in Engine				
Combustor		$\Delta P/P_3$	-	.033
Bypass Stream (Fan) Exhaust Duct		$\Delta P/P_{13}$	-	.01
Nozzle Velocity Ratios				
Primary (Engine Nozzle)		C_{VP}	-	.99
Secondary (Bypass Nozzle)		C_{VS}	-	.99
Component Efficiencies				
Fan	Polytropic	η_{FP}	-	.88
	Adiabatic	η_{Fa}	-	.876
Supercharger	Polytropic	η_{SCP}	-	.86
	Adiabatic	η_{Sa}	-	.855
Gas Generator Compressor	Polytropic	η_{CP}	-	.858
	Adiabatic	η_{C}	-	.816
Combustor		η_{B}	-	.98
Gas Generator Turbine	Polytropic	η_{TP}	-	.897
	Adiabatic	η_{T}	-	.907
Power Turbine	Polytropic	η_{TP}	-	.871
	Adiabatic	η_{T}	-	.887
Mechanical Rotor Efficiencies				
Gas Generator		η_{MG}	-	.993
Fan		η_{MF}	-	.985
Equivalent Cooling Air Flow (Bypassing Gas Generator Turbine)		W_c/W_{aP}	%	3.5
Rotating Seal and Overboard Leakage		W_L/W_{aP}	%	0.5

TABLE XIII. TURBOFAN ENGINE STATION CYCLE DATA

Component		Total Pressure (psia)	Total Temperature (°R)	Flow Rate (lb/sec)
Engine Inlet		14.7	518.7	421
Fan	Inlet	14.7	518.7	390
	Exit	18.4	558	390
Bypass Stream (Fan) Exhaust Duct	Inlet	18.4	558	390
	Exit	18.2	558	390
Supercharger	Inlet	14.7	518.7	31.2
	Exit	18.4	559	31.2
Gas Generator Compressor	Inlet	18.4	559	31.2
	Exit	144	1096	31.2
Combustor:	Inlet	144	1096	30.0
	Exit	139.3	2527	30.7
Gas Generator Turbine	Inlet	139.3	2527	30.7
	Exit	53.5	2040	30.7
Power Turbine	Inlet	53.5	2040	31.7
	Exit	16.8	1598	31.7
Engine Stream (Gas) Exhaust Duct	Inlet	16.8	1598	31.7
	Exit	16.8	1598	31.7

$N/\sqrt{\theta_2}$) and fan B, which has the more moderate design surge margin (SM = 14 percent at 100 percent $N/\sqrt{\theta_2}$) normally associated with fan engines configured for cruise. For each configuration, the aerodynamic fan design point has the same pressure ratio, flow, and efficiency, so Tables XI through XIII apply to both. Insofar as the effect of redesign influences only the bypass stream portion of the fan, the supercharger characteristic remains unaltered.

Fan A (Surge Margin = 21 Percent at 100 Percent $N/\sqrt{\theta_2}$). - Standard and tropical day performance from sea level to 20,000 feet at various flight Mach numbers is shown, for this design, in Figures 27 through 36. Lines are presented on these curves through the loci of maximum (5 minute) ratings, military (30 minute) ratings, and continuous ratings, as well as the power turbine maximum speed where this limits engine operation.

To obtain perspective with respect to component matching, operating lines within the suitable flight envelope are superimposed on the fan, supercharger, and high-pressure compressor characteristics, and are presented as Figures 37 through 39 respectively. The design surge margins* at 100 percent referred speed are 21 percent for the fan and 29 percent for the supercharger. The problem inherent to low-pressure-ratio fan designs shows up clearly as a rapid unloading of the fan with increased M_f (flight Mach number) with the associated severe decrease in efficiency. This is exemplified by the decay of fan efficiency at standard day maximum rating going from static to 0.4 M_f, on the order of 17 percent.

Fan B (Surge Margin = 14 Percent at 100 Percent $N/\sqrt{\theta_2}$). - The selection of a fan design with more moderate surge margin at the aerodynamic fan design point has the direct benefit of improved performance at the flight Mach numbers associated with cruise. The fan B characteristic is presented in Figure 40 with operating lines equivalent to those shown in Figure 37. The efficiency decay in this case traversing from the sea level, static operating line to the sea level, 0.4 M_f operating line is 8 percent at maximum rating. Sea level performance for both fan designs is shown comparatively in Figure 41 to illustrate the described effect on TSFC (thrust specific fuel consumption) and thrust. It is seeen that the lower surge margin fan design provides 8 1/2 percent more net thrust with 8 1/2 percent less TSFC at 0.4 M_f maximum rating. Standard and tropical day performance from sea level to 20,000 feet is shown for this configuration in Figures 42 through 51.

---

* $SM = \left[\left(\frac{P_{rs}}{P_{ro}} \times \frac{W_{ao}}{W_{as}}\right) - 1\right] \times 100$ (at constant referred speed)

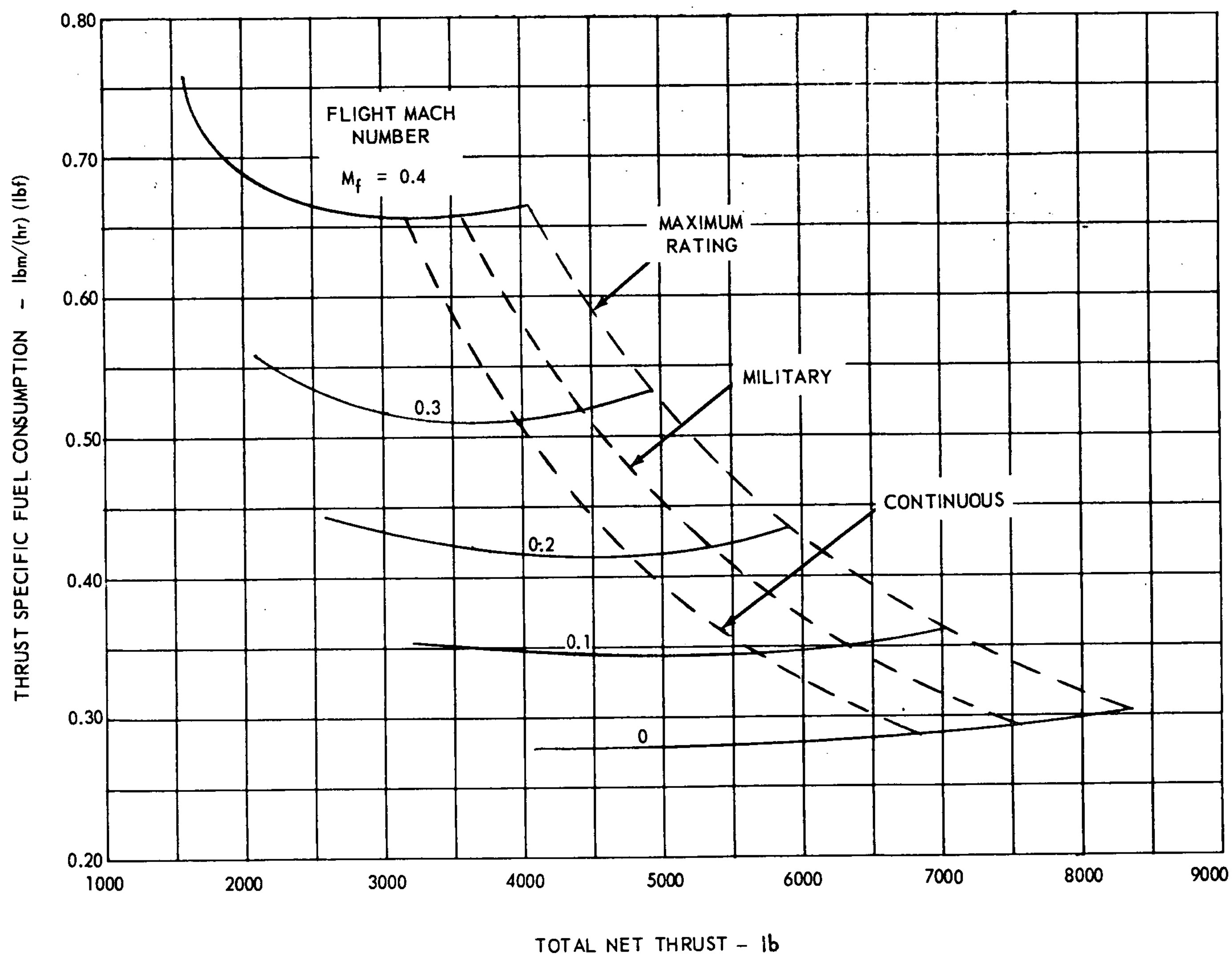


Figure 27. Fan Configuration A (SM = 21 Percent, A_{18} = 1190 Square Inches) Estimated Performance at Sea Level on Standard Day.

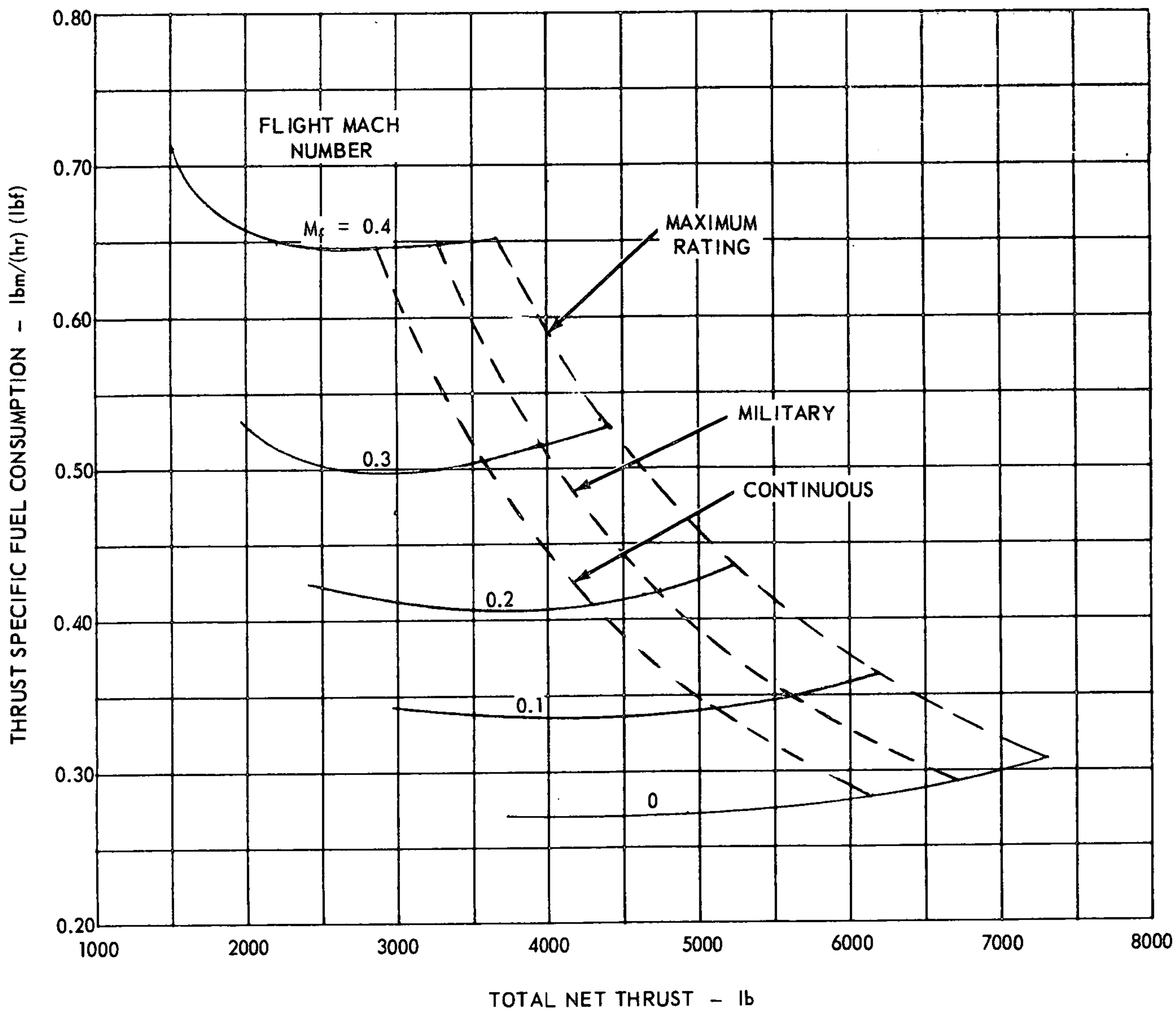


Figure 28. Fan Configuration A (SM = 21 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 5000 Feet on Standard Day.

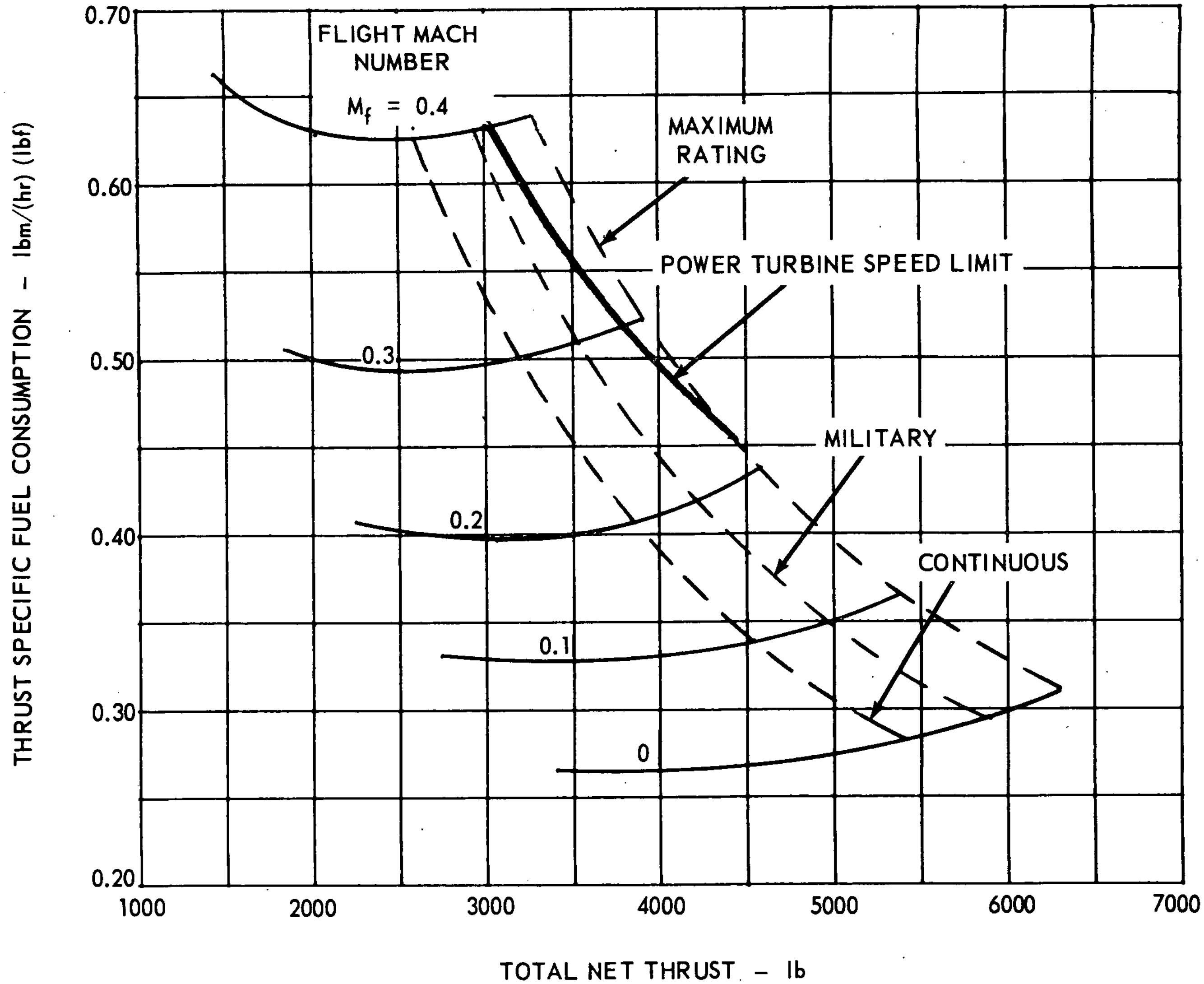


Figure 29. Fan Configuration A (SM = 21 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 10,000 Feet on Standard Day.

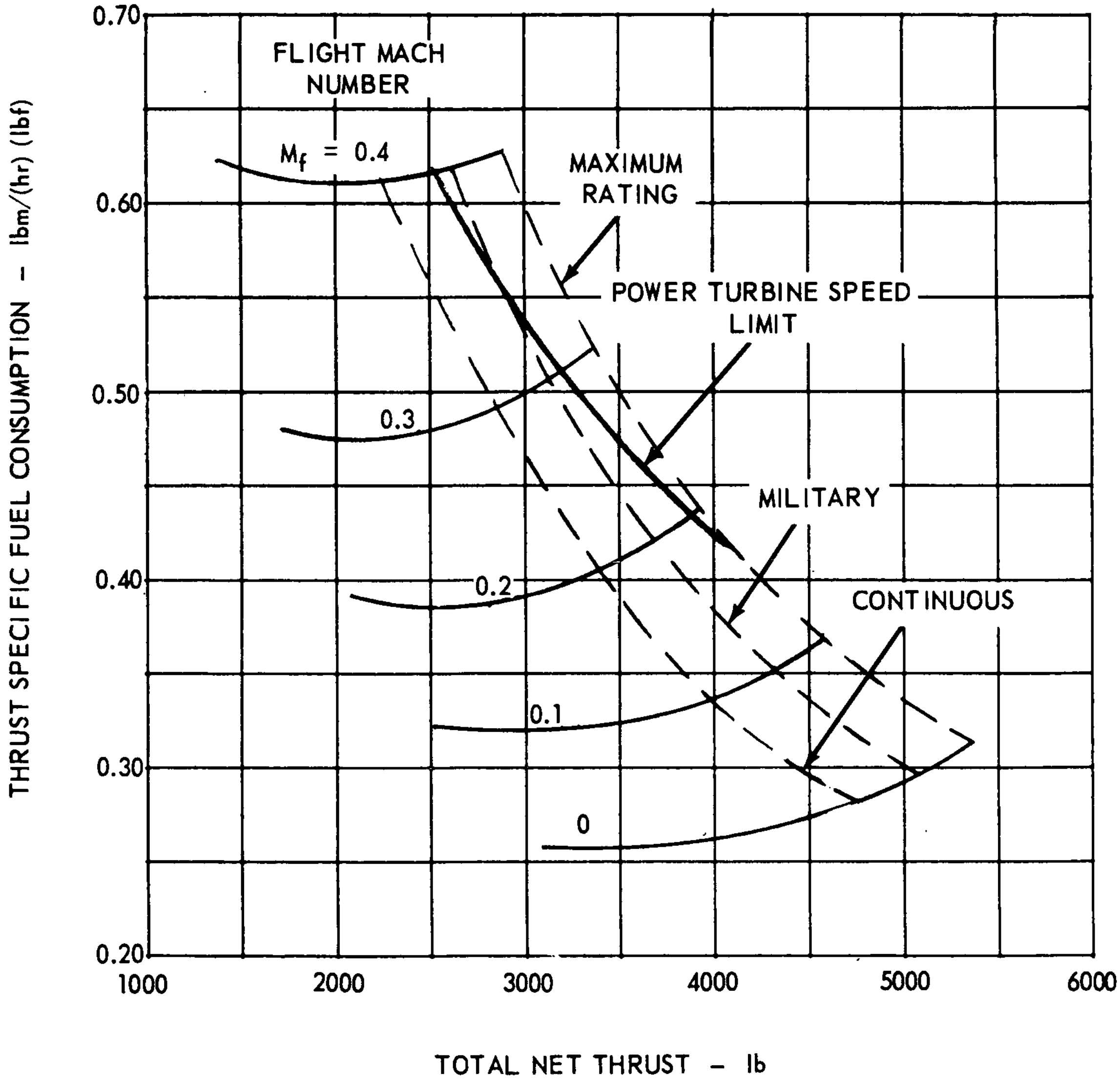


Figure 30. Fan Configuration A (SM = 21 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 15,000 Feet on Standard Day.

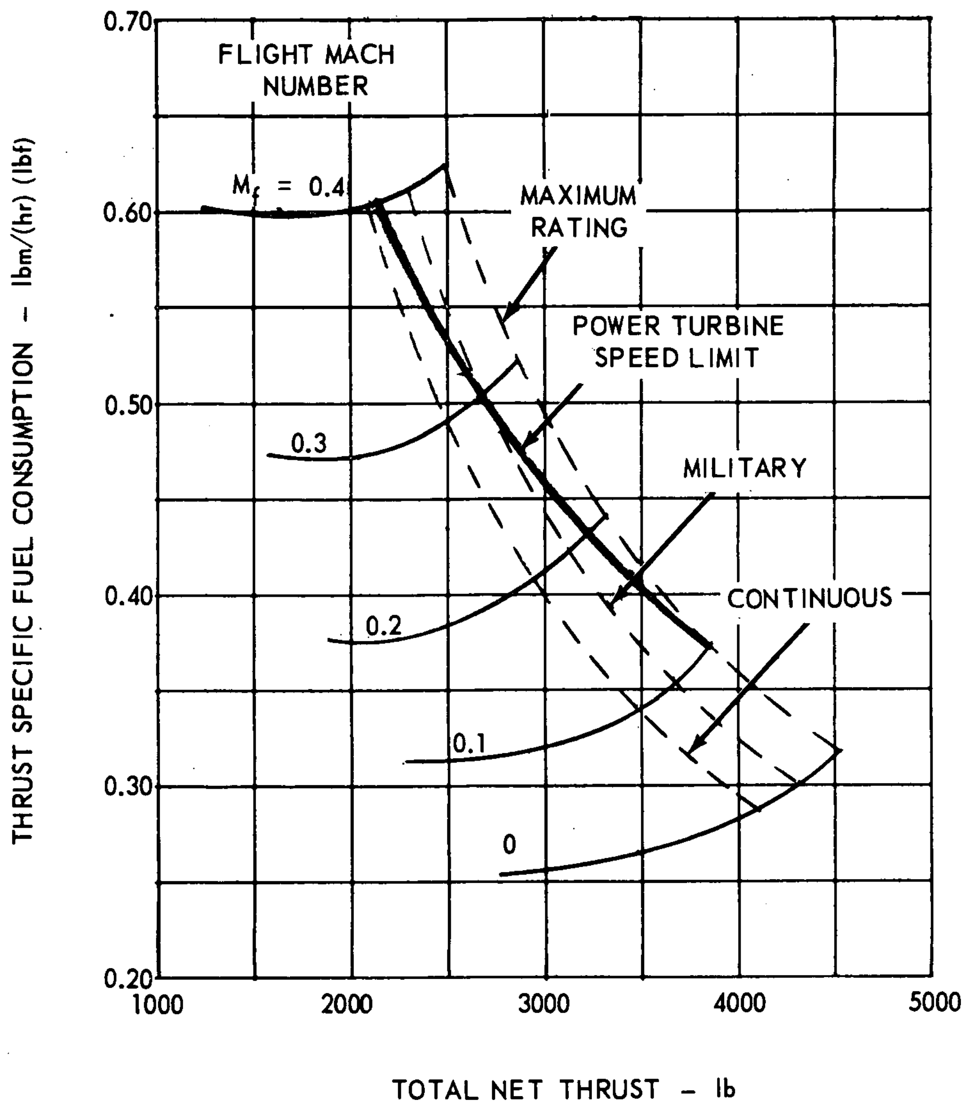


Figure 31. Fan Configuration A (SM = 21 Percent, A_{18} = 1190 Square Inches) Estimated Peformance at 20, 000 Feet on Standard Day.

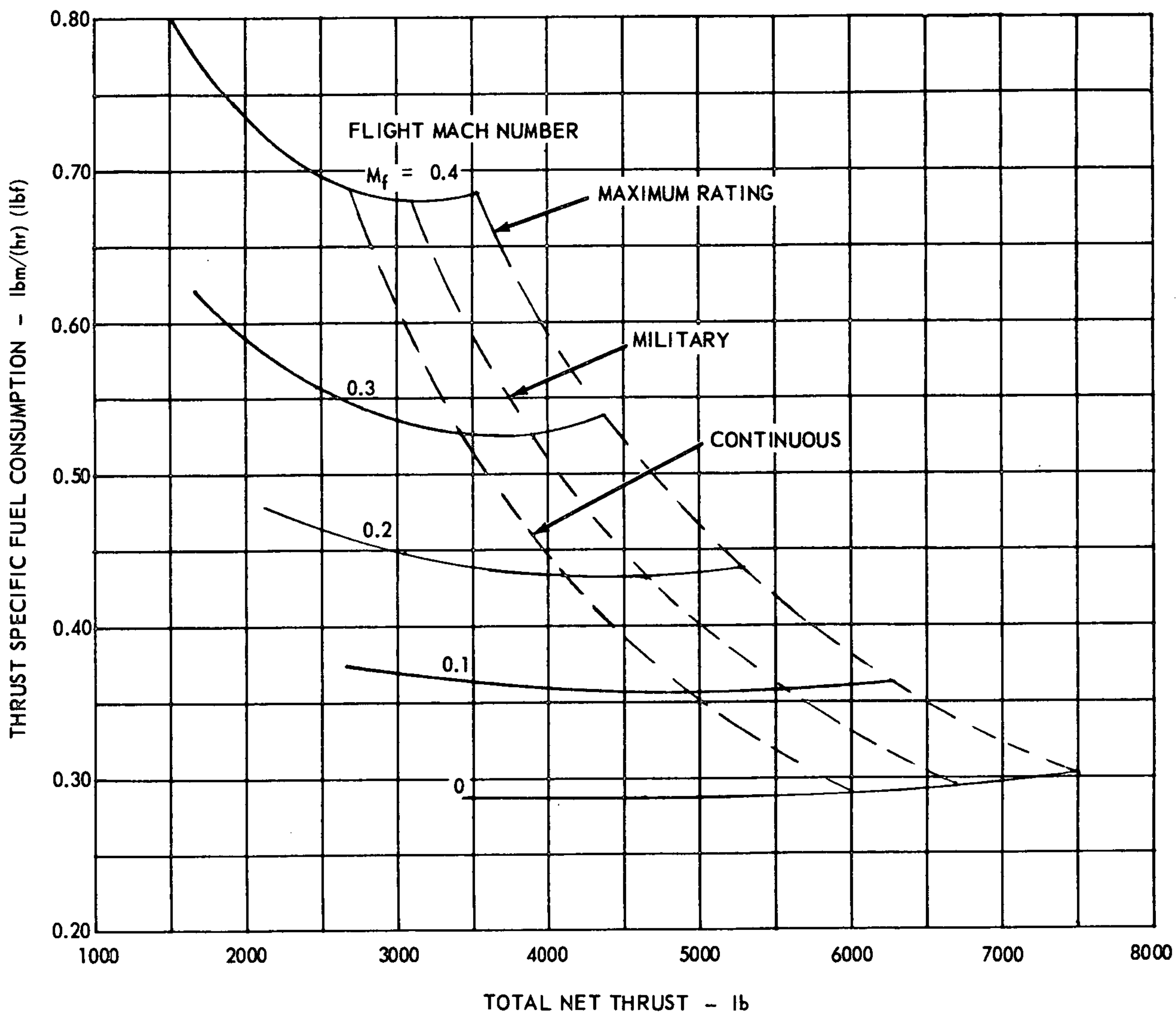


Figure 32. Fan Configuration A (SM = 21 Percent, A_{18} = 1190 Square Inches) Estimated Performance at Sea Level on Tropical Day (90° F).

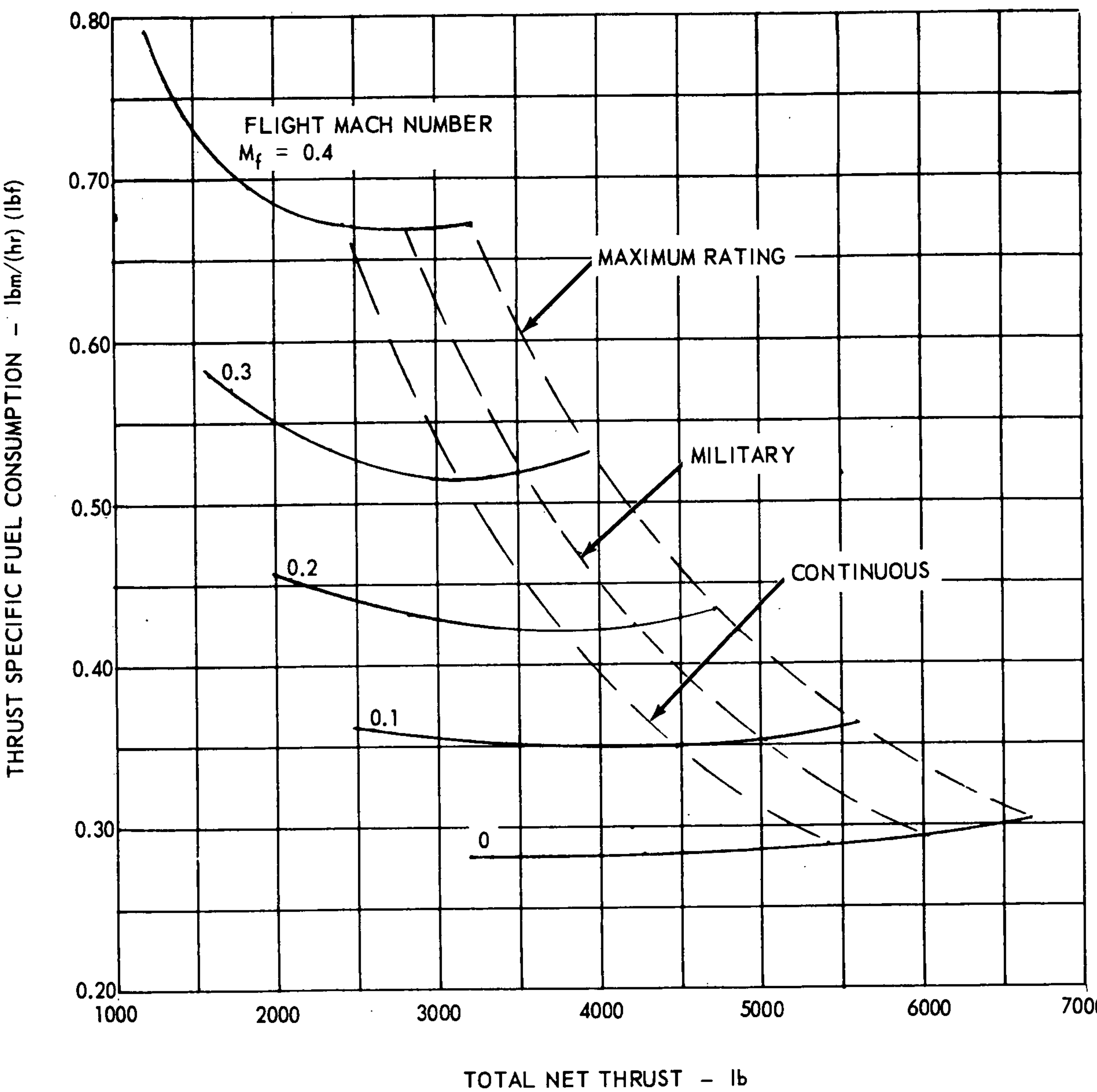


Figure 33. Fan Configuration A (SM = 21 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 5000 Feet on Tropical Day (70° F).

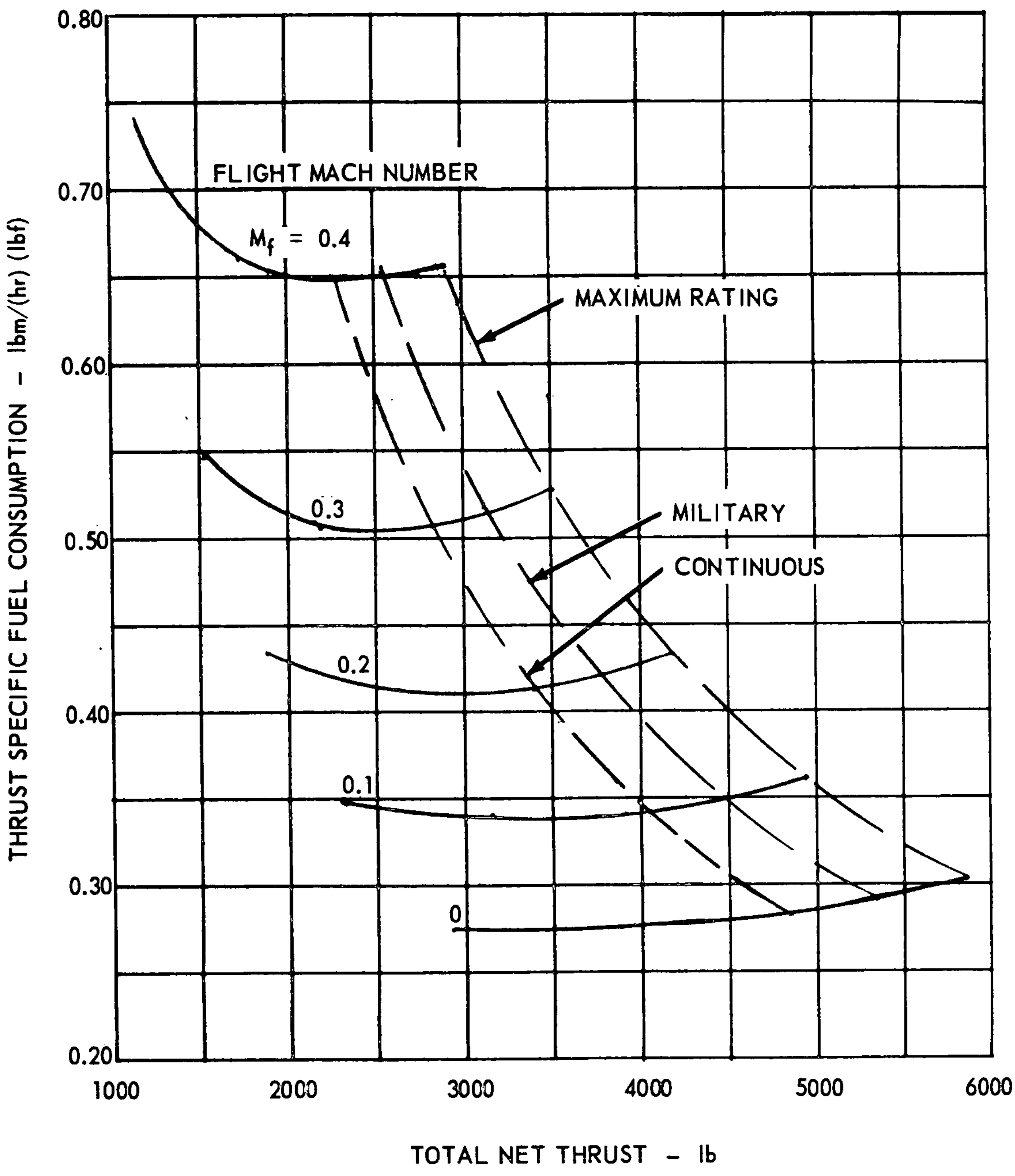


Figure 34. Fan Configuration A (SM = 21 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 10,000 Feet on Tropical Day (51° F).

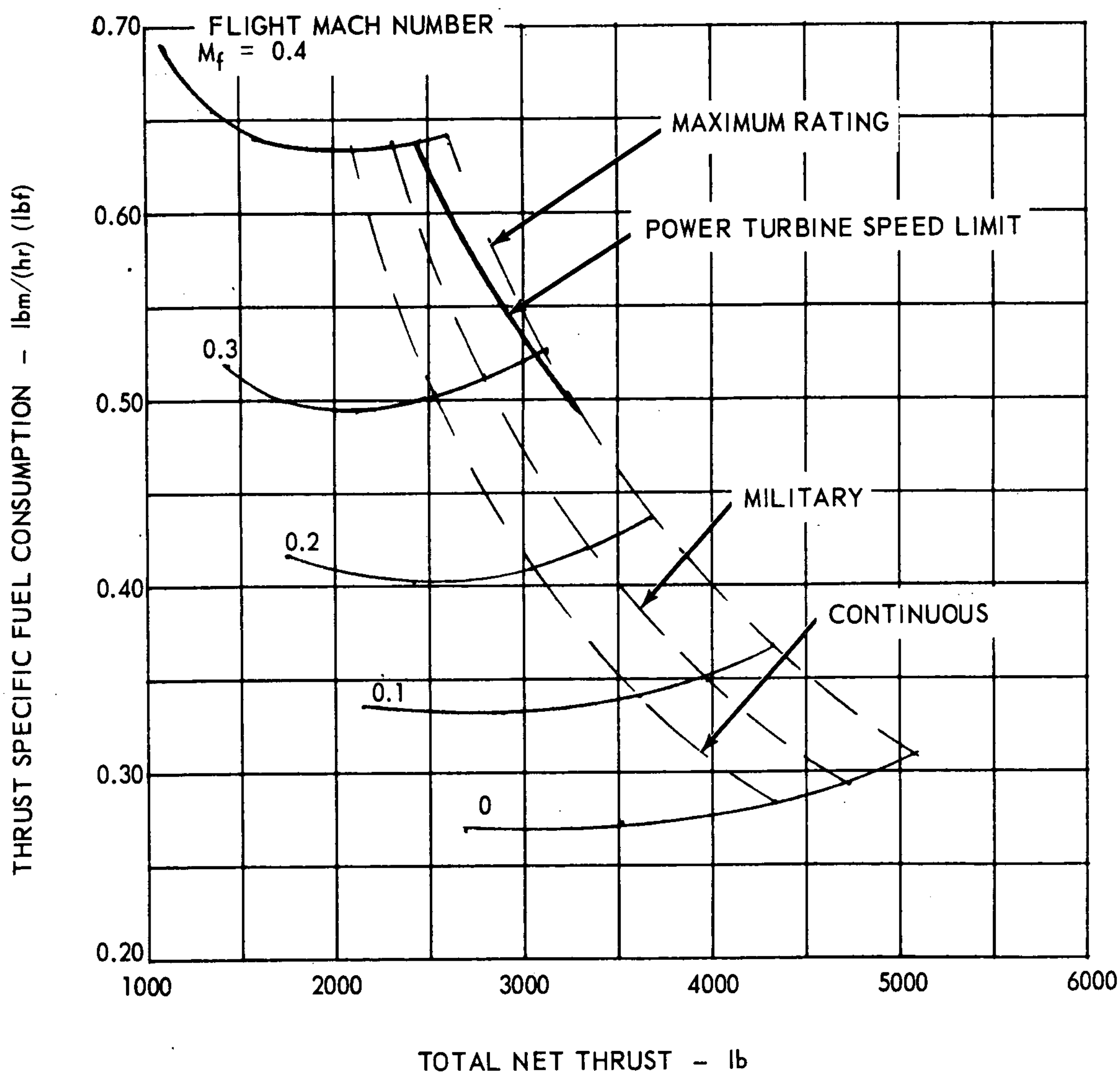


Figure 35. Fan Configuration A (SM = 21 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 15,000 Feet on Tropical Day (32° F).

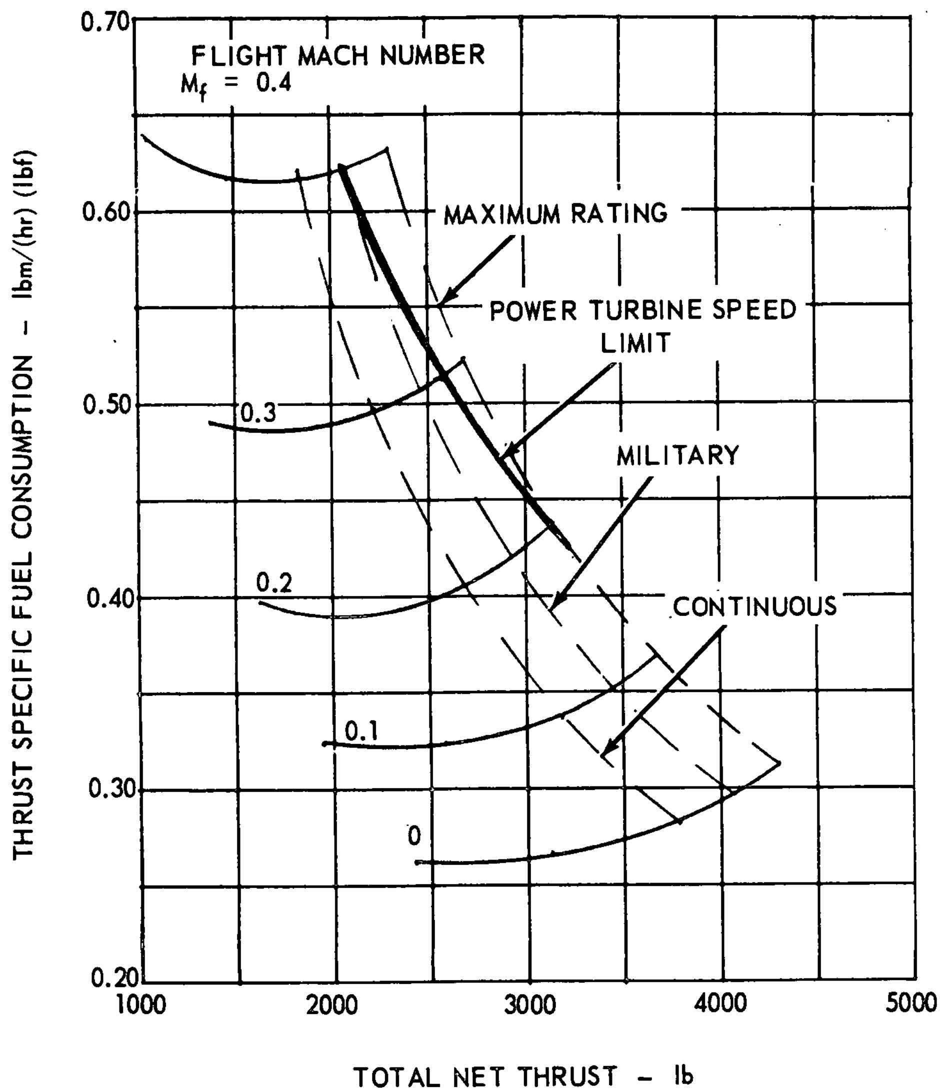


Figure 36. Fan Configuration A (SM = 21 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 20,000 Feet on Tropical Day (12° F).

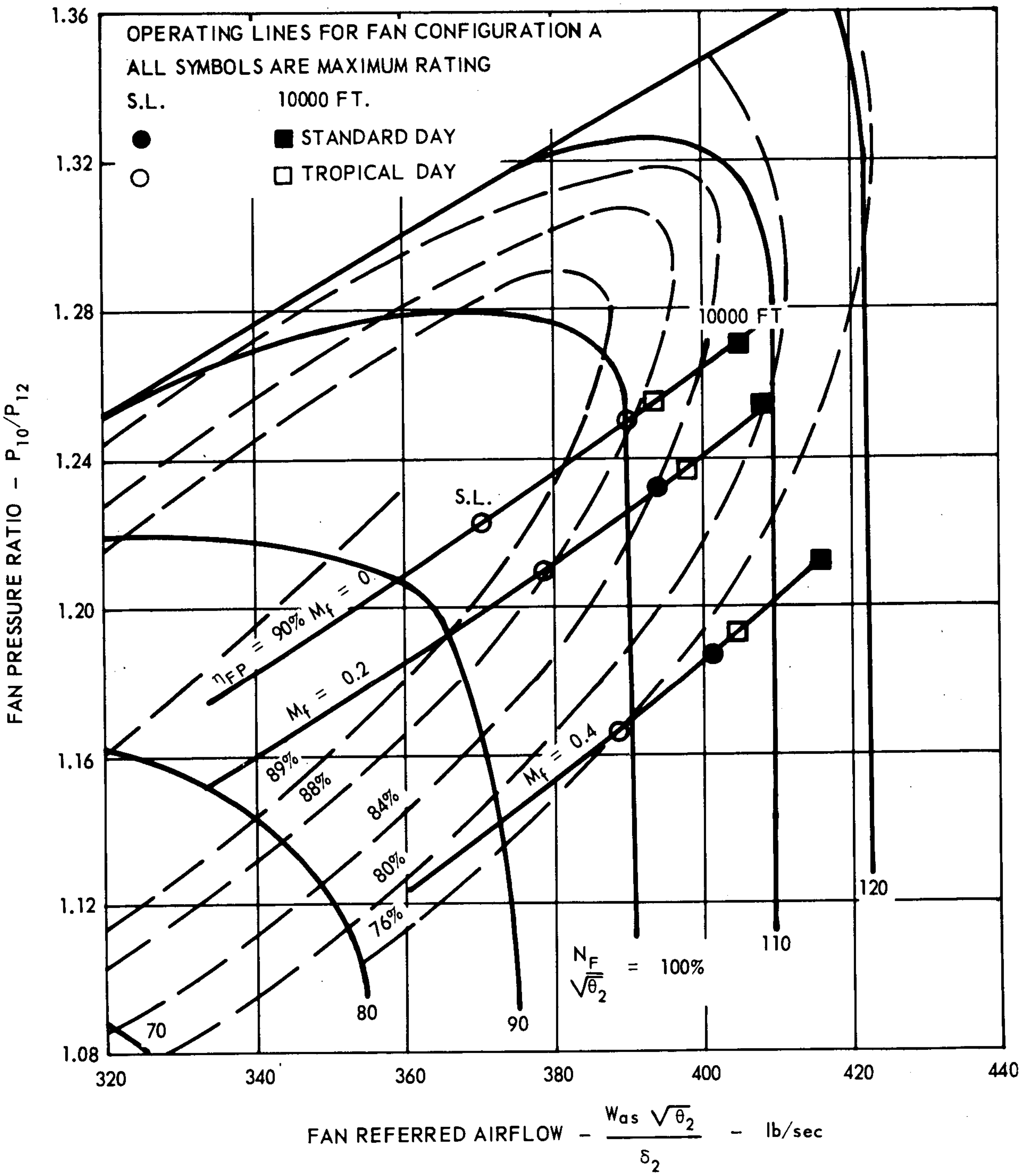


Figure 37. Estimated Fan Performance Map for Configuration A With Fixed Fan Exhaust Nozzle (A_{18} = 1190 Square Inches) Showing Operating Lines.

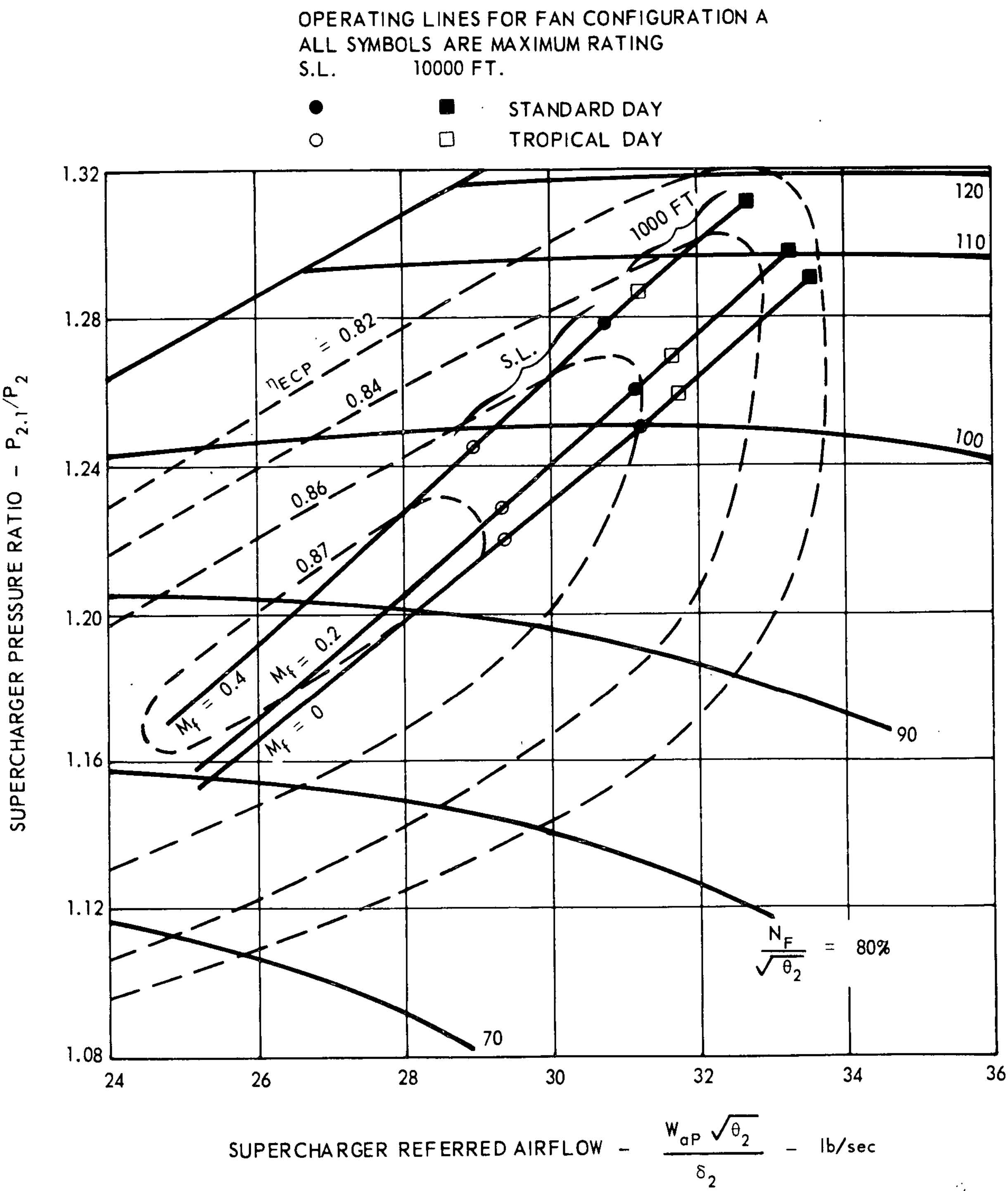


Figure 38. Estimated Supercharger Performance Map With Fixed Fan Exhaust Nozzle (A_{18} = 1190 Square Inches) Showing Operating Lines.

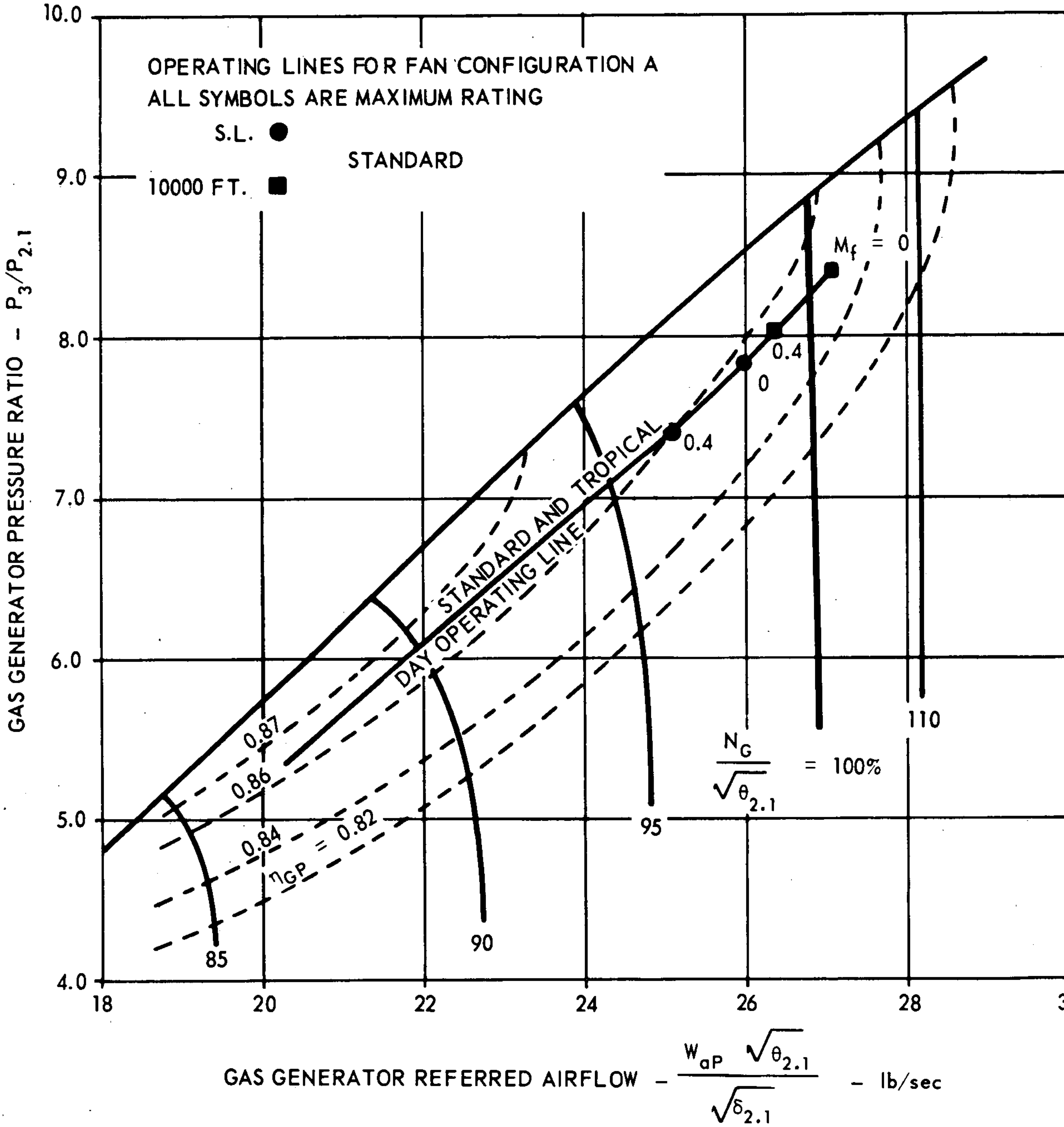


Figure 39. Gas Generator Performance Map Showing Operating Lines.

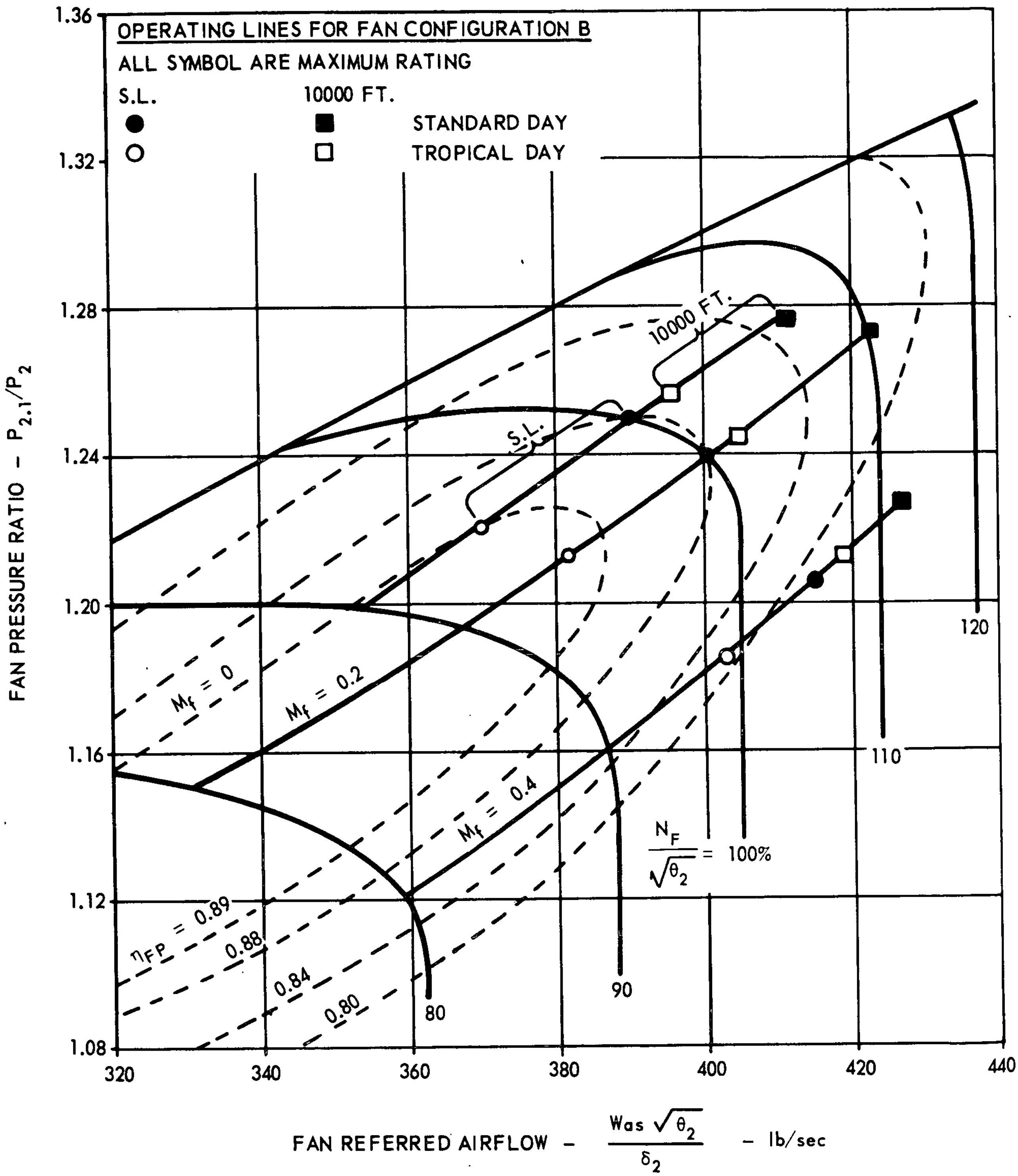


Figure 40. Estimated Fan Performance Map for Configuration B With Fixed Fan Exhaust Nozzle (A_{18} = 1190 Square Inches) Showing Operating Lines.

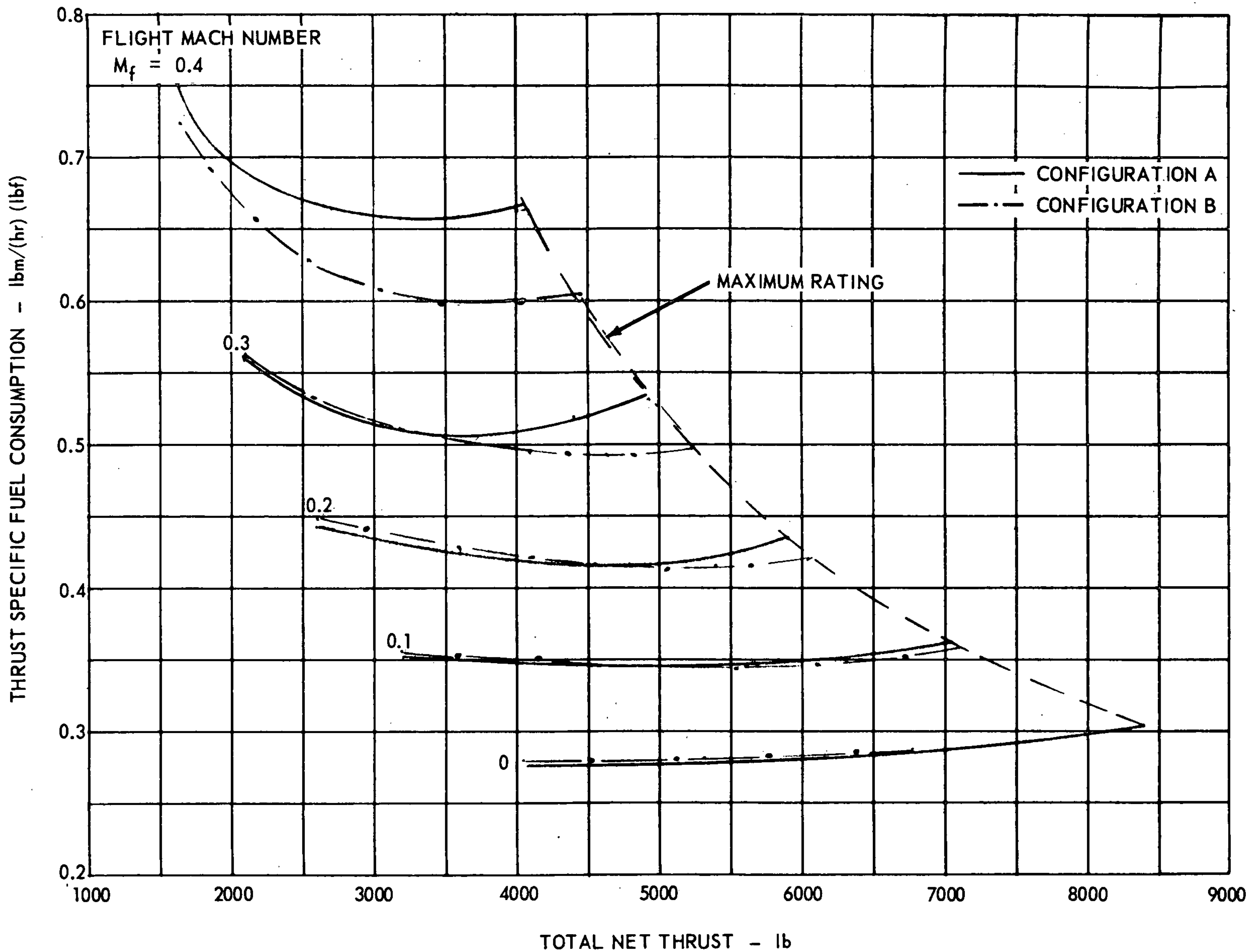


Figure 41. Fan Configurations A and B (A_{18} = 1190 Square Inches) Estimated Performance at Sea Level on Standard Day.

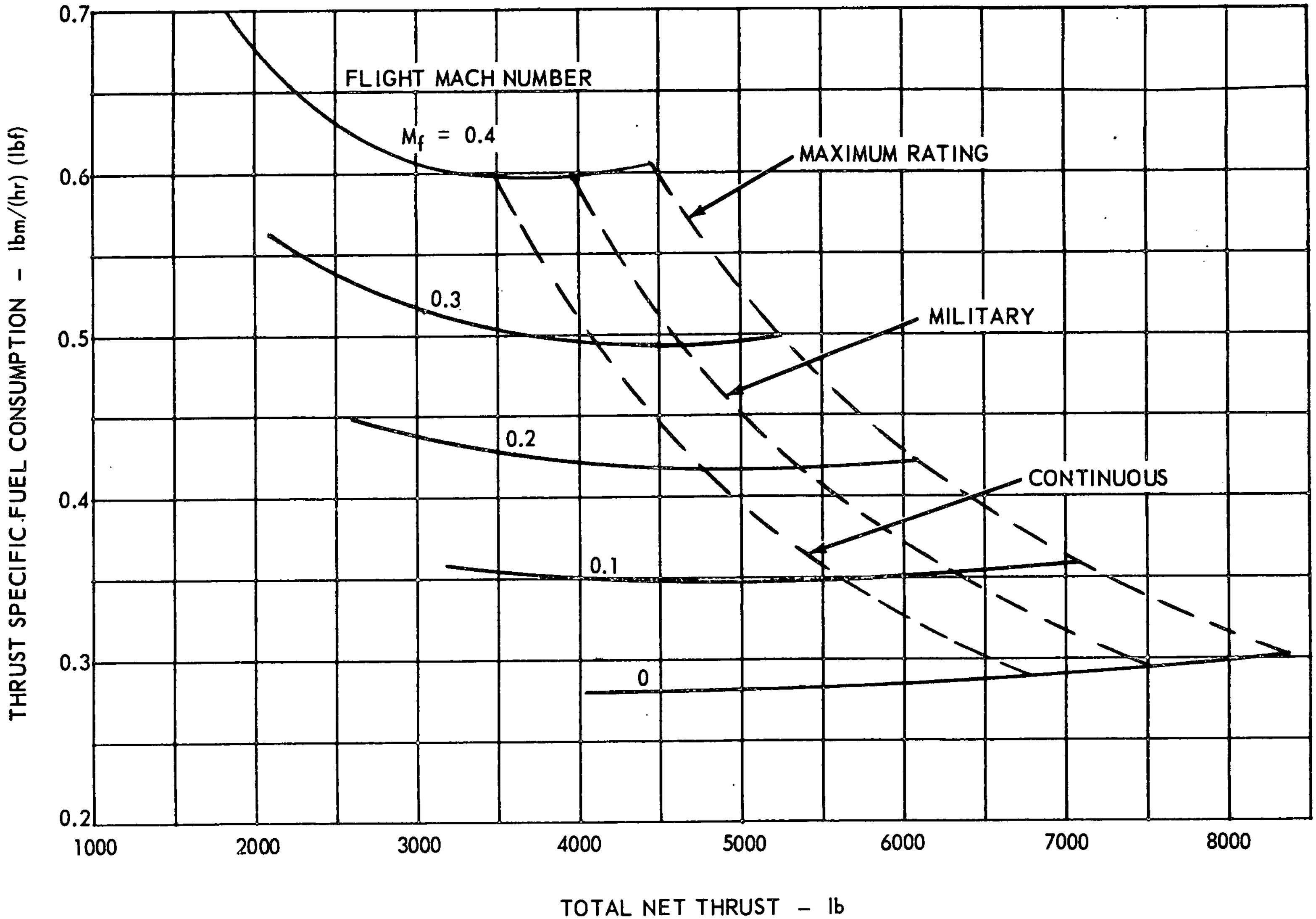


Figure 42. Fan Configuration B (SM = 14 Percent, A_{18} = 1190 Square Inches) Estimated Performance at Sea Level on Standard Day.

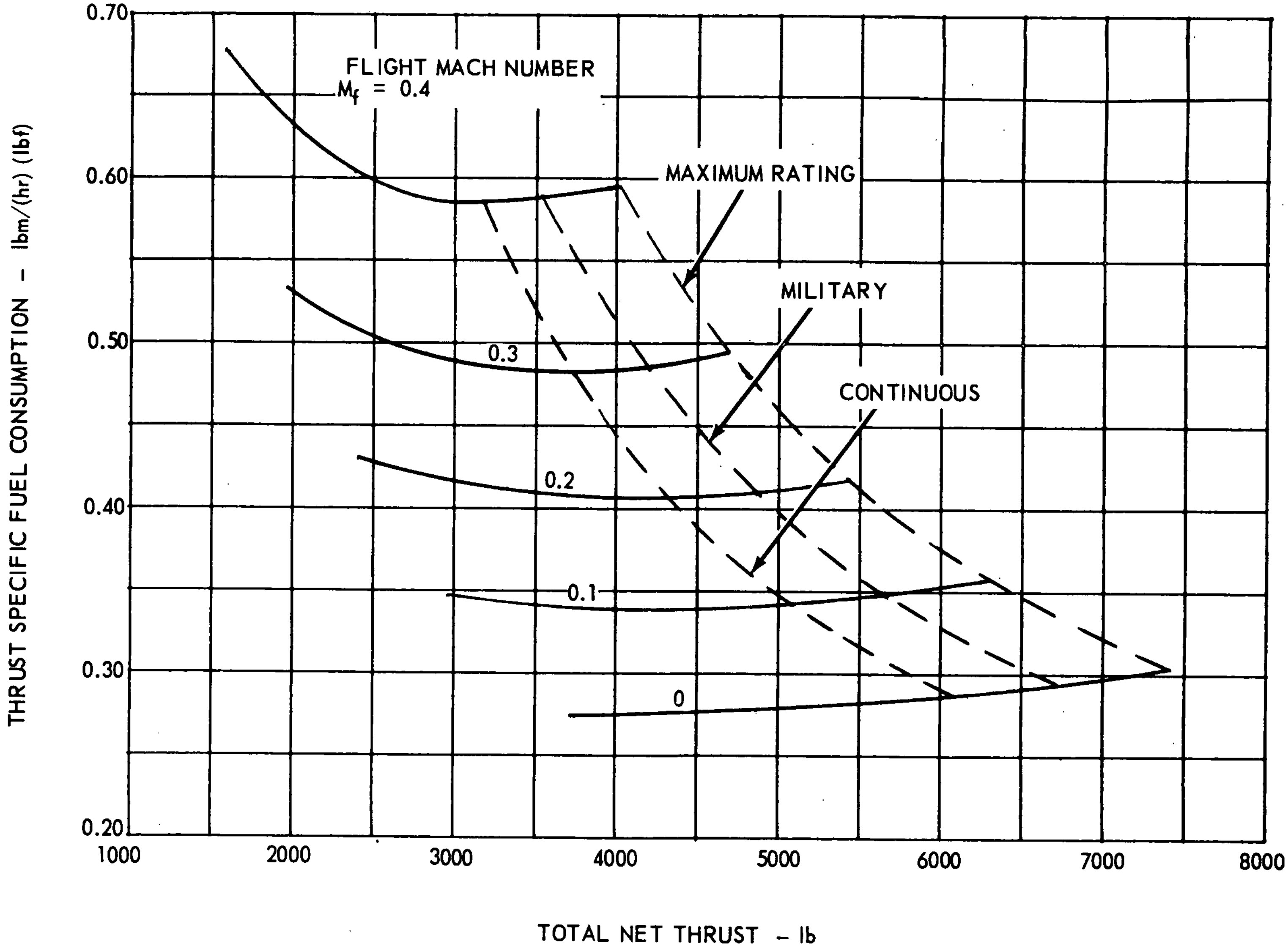


Figure 43. Fan Configuration B (SM = 14 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 5000 Feet on Standard Day.

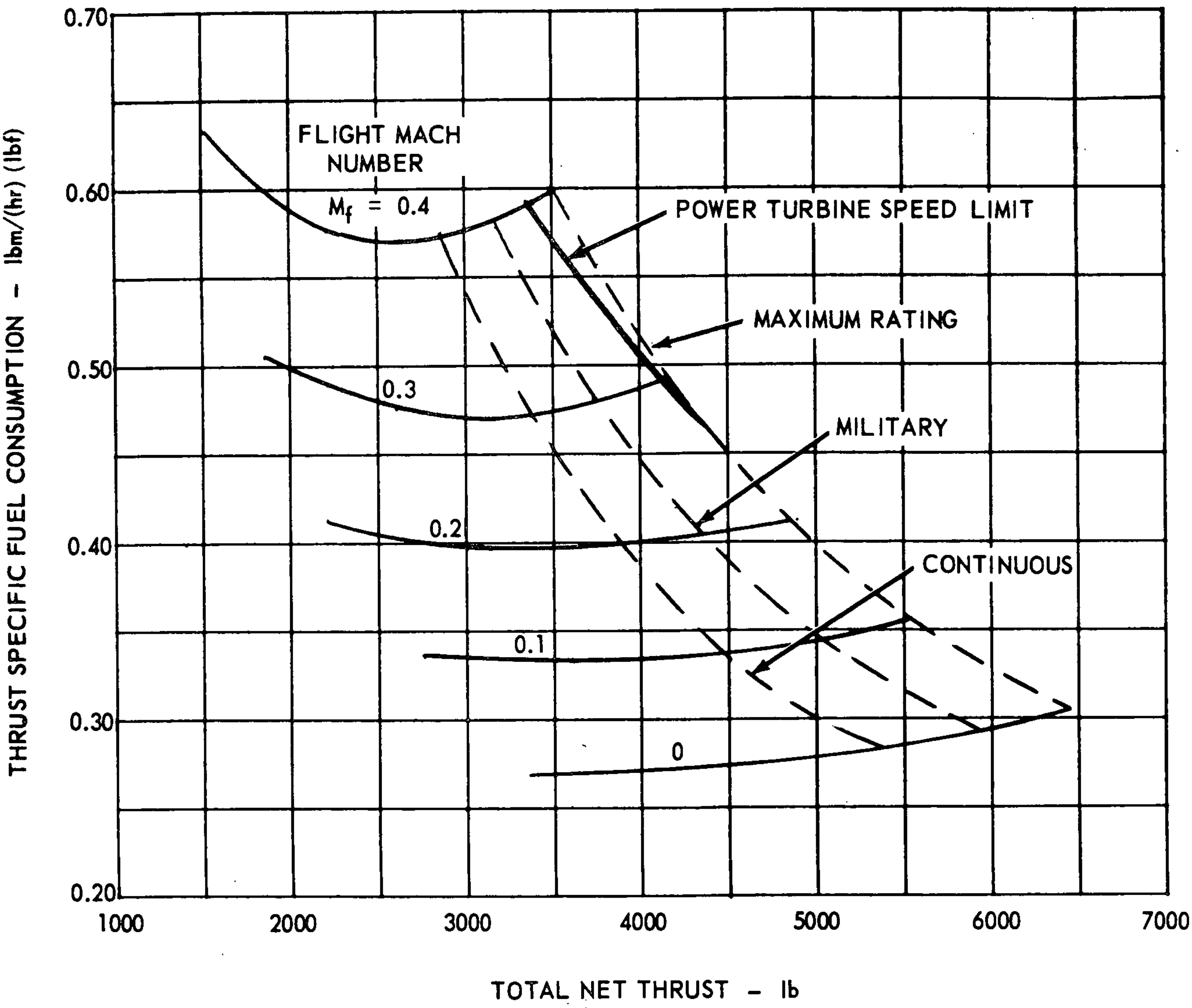


Figure 44. Fan Configuration B (SM = 14 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 10,000 Feet on Standard Day.

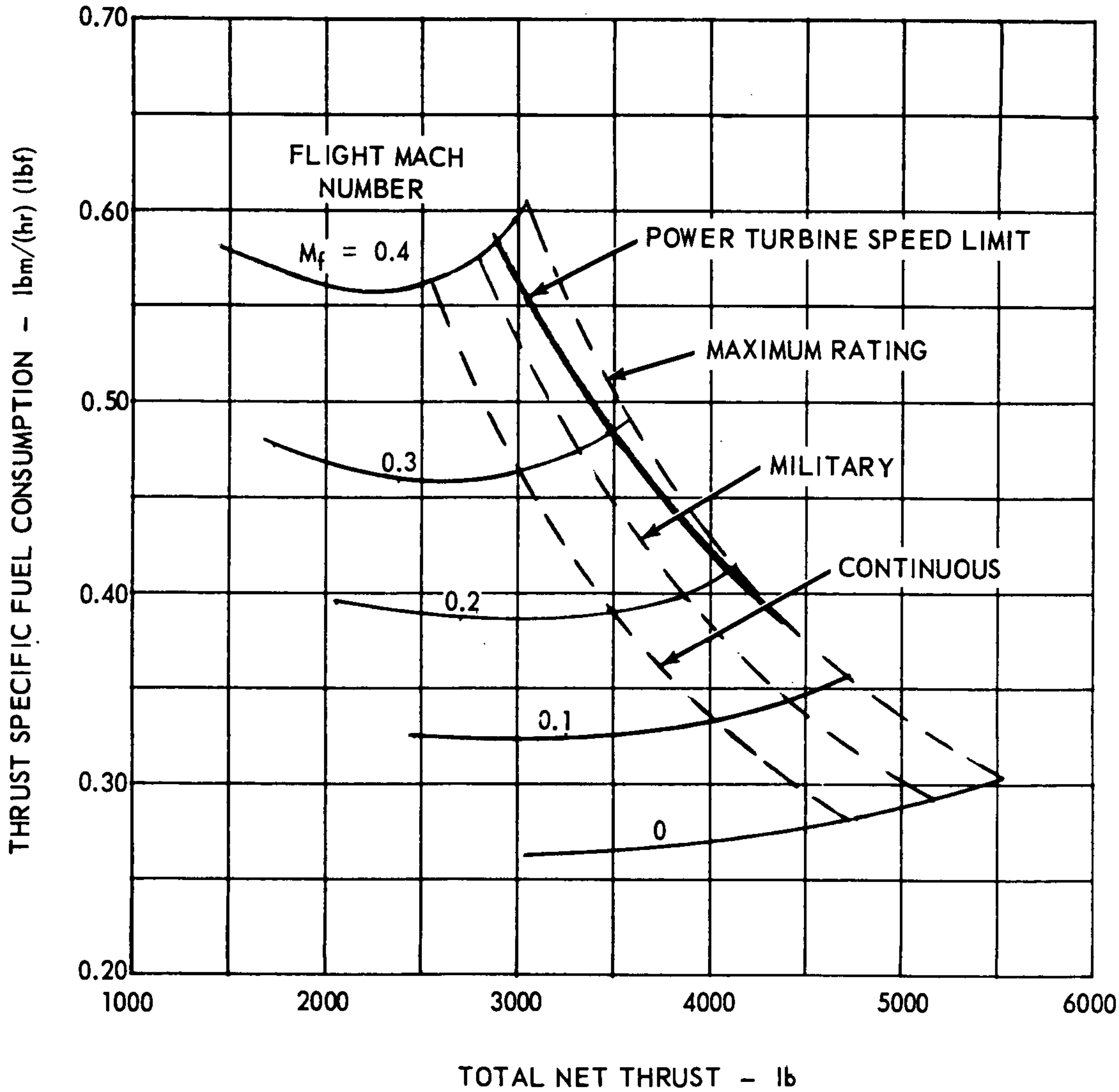


Figure 45. Fan Configuration B (SM = 14 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 15,000 Feet on Standard Day.

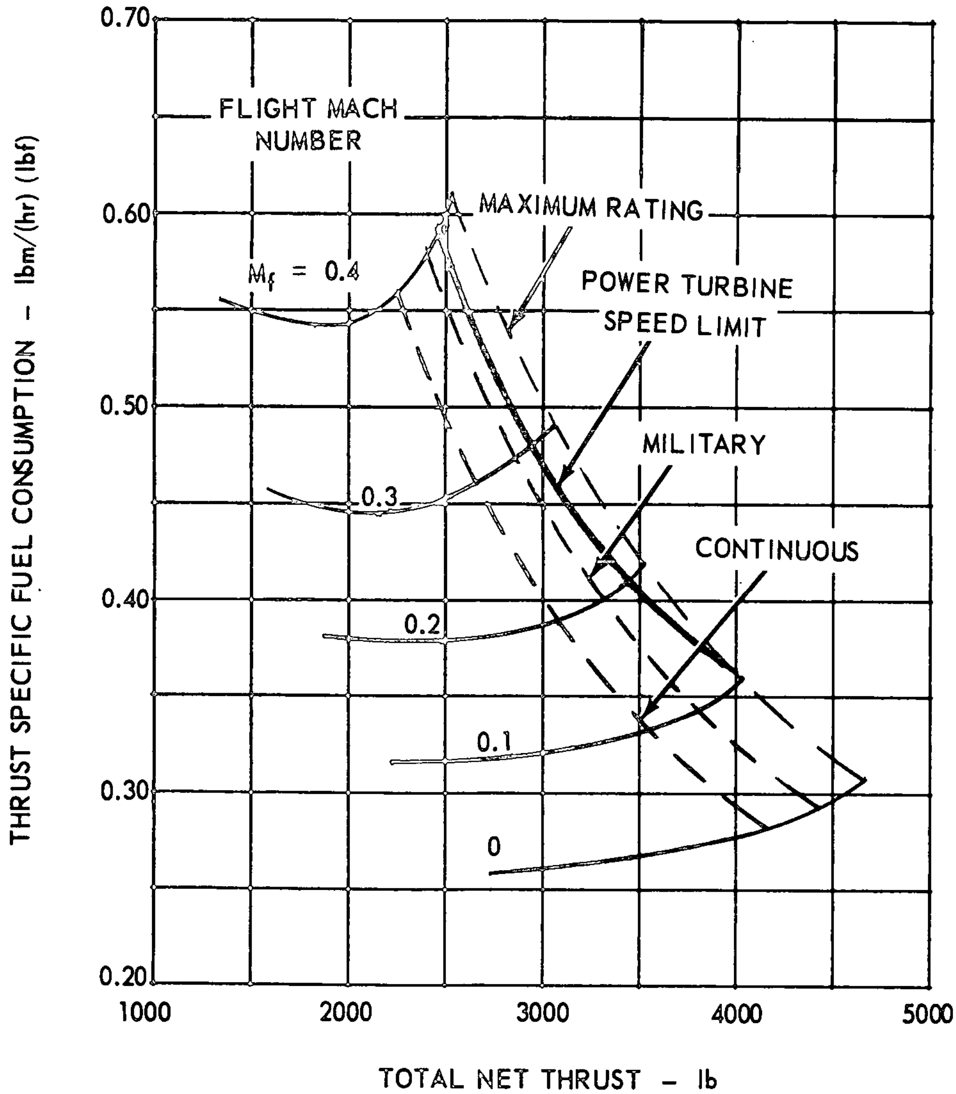


Figure 46. Fan Configuration B (SM = 14 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 20,000 Feet on Standard Day.

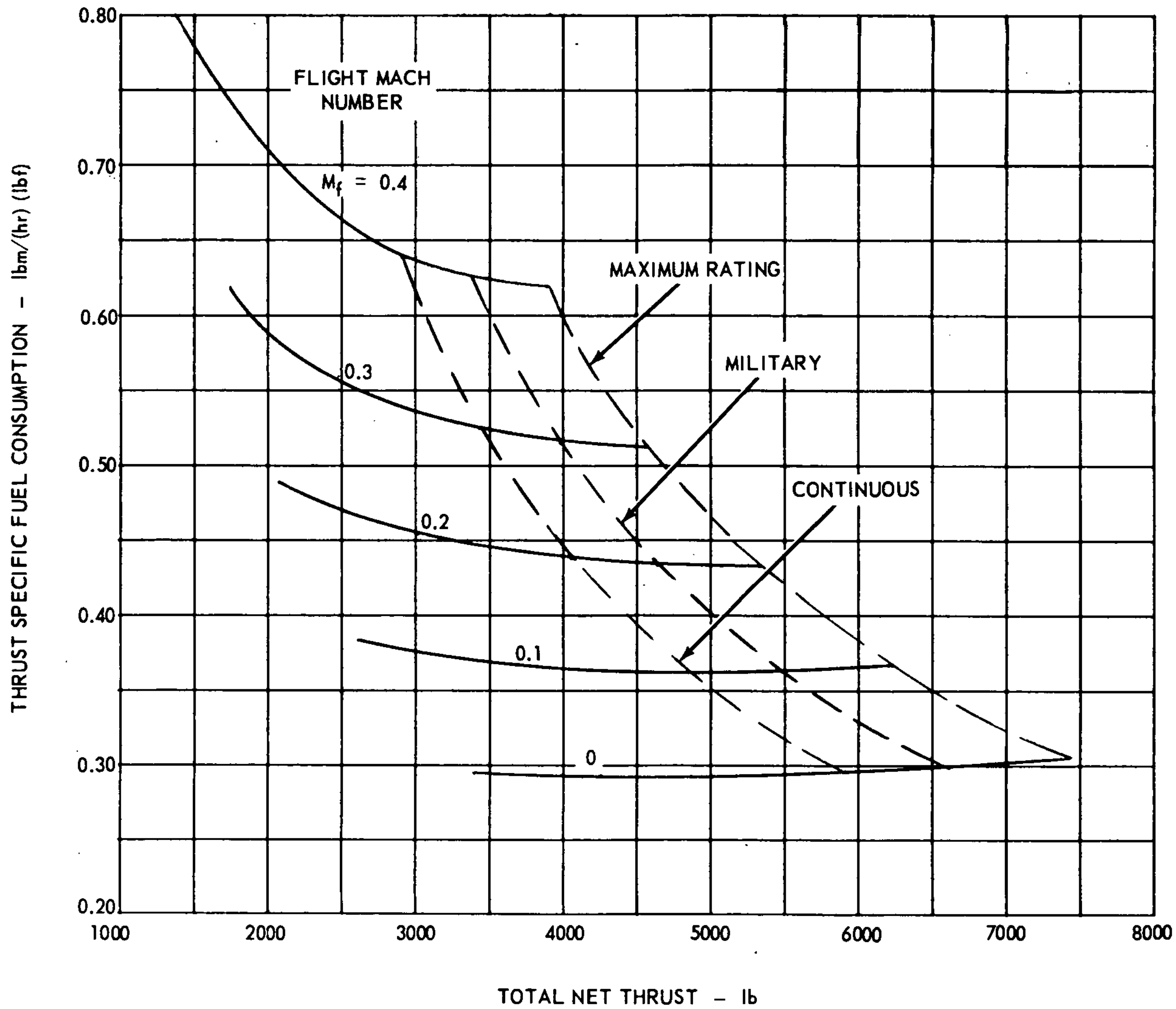


Figure 47. Fan Configuration B (SM = 14 Percent, A_{18} = 1190 Square Inches) Estimated Performance at Sea Level on Tropical Day (90° F).

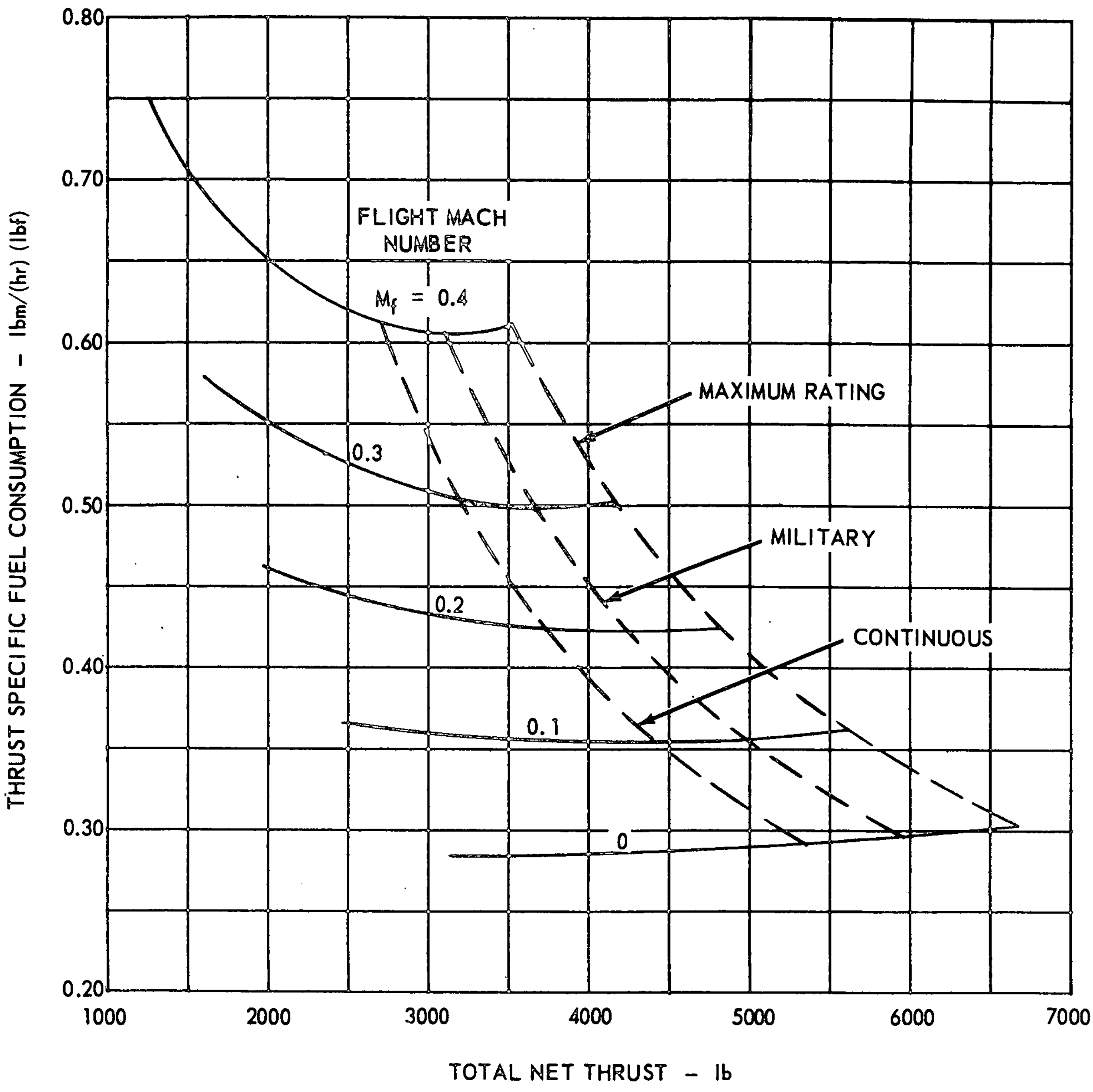


Figure 48. Fan Configuration B (SM = 14 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 5000 Feet on Tropical Day (70° F).

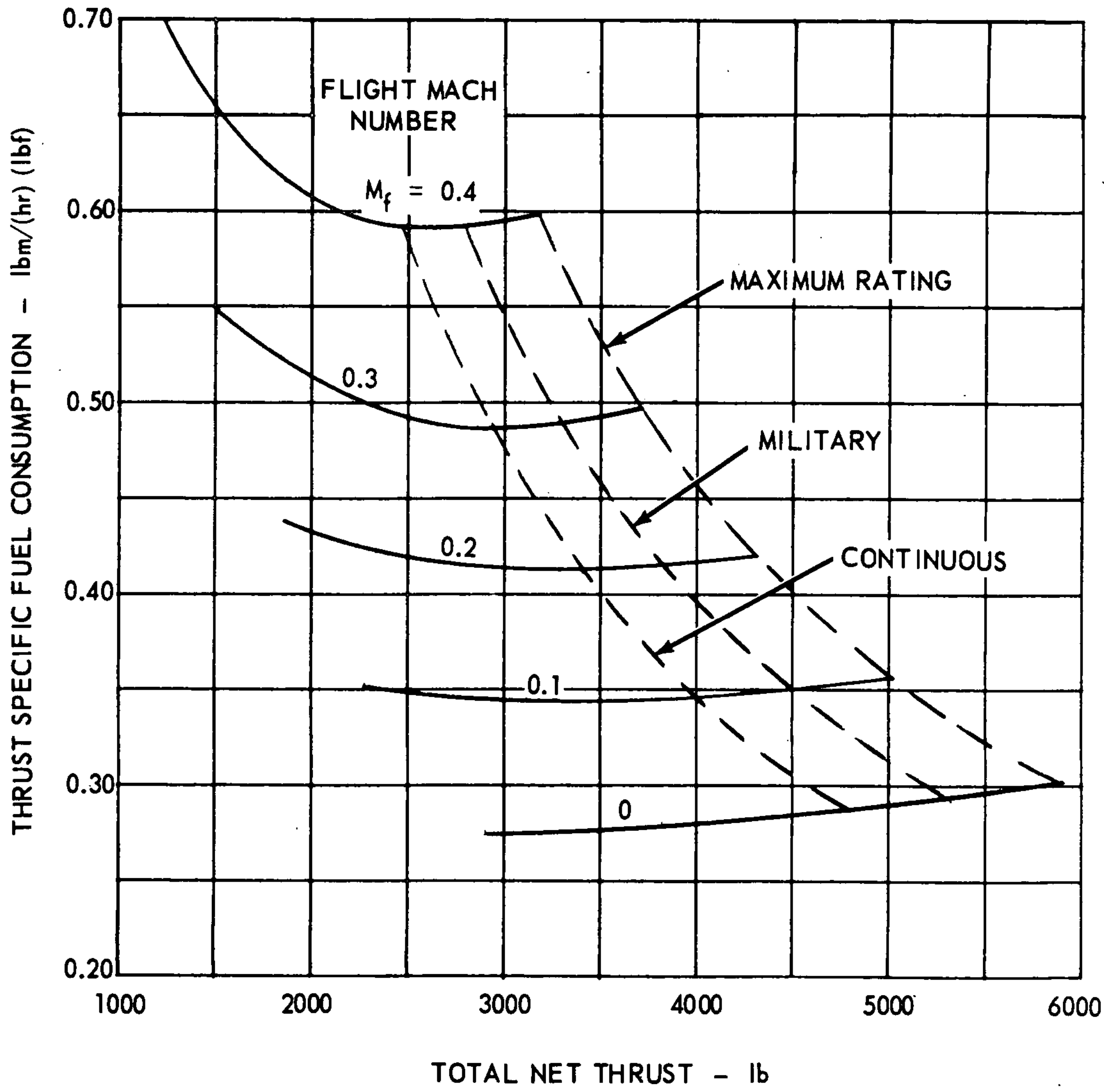


Figure 49. Fan Configuration B (SM = 14 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 10,000 Feet on Tropical Day (51° F).

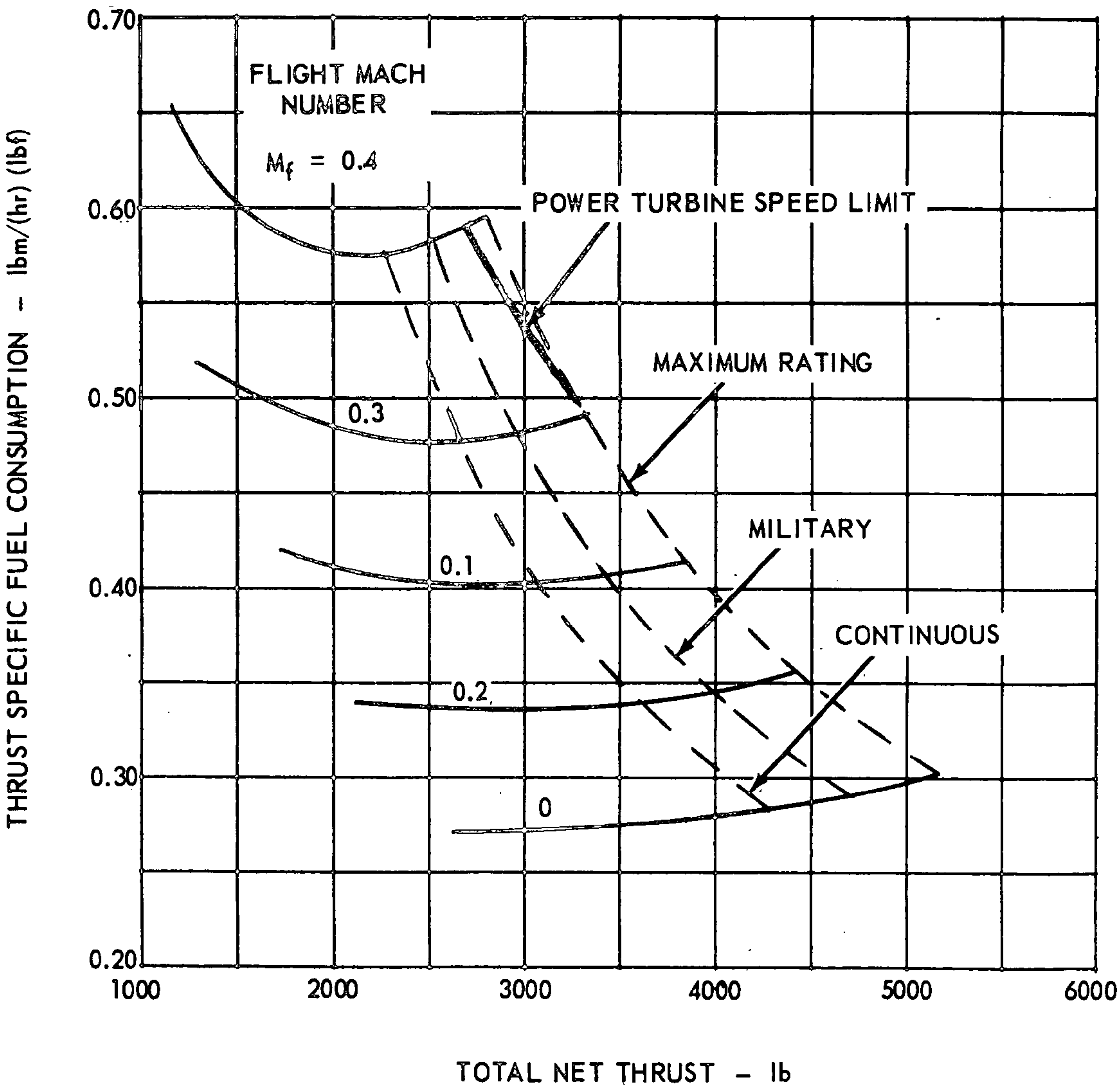


Figure 50. Fan Configuration B (SM = 14 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 15,000 Feet on Tropical Day (32^{o} F).

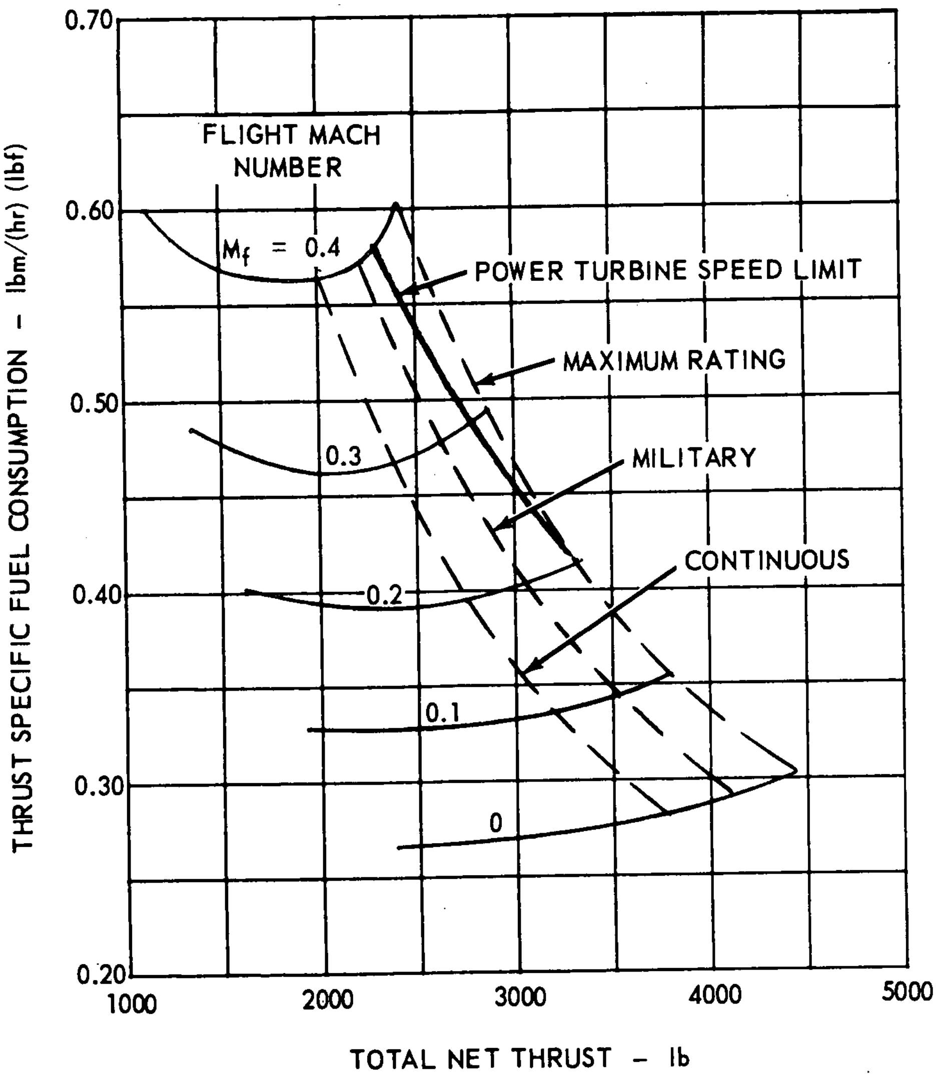


Figure 51. Fan Configuration B (SM = 14 Percent, A_{18} = 1190 Square Inches) Estimated Performance at 20,000 Feet on Tropical Day (12° F).

Estimated acceleration time for 66 percent of the interval between 80 percent maximum F_{NT} (total net thrust) and maximum F_{NT} (or, 80 percent maximum F_{NT} to 93.2 percent maximum F_{NT}) for sea level standard conditions at Mach numbers from static to 0.4 M_f is 2.5 seconds. The accelration schedule used is the same $W_f/\delta_{2.1}\sqrt{\theta_{2.1}}$ versus $N_G/\sqrt{\theta_{2.1}}$ as that of the B-12 shaft engine and has full high compressor interstage bleed along the transient schedule. This insures the same high compressor referred acceleration surge margin for the fan that has been proven to be safe for the shaft engine using the same core components.

Variable Bypass Nozzle

The degradation in fan efficiency associated with increasing flight Mach number can be neutralized with the use of an infinitely variable bypass stream exhaust nozzle. Reduction of nozzle area moves the fan operating line toward surge, thereby reversing the deleterious effect of increased Mach number with constant nozzle area. Of course, the control system associated with a nozzle that is made to vary continuously is quite complex, and the concept of a "two-position" exhaust nozzle with a more simple control requirement still affords the basic advantage of improved cruise performance.

Figure 52 is the Fan A characteristic with sea level operating lines shown at static and 0.4 M_f for the base fan stream exhaust nozzle area. The result of reducing the nozzle area (12.0 percent) to relocate the 0.4 M_f maximum rating match point into the static operating line, with the associated higher fan efficiency, provides a performance improvement of 16 percent F_{NT} and 15 percent TSFC. Now, free stream Mach number may be increased to 0.7 M_f before returning the maximum rating point to the operating efficiency of the 0.4M_f point of the base configuration. The resultant performance improvement at cruise Mach numbers above 0.4 M_f is shown in Figure 53, which presents comparative sea level standard day performance for both bypass exhaust nozzle areas.

POWER TURBINE ANALYSIS

General

An important aspect of the integral fan engine design includes use of the 502 MQT power turbine. This turbine has been designed with a 14 percent increased exhaust annular area, and will be phased into the 502 fan engine program much in advance of NASA time requirements. Use of the MQT power turbine reduces the exit velocity from 1,000 to 870 ft/sec for a

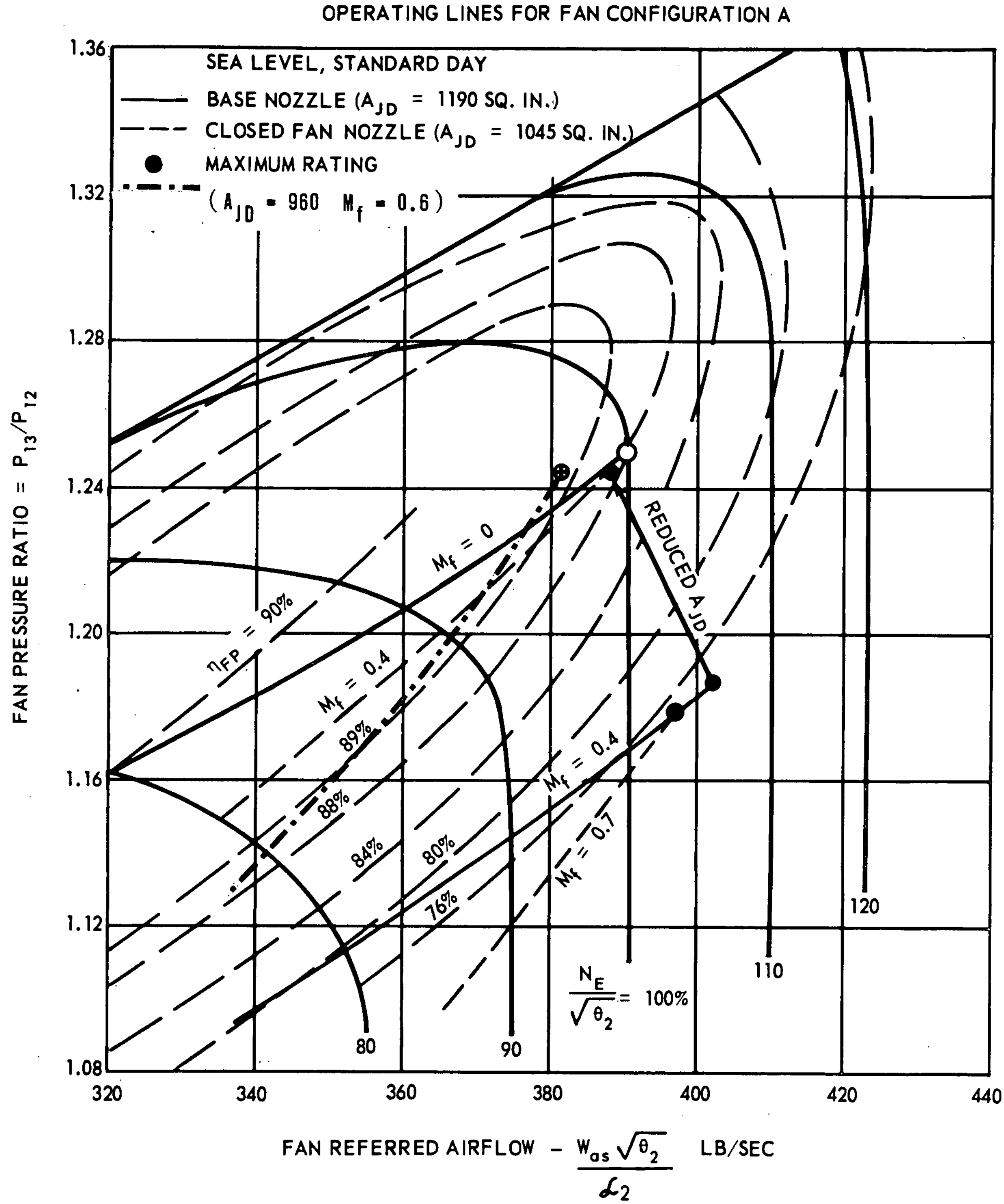


Figure 52. Estimated Fan Performance Map for Configuration A Showing Operating Lines With Two-Position Fan Exhaust Nozzle.

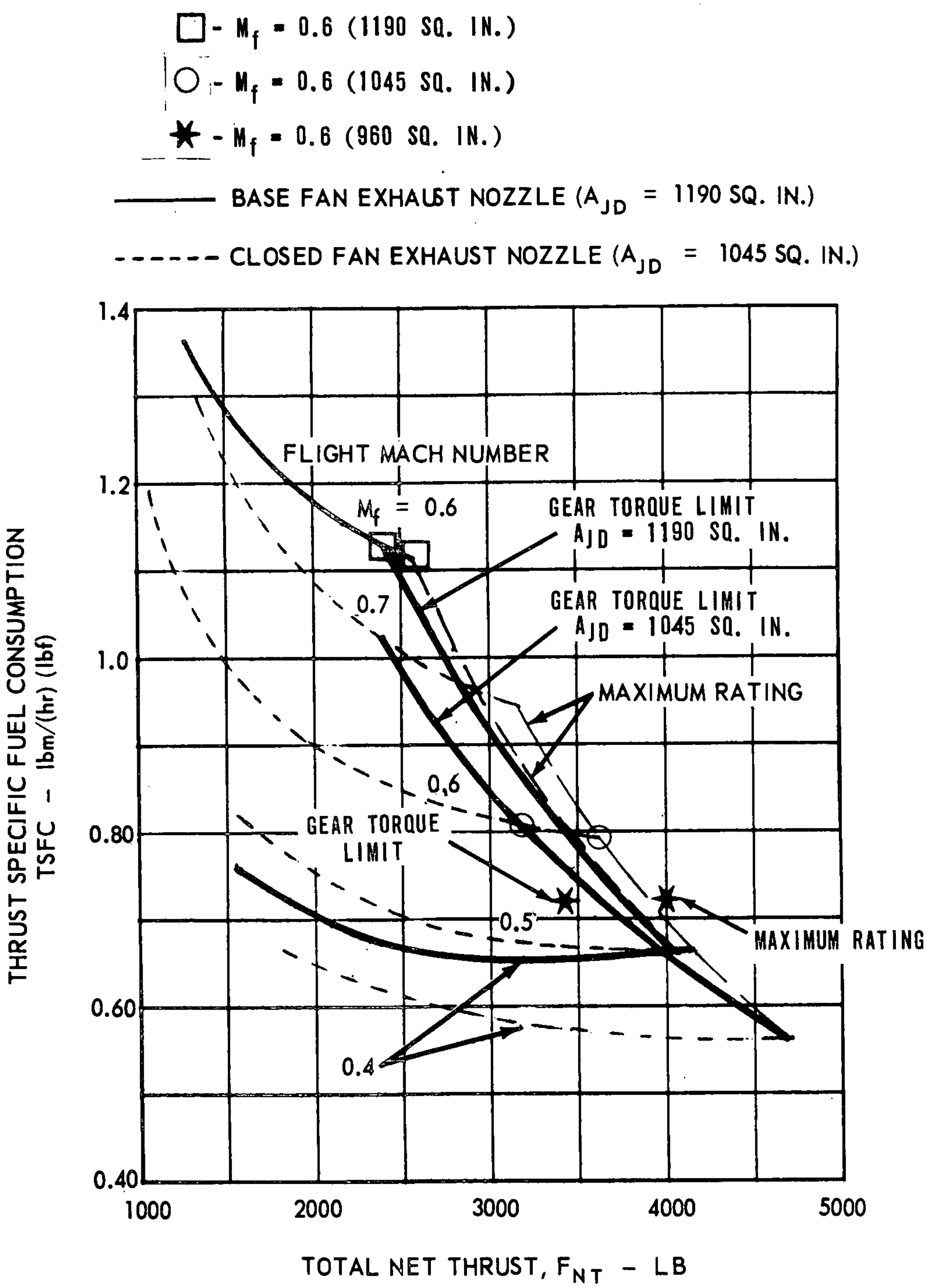


Figure 53. Fan Configuration A (SM = 21 Percent at 100 Percent $N/\sqrt{\theta}$) Estimated Performance at Sea Level on Standard Day With Two-Position Fan Exhaust Nozzle.

condition of exit static pressure equal to ambient. This reduction in hot jet exhaust velocity will have an important effect on the jet noise, since the use of a diffuser after the turbine was not acceptable because of the increase in engine length and related problems of ground clearance in the aircraft installation.

Cycle Requirements and Turbine Aerothermodynamic Analysis

Matching studies of the 502 core engine supercharged by a 1.25:1 pressure-ratio fan show that the flow capacity $W\sqrt{\theta_{cr}}/\delta$ of the MQT power turbine is 8.5 percent too large. As a consequence, an off-design analysis was made on the turbine blading to reduce the flow capacity to the required value of 17.03 lb/sec. Since a relatively small change in flow capacity was required to produce the proper engine matching condition at the desired compressor pressure ratio and maximum temperature, it was possible to accomplish the reduction by increasing the fist stator stagger angle by 3.6 degrees to decrease the area and give the required flow capacity. The analysis accounted for change in incidence from the optimum value and Mach number change effects on each of the four cascades involved. The results showed that the loss in overall turbine efficiency resulting from the nozzle stagger angle change was 0.6 points, which assures the 0.887 value used in the cycle calculation since the MQT turbine target efficiency is 0.89 to 0.90.

Of particular interest in the analysis is the lowering of the second stage hub reaction when the flow reduction is made by the most simple change in turbine geometry involving only the first stage nozzle. The analysis indicated that a small acceleration was maintained at the second rotor hub, which should be adequate for the low camber (fluid turning 79 degrees) and low hub tip ratio (0.54) of this cascade.

Figures 54 and 55 show the hub, mean, and tip velocity triangles for the modified MQT power turbine at the sea level static design point. The thermodynamic state points are also included for additional information.

ENGINE WEIGHT

Weight analysis for the integral life fan engine was relatively simple since the core is made up of the Lycoming T55-B12 turboshaft engine with the MQT power turbine; therefore, the weight is accurately known for these components, and only the new fan component, bypass duct including exhaust nozzle and the duct sound-attenuating rings and wall treatment had to be calculated. The weight of these new components was determined from basic aerodynamic design and mechanical design considerations already described.

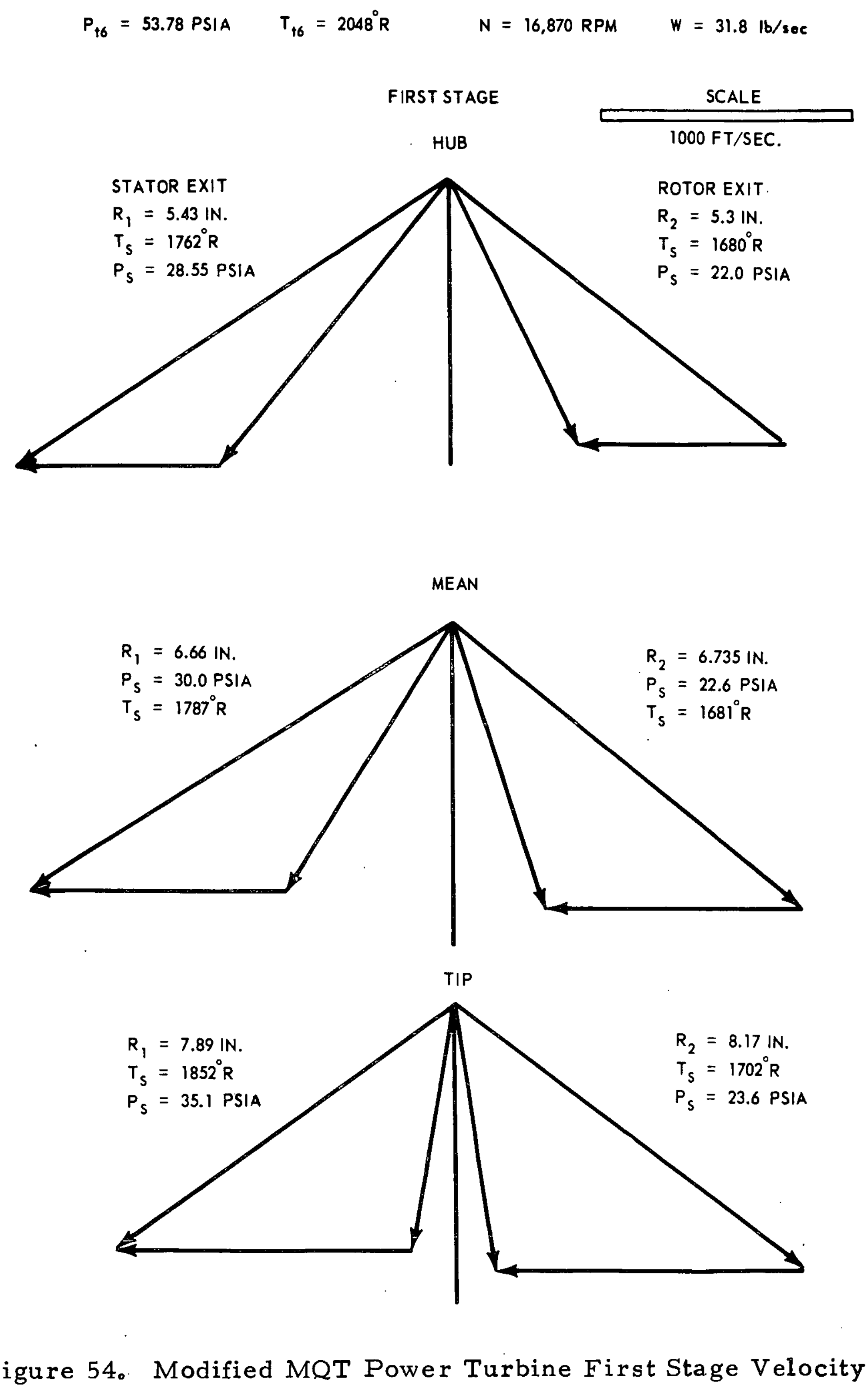


Figure 54. Modified MQT Power Turbine First Stage Velocity Triangles for 8.5 Percent Reduced Inlet Flow Function.

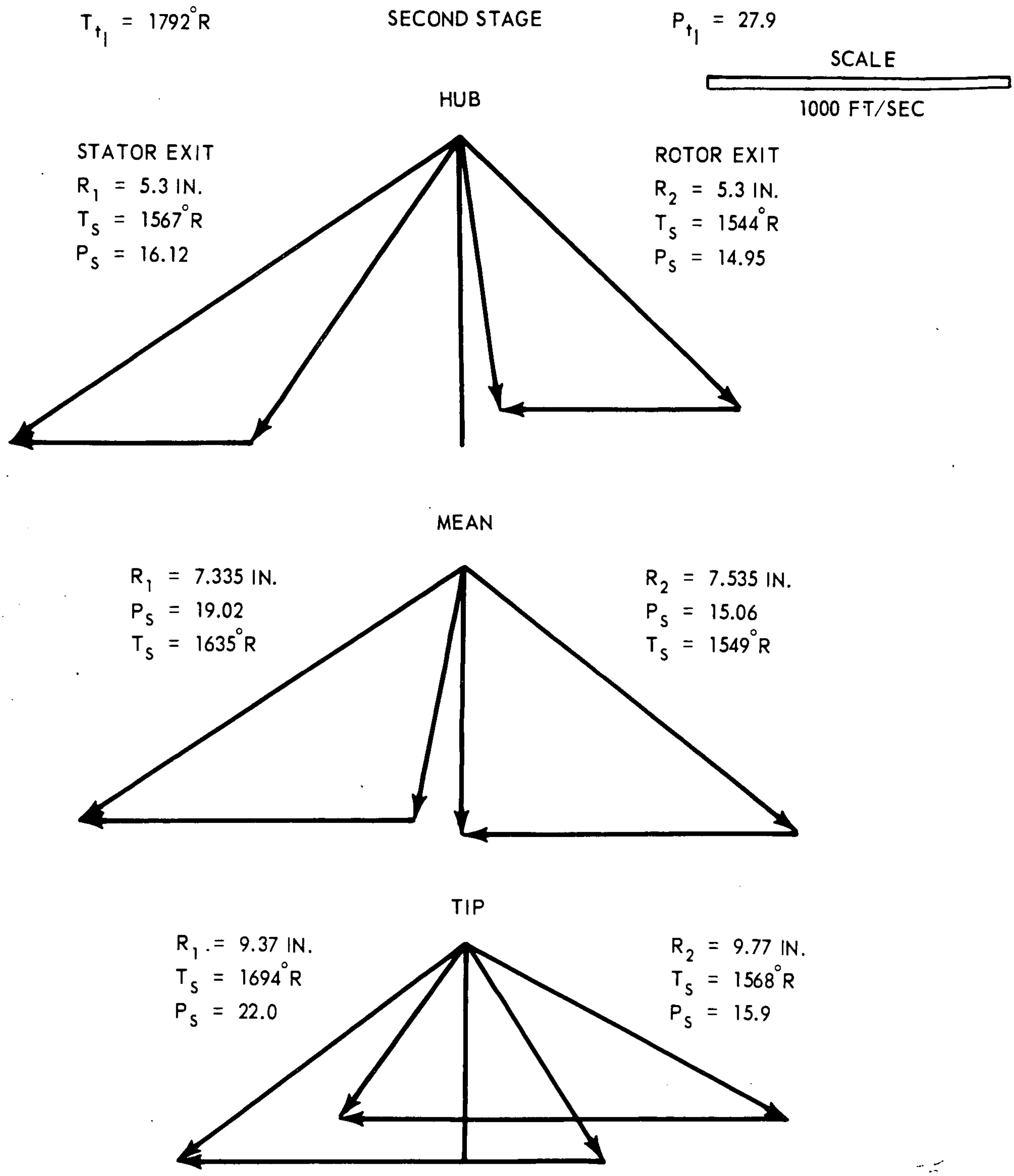


Figure 55. Modified MQT Power Turbine Second Stage Velocity Triangles for 8.5 Percent Reduced Inlet Flow Function.

The dry weight of the engine without starter is 1419 pounds, * and is made up of the following components:

	Weight (lb)
Core With Accessories (excluding power turbine)	510.50
MQT Power Turbine and Drive Shaft	165.00
5-Planet Reduction Gear	172.90
Fan Rotor Plus Blades and Spinner (titanium)	153.30
Fan Shroud (titanium)	58.00
Straightening Vanes for Duct and Core (aluminum)	66.10
Support Frame (magnesium)	194.00
Bypass Duct and Nozzle (aluminum and polyimid resin)	41.00
Bypass Duct Noise-Attenuating Rings (polyimid resin)	58.40
Total	1,419.20

---

* Based on fixed-area bypass duct exhaust nozzle

SCHEDULE AND COST ESTIMATE OF INTEGRAL LIFT ENGINE

Program Planning

An engineering program has been planned that would lead to development of the integral lift engine to a point where flightworthy engines could be provided for experimental aircraft. The overall 22-month program has been planned such that lesser objectives could be achieved in shorter periods of time.

Figure 56 shows a program schedule detailing major tasks, hardware development, and delivery schedules. This overall program schedule is segmented into three phases.

Phase I - Demonstrator Engine. - The intent of the Phase I program is to establish the credibility of the engine design by measuring static performance and establishing its noise signature. A single demonstrator engine would be procured and tested. The configuration would include downstream fan noise suppression (reference design); however, a conventional test cell bellmouth assembly would be used at the fan inlet. Suitable aerodynamic instrumentation would be installed. Preliminary testing would be limited to that necessary to establish adequate lubrication system and fuel system operation to assure satisfactory steady-state operation. Mechanical integrity instrumentation would be limited to that required for safe engine operation.

A 2- to 4-month engine test program is envisioned with 50 to 80 test hours logged in the test cell and at the free field noise site. After partial disassembly and inspection, it is anticipated that the engine could be reassembled for continued testing and evaluation either locally or at an off-site test facility.

The demonstrator engine program would validate the design point performance of the configuration and sea level static operating line performance.

The demonstrator engine program would underwrite the detail design of the design study engine and design of required special test equipment for cell and field site operation. It would also procure soft tooling for any subsequent procurements.

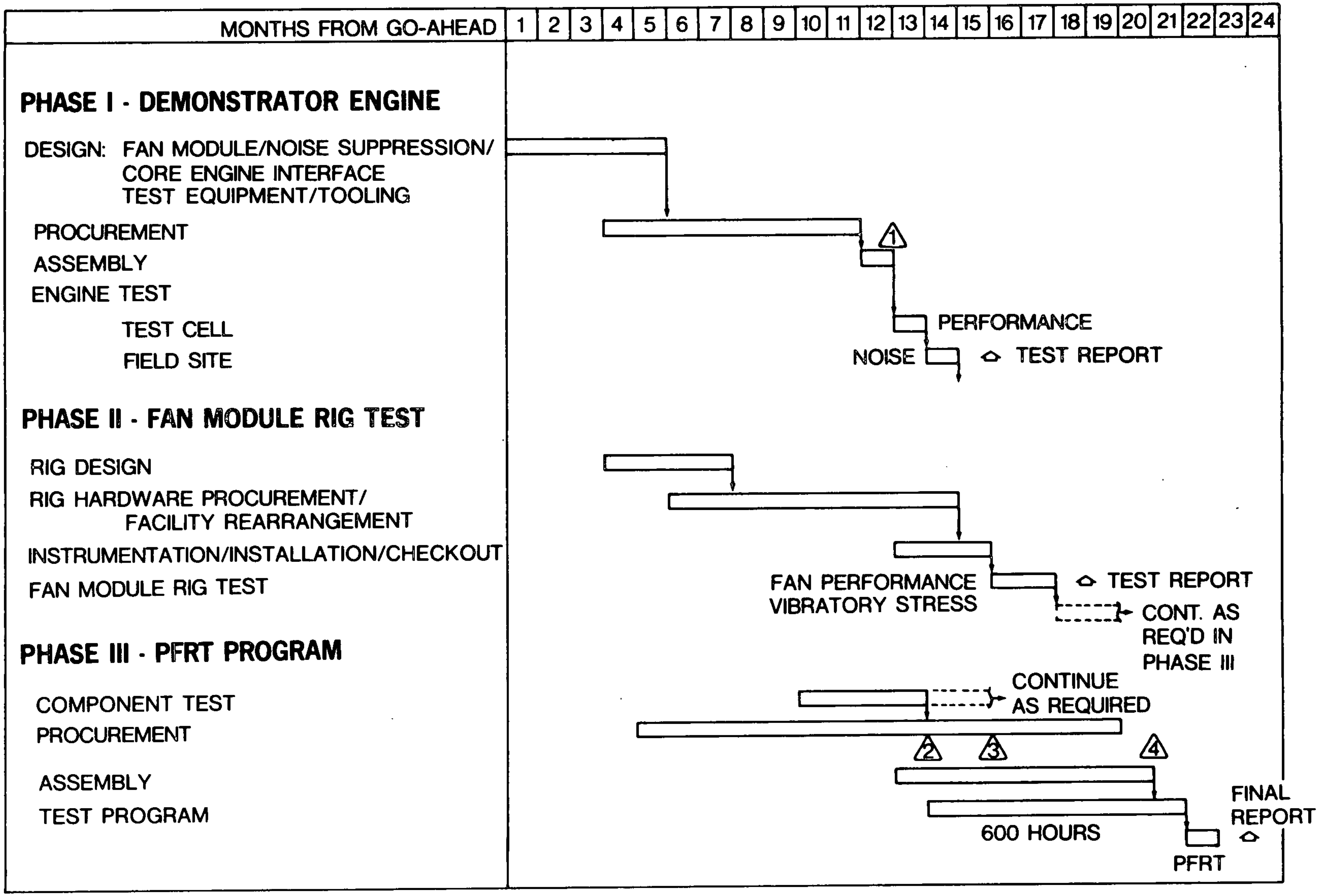


Figure 56. ALF-504 Engine Program.

Phase II - Fan Module Rig Test. - The intent of the Phase II rig test program is to enhance the demonstrator engine program by validating the predicted performance of the fan component. An overall performance map would be produced from part speed to overspeed up to, and including, the surge line for the anticipated operating range of representative aircraft applications. Available facility power may impose certain operating limitations.

Installed aerodynamic instrumentation would permit computation of overall and blade row performance parameters, including adiabatic and polytropic efficiencies and vector diagrams.

Vibratory stress instrumentation would also be installed to sense regions of rotating stall, and sufficient stall data would be gathered to define potential areas of blade vibration resonances.

In Figure 56, the fan module test rig has been planned to complement the objectives of the demonstrator engine program. It could also be considered an independent program of 16 month's duration. This latter case was the basis assumed for the Phase II budgetary cost estimate. To integrate the program with the demonstrator engine program, the rig test has been scheduled to receive the second fan module fabricated. As an independent program, rig testing could start in the fourteenth month.

Phase III - PFRT Program. - Phase I and Phase II were planned to validate in hardware the results of the engine design study by confirming predicted component and overall performance values. From this base, Phase III is a continuing development program intended to bring the configuration to limited operational status, suitable for use in experimental prototype aircraft.

Phase III will culminate in the successful completion of a PFRT (preliminary flight rating test). It is essentially an engine program with limited effort at the component level. Three additional in-house test engines would be procured with a goal of 600 engine hours to be logged before initiation of the PFRT.

Types of engine tests planned are:

Steady-State Performance

Transient Performance

Variable Attitude Operation

Determination of Surface Temperatures

Overall Vibration Survey

Oil/Fuel System Operational Evaluation and Optimization

Cyclic Endurance Testing.

The task requirements of this program are very similar to those of our ALF-502A/YF-102 engine development program where the PFRT was successfully completed in the spring of 1972. Northrop A9A aircraft are now flying powered by these Avco Lycoming high-bypass-ratio turbofans.

The ALF-502 program schedule and costing were based on this recent history.

Budgetary and Planning Cost Estimate

1. PFRT Engine Program - $6.5M

NOTES:
1. Total program shown on schedule, Figure 56.
2. PFRT complete 22 months ATP.
3. Summation of Phases I, II, and III schedules.
4. Costs include procurement of 4 engines and 2.5 equivalent engines for component test and in-house spares.
5. Cost assumes Government-furnished fuel and lubricants.

2. Unit Cost of Deliverable Flight Rated (PFRT) Engines - $485K

3. Phase I - Demonstrator Engine Program - $2.4M

NOTES:
1. Cost based on 14 months, one engine program.
2. Cost includes detail design of engine and special test support equipment, procurement of tooling, 1/2 equivalent engine for in-house spares, and one set engine test support equipment.

3. Cost assumes Government-furnished fuel and lubricants.

4. Phase II - Fan Rig Test Program - $750K

NOTES:
1. Costs include fan module detail design and tooling. If Phase I and Phase II are implemented concurrently, reduce Phase II cost by $300K.
2. Assumes a 16-month program.

5. General Assumptions and Conditions

The costs shown are based on rent-free use of the Stratford facility and tooling.

For purposes of cost estimating, an assumed go-ahead date of 1 January 1973 was selected. Average labor rates were used and represent those anticipated for the CY 1973 and CY 1974 period. Material costs were estimated at current rates and increased to represent CY 1973 and CY 1974 procurements.

APPENDIX I
AERODYNAMIC INFLUENCE OF THE PART-SPAN SHROUD

The part-span shroud creates an additional channel flow blockage effect that must be taken into account in the fan design.

In Reference 1, detailed radial surveys of the various flow parameters were taken at the exit of a part-span shrouded fan rotor and compared with the corresponding data for the same rotor without shroud. It was shown that the presence of the part-span shroud substantially modifies the tangential and meridional velocity profiles at the rotor exit station over the entire channel height. This finding prompted the following investigation, which is aimed at taking into account the effect of the annulus wake of the part-span shroud on the fan rotor flow conditions.

Figure 57 reproduces the axial and tangential velocity distributions measured at rotor exit station of the fan of Reference 1. It will be seen that the part-span shroud creates a wake with lower axial velocity and a higher tangential velocity than in the surrounding flow region.

Figure 58 shows, among other data, a total temperature survey taken at exit of the 502 fan rotor, which confirms the higher work input to the wake flow by the part-span shroud. At any point in the wake, the total temperature results from the mixing of particles undergoing the normal compression process outside the shroud boundary layer and particles inside that boundary layer. Since the tangential velocity in the shroud boundary layer varies from U_s (part-span shroud rotational speed) to V_θ (tangential flow velocity immediately outside of the boundary layer), the entire U_s, V_θ tangential velocity spectrum is involved in the mixing process. The situation, however, can be conveniently schematized by considering the temperature at any wake point to result from the mixing of particles with only two different tangential velocities, namely U_s and V_θ (as imparted by the rotor blading just outside of the boundary layer). This scheme enables an equivalent mixing mass flow ratio to be defined for each temperature point in the wake downstream of the rotor. Accordingly, we write for the unit mass in the wake:

$$T_{wake} = m_1 \, T_{V_\theta} + m_2 \, T_{U_s} \qquad (1)$$

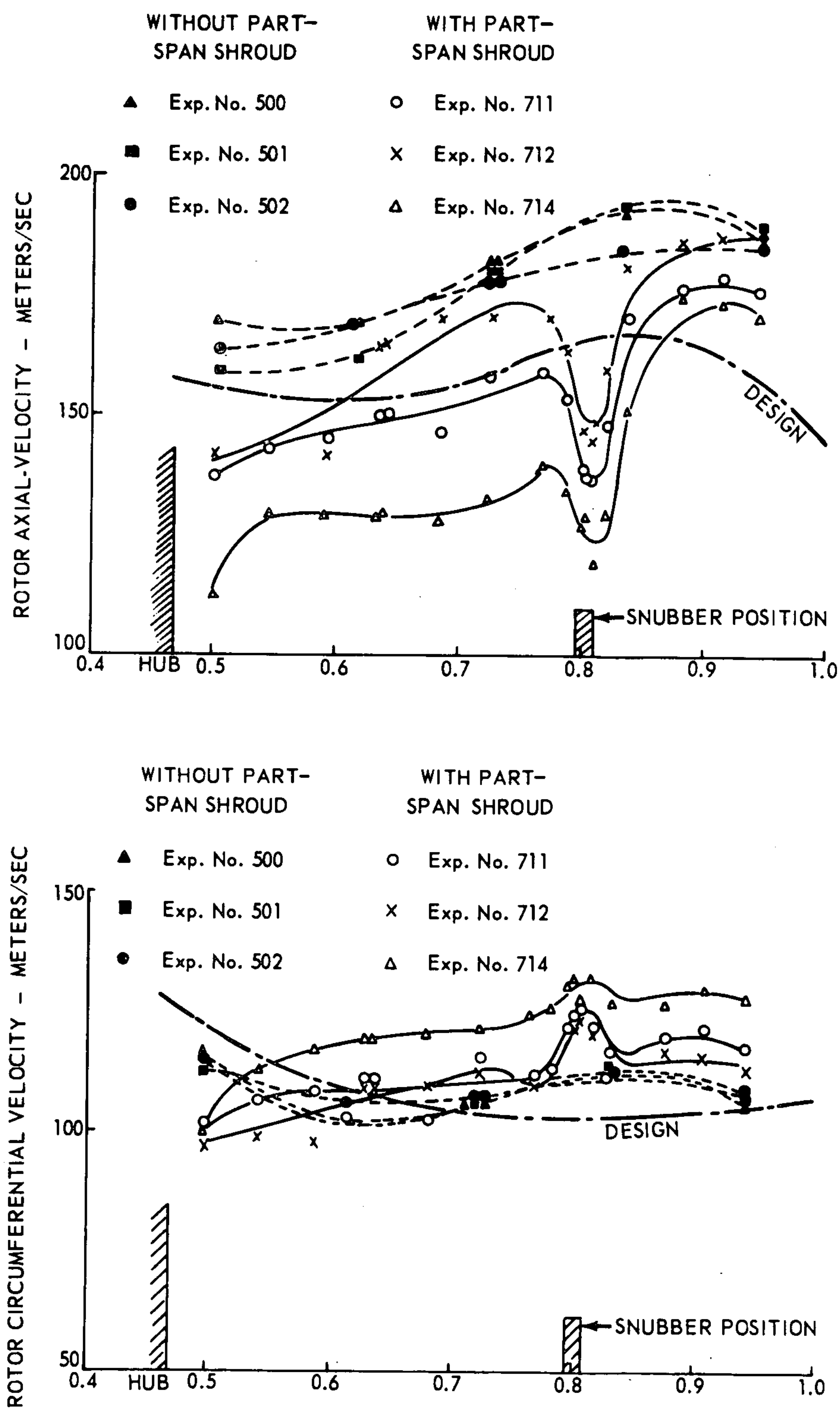


Figure 57. Measured Flow Conditions Downstream of Rotor (Reference 1, "Some Studies of Front Fans With and Without Snubbers").

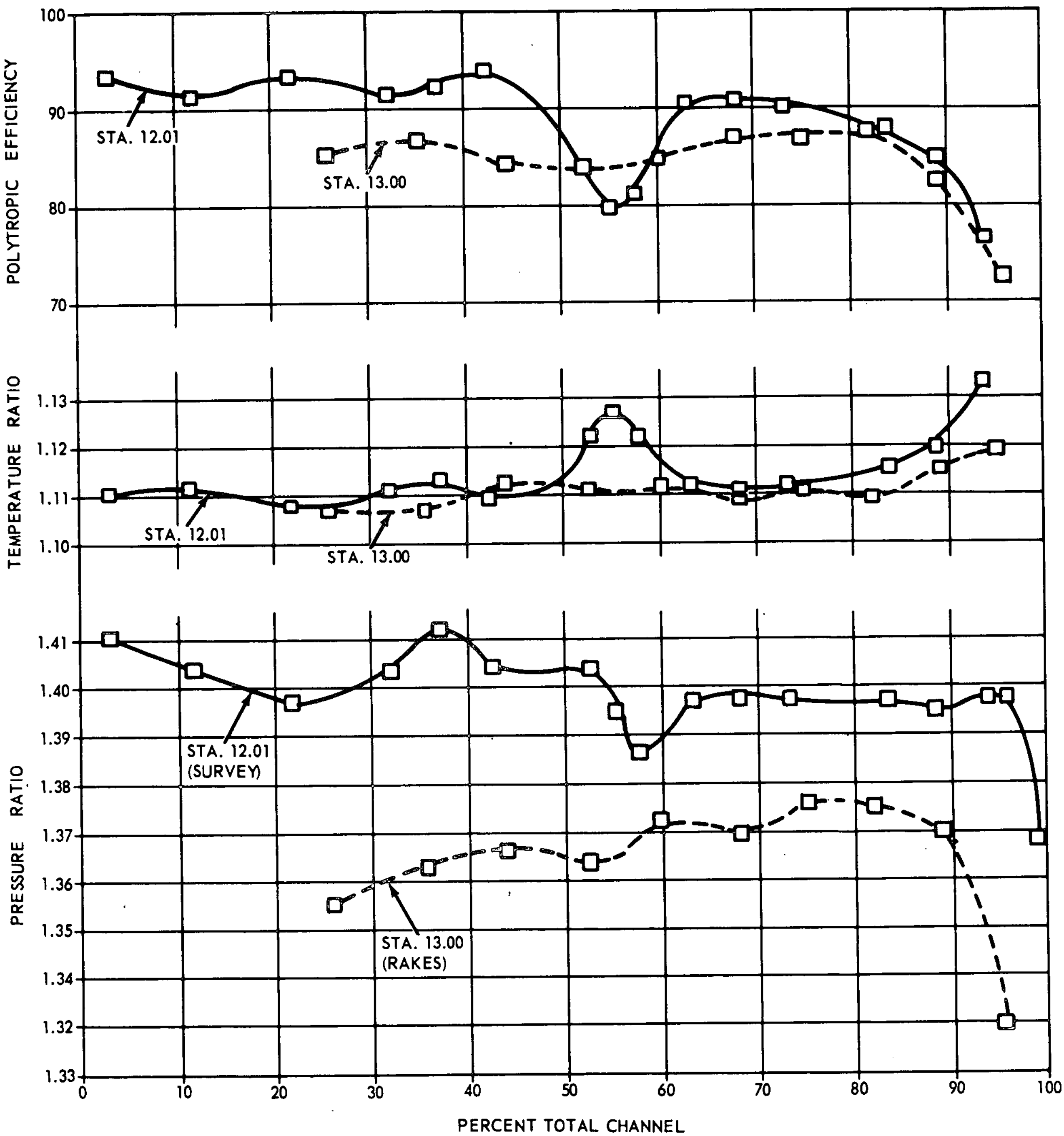


Figure 58. Radial Surveys Downstream of ALF-502 Fan Rotor, Test -02.

where $m_1 + m_2 = 1$ and T_{V_θ} and T_{U_s} are the total temperatures at rotor exit station resulting from the work input of the blading and of the shroud at its rotaitional speed U_s respectively. Hence:

$$\frac{m_2}{m_1} = \frac{T_{wake} - T_{V_\theta}}{T_{U_s} - T_{wake}} \tag{2}$$

It is now assumed that the above equivalent mixing ratio, which characterizes the local degree of mixing, is independent of the thermodynamic state of the mixing components and thus can be assumed to have essentially identical values at corresponding locations in the part-span shroud wake of different rotors.

Taking the highest wake temperature point at rotor exit of the 502 fan from the 90 percent referred design speed survey shown in Figure 58, namely:

$$T_{wake} = 1.127\ T_{amb} = 584.6^{o}\ R \tag{3}$$

and

$$T_{v_\theta} = 1.110\ T_{amb} = 575.8^{o}\ R \tag{4}$$

and with

$$U_s = 905\ \text{ft/sec}, \tag{5}$$

that is, $$T_{U_s} = 655.3^{o}\ R \tag{6}$$

Equation (2) yields $m_2/m_1 = 0.1244$.

Applying this equivalent ratio for the present fan with the design point parameters

$$T_{v_\theta} = 556.5^{o}\ R \tag{7}$$

$$U_s = 824\ \text{ft/sec}, \tag{8}$$

that is, $$T_{U_s} = 631.5^{o}\ R \tag{9}$$

Equation (1) yields $T_{wake} = 564.8^{o}R$.

The corresponding rotor efficiency can be calculated from the above total temperature, the resulting V_θ component, and tentatively assumed values of the static pressure and meridional velocity component. The meridional velocity is assumed to be in the same ratio the the unperturbed value as measured in Reference 1 and shown in Figure 57. A close value of the static pressure is available from a previous calculation without part-span shroud effect. (It can be iterated for final design purposes.) The resulting polytropic efficiency is $\eta_{p\,wake} = 0.67$ and the total wake pressure ratio $(P/P)_{wake} = 1.221$. The results are compared in the following table:

	Rotor Data	ALF-502 Fan Measured at 90 Pct Ref Design Speed	NASA Fan Calculated at 100 Pct Ref Design Speed
Outside of Part-Span Shroud Wake	P/P η_p	1.40 0.935	1.262 0.945
At Part Span Shroud Wake Core	P/P η_p	1.386 0.80	1.221 0.67
	$\Delta T_{wake_{max}}$ (°R)	8.8	8.3

The wake core total temperature excess $\Delta T_{wake_{max}}$ is practically the same in both cases. This is due to similar values of the difference $U_s^2 - UV\theta$ for both rotors and follows immediately from the basic assumption of equal equivalent mixing mass ratios. The mixing losses in the present case, however, represent a substantially larger portion of the rotor work input and this is correctly reflected in both the calculated lower polytropic efficiency and the larger relative total wake pressure defect.

For the computer flow calculation procedure a 1.5-inch wake thickness has been assumed at rotor exit station 12, and the wake flow has been represented only by the two wake-limiting streamlines and the wake core streamline with the above-calculated input data. The calculated wake blockage effect is approximately 1 percent of the total annulus area.

Figure 59 compares the meridional velocity profiles at rotor exit station with and without wake effect, but with identical overall flow blockage factors. It will be seen that the part-span shroud actually influences the flow field over a large portion of the annulus and that the modification of the velocity profile is qualitatively similar to that shown in Reference 1, although both effects are less pronounced in the present case.

This preliminary investigation shows that the influence of the part-span shroud on the fan flow conditions cannot be properly accounted for by a mere additional global flow blockage factor. A proper assessment of the resulting effect on the actual blading geometry, however, would require a more detailed description of the wake and its downstream dissipation, and possibly take into account the obstruction effect of the shroud itself on the rotor inlet flow conditions.

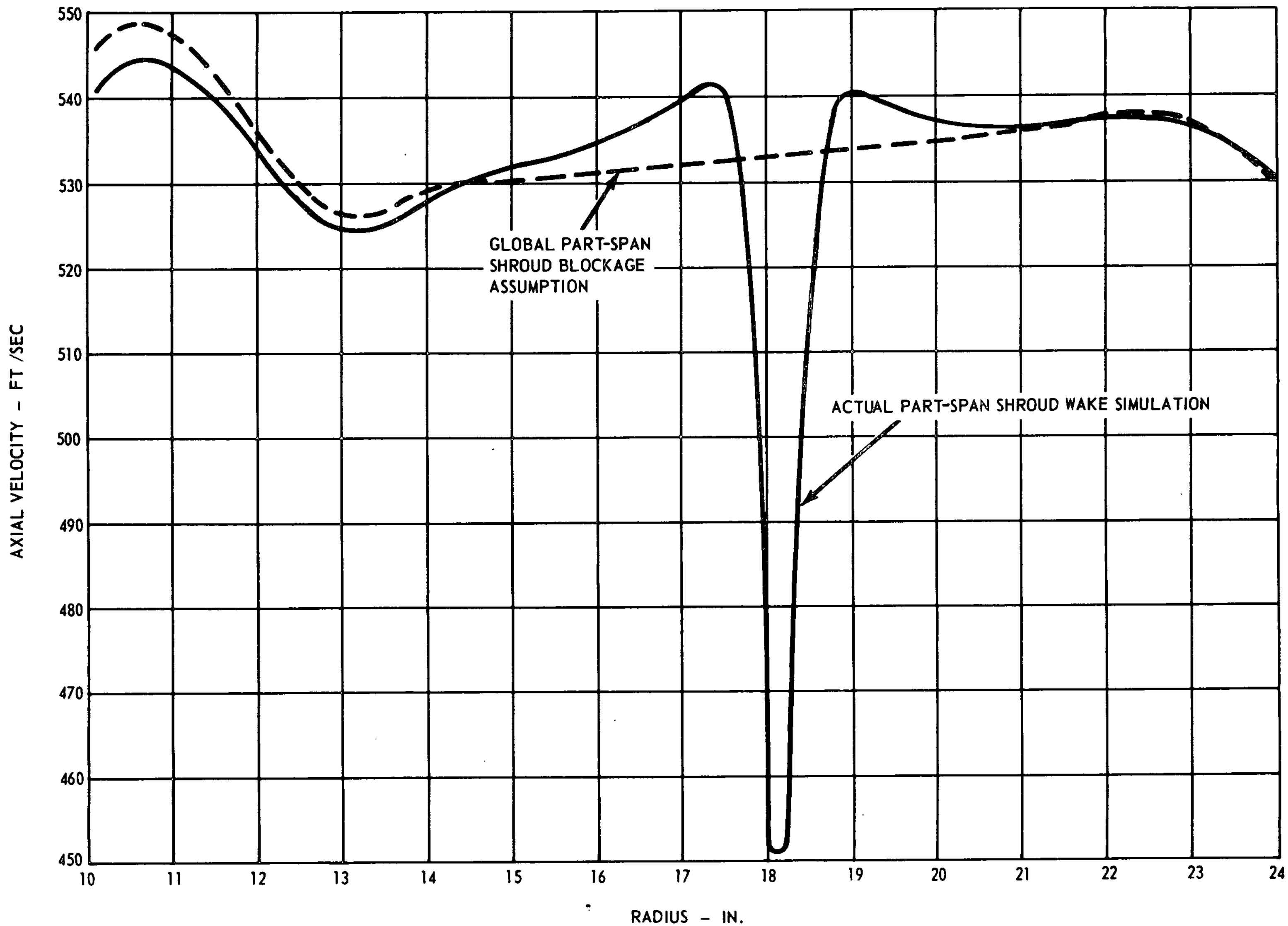


Figure 59. Analysis of Part-Span Shroud on Axial Velocity Profile Downstream of Fan Rotor.

APPENDIX II
FAN FLOW CONDITIONS

Main Output

GROUP I

Group I output is repeated for each computing station in accordance with the input specification of Identifier 500. The sequence in which the stations appear in Output is:

1. Stations of the flow region upstream of splitter.
2. Stations of the lower flow region downstream, of splitter.
3. Stations of the uppper flow region downstream of splitter.

A. Mass Averaged Conditions

Line 1

Word 1: $\overline{T}$, average total temperature, °R.

Word 2: $\overline{P}$, average total pressure, psf.

Word 3: $\overline{P}$/P-upstream for compressor
P-upstream/$\overline{P}$ for turbine.

Word 4: η_{poly-T} (upstream to n-station).

Word 5: η_{adi-T} (upstream to n-station).

Word 6: $\overline{P}/\overline{P}_I$ for compressor.
$\overline{P}_I/\overline{P}$ for turbine.

Word 7: η_{poly-T} (stage inlet to n-station). *

* NOTE:

Stage inlet definition:

1. For compressor, the n-station directly preceding the rotor exit station or the first blade station of the rotor, if blade stations are used.

2. For turbine, the n-station directly preceding the stator exit station or the first blade station of the stator, if blade stations are used.

Word 8: η_{adi-T} (stage inlet to n-station).

Word 9: $\overline{T_S}$, average static temperature, °R.

Word 10: $\overline{rV_t}$, average moment of tangential momentum, in x ft/sec.

Word 11: $\overline{\Delta H}$, average total enthalpy change from upstream temperature, Btu/lb.

Word 12: Station Identification. *

<u>Line 2</u>

Word 1: W, computed weight flow, lb/sec.

Word 2: N, rotational speed, RPM.

Word 3: $W\sqrt{\theta}/\delta$, referred computed weight flow, lb/sec, where:

$\theta = T/518.688$

$\delta = P/2116.216$

Word 4: $N/\sqrt{\theta}$, referred speed, RPM.

Word 5: Wf/Wa, fuel-air ratio.

Word 6: τ, uniform blockage factor.

Word 7: Number of streamlines.

Word 8: Axial coordinate of the hub, in.

Word 9: cotan ϵ, slope of the computing station.

<u>*NOTE</u>:

Output station Identification:

n-Station = 10x input station identification plus iteration pass identification.

b-station = Output identification of corresponding trailing edge station plus number of order of the blade station from leading edge.

B. Primary Option Definition

Line 1

Rotor or Station Option 1, 2, 3, or 4.

Rotor Blade or Station Blade.

Line 2

ISRE or NISRE, if the entropy terms in the equilibrium equation and blade force components are neglected o included respectively.

Line 3

Blank or COUNTER ROTATING

NOTE:

One or more of the following lines may appear after Line 3 depending upon the options used:

MASS AVERAGE TOTAL PRESSURE

COOLING AIR EFFECT

TEST FACTOR SIMULATION

C. Title

D. Flow conditions at Each Streamline

Six lines for stations outside blade rows or at the trailing edge.

Four lines for stations within blade rows. *

Line 1

Word 1: r, radius, in.

Word 2: V_z, axial velocity, ft/sec.

Word 3: V_m, meridional velocity, ft/sec.

* NOTE

The blade station output is printed in the sequence corresponding to the location of the station in the machine.

Word 4: V/V_{n-1} or W/W_{n-1}, velocity ratio.*

Word 5: $\varphi_{n-1} - \varphi_n$ or $(\varphi_{n-1} - \varphi_n)_W$, turning angle, deg.

Word 6: $T_n - T_{n-1}$, total temperature change, $^{\circ}R$.

Word 7: β or β_W projected flow angle, degree.

Word 8:

$$C_z = \frac{P_{s_n} - P_{s_{min}} - (P_n' - P_{n-1})_R}{P_{R_{n-1}} - P_{s_{min}}}$$

where $P_{s_{min}}$ is calculated using Zweifel solidity and $(P_n' - P_{n-1})_R = 0$ for stator.

Word 9: Same as Word 8 except calculated using input solidity.

<u>Line 2</u>

Word 1: V_θ absolute tangential velocity, ft/sec.

Word 2: V absolute velocity, ft/sec.

Word 3: M absolute Mach number.

Word 4: rV_t absolute moment of tangential momentum, in. ft/sec.

Word 5: φ absolute flow angle, deg.

Word 6: T absolute total temperature, $^{\circ}R$.

Word 7: P absolute total pressure, psf.

<u>* NOTE</u>

The subscript n-1 refers to the station preceding the n-station, or the first blade station when blade stations are present.

Word 8:	σ_z Zweifel solidity (for load coefficient of 1.0).
Word 9:	Input solidity.

Line 3

Word 1:	$V_{\theta w}$ relative tangential velocity, ft/sec.
Word 2:	V_w relative velocity, ft/sec.
Word 3:	M_w relative Mach number.
Word 4:	U blade speed, ft/sec.
Word 5:	φ_w relative flow angle, deg.
Word 6:	T_w total relative temperature.
Word 7:	P_w total relative pressure, psf.
Word 8:	$(V_{max}/V_n)_R$ where $V_{max\ R}$ is estimated using Zweifel solidity.
Word 9:	Same as Word 8 except calculated using input solidity.

Line 4

Word 1:	$\tan \alpha = \frac{dr}{dz}$, streamline slope.
Word 2:	$Q = -\frac{d^2r}{dz^2} = -\frac{d \tan \alpha}{dz}$, in^{-1}.
Word 3:	$\frac{dV_z}{dz}$, ft/sec x in^{-1}.
Word 4:	Axial coordinate, in.
Word 5:	ρ_s, static density, lb/cu ft.
Word 6:	T_s, static temperature, ^oR.
Word 7:	P_s, static pressure, psf.
Word 8:	$(M_{max})_R$ using Zweifel solidity.
Word 9:	Same as Word 8 except calculated using input solidity.

Line 5

Word 1: Cpr, static pressure rise coefficient.

Word 2: D, diffusion factor.

Word 3: Deq, equivalent diffusion factor.

Word 4: Δi, incidence angle, deg., defined as

$\Delta i = \beta_{n-1} - \beta$ for compressor

$\Delta i = \beta - \beta_{n-1}$ for turbine.

Word 5: η_b, blade efficiency defined as

$$\eta_b = \frac{C_p\ (T - T_S)}{C_p\ (T - T_S)_{iso}}$$

where the total temperature T is absolute for stator and relative for rotor.

Word 6: L, total pressure loss coefficient, defined as

$$L = \frac{(P_{iso} - P)_n}{(P - P_s)_{n-1}} \quad \text{for compressor}$$

and as

$$L = \frac{(P_{iso} - P)_n}{(P - P_s)_n} \quad \text{for turbine}$$

where the total pressures P, P_{iso} are absolute for stator and relative for rotor.

Word 7: L', total pressure loss coefficient, defined as:

$$L' = \frac{(P_{iso} - P)_n}{P_{n-1}}$$

where the total pressures P, P_{iso} are absolute for stator and relative for rotor.

Word 8: σ_x, computed axial solidity for Zweifel load coefficient of 1.0.

Word 9: $(P_{s_{n-1}} - P_{s_{min}})/(P_R - P_s)_{n-1}$ calculated using input solidity.

Line 6

Word 1: P/P-upstream for compressor,
P-upstream/P for turbine.

Word 2: $\eta_{poly\ T}$ (upstream to n station).

Word 3: $\eta_{adi\ T}$ (upstream to n station).

Word 4: P/P_I for compressor,
P_I/P for turbine.

Word 5: $\eta_{poly\ T}$ (inlet of stage to n station).

Word 6: $\eta_{adi\ T}$ (inlet of stage to n station).

Word 7: $P_s/P_{s_{n-1}}$ for compressor,
$P_{s_{n-1}}/P_s$ for turbine.

Word 8: $\eta_{poly\ S}$ (n-1 station to n station).

Word 9: $\eta_{adi\ S}$ (n-1 station to n station).

Word 10: P/P_{n-1} for compressor,
P_{n-1}/P for turbine.

Word 11: $\eta_{poly\ T}$ (n-1 station to n station).

Word 12: $\eta_{adi\ T}$ (n-1 station to n station).

Word 13: V_{n-1} velocity at previous station, absolute for stator, relative for rotor, ft/sec.

Word 14: Station Identification.

NOTE:

Words 8 and 9 of Lines 1 to 5 are printed if the calculated Zweifel solidity is > 0.050.

Lines 5 and 6 are omitted in the case of a blade station.

DEFINITION OF INPUT OF PROGRAM R136 . (Flow Path Geometry, Stations Definition, Inlet State, Mass Flow Rates)

NASA FAN ENGINE STUDY

```
   EPSL1       EPSL2       EPSL3       EPSL4       RJUMP       VJUMP       QJUMP       FJUMP       FORCER 1     FORCER 2
0.0000100   0.0005000   0.0002000   0.0000100    0.05000     1.00000     0.20000      0.0         1.50000     -0.40000
   EPSL5       QFRC        XA1         YA1          DXA         DYA         SW
0.0000500    0.10000      0.0         0.0         4.00000     4.00000    15.00000

ICMPAS =  200     NCMPAS =  300     IPASS =        0
NR     = 16 NRL    =  4 NSTAT1 = 13 NSTAT2 =  5 NSTAT3 =  5 NEU    =  0 NE2    =  0 NE3    =  0 IND1   =  0 IND2   =  0
IND3   =  0 INDV   =  1 NEND   =  1 NOUT   =  1 ITCNT  = 25 INTRVL =  0 NUBRUT = 10 NIPRNT =  1 INTBFR =  0 NUMBFR =100
NDROUT =  0 KSPPPP =  0 NFS    =  0 NRUSE  = 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

VALUES OF SHUB — Station Abscissas Lower Flow Path Contour

```
 0.0        7.87400    12.59800    15.74800    18.89699    22.04700    25.19600    28.34599    31.49599    34.64499
37.48000   41.10199    42.36200    44.64600    45.82700    47.48000    49.44800    51.41699
```

VALUES OF RHUB — Radial Coordinates Lower Flow Path Contour

```
 0.10000    0.10000     0.10000     0.10000     1.00000     2.00000     3.50000     5.50000     7.38180     8.52360
 9.37000   10.09840    10.17710     9.95000     9.65000     9.05510     8.11020     6.90000
```

VALUES OF SSHRD — Station Abscissas Upper Flow Path Contour

```
 0.0        7.87400    12.59800    15.74800    18.89699    22.04700    25.19600    28.34599    31.49599    34.64499
37.48000   41.10199    42.36200    43.93660    48.26729    50.74759    53.81870    57.63759
```

VALUES OF RSHRD — Radial Coordinates Upper Flow Path Contour

```
24.01569   24.01569    24.01569    24.01569    24.01569    24.01569    24.01569    24.01569    24.01569    24.01569
24.01569   24.01569    24.01569    24.01569    24.54999    24.87999    25.23999    25.23999
```

VALUES OF SLSP

```
44.64600   45.82700    47.48000    49.44800    51.41699
```

Station Abscissas Upper Core Flow Path Contour

VALUES OF RLSP

```
11.73000   11.28000    10.78730    10.09840     9.33060
```

Radial Coordinate Upper Core Flow Path Contour

VALUES OF SUSP

```
43.93660   45.90509    48.26729    51.33839    57.63759
```

Station Abscissas Lower Bypass Duct Contour

VALUES OF RUSP

```
12.43000   12.78000    12.95000    12.95000    12.95000
```

Radial Coordinate Lower Bypass Duct Contour

VALUES OF SZSP, RSSP, RLESP, ENDSP

```
43.54199   12.12900     0.19670    -0.05240     0.24930
```

Splitter Nose Definition

```
LOWER FLOW REGION TOTAL NO. OF STATIONS  18          END CONDITION FOR SPLINE  1

UPPER FLOW REGION TOTAL NO. OF STATIONS  18          END CONDITION FOR SPLINE  1

W     =   421.11987 WFWA  =      0.0     RPM1   =  5245.00000 RPM2  =     0.0     RPM3  =     0.0
PREF  =  2116.00000 TREF  =    518.68799

LOWER FLOW REGION MASS FLOW    WL =    30.74719
STREAMLINE FLOW DISTRIBUTION
 0.0        0.33725     0.33725     0.32551
```

Bypass Ratio = 12.696

```
UPPER FLOW REGION MASS FLOW    WU =   390.37256
STREAMLINE FLOW DISTRIBUTION
 0.0        0.02759     0.05313     0.05313     0.10625     0.13388     0.05419     0.05876     0.19433     0.10625
 0.10625    0.05313     0.05313
```

```
  518.68799   2115.99634    1.00000  1.0000  1.0000    1.00000  1.0000  1.0000    499.42554     0.0          0.0          10010
  421.12158   5245.00000    421.16528   5245.00000       0.0           1.00000     16.00000     0.0          0.0
*STATOR    OPT4
* NISRF
*MASS AVERAGE TOTAL PRESSURE                       DELTA-T COOLING =    0.0         TOTAL DELTA-T =   0.0
*
                  NASA FAN ENGINE SPLITTER STUDY                                               LOOP= 0
    0.10000     481.14282    481.14282      2.40571      0.0          0.0         0.0
    0.0         481.14282      0.43919      0.0          0.0        518.68799   2115.99341
    4.57712     481.16455      0.43921      4.57712      0.54504    518.68970   2116.01539
    0.00020       0.00000     -0.29432      0.0          0.06956    499.42456   1853.43774
   -4.56792      -1.40571      0.46556      0.0          0.99999      0.00014      0.00000
  1.00000  1.0000  1.0000    1.00000  1.0000  1.0000     0.89588  1.0000  1.0000    1.00000  1.0000  1.0000  200.00000     10010
*
    3.76977     481.12769    481.12793      2.40564      0.0          0.0         0.0
    0.0         481.12793      0.43918      0.0          0.0        518.68799   2115.99707
  172.54715     511.13257      0.46657    172.54715     19.72937    521.16479   2151.58594
    0.00120      -0.00000     -0.49795      0.0          0.06956    499.42578   1853.45337
   -4.56759      -1.40564      0.46557      0.0          0.99999      0.00006      0.00000
  1.00000  1.0000  1.0000    1.00000  1.0000  1.0000     0.89589  1.0000  1.0000    1.00000  1.0000  1.0000  200.00000     10010
*
    5.33032     481.14526    481.14600      2.40573      0.0          0.0         0.0
    0.0         481.14600      0.43920      0.0          0.0        518.68799   2115.99683
  243.97533     539.46777      0.49243    243.97533     26.88924    523.63965   2187.57422
    0.00182      -0.00000     -0.37625      0.0          0.06956    499.42432   1853.43457
   -4.56799      -1.40573      0.46556      0.0          0.99999      0.00007      0.00000
  1.00000  1.0000  1.0000    1.00000  1.0000  1.0000     0.89589  1.0000  1.0000    1.00000  1.0000  1.0000  200.00000     10010
*
    6.48996     481.09790    481.09888      2.40549      0.0          0.0         0.0
    0.0         481.09888      0.43915      0.0          0.0        518.68799   2115.99292
  297.05347     565.41748      0.51612    297.05347     31.69316    526.02856   2222.71509
    0.00212      -0.00000     -0.34636      0.0          0.06956    499.42922   1853.49535
   -4.56691      -1.40549      0.46560      0.0          0.99999      0.00015      0.00000
  1.00000  1.0000  1.0000    1.00000  1.0000  1.0000     0.89590  1.0000  1.0000    1.00000  1.0000  1.0000  200.00000     10010
*
    7.54135     481.14233    481.14355      2.40572      0.0          0.0         0.0
    0.0         481.14355      0.43919      0.0          0.0        518.68799   2115.99341
  345.17749     592.15405      0.54053    345.17749     35.65605    528.59937   2260.98828
    0.00232      -0.00000     -0.26528      0.0          0.06956    499.42456   1853.43774
   -4.56792      -1.40572      0.46556      0.0          0.99999      0.00014      0.00000
  1.00000  1.0000  1.0000    1.00000  1.0000  1.0000     0.89588  1.0000  1.0000    1.00000  1.0000  1.0000  200.00000     10010
*
    9.23444     481.11670    481.11816      2.40559      0.0          0.0         0.0
    0.0         481.11816      0.43917      0.0          0.0        518.68799   2115.99561
  422.67139     640.41064      0.58457    422.67139     41.29991    533.54858   2336.00879
    0.00256      -0.00000     -0.23838      0.0          0.06956    499.42651   1853.46289
   -4.56739      -1.40559      0.46559      0.0          0.99999      0.00009      0.00000
  1.00000  1.0000  1.0000    1.00000  1.0000  1.0000     0.89589  1.0000  1.0000    1.00000  1.0000  1.0000  200.00000     10010
*
   10.66209     481.02393    481.02539      2.40513      0.0          0.0         0.0
    0.0         481.02539      0.43908      0.0          0.0        518.68799   2115.99854
  488.01709     685.23438      0.62549    488.01709     45.41336    538.49780   2412.73979
    0.00266      -0.00000     -0.12330      0.0          0.06957    499.43408   1853.56152
   -4.56530      -1.40513      0.46567      0.0          0.99999      0.00103      0.00000
  1.00000  1.0000  1.0000    1.00000  1.0000  1.0000     0.89594  1.0000  1.0000    1.00000  1.0000  1.0000  200.00000     10010
```

```
 13.05729    481.09423    481.08569     2.40543    0.0         0.0          0.0
  0.0        481.08569      0.43914     0.0        0.0       518.68799   2115.99512
597.64795    767.21997      0.70032   597.64795   51.16711   549.39502   2571.73535
  0.00256     -0.00000     -0.07998     0.0        0.06956   499.42920   1853.49805
 -4.56664     -1.40543      0.46561     0.0        0.99999     0.00010      0.00000
1.00000  1.0000  1.0000   1.00000  1.0000  1.0000   0.89591  1.0000  1.0000   1.00000  1.0000  1.0000  200.00000     10010
*
 15.55868    481.08813    481.08911     2.40545    0.0         0.0          0.0
  0.0        481.08911      0.43914     0.0        0.0       518.68799   2115.99683
712.14014    859.41284      0.78448   712.14014   55.95983   560.86206   2782.48438
  0.00226     -0.00000      0.03577     0.0        0.06956   499.42896   1853.49487
 -4.56671     -1.40545      0.46561     0.0        0.99999     0.00007      0.00000
1.00000  1.0000  1.0000   1.00000  1.0000  1.0000   0.89591  1.0000  1.0000   1.00000  1.0000  1.0000  200.00000     10010
*
 16.46344    481.08838    481.08936     2.40545    0.0         0.0          0.0
  0.0        481.08936      0.43914     0.0        0.0       518.68799   2115.99683
753.55200    894.02881      0.81608   753.55200   57.44461   565.90723   2871.19849
  0.00208     -0.00000      0.07491     0.0        0.06956   499.42896   1853.49487
 -4.56671     -1.40545      0.46561     0.0        0.99999     0.00007      0.00000
1.00000  1.0000  1.0000   1.00000  1.0000  1.0000   0.89591  1.0000  1.0000   1.00000  1.0000  1.0000  200.00000     10010
*
 17.39133    481.16333    481.16406     2.40582    0.0         0.0          0.0
  0.0        481.16406      0.43921     0.0        0.0       518.68799   2115.99438
796.02246    930.14551      0.84905   796.02246   58.84863   571.37695   2969.63574
  0.00183     -0.00000      0.12637     0.0        0.06956   499.42285   1853.41553
 -4.56839     -1.40582      0.46554     0.0        0.99999     0.00012      0.00000
1.00000  1.0000  1.0000   1.00000  1.0000  1.0000   0.89587  1.0000  1.0000   1.00000  1.0000  1.0000  200.00000     10010
*
 20.15814    481.14282    481.14307     2.40571    0.0         0.0          0.0
  0.0        481.14307      0.43919     0.0        0.0       518.68799   2115.99341
922.66309   1040.57910      0.94985   922.66309   62.45917   589.46240   3312.43481
  0.00117     -0.00000      0.21533     0.0        0.06956   499.42456   1853.43774
 -4.56792     -1.40571      0.46556     0.0        0.99999     0.00014      0.00000
1.00000  1.0000  1.0000   1.00000  1.0000  1.0000   0.89588  1.0000  1.0000   1.00000  1.0000  1.0000  200.00000     10010
*
 21.52095    481.21582    481.21582     2.40608    0.0         0.0          0.0
  0.0        481.21582      0.43926     0.0        0.0       518.68799   2115.99487
985.04053   1096.29980      1.00072   985.04053   63.96335   599.34741   3511.34839
  0.00076     -0.00000      0.19561     0.0        0.06956   499.41870   1853.36157
 -4.56954     -1.40608      0.46549     0.0        0.99999     0.00011      0.00000
1.00000  1.0000  1.0000   1.00000  1.0000  1.0000   0.89584  1.0000  1.0000   1.00000  1.0000  1.0000  200.00000     10010
*
 22.80249    481.09644    481.09644     2.40548    0.0         0.0          0.0
  0.0        481.09644      0.43915     0.0        0.0       518.68799   2115.99292
1043.69824  1149.24268      1.04904  1043.69824   65.25244   609.22681   3719.66699
  0.00036     -0.00000      0.24806     0.0        0.06956   499.42822   1853.49535
 -4.56691     -1.40548      0.46560     0.0        0.99999     0.00015      0.00000
1.00000  1.0000  1.0000   1.00000  1.0000  1.0000   0.89590  1.0000  1.0000   1.00000  1.0000  1.0000  200.00000     10010
```

```
   23.41698    481.22852    481.22852      2.40614      0.0          0.0          0.0
    0.0        481.22852      0.43927      0.0          0.0        518.68799    2115.99438
 1071.82397   1174.99819      1.07247   1071.82397     65.82077    614.16528    3825.54932
    0.00018     -0.00000      0.13753      0.0          0.06956    499.41772    1853.34888
   -4.56980     -1.40614      0.46548      0.0          0.99999      0.00012       0.00000
 1.00000  1.0000  1.0000   1.00000  1.0000  1.0000    0.89584  1.0000  1.0000   1.00000  1.0000  1.0000  200.00000      10010
*
   24.01569    481.22778    481.22778      2.40614      0.0          0.0          0.0
    0.0        481.22778      0.43927      0.0          0.0        518.68799    2115.99438
 1099.22754   1199.25044      1.09534   1099.22754     66.35675    619.10278    3934.59448
   -0.00000      0.00000      0.09523      0.0          0.06956    499.41772    1853.34888
   -4.56980     -1.40614      0.46548      0.0          0.99999      0.00012       0.00000
 1.00000  1.0000  1.0000   1.00000  1.0000  1.0000    0.89584  1.0000  1.0000   1.00000  1.0000  1.0000  200.00000      10010


  518.68799   2115.99194   1.00000  1.0000  1.0000   1.00000  1.0000  1.0000   499.41797      0.0          0.0           10020
  421.17285   5245.00000   421.21729   5245.00000     0.0          1.00000     16.00000      7.87400      0.0
*STATOR    OPT4
* NISPE
*MASS AVERAGE TOTAL PRESSURE                      DELTA-T COOLING =    0.0         TOTAL DELTA-T =    0.0
*
                NASA FAN ENGINE SPLITTER STUDY                                              LOOP= 0
    0.10000    475.77734    475.77734      0.98885      0.0          0.0          0.0
    0.0        475.77734      0.43411      0.0          0.0        518.68799    2115.99316
    4.57712    475.79932      0.43413      4.57712      0.55119    518.68970    2116.01514
   -0.00040      0.00015     -1.45413      7.87400      0.06971    499.85181    1858.98755
    0.02116      0.01115      1.13263      0.0          0.99999      0.00000       0.00000
 1.00000  1.0000  1.0000   1.00000  1.0000  1.0000    1.00300  0.9997  0.9994   1.00000  1.0000  1.0000  481.14292      10020
*
    3.78627    476.30566    476.30908      0.98998      0.0          0.0          0.0
    0.0        476.30908      0.43461      0.0          0.0        518.68799    2115.99121
  173.30219    506.35693      0.46249    173.30219     19.99361    521.18652    2151.89478
    0.00388     -0.00069     -0.84036      7.87400      0.06970    499.80981    1858.44238
    0.01901      0.01002      1.13133      0.0          0.99999      0.00002       0.00000
 1.00000  1.0000  1.0000   1.00000  1.0000  1.0000    1.00269  0.9997  0.9994   1.00000  1.0000  1.0000  481.12793      10020
*
    5.35257    476.72998    476.73535      0.99083      0.0          0.0          0.0
    0.0        476.73535      0.43502      0.0          0.0        518.68799    2115.99170
  244.99382    536.00244      0.48910    244.99382     27.19358    523.68115    2188.17822
    0.00481     -0.00077     -0.92917      7.87400      0.06968    499.77598    1858.00098
    0.01740      0.00917      1.13036      0.0          0.99999      0.00002       0.00000
 1.00000  1.0000  1.0000   1.00000  1.0000  1.0000    1.00246  0.9995  0.9993   1.00000  1.0000  1.0000  481.14600      10020
*
    6.51583    477.16821    477.17554      0.99185      0.0          0.0          0.0
    0.0        477.17554      0.43543      0.0          0.0        518.68799    2115.98486
  298.23730    562.70947      0.51349    298.23730     32.00560    526.08716    2223.57837
    0.00559     -0.00089     -0.80552      7.87400      0.06967    499.74097    1857.54077
    0.01547      0.00815      1.12921      0.0          0.99997      0.00003       0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000    1.00219  0.9997  0.9984   1.00000  1.0000  1.0000  481.09898      10020
*
    7.56974    477.32764    477.83643      0.99313      0.0          0.0          0.0
    0.0        477.83643      0.43606      0.0          0.0        518.68799    2115.98633
  346.47607    590.23145      0.53863    346.47607     35.94562    528.67407    2262.10083
    0.00615     -0.00098     -0.73066      7.87400      0.06965    499.68848    1856.86108
    0.01306      0.00687      1.12775      0.0          0.99999      0.00003       0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000    1.00195  0.9993  0.9991   1.00000  1.0000  1.0000  481.14355      10020
```

```
*
 9.26553    478.48608    478.49683    0.99455    0.0        0.0         0.0
 0.0        478.49683    0.43669      0.0        0.0        518.68799   2115.98804
 424.09448  639.38672    0.58352      424.09448  41.55075   533.64893   2337.53198
 0.00672    -0.00107     -0.52643     7.87400    0.06964    499.63599   1856.17603
 0.01035    0.00545      1.12613      0.0        0.99998    0.00003     0.00000
 0.99999 1.0000 1.0000   0.99999 1.0000 1.0000   1.00146    0.9992 0.9977  1.00000  1.0000  1.0000  481.11816   10020
*
 10.69401   479.36914    479.38037    0.99658    0.0        0.0         0.0
 0.0        479.38037    0.43752      0.0        0.0        518.68799   2115.98706
 489.47778  695.12329    0.62530      489.47778  45.59708   538.61646   2414.64136
 0.00686    -0.00109     -0.38453     7.87400    0.06961    499.56543   1855.26245
 0.00649    0.00342      1.12384      0.0        0.99998    0.00004     0.00001
 0.99999 1.0000 1.0000   0.99999 1.0000 1.0000   1.00092    0.9992 0.9963  0.99999  1.0000  1.0000  481.07539   10020

 13.08793   480.38770    480.39819    0.99857    0.0        0.0         0.0
 0.0        480.39819    0.43849      0.0        0.0        518.68799   2115.99341
 599.05078  767.88281    0.70089      599.05078  51.27271   548.53467   2574.02563
 0.00662    -0.00105     -0.10542     7.87400    0.06958    499.48413   1854.20605
 0.00271    0.00143      1.12160      0.0        0.99999    0.00001     0.00000
 1.00000 1.0000 1.0000   1.00000 1.0000 1.0000   1.00038    0.9986 0.9956  1.00000  1.0000  1.0000  481.08569   10020
*
 15.58515   481.55322    481.56079    1.00098    0.0        0.0         0.0
 0.0        481.56079    0.43959      0.0        0.0        518.68799   2115.99048
 713.35156  860.68066    0.78567      713.35156  55.97795   561.00562   2784.98022
 0.00567    -0.00089     0.10790      7.87400    0.06955    499.39111   1853.00024
 -0.00187   -0.00098     1.11890      0.0        0.99999    0.00002     0.00000
 1.00000 1.0000 1.0000   1.00000 1.0000 1.0000   0.99973    1.0003 1.0065  1.00000  1.0000  1.0000  481.08911   10020
*
 16.48766   481.96255    481.86890    1.00162    0.0        0.0         0.0
 0.0        481.86890    0.43988      0.0        0.0        518.68799   2115.99243
 754.66040  895.38257    0.81736      754.66040  57.44073   566.04614   2873.65649
 0.00519    -0.00081     0.14216      7.87400    0.06954    499.36646   1852.68018
 -0.00309   -0.00162     1.11819      0.0        0.99999    0.00002     0.00000
 1.00000 1.0000 1.0000   1.00000 1.0000 1.0000   0.99956    1.0003 1.0039  1.00000  1.0000  1.0000  481.08936   10020
*
 17.41299   482.20264    482.20776    1.00217    0.0        0.0         0.0
 0.0        482.20776    0.44020      0.0        0.0        518.68799   2115.99194
 797.01416  931.53418    0.85039      797.01416  58.82524   571.50806   2972.02148
 0.00465    -0.00072     0.14231      7.87400    0.06953    499.33911   1852.32251
 -0.00414   -0.00217     1.11758      0.0        0.99999    0.00001     0.00000
 1.00000 1.0000 1.0000   1.00000 1.0000 1.0000   0.99941    1.0001 1.0029  1.00000  1.0000  1.0000  481.16406   10020
*
 20.17101   482.96509    482.96680    1.00379    0.0        0.0         0.0
 0.0        482.96680    0.44092      0.0        0.0        518.68799   2115.98730
 923.25171  1041.94531   0.95124      923.25171  62.38519   589.55273   3314.19897
 0.00281    -0.00042     0.26362      7.87400    0.06951    499.27832   1851.53320
 -0.00723   -0.00379     1.11577      0.0        1.00000    0.00002     0.00000
 0.99999 1.0000 1.0000   0.99999 1.0000 1.0000   0.99898    1.0000 1.0017  1.00000  1.0000  1.0000  481.14307   10020
*
 21.52924   482.95313    482.95386    1.00361    0.0        0.0         0.0
 0.0        482.95386    0.44091      0.0        0.0        518.68799   2115.98853
 985.41968  1097.40430   1.00187      985.41968  63.89050   599.40942   3512.60718
 0.00182    -0.00027     0.36325      7.87400    0.06951    499.27930   1851.54663
 -0.00689   -0.00361     1.11597      0.0        0.99999    0.00002     0.00000
 0.99999 1.0000 1.0000   0.99999 1.0000 1.0000   0.99902    1.0001 1.0018  1.00000  1.0000  1.0000  481.21582   10020
```

```
*
   22.80650    483.18091    483.18091     1.00433     0.0          0.0         0.0
    0.0        483.18091      0.44113     0.0          0.0        518.68799   2115.98706
 1043.88184   1150.28345     1.05017   1043.88184    65.16196    609.25854   3719.33276
    0.00088     -0.00013     0.34932      7.87400     0.06951    499.26099   1851.30737
   -0.00827     -0.00433     1.11517      0.0         0.99999      0.00002      0.00000
  0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99883  1.0002  1.0015   1.00000  1.0000  1.0000  481.09644      10020



   23.41890    483.20166    483.20166     1.00410     0.0          0.0         0.0
    0.0        483.20166      0.44115     0.0          0.0        518.68799   2115.99121
 1071.91187   1175.78833     1.07345   1071.91187    65.73482    614.18115   3825.89087
    0.00043     -0.00006     0.44527      7.87400     0.06950    499.25928   1851.28638
   -0.00783     -0.00410     1.11543      0.0         0.99999      0.00001      0.00000
  1.00000  1.0000  1.0000   1.00000  1.0000  1.0000   0.99889  1.0001  1.0015   1.00000  1.0000  1.0000  481.22852      10020
*
   24.01569    483.20898    483.20898     1.00412     0.0          0.0         0.0
    0.0        483.20898      0.44115     0.0          0.0        518.68799   2115.99072
 1099.22754   1200.74609     1.09624   1099.22754    66.27014    619.10278   3934.58765
    0.00000     -0.00000     0.47098      7.87400     0.06950    499.25879   1851.27979
   -0.00786     -0.00412     1.11541      0.0         0.99999      0.00001      0.00000
  1.00000  1.0000  1.0000   1.00000  1.0000  1.0000   0.99889  1.0001  1.0015   1.00000  1.0000  1.0000  481.22778      10020



  518.68799   2115.98486    0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   499.41797     0.0        0.0      10030
  421.09253   5245.00000  421.13843   5245.00000      0.0          1.00000       16.00000    12.59800     0.0
*STATOR    OPT4
* NISPE
*MASS AVERAGE TOTAL PRESSURE                  DELTA-T COOLING =    0.0         TOTAL DELTA-T =    0.0
*
              NASA FAN ENGINE SPLITTER STUDY                                           LOOP= 0
    0.10000    466.67749    466.67773     0.98087     0.0          0.0         0.0
    0.0        466.67773      0.42550     0.0          0.0        518.68799   2115.98755
    4.57712    466.70020      0.42552     4.57712     0.56193    518.68970   2116.00952
    0.00116     -0.00081     -2.17543    12.59800     0.06996    500.56567   1868.29321
    0.03621      0.01913      1.14184     0.0         0.99997      0.00002      0.00000
  0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   1.00500  0.9998  0.9993   1.00000  1.0000  1.0000  475.77734      10030
*
    3.81383    468.38428    468.40161     0.98340     0.0          0.0         0.0
    0.0        468.40161      0.42713     0.0          0.0        518.68799   2115.98364
  174.56361    499.87256      0.45583   174.56361    20.43938    521.22290   2152.40967
    0.00865     -0.00132     -3.15722    12.59800     0.06991    500.43140   1866.54053
    0.03146      0.01660      1.13891     0.0         0.99999      0.00003      0.00000
  0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   1.00436  0.9998  0.9996   1.00000  1.0000  1.0000  476.30908      10030
*
    5.38911    469.68701    469.72314     0.98529     0.0          0.0         0.0
    0.0        469.72314      0.42838     0.0          0.0        518.68799   2115.98511
  246.66618    530.55054      0.48386   246.66618    27.70535    523.74951   2189.17041
    0.01244     -0.00245     -2.27501    12.59800     0.06988    500.32837   1865.19556
    0.02790      0.01471      1.13672     0.0         0.99999      0.00003      0.00000
  0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   1.00387  0.9997  0.9996   1.00000  1.0000  1.0000  476.73535      10030
```

```
*
  6.55759      471.12744     471.17383       0.98742       0.0          0.0          0.0
  0.0          471.17383       0.42975       0.0           0.0        518.68799    2115.97266
300.14893      558.55381       0.50954     300.14893      32.49809    576.18237    2224.97192
  0.01407       -0.00268      -1.97420      12.59800       0.06984    500.21460    1863.70239
  0.02385        0.01258       1.13427       0.0           0.99997      0.00005       0.00001
0.99999  1.0000  1.0000     0.99999  1.0000  1.0000     1.00332  0.9998  0.9990    0.99999  1.0000  1.0000  477.17554     10030
*
  7.61520      472.37378     472.42798       0.98868       0.0          0.0          0.0
  0.0          472.42798       0.43094       0.0           0.0        518.68799    2115.97705
348.55688      587.09448       0.53554     348.55688      36.41986    528.79443    2263.89893
  0.01516       -0.00282      -1.69938      12.59800       0.06980    500.11621    1862.42188
  0.02148        0.01132       1.13282       0.0           0.99997      0.00004       0.00000
0.99999  1.0000  1.0000     0.99999  1.0000  1.0000     1.00300  0.9997  0.9989    1.00000  1.0000  1.0000  477.83643     10030
*
  9.31466      474.63867     474.70044       0.99207       0.0          0.0          0.0
  0.0          474.70044       0.43309       0.0           0.0        518.68799    2115.97827
426.34326      638.05103       0.58212     426.34326      41.92799    533.80786    2339.96704
  0.01616       -0.00292      -1.19996      12.59800       0.06974    499.93701    1860.08716
  0.01506        0.00793       1.12896       0.0           0.99997      0.00004       0.00000
0.99999  1.0000  1.0000     0.99999  1.0000  1.0000     1.00211  0.9995  0.9984    1.00000  1.0000  1.0000  478.49683     10030
*
 10.74388      476.58252     476.64526       0.99429       0.0          0.0          0.0
  0.0          476.64526       0.43493       0.0           0.0        518.68799    2115.98242
491.76050      634.84961       0.62492     491.76050      45.89420    538.80273    2417.55811
  0.01626       -0.00286      -0.82853      12.59800       0.06969    499.78320    1858.08765
  0.01086        0.00571       1.12643       0.0           0.99999      0.00002       0.00000
0.99999  1.0000  1.0000     0.99999  1.0000  1.0000     1.00152  0.9991  0.9989    1.00000  1.0000  1.0000  479.38037     10030


 13.13482      479.64722     479.70190       0.99855       0.0          0.0          0.0
  0.0          479.70190       0.43783       0.0           0.0        518.68799    2115.98267
601.19702      769.12402       0.70199     601.19702      51.41321    548.74878    2577.53613
  0.01511       -0.00251      -0.24414      12.59800       0.06960    499.53979    1854.92358
  0.00274        0.00145       1.12162       0.0           0.99998      0.00004       0.00001
0.99999  1.0000  1.0000     0.99999  1.0000  1.0000     1.00039  0.9974  0.9912    0.99999  1.0000  1.0000  480.39819     10030
*
 15.62402      482.36792     482.40601       1.00175       0.0          0.0          0.0
  0.0          482.40601       0.44039       0.0           0.0        518.68799    2115.98462
715.13062      862.62817       0.78750     715.13062      55.99754    561.21680    2788.63916
  0.01258       -0.00200       0.24450      12.59800       0.06953    499.32324    1852.11353
 -0.00335       -0.00175       1.11804       0.0           0.99999      0.00002       0.00000
0.99999  1.0000  1.0000     0.99999  1.0000  1.0000     0.99952  1.0001  1.0036    1.00000  1.0000  1.0000  481.56079     10030
*
 16.52283      482.98608     483.01733       1.00238       0.0          0.0          0.0
  0.0          483.01733       0.44097       0.0           0.0        518.68799    2115.98608
756.27026      897.35742       0.81924     756.27026      57.43423    566.24829    2877.24976
  0.01138       -0.00178       0.40014      12.59800       0.06951    499.27417    1851.47803
 -0.00455       -0.00238       1.11734       0.0           0.99999      0.00002       0.00000
0.99999  1.0000  1.0000     0.99999  1.0000  1.0000     0.99935  1.0003  1.0026    1.00000  1.0000  1.0000  481.86890     10030
*
 17.44431      483.53003     483.55444       1.00279       0.0          0.0          0.0
  0.0          483.55444       0.44148       0.0           0.0        518.68799    2115.98926
798.44727      933.45752       0.85224     798.44727      58.80005    571.69824    2975.49072
  0.01006       -0.00154       0.55621      12.59800       0.06949    499.23096    1850.91699
 -0.00533       -0.00279       1.11688       0.0           0.99999      0.00001       0.00000
0.99999  1.0000  1.0000     0.99999  1.0000  1.0000     0.99924  1.0002  1.0023    1.00000  1.0000  1.0000  482.20776     10030
```

```
*
  20.19009     485.14502     485.15332       1.00453      0.0          0.0          0.0
   0.0         485.15332       0.44300       0.0          0.0        518.68799    2115.98218
 924.12549    1043.73413       0.95304     924.12549     62.30110    589.68677    3316.83447
   0.00592      -0.00088       0.83453      12.59800      0.06945    499.10205    1849.24023
  -0.00865      -0.00453       1.11495       0.0          0.99999      0.00002       0.00000
 0.99999  1.0000  1.0000    0.99999  1.0000  1.0000      0.99876  1.0001  1.0014   1.00000  1.0000  1.0000  482.96680     10030
*
  21.54160     485.53037     485.63379       1.00555      0.0          0.0          0.0
   0.0         485.63379       0.44345       0.0          0.0        518.68799    2115.98633
 985.98535    1099.09375       1.00363     985.98535     63.77800    599.50220    3514.51660
   0.00381      -0.00056       0.87528      12.59800      0.06944    499.06323    1848.73828
  -0.01060      -0.00555       1.11382       0.0          0.99999      0.00001       0.00000
 0.99999  1.0000  1.0000    0.99999  1.0000  1.0000      0.99849  1.0000  1.0011   1.00000  1.0000  1.0000  482.95386     10030
*
  22.81239     485.89282     485.89355       1.00561      0.0          0.0          0.0
   0.0         485.89355       0.44370       0.0          0.0        518.68799    2115.98560
1044.15137    1151.67017       1.05166    1044.15137     65.04514    609.30542    3720.33911
   0.00182      -0.00027       0.94979      12.59800      0.06943    499.04224    1848.46509
  -0.01072      -0.00561       1.11375       0.0          0.99999      0.00001       0.00000
 0.99999  1.0000  1.0000    0.99999  1.0000  1.0000      0.99847  1.0001  1.0011   1.00000  1.0000  1.0000  483.18091     10030


  23.42178     485.95361     485.95361       1.00569      0.0          0.0          0.0
   0.0         485.95361       0.44376       0.0          0.0        518.68799    2115.98389
1072.04395    1177.04199       1.07484    1072.04395     65.61533    614.20459    3826.38599
   0.00089      -0.00014       0.93604      12.59800      0.06943    499.03735    1848.40503
  -0.01088      -0.00569       1.11366       0.0          0.99999      0.00003       0.00000
 0.99999  1.0000  1.0000    0.99999  1.0000  1.0000      0.99844  1.0001  1.0011   1.00000  1.0000  1.0000  483.20166     10030
*
  24.01569     485.99854     485.99854       1.00577      0.0          0.0          0.0
   0.0         485.99854       0.44380       0.0          0.0        518.68799    2115.98364
1099.22754    1201.87134       1.09751    1099.22754     66.14841    619.10278    3934.57446
  -0.00000       0.00000       0.95667      12.59800      0.06943    499.03369    1848.35718
  -0.01103      -0.00577       1.11357       0.0          0.99999      0.00003       0.00000
 0.99999  1.0000  1.0000    0.99999  1.0000  1.0000      0.99842  1.0001  1.0011   1.00000  1.0000  1.0000  483.20898     10030


 518.68799    2115.97949     0.99999  1.0000  1.0000    0.99999  1.0000  1.0000    499.38745      0.0          0.0         10040
 421.15039    5245.00000   421.19727    5245.00000      0.0          1.00000       15.00000      15.74800      0.0
*STATOR     OPT4
* NISRF
*MASS AVERAGE TOTAL PRESSURE                  DELTA-T COOLING =    0.0          TOTAL DELTA-T =    0.0
*
              NASA FAN ENGINE SPLITTER STUDY                                             LOOP= 0
   0.10000     453.97485     453.97754       0.97279      0.0          0.0          0.0
   0.0         453.97754       0.41352       0.0          0.0        518.68799    2115.98413
   4.57712     454.00049       0.41355       4.57712      0.57765    518.68970    2116.00610
  -0.00360       0.00383      -7.74313      15.74800      0.07030    501.53882    1881.03271
   0.05144       0.02721       1.15133       0.0          0.99999      0.00001       0.00000
 0.99999  1.0000  1.0000    0.99999  1.0000  1.0000      1.00682  0.9999  0.9995   1.00000  1.0000  1.0000  466.67773     10040
```

```
 3.85708    455.97266    456.07056     0.97367     0.0          0.0           0.0
 0.0        456.07056      0.41550     0.0         0.0        518.68799    2115.97388
176.54321   489.04785      0.44554   176.54321    21.16122    521.28076    2153.23730
 0.02074     -0.00637     -4.08356    15.74800     0.07024    501.38013    1879.94336
 0.04974      0.02633      1.15028     0.0         0.99997      0.00004       0.00000
0.99999 1.0000 1.0000   0.99999 1.0000 1.0000      1.00665  0.9998 0.9995    1.00000  1.0000  1.0000  468.40161    10040
*
 5.44644    459.09072    460.12817     0.97957     0.0          0.0           0.0
 0.0        460.12817      0.41932     0.0         0.0        518.68799    2115.97192
249.29047   523.31982      0.47691   249.29047    28.44915    523.85791    2190.74292
 0.02445     -0.00519     -4.01365    15.74800     0.07014    501.07080    1874.89111
 0.03868      0.02043      1.14335     0.0         0.99997      0.00005       0.00001
0.99999 1.0000 1.0000   0.99999 1.0000 1.0000      1.00520  0.9999 0.9993    0.99999  1.0000  1.0000  469.72314    10040
*
 6.62188    462.77539    462.94580     0.98254     0.0          0.0           0.0
 0.0        462.94580      0.42198     0.0         0.0        518.68799    2115.96558
303.09155   553.33838      0.50437   303.09155    33.21284    526.33008    2227.15405
 0.02715     -0.00565     -3.36171    15.74800     0.07006    500.85425    1872.04614
 0.03310      0.01746      1.13990     0.0         0.99997      0.00003       0.00000
0.99998 1.0000 1.0000   0.99998 1.0000 1.0000      1.00448  0.9999 0.9992    1.00000  1.0000  1.0000  471.17383    10040
*
 7.68390    465.48953    465.68018     0.98572     0.0          0.0           0.0
 0.0        465.68018      0.42456     0.0         0.0        518.68799    2115.96899
351.70142   583.56812      0.53204   351.70142    37.06165    528.97754    2266.63672
 0.02872     -0.00581     -2.70883    15.74800     0.06999    500.64307    1869.28906
 0.02710      0.01428      1.13623     0.0         0.99997      0.00003       0.00000
0.99999 1.0000 1.0000   0.99999 1.0000 1.0000      1.00369  0.9997 0.9991    1.00000  1.0000  1.0000  472.42798    10040
*
 9.38670    469.92822    470.13403     0.99038     0.0          0.0           0.0
 0.0        470.13403      0.42877     0.0         0.0        518.68799    2115.97119
429.64087   636.98086      0.58085   429.64087    42.42322    534.04272    2343.56738
 0.02960     -0.00565     -1.74722    15.74800     0.06987    500.29614    1864.76318
 0.01829      0.00962      1.13088     0.0         0.99999      0.00003       0.00000
0.99999 1.0000 1.0000   0.99999 1.0000 1.0000      1.00251  0.9997 0.9993    1.00000  1.0000  1.0000  474.70044    10040
*
10.81551    473.54102    473.73950     0.99390     0.0          0.0           0.0
 0.0        473.73950      0.43218     0.0         0.0        518.68799    2115.97974
495.03931   695.19556      0.62509   495.03931    46.25949    539.07178    2421.78662
 0.02897     -0.00522     -1.03200    15.74800     0.06977    500.01294    1861.07617
 0.01160      0.00610      1.12687     0.0         0.99999      0.00001       0.00000
0.99999 1.0000 1.0000   0.99999 1.0000 1.0000      1.00161  0.9994 0.9989    1.00000  1.0000  1.0000  476.64526    10040


13.20076    478.95386    479.11353     0.99877     0.0          0.0           0.0
 0.0        479.11353      0.43727     0.0         0.0        518.68799    2115.97681
604.21533   771.11987      0.70377   604.21533    51.58725    549.05127    2582.51514
 0.02583     -0.00431     -0.08975    15.74800     0.06962    499.58667    1855.52661
 0.00232      0.00123      1.12138     0.0         0.99999      0.00002       0.00000
0.99999 1.0000 1.0000   0.99999 1.0000 1.0000      1.00033  0.9970 0.9948    1.00000  1.0000  1.0000  479.70190    10040
*
15.67907    483.49341    483.59741     1.00247     0.0          0.0           0.0
 0.0        483.59741      0.44152     0.0         0.0        518.68799    2115.97852
717.65015   865.38330      0.79009   717.65015    56.02542    561.51685    2793.86377
 0.02076     -0.00319      0.60461    15.74800     0.06949    499.22754    1850.86597
-0.00471     -0.00247      1.11724     0.0         0.99999      0.00002       0.00000
0.99999 1.0000 1.0000   0.99999 1.0000 1.0000      0.99933  1.0001 1.0026    1.00000  1.0000  1.0000  482.40601    10040
```

```
*
  16.57283    484.90063   484.98462      1.00407     0.0          0.0          0.0
   0.0        484.98462     0.44284      0.0         0.0        518.68799   2115.97974
 758.55884    900.34521     0.82210    758.55884    57.40714    566.53638   2882.37085
   0.01864     -0.00282     0.83032     15.74800     0.06945    499.11572   1849.41675
  -0.00777     -0.00407     1.11546      0.0         0.99999      0.00002      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99889  1.0001  1.0015   1.00000  1.0000  1.0000  483.01733     10040
*
  17.48948    486.11108   486.17578      1.00542     0.0          0.0          0.0
   0.0        486.17578     0.44397      0.0         0.0        518.68799   2115.98340
 800.46924    936.54565     0.85524    800.46924    58.72699    571.96680   2980.38623
   0.01635     -0.00246     1.02962     15.74800     0.06942    499.01953   1848.17212
  -0.01035     -0.00542     1.11396      0.0         0.99999      0.00002      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99852  1.0000  1.0012   1.00000  1.0000  1.0000  483.55444     10040
*
  20.21567    488.72437   488.74585      1.00740     0.0          0.0          0.0
   0.0        488.74585     0.44641      0.0         0.0        518.68799   2115.97607
 925.29614   1046.44409     0.95579    925.29614    62.15674    589.86670   3320.37646
   0.00940     -0.00136     1.35568     15.74800     0.06935    498.81079   1845.46191
  -0.01415     -0.00740     1.11177      0.0         0.99999      0.00002      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99796  1.0000  1.0008   1.00000  1.0000  1.0000  485.15332     10040
*
  21.55779    489.47485   489.48340      1.00793     0.0          0.0          0.0
   0.0        489.48340     0.44711      0.0         0.0        518.68799   2115.98022
 986.72632   1101.46362     1.00611    986.72632    63.61539    599.62354   3516.99854
   0.00598     -0.00084     1.38911     15.74800     0.06933    498.75098   1844.69067
  -0.01514     -0.00793     1.11119      0.0         0.99999      0.00002      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99781  1.0000  1.0008   1.00000  1.0000  1.0000  485.63379     10040
*
  22.81993    489.86914   489.87109      1.00819     0.0          0.0          0.0
   0.0        489.87109     0.44748      0.0         0.0        518.68799   2115.98511
1044.49634   1153.66602     1.05383   1044.49634    64.87329    609.36523   3721.61987
   0.00284     -0.00038     1.40428     15.74800     0.06932    498.71924   1844.27930
  -0.01564     -0.00819     1.11091      0.0         0.99999      0.00000      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99774  1.0000  1.0008   1.00000  1.0000  1.0000  485.89355     10040

  23.42542    489.71387   489.71411      1.00774     0.0          0.0          0.0
   0.0        489.71411     0.44733      0.0         0.0        518.68799   2115.97876
1072.21021   1178.75049     1.07673   1072.21021    65.45216    614.23413   3927.02466
   0.00139     -0.00019     1.40545     15.74800     0.06932    498.73218   1844.44556
  -0.01477     -0.00774     1.11140      0.0         0.99999      0.00002      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99786  1.0000  1.0008   1.00000  1.0000  1.0000  485.95361     10040
*
  24.01569    489.74365   489.74365      1.00771     0.0          0.0          0.0
   0.0        489.74365     0.44736      0.0         0.0        518.68799   2115.98291
1099.22754   1203.39063     1.09923   1099.22754    65.98535    619.10278   3934.57300
   0.00000     -0.00000     1.40317     15.74800     0.06932    498.72974   1844.41382
  -0.01471     -0.00771     1.11143      0.0         1.00000      0.00000      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99787  1.0000  1.0008   1.00000  1.0000  1.0000  485.99854     10040
*
```

```
   518.68799   2115.97607    0.99999 1.0000  1.0000    0.99999 1.0000 1.0000    499.30737      0.0         0.0        10050
   421.20776   5245.00000   421.25537  5245.00000       0.0         1.00000     16.00000    18.89699      0.0
*STATOR    OPT4
* NISRF
*MASS AVERAGE TOTAL PRESSURE                        DELTA-T COOLING =   0.0         TOTAL DELTA-T =   0.0
*
                NASA FAN ENGINE SPLITTER STUDY                                                LOOP= 0
     0.10000    420.60864    420.64526     0.92658      0.0        0.0        0.0
     0.0        420.64526      0.38224     0.0          0.0      518.68799   2115.97827
     4.57712    420.67017      0.38227     4.57712      0.62342  518.68970   2116.00024
     0.01323     -0.01452    -10.70351    18.89699      0.07115  503.96484   1913.07251
     0.13637      0.07342      1.20875     0.0          0.99998    0.00002      0.00000
   0.99999  1.0000  1.0000   0.99999  1.0000  1.0000    1.01703  1.0000  0.9999   1.00000  1.0000  1.0000  453.97754     10050
*
     3.95506    436.72559    437.10913     0.95842      0.0        0.0        0.0
     0.0        437.10913      0.39767     0.0          0.0      518.68799   2115.96582
   181.02803    473.11255      0.43042   181.02803     22.49681  521.41431   2155.16016
     0.04192     -0.00707    -10.61028    18.89699      0.07074  502.78979   1897.49561
     0.07828      0.04158      1.16858     0.0          0.99998    0.00003      0.00000
   0.99998  1.0000  1.0000   0.99998  1.0000  1.0000    1.00987  0.9999  0.9998   1.00000  1.0000  1.0000  456.07056     10050
*
     5.56229    443.00781    443.63989     0.95417      0.0        0.0        0.0
     0.0        443.63989      0.40380     0.0          0.0      518.68799   2115.96265
   254.59291    511.50146      0.46557   254.59291     29.85034  524.08008   2193.98608
     0.05344     -0.01321     -7.06423    18.89699      0.07057  502.31104   1891.17529
     0.06757      0.03583      1.16162     0.0          0.99999    0.00004      0.00000
   0.99998  1.0000  1.0000   0.99998  1.0000  1.0000    1.00869  0.9999  0.9998   1.00000  1.0000  1.0000  460.12817     10050
*
     6.74743    449.45557    450.17578     0.97242      0.0        0.0        0.0
     0.0        450.17578      0.40995     0.0          0.0      518.68799   2115.95850
   308.83813    545.02969      0.49714   308.83813     34.45163  526.62256   2231.48120
     0.05664     -0.01307     -5.15782    18.89699      0.07040  501.82471   1884.76660
     0.05216      0.02758      1.15177     0.0          0.99997    0.00003      0.00000
   0.99998  1.0000  1.0000   0.99998  1.0000  1.0000    1.00679  0.9999  0.9995   1.00000  1.0000  1.0000  462.94580     10050
*
     7.81358    455.76636    456.01196     0.97924      0.0        0.0        0.0
     0.0        456.01196      0.41544     0.0          0.0      518.68799   2115.96387
   357.63696    579.52661      0.52797   357.63696     38.10605  529.32788   2271.88989
     0.05726     -0.01230     -3.75392    18.89699      0.07025  501.38477   1878.99487
     0.03936      0.02076      1.14375     0.0          0.99999    0.00002      0.00000
   0.99998  1.0000  1.0000   0.99998  1.0000  1.0000    1.00519  0.9999  0.9997   1.00000  1.0000  1.0000  465.68018     10050
*
     9.51576    463.98193    464.69067     0.98842      0.0        0.0        0.0
     0.0        464.69067      0.42363     0.0          0.0      518.68799   2115.96460
   435.54810    636.83844      0.58062   435.54810     43.14586  534.46777   2350.09814
     0.05530     -0.01065     -1.96698    18.89699      0.07001  500.71973   1870.28564
     0.02200      0.01158      1.13312     0.0          0.99997    0.00003      0.00000
   0.99998  1.0000  1.0000   0.99998  1.0000  1.0000    1.00296  0.9997  0.9988   1.00000  1.0000  1.0000  470.13403     10050
*
    10.93848    470.52295    471.14844     0.99453      0.0        0.0        0.0
     0.0        471.14844      0.42973     0.0          0.0      518.68799   2115.97437
   500.66772    687.49463      0.62706   500.66772     46.73981  539.53784   2429.11987
     0.05158     -0.00913     -0.82379    18.89699      0.06984  500.21680   1863.72754
     0.01041      0.00547      1.12616     0.0          0.99997    0.00002      0.00000
   0.99999  1.0000  1.0000   0.99999  1.0000  1.0000    1.00142  0.9992  0.9988   1.00000  1.0000  1.0000  473.73950     10050
```

```
 13.30674    479.57739    480.02612     1.00190     0.0          0.0          0.0
  0.0        480.02612      0.43813     0.0         0.0        518.68799   2115.97559
609.06592    775.49097      0.70781   609.06592    51.75710    549.54053   2590.58350
  0.04328     -0.00675      0.53689    18.89699     0.06959    499.51392   1854.57788
 -0.00363     -0.00190      1.11787     0.0         0.99999      0.00000      0.00000
0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99949  1.0002  1.0034   1.00000  1.0000  1.0000  479.11353      10050
*
 15.76185    486.60669    486.87427     1.00678     0.0          0.0          0.0
  0.0        486.87427      0.44463     0.0         0.0        518.68799   2115.97485
721.43945    870.35693      0.79484   721.43945    55.98593    561.97021   2801.77539
  0.03318     -0.00469      1.36991    18.89699     0.06940    498.96289   1847.42920
 -0.01294     -0.00678      1.11246     0.0         0.99999      0.00001      0.00000
0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99815  1.0000  1.0009   1.00000  1.0000  1.0000  483.59741      10050
*
 16.64650    488.57593    488.78687     1.00784     0.0          0.0          0.0
  0.0        488.78687      0.44645     0.0         0.0        518.68799   2115.97388
761.93091    905.23535      0.82682   761.93091    57.31932    566.96265   2889.97266
  0.02940     -0.00400      1.57205    18.89699     0.06935    498.80762   1845.41846
 -0.01498     -0.00784      1.11129     0.0         0.99999      0.00002      0.00000
0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99784  1.0000  1.0008   1.00000  1.0000  1.0000  484.98462      10050
*
 17.55273    490.30396    490.46362     1.00882     0.0          0.0          0.0
  0.0        490.46362      0.44804     0.0         0.0        518.68799   2115.97729
803.41040    941.28784      0.85987   803.41040    58.59683    572.35889   2987.53931
  0.02553     -0.00337      1.73267    18.89699     0.06930    498.67090   1843.65186
 -0.01686     -0.00882      1.11021     0.0         0.99999      0.00002      0.00000
0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99756  1.0000  1.0007   1.00000  1.0000  1.0000  486.17578      10050
*
 20.25233    493.91455    493.96533     1.01068     0.0          0.0          0.0
  0.0        493.96533      0.45137     0.0         0.0        518.68799   2115.97144
926.97437   1050.37280      0.95979   926.97437    61.94772    590.12476   3325.46851
  0.01438     -0.00178      2.04676    18.89699     0.06920    498.38403   1839.93628
 -0.02041     -0.01068      1.10816     0.0         1.00000      0.00002      0.00000
0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99701  1.0000  1.0006   1.00000  1.0000  1.0000  488.74585      10050
*
 21.58118    494.93555    494.95581     1.01118     0.0          0.0          0.0
  0.0        494.95581      0.45231     0.0         0.0        518.68799   2115.97900
987.79712   1104.86377      1.00967   987.79712    63.38583    599.79907   3520.60864
  0.00909     -0.00112      2.14050    18.89699     0.06917    498.30249   1838.88599
 -0.02138     -0.01118      1.10762     0.0         0.99999      0.00000      0.00000
0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99686  1.0000  1.0005   1.00000  1.0000  1.0000  489.48340      10050
*
 22.83127    495.48340    495.48779     1.01147     0.0          0.0          0.0
  0.0        495.48779      0.45282     0.0         0.0        518.68799   2115.97852
1045.01538  1156.53149      1.05693  1045.01538    64.63226    609.45532   3723.53735
  0.00430     -0.00054      2.17054    18.89699     0.06916    498.25879   1838.32642
 -0.02191     -0.01147      1.10730     0.0         1.00000      0.00002      0.00000
0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99677  1.0000  1.0005   1.00000  1.0000  1.0000  489.87109      10050
```

```
   23.43100    495.60547    495.60645     1.01203     0.0         0.0         0.0
    0.0        495.60645      0.45293     0.0         0.0       518.68799   2115.97363
 1072.46582   1181.44287      1.07971  1072.46582    65.19742   614.27954   3878.01221
    0.00210     -0.00026      2.19763    18.89690     0.06915   498.24879   1938.19116
   -0.02302     -0.01203      1.10669     0.0         0.99999     0.00002      0.00000
  0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99661  1.0000  1.0005   1.00000  1.0000  1.0000  489.71411     10050
*
   24.01569    495.64624    495.64624     1.01205     0.0         0.0         0.0
    0.0        495.64624      0.45297     0.0         0.0       518.68799   2115.97754
 1099.22754   1205.10518      1.10198  1099.22754    65.72914   619.10278   3934.56299
   -0.00000      0.00000      2.20298    18.89690     0.06915   498.24561   1838.15356
   -0.02305     -0.01205      1.10666     0.0         0.99999     0.00002      0.00000
  0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99661  1.0000  1.0005   1.00000  1.0000  1.0000  489.74365     10050


  518.68799   2115.17021    0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   499.07593     0.0        0.0      10050
  421.20093   5245.00000    421.24976   5245.00000    0.0        1.00000       16.00000    22.04700    0.0
*STATOR    OPT4
* NISPF
*MASS AVERAGE TOTAL PRESSURE                   DELTA-T COOLING =    0.0          TOTAL DELTA-T =    0.0
*
              NASA FAN ENGINE SPLITTER STUDY                                          LOOP= 0
    0.20000    359.22508    359.58325     0.35494     0.0         0.0         0.0
    0.0        359.58325      0.32548     0.0         0.0       518.68799   2115.97095
    9.15425    359.69971      0.32559     9.15425     1.45932   518.69492   2116.06372
    0.04590     -0.00622    -39.74564    22.04700     0.07256   507.92944   1966.26270
    0.26216      0.14516      1.31019     0.0         0.93996     0.00004      0.00000
  0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   1.02781  1.0000  0.9999   1.00000  1.0000  1.0000  420.64526     10060
*
    4.19022    393.27222    396.57324     0.90726     0.0         0.0         0.0
    0.0        396.57324      0.35979     0.0         0.0       518.68799   2115.96313
  191.79160    440.51587      0.39965   191.79160    25.90343   521.74805   2159.99438
    0.12384     -0.04874    -13.22929    22.04700     0.07173   505.60205   1934.89868
    0.17123      0.00274      1.23448     0.0         0.99998     0.00001      0.00000
  0.99998  1.0000  1.0000   0.99999  1.0000  1.0000   1.01371  0.9999  0.9999   1.00000  1.0000  1.0000  437.10913     10060
*
    5.82836    417.80420    421.15137     0.94931     0.0         0.0         0.0
    0.0        421.15137      0.38272     0.0         0.0       518.68799   2115.95483
  266.77100    498.53296      0.45304   266.77100    32.35149   524.60915   2201.73291
    0.12684     -0.02338     -7.95527    22.04700     0.07114   503.92944   1912.57959
    0.09524      0.05069      1.17980     0.0         0.99997     0.00003      0.00000
  0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   1.01132  0.9999  0.9998   1.00000  1.0000  1.0000  443.63989     10060
*
    7.01315    432.22363    435.34888     0.96706     0.0         0.0         0.0
    0.0        435.34888      0.39601     0.0         0.0       518.68799   2115.95410
  321.00049    540.89746      0.49203   321.00049    36.40296   527.25977   2240.94653
    0.12047     -0.02745     -5.15686    22.04700     0.07078   502.91748   1899.16772
    0.06230      0.03294      1.15914     0.0         0.99998     0.00002      0.00000
  0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   1.00764  0.9999  0.9998   1.00000  1.0000  1.0000  450.17578     10060
*
    8.07144    443.53403    446.46094     0.97906     0.0         0.0         0.0
    0.0        446.46094      0.40645     0.0         0.0       518.68799   2115.95898
  369.43970    579.49365      0.52756   369.43970    39.60724   530.04150   2282.63232
    0.11307     -0.02312     -3.14217    22.04700     0.07050   502.10205   1888.41797
    0.03977      0.02094      1.14396     0.0         0.99999     0.00002      0.00000
  0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   1.00502  0.9999  0.9997   1.00000  1.0000  1.0000  456.01196     10060
```

```
*
   9.75263    459.00058    461.36548     0.99284     0.0         0.0        0.0
   0.0        461.36548      0.42049     0.0         0.0       518.68799   2115.95532
 446.38965    641.96704      0.58509   446.38965    44.05487   535.26294   2362.35278
   0.09968     -0.01751     -0.76146    22.04700     0.07010   500.97583   1873.63208
   0.01363      0.00716      1.12807     0.0         0.99999     0.00004      0.00000
 0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   1.00179  0.9993  0.9990   1.00000  1.0000  1.0000  464.69067     10060
*
  11.15249    469.55820    471.46143     1.00066     0.0         0.0        0.0
   0.0        471.46143      0.43003     0.0         0.0       518.68799   2115.96851
 510.46289    694.87280      0.63380   510.46289    47.27454   540.36157   2442.13477
   0.08772     -0.01379      0.57360    22.04700     0.06983   500.19214   1863.40454
  -0.00128     -0.00066      1.11926     0.0         0.99999     0.00002      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99983  0.0     0.0       1.00000  1.0000  1.0000  471.14844     10060

  13.47910    483.16016    484.28760     1.00888     0.0         0.0        0.0
   0.0        484.28760      0.44218     0.0         0.0       518.68799   2115.97339
 616.95532    784.32666      0.71612   616.95532    51.86934   550.34473   2603.88916
   0.06376     -0.00915      1.94824    22.04700     0.06947   499.17188   1850.13599
  -0.01699     -0.00888      1.11014     0.0         0.99999     0.00001      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99761  1.0000  1.0007   1.00000  1.0000  1.0000  480.02612     10060
*
  15.80014    492.73999    493.34888     1.01330     0.0         0.0        0.0
   0.0        493.34888      0.45078     0.0         0.0       518.68799   2115.97168
 727.31152    978.84363      0.80302   727.31152    55.85020   562.67725   2814.14111
   0.04973     -0.00581      2.66884    22.04700     0.06922   498.43481   1840.59131
  -0.02545     -0.01330      1.10530     0.0         0.99999     0.00001      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.97630  1.0000  1.0005   1.00000  1.0000  1.0000  486.87427     10060
*
  16.75922    495.29224    495.76001     1.01427     0.0         0.0        0.0
   0.0        495.76001      0.45308     0.0         0.0       518.68799   2115.97290
 767.09009    913.34339      0.83471   767.09009    57.12592   567.61915   2901.69751
   0.04347     -0.00492      2.83872    22.04700     0.06915   498.23633   1839.02612
  -0.02730     -0.01427      1.10425     0.0         0.99999     0.00002      0.00000
 0.99993  1.0000  1.0000   0.99999  1.0000  1.0000   0.97600  1.0000  1.0004   1.00000  1.0000  1.0000  488.78687     10060
*
  17.64593    497.51123    497.85718     1.01507     0.0         0.0        0.0
   0.0        497.85718      0.45507     0.0         0.0       518.68799   2115.97266
 807.85913    948.04580      0.86739   807.85913    58.35576   572.95459   2998.44165
   0.03731     -0.00409      2.95246    22.04700     0.06909   498.06274   1835.78882
  -0.02885     -0.01507      1.10337     0.0         0.99999     0.00002      0.00000
 0.99999  1.0000  1.0000   0.99999  1.0000  1.0000   0.99574  1.0000  1.0004   1.00000  1.0000  1.0000  490.46362     10060
*
  20.30608    502.05347    502.15845     1.01659     0.0         0.0        0.0
   0.0        502.15345      0.45917     0.0         0.0       518.68799   2115.96484
 929.43408   1056.41382      0.96597   929.43408    61.61930   590.50415   3332.96094
   0.02047     -0.00207      3.21233    22.04700     0.06896   497.70483   1831.17017
  -0.03174     -0.01659      1.10173     0.0         0.99999     0.00002      0.00000
 0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.99524  1.0000  1.0004   1.00000  1.0000  1.0000  493.96533     10060
*
  21.61490    503.23833    503.32959     1.01692     0.0         0.0        0.0
   0.0        503.32959      0.46029     0.0         0.0       518.68799   2115.97363
 989.34058   1110.01587      1.01509   989.34058    63.03510   600.05249   3525.81616
   0.01285     -0.00125      3.26275    22.04700     0.06393   497.60693   1829.91675
  -0.03237     -0.01692      1.10137     0.0         0.99999     0.00002      0.00000
 0.99992  1.0000  1.0000   0.99999  1.0000  1.0000   0.99512  1.0000  1.0004   1.00000  1.0000  1.0000  494.95581     10060
```

```
*
   22.84726     503.73193     503.74121       1.01666       0.0          0.0          0.0
    0.0         503.74121       0.46068       0.0           0.0        518.68799   2115.97192
 1045.74731    1160.75073       1.06152    1045.74731      64.27360    609.58229   3726.25391
    0.00610      -0.00059       3.37058      22.04700       0.06892    497.57227   1829.46997
   -0.03187      -0.01666       1.10165       0.0           0.99999      0.00002      0.00000
  0.99999  1.0000  1.0000    0.99999  1.0000  1.0000     0.93519  1.0000  1.0004    1.00000  1.0000  1.0000  495.48779    10060

   23.43881     504.00391     504.00610       1.01695       0.0          0.0          0.0
    0.0         504.00610       0.46093       0.0           0.0        518.68799   2115.96753
 1072.82349    1185.31519       1.08401    1072.82349      64.83607    614.34326   3829.39746
    0.00298      -0.00029       3.30951      22.04700       0.06891    497.55005   1829.17969
   -0.03242      -0.01695       1.10133       0.0           0.99999      0.00002      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000     0.99310  1.0000  1.0003    1.00000  1.0000  1.0000  495.60645    10060
*
   24.01569     504.05493     504.05493       1.01696       0.0          0.0          0.0
    0.0         504.05493       0.46098       0.0           0.0        518.68799   2115.97119
 1099.22754    1209.23564       1.10593    1099.22754      65.36594    519.10278   3934.55127
    0.00000      -0.00000       3.30895      22.04700       0.06891    497.54590   1829.13013
   -0.03246      -0.01696       1.10132       0.0           1.00000      0.00002      0.00000
  0.99999  1.0000  1.0000    0.99999  1.0000  1.0000     0.99509  1.0000  1.0003    1.00000  1.0000  1.0000  495.64624    10060


  518.68799    2115.96533     0.99998  1.0000  1.0000   0.99978  1.0000  1.0000    498.32349     0.0          0.0       10070
  421.16064    5245.00000   421.21045   5245.00000        0.0         1.00000        16.00000    25.19600      0.0
*STATOR     OPT4
* NISRF
*MASS AVERAGE TOTAL PRESSURE                    DELTA-T COOLING =    0.0          TOTAL DELTA-T =    0.0
*
            NASA FAN ENGINE SPLITTER STUDY                                              LOOP= 0
    1.00000     209.37054     249.72566       0.69449       0.0          0.0          0.0
    0.0         249.72566       0.22432       0.0           0.0        518.68799   2115.96558
   45.77124     253.13562       0.22856      45.77124      10.39624    518.86206   2118.44556
    0.66055      -0.38416     -32.56863      25.19600       0.07457    513.49927   2042.78149
    0.51112       0.30551       1.61270       0.0           0.99995      0.00004      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000     1.03892  1.0000  1.0000    1.00000  1.0000  1.0000  359.58325    10070
*
    4.88578     360.91382     379.57813       0.95715       0.0          0.0          0.0
    0.0         379.57813       0.34400       0.0           0.0        518.68799   2115.95410
  223.62813     449.55542       0.39926     223.62813      30.50443    522.84814   2175.97534
    0.32574      -0.07569      -8.71924      25.19600       0.07212    506.69971   1949.63818
    0.08142       0.04285       1.17015       0.0           0.99998      0.00005      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000     1.00762  0.9999  0.9998    1.00000  1.0000  1.0000  396.57324    10070
*
    6.42750     399.12915     412.78369       0.98013       0.0          0.0          0.0
    0.0         412.78369       0.37490       0.0           0.0        518.68799   2115.94995
  294.19434     536.39307       0.46037     294.19434      35.47777    525.88794   2220.59155
    0.26380      -0.05363      -2.93189      25.19600       0.07135    504.51025   1920.29883
    0.03797       0.01987       1.14270       0.0           0.99997      0.00002      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000     1.00404  0.9997  0.9992    1.00000  1.0000  1.0000  421.15137    10070
*
    7.55135     422.56470     433.37427       0.99546       0.0          0.0          0.0
    0.0         433.37427       0.39416       0.0           0.0        518.68799   2115.94556
  345.63477     554.32544       0.50417     345.63477      38.57387    528.62573   2261.33887
    0.22763      -0.04063       0.14450      25.19600       0.07093    503.06030   1901.04932
    0.00869       0.00454       1.12510       0.0           0.99997      0.00004      0.00000
  0.99997  1.0000  1.0000    0.99997  1.0000  1.0000     1.00099  0.9991  0.9966    1.00000  1.0000  1.0000  435.34888    10070
*
```

```
 8.55742     440.20142      448.86206      1.00538     0.0          0.0          0.0
 0.0         448.86206        0.40871      0.0         0.0        518.68799   2115.95239
391.68335    595.72900        0.54244    391.68335    41.10840    531.44971   2303.93652
 0.19934      -0.03168        1.94186     25.19600     0.07043    501.92310   1886.05884
-0.01035      -0.00538        1.11401      0.0         0.99999      0.00003      0.00000
0.99993  1.0000  1.0000     0.99998  1.0000  1.0000    0.99875  1.0001  1.0014    1.00000  1.0000  1.0000  446.46094      10070
*
 10.16122    462.42480      468.38379      1.01521     0.0          0.0          0.0
 0.0         468.38379        0.42712      0.0         0.0        518.68799   2115.95020
465.09155    660.07080        0.60191    465.09155    44.79791    536.68066   2384.33447
 0.16106      -0.02149        3.51453     25.19600     0.06991    500.43286   1866.52832
-0.02929      -0.01521        1.10322      0.0         0.99999      0.00002      0.00000
0.99998  1.0000  1.0000     0.99998  1.0000  1.0000    0.99621  1.0000  1.0004    1.00000  1.0000  1.0000  461.36548      10070
*
 11.50174    476.41040      480.68188      1.01956     0.0          0.0          0.0
 0.0         480.68188        0.43876      0.0         0.0        518.68799   2115.96387
526.44873    712.98379        0.65071    526.44873    47.60187    541.73999   2464.01611
 0.13421      -0.01576        4.13005     25.19600     0.06957    499.46143   1853.88892
-0.03766      -0.01956        1.09852      0.0         0.99999      0.00002      0.00000
0.99998  1.0000  1.0000     0.99998  1.0000  1.0000    0.99490  1.0000  1.0003    1.00000  1.0000  1.0000  471.46143      10070


 13.74202    493.00391      495.35864      1.02286     0.0          0.0          0.0
 0.0         495.35864        0.45269      0.0         0.0        518.68799   2115.96606
628.98901    800.62939        0.73167    628.98901    51.77785    551.59131   2624.60254
 0.09786      -0.00961        4.46060     25.19600     0.06916    498.26929   1938.45117
-0.04395      -0.02286        1.09497      0.0         0.99999      0.00003      0.00000
0.99999  1.0000  1.0000     0.99998  1.0000  1.0000    0.99369  1.0000  1.0003    1.00000  1.0000  1.0000  484.28760      10070
*
 16.07721    503.78608      505.15161      1.02392     0.0          0.0          0.0
 0.0         505.15161        0.46202      0.0         0.0        518.68799   2115.97119
735.87378    992.57397        0.81637    735.87378    55.53172    563.71875   2932.43311
 0.06305      -0.00586        4.52107     25.19600     0.06388    497.45386   1927.94116
-0.04593      -0.02392        1.09383      0.0         1.00000      0.00000      0.00000
0.99999  1.0000  1.0000     0.99999  1.0000  1.0000    0.99313  1.0000  1.0002    1.00000  1.0000  1.0000  493.34889      10070
*
 16.92183    506.79932      507.67676      1.02404     0.0          0.0          0.0
 0.0         507.67676        0.46443      0.0         0.0        518.68799   2115.97046
774.53296    926.08691        0.84720    774.53296    56.75667    568.57178   2918.81641
 0.05887      -0.00489        4.44957     25.19600     0.06890    497.24097   1825.20532
-0.04612      -0.02404        1.09371      0.0         0.99999      0.00001      0.00000
0.99999  1.0000  1.0000     0.99999  1.0000  1.0000    0.99302  1.0000  1.0002    1.00000  1.0000  1.0000  495.76001      10070
*
 17.78839    509.21118      509.84912      1.02409     0.0          0.0          0.0
 0.0         509.84912        0.46650      0.0         0.0        518.68799   2115.96582
814.21973    960.67676        0.87900    814.21973    57.94589    573.81201   3014.19629
 0.05007      -0.00404        4.49064     25.19600     0.06874    497.05713   1922.94399
-0.04619      -0.02409        1.09366      0.0         0.99999      0.00002      0.00000
0.99993  1.0000  1.0000     0.99998  1.0000  1.0000    0.99295  1.0000  1.0002    1.00000  1.0000  1.0000  497.85718      10070
*
 20.38173    514.11230      514.29761      1.02417     0.0          0.0          0.0
 0.0         514.29761        0.47075      0.0         0.0        518.68799   2115.96494
932.89697   1065.26904        0.97598    932.89697    61.13242    591.04004   3343.57520
 0.02686      -0.00202        4.36856     25.19600     0.06861    496.67798   1917.97559
-0.04631      -0.02417        1.09356      0.0         0.99999      0.0          0.0
0.99998  1.0000  1.0000     0.99998  1.0000  1.0000    0.99280  1.0000  1.0002    1.00000  1.0000  1.0000  502.15845      10070
*
```

```
   21.66251    515.44212    515.51537     1.02421      0.0         0.0         0.0
    0.0        515.51587      0.47102     0.0          0.0       518.68799   2115.96997
  991.51953   1117.52710      1.02302   991.51953     62.52890   600.41099   3533.20972
    0.01681     -0.00129      4.37679    25.19600      0.06357   496.57349   1816.64478
   -0.04538     -0.02421      1.09352     0.0          0.99999     0.00001      0.00000
  0.99999  1.0000  1.0000    0.99999  1.0000  1.0000   0.99275  1.0000  1.0002    1.00000  1.0000  1.0000  503.32959   10070
*
   22.86981    516.14990    516.16602     1.02466      0.0         0.0         0.0
    0.0        516.16602      0.47254     0.0          0.0       518.68799   2115.96558
 1046.77954   1167.12207      1.06849  1046.77954     63.75211   609.76147   3730.09496
    0.00776     -0.00060      4.20537    25.19600      0.06355   496.51758   1815.92725
   -0.04725     -0.02466      1.09394     0.0          0.99999     0.00002      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000   0.99260  1.0000  1.0002    1.00000  1.0000  1.0000  503.74121   10070

   23.44980    516.30957    516.31323     1.02442      0.0         0.0         0.0
    0.0        516.31323      0.47268     0.0          0.0       518.68799   2115.96460
 1073.32617   1191.05322      1.09040  1073.32617     64.31053   614.43286   3831.35156
    0.00398     -0.00029      4.38305    25.19600      0.06355   496.50513   1815.76440
   -0.04676     -0.02442      1.09330     0.0          0.99999     0.00001      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000   0.99267  1.0000  1.0002    1.00000  1.0000  1.0000  504.00610   10070
*
   24.01569    516.36304    516.36304     1.02442      0.0         0.0         0.0
    0.0        516.36304      0.47273     0.0          0.0       518.68799   2115.96484
 1099.22754   1214.46729      1.11184  1099.22754     64.83910   619.10278   3934.53955
   -0.00000      0.00000      4.39928    25.19600      0.06355   496.50073   1815.71119
   -0.04676     -0.02442      1.09330     0.0          0.99999     0.00002      0.00000
  0.99993  1.0000  1.0000    0.99998  1.0000  1.0000   0.99267  1.0000  1.0002    1.00000  1.0000  1.0000  504.05493   10070

  518.68799   2115.96265    0.99998  1.0000  1.0000   0.99999  1.0000  1.0000   496.56958    0.0      0.0      10090
  421.11377   5245.00000    421.16406   5245.00000     0.0         1.00000        16.00000    28.34599    0.0
*STATOR    OPT4
* NISRF
*MASS AVERAGE TOTAL PRESSURE                    DELTA-T COOLING =    0.0         TOTAL DELTA-T =    0.0
*
                NASA FAN ENGINE SPLITTER STUDY                                            LOOP= 0
    4.18000    241.83716    360.03955     1.44174      0.0         0.0         0.0
    0.0        360.03955      0.32590     0.0          0.0       518.68799   2115.96265
  191.32375    407.71704      0.36906   191.32375     27.99601   521.73315   2159.78003
    1.10242      0.10360     58.28232    28.34599      0.07255   507.90234   1965.89916
   -1.05059     -1.44174      0.77684     0.0          0.99998     0.00004      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000   0.96236  1.0000  1.0000    1.00000  1.0000  1.0000  249.72566   10080
*
    6.25538    379.04761    419.37524     1.10485      0.0         0.0         0.0
    0.0        419.37524      0.38106     0.0          0.0       518.68799   2115.94995
  286.31665    507.79199      0.46139   286.31665     34.32220   525.50757   2214.97144
    0.53326     -0.05607     26.00916    28.34599      0.07118   504.05371   1914.22681
   -0.21287     -0.10485      1.01372     0.0          0.99998     0.00002      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000   0.98184  1.0000  1.0001    1.00000  1.0000  1.0000  379.57813   10080
*
```

```
   7.49459     418.44922     451.26953      1.09323      0.0          0.0           0.0
   0.0         451.26953       0.41097      0.0          0.0        518.68799    2115.94653
 343.03662     566.34927       0.51623    343.03662     37.24060    528.47681    2259.11011
   0.40376      -0.03522      20.31541     28.34599      0.07037    501.74268    1883.67896
  -0.18717      -0.09323       1.02448      0.0          0.99999      0.00002       0.00000
 0.99997  1.0000  1.0000      0.99997  1.0000  1.0000    0.98093  1.0000  1.0001    1.00000  1.0000  1.0000  412.78369     10080
*
   8.44508     445.11084     468.92603      1.08203      0.0          0.0           0.0
   0.0         468.92603       0.42763      0.0          0.0        518.68799    2115.94165
 386.54175     607.70557       0.55419    386.54175     39.40919    531.11694    2298.87402
   0.33147      -0.02529      16.87584     28.34599      0.06990    500.39063    1865.96826
  -0.16323      -0.08203       1.03509      0.0          0.99999      0.00002       0.00000
 0.99997  1.0000  1.0000      0.99997  1.0000  1.0000    0.98155  1.0000  1.0001    1.00000  1.0000  1.0000  433.37427     10080
*
   9.32226     463.62524     481.38647      1.07246      0.0          0.0           0.0
   0.0         481.38647       0.43942      0.0          0.0        518.68799    2115.94995
 426.69116     643.27148       0.58720    426.69116     41.55312    533.83252    2340.31519
   0.27944      -0.01916      14.43035     28.34599      0.06955    499.40503    1953.14282
  -0.14315      -0.07246       1.04433      0.0          1.00000      0.00001       0.00000
 0.99998  1.0000  1.0000      0.99998  1.0000  1.0000    0.98255  1.0000  1.0001    1.00000  1.0000  1.0000  448.86206     10080
*
  10.76099     485.31616     496.40137      1.05982      0.0          0.0           0.0
   0.0         496.40137       0.45369      0.0          0.0        518.68799    2115.94995
 492.54370     699.29517       0.63912    492.54370     44.77649    539.86694    2418.53198
   0.21495      -0.01272      11.69295     28.34599      0.06913    498.18335    1837.32275
  -0.11708      -0.05982       1.05679      0.0          1.00000      0.00000       0.00000
 0.99998  1.0000  1.0000      0.99998  1.0000  1.0000    0.98436  1.0000  1.0001    1.00000  1.0000  1.0000  463.38379     10080
*
  11.99247     498.05396     505.52979      1.05169      0.0          0.0           0.0
   0.0         505.52979       0.46238      0.0          0.0        518.68799    2115.95850
 548.91016     746.23218       0.68254    548.91016     47.35583    543.74854    2496.16553
   0.17391      -0.10943       9.96200     28.34599      0.06887    497.42212    1827.52661
  -0.10057      -0.05169       1.06495      0.0          1.00000      0.00002       0.00000
 0.99998  1.0000  1.0000      0.99998  1.0000  1.0000    0.93578  1.0000  1.0001    1.00000  1.0000  1.0000  480.68188     10080


  14.09190     512.55127     516.37500      1.04243      0.0          0.0           0.0
   0.0         516.37500       0.47274      0.0          0.0        518.68799    2115.96509
 645.00366     826.24023       0.75642    645.00366     51.32001    553.28760    2652.98755
   0.12238      -0.00594       8.20345     28.34599      0.06855    496.49976    1815.69507
  -0.08198      -0.04243       1.07442      0.0          1.00000      0.00000       0.00000
 0.99993  1.0000  1.0000      0.99998  1.0000  1.0000    0.98763  1.0000  1.0001    1.00000  1.0000  1.0000  495.35864     10080
*
  16.31728     521.92969     523.74316      1.03680      0.0          0.0           0.0
   0.0         523.74316       0.47979      0.0          0.0        518.68799    2115.96680
 746.86182     912.20044       0.83565    746.86182     54.95159    565.07275    2856.34790
   0.08343      -0.00389       7.02922     28.34599      0.06833    495.86182    1807.54614
  -0.07081      -0.03680       1.08024      0.0          0.99999      0.00002       0.00000
 0.99998  1.0000  1.0000      0.99998  1.0000  1.0000    0.98884  1.0000  1.0002    1.00000  1.0000  1.0000  505.15161     10080
*
  17.12863     524.34912     525.69482      1.03549      0.0          0.0           0.0
   0.0         525.69482       0.48166      0.0          0.0        518.68799    2115.96704
 783.99854     943.23262       0.86487    783.99854     56.15691    569.79785    2940.93457
   0.07162      -0.00324       7.01830     28.34599      0.06827    495.69141    1805.37256
  -0.06820      -0.03549       1.08161      0.0          0.99999      0.00001       0.00000
 0.99993  1.0000  1.0000      0.99998  1.0000  1.0000    0.98914  1.0000  1.0002    1.00000  1.0000  1.0000  507.67676     10080
*
```

```
  17.96422    526.39502    527.36270      1.03435     0.0          0.0          0.0
   0.0        527.36270      0.48326      0.0         0.0        519.68799   2115.96265
 822.24439    976.33032      0.89515    822.24439    57.32506    574.20332   3734.33276
   0.06067     -0.00267      6.57595     23.34599     0.06422    495.54517   1893.50513
  -0.06596     -0.03435      1.08230      0.0         0.99999      0.00001      0.00007
   0.99993  1.0000  1.0000   0.99998  1.0000  1.0000   0.99939  1.0000  1.0002   1.00000  1.0000  1.0000  529.84912   10980

  20.47522    530.61011    530.68802      1.03226     0.0          0.0          0.0
   0.0        530.88802      0.49665      0.0         0.0        519.68799   2115.96069
 937.17603   1077.09830      0.98734    937.17603    60.46035    591.70484   3356.77612
   0.03243     -0.00151      6.47209     23.34599     0.06311    495.23462   1799.55103
  -0.06183     -0.03226      1.09500      0.0         0.99999      0.00001      0.00000
   0.99999  1.0000  1.0000   0.99998  1.0000  1.0000   0.99987  1.0000  1.0002   1.00000  1.0000  1.0000  514.29761   10980

  21.72079    531.78052    531.99216      1.03176     0.0          0.0          0.0
   0.0        531.19216      0.48751      0.0         0.0        519.69799   2115.96558
 994.18750   1127.52563      1.03366    994.18750    61.85320    590.85083   3542.29931
   0.02724     -0.00088      6.32621     23.34599     0.06309    495.14624   1798.43213
  -0.06083     -0.03176      1.08552      0.0         0.99999      0.00001      0.00000
   0.99998  1.0000  1.0000   0.99999  1.0000  1.0000   0.99998  1.0000  1.0002   1.00000  1.0000  1.0000  515.51537   10980

  22.89737    532.15869    532.18296      1.03103     0.0          0.0          0.0
   0.0        532.18286      0.48780      0.0         0.0        519.68799   2115.96509
1048.04077   1175.41772      1.07759   1048.04077    63.07303    599.99071   3734.79199
   0.02356     -0.00042      6.24349     23.34599     0.06917    495.12036   1798.02937
  -0.05940     -0.03103      1.08629      0.0         0.99999      0.00000      0.00007
   0.99993  1.0000  1.0000   0.99999  1.0000  1.0000   0.99919  1.0000  1.0002   1.00000  1.0000  1.0000  516.16602   10980

  23.46326    532.45703    532.46265      1.03128     0.0          0.0          0.0
   0.0        532.46265      0.48816      0.0         0.0        519.69799   2115.96191
1073.94214   1193.59385      1.09276   1073.94214    63.62762    614.54248   3973.73999
   0.00466     -0.00021      6.14469     23.34599     0.06806    495.09546   1797.78199
  -0.05949     -0.03128      1.08603      0.0         0.99999      0.00001      0.00000
   0.99993  1.0000  1.0000   0.99998  1.0000  1.0000   0.99919  1.0000  1.0002   1.00000  1.0000  1.0000  516.31323   10980

  24.01569    532.50464    532.50464      1.03126     0.0          0.0          0.0
   0.0        532.50464      0.48920      0.0         0.0        519.69799   2115.96216
1099.22754   1221.41797      1.11979   1099.22754    64.15279    619.10279   3934.53442
   0.00002     -0.00002      6.11706     23.34599     0.06306    495.09180   1797.73560
  -0.05985     -0.03126      1.08695      0.0         0.99999      0.00001      0.00000
   0.99991  1.0000  1.0000   0.99999  1.0000  1.0000   0.99919  1.0000  1.0002   1.00000  1.0000  1.0000  516.36304   10980
```

```
  518.68799   2115.95801     0.99998  1.0000  1.0000     0.99398  1.0000  1.0000     493.51416       0.0          0.0          10090
  421.18348   5245.00000   421.23975   5245.00000          0.0            1.00000     16.00000      31.49599      0.0
*STATOR    OPT4
* NISPF
*MASS AVERAGE TOTAL PRESSURE                    DELTA-T COOLING =   0.0         TOTAL DELTA-T =   0.0
*
             NASA FAN ENGINE SPLITTER STUDY                                                  LOOP= 0
    7.03000     486.69352     586.43579      1.62881      0.0          0.0         0.0
    0.0         586.43579       0.54039      0.0          0.0        518.68799   2115.96069
  321.77173     668.91235       0.61639    321.77173     28.75314    527.30103   2241.57104
    0.67262       0.16929      64.47115     31.49599      0.06635    490.06909   1734.70972
   -1.54040      -0.62881       0.68762      0.0          1.00000      0.00001      0.00000
  0.99998  1.0000  1.0000     0.99998  1.0000  1.0000     0.89241  1.0000  1.0000   1.00000  1.0000  1.0000  360.03955   10090
*
    7.98771     503.69897     562.09790      1.34032      0.0          0.0         0.0
    0.0         562.09790       0.51674      0.0          0.0        518.68799   2115.94775
  365.60742     670.53906       0.61643    365.60742     33.04132    522.30713   2279.08667
    0.49530       0.08017      40.67438     31.49599      0.06714    492.39575   1763.69385
   -0.74621      -0.34032       0.83562      0.0          1.00000      0.00001      0.00000
  0.99993  1.0000  1.0000     0.99998  1.0000  1.0000     0.92136  1.0000  1.0000   1.00000  1.0000  1.0000  419.37524   10090
*
    8.81488     512.49561     550.99438      1.22099      0.0          0.0         0.0
    0.0         550.99438       0.50600      0.0          0.0        518.68799   2115.94116
  403.46802     682.92114       0.62716    403.46802     36.21361    532.22900   2315.77344
    0.39482       0.04088      29.63449     31.49599      0.06749    493.42432   1776.61890
   -0.46092      -0.22099       0.91729      0.0          1.00000      0.00002      0.00000
  0.99997  1.0000  1.0000     0.99997  1.0000  1.0000     0.94317  1.0000  1.0000   1.00000  1.0000  1.0000  451.26953   10090
*
    9.53307     518.25391     546.37012      1.16515      0.0          0.0         0.0
    0.0         546.37012       0.50154      0.0          0.0        518.68799   2115.94214
  436.34009     699.22314       0.64185    436.34009     33.61142    534.52515   2350.95703
    0.33394       0.02377      23.48830     31.49599      0.06763    493.84668   1781.94336
   -0.23612      -0.16515       0.96125      0.0          1.00000     -0.00000     -0.00000
  0.99997  1.0000  1.0000     0.99997  1.0000  1.0000     0.95437  1.0000  1.0000   1.00000  1.0000  1.0000  468.92603   10090
*
   10.24184     523.07910     544.21582      1.13052      0.0          0.0         0.0
    0.0         544.21582       0.49947      0.0          0.0        518.68799   2115.95020
  468.78174     719.28076       0.65922    468.78174     40.74124    536.96729   2388.80200
    0.28714       0.01426      19.26358     31.49599      0.06770    494.04224   1794.42090
   -0.26148      -0.13052       0.99070      0.0          1.00000     -0.00000     -0.00000
  0.99993  1.0000  1.0000     0.99998  1.0000  1.0000     0.96292  1.0000  1.0000   1.00000  1.0000  1.0000  481.39647   10090
*
   11.47019     529.76611     543.10693      1.09409      0.0          0.0         0.0
    0.0         543.10693       0.49840      0.0          0.0        518.68799   2115.94458
  525.00464     755.37744       0.69319    525.00464     44.02394    541.61377   2461.98534
    0.22593       0.01579      13.84368     31.49599      0.06774    494.14258   1795.68972
   -0.18531      -0.10409       1.02369      0.0          1.00000      0.00002      0.00000
  0.99997  1.0000  1.0000     0.99997  1.0000  1.0000     0.97190  1.0000  1.0000   1.00000  1.0000  1.0000  496.40137   10090
*
   12.56759     534.35493     543.65820      1.07542      0.0          0.0         0.0
    0.0         543.65820       0.49893      0.0          0.0        518.68799   2115.95410
  575.23389     791.49121       0.72637    575.23389     46.61546    544.29023   2575.95410
    0.18534       0.10216      11.39636     31.49599      0.06772    494.09277   1785.96522
   -0.14719      -0.07542       1.04145      0.0          0.99999      0.00002      0.00000
  0.99998  1.0000  1.0000     0.99998  1.0000  1.0000     0.97677  1.0000  1.0001   1.00000  1.0000  1.0000  505.52979   10090
```

```
 14.49749    541.14844    545.86890     1.05712     0.0          0.0          0.0
  0.0        545.86990      0.50106     0.0         0.0        518.68799   2115.96119
663.56738    359.24072      0.78871   663.56738    50.55830    555.30713   2687.06177
  0.13237     -0.00041      8.57759    31.49599     0.06765    493.89233   1782.53784
 -0.11042     -0.05712      1.05949     0.0         0.99999      0.00001      0.00000
0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98174  1.0000  1.0001   1.00000  1.0000  1.0000  516.37500   10090
*
 16.59398    546.11499    548.35034     1.04698     0.0          0.0          0.0
  0.0        548.35034      0.50345     0.0         0.0        518.68799   2115.96119
759.52686    935.78662      0.86009   759.52686    54.17207    566.65869   2884.53296
  0.00057     -0.00064      7.48894    31.49599     0.06757    493.66626   1779.69530
 -0.09032     -0.04698      1.06974     0.0         0.99999      0.00002      0.00000
0.99993  1.0000  1.0000   0.99998  1.0000  1.0000   0.98459  1.0000  1.0001   1.00000  1.0000  1.0000  523.74316   10090
*
 17.36696    547.47314    549.15674     1.04463     0.0          0.0          0.0
  0.0        549.15674      0.50423     0.0         0.0        518.68799   2115.96484
794.90723    966.15234      0.88711   794.90723    55.36156    571.22949   2966.91040
  0.07349     -0.00106      6.21939    31.49599     0.06755    493.59253   1778.75537
 -0.08569     -0.04463      1.07215     0.0         0.99999      0.00001      0.00000
0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98526  1.0000  1.0001   1.00000  1.0000  1.0000  525.69492   10090
*
 18.16635    549.32715    550.05762     1.04303     0.0          0.0          0.0
  0.0        550.05762      0.50510     0.0         0.0        518.68799   2115.95509
831.49634    936.97021      0.91548   831.49634    56.51425    576.17480   3057.90552
  0.06700     -0.00134      6.94718    31.49599     0.06752    493.51025   1777.71387
 -0.08253     -0.04303      1.07379     0.0         0.99999      0.00002      0.00000
0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98579  1.0000  1.0001   1.00000  1.0000  1.0000  527.36279   10090
*
 20.58311    551.72974    552.07886     1.03991     0.0          0.0          0.0
  0.0        552.07986      0.50705     0.0         0.0        518.68799   2115.95729
942.11450   1091.95703      1.00290   942.11450    59.62367    597.47583   3372.12524
  0.03559     -0.00050      5.59017    31.49599     0.06746    493.32471   1775.37427
 -0.07640     -0.03991      1.07701     0.0         0.99999      0.00001      0.00000
0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98557  1.0000  1.0001   1.00000  1.0000  1.0000  530.88892   10090
*
 21.78324    552.47314    552.61157     1.03896     0.0          0.0          0.0
  0.0        552.61157      0.50757     0.0         0.0        518.68799   2115.95996
997.27466   1140.14746      1.04721   997.27466    61.00816    601.36133   3552.84985
  0.02240     -0.00050      5.60928    31.49599     0.06744    493.27588   1774.76318
 -0.07453     -0.03896      1.07800     0.0         0.99999      0.00002      0.00000
0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98584  1.0000  1.0001   1.00000  1.0000  1.0000  531.88916   10090
*
 22.92914    552.92017    552.95117     1.03902     0.0          0.0          0.0
  0.0        552.95117      0.50789     0.0         0.0        518.68799   2115.96094
1049.49487  1136.25171      1.08959  1049.49487    62.21640    610.23389   3740.22900
  0.01062     -0.00024      5.76750    31.49599     0.06743    493.24463   1774.36938
 -0.07455     -0.03902      1.07793     0.0         0.99999      0.00001      0.00000
0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98680  1.0000  1.0001   1.00000  1.0000  1.0000  532.18286   10090
```

```
  23.47868     552.79956    552.80664      1.03821       0.0          0.0          0.0
   0.0         552.80664      0.50775      0.0           0.0        518.68799   2115.95435
1074.64844    1208.49658      1.11000   1074.64844      62.77834    614.66846   3836.48682
   0.00515      -0.00010      5.80361     31.49599       0.06743    493.25781   1774.53271
  -0.07306      -0.03821      1.07878      0.0           0.99999      0.00002      0.00000
 0.99998 1.0000 1.0000     0.99998 1.0000 1.0000       0.98707 1.0000 1.0001     1.00000 1.0000 1.0000 532.46265      10090
*
  24.01569     552.82129    552.82129      1.03815       0.0          0.0          0.0
   0.0         552.82129      0.50777      0.0           0.0        518.68799   2115.95654
1099.22754    1230.41138      1.13014   1099.22754      63.30132    619.10278   3934.52417
  -0.00006       0.00006      5.88111     31.49599       0.06743    493.25659   1774.51758
  -0.07295      -0.03815      1.07884      0.0           0.99999      0.00002      0.00000
 0.99998 1.0000 1.0000     0.99998 1.0000 1.0000       0.98709 1.0000 1.0001     1.00000 1.0000 1.0000 532.50464      10090

 518.68799    2115.95215   0.99998 1.0000 1.0000     0.99998 1.0000 1.0000     490.67749      0.0          0.0          10100
 421.08716    5245.00000   421.13940   5245.00000    0.0          1.00000       16.00000      34.64499      0.0
*STATOR    OPT4
* NISRE
*MASS AVERAGE TOTAL PRESSURE                      DELTA-T COOLING =   0.0        TOTAL DELTA-T =   0.0
*
              NASA FAN ENGINE SPLITTER STUDY                                       LOOP= 0
   8.52360     590.32739    624.32520      1.06461       0.0          0.0          0.0
   0.0         624.32520      0.57756      0.0           0.0        518.68799   2115.95068
 390.13550     736.19800      0.68105    390.13550      37.00090    531.34912   2302.40308
   0.34424       0.03927     15.63171     34.64499       0.06506    486.25073   1687.85962
  -0.12288      -0.06461      1.05203      0.0           0.99999      0.00003      0.00000
 0.99998 1.0000 1.0000     0.99998 1.0000 1.0000       0.97299 1.0000 1.0001     1.00000 1.0000 1.0000 586.43579      10100
*
   9.22180     595.25830    612.96631      1.09050       0.0          0.0          0.0
   0.0         612.96631      0.56637      0.0           0.0        518.68799   2115.93628
 422.09302     744.23804      0.68766    422.09302      34.55157    533.50806   2335.32178
   0.31133       0.03667     16.23282     34.64499       0.06546    487.42065   1702.10425
  -0.17484      -0.09050      1.02705      0.0           0.99998      0.00003      0.00001
 0.99997 1.0000 1.0000     0.99997 1.0000 1.0000       0.96508 1.0000 1.0000     0.99999 1.0000 1.0000 562.09790      10100
*
   9.87234     581.00220    603.69189      1.09564       0.0          0.0          0.0
   0.0         603.69189      0.55727      0.0           0.0        518.68799   2115.93115
 451.86938     754.07544      0.69608    451.86938      36.81522    535.67236   2369.66211
   0.28219       0.13065     15.95269     34.64499       0.06577    488.35986   1713.60547
  -0.18569      -0.09564      1.02223      0.0           0.99998      0.00003      0.00000
 0.99997 1.0000 1.0000     0.99997 1.0000 1.0000       0.96453 1.0000 1.0000     1.00000 1.0000 1.0000 550.99438      10100
*
  10.46305     578.18799    596.80420      1.09231       0.0          0.0          0.0
   0.0         596.80420      0.55052      0.0           0.0        518.68799   2115.93530
 478.90649     765.19702      0.70585    478.90649      38.74535    537.76514   2401.24194
   0.25590       0.02580     15.90219     34.64499       0.06600    489.04810   1722.07324
  -0.17725      -0.09231      1.02535      0.0           0.99998      0.00002      0.00000
 0.99997 1.0000 1.0000     0.99997 1.0000 1.0000       0.96640 1.0000 1.0001     1.00000 1.0000 1.0000 546.37012      10100
*
  11.06433     575.99917    591.17529      1.08629       0.0          0.0          0.0
   0.0         591.17529      0.54502      0.0           0.0        518.68799   2115.93921
 506.42822     778.43286      0.71765    506.42822      40.58488    540.02026   2436.70313
   0.23185       0.02086     15.44038     34.64499       0.06619    489.60474   1728.94971
  -0.16732      -0.08629      1.03103      0.0           0.99998      0.00003      0.00001
 0.99997 1.0000 1.0000     0.99997 1.0000 1.0000       0.96891 1.0000 1.0001     0.99999 1.0000 1.0000 544.21582      10100
```

```
*
  12.13934     573.33247     584.35010      1.07594      0.0          0.0          0.0
   0.0         534.35010      0.53936      0.0          0.0        518.68799    2115.94165
 555.63257     806.34521      0.74288    555.63257     43.55695    544.36597    2506.09813
   0.19514       0.01370     16.94917     34.64499      0.06642    490.27246    1737.21216
  -0.14577      -0.07594      1.04095      0.0          0.99999      0.00001      0.00000
 0.99997  1.0000  1.0000   0.99997  1.0000  1.0000   0.97286  1.0000  1.0001   1.00000  1.0000  1.0000  543.10693      10100
*
  13.12671     572.71553     580.51782      1.06780      0.0          0.0          0.0
   0.0         580.51782      0.53462      0.0          0.0        518.68799    2115.94459
 600.82593     835.45947      0.76941    600.82593     45.93483    548.71167    2576.88013
   0.16563       0.01035     15.56934     34.64499      0.06654    490.64404    1741.83252
  -0.13065      -0.06780      1.04889      0.0          0.99999      0.00003      0.00000
 0.99997  1.0000  1.0000   0.99997  1.0000  1.0000   0.97578  1.0000  1.0001   1.00000  1.0000  1.0000  543.65820      10100


  14.90572     571.76855     576.13013      1.05544      0.0          0.0          0.0
   0.0         576.13013      0.53036      0.0          0.0        518.68799    2115.95581
 682.25317     832.36997      0.82202    682.25317     49.82049    557.39771    2722.67529
   0.12375       0.00588     13.89230     34.64499      0.06669    491.06641    1747.09204
  -0.10630      -0.05544      1.06117      0.0          0.99999      0.00002      0.00000
 0.99999  1.0000  1.0000   0.99998  1.0000  1.0000   0.98012  1.0000  1.0001   1.00000  1.0000  1.0000  545.86890      10100
*
  16.87984     572.79858     575.13477      1.04885      0.0          0.0          0.0
   0.0         575.13477      0.52939      0.0          0.0        518.68799    2115.95361
 772.61084     963.17578      0.88656    772.61084     53.33593    569.32471    2914.35571
   0.09341       0.00072     11.48391     34.64499      0.06672    491.16162    1748.27832
  -0.09338      -0.04885      1.06784      0.0          0.99999      0.00002      0.00000
 0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98235  1.0000  1.0001   1.00000  1.0000  1.0000  548.35034      10100
*
  17.61473     573.77344     575.49854      1.04797      0.0          0.0          0.0
   0.0         575.49854      0.52974      0.0          0.0        518.68799    2115.95654
 806.24805     990.57275      0.91181    806.24805     54.48070    572.73853    2994.46582
   0.07761       0.00169     15.18045     34.64499      0.06671    491.12695    1747.84961
  -0.09165      -0.04797      1.06874      0.0          0.99999      0.00002      0.00000
 0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98263  1.0000  1.0001   1.00000  1.0000  1.0000  549.15674      10100
*
  18.37747     574.37036     575.58984      1.04642      0.0          0.0          0.0
   0.0         575.58984      0.52983      0.0          0.0        518.68799    2115.94702
 841.15967    1019.24146      0.93821    841.15967     55.61687    577.51807    3092.96240
   0.06520       0.00246     11.33661     34.64499      0.06670    491.11816    1747.73169
  -0.08862      -0.04642      1.07032      0.0          0.99999      0.00002      0.00000
 0.99997  1.0000  1.0000   0.99997  1.0000  1.0000   0.98314  1.0000  1.0001   1.00000  1.0000  1.0000  550.05762      10100
*
  20.69812     575.31714     575.72729      1.04284      0.0          0.0          0.0
   0.0         575.72729      0.52996      0.0          0.0        518.68799    2115.95239
 947.37842    1108.59692      1.02048    947.37842     58.71268    593.30200    3398.64429
   0.03777      -0.00088     13.74730     34.64499      0.06670    491.10498    1747.56958
  -0.08163      -0.04284      1.07399      0.0          0.99999      0.00001      0.00000
 0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98434  1.0000  1.0001   1.00000  1.0000  1.0000  552.07886      10100
*
  21.86127     576.41846     576.58350      1.04338      0.0          0.0          0.0
   0.0         576.58350      0.53080      0.0          0.0        518.68799    2115.95386
1000.61719    1154.35205      1.06314   1000.61719     60.24823    601.91577    3564.34790
   0.02394      -0.00048     13.74757     34.64499      0.06667    491.02295    1746.55005
  -0.08268      -0.04338      1.07343      0.0          0.99999      0.00002      0.00000
 0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98411  1.0000  1.0001   1.00000  1.0000  1.0000  552.61157      10100
```

```
*
   22.96419    577.24805    577.28638      1.04401      0.0          0.0          0.0
    0.0        577.28638      0.53148      0.0          0.0        518.68799   2115.95776
 1051.09912   4199.19482      1.10404   1051.09912     61.22340    610.51367   3746.24902
    0.01155     -0.00035     13.63923     34.64499      0.06665    490.95532   1745.70947
   -0.08399     -0.04401      1.07279      0.0          0.99999      0.00001      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000    0.98385  1.0000  1.0001    1.00000  1.0000  1.0000  552.95117      10100


   23.49588    577.48291    577.49243      1.04465      0.0          0.0          0.0
    0.0        577.49243      0.53168      0.0          0.0        518.68799   2115.94727
 1075.43555   1220.67920      1.12384   1075.43555     61.76485    614.80884   3839.55347
    0.00580     -0.00031     13.52541     34.64499      0.06664    490.93555   1745.45776
   -0.08514     -0.04465      1.07212      0.0          0.99999      0.00002      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000    0.98362  1.0000  1.0001    1.00000  1.0000  1.0000  552.80664      10100
*
   24.01569    577.59546    577.59546      1.04481      0.0          0.0          0.0
    0.0        577.59546      0.53178      0.0          0.0        518.68799   2115.95190
 1099.22754   1241.73950      1.14324   1099.22754     62.28000    619.10278   3934.51538
    0.00021     -0.00023     13.30057     34.64499      0.06664    490.92554   1745.33521
   -0.08546     -0.04481      1.07196      0.0          0.99999      0.00001      0.00000
  0.99998  1.0000  1.0000    0.99998  1.0000  1.0000    0.98356  1.0000  1.0001    1.00000  1.0000  1.0000  552.82129      10100


  518.68799   2115.94482    0.99997  1.0000  1.0000    0.99937  1.0000  1.0000    488.33081      0.0          0.0          10110
  421.11621   5245.00000    421.16992   5245.00000      0.0          1.00000     16.00000     37.48000      0.0
*STATOR    OPT4
* NISPF
*MASS AVERAGE TOTAL PRESSURE                      DELTA-T COOLING =    0.0          TOTAL DELTA-T =    0.0
*
              NASA FAN ENGINE SPLITTER STUDY                                          LOOP= 0            Fan Rotor Inlet Station
    9.37000    613.87305    634.72510      1.01666      0.0          0.0          0.0
    0.0        634.72510      0.58784      0.0          0.0        518.68799   2115.94189              Blading Station 1
  428.87646    766.03589      0.70945    428.87646     34.04643    533.98804   2342.69141
    0.26285      0.01814     -3.54463     37.48000      0.06470    485.16089   1674.65308
   -0.03094     -0.01666      1.10165      0.0          0.99999      0.00002      0.00000
  0.99997  1.0000  1.0000    0.99997  1.0000  1.0000    0.99218  1.0000  1.0002    1.00000  1.0000  1.0000  624.32520      10110
*
    9.98851    611.16626    628.61475      1.02553      0.0          0.0          0.0
    0.0        628.61475      0.58180      0.0          0.0        518.68799   2115.93091
  457.18652    777.28760      0.71940    457.18652     36.02309    536.07422   2374.88916
    0.24065      0.01318     -0.90825     37.48000      0.06491    485.80347   1682.41577
   -0.04756     -0.02553      1.09212      0.0          0.99999      0.00001      0.00000
  0.99997  1.0000  1.0000    0.99997  1.0000  1.0000    0.98844  1.0000  1.0002    1.00000  1.0000  1.0000  612.96631      10110
*
   10.57127    609.51465    623.91797      1.03350      0.0          0.0          0.0
    0.0        623.91797      0.57716      0.0          0.0        518.68799   2115.92505
  483.85986    789.55298      0.73038    483.85986     37.79422    538.16187   2407.43921
    0.21368      0.01415      1.65305     37.48000      0.06509    486.29297   1688.35156
   -0.06276     -0.03350      1.08369      0.0          0.99999      0.00002      0.00000
  0.99996  1.0000  1.0000    0.99996  1.0000  1.0000    0.98526  1.0000  1.0001    1.00000  1.0000  1.0000  603.69189      10110
*
```

```
  11.10513    607.59229    620.15845     1.03913     0.0         0.0          0.0
   0.0        620.15845      0.57345     0.0         0.0       518.68799   2115.92871
 508.29541    801.84814      0.74146   508.29541    39.33978   540.17798   2439.18506
   0.20443      0.01043      0.96494    37.48000     0.06521   486.68237   1693.09058
  -0.07358     -0.03913      1.07782     0.0         0.99999     0.00002      0.00000
 0.99997  1.0000  1.0000   0.99997  1.0000  1.0000   0.98317  1.0000  1.0001   1.00000  1.0000  1.0000  596.80420      10110
*
  11.65282    606.32471    617.01563     1.04371     0.0         0.0          0.0
   0.0        617.01563      0.57036     0.0         0.0       518.68799   2115.93115
 533.36401    815.58887      0.75391   533.36401    40.84096   542.34937   2473.70239
   0.18862      0.00763      1.50422    37.48000     0.06532   487.00610   1697.03833
  -0.08244     -0.04371      1.07309     0.0         0.99998     0.00002      0.00000
 0.99997  1.0000  1.0000   0.99997  1.0000  1.0000   0.98155  1.0000  1.0001   1.00000  1.0000  1.0000  591.17529      10110
*
  12.64198    602.86035    610.62891     1.04497     0.0         0.0          0.0
   0.0        610.62891      0.56407     0.0         0.0       518.68799   2115.93115
 578.63916    841.24365      0.77711   578.63916    43.45918   546.53589   2541.24780
   0.16106      0.01033     -8.28319    37.48000     0.06554   487.65869   1705.01172
  -0.08502     -0.04497      1.07180     0.0         0.99999     0.00003      0.00000
 0.99997  1.0000  1.0000   0.99997  1.0000  1.0000   0.98146  1.0000  1.0001   0.99999  1.0000  1.0000  584.35010      10110
*
  13.56178    599.03130    605.24365     1.04259     0.0         0.0          0.0
   0.0        605.24365      0.55879     0.0         0.0       518.68799   2115.93945
 620.73950    866.07021      0.80042   620.73950    45.72412   550.73413   2610.30688
   0.14380      0.00503     -8.78563    37.48000     0.06572   488.20361   1711.69141
  -0.08055     -0.04259      1.07425     0.0         0.99999     0.00001      0.00000
 0.99997  1.0000  1.0000   0.99997  1.0000  1.0000   0.98270  1.0000  1.0001   1.00000  1.0000  1.0000  580.51782      10110


  15.23975    596.65942    600.54150     1.04237     0.0         0.0          0.0
   0.0        600.54150      0.55418     0.0         0.0       518.68799   2115.95044
 697.54199    920.44287      0.84939   697.54199    49.27350   559.15137   2752.80029
   0.11426      0.00079     -7.91904    37.48000     0.06598   488.67554   1717.47854
  -0.08072     -0.04237      1.07447     0.0         0.99999     0.00001      0.00000
 0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98306  1.0000  1.0001   1.00000  1.0000  1.0000  576.13013      10110
*
  17.12546    593.31152    595.21460     1.03491     0.0         0.0          0.0
   0.0        595.21460      0.54896     0.0         0.0       518.68799   2115.94531
 783.85327    984.22376      0.90775   783.85327    52.78896   569.77295   2940.56519
   0.08016      0.00648     -5.81019    37.48000     0.06606   489.20581   1724.02832
  -0.06594     -0.03491      1.08222     0.0         0.99999     0.00002      0.00000
 0.99997  1.0000  1.0000   0.99997  1.0000  1.0000   0.98613  1.0000  1.0001   1.00000  1.0000  1.0000  575.13477      10110
*
  17.83376    591.77930    593.61597     1.03149     0.0         0.0          0.0
   0.0        593.61597      0.54740     0.0         0.0       518.68799   2115.95093
 816.27295   1009.29736      0.93072   816.27295    53.97430   574.09033   3019.29639
   0.07885     -0.00252    -21.70169    37.48000     0.06611   489.36401   1725.98291
  -0.05939     -0.03148      1.08582     0.0         0.99999     0.00002      0.00000
 0.99998  1.0000  1.0000   0.99998  1.0000  1.0000   0.98749  1.0000  1.0001   1.00000  1.0000  1.0000  575.49854      10110
*
  18.57094    594.03247    595.82861     1.03516     0.0         0.0          0.0
   0.0        595.82861      0.54957     0.0         0.0       518.68799   2115.94019
 850.01465   1038.04443      0.95745   850.01465    54.97095   578.76245   3106.30396
   0.07783     -0.01140     -6.64928    37.48000     0.06604   489.14478   1723.27026
  -0.06642     -0.03516      1.08196     0.0         0.99999     0.00002      0.00000
 0.99997  1.0000  1.0000   0.99997  1.0000  1.0000   0.98601  1.0000  1.0001   1.00000  1.0000  1.0000  575.58984      10110
```

```
*
  20.80954     602.90137     603.40991      1.04808      0.0          0.0          0.0
   0.0         603.40991       0.55699      0.0          0.0        518.68799    2115.94873
 952.47827    1127.52734       1.04078    952.47827     57.64503    594.10693    3404.78369
   0.04108      -0.00149      -7.89181     37.48000      0.06578    488.38918    1713.96387
  -0.09122      -0.04808       1.06862      0.0          0.99999      0.00001       0.00000
 0.99993  1.0000  1.0000     0.99998  1.0000  1.0000    0.98077  1.0000  1.0001    1.00000  1.0000  1.0000  575.72729      10110
*
  21.93065     603.51587     603.70264      1.04703      0.0          0.0          0.0
   0.0         603.70264       0.55728      0.0          0.0        518.68799    2115.94604
1003.79297    1171.34839       1.08127   1003.79297     58.97532    602.44409    3575.32422
   0.02489      -0.00020      -8.08308     37.48000      0.06577    488.35864    1713.60181
  -0.08918      -0.04703       1.06969      0.0          0.99998      0.00002       0.00000
 0.99997  1.0000  1.0000     0.99997  1.0000  1.0000    0.98114  1.0000  1.0001    1.00000  1.0000  1.0000  576.58350      10110
*
  22.99654     603.56274     603.59863      1.04558      0.0          0.0          0.0
   0.0         603.59863       0.55717      0.0          0.0        518.68799    2115.95068
1052.58472    1213.36338       1.12004   1052.58472     60.16806    610.77319    3751.82202
   0.01092       0.00079      -8.32868     37.48000      0.06578    498.36914    1713.73389
  -0.08636      -0.04558       1.07118      0.0          0.99998      0.00002       0.00000
 0.99998  1.0000  1.0000     0.99998  1.0000  1.0000    0.98168  1.0000  1.0001    1.00000  1.0000  1.0000  577.28638      10110

  23.51160     603.17944     603.18628      1.04449      0.0          0.0          0.0
   0.0         603.18628       0.55677      0.0          0.0        518.68799    2115.93726
1076.15479    1233.67017       1.13874   1076.15479     60.72928    614.93750    3842.35620
   0.00481       0.00100      -8.26132     37.48000      0.06579    488.41064    1714.23535
  -0.08426      -0.04449       1.07229      0.0          0.99999      0.00003       0.00000
 0.99997  1.0000  1.0000     0.99997  1.0000  1.0000    0.98211  1.0000  1.0001    1.00000  1.0000  1.0000  577.49243      10110
*
  24.01569     602.95581     602.95581      1.04391      0.0          0.0          0.0
   0.0         602.95581       0.55654      0.0          0.0        518.68799    2115.94189
1099.22754    1253.73682       1.15723   1099.22754     61.25400    619.10278    3934.49683
  -0.00075       0.00090      -7.75506     37.48000      0.06580    498.43384    1714.52393
  -0.08313      -0.04391       1.07280      0.0          0.99999      0.00003       0.00000
 0.99997  1.0000  1.0000     0.99997  1.0000  1.0000    0.98235  1.0000  1.0001    1.00000  1.0000  1.0000  577.59546      10110

 557.73328    2567.10977    1.26040  0.9103  0.9072   1.26043  0.9104  0.9074   526.05811   5129.49219    9.37761     10120
 421.30664    5245.00000    346.65332  5058.05469     0.0           0.99000      16.00000     41.10199      0.0
*ROTOR     OPT3
* NISRE
*MASS AVERAGE TOTAL PRESSURE                 DELTA-T COOLING =   0.0        TOTAL DELTA-T =   0.0
*
                 NASA FAN ENGINE SPLITTER STUDY                                     LOOP= 3
  10.09840     540.73003    544.06982      0.72205      44.42227     43.19116    -10.43758     0.31854     0.31854
 561.83447     792.09326      0.70580   5673.62500     45.92026    561.87915   2684.90576     2.33175     1.00000
 -99.61941     553.11450      0.49916    462.21606    -10.37584    536.45898   2282.99697     1.38495     1.38495
   0.11047       0.06599    -32.59427     41.10199      0.07163    511.00003   1925.63623     0.70951     0.70951
   0.31854       0.65839      2.08376      0.0          0.00676      0.14667      0.04182     2.32482     0.0
 1.26886  0.8439  0.9448   1.26889  0.8500  0.8448   1.14987  0.7687  0.7640   1.26989  0.8500  0.8448  766.03589   10120
```

Fan Rotor Exit Station

Blading Station 2

```
*
   10.69295    544.74219    549.05200      0.70649    37.06828    40.65308    -1.04842     0.38297    0.38297
  499.39844    742.19727      0.66816   5340.04297    42.28954   559.34106  2680.62012     2.15724    1.00000
   -9.96899    549.14258      0.49436    489.42944    -1.04019   538.61304  2348.43872     1.41546    1.41546
    0.12604      0.05011    -36.65102     41.10199     0.07254   513.52856  1987.23218     0.71946    0.71946
    0.38297      0.52570      2.04923      0.0         0.86091     0.09541     0.02782     2.11539    0.0
 1.26683  0.8949  0.8913  1.26687  0.8950  0.8914  1.18118  0.8572  0.8537  1.26687  0.8950  0.8914  777.28760   10120
*
   11.24340    542.12329    547.79297      0.69777    31.68158    39.02856     6.17609     0.42084    0.42084
  455.95972    712.72461      0.64042   5126.53516    39.77255   557.71655  2676.60132     1.99949    1.00000
   58.66455    550.92529      0.49503    514.62427     6.11265   540.71704  2401.50635     1.43314    1.43314
    0.14500      0.02655    -45.23656     41.10199     0.07386   515.47046  2031.24438     0.73045    0.73045
    0.42084      0.59987      2.01635      0.0         0.90026     0.06426     0.01919     1.91553    0.0
 1.26493  0.9249  0.9223  1.26498  0.9250  0.9225  1.20309  0.9066  0.9041  1.26498  0.9250  0.9225  789.55298   10120
*
   11.74520    537.17651    542.49634      0.68971    29.13351    38.46802    11.31338     0.44233    0.44233
  430.16895    692.34937      0.62102   5052.94766    38.41241   557.15601  2676.60132     1.90232    1.00000
  107.46899    553.03882      0.49606    537.63794    11.20527   542.73120  2441.58252     1.44989    1.44989
    0.14109      0.02457    -43.33667     41.10199     0.07478   517.29126  2063.73486     0.74154    0.74154
    0.44233      0.58606      2.00114      0.0         0.91743     0.05123     0.01567     1.78099    0.0
 1.26493  0.9379  0.9358  1.26498  0.9380  0.9359  1.21892  0.9272  0.9252  1.26498  0.9380  0.9359  801.84814   10120
*
   12.26445    529.31201    535.50000      0.68171    25.23695    38.45058    15.76324     0.45638    0.45638
  411.80420    675.53149      0.60483   5050.55078    37.56059   557.13967  2679.01514     1.83026    1.00000
  149.55469    555.19170      0.49780    561.35889    15.60401   544.89917  2478.42285     1.46691    1.46691
    0.14603      0.01342    -48.87311     41.10199     0.07554   519.18774  2092.46045     0.75399    0.75399
    0.45638      0.57721      1.99348      0.0         0.92289     0.04668     0.01466     1.67192    0.0
 1.26608  0.9419  0.9399  1.26612  0.9420  0.9400  1.23301  0.9352  0.9332  1.26612  0.9420  0.9400  815.58887   10120
*
   13.20625    524.33984    531.35889      0.68583    20.52789    38.17285    23.20595     0.45309    0.45309
  379.66943    653.06299      0.58348   5014.00781    35.54675   556.86084  2676.60132     1.62735    1.00000
  224.79688    576.95386      0.51548    604.46631    22.93129   549.07837  2547.80933     1.45808    1.45808
    0.16417     -0.01202     -9.35627     41.10199     0.07641   521.39331  2125.54834     0.77720    0.77720
    0.45309      0.54475      1.93078      0.0         0.93162     0.04196     0.01381     1.41262    0.0
 1.26493  0.9449  0.9430  1.26498  0.9450  0.9431  1.24665  0.9416  0.9397  1.26498  0.9450  0.9431  841.24365   10120
*
   14.07916    529.43286    534.36597      0.70103    17.27281    38.03760    28.72006     0.43209    0.43209
  354.87109    641.46729      0.57251   4996.28516    33.58803   556.72559  2674.45972     1.42745    1.00000
  289.54932    607.77100      0.54244    644.42041    28.45129   553.22656  2616.02197     1.42647    1.42647
    0.15027     -0.00855     -2.49829     41.10199     0.07683   522.50659  2141.59131     0.80053    0.80053
    0.43209      0.50746      1.85095      0.0         0.93803     0.03996     0.01376     1.18057    0.0
 1.26392  0.9449  0.9430  1.26396  0.9450  0.9431  1.25115  0.9426  0.9403  1.26396  0.9450  0.9431  866.97021   10120


   15.65703    533.36108    537.09766      0.72743    12.61113    37.76709    36.85414     0.39467    0.39467
  316.84937    623.59229      0.55571   4960.91797    30.53757   556.45508  2670.17407     1.13222    1.00000
  399.79199    669.55762      0.59667    716.64136    36.66237   561.39551  2754.16895     1.37470    1.37470
    0.11358     -0.00311     -0.40697     41.10199     0.07743   524.11694  2165.00757     0.84951    0.84951
    0.39467      0.44701      1.73055      0.0         0.94856    -0.03626     0.01364     0.85628    0.0
 1.26190  0.9449  0.9431  1.26193  0.9450  0.9432  1.26056  0.9449  0.9429  1.26193  0.9450  0.9432  920.44287   10120
*
   17.41205    541.41064    543.53369      0.75871     9.49748    37.76758    43.40340     0.34898    0.34898
  284.92334    613.69555      0.54635   4961.09766    27.66376   556.45557  2670.17407     0.88879    1.00000
  512.04761    746.74072      0.66480    796.97095    43.29147   571.49854  2931.81567     1.31803    1.31803
    0.08865     -0.01107     -3.34676     41.10199     0.07781   525.13721  2179.79443     0.90790    0.90790
    0.34898      0.38724      1.61812      0.0         0.95814     0.03285     0.01359     0.61232    0.0
 1.26190  0.9449  0.9430  1.26193  0.9450  0.9432  1.25436  0.9454  0.9436  1.26193  0.9450  0.9432  984.22876   10120
```

```
*
  18.13322    450.77241    452.62134      0.66534      6.35230     46.09033     47.72610      0.32917      0.32917
 333.91357    562.46265      0.49453   6054.92969     36.41740    564.77832   2583.90991      1.25311      1.00000
 496.06641    671.52661      0.59042    829.97998     47.62199    575.96021   2767.69824      1.50299      1.50299
   0.08560     -0.00112    -12.68855     41.10199      0.07610    538.47559   2186.30273      0.93090      0.93090
   0.32917      0.50146      1.86323      0.0          0.71541      0.22130      0.09479      0.80988      0.0
 1.22113   0.6699  0.6605   1.22116   0.6700  0.6605   1.26670  0.7061  0.6961   1.22116   0.6700  0.6605  1009.29736     10120
*
  18.88324    539.46729    541.28516      0.77959      6.95094     37.76758     48.11586      0.31515      0.31515
 262.72754    601.67700      0.53504   4961.14453     25.89087    556.45557   2670.17407      0.74592      1.00000
 601.58154    809.25269      0.71963    864.30908     48.02002    580.79272   3102.38037      1.28272      1.28272
   0.08217      0.00908     -2.89775     41.10199      0.07826    526.35132   2197.49365      0.95762      0.95762
   0.31515      0.34801      1.55127      0.0          0.96406      0.03058      0.01361      0.47612      0.0
 1.26190   0.9449  0.9430   1.26193   0.9450  0.9432   1.27519  0.9472  0.9454   1.26193   0.9450  0.9432  1038.04443     10120
*
  20.97162    536.12622    536.77710      0.79892      4.22090     37.75635     53.45738      0.28388      0.28388
 236.48897    536.56348      0.52087   4959.55469     23.77693    556.44434   2668.03003      0.59303      1.00000
 723.40796    900.90444      0.79992    959.89697     53.42413    595.28174   3379.85767      1.25169      1.25169
   0.04930     -0.00297      0.28185     41.10199      0.07875    527.83374   2217.61816      1.04100      1.04100
   0.28388      0.30636      1.48793      0.0          0.96918      0.02874      0.01427      0.34159      0.0
 1.26088   0.9419  0.9400   1.26091   0.9420  0.9401   1.29395  0.9475  0.9455   1.26091   0.9420  0.9401  1127.52734     10120
*
  22.02863    537.44287    537.70068      0.80816      3.58791     38.43237     55.40126      0.26423      0.26423
 229.17210    534.50122      0.51861   5048.34375     23.08406    557.12036   2668.03003      0.54259      1.00000
 779.10522    946.63989      0.83993   1008.27734     55.38841    603.19141   3524.99438      1.23737      1.23737
   0.03099     -0.00313      1.14084     41.10199      0.07874    528.71118   2221.08594      1.08150      1.08150
   0.26423      0.28388      1.46214      0.0          0.96393      0.03540      0.01843      0.29882      0.0
 1.26088   0.9259  0.9234   1.26092   0.9260  0.9235   1.29615  0.9333  0.9308   1.26092   0.9260  0.9235  1171.34839     10120
*
  23.03816    536.41528    536.46777      0.81091      3.20818     40.27905     56.96245      0.24675      0.24675
 229.66136    583.55981      0.51683   5290.97266     23.17572    558.96704   2668.03003      0.52151      1.00000
 824.82373    983.23677      0.87143   1054.48511     56.95988    611.10620   3647.44531      1.23318      1.23318
   0.01402     -0.00247      0.50972     41.10199      0.07855    530.65039   2223.80981      1.12031      1.12031
   0.24675      0.28381      1.45205      0.0          0.94657      0.05473      0.02973      0.27614      0.0
 1.26088   0.8849  0.8811   1.26091   0.8850  0.8812   1.29764  0.8964  0.8924   1.26091   0.8850  0.8812  1213.36938     10120

  23.52960    534.00562    534.01880      0.80756      3.14282     42.26172     57.58711      0.23843      0.23843
 235.93694    583.81689      0.51611   5551.50000     23.83650    560.94971   2668.03003      0.53009      1.00000
 841.04199    996.25684      0.88073   1076.97900     57.58646    615.08716   3685.49683      1.23831      1.23831
   0.00708     -0.00223     -2.09129     41.10199      0.07830    532.60913   2224.91357      1.13902      1.13902
   0.23843      0.28811      1.45756      0.0          0.92775      0.07525      0.04168      0.27592      0.0
 1.26088   0.8449  0.8397   1.26092   0.8450  0.8398   1.29791  0.8598  0.8545   1.26092   0.8450  0.8398  1233.67017     10120
*
  24.01569    529.60400    529.60645      0.80187      3.04342     44.73682     58.21069      0.23096      0.23096
 244.70512    583.40674      0.51454   5876.75781     24.79933    563.42480   2668.03003      0.54677      1.00000
 854.52222   1005.33130      0.88666   1099.22754     58.21057    619.10669   3712.99487      1.24709      1.24709
   0.00313     -0.00305     -7.91960     41.10199      0.07802    535.12549   2227.31738      1.15753      1.15753
   0.23096      0.29572      1.46814      0.0          0.90540      0.09981      0.05632      0.27977      0.0
 1.26088   0.7999  0.7932   1.26092   0.8000  0.7933   1.29909  0.8187  0.8119   1.26092   0.8000  0.7933  1253.73682     10120
*
```

Ɛ

```
 57.73853   2667.00366    1.26040  0.9102  0.9072    1.26043  0.9103  0.9073    525.94165   5129.57422     9.37764      10130
420.97729   5245.00000    346.38354   5058.05078      0.0             0.99000     16.00000     42.36200      0.0
*STATOR    OPT4
* NISRF
*MASS AVERAGE TOTAL PRESSURE                      DELTA-T COOLING =    0.0         TOTAL DELTA-T =    0.0
*
                 NASA FAN ENGINE SPLITTER STUDY                                          LOOP= 0
   10.17710     508.17712    509.18923     0.96453      -1.72946        0.0         47.64964
  557.48926     754.35376     0.67842   5673.62109      47.64971     561.87915   2684.89941
  -91.67090     516.30014     0.46441    465.81836     -10.22549     536.73706   2287.04370
    0.00801       0.09665    -9.47795     42.36200       0.07187     514.55542   1972.82861
    0.06215       0.03547     1.16119      0.0           1.00000       0.00001      0.00000
  1.26886  0.8499  0.8447    1.26889  0.8500  0.8448    1.02451   1.0000  0.9999    1.00000  1.0000  1.0000  782.09326     10130
*
   10.79681     503.93457    504.11865     0.95153      -2.16469        0.0         44.46370
  494.58813     796.72437     0.63312   5339.96875      44.45325     559.34106   2680.61304
   -0.40503     504.11965     0.45193    494.18311      -0.04503     539.00244   2354.38525
    0.02704       0.19703   -17.07164     42.36200       0.07408     517.86353   2046.58325
    0.08560       0.04947     1.17705      0.0           1.00000       0.00001      0.00000
  1.26683  0.8949  0.8913    1.26697  0.8950  0.8914    1.02997   1.0000  0.9999    1.00000  1.0000  1.0000  742.19727     10130
*
   11.38050     484.93765    485.53467     0.92927      -3.08113        0.0         42.89473
  450.45605     662.31006     0.59183   5126.41406      42.85368     557.71655   2676.58936
   70.44360     499.51916     0.43841    520.89966       8.23513     541.25830   2409.93359
    0.05364       0.11846   -34.34866     42.36200       0.07595     521.23755   2111.93018
    0.12503       0.07074     1.20526      0.0           0.99999       0.00002      0.00000
  1.26493  0.9249  0.9223    1.26497  0.9250  0.9224    1.03972   1.0000  1.0000    1.00000  1.0000  1.0000  712.72461     10130
*
   11.92361     472.91992    478.66699     0.92336      -3.10540        0.0         41.86154
  423.75439     639.78857     0.57021   5057.67969      41.51782     557.15601   2676.59375
  122.00391     493.07070     0.44059    545.75830      14.29924     543.46362   2453.13794
    0.15637      -0.04886   -56.73141     42.36200       0.07692     523.16943   2147.01807
    0.13599       0.07665     1.21297      0.0           0.99999       0.00001      0.00000
  1.26493  0.9379  0.9357    1.26497  0.9380  0.9359    1.04035   1.0000  1.0000    1.00000  1.0000  1.0000  692.34937     10130
*
   12.47558     490.52881    502.05615     0.95470      -1.31937        0.0         39.53191
  404.81860     644.93286     0.57558   5059.34766      38.87096     557.13867   2679.00562
  166.20410     528.35181     0.47198    571.02271      18.31596     545.81030   2492.96240
    0.21807      -0.12637    15.64130     42.36200       0.07677     522.54907   2140.27515
    0.08152       0.04531     1.17315      0.0           0.99999       0.00002      0.00000
  1.26507  0.9419  0.9399    1.26611  0.9420  0.9400    1.02235   1.0000  0.9999    1.00000  1.0000  1.0000  675.53149     10130
*
   13.42499     529.62695    538.67310     1.00369       0.81296        0.0         35.19959
  373.46680     655.47388     0.58579   5013.74609      34.73390     556.96084   2676.59131
  241.00659     590.12939     0.52738    614.47339      24.10411     559.09399   2564.35327
    0.18562      -0.02207    18.06119     42.36200       0.07532     521.13086   2121.80371
   -0.00680      -0.00368     1.11590      0.0           0.99999       0.00002      0.00000
  1.26493  0.9449  0.9430    1.26497  0.9450  0.9431    0.99324   1.0001  1.0002    1.00000  1.0000  1.0000  653.06299     10130
*
   14.27316     539.37085    545.99634     1.01106       0.92493        0.0         32.99172
  350.02710     648.56079     0.57926   4995.99219      32.66309     556.72559   2674.45581
  303.27319     624.56909     0.55784    653.30029      29.04993     554.18628   2631.95630
    0.15722      -0.00255    14.76846     42.36200       0.07655     521.74536   2130.68579
   -0.02047      -0.01104     1.10777      0.0           0.99999       0.00001      0.00000
  1.26392  0.9449  0.9430    1.26396  0.9450  0.9431    0.99491   1.0000  1.0003    1.00000  1.0000  1.0000  641.46729     10130
```

```
  15.80673    543.30884    547.66650      1.01222     0.72348      0.0        29.98911
 313.83057    631.21167      0.56292   4960.63281    29.81409    556.45508  2670.16577
 409.66234    683.93140      0.60994    723.49341    36.79703    562.21851  2768.33447
   0.11933      0.00183     10.37222     42.36200     0.07713    523.32179  2153.52734
  -0.02273     -0.01220      1.10649      0.0         0.99999      0.00002     0.00000
 1.26189  0.9447  0.9430   1.26192  0.9450  0.9431    0.99470  1.0000  1.0003   1.00000  1.0000  1.0000  623.59229      10130
*
  17.52808    545.21436    547.65039      1.00452     0.33398      0.0        27.43410
 283.02417    616.46045      0.54897   4960.96719    27.32977    556.45557  2670.16748
 519.25757    754.69481      0.67206    802.28174    43.47559    572.20874  2944.60547
   0.09464      0.00145      4.97698     42.36200     0.07770    524.85327  2175.66968
  -0.00841     -0.00451      1.11497      0.0         0.99999      0.00001     0.00000
 1.26189  0.9449  0.9430   1.26193  0.9450  0.9431    0.98811  1.0000  1.0009   1.00000  1.0000  1.0000  613.68555      10130
*
  18.24022    453.69287    455.35571      1.00185     0.32649      0.0        36.19075
 331.94067    563.50098      0.49549   6054.66727    36.09091    564.77832  2583.90161
 502.93677    673.44995      0.59656    934.87744    47.84247    576.64282  2779.20654
   0.08570      0.00080      7.60478     42.36200     0.07607    539.37842  2184.92065
  -0.00349     -0.00183      1.11795      0.0         0.99999      0.00002     0.00000
 1.22112  0.6690  0.6604   1.22115  0.6700  0.6605    0.99937  1.0002  1.0025   1.00000  1.0000  1.0000  562.46265      10130
*
  18.98096    543.95569    545.45801      1.00526     0.24879      0.0        25.66780
 261.36426    604.34351      0.53802   4960.94141    25.60208    556.45557  2670.16992
 607.41748    916.38257      0.72619    968.78174    48.07628    591.44238  3114.56226
   0.07680     -0.00069      5.35257     42.36200     0.07814    526.03345  2192.84937
  -0.00983     -0.00525      1.11415      0.0         0.99999      0.00001     0.00000
 1.26189  0.9449  0.9430   1.26193  0.9450  0.9432    0.99789  1.0000  1.0008   1.00000  1.0000  1.0000  601.67700      10130
*
  21.03578    547.45801    548.26001      1.01745     0.50843      0.0        23.29897
 235.76105    596.90176      0.53047   4959.41406    23.26851    556.44434  2668.02588
 727.07251    910.61694      0.80940    962.93374    52.98131    595.75464  3389.28442
   0.05416     -0.00488     10.98478     42.36200     0.07838    526.82593  2202.82544
  -0.03284     -0.01745      1.10079      0.0         0.99999      0.00001     0.00000
 1.26088  0.9419  0.9399   1.26091  0.9420  0.9401    0.99333  1.0000  1.0002   1.00000  1.0000  1.0000  586.56348      10130
*
  22.07104    550.36060    551.26392      1.02110     0.54376      0.0        22.54915
 228.72787    596.83179      0.53016   5049.26172    22.53430    557.12036  2668.02954
 781.49097    956.35767      0.84952   1010.21899    54.80081    603.51929  3531.71362
   0.03828     -0.00851     13.65485     42.36200     0.07829    527.49951  2203.31079
  -0.03977     -0.02109      1.09636      0.0         0.99999      0.00000     0.00000
 1.26088  0.9259  0.9234   1.26091  0.9260  0.9235    0.99200  1.0000  1.0002   1.00000  1.0000  1.0000  584.50122      10130
*
  23.05824    551.65796    551.75391      1.02400     0.59457      0.0        22.58467
 229.46001    597.55519      0.52992   5290.94141    22.58115    558.96704  2668.02319
 825.94409    993.28540      0.88085   1055.40430    56.25594    611.26855  3650.80225
   0.01867     -0.00496     19.11859     42.36200     0.07804    529.27441  2203.68042
  -0.04531     -0.02400      1.09375      0.0         0.99999      0.00002     0.00000
 1.26089  0.8849  0.8811   1.26091  0.8850  0.8811    0.99095  1.0000  1.0002   1.00000  1.0000  1.0000  583.55981      10130
```

```
   23.53880     549.37573     548.38721      1.02250      0.56543      0.0         23.27150
  235.84476     596.25166       0.52836   5551.50000     23.27107    560.94971    2668.02832
  841.55518    1004.46191       0.88905   1077.40015     56.91029    615.16284    3687.03931
    0.00650       0.00311      23.10371     42.36200      0.07783    531.31909    2206.09668
   -0.04246      -0.02250       1.09536      0.0          0.99999      0.00000       0.00000
  1.26088  0.8449  0.8397     1.26092  0.8450  0.8398    0.93154  1.0000  1.0002    1.00000  1.0000  1.0000  583.91689     10130
*
   24.01569     540.46753     540.48560      1.01696      0.44068      0.0         24.35936
  244.70497     593.30029       0.52374   5876.75391     24.35864    563.42480    2668.02295
  854.52246    1011.10498       0.89256   1099.22754     57.68657    619.10669    3712.93164
   -0.00818       0.02100      28.69099     42.36200      0.07766    534.15723    2213.23389
   -0.03196      -0.01696       1.10132      0.0          0.99999      0.00002       0.00000
  1.26088  0.7999  0.7932     1.26091  0.8000  0.7933    0.99368  1.0000  1.0003    1.00000  1.0000  1.0000  583.40674     10130


  559.88135    2679.34863     1.26623  0.9029  0.8996    1.26626  0.9030  0.8997    516.40527   5279.53906     9.65220     10140
   30.76004    5245.00000    25.21880   5052.87891       0.0          0.99000       4.00000     44.64600     0.0
*STATOR    OPT4
* NISRE
*MASS AVERAGE TOTAL PRESSURE                     DELTA-T COOLING =    0.0          TOTAL DELTA-T =   0.0
*
                NASA FAN ENGINE SPLITTER STUDY                                          LOOP= 0        Core Stator Inlet Station
    9.95000     537.33594     548.39624      1.04875      1.53142      0.0         46.70027
  570.21313     791.12671       0.71477   5673.61719     46.11729    561.87915    2694.89111        Blading Station 4
 -114.78931     560.28101       0.50621    455.42383    -11.82236    535.94067    2275.17285
   -0.20394       0.08895      10.46584     44.64600      0.07023    509.82666    1910.07861
   -0.08812      -0.04375       1.06794      0.0          1.00000      0.00001       0.00000
  1.26885  0.8499  0.8447     1.26889  0.8500  0.8448    0.96919  1.0000  1.0001    1.00000  1.0000  1.0000  754.35376     10140
*
   10.56654     525.95117     540.21680      1.04747      1.36230      0.0         43.85652
  505.36597     730.74927       0.66576   5339.96875     43.09094    559.34106    2680.60303
  -21.72241     540.65332       0.48657    483.64355     -2.30265    538.14526    2341.28809
   -0.23449       0.12198      15.69990     44.64600      0.07264    513.83032    1991.31738
   -0.08716      -0.04747       1.06924      0.0          1.00000      0.00002       0.00000
  1.26682  0.8949  0.8913     1.26687  0.8950  0.8914    0.97300  1.0000  1.0001    1.00000  1.0000  1.0000  706.22437     10140
*
   11.15536     492.11719     509.48950      1.03595      0.90401      0.0         43.03984
  459.54712     686.12183       0.61468   5126.41406     42.04969    557.71655    2676.58765
   51.04736     512.04028       0.45872    510.59448      5.72155    540.37427    2396.17236
   -0.26805       0.16322      37.91321     44.64600      0.07498    518.56641    2074.27002
   -0.06668      -0.03595       1.08113      0.0          1.00000      0.00000       0.00000
  1.26493  0.9249  0.9223     1.26497  0.9250  0.9224    0.98217  1.0000  1.0001    1.00000  1.0000  1.0000  662.31006     10140
*
   11.73000     434.11060     455.19629      0.98030     -1.90147      0.0         44.77724
  430.74829     626.69580       0.55827   5052.67578     43.41928    557.15601    2676.58496
  106.14819     467.40894       0.41638    536.89648     13.12634    542.66602    2440.54102
   -0.31544       0.24754      69.69545     44.64600      0.07741    524.49561    2166.13184
    0.03610       0.01970       1.14250      0.0          0.99999      0.00002       0.00000
  1.26493  0.9379  0.9357     1.26497  0.9380  0.9359    1.00890  0.9999  0.9998    1.00000  1.0000  1.0000  639.28857     10140
*
```

```
  558.87305   2637.87085     1.24663  0.8434  0.8384    1.24666  0.8435  0.8385    532.18994      0.0          9.65023     10150
   30.73781   5245.00000     25.59663    5052.91406       0.0            0.98000      4.00000      45.82700     0.0
*STATOR    OPT2
* NISRF
*MASS AVERAGE TOTAL PRESSURE                    DELTA-T COOLING =    0.0        TOTAL DELTA-T =    0.0    Core Stator Exit Station
*
                NASA FAN ENGINE SPLITTER STUDY                                         LOOP= 0               Blading Station 5
    9.65000     540.07031     564.10864      0.71304       46.11729      0.0           0.0           0.39101        0.39101
    0.0         564.10864      0.49739       0.0            0.0         561.87915    2620.45361      2.27437        1.00000
  441.69238     716.45703      0.63171     441.69238       38.06064     578.09302    2895.19995      1.40244        1.40244
   -0.30166       0.07655     -0.00825      45.82700        0.07747     535.42065    2213.03149      0.71488        0.71488
    0.39101       0.45285      2.00469       0.0            0.87732       0.08316       0.02400      2.19316        0.0
  1.23840  0.7632  0.7559    1.23843  0.7633  0.7560    1.15861   0.8584  0.8554     0.97600   0.0       0.0     791.12671     10150
*
   10.22986     539.40039     564.36157      0.76291       43.09094      0.0           0.0           0.34961        0.34961
    0.0         564.36157      0.49880       0.0            0.0         559.34106    2645.75513      1.95854        1.00000
  468.23340     733.31201      0.64812     468.23340       39.68143     577.56274    2960.35889      1.31077        1.31077
   -0.31427       0.01313      7.83427      45.82700        0.07852     532.85742    2232.29468      0.66583        0.66583
    0.34961       0.58420      1.87342       0.0            0.93022       0.05056       0.01300      1.89744        0.0
  1.25036  0.8454  0.8404    1.25040  0.8455  0.8405    1.12102   0.8972  0.8955     0.98700   0.0       0.0     739.74927     10150
*
   10.77542     538.25024     567.25879      0.82676       42.04968      0.0           0.0           0.25577        0.25577
    0.0         567.25879      0.50225       0.0            0.0         557.71655    2647.14502      1.70089        1.00000
  493.20410     751.68652      0.66554     493.20410       41.00537     577.93384    2998.99658      1.20954        1.20954
   -0.33271      -0.05371     24.90669      45.82700        0.07867     530.95947    2228.32568      0.61474        0.61474
    0.25577       0.51393      1.72799       0.0            0.94112       0.04883       0.01100      1.65035        0.0
  1.25101  0.8813  0.8775    1.25106  0.8815  0.8776    1.07427   0.8663  0.8649     0.98900   0.0       0.0     686.12183     10150
*
   11.28000     536.18208     571.71875      0.91227       43.41928      0.0           0.0           0.06490        0.06490
    0.0         571.71875      0.50667       0.0            0.0         557.15601    2620.37646      1.49623        1.00000
  516.29956     770.34253      0.68269     516.29956       42.08411     579.31079    3004.11060      1.09616        1.09616
   -0.36604      -0.15186     52.63927      45.82700        0.07778     529.97607    2199.25342      0.55831        0.55831
    0.06490       0.43811      1.56805       0.0            0.89463       0.11011       0.02100      1.44884        0.0
  1.23836  0.8532  0.8486    1.23840  0.8533  0.8488    1.01529   0.4170  0.4157     0.97900   0.0       0.0     626.69580     10150
*


  558.87183   2637.05752     1.24667  0.8436  0.8386    1.24670  0.8437  0.8387    532.05396      0.0          9.64994     10160
   30.73798   5245.00000     25.59590    5052.91797       0.0            0.98000      4.00000      47.48000     0.0
*STATOR    OPT4
* NISRF
*MASS AVERAGE TOTAL PRESSURE                    DELTA-T COOLING =    0.0        TOTAL DELTA-T =    0.0
*
                NASA FAN ENGINE SPLITTER STUDY                                         LOOP= 0
    9.05510     537.23315     581.26343      1.03041        0.0           0.0           0.0
    0.0         581.26343      0.51329       0.0            0.0         561.87915    2620.44995
  414.46289     713.39526      0.63041     414.46289       35.49030     576.15576    2861.32373
   -0.41308       0.05825    -10.02024      47.48000        0.07688     533.78662    2189.45655
   -0.05784      -0.03041      1.08695       0.0            1.00000       0.00001       0.00000
  1.23840  0.7632  0.7559    1.23843  0.7633  0.7560    0.98935   1.0000  1.0001     1.00000   1.0000   1.0000   564.10864     10160
*
    9.67374     543.47095     579.46167      1.02676        0.0           0.0           0.0
    0.0         579.46167      0.51293       0.0            0.0         559.34106    2645.74731
  442.77681     729.26611      0.64541     442.77881       37.38419     575.63574    2925.87842
   -0.36991       0.05419     -6.10872      47.48000        0.07800     531.42090    2211.28857
   -0.05081      -0.02676      1.09081       0.0            0.99999       0.00002       0.00000
  1.25035  0.8453  0.8403    1.25039  0.8455  0.8405    0.99059   1.0000  1.0002     1.00000   1.0000   1.0000   564.36157     10160
*
```

```
   10.24911     536.91831     565.15381     0.99629     0.0         0.0          0.0
    0.0         565.15381       0.50029     0.0         0.0       557.71655   2647.13403
  469.11426     734.48413       0.65019   469.11426    39.69485   576.00732   2964.08789
   -0.33416       0.05547     -12.63611    47.48000     0.07874   531.15771   2231.23706
    0.00695       0.00371       1.12417     0.0         0.99998     0.00003      0.00000
  1.25101  0.8313  0.8775    1.25105  0.8814  0.8776    1.00131  0.9993  0.9975    1.00000  1.0000  1.0000  567.25879      10160
*
   10.78730     511.72656     533.65747     0.93343     0.0         0.0          0.0
    0.0         533.65747       0.47139     0.0         0.0       557.15601   2620.36670
  493.74805     727.03320       0.64220   493.74805    42.77547   577.41797   2969.83350
   -0.29589       0.07698     -30.41596    47.48000     0.07907   533.47534   2250.52783
    0.12176       0.06657       1.19988     0.0         0.99999     0.00002      0.00000
  1.23936  0.8531  0.8486    1.23840  0.8533  0.8487    1.02331  1.0000  0.9999    1.00000  1.0000  1.0000  571.71875      10160
*


  558.86279    2637.97339    1.24668  0.8438  0.8388    1.24671  0.8439  0.8389    533.27051     0.0          9.64774      10170
   30.74007    5245.00000      25.59727   5052.96094      0.0          0.98000      4.00000    49.44800      0.0
*STATCR    OPT4
* NISRF
*MASS AVERAGE TOTAL PRESSURE                        DELTA-T COOLING =    0.0          TOTAL DELTA-T =    0.0
*
                NASA FAN ENGINE SPLITTER STUDY                                              LOOP= 0
    8.11020     487.79541     558.34106     0.96056     0.0         0.0          0.0
    0.0         558.34106       0.49205     0.0         0.0       561.87915   2620.44165
  371.21387     670.48071       0.59088   371.21387    33.61800   573.33203   2812.46582
   -0.55692       0.08793     -37.58357    49.44800     0.07767   535.95898   2220.82764
    0.07277       0.03944       1.16598     0.0         0.99998     0.00002      0.00000
  1.23839  0.7632  0.7559    1.23843  0.7633  0.7560    1.01432  0.9999  0.9999    1.00000  1.0000  1.0000  581.26343      10170
*
    8.84493     509.27441     561.67334     0.96930     0.0         0.0          0.0
    0.0         561.67334       0.49631     0.0         0.0       559.34106   2645.74048
  404.84351     692.36938       0.61179   404.84351    35.78334   572.96362   2878.53101
   -0.47027       0.04780     -25.26115    49.44800     0.07962   533.10938   2235.98291
    0.05685       0.03070       1.15547     0.0         0.99998     0.00002      0.00000
  1.25035  0.8453  0.8403    1.25039  0.8455  0.8405    1.01117  1.0000  0.9997    1.00000  1.0000  1.0000  579.46167      10170
*
    9.50154     512.72681     555.45459     0.98284     0.0         0.0          0.0
    0.0         555.45459       0.49129     0.0         0.0       557.71655   2647.11865
  434.89722     715.45410       0.62397   434.89722    38.05942   573.43677   2917.96338
   -0.41667       0.02838     -14.61722    49.44800     0.07907   532.06177   2244.55396
    0.03203       0.01716       1.13956     0.0         0.99998     0.00004      0.00001
  1.25100  0.8813  0.8774    1.25105  0.8814  0.8776    1.00537  0.9998  0.9995    0.99999  1.0000  1.0000  565.15381      10170
*
   10.09340     499.35059     534.65454     1.00187     0.0         0.0          0.0
    0.0         534.65454       0.47231     0.0         0.0       557.15601   2620.36108
  462.21606     706.75244       0.62434   462.21606    40.84384   574.91309   2924.91309
   -0.38262       0.01116      -2.61552    49.44800     0.07904   533.38672   2249.21313
   -0.00354      -0.00187       1.11791     0.0         0.99999     0.00002      0.00000
  1.23936  0.8531  0.8486    1.23840  0.8533  0.8487    0.99942  1.0000  1.0028    1.00000  1.0000  1.0000  533.65747      10170
*
```

```
   558.84229   2638.08813     1.24673  0.8444  0.8394     1.24677  0.8445  0.8395     537.32690      0.0          9.64285       10180
    30.74243   5245.00000      25.59766    5053.05469       0.0           0.98000       4.00000     51.41699      0.0
*STATOR    OPT4
* NISRE
*MASS AVERAGE TOTAL PRESSURE                          DELTA-T COOLING =    0.0          TOTAL DELTA-T =    0.0
*
                 NASA FAN ENGINE SPLITTER STUDY                                            LOOP= 0
     6.90000     400.88892    476.71582       0.85381       0.0           0.0        0.0
     0.0         476.71582      0.41740       0.0           0.0         561.87915   2620.42993
   315.82153     571.84009      0.50069     315.82153      33.52423     570.16943   2758.45166
    -0.64348      -0.00000    -47.41689      51.41699       0.08024     542.98511   2324.48486
     0.25940       0.14619      1.31177       0.0           0.99999       0.00003      0.00000
   1.23839  0.7632  0.7559    1.23842  0.7633  0.7560     1.04668  1.0000  1.0000     1.00000  1.0000  1.0000  558.34106       10180
*
     7.85717     454.62427    511.85864       0.91131       0.0           0.0        0.0
     0.0         511.85864      0.45042       0.0           0.0         559.34106   2645.72388
   359.63257     625.56763      0.55048     359.63257      35.09192     570.09106   2828.24902
    -0.51734      -0.00000    -28.24065      51.41699       0.08027     537.55688   2301.99341
     0.16110       0.08869      1.22900       0.0           0.99997       0.00004      0.00001
   1.25034  0.8453  0.8403    1.25038  0.8454  0.8404     1.02952  1.0000  0.9999     0.99999  1.0000  1.0000  561.67334       10180
*
     8.64444     475.58398    520.47070       0.93702       0.0           0.0        0.0
     0.0         520.47070      0.45901       0.0           0.0         557.71655   2647.10791
   395.66650     653.79028      0.57658     395.66650      37.24242     570.72900   2869.94849
    -0.44460      -0.00000    -20.98418      51.41699       0.08024     535.19214   2291.13867
     0.11573       0.06298      1.19528       0.0           0.99999       0.00003      0.00000
   1.25100  0.8813  0.8774    1.25104  0.8814  0.8776     1.02076  1.0000  0.9999     1.00000  1.0000  1.0000  555.45459       10180
*
     9.33060     472.15186    507.40967       0.94904       0.0           0.0        0.0
     0.0         507.40967      0.44726       0.0           0.0         557.15601   2620.36060
   427.07300     663.21631      0.58459     427.07300      40.08640     572.31592   2878.85889
    -0.39361      -0.00000    -19.41212      51.41699       0.07992     535.74805   2284.27710
     0.09449       0.05096      1.18014       0.0           0.99999       0.00000      0.00000
   1.23336  0.8531  0.8486    1.23840  0.8533  0.8487     1.01559  1.0000  0.9999     1.00000  1.0000  1.0000  534.65454       10180
*
```

```
  557.65283   2666.02490    1.25994  0.9107  0.9077    1.25997  0.9108  0.9079    524.69141   5118.16016      9.35709      20140
  390.33081   5245.00000  321.26025    5058.44141        0.0          0.99000      13.00000     43.93660     0.0
*STATOR    OPT4
* NISRE
*MASS AVERAGE TOTAL PRESSURE                    DELTA-T COOLING =    0.0          TOTAL DELTA-T =    0.0
*
                NASA FAN ENGINE SPLITTER STUDY                                          LOOP= 0
   12.43000    600.00244    617.18115      1.15600      8.14795       0.0        34.11691
  406.49072    739.01782      0.66645   5052.67578     33.36987     557.15601   2676.58521
  162.44556    638.20142      0.57554    568.93628     14.74612     545.61206   2487.27124
    0.24100      0.07202     75.19234     43.93660      0.07279     511.73340   1987.13745
   -0.30189     -0.15600      0.96886      0.0          1.00000       0.00002      0.00000
  1.26493  0.9379  0.9357    1.26497  0.9380  0.9359    0.92554  1.0000  1.0000    1.00000  1.0000  1.0000  639.28857      20140
*
   12.88327    586.95997    603.66260      1.11605      5.88093       0.0        33.73703
  392.00979    719.77734      0.64764   5050.35156     32.99904     557.13867   2679.00342
  197.67407    635.20361      0.57155    589.68286     18.13144     547.61108   2521.89429
    0.24018      0.09824     57.97983     43.93660      0.07369     514.05151   2020.87012
   -0.22164     -0.11605      1.00354      0.0          1.00000       0.00000      0.00000
  1.26607  0.9419  0.9399    1.26611  0.9420  0.9400    0.94421  1.0000  1.0000    1.00000  1.0000  1.0000  644.93286      20140
*
   13.72128    570.77002    579.42700      1.04508      2.49746       0.0        32.62685
  365.39966    695.02002      0.61412   5013.75000     32.23543     556.86084   2676.58447
  262.64014    636.17261      0.57033    628.03979     24.38362     551.49536   2587.30713
    0.17483      0.03573     24.89597     43.93660      0.07512     517.83569   2075.19092
   -0.08401     -0.04508      1.07169      0.0          0.99999       0.00001      0.00000
  1.26493  0.9449  0.9430    1.26497  0.9450  0.9431    0.97803  1.0000  1.0001    1.00000  1.0000  1.0000  655.47388      20140
*
   14.51550    563.33179    569.12622      1.02551      1.49936       0.0        31.42398
  344.18311    665.10645      0.59507   4995.98828     31.16374     556.72559   2674.45117
  320.20923    633.02271      0.58426    664.39233     29.36354     555.40137   2652.22681
    0.14380      0.01953     14.12372     43.93660      0.07588     519.93726   2104.94019
   -0.04734     -0.02551      1.09214      0.0          0.99999       0.00001      0.00000
  1.26392  0.9449  0.9430    1.26395  0.9450  0.9431    0.98792  1.0000  1.0001    1.00000  1.0000  1.0000  648.56079      20140
*
   15.99020    554.52466    557.92065      1.01134      0.73809       0.0        29.22491
  310.22876    638.37085      0.56972   4960.61719     29.07600     556.45508   2670.16382
  421.66235    699.33962      0.62413    731.89111     37.08105     563.23462   2785.90820
    0.11084      0.00986      5.74125     43.93660      0.07686     572.56567   2142.64551
   -0.02105     -0.01134      1.10744      0.0          1.00000       0.00000      0.00000
  1.26189  0.9449  0.9430    1.26192  0.9450  0.9431    0.99495  1.0000  1.0003    1.00000  1.0000  1.0000  631.71167      20140
*
   17.67496    550.42139    552.65308      1.00548      0.40531       0.0        27.01817
  280.67383    619.84131      0.55216   4960.89453     26.92447     556.45557   2670.16211
  528.33081    754.55445      0.68108    809.00464     43.71104     573.10864   2960.85620
    0.09014      0.00415      2.63251     43.93660      0.07757     524.50562   2170.62207
   -0.01020     -0.00548      1.11389      0.0          0.99999       0.00001      0.00000
  1.26183  0.9449  0.9430    1.26192  0.9450  0.9431    0.99768  1.0000  1.0007    1.00000  1.0000  1.0000  616.46045      20140
*
   18.37500    459.61816    461.25464      1.00596      0.54992       0.0        35.63737
  329.50806    566.86084      0.49859   6054.70703     35.54100     564.77832   2583.89478
  511.53933    688.78687      0.60583    841.04639     47.95995     577.50171   2793.74048
    0.08447      0.00065      0.64856     43.93660      0.07526     538.06250   2180.42578
   -0.01125     -0.00596      1.11336      0.0          0.99999       0.00002      0.00000
  1.22112  0.6699  0.6604    1.22115  0.6700  0.6605    0.99795  1.0001  1.0008    1.00000  1.0000  1.0000  563.50098      20140
```

```
  19.10442     548.23467     550.01270      1.00560      0.32871      0.0          25.34305
 259.67725     608.23193       0.54121   4960.98047     25.27338    556.45557   2670.16919
 614.75537     824.38672       0.73399    874.43262     48.18144    582.26074   3129.95483
   0.07946      -0.00278       1.43112     43.93660      0.07801    525.69141   2187.85742
  -0.01045      -0.00560       1.11376      0.0          0.99999      0.00000      0.00000
 1.26189   0.9449   0.9430     1.26193   0.9450   0.9432   0.99772   1.0000   1.0007   1.00000   1.0000   1.0000   604.84351        20140
*
  21.13042     555.63042     556.92407      1.01266      0.41631      0.0          22.89807
 234.70667     604.36035       0.53757   4959.44922     22.85220    556.44434   2668.02319
 732.45850     920.14111       0.81845    967.16528     52.75247    596.44873   3403.14819
   0.06695      -0.01151       0.26801     43.93660      0.07809    526.07080   2191.78516
  -0.02373      -0.01266       1.10599      0.0          0.99999      0.00001      0.00000
 1.26083   0.9419   0.9399     1.26091   0.9420   0.9401   0.99499   1.0000   1.0003   1.00000   1.0000   1.0000   596.80176        20140
*
  22.14732     563.51147     564.56641      1.02013      0.54812      0.0          22.02341
 227.94144     608.84521       0.54145   5048.28906     21.98619    557.12036   2668.02637
 785.76880     967.55762       0.86045   1013.71045     54.30313    604.10596   3543.76489
   0.06122      -0.02069       1.61494     43.93660      0.07735    526.29468   2185.73779
  -0.03781      -0.02013       1.09790      0.0          0.99999      0.00001      0.00000
 1.26088   0.9259   0.9234     1.26091   0.9260   0.9235   0.99202   1.0000   1.0002   1.00000   1.0000   1.0000   596.83179        20140
*
  23.10759     576.82129     577.61255      1.03979      0.95732      0.0          21.65074
 228.97090     621.34033       0.55226   5290.96484     21.62383    558.96704   2668.01758
 828.69189    1010.13184       0.89783   1057.66284     55.12280    611.66455   3659.10205
   0.05240      -0.03793       6.72982     43.93660      0.07716    526.86377   2168.72583
  -0.07527      -0.03979       1.07714      0.0          0.99999      0.00001      0.00000
 1.26088   0.8849   0.8810     1.26091   0.8850   0.8811   0.98414   1.0000   1.0001   1.00000   1.0000   1.0000   597.56519        20140
*
  23.56905     585.94165     586.53589      1.05882      1.39067      0.0          21.90050
 235.55296     632.05763       0.56134   5551.52344     21.88040    560.94971   2668.02588
 843.18604    1027.12573       0.91219   1078.73901     55.17677    615.40234   3692.07919
   0.04505      -0.05212      12.74344     43.93660      0.07652    527.72949   2154.33838
  -0.11205      -0.05882       1.05778      0.0          0.99999      0.00001      0.00000
 1.26083   0.8449   0.8397     1.26092   0.8450   0.8398   0.97654   1.0000   1.0001   1.00000   1.0000   1.0000   596.95166        20140
*
  24.01569     599.00269     599.32666      1.09111      2.14848      0.0          22.22101
 244.70480     647.35840       0.57446   5876.75000     22.21016    563.42480   2668.01978
 854.52271    1043.74365       0.92620   1099.22754     54.95575    619.10669   3712.92725
   0.03290      -0.07317      23.96452     43.93660      0.07565    528.57886   2133.33203
  -0.17568      -0.09111       1.02647      0.0          0.99999      0.00001      0.00000
 1.26088   0.7999   0.7932     1.26091   0.8000   0.7933   0.96390   1.0000   1.0000   1.00000   1.0000   1.0000   593.30029        20140
*
```

```
557.64917  2666.01440   1.25993  0.9108  0.9078   1.25996  0.9109  0.9079   526.32520  5117.69531   9.35620   20150
390.33862  5245.00000   321.26709  5058.45313     0.0              0.99000   13.00000   45.90509    0.20070
*STATOR    OPT4
* NISRF
*MASS AVERAGE TOTAL PRESSURE                  DELTA-T COOLING =   0.0        TOTAL DELTA-T =   0.0
*
               NASA FAN ENGINE SPLITTER STUDY                                     LOOP= 0
  12.78000   619.69531   624.31104    0.99993    1.02500      0.0       32.53735
 395.35791   733.36704     0.66640  5052.67188   32.34486   557.15601  2676.57642
 189.59839   652.46582     0.58840   584.95630   16.89311   547.14917  2511.89746
   0.12228     0.04860   -23.35367    45.90509    0.07279   511.73950  1987.21118
   0.00012     0.00007     1.17008     0.0        1.00000     0.00001     0.00000
 1.26492  0.9378  0.9357   1.26497  0.9380  0.9359   1.00004  1.0000  1.0000   1.00000  1.0000  1.0000  739.01782   20150
*
  13.21668   609.01392   612.49756    1.00298    1.04022      0.0       32.10576
 382.11914   721.91992     0.64973  5050.34375   31.95882   557.13867  2678.99365
 222.82446   651.76978     0.58660   604.94360   19.93121   549.12695  2546.42676
   0.10711     0.03121   -15.42428    45.99272    0.07360   513.79443  2017.33179
  -0.00537    -0.00298     1.11668     0.0        0.99999     0.00001     0.00000
 1.26605  0.9419  0.9399   1.26611  0.9420  0.9400   0.99825  1.0000  1.0009   1.00000  1.0000  1.0000  719.77734   20150
*
  14.02493   592.06055   595.05103    1.01337    1.24037      0.0       31.12366
 357.48730   634.17773     0.62296  5013.73047   30.99606   556.86084  2676.57886
 284.45093   659.54370     0.59188   641.93823   25.54909   552.96289  2611.59415
   0.10064     0.03119    -5.87165    46.15494    0.07474   516.78491  2060.48022
  -0.02445    -0.01337     1.10523     0.0        1.00000     0.00001     0.00000
 1.26492  0.9449  0.9430   1.26496  0.9450  0.9431   0.99291  1.0000  1.0002   1.00000  1.0000  1.0000  685.02002   20150
*
  14.79710   578.31519   580.73193    1.00998    0.99049      0.0       30.27718
 337.63135   671.74731     0.60144  4995.96484   30.17325   556.72559  2674.44214
 339.65039   672.76440     0.60235   677.28174   30.32190   556.83911  2676.34717
   0.09152     0.02456    -5.10427    46.30992    0.07562   519.19849  2094.48315
  -0.01836    -0.00998     1.10893     0.0        0.99999     0.00002     0.00000
 1.26391  0.9449  0.9430   1.26395  0.9450  0.9431   0.99503  1.0000  1.0003   1.00000  1.0000  1.0000  665.10645   20150
*
  16.24389   559.37378   561.20776    1.00078    0.53020      0.0       28.62460
 305.29224   639.37207     0.57019  4960.65625   28.54581   556.45508  2670.15527
 438.43921   712.16797     0.63561   743.73145   37.99344   564.68652  2811.14990
   0.08105     0.01356    -5.71450    46.60126    0.07684   522.51245  2141.87964
  -0.00145    -0.00078     1.11912     0.0        1.00000     0.00002     0.00000
 1.26189  0.9449  0.9430   1.26192  0.9450  0.9431   0.99764  1.0001  1.0046   1.00000  1.0000  1.0000  639.37085   20150
*
  17.92946   548.83618   550.59302    0.99414    0.24338      0.0       26.75462
 276.69189   616.20703     0.54873  4960.93359   26.68109   556.45557  2670.14917
 543.96143   773.98096     0.68922   820.65332   44.65285   574.68604  2989.51245
   0.08008     0.00261    -7.70485    46.93854    0.07771   524.87915  2176.03174
   0.01094     0.00587     1.12661     0.0        0.99998     0.00003     0.00000
 1.26188  0.9449  0.9430   1.26192  0.9450  0.9431   1.00249  0.9998  0.9987   1.00000  1.0000  1.0000  619.84131   20150
*
  18.63219   457.29956   458.66528    0.99163    0.22360      0.0       35.39804
 324.96240   562.11597     0.49421  6054.75781   35.31740   564.77832  2583.89014
 527.85571   609.29931     0.61482   852.81812   49.01199   579.15820  2821.92334
   0.07735     0.00394     0.78030    47.07956    0.07612   538.50906  2186.74829
   0.01568     0.00837     1.12946     0.0        0.99999     0.00001     0.00000
 1.22112  0.6699  0.6604   1.22115  0.6700  0.6605   1.00290  0.9995  0.9995   1.00000  1.0000  1.0000  566.86084   20150
```

Bypass Duct Stator Inlet Station

Blading Station 4

```
   19.36664     542.72998     544.26880      0.98899      0.06904      0.0         25.26689
  256.16382     601.53833       0.53491   4961.03125     25.20433    556.45557   2670.15771
  630.27100     832.74854       0.74051    886.43481     49.18781    584.01636   3163.16016
    0.07536       0.00532      -7.96799     47.22696      0.07826    526.36499   2197.68457
    0.02038       0.01101       1.13246      0.0          0.99998      0.00002      0.00000
  1.26189  0.9449  0.9430     1.26192  0.9450  0.9431     1.00449  0.9997  0.9993   1.00000  1.0000  1.0000  608.23193     20150
*
   21.43771     533.53906     535.85645      0.96575     -0.49900      0.0         23.44170
  231.34424     583.56284       0.51816   4959.48828     23.35120    556.44434   2668.00830
  749.88647     921.46797       0.81823    981.23071     54.45099    598.72485   3448.88794
    0.09331      -0.00266     -10.83584     47.64262      0.07886    528.11621   2221.76392
    0.06295       0.03425       1.15972      0.0          0.99997      0.00003      0.00001
  1.26087  0.9419  0.9399     1.26090  0.9420  0.9400     1.01368  0.9999  0.9998   0.99999  1.0000  1.0000  604.36035     20150
*
   22.50113     529.34302     532.40430      0.94892     -0.86467      0.0         22.96933
  224.35851     577.74658       0.51230   5048.31641     22.85086    557.12036   2669.01880
  805.54590     965.58716       0.85621   1029.90454     56.53831    606.85352   3600.62012
    0.10771      -0.00301     -13.40935     47.85605      0.07999    529.36401   2230.69946
    0.09323       0.05108       1.18029      0.0          0.99999      0.00002      0.00000
  1.26088  0.9259  0.9234     1.26091  0.9260  0.9235     1.02057  0.9999  0.9999   1.00000  1.0000  1.0000  608.84521     20150
*
   23.53130     520.26782     524.30811      0.91816     -1.58829      0.0         23.37309
  224.85004     570.49779       0.50466   5291.01172     23.21211    558.96704   2668.00732
  852.20630    1000.57715       0.88513   1077.05640     58.39961    615.10083   3731.73096
    0.12487       0.00281     -16.09563     48.06279      0.07902    531.90503   2242.26636
    0.14730       0.08184       1.21984      0.0          0.99999      0.00002      0.00000
  1.26087  0.8849  0.8810     1.26090  0.8850  0.8811     1.03391  1.0000  1.0000   1.00000  1.0000  1.0000  621.34033     20150
*
   24.03986     511.46143     516.05640      0.89448     -2.22780      0.0         24.29982
  230.93188     565.37036       0.49899   5551.56641     24.10820    560.94971   2668.02002
  869.40210    1011.02637       0.89231   1100.33398     59.30756    619.30786   3774.96313
    0.13435       0.00989     -18.13858     48.16486      0.07895    534.37231   2250.81372
    0.18781       0.10552       1.25213      0.0          1.00000      0.00001      0.00000
  1.26088  0.8449  0.8397     1.26092  0.8450  0.8398     1.04478  1.0000  1.0000   1.00000  1.0000  1.0000  632.06763     20150
*
   24.54999     498.39331     503.66895      0.86144     -3.21019      0.0         25.65503
  239.37894     557.65991       0.49072   5876.74609     25.42035    563.42480   2668.01563
  884.30420    1017.68188       0.89552   1123.68335     60.33563    623.61965   3808.76709
    0.14589       0.02099     -22.91118     48.26729      0.07391    537.56885   2263.13306
    0.24276       0.13856       1.30015      0.0          0.99999      0.00001      0.00000
  1.26088  0.7999  0.7932     1.26091  0.8000  0.7933     1.06084  1.0000  1.0000   1.00000  1.0000  1.0000  647.35840     20150
*
```

```
 557.66260   2639.52124    1.24741  0.8711  0.8670    1.24744  0.8712  0.8671   535.44653     0.0         9.35939     20160
 390.33960   5245.00000    324.49634   5058.39453      0.0           0.98000     13.00000    48.26729     0.20790
*STATOR   OPT2
* NISRF
*MASS AVERAGE TOTAL PRESSURE                    DELTA-T COOLING =    0.0          TOTAL DELTA-T =    0.0    B.P. Duct Stator Exit Station
*
                   NASA FAN ENGINE SPLITTER STUDY                                             LOOP= 0              Blading Station 5
   12.95000     563.21606     563.44849     0.76249     32.34486      0.0          0.0          0.32407       0.32407
    0.0         563.44849     0.49897       0.0          0.0         557.15601   2620.36816     1.54863       1.00000
  592.73755     917.90933     0.72423     592.73755     46.45110     536.35449   3134.11279     1.31151       1.31151
    0.02875       0.03059   -23.37193      48.26729      0.07907     530.75684   2210.61377     0.66648       0.66648
    0.32407       0.50326     1.82811       0.0          0.89171       0.09154      0.02100    1.52135       0.0
  1.23836  0.8531  0.8486    1.23840  0.8533  0.8498    1.11242  0.8339  0.8313    0.97900  0.0      0.0    738.96704     20160
*
   13.38602     564.25191     565.35791     0.78313     31.35982      0.0          0.0          0.31164       0.31164
    0.0         565.35791     0.50076       0.0          0.0         557.13867   2638.80859     1.47096       1.00000
  612.69459     833.69115     0.73842     612.69459     47.30098     598.33560   3194.07568     1.27693       1.27693
    0.03745       0.02769   -19.39099      48.35793      0.07855     530.56030   2223.52759     0.64981       0.64981
    0.31164       0.47984     1.77773       0.0          0.92086       0.06073      0.01500    1.44565       0.0
  1.24707  0.8815  0.8777    1.24711  0.8816  0.8779    1.10222  0.8656  0.8637    0.98500  0.0      0.0    721.91992     20160
*
   14.18866     555.97925     556.49023     0.80165     30.99606      0.0          0.0          0.29555       0.29555
    0.0         556.49023     0.49265       0.0          0.0         556.96084   2647.13647     1.38391       1.00000
  649.43237     955.24487     0.75713     649.43237     49.40712     591.91016   3278.65918     1.24742       1.24742
    0.04289       0.01753   -17.30806      48.52480      0.07915     531.10986   2242.56323     0.62303       0.62303
    0.29555       0.45434     1.73107       0.0          0.93895       0.04779      0.01109    1.36141       0.0
  1.25101  0.9004  0.8971    1.25105  0.9005  0.8973    1.08837  0.8945  0.8831    0.98900  0.0      0.0    694.17773     20160
*
   14.95687     546.72803     547.35425     0.81482     30.17325      0.0          0.0          0.27743       0.27743
    0.0         547.35425     0.48424       0.0          0.0         556.72559   2647.69751     1.31989       1.00000
  684.59424     875.50781     0.77544     684.59424     51.35657     595.67163   3355.86279     1.22726       1.22726
    0.04788       0.01218   -14.72865      48.68451      0.07949     531.81323   2255.37817     0.60149       0.60149
    0.27743       0.43514     1.69808       0.0          0.94236       0.04611      0.01000    1.29965       0.0
  1.25127  0.9043  0.9012    1.25131  0.9044  0.9013    1.07682  0.8905  0.8792    0.99000  0.0      0.0    671.74731     20160
*
   16.40988     532.35840     533.70776     0.83539     28.54581      0.0          0.0          0.24657       0.24657
    0.0         533.70776     0.47175       0.0          0.0         556.45508   2646.12378     1.21227       1.00000
  751.10059     921.40967     0.81444     751.10059     54.60359     603.33154   3513.57300     1.19704       1.19704
    0.05649       0.00701   -11.51095      48.98656      0.07994     532.76953   2272.13062     0.57024       0.57024
    0.24657       0.40236     1.64569       0.0          0.94519       0.04549      0.00900    1.19563       0.0
  1.25053  0.9082  0.9052    1.25056  0.9083  0.9053    1.06291  0.8672  0.8661    0.99100  0.0      0.0    639.87207     20160
*
   18.10905     520.77661     521.95679     0.84705     26.68109      0.0          0.0          0.22575       0.22575
    0.0         521.95679     0.46091       0.0          0.0         556.45557   2646.11769     1.11935       1.00000
  828.87378     979.52563     0.86497     828.87378     57.80060     613.53369   3725.47559     1.18057       1.18057
    0.06736       0.00795   -10.69084      49.33933      0.08033     533.80176   2287.57397     0.54877       0.54877
    0.22575       0.37635     1.60973       0.0          0.94274       0.04863      0.00900    1.10592       0.0
  1.25053  0.9081  0.9052    1.25056  0.9082  0.9053    1.05126  0.8468  0.8457    0.99100  0.0      0.0    616.20703     20160
*
   18.80687     459.50635     460.56616     0.81934     35.31740      0.0          0.0          0.26376       0.26376
    0.0         460.56616     0.40174       0.0          0.0         564.77832   2560.89331     1.48667       1.00000
  860.81372     976.27930     0.85157     860.81372     61.85156     626.32349   3680.71753     1.22049       1.22049
    0.06796       0.00383    -2.19269      49.48491      0.07959     547.14390   2291.49707     0.49424       0.49424
    0.26376       0.46836     1.71650       0.0          0.92673       0.05791      0.00890    1.45546       0.0
  1.21025  0.6399  0.6301    1.21028  0.6400  0.6302    1.04790  0.8396  0.8385    0.99110  0.0      0.0    562.11597     20160
```

```
  19.53830     516.01367     517.25732      0.85989     25.20433      0.0           0.0           0.20368       0.20368
   0.0         517.25732       0.45659      0.0          0.0        556.45557    2646.39331       1.04089       1.00000
 894.29199    1033.10840       0.91194    894.29199     59.95490    622.88989    3930.17065       1.16294       1.16294
   0.06947      -0.00046     -10.41022     49.63698      0.08049    534.20801    2293.91626       0.53495       0.53495
   0.20368       0.35209       1.57462      0.0          0.94232      0.05030       0.00890       1.02974       0.0
 1.25066   0.9086   0.9056   1.25069   0.9087   0.9057   1.04379   0.9274   0.8263   0.99110   0.0   0.0   601.53833   20160
*
  21.66588     505.03247     507.12378      0.86886     23.35120      0.0           0.0           0.18667       0.18667
   0.0         507.12378       0.44729      0.0          0.0        556.44434    2644.26294       0.95594       1.00000
 991.67407    1113.91812       0.98241    991.67407     62.91559    638.11646    4274.81641       1.15093       1.15093
   0.09110       0.00444     -11.14848     50.07932      0.08075    535.06006    2305.06226       0.51819       0.51819
   0.18667       0.32827       1.54317      0.0          0.94005      0.05321       0.00890       0.94715       0.0
 1.24965   0.9056   0.9025   1.24968   0.9057   0.9026   1.03749   0.8046   0.8036   0.99110   0.0   0.0   583.66284   20160
*
  22.76546     499.04810     500.75000      0.86673     22.85086      0.0           0.0           0.18941       0.18941
   0.0         500.75000       0.44117      0.0          0.0        557.12036    2644.27344       0.94043       1.00000
1042.00317    1156.07959       1.01853   1042.00317     64.33267    647.27637    4475.21094       1.15376       1.15376
   0.10431       0.00577     -12.08597     50.30792      0.08086    536.27075    2313.52783       0.51234       0.51234
   0.18941       0.32630       1.54260      0.0          0.93348      0.05430       0.00890       0.93215       0.0
 1.24966   0.8902   0.8866   1.24969   0.8903   0.8867   1.03713   0.8031   0.8020   0.99110   0.0   0.0   577.74658   20160
*
  23.83064     491.86475     495.26685      0.86815     23.21211      0.0           0.0           0.18590       0.18590
   0.0         495.26685       0.43541      0.0          0.0        558.96704    2644.26196       0.95102       1.00000
1090.75806    1137.93237       1.05316   1090.75806     65.57915    657.72900    4679.98828       1.15188       1.15188
   0.11782       0.00290     -11.72715     50.52937      0.08079    538.57227    2321.40747       0.50470       0.50470
   0.18590       0.32768       1.54302      0.0          0.93694      0.05577       0.00890       0.94238       0.0
 1.24965   0.8508   0.8460   1.24968   0.8508   0.8461   1.03530   0.7951   0.7941   0.99110   0.0   0.0   570.48779   20160
*
  24.35410     486.30005     490.06396      0.86680     24.10820      0.0           0.0           0.17542       0.17542
   0.0         490.06396       0.42988      0.0          0.0        560.94971    2638.67163       0.98616       1.00000
1114.71704    1217.68457       1.06815   1114.71704     66.26817    664.07813    4771.08203       1.15367       1.15367
   0.12466      -0.00205     -11.40911     50.63820      0.08052    540.98219    2323.99683       0.49902       0.49902
   0.17542       0.33610       1.55278      0.0          0.92131      0.07034       0.01100       0.97650       0.0
 1.24701   0.8046   0.7984   1.24705   0.8047   0.7985   1.03252   0.7431   0.7419   0.98990   0.0   0.0   565.37036   20160
*
  24.87999     472.71436     476.00210      0.85519     25.42035      0.0           0.0           0.15193       0.15193
   0.0         476.00210       0.41698      0.0          0.0        563.42480    2619.99121       1.05528       1.00000
1138.78784    1234.61401       1.07949   1138.78784     67.27696    671.03198    4838.99219       1.16934       1.16934
   0.13341      -0.01093     -12.65724     50.74759      0.08002    544.51660    2324.64478       0.49075       0.49075
   0.15193       0.35901       1.58435      0.0          0.87038      0.11861       0.01800       1.04378       0.0
 1.23819   0.7372   0.7291   1.23821   0.7373   0.7292   1.02718   0.5962   0.5946   0.98200   0.0   0.0   557.65991   20160
*
```

```
  557.65796   2639.54565    1.24742  0.8713  0.8672    1.24745  0.8714  0.8673    537.89307      0.0        9.35833      20170
  390.36719   5245.00000    324.51480   5058.41797     0.0            0.98000     13.00000     51.33839      0.20181
*STATOR    OPT4
* NISPF
*MASS AVERAGE TOTAL PRESSURE                     DELTA-T COOLING =    0.0         TOTAL DELTA-T =   0.0
*
                  NASA FAN ENGINE SPLITTER STUDY                                        LOOP= 1
   12.95000      502.24585     502.27344      0.89143      0.0          0.0          0.0
    0.0          502.27344       0.44255      0.0          0.0        557.15601   2620.36035
  592.73755      776.92749       0.68455    592.73755     49.72273    586.35449   3134.10352
   -0.01052       -0.00501     -14.83423     51.33839      0.08008    536.17920   2290.72339
    0.19551        0.10857       1.25641      0.0          0.99998      0.00002      0.00000
  1.23835  0.8531  0.8486    1.23840  0.8533  0.8487     1.03624  1.0000  0.9999    1.00000  1.0000  1.0000  563.44849     20170
*
   13.41822      514.61914     514.61914      0.91025      0.0          0.0          0.0
    0.0          514.61914       0.45388      0.0          0.0        557.13867   2638.80249
  614.16345      801.27124       0.70670    614.16346     50.03992    588.48608   3196.93213
   -0.00093       -0.00273     -12.40509     51.43288      0.08025    535.11792   2291.14233
    0.16282        0.08975       1.23043      0.0          0.99999      0.00001      0.00000
  1.24707  0.8815  0.8777    1.24711  0.8816  0.8779     1.03041  1.0000  0.9999    1.00000  1.0000  1.0000  565.35791     20170
*
   14.26370      518.57056     518.62354      0.93195      0.0          0.0          0.0
    0.0          518.62354       0.45767      0.0          0.0        556.86084   2647.12109
  652.86743      833.79028       0.73580    652.86743     51.53712    592.28174   3285.85522
    0.01431        0.00104      -8.48444     51.60350      0.08041    534.49585   2293.02954
    0.12474        0.06805       1.20177      0.0          0.99998      0.00004      0.00001
  1.25100  0.9004  0.8971    1.25104  0.9005  0.8973     1.02250  1.0000  0.9998    0.99999  1.0000  1.0000  556.49023     20170
*
   15.06107      516.59717     516.75122      0.94409      0.0          0.0          0.0
    0.0          516.75122       0.45601      0.0          0.0        556.72559   2647.68945
  689.36401      861.54199       0.76027    689.36401     53.14453    596.21606   3366.62939
    0.02443        0.00307      -6.76444     51.76442      0.08051    534.52173   2295.86230
    0.10319        0.05591       1.18633      0.0          0.99999      0.00002      0.00000
  1.25127  0.9043  0.9012    1.25131  0.9044  0.9013     1.01795  1.0000  0.9999    1.00000  1.0000  1.0000  547.35425     20170
*
   16.55354      509.29364     510.34644      0.95623      0.0          0.0          0.0
    0.0          510.34644       0.45024      0.0          0.0        556.45508   2646.11084
  757.67603      913.52417       0.80594    757.67603     56.03703    604.15527   3530.41040
    0.03773        0.00519      -5.18739     52.06558      0.08070    534.79810   2302.57080
    0.08139        0.04377       1.17127      0.0          0.99998      0.00003      0.00000
  1.25052  0.9081  0.9052    1.25055  0.9082  0.9053     1.01340  0.9999  0.9998    1.00000  1.0000  1.0000  533.70776     20170
*
   18.28223      503.22266     503.76221      0.96514      0.0          0.0          0.0
    0.0          503.76221       0.44420      0.0          0.0        556.45557   2646.10986
  836.80005      976.73462       0.86126    836.80005     58.95157    614.62964   3749.87524
    0.04633        0.00576      -3.38793     52.41444      0.08091    535.35400   2310.95630
    0.06521        0.03486       1.16045      0.0          0.99999      0.00002      0.00000
  1.25052  0.9081  0.9052    1.25056  0.9082  0.9053     1.01022  0.9999  0.9998    1.00000  1.0000  1.0000  521.95679     20170
*
   18.99283      439.26147     439.84033      0.95500      0.0          0.0          0.0
    0.0          439.84033       0.38312      0.0          0.0        564.77832   2560.88062
  869.32520      974.26172       0.84862    869.32520     63.16252    627.54541   3705.97388
    0.05136        0.00700      -7.26288     52.55786      0.07906    548.69556   2314.34033
    0.08479        0.04500       1.17278      0.0          0.99997      0.00005      0.00000
  1.21025  0.6399  0.6301    1.21027  0.6400  0.6301     1.00997  0.9999  0.9997    0.99999  1.0000  1.0000  460.56616     20170
```

```
 19.73936    496.76440   497.55884     0.96192     0.0          0.0          0.0
  0.0        497.55884     0.43852     0.0         0.0        556.45557   2646.38721
903.49512   1031.43970     0.90906   903.49512    61.15816    624.26294   3960.66162
  0.05659      0.00888    -3.70825    52.70853     0.08112    535.87061   2319.01514
  0.07121      0.03808     1.16434     0.0         0.99998      0.00002      0.00000
 1.25066  0.9086  0.9056   1.25069  0.9087  0.9057   1.01094  0.9999  0.9999   1.00000  1.0000  1.0000  517.25732   20170
*
 21.90883    480.64331   481.56982     0.94961     0.0          0.0          0.0
  0.0        481.56982     0.42392     0.0         0.0        556.44434   2644.25464
1002.79419  1112.43213     0.97927  1002.79419    64.34834    639.95630   4318.24609
  0.06213      0.01447    -4.10386    53.14636     0.08155    537.16138   2336.92407
  0.09393      0.05039     1.17943     0.0         0.99999      0.00002      0.00000
 1.24965  0.9055  0.9025   1.24968  0.9056  0.9026   1.01382  0.9999  0.9999   1.00000  1.0000  1.0000  507.12378   20170
*
 23.03484    470.36011   471.31445     0.94122     0.0          0.0          0.0
  0.0        471.31445     0.41433     0.0         0.0        557.12036   2644.25562
1054.33276  1154.98257     1.01524  1054.33276    65.91405    649.41797   4527.45703
  0.06374      0.02071    -3.88045    53.37361     0.08177    538.65039   2349.67871
  0.10930      0.05878     1.18995     0.0         0.99996      0.00005      0.00001
 1.24965  0.8902  0.8866   1.24968  0.8903  0.8867   1.01563  0.9999  0.9998   0.99999  1.0000  1.0000  500.75000   20170
*
 24.13333    456.63892   457.59985     0.92395     0.0          0.0          0.0
  0.0        457.59985     0.40119     0.0         0.0        558.96704   2644.25269
1104.61230  1195.64429     1.04826  1104.61230    67.49756    660.24756   4743.30469
  0.06491      0.03162    -4.84103    53.59529     0.08192    541.55713   2366.78271
  0.14054      0.07605     1.21219     0.0         0.99997      0.00003      0.00000
 1.24965  0.8507  0.8459   1.24968  0.8508  0.8460   1.01955  0.9999  0.9999   1.00000  1.0000  1.0000  495.26685   20170
*
 24.67976    443.46558   444.42944     0.90688     0.0          0.0          0.0
  0.0        444.42944     0.38859     0.0         0.0        560.94971   2638.65894
1129.62329  1213.90479     1.06137  1129.62329    68.52373    666.84766   4841.44141
  0.06597      0.04033    -6.16991    53.70557     0.08195    544.52832   2377.79614
  0.17097      0.09312     1.23500     0.0         0.99997      0.00004      0.00000
 1.24700  0.8046  0.7983   1.24704  0.8047  0.7984   1.02315  0.9999  0.9999   1.00000  1.0000  1.0000  490.06396   20170
*
 25.23999    416.67578   417.63989     0.87574     0.0          0.0          0.0
  0.0        417.63989     0.36370     0.0         0.0        563.42480   2619.97876
1155.26563  1228.43848     1.06979  1155.26563    70.12450    674.16040   4918.83984
  0.06807      0.05348    -8.18967    53.81870     0.08165    548.92432   2391.23096
  0.22545      0.12426     1.27892     0.0         0.99995      0.00004      0.00000
 1.23817  0.7372  0.7291   1.23821  0.7373  0.7292   1.02864  1.0000  0.9999   1.00000  1.0000  1.0000  476.90210   20170
*
```

F

```
   557.65820   2639.55811     1.24743  0.8713  0.9672    1.24746  0.8714  0.8673    538.54956      0.0          9.35834       20180
   390.34937   5245.00000   324.49854   5058.41797        0.0             0.98000    13.00000    57.63759      0.0
*STATOR    OPT4
* NISRF
*MASS AVERAGE TOTAL PRESSURE                        DELTA-T COOLING =   0.0          TOTAL DELTA-T =   0.0
*
                NASA FAN ENGINE SPLITTER STUDY                                          LOOP= 0
    12.95000    465.03442    465.04077      0.92587       0.0          0.0         0.0
     0.0        465.04077      0.40861      0.0           0.0        557.15601   2620.34570
   592.73755    753.39282      0.66198    592.73755      51.88350    586.35449   3134.08594
     0.00526      0.00000     -1.44661     57.63759       0.08120    539.17456   2335.85352
     0.13691      0.07413      1.20967      0.0           0.99997      0.00004      0.00001
   1.23835  0.8531  0.8486    1.23839  0.8532  0.8487    1.01970  1.0000  0.9998    0.99999  1.0000  1.0000  502.27344     20180
*
    13.44751    478.76099    478.77441      0.93035       0.0          0.0         0.0
     0.0        478.77441      0.42111      0.0           0.0        557.13867   2638.79590
   615.50928    779.79272      0.68587    615.50928      52.12238    588.62305   3199.52368
     0.00753      0.00000     -2.46888     57.63759       0.08137    538.07910   2335.85229
     0.12861      0.06965      1.20385      0.0           0.99998      0.00002      0.00000
   1.24707  0.8815  0.8777    1.24711  0.8816  0.8778    1.01951  0.9999  0.9998    1.00000  1.0000  1.0000  514.61914     20180
*
    14.33751    484.63037    484.66040      0.93451       0.0          0.0         0.0
     0.0        484.66040      0.42658      0.0           0.0        556.86084   2647.11450
   656.24536    815.81470      0.71805    656.24536      53.55278    592.64917   3293.00146
     0.01117      0.00000     -4.19658     57.63759       0.08148    537.32959   2335.88428
     0.12104      0.06549      1.19849      0.0           0.99999      0.00002      0.00000
   1.25100  0.9003  0.8971    1.25104  0.9005  0.8973    1.01869  0.9999  0.9999    1.00000  1.0000  1.0000  518.62354     20180
*
    15.16939    485.11548    485.17310      0.93883       0.0          0.0         0.0
     0.0        485.17310      0.42710      0.0           0.0        556.72559   2647.67651
   694.32178    847.03931      0.74565    694.32178      55.05518    596.78589   3377.90747
     0.01542     -0.00000     -4.66109     57.63759       0.08150    537.15308   2335.68042
     0.11319      0.06111      1.19290      0.0           0.99996      0.00004      0.00000
   1.25126  0.9043  0.9012    1.25130  0.9044  0.9013    1.01734  0.9999  0.9998    1.00000  1.0000  1.0000  516.75122     20180
*
    16.71014    483.85986    483.99072      0.94836       0.0          0.0         0.0
     0.0        483.99072      0.42613      0.0           0.0        556.45508   2646.10547
   764.84399    905.11499      0.79691    764.84399      57.67444    605.06128   3549.00928
     0.02328     -0.00000     -4.43726     57.63759       0.08153    536.97778   2335.59717
     0.09615      0.05164      1.18099      0.0           0.99998      0.00002      0.00000
   1.25052  0.9081  0.9052    1.25055  0.9082  0.9053    1.01435  0.9999  0.9998    1.00000  1.0000  1.0000  510.34644     20180
*
    18.47171    483.60767    483.84399      0.96046       0.0          0.0         0.0
     0.0        483.84399      0.42599      0.0           0.0        556.45557   2646.10400
   845.47290    974.13013      0.85766    845.47290      60.21849    615.84058   3775.85913
     0.03127      0.00000     -3.93549     57.63759       0.08153    536.98999   2335.77686
     0.07407      0.03954      1.16611      0.0           0.99999      0.00002      0.00000
   1.25052  0.9081  0.9057    1.25055  0.9082  0.9053    1.01074  0.9999  0.9999    1.00000  1.0000  1.0000  503.76221     20180
*
    19.19322    419.44556    419.68140      0.95417       0.0          0.0         0.0
     0.0        419.68140      0.36508      0.0           0.0        564.77832   2560.87646
   878.49756    973.59668      0.84693    878.49756      64.46490    628.87573   3733.62158
     0.03355      0.00000     -2.71823     57.63759       0.07958    550.13623   2335.69287
     0.08663      0.04583      1.17380      0.0           0.99998      0.00002      0.00000
   1.21024  0.6399  0.6301    1.21027  0.6400  0.6301    1.00923  0.9999  0.9993    1.00000  1.0000  1.0000  439.84033     20180
```

```
   19.94604    433.53135    483.92212      0.97259     0.0          0.0          0.0
    0.0        483.92212      0.42607      0.0         0.0        556.45557   2646.37671
  912.95508   1033.27979      0.90974    912.95508    62.07362    625.68872   3992.48584
    0.03468      0.00000     -2.13699     57.63759     0.08154    536.98364   2335.92114
    0.05165      0.02741      1.15156      0.0         0.99998      0.00003      0.00000
   1.25065  0.9085  0.9056   1.25069  0.9087  0.9057   1.00729  0.9999  0.9993   1.00000  1.0000  1.0000  497.55884      20180
*
   22.09024    481.95239    482.16333      1.00123     0.0          0.0          0.0
    0.0        482.16333      0.42447      0.0         0.0        556.44434   2644.24683
 1011.09766   1120.17822      0.98613   1011.09766    64.50484    641.34326   4351.19531
    0.02961      0.00000      2.48751     57.63759     0.08153    537.11377   2336.19263
   -0.00236     -0.00123      1.11862      0.0         0.99999      0.00003      0.00000
   1.24964  0.9055  0.9025   1.24967  0.9056  0.9026   0.99969  1.0004  1.0051   1.00000  1.0000  1.0000  481.56982      20180
*
   23.18089    482.46875    482.56079      1.02386     0.0          0.0          0.0
    0.0        482.56079      0.42456      0.0         0.0        557.12036   2644.25049
 1061.01733   1165.59888      1.02551   1061.01733    65.54347    650.58936   4556.23047
    0.01956      0.00000      6.19831     57.63759     0.08143    537.75806   2336.06396
   -0.04619     -0.02386      1.09390      0.0         0.99999      0.00002      0.00000
   1.24965  0.8901  0.8866   1.24968  0.8902  0.8367   0.99421  1.0000  1.0003   1.00000  1.0000  1.0000  471.31445      20180
*
   24.22324    483.42334    483.42334      1.05643     0.0          0.0          0.0
    0.0        483.42334      0.42462      0.0         0.0        558.96704   2644.25049
 1108.72754   1209.53467      1.06241   1108.72754    66.44194    661.00171   4762.39453
    0.00098      0.00000     12.35440     57.63759     0.08116    539.53638   2335.98730
   -0.11097     -0.05643      1.06017      0.0         0.99999      0.00001      0.00000
   1.24965  0.8507  0.8459   1.24967  0.8509  0.8460   0.98699  1.0000  1.0001   1.00000  1.0000  1.0000  457.59985      20180
*
   24.73105    480.09546    480.13794      1.08035     0.0          0.0          0.0
    0.0        480.13794      0.42086      0.0         0.0        560.94971   2638.65112
 1131.97070   1229.58887      1.07780   1131.97070    67.01518    667.28711   4852.67188
   -0.01333     -0.00000     17.05350     57.63759     0.08082    541.78296   2336.05737
   -0.15997     -0.08035      1.03670      0.0         0.99999      0.00003      0.00000
   1.24700  0.8045  0.7983   1.24704  0.8047  0.7984   0.98245  1.0000  1.0001   1.00000  1.0000  1.0000  444.42944      20180
*
   25.23999    466.64526    466.91528      1.11798     0.0          0.0          0.0
    0.0        466.91528      0.40796      0.0         0.0        563.42480   2619.97510
 1155.26563   1246.05249      1.08871   1155.26563    67.99321    674.16040   4918.83203
   -0.03404      0.00000     23.70813     57.63759     0.08031    545.30029   2336.37524
   -0.23978     -0.11798      1.00180      0.0         0.99999      0.00002      0.00000
   1.23817  0.7372  0.7291   1.23821  0.7373  0.7292   0.97706  1.0000  1.0001   1.00000  1.0000  1.0000  417.63989      20180
*


 SPLITTER LEADING EDGE
 Z, R, TAN A  OF LEADING EDGE, LOWER AND UPPER SURFACE TANGENT POINT
43.34840  43.53169  43.49440
12.09408  11.93257  12.31986
 0.18046  -0.05240   0.24930
```

APPENDIX III
DYNAMIC ANALYSIS METHODS

Blade Vibration Analysis

The method used to analyze the compressor and turbine blades is a transfer matrix technique. This method has proven to be extremely useful and easily adaptable to digital computer computation. It can be used to compute the coupling between two orthogonal bending and torsional modes of vibration. The coupling arises from the pretwist and noncolinearity of the elastic and centroidal axes.

The dynamic system assumed for the blade has two related but not colinear spanwise axes. These axes are the centroidal axis, which is assumed to be straight and colinear with a radial axis, and the elastic axis which, in general, is neither straight nor colinear with the centroidal axis. The elastic axis is a line along which the principle elastic bending and torsional properties are assumed to act.

For the analysis the blade is broken into segments of length (l) with two principle axes of inertia. The axis of minimum area moment of inertia is designated by using the Greek symbol eta (η). The other principle axis is designated the zeta (ζ) axis. These two axes form a coordinate system which will be called the gamma(γ) system. This system makes an angle γ with the selected Y-Z coordinate system of the blade.

The unknown quantities at the end of any section to be determined are the shears (V_Y, V_Z), bending moments (M_Z, M_Y), slopes (θ, ψ), and deflections (W, V). In addition, the torque (T) and angular deflection (θ) about the X-axis are also computed. These quantities at the right or left of any section will be called the state vector at that point. The state vector of a point in the X, Y, Z, coordinate system will be labeled Z_i.

The state vector in the gamma system ($Z^{\gamma}{}_i$) at point i can be related to the state vector in the X, Y, Z coordinate system (Z_i) by a transformation of coordinates

$$Z^{\gamma}{}_i = G^{\gamma}{}_i \cdot Z_i \qquad (10)$$

Superscript γ indicates Gamma system. The transformation equation, assuming no torsional coupling, is shown below in matrix form.

$$
\begin{Bmatrix} \Phi \\ T \\ v \\ \theta \\ M_z \\ -V_y \\ -w \\ \psi \\ M_y \\ V_z \end{Bmatrix}^{\gamma}
=
\begin{bmatrix}
1 & & & & & & & & & \\
 & 1 & & & & & & & & \\
 & & \cos\gamma_i & & & & -\sin\gamma_i & & & \\
 & & & \cos\gamma_i & & & & -\sin\gamma_i & & \\
 & & & & \cos\gamma_i & & & & -\sin\gamma_i & \\
 & & & & & \cos\gamma_i & & & & -\sin\gamma_i \\
 & & \sin\gamma_i & & & & \cos\gamma_i & & & \\
 & & & \sin\gamma_i & & & & \cos\gamma_i & & \\
 & & & & \sin\gamma_i & & & & \cos\gamma_i & \\
 & & & & & \sin\gamma_i & & & & \cos\gamma_i
\end{bmatrix}^{T}
\begin{Bmatrix} \Phi \\ T \\ v \\ \theta \\ M_z \\ -V_y \\ -w \\ \psi \\ M_y \\ V_z \end{Bmatrix}
$$

Also the state vector at the right of point i in the Gamma system (Z_i) can be related to the state vector at the left of i in the Gamma system as

$$Z^{\gamma R}_{i} = F^{\gamma}_{i} \cdot Z^{\gamma\, i}_{i} \tag{11}$$

where F_i is a field transfer matrix.

$$
\begin{Bmatrix} \Phi \\ T \\ V \\ \theta \\ M_z \\ -V_y \\ -w \\ \psi \\ M_y \\ V_z \end{Bmatrix}^{R}
= F_i^{\gamma}
\begin{Bmatrix} \Phi \\ T \\ V \\ \theta \\ M_z \\ -V_y \\ -w \\ \psi \\ M_y \\ V_z \end{Bmatrix}^{L}_{i}
=
\begin{bmatrix}
1 & \frac{l}{GK} & & & & & & & & \\
 & 1 & & & & & & & & \\
 & & 1 & l & \frac{l^2}{2EI_\zeta} & \frac{l^3}{6EI_\zeta} & & & & \\
 & & & 1 & \frac{l}{EI_\zeta} & \frac{l^2}{2EI_\zeta} & & & & \\
 & & & & 1 & l & & & & \\
 & & & & & 1 & & & & \\
 & & & & & & 1 & l & \frac{l^2}{2EI_\eta} & \frac{l^3}{6EI_\eta} \\
 & & & & & & & 1 & \frac{l}{EI_\eta} & \frac{l^2}{ZEI_\eta} \\
 & & & & & & & & 1 & l \\
 & & & & & & & & & 1
\end{bmatrix}
\begin{Bmatrix} \Phi \\ T \\ V \\ \theta \\ M_z \\ -V_y \\ -w \\ \psi \\ M_y \\ V_z \end{Bmatrix}^{L}_{i}
$$

Field Transfer Matrix

By using the transformation Eq (10) for the left side

$$Z_i^{L} = G^{\gamma}_i \cdot Z^{L}_i \tag{12}$$

and by substitution into Eq (11), the following is obtained

$$Z^{\gamma R} = F^{\gamma}_i \cdot G^{\gamma}_i \cdot Z^{L}_i \tag{13}$$

also for the right side of section i

$$Z^{\gamma}_i R = G^{\gamma}_i \cdot Z^{R}_i \tag{14}$$

or

$$Z^{R}_i = G^{\gamma -1}_i \cdot Z^{\gamma R}_i \tag{15}$$

$G^{\gamma -1}_i$ = the inverse of G^{γ}_i

therefore, by substituting Eq (13) into Eq (15), the following is obtained

$$Z_i^{R} = G^{\gamma -1}_i \cdot F^{\gamma}_i \cdot G^{\gamma}_L \cdot Z^{L}_I \tag{16}$$

or

$$Z_i^{R} = F_i Z_i^{L} \tag{17}$$

This relates the state vector at the right of section i to the state vector on the left in the X, Y, Z coordinate system. Also since

$$Z_i^{R} = Z^{L}_{i+1} \tag{18}$$

and as for Eq (16) but for section i + 1

$$Z^{R}_{i+1} = G^{\gamma -1}_{i+1} \cdot F^{\gamma}_{i+1} \cdot G^{\gamma}_{i+1} \cdot Z^{L}_{i+1} \tag{19}$$

or

$$Z^{R}_{i+1} = F_{i+1} Z^{L}_{i+1} \tag{20}$$

By substituting the expression for $Z^{R}_i = Z^{L}_{i+1}$, the following is obtained

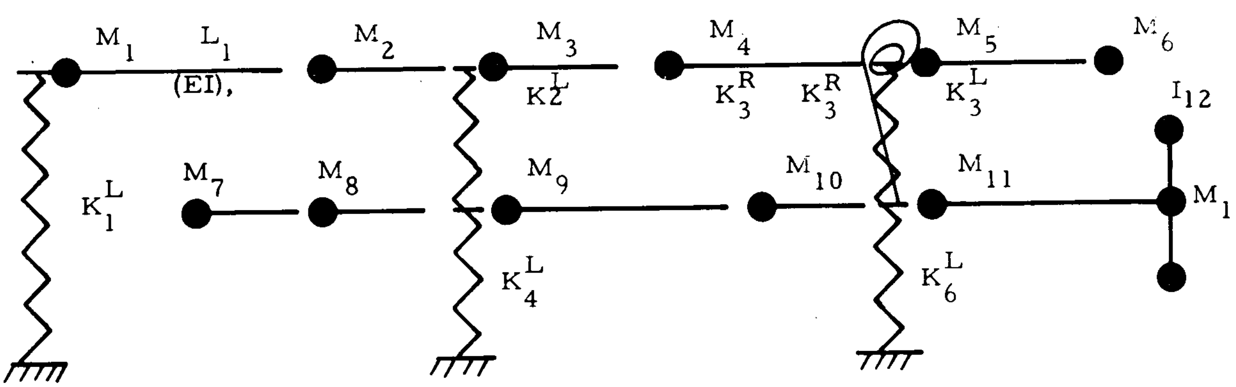
$$Z^{R}_{i+1} = \left| G^{\gamma -1}_{i+1} \; F^{\gamma}_{i+1} \; G_{i+1} \right| \cdot \left| G^{\gamma -1}_i \; G^{\gamma}_i \; G^{\gamma}_i \right| Z^{L}_i \text{ etc.}$$

As shown, the state vector at the right end of a system can be related by a product of the above transformation matrices, field transfer matrices, and a mass point matrix for each individual section. The boundary conditions that exist at the extreme ends of the system can then be inserted upon obtaining the system transfer matrix. With this, a reduced frequency determinant can be determined at a number of discrete frequencies and the frequencies, at which the determinant becomes zero, signify the eigenvalues or natural frequencies.

Rotor Analysis In Critical Speed

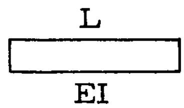
The methods employed to anlyze the rotor systems use a matrix technique similar to that described for the blades. The method selected depends upon the system being analyzed. One method can include the effects of damping and unbalance if these quantities are known. Another method which is employed extensively is based on the classical influence coefficient method. The procedure used to calculate the influence coefficients is again a transfer matrix method. This method will be described here to illustrate the general procedure.

The system to be analyzed is reduced to an equivalent mass elastic system. A typical two beam level system is shown in the following sketch:



The system is made up of sections of length L and constant stiffness EI. The matrix equation for a shaft section relating the shear, moment, slope, and deflection at the right end in terms of these quantities on the left is as follows:

$$\begin{vmatrix} V_L \\ M_L \\ \theta_L \\ Y_L \end{vmatrix}$$



$$\begin{vmatrix} V_R \\ M_R \\ \theta_R \\ Y_R \end{vmatrix}$$

$$\begin{bmatrix} V \\ M \\ \theta \\ Y \\ 1 \end{bmatrix}_R = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ L & 1 & 0 & 0 & 0 \\ \frac{L^2}{2EI} & \frac{L}{EI} & 1 & 0 & 0 \\ \frac{L^3}{6EI} & \frac{L^2}{2EI} & L & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} V \\ M \\ \theta \\ Y \\ 1 \end{bmatrix}_L$$

To compute the influence coefficients, a unit load has to be placed at each mass point individually in the system. The transfer matrix representing a unit load would be:

$$\begin{bmatrix} V \\ M \\ \theta \\ Y \\ 1 \end{bmatrix}_R = \begin{bmatrix} 1 & 0 & 0 & 0 & -1 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} V \\ M \\ \theta \\ Y \\ 1 \end{bmatrix}_L$$

This matrix simply states that a change in the shear across a load is unity. It is similar for a unit moment.

$$\begin{bmatrix} V \\ M \\ \theta \\ Y \\ 1 \end{bmatrix}_R = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} V \\ M \\ \theta \\ Y \\ 1 \end{bmatrix}_L$$

The matrix relation for a support point anywhere in the system would depend on the number of beam levels in the system. For a two level system this relation is:

$$
\begin{bmatrix} V^1 \\ M^1 \\ \theta^1 \\ Y^1 \\ 1 \\ V^2 \\ M^2 \\ \theta^2 \\ Y^2 \\ 1 \end{bmatrix}_R = \begin{bmatrix} 1 & 0 & 0 & -(S_2) & 0 & 0 & 0 & 0 & K_2 & 0 \\ 0 & 1 & S_2^T & 0 & 0 & 0 & 0 & -K_2^T & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & K_2 & 0 & 1 & 0 & 0 & -(S_3) & 0 \\ 0 & 0 & -K_2^T & 0 & 0 & 0 & 1 & S_3^T & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}_N \begin{bmatrix} V^1 \\ M^1 \\ \theta^1 \\ Y^1 \\ 1 \\ V^2 \\ M^2 \\ \theta^2 \\ Y^2 \\ 1 \end{bmatrix}_L
$$

The superscripts stand for level 1 and 2.

Here:

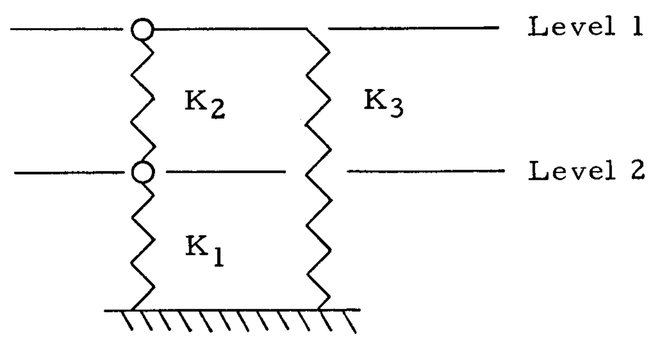
$$S_2 = K_2 + K_3$$

$$S_3 = K_2 + K_1$$

$$S_2^T = K_2^T + K_3^T$$

$$S_3^T = K_2^T + K_1^T$$

Spring Location Number System



Where:

K = Lateral Stiffness (lb/in.)
K^T = Rotational Stiffness (in.-lb/rad)

It can be observed that by placing section matrices together, the quantities, shear, etc., on the right of one section is the same as those same quantities on the left of the next section. Therefore, a matrix representing the entire beam can be produced by multiplying through these matrices and representing loads, moments and supports by their respective matrices at the proper section. Using the product matrix and boundary conditions, the shear, moment, slope, and deflection at the left end can be determined. Using these values and stepping back through the individual matrices, these quantities are determined at all selected sections. The deflection and slope at the mass points selected are singled out and placed in matrix form.

The method used to solve for the frequencies and mode shapes is the matrix iteration method. For a linear system with N degrees of freedom, the equations of motion may be expressed in terms of influence coefficients with the loads, the inertia loads $(m_i\omega^2 y_i)$ at each mass.

$$
\begin{aligned}
y_1 &= \alpha_{11}(m_1\omega^2 y_1) + \alpha_{12}(m_2\omega^2 y_2) + \alpha_{13}(m_3\omega^2 y_3) + \cdots \\
y_2 &= \alpha_{21}(m_1\omega^2 y_1) + \alpha_{22}(m_2\omega^2 y_2) + \alpha_{23}(m_3\omega^2 y_3) + \cdots \\
y_3 &= \alpha_{31}(m_1\omega^2 y_1) + \alpha_{32}(m_2\omega^2 y_2) + \alpha_{33}(m_3\omega^2 y_3) + \cdots
\end{aligned}
\tag{21}
$$

A convenient way to write these equations is by means of the matrix notation.

$$
\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ y_n \end{bmatrix}
= \omega^2
\begin{bmatrix}
\alpha_{11} & \alpha_{12} & \alpha_{13}\cdots \\
\alpha_{21} & \alpha_{22} & \alpha_{23}\cdots \\
\alpha_{31} & \alpha_{32} & \alpha_{33}\cdots \\
\cdot & \cdot & \cdots\cdot \\
\cdot & \cdot & \cdots\cdot \\
\cdot & \cdot & \cdots\cdot \\
\cdot & \cdot & \cdots\cdot \\
\cdot & \cdot & \cdots\cdot
\end{bmatrix}
\begin{bmatrix}
m_1 & 0 & 0 & 0 \\
0 & m_2 & 0 & 0 \\
0 & 0 & m_3 & 0 \\
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot
\end{bmatrix}
\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ y_n \end{bmatrix}
\tag{22}
$$

The iteration procedure is started by assuming a set of deflections y_1, y_2, y_3, ... for the right column of the matrix equation. After multiplying, the resulting column is normalized; i.e., reducing one of the amplitudes to unity by dividing each term of the column by the particular amplitude. The procedure is now repeated by using the normalized column as the new set of deflections. The amplitude will then stabilize, and the fundamental frequency can be found from the matrix equation. Since the iteration procedure converges to the lowest mode, certain manipulations are required to obtain the higher modes. Upon performing these manipulations, all desired modes can be obtained.

APPENDIX IV
LIST OF SYMBOLS

A	area - ft^2, $in.^2$
BR	bypass ratio - W_{aS}/W_{aP}
C	blade chord - ft or in.
C_P	specific heat at constant pressure - Btu/lb - ^oF
C_V	specific heat at constant volume - Btu/lb - ^oF, or nozzle velocity coefficient
D	diameter - ft, or blade diffusion factor
Fg	gross thrust - lb
F_n	net (total) thrust - lb
$F_{t,y}$	tensile yield stress - $lb/in.^2$
$F_{t,u}$	tensile ultimate stress - $lb/in.^2$
f	blade or sound frequency - cps
g	gravitational constant - 32.17 ft/sec^2
h	specific enthalphy - Btu/lb
i	blade incidence - deg
J	mechanical equivalent of heat - 778 ft-lb/Btu
k	C_P/C_V
k_h	stress concentration factor in hoop stress
k_t	stress concentration factor in tension
M	Mach number
N	rotative speed - rpm

P	pressure - lb/in.^{2} or lb/ft^2
PNL	perceived noise level
PNdB	perceived noise in decibels
q	dynamic pressure - $1/2 \rho V^2$
S	blade pitch - ft or in.
SM	surge margin = $\left[\left(\frac{P_{rs}}{P_{ro}} \times \frac{W_{ao}}{W_{as}}\right)\right]-1 \quad x100$
SPL	sideline perceived level or sound pressure level
T	temperature, ^{o}R or ^{o}F
TSFC	thrust specific fuel consumption - lb/hr-lb
U	wheel speed - ft/sec
V	absolute velocity vector - ft/sec
W	flow - lb/sec, or relative velocity - ft/sec
W_{aP}	primary or core flow - lb/sec
W_{as}	secondary or bypass flow - lb/sec
W_c	cooling air - lb/sec
W_L	leakage air overboard - lb/sec
α	absolute flow angle measured from axis - deg
β	relative flow angle measured from axis - deg
γ	setting angle - deg
δ	blade deviation - deg, or referred pressure - P/14.69

η	efficiency
θ	camber angle - deg, or referred temperature - T/518.7
θ_{cr}	$= \dfrac{\left(\frac{2k}{k+1}\right) T_t}{\left(\frac{2k}{k+1}\right) (518.7)}$
λ	blade flutter coefficient $= \dfrac{W}{2 \pi f C}$
ν	relative thickness - pct
ρ	mass density - slugs/ft^3
σ	blade solidity - C/S, or stress
σ_h	hoop stress - lb/in.^{2}
σ_r	radial stress component - lb/in.^{2}
σ_t	tangential stress component - lb/in.^{2}
ϕ	flow coefficient - nondimensional (V_z/U)
ψ	pressure coefficient - nondimensional ($\Delta h/U^2/2gJ$)
ψ_a	Zweifel load coefficient
ω	pressure loss coefficient - $\Delta Pt/q_1$, or radians/sec

Subscripts

a	adiabatic
am	ambient
B	burner
f	flight
h	hub

M	mechanical
o	operating
p	polytropic
r	radial component
s	surge
T	turbine
t	total or tip
W	relative
Z	axial component
θ	tangential component
1	inlet
2	exit

REFERENCES

1. Fujjii, Shoichi, "Some Studies of Front Fans With and Without Snubbers," ASME Paper 72-GT-4, 1972.

2. Smith, M. J. T., and House, M. E., "Internally Generated Noise From Gas Turbine Engines, Measurement and Prediction," Journal of Engineering for Power, pp. 177-190, April 1967.

3. Kobrynski, M., "General Methods for Calculating the Sound Pressure Field Emitted by Stationary or Moving Jets," O. N. E. R., May 1969.

BIBLIOGRAPHY

Lycoming ALF-502A Turbofan Engine, Volume II, Technical Description, No. 4510-8, August 1970.