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**CENTRIFUGAL COMPRESSOR DESIGN CRITERIA -
A COMPARISON OF THEORY AND EXPERIMENT**

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General Motors Corporation

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objective of this program was to define the utility of the Detroit Diesel Allison Centrifugal Compressor Performance (CCP) analysis. This objective was accomplished by comparing the preexisting analysis of the performance of a new high-pressure-ratio centrifugal compressor (RC-2) with the test data obtained in the course of this program. After the first		

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20. Continued.

or baseline compressor tests, the test results were analyzed on the basis of the CCP program, and initial compressor modifications were recommended and carried out. An additional modification was also completed. Prior to each test of the modified compressor, an estimate of the unit's performance was obtained by using the CCP program, and the test results were subsequently compared with this estimate.

In general, the CCP calculation was in agreement with the test data as far as the compressor's overall pressure ratio was concerned. However, the program's efficiency calculation appeared to be high by amounts progressively decreasing from 4.5% in the initial test to 0.7% in the final test. The test data also indicate that the hardware is sensitive to certain profile parameters at the inlet of both the diffuser and the inducer in a manner which the calculation does not predict. This sensitivity to flow profile was deduced from the intrastage performance measurements and is not accounted for in the CCP program. The CCP calculated mass flow rate through the compressor was found to differ from the measured value by amounts varying from 1 to 6% as a function of the accuracy with which the program distributed the compressor's internal losses.

The final modification to the compressor consisted of cutting back the rotor to a radius 8% smaller than the original radius. In spite of the consequent mismatch between the impeller and the diffuser, the overall compressor efficiency was increased by this modification. The overall compressor efficiency probably would be further increased if a properly matched diffuser were substituted for the current one.

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EUSTIS DIRECTORATE POSITION STATEMENT

The conclusions derived from work performed during this centrifugal compressor design criteria program underscore a primary, long-standing problem: neither the compressor design nor the prediction of a "paper" compressor's performance can be accurately completed without benefit of detailed definition of the internal aerodynamics of the machine either by rigorous analytical treatment of the geometry or by acquisition of test data. While it may be possible to complete designs or performance predictions using advanced internal-aerodynamics computer analyses, the most successful attempts at the effort rely on test data either from the hardware under investigation or from another compressor closely related to it.

This report has been reviewed by technical personnel from this Directorate, and the conclusions and recommendations contained herein are concurred in by this Directorate. The project engineer for this contract was Mr. Robert A. Langworthy, Technology Applications Division.

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The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

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PREFACE

The program reported herein was conducted by the Detroit Diesel Allison Division (DDA) of General Motors Corporation for the U. S. Army Air Mobility Research and Development Laboratory, Eustis Directorate, under the terms of Contract DAAJ02-73-C-0089, DA Project 1G262207AH89.

The program was directed at DDA by Dr. S. Baghdadi; Dr. W. F. Osborn, the principal analyst, developed the centrifugal compressor performance calculation; and Mr. B. A. Hopkins was responsible for the design of the RC-2 Compressor. The compressor tests were performed under the direction of Mr. W. C. Gitzlaff of the DDA Test Department. Mr. R. M. Kaufman was responsible for the test stand computer programming.

The authors gratefully acknowledge the program guidance provided by Mr. R. A. Langworthy of the Eustis Directorate, USAAMRDL.

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I. PROGRAM THEORY

THERMODYNAMIC FRAMEWORK

The Detroit Diesel Allison (DDA) CCP calculation computes compressor pressure ratio and efficiency for each speed line as a function of the mass flow rate.

The relationship between rotor pressure ratio and rotor internal efficiency is

$$R_{c, \text{rotor}} = \left[1 + \frac{\eta_{ri} U_2^2}{g J C_p T_{01}} \Delta q_{th} \right]^{\gamma/(\gamma-1)}$$

where η_{ri} is the rotor internal efficiency defined by

$$\eta_{ri} = \frac{\Delta q_{th} - \Delta q_{ri}}{\Delta q_{th}}$$

where Δq_{ri} represents rotor internal losses which degrade the rotor pressure, such as aerodynamic friction losses along the flow surface, losses caused by the growth of the boundary layers in the rotor, blade wake mixing, shock wave losses, and secondary flow losses; Δq_{th} is the theoretical head

$$q_{th} = \frac{C_{\theta 2}}{U_2} - \frac{C_{\theta 1} U_1}{U_2^2}$$

= (SF' - PF) for a radial exducer. (Note that all the q values are nondimensionalized by dividing by U_2^2/Jg .)

The adiabatic (overall) rotor efficiency must account for aerodynamic losses external to the rotor, such as frictional losses* on the rotor back plate, losses caused by the recirculation of low energy fluid in and out of the rotor, and losses associated with the clearance between the rotor and the stationary shroud.

Thus, the compressor's adiabatic efficiency is defined as

$$\eta_{ad} = \frac{\Delta q_{th} - (\Delta q_{ri} + \Delta q_{diffuser} + \Delta q_{IGV})}{\Delta q_{th} + \Delta q_{external}}$$

The sum in parentheses in the numerator may be termed the total internal flow losses. This equation expresses the fact that the internal flow losses decrease the useful output of the compressor, while external losses increase the work input required to run the compressor. Figure 1 shows the various losses according to their origins.

*Mechanical losses (such as those caused by bearing and seal friction) cannot be accounted for in an aerodynamic calculation.

Clearly, the rotor external losses increase the temperature of the fluid at the diffuser exit. However, it is difficult to determine what fraction of this heat addition is fed into the working fluid while it is in the rotor, and what fraction is fed into the fluid outside the rotor. The CCP program somewhat arbitrarily splits or assigns half the rotor external losses to the fluid inside the rotor, and the other half to the fluid as it leaves the rotor (at the rotor "dump" station). Checks of the effect on the program of varying this fraction show the overall performance parameters to be relatively insensitive to the split. O. E. Balje^{*1} recommends adding the entire rotor external loss at the rotor exit; however, this was found to be extreme.

The compressor overall pressure ratio may be written

$$R_{COA} = \left[1 + \eta_{ad} U_2^2 \frac{(\Delta q_{th} + \Delta q_{ex})}{Jg C_p T_0} \right]^{\gamma/(\gamma-1)}$$

The thermodynamic framework described here may be represented conveniently in an H-S diagram, Figure 2.

Figure 1. Centrifugal compressor loss mechanisms.

Figure 2. Mollier diagram for centrifugal compressor.

*Superscript numbers correspond to the references listed in Section VII.

¹ Balje, O.E. A Study on Design Criteria and Matching of Turbo Machines. Part B—Compressor and Pump Performance and Matching of Turbo Components. ASME Paper 60-WA-231.

LOSS CALCULATIONS

The CCP program calculates both internal and external losses by means of equations derived theoretically from data correlations and from the literature.

Inlet Guide Vane Losses

The inlet guide vane losses are computed as a function of the blade turning and the exit Mach number. Typically, this loss amounts to 1.5% of the inlet total pressure at the design point for RC-2.

Rotor Internal Losses

The calculation of the rotor internal losses is the heart of the CCP program. The calculation was developed for radial rotors and subsequently modified to take into account back-curved rotors. The radial rotor theory is based on a unique relationship between the rotor pressure coefficient and the tip speed and inlet swirl. The following description applies to radial rotors.

The rotor pressure coefficient, ψ , is defined as

$$\begin{aligned}\psi &= (SF - PF) - \Delta q_{ri} (SF, PF, U, \alpha) \\ &= \Delta q_{th} - \Delta q_{ri}\end{aligned}\tag{1}$$

where Δq_{ri} is the rotor internal loss. The relationship $\psi = \psi(U, \alpha)$ has been derived from correlation studies for rotors close to the state of the art, which will be referred to as "model rotors" in this report. This key relationship may be derived from the assumption that, for a given rotor ideal (isentropic) head, the rotor internal losses are directly related to the rotor tip speed. Thus, the model rotor internal loss may be obtained from equation (1),

$$(\Delta q_{ri})_{\text{model}} = \psi(U, \alpha)_{\text{model}} - SF + PF$$

This rotor internal loss is modified by a factor F_m , which accounts for various effects which cause deviation from $(\Delta q_{ri})_{\text{model}}$ as computed here, so that, for real rotors, $\Delta q_{ri} = F_m (\Delta q_{ri})_{\text{model}}$, where

$$F_m = f_1 \times f_2 \times f_3 \times \dots \times f_n = \prod_{i=1}^n f_i$$

Each of the factors f_i is a modifier by which the rotor internal loss is multiplied to account for a particular effect. Some of the factors f_i follow:

(a) The inlet axial Mach number

$$\begin{aligned} f_1 &= 1 + C_1 (M - M_{cr1}) \\ C_1 &> 0, M > M_{cr1} \\ C_1 &= 0, M < M_{cr1} \end{aligned}$$

where the subscript cr_1 indicates a critical value,

(b) The inducer tip relative Mach number

$$\begin{aligned} f_2 &= 1 + C_2 (M_{rel} - M_{cr2}) \\ C_2 &> 0, M_{rel} > M_{cr2} \\ C_2 &= 0, M < M_{cr2} \end{aligned}$$

(c) Rotor negative incidence at high Mach number

$$\begin{aligned} f_3 &= 1 + C_3 i \\ C_3 &> 0, i < 0, \text{ if } M_{rel} > M_{cr2} \\ C_3 &= 0, i > 0, \text{ or if } M_{rel} < M_{cr2} \end{aligned}$$

(d) Rotor blade surface roughness

$$\begin{aligned} f_4 &= 1 + C_4 (\epsilon - \epsilon_{cr}) \\ C_4 &> 0, \epsilon > \epsilon_{cr} \\ C_4 &= 0, \epsilon < \epsilon_{cr} \end{aligned}$$

where ϵ is the blade surface roughness.

For rotors close to choking in the inducer, a choke flow coefficient factor is also included. Except for the latter, all the functions are linear.

The rotor outlet axial (or "wall") blockage at design point is input. Typically, the values range from 0.85 to 0.95. The rotor outlet wake (or tangential blockage) is calculated at design point as a function of the rotor pressure ratio, the number of blades, the inlet hub/tip ratio, and one of three flow quality factors. (Refer to the CCP Calculation Flow Chart, Figure 3.) These flow quality factors may only be used a posteriori in analyzing test data; obviously, in doing an a priori analysis (i.e., before the machine has been tested) of a machine, the quality of the flow (which is a function of the impeller blading design and the diffuser entry conditions) cannot at present be determined.

Figure 3. CCP Calculation flow chart.

Clearly, the designer intends his blading to produce the highest quality flow (i.e., the lowest wake amplitude). The designer typically uses an inviscid or quasi-inviscid flow calculation to schedule the impeller blading, and his quality criteria are usually based on the blade surface diffusion factors indicated by this program. However, such programs do not accurately take into account boundary layer migration and other secondary flow effects that are known to affect the blading velocity gradients. The proximity of the diffuser leading edges to the impeller and the number of diffuser passages are also known to affect the impeller flow quality, although these effects are not yet included in the CCP correlations. This aspect of the compressor performance calculation is still an art. In general, when the CCP program is run a priori, the blading is assumed to produce high-quality flow and thus a low-amplitude tangential blade wake.

Both the "wall" and "wake" values of the impeller exit blockage are calculated at off-design operating points by means of modifiers applied to the design point value (or "amplitude"). These modifiers are functions of dimensionless quantities ϕ/ϕ_{DP} , where

$$\phi = \text{inlet flow coefficient} = V_a/U_2$$

U_2 is the rotor tip speed, and the subscript DP indicates a design point value.

The aerodynamic slip factor is calculated at design point by a formula which is based on data correlations. The slip factor relationship depends strongly on the value of the wake blockage as well as on the number of blades. The off-design value of the slip factor depends on the flow factor and tip speed in a manner similar to the impeller exit blockages.

Once the slip factor amplitude has been calculated at the design point, the program returns to the calculation of the rotor pressure coefficient and blockages as indicated in the flow chart, Figure 3. Finally, a new rotor pressure coefficient is computed, and then Δq_{r1} is calculated from equation (1).

The correlations and calculations used in CCP were derived originally for impellers with radial exducer blading. The calculation was subsequently modified to take into consideration rotors with back-curved exducer blading. This was done primarily by using the pressure coefficient-tip speed correlation to transform a given back-curved rotor into an equivalent radial machine at each calculation point. In addition, the rotor slip factor and blockage relations contain terms accounting for back-curvature.

Rotor External Losses

The rotor external losses consist of the rear disk frictional loss, the impeller tip recirculation loss, and the losses associated with the clearance between the rotor and the shroud.

The external loss is calculated in two parts in CCP:

$$\Delta q_{\text{ext}} = f_1 + f_2$$

f_1 is the contribution resulting from clearance effects in the inducer section of the rotor. This parameter is a function of the inlet hub/tip ratio and the inlet hub diameter as well as the clearance between the rotor and the shroud.

f_2 is the contribution resulting from the radial section of the impeller and, thus, includes the rear disk friction, the clearance effects, and the recirculating flow losses at the impeller exit. f_2 is a function of the rotor tip Reynolds number, the static pressure rise across the impeller, the rotor tip speed, and the clearance.

Diffuser Losses

The diffuser losses include the rotor wake mixing loss, the frictional losses in the vaneless space, the passage entry loss, and the diffusing passage losses.

The mixing of the rotor wakes is assumed to occur instantaneously and at constant static pressure. This loss includes the loss caused by the addition of half the rotor external losses at this station.

The diffuser throat blockage is computed using boundary layer considerations. Once the throat blockage is known, the total pressure at the throat of the diffuser is deduced from an empirical curve correlating the product of throat blockage and pressure at the throat with the diffuser leading-edge Mach number. This curve is similar to—but not identical to—that of Kenny.² The losses and pressure recovery in the diffuser downstream of the throat are obtained from a correlation of the total pressure loss in such a diffuser with throat blockage and Mach number. Consideration is being given to replacing this section of the calculation with a calculation based on the published results of two-dimensional and conical diffuser testing by Creare, Inc.^{3,4}

² Kenny, D. P. A Novel, Low-Cost Diffuser for High Performance Centrifugal Compressors, ASME 68/GT-38.

³ Dean, R. C., Jr., and Runstadler, P. W., Jr. Straight Channel Diffuser Performance at High Inlet Mach Numbers. Creare, Inc., Hanover, New Hampshire.

⁴ Dolan, F. K., and Runstadler, P. W., Jr. Pressure Recovery Performance of Conical Diffusers at High Subsonic Mach Numbers. Creare Report TN-165, Hanover, New Hampshire, July 1973.

II. COMPRESSOR DESIGN

The RC-2 compressor is the second in a series of high-pressure-ratio research compressors designed and built at DDA. The first compressor of this series, RC-1, had a design point pressure ratio of 8:1 and a mass flow of 4.2 lbm/sec at a specific speed of 70.* The RC-1 design, which used an impeller with a straight radial exducer of high solidity, proved to have an unusually wide range of operation with the peak efficiencies well removed from the surge line.

DESIGN PHILOSOPHY

The purpose of the second design (RC-2) is to provide a unit with a higher efficiency potential than the original design (RC-1). The RC-2 was to use as much of the existing RC-1 hardware as was compatible with a reasonable performance improvement increment. Thus, only features believed to be quantitatively important would be included if these features materially influenced costs. On the other hand, any features which could be added at little or no cost could be considered for inclusion.

In the new design the flow and pressure ratio could be specified to values other than those used for the RC-1. From a research standpoint alone, there is merit in maintaining the same design goals for a series of units to minimize the difficulties of rigorous comparison. Therefore, it was the intent of DDA to carry over the original flow and pressure ratio goals unless detailed study dictated otherwise.

The major changes to which study was directed were related to:

- Increased specific speed
- Decreased friction-producing surface (wetted area)
- Scheduled impeller diffusion
- Back-curved impeller blading

A basic change in the design of the RC-2 as compared with the RC-1 was in the area of specific speed (N_s). While specific speed as a performance parameter is not independent of other factors (e.g., Mach number), there are considerable data in the literature which show that an optimum exists at a higher value than that of the RC-1. Figure 4 shows examples. Data for Figure 4 are from O. E. Balje¹ and C. Rodgers.² While these curves do not agree on the optimum specific speed, they do show that a value of 70 as used for the RC-1 is lower than desirable. The original value of 70 was chosen low in order to achieve a reasonably low inducer Mach number (0.87).

¹Rodgers, C. A Cycle Analysis Technique for Small Gas Turbines; Technical Advances in Gas Turbine Design. Paper No. 5, Institution of Mechanical Engineers. April 1969.

*See N_s under List of Symbols for definition and units.

Figure 4. Effect of specific speed on efficiency.

A specific speed of 90 was believed to be a suitable increment above the 70 value, and, therefore, was used as the design goal. Specific speed can be increased by an increase in airflow per unit area, an increase in rotative speed, or a reduction in pressure ratio. A change in airflow consistent with retention of inlet ducting would produce only a fraction of the desired specific speed change. In any case, both flow and pressure ratio should be the same as for the RC-1 for good parametric comparisons of test data. On the other hand, shaft speed could be readily changed. The change in specific speed from 70 to 90 produces a comparable change (+28%) in shaft speed. The existing shaft support system and bearings were considered to be capable of accommodating this speed change. Thus, the specific speed was increased by a shaft speed change only.

Included in the design philosophy was the intent to decrease the friction-producing wetted area. In principle, this results in increasing the rate of diffusion, which is also generally referred to as increasing "loading."

Several interrelated factors are involved in pursuing a loading change. Foremost among these factors is the problem of computing the impeller velocities with sufficient reality so that a particular diffusion rate can be identified. Then, of course, there is the problem of establishing the criteria for the appropriate diffusion gradients throughout the impeller on both suction and pressure surfaces. Also pertinent to a change in loading is a review, in general terms, of the relationship of the impeller design procedures to the real flow field therein. A thorough discussion of these generalities has been presented in an ASME publication.⁶

⁶Advanced Centrifugal Compressors. ASME Turbomachinery Committee, Gas Turbine Division, New York. 1971.

The ideal inviscid flow field in an impeller is generally computed by a quasi-two-dimensional potential flow solution, such as DDA BC46 computer program. The real flow develops secondary flows; this means that there is a transverse migration of low-energy fluid toward the low-pressure corner of the flow passage. The boundary-layer loss is generated to different degrees on hub, pressure, and suction walls. In addition, the stationary-shroud-rotating-impeller relationship produces "extra" tangential shear forces. The result is that the total energy head becomes distributed in a different manner from that postulated by the inviscid analytical solution. In a short flow-path length, such as a typical axial stage, there is insufficient time for this cross flow to produce any significant discrepancy between the computed and real flow field. However, the centrifugal compressor is inherently one of considerably longer passages. This can produce the situation wherein the exit transverse velocity distribution at the impeller exit is "reversed" when measured in test, as compared with the computed distribution. This is produced by a displacement of energy heads by the cross-flow effects.

Despite its limitations, potential flow impeller flow field calculation has considerable merit. Through use of an allowance for bulk loss and blockage, the average velocity level is reasonably correct through the impeller. In the "early" part of the impeller the computation of surface velocities should be reasonably valid. Further, major deviations from rational design velocities can be avoided even though exact velocities may be in doubt.

A major advantage of the potential flow calculation is the obvious capability of comparing one design with another. Here the differences in comparable analytical results are important and useful, keeping in mind the computational limitations.

As stated, the intent was to decrease the RC-2 impeller friction surface compared with the RC-1. The increase in specific speed contributes directly to this by the reduction in required diameter and indirectly through requiring less tangential loading (force), allowing return to original loading by using fewer vanes. A further decrease in the number of vanes, other factors remaining fixed, has the effect of increasing, in proportion, the velocity differential vane to vane. This trend is shown schematically in Figure 5 and illustrates that the magnitude of local diffusion is increased on each surface. In addition, the impeller channel cross-flow driving forces will be greater when the velocity (pressure) differentials, vane-to-vane, are greater.

The amount of diffusion which can be tolerated is not quantitatively known. It would seem that optimum loading should be qualitatively of the same nature as an optimum diffuser (i. e., a carefully adjusted "ratio" of diffusion to the friction-producing wetted surfaces producing the diffusion). It is generally agreed that boundary layer calculations in the impeller are not sufficiently accurate to warrant detailed application. Cross flows, pressure gradients normal to the vane, and rotation of the flow path all conflict with the conventional assumptions. F. Dallenbach⁷ proposes a diffusion velocity ratio limit. He derived this limit from simple

⁷Dallenbach, F. The Aerodynamic Design and Performance of Centrifugal and Mixed-Flow Compressors; Symposium on Centrifugal Compressors. ASME. 1962.

Figure 5. Effect of vane number change on impeller loading.

boundary layer propositions, but it gained credibility by use in a series of designs wherein better performance was obtained than in a series where the proposed limit was exceeded. A value of impeller final relative velocity divided by an initial relative velocity of 0.6 is suggested as a minimum value. The application of this criterion was considered in the RC-2 design.

Qualitative scheduling of the impeller internal diffusion in a manner consistent with simple boundary layer characteristics was considered desirable for the RC-2. Such calculations show that the accumulated energy loss is less when a given diffusion is obtained by a more rapid velocity reduction in the early portion than in the latter portion of a diffuser.

Use of an impeller that incorporated back-curvature at the outlet was also considered desirable for the RC-2. Such a design reduces the diffuser inlet Mach number for a given vaneless space while adding somewhat to the impeller diameter. Curves showing such trends are shown in Figures 6 and 7. One obstacle to the use of a back-curved impeller is the stress produced at the tip as a result of centrifugal force acting on the nonradial section. However, improvements in the last few years in the stress calculation capability indicate that the stresses in this zone are not as high as previously assessed and, further, that the use of the titanium material provides superior strength.

Figure 6. Effect of impeller back-turn angle on diffuser inlet Mach No. potential flow calculation.

Figure 7. Effect of back-turn angle on tip speed.

IMPELLER AERODYNAMIC DESIGN

The impeller velocity patterns were computed using the DDA BC46 computer program described by D. M. Davis.⁸ The calculation is basically straightforward, inviscid solution à la J. D. Stanitz,⁹ wherein various clerical features (e.g., data input, solution stations) were most recently influenced by the methods of T. Katsantis.¹⁰

The impeller inlet vector diagram quantities are displayed in Table 1. The inlet guide vanes, for which the design is reported by B. A. Hopkins,¹¹ and the inlet ducting were retained from the RC-1 design. Shaft speed was chosen through use of a specific speed of 90 and the RC-1 values of flow and pressure ratio of 4.2 lb/sec and 8:1. The resulting shaft speed is 56,000 rpm as compared with 43,800 rpm for the RC-1.

The impeller exit radial velocity choice was a matter of considerable deliberation. A high value of exit velocity decreases impeller diffusion but increases the absolute Mach number at the impeller exit. Logically, the proper value of exit velocity would seem to be that which produces maximum diffusion consistent with off-design requirements. However, the issue is clouded by the possibility that the impeller exit flow quality may deteriorate, even at modest diffusion levels, to the point where subsequent diffusion recovery is reduced.

The impeller internal flow field is considered to be too complex for boundary layer analysis. Simple flat plate calculations were nonetheless used as a guide by F. Dallenbach,⁷ who suggested that a relative velocity ratio, outlet to inlet, be 0.6 or above. This value is supported with several sets of test results showing improvements in performance by the elimination of excess diffusion.

The bulk performance correlation indicates that overall efficiency of the RC-2 compressor should vary with exit velocity as shown in Figure 8. In this range of interest, efficiency continues to rise as exit velocity reduces. If a meridional velocity of 400 ft/sec exists at the impeller exit, the shroud stream surface relative velocity ratio, outlet to inlet, will be 0.52. If computed using maximum suction surface velocity, a value of more nearly 0.46 might result. These values are appreciably less than 0.6 minimum as suggested by F. Dallenbach.⁷ On the other hand, to achieve a 0.6 value, a meridional exit velocity of 600 ft/sec or higher might be required. At this value the CCP calculation would indicate a considerable loss in efficiency.

⁸ Davis, D. M. Radial Flow Compressor and Turbine Design Program. Mathematics Sciences Report. Detroit Diesel Allison Division, General Motors. August 1971.

⁹ Stanitz, J. D. Some Theoretical Aerodynamic Investigations of Impellers in Radial and Mixed-Flow Centrifugal Compressors. Trans. ASME, Vol 74, pp 473-497. 1952.

¹⁰ Katsantis, T. Computer Program for Calculating Velocities and Streamlines on a Blade-to-Blade Stream Surface of a Turbomachine. NASA TN D-4525. April 1968.

¹¹ Hopkins, B. A. Inlet Guide Vane Design for Centrifugal Compressor. Research Note RN 69-79, Detroit Diesel Allison Division, General Motors. December 1969.

TABLE 1. ROTOR INLET VECTOR QUANTITIES.

	<u>Hub</u>	<u>Mean</u>	<u>Tip</u>
Radius, ft	0.100	0.171	0.216
Relative velocity, ft/sec	586	944	1203
Absolute velocity, ft/sec	538	619	699
Axial velocity, ft/sec	478	567	651
Absolute tangential velocity, ft/sec	247	248	255
Blade velocity, ft/sec	587	1003	1268
Relative Mach number	0.54	0.87	1.12
Absolute angle, deg	27.3	23.6	21.4
Relative angle, deg	35.4	53.1	57.2
Inlet guide vane exit angle, deg	22.3	24.2	25.0

The final choice in velocity at the exit was taken more nearly after the indications of the performance calculations than the recommendations of F. Dallenbach.⁷ Impeller exit blockage, slip factor, and impeller loss numbers were acquired from the CCP calculations. Impeller internal exit design values are shown in Table 2.

Figure 8. Computed efficiency—velocity trade-off.

TABLE 2. IMPELLER INTERNAL EXIT VALUES.

Radius, in.	4.224
Wheel speed, ft/sec	2064
Average velocities, ft/sec	
Radial	480
Relative	672
Tangential	1593
Absolute	1664
Average angles, deg	
Blade (from radial)	32.5
Relative (from radial)	44.5
Absolute (from tangential)	16.8
Average absolute Mach number	1.205
Slip factor	0.920
Aerodynamic blockage, %	24.5
Exit flow-path width, in.	0.336
Exit vane metal blockage (circumferential), %	5.9

The impeller vane surface velocities, as computed, are shown in Figures 9 and 10. Shown are shroud and hub streamline velocities for pressure and suction sides of the vane. The velocities on the shroud stream surfaces (Figure 9) show a rapid diffusion in the very early portion of the impeller. This is primarily caused by inducer throat sizing. With a desire to maintain inlet dimensions, suitable maximum flow capacity must be obtained by incidence or blade angle change from inlet to throat. The blade tip incidence was adjusted according to experience on transonic axial stages. In so doing, consideration was given to the fact that the flow field at the inducer inlet was not computed in the same manner as normally used for transonic stages. In axial stages, the flow field within the blade row has not been computed. In consequence, the effect of blade blockage and local blade turning has not been reflected in the vector diagrams normally computed as stage inlet. In the centrifugal impeller calculation, considerable effect of blade presence is seen. For this reason, a computation station about 0.6 in. upstream was used as a reference station for considering incidence.

Figure 11 shows the air angles as computed both at the incidence reference station and at the inducer leading edge. Also shown is the blade leading-edge angle. Incidence is defined as air angle minus blade angle. The restrictions imposed on the physical blade shape include the requirement for a straight-line mean blade element at a constant percentage of meridional distance running between specified blade angle schedules, hub and shroud. The result is that only incidence at hub and shroud can be specified. A slightly negative hub incidence was chosen to minimize the magnitude of positive incidence at the mean radius.

Figure 9. Impeller vane surface velocities at design point—RC-2 shroud.

Figure 10. Impeller vane surface velocities at design point—RC-2 hub.

Figure 11. Angle distribution at impeller inlet.

Choke margin has been assessed at 7% by using the average velocity at the throat location as computed by the potential flow solution. This simple method of computed flow capacity was 1% low when compared with test data on a similar design.

The vane surface velocities—and particularly the vane-to-vane differential—are largely a function of the turning angle distribution and the number of vanes. The RC-1 impeller contained 16 primary vanes, 16 splitters, and 32 secondary splitters. In reducing the wetted area, all of the vanes could be reduced in proportion. A different choice was made in the RC-2, according to the following reasoning. The introduction of splitters abruptly reduces the loading by a factor of 2 and introduces local blockage at the same point. Uniformity of loading distribution is thus compromised. However, maintenance of a reasonable maximum level of loading does require splitters. The secondary splitter location, necessarily well aft in the flow path, produces the possibility of poor incidence matching because of the questionable flow field calculation.

For the RC-2 design, the secondary splitters were abandoned, while the number of vanes was maintained at 16. The loading distribution was adjusted by scheduling the tangential turning. In the zone where the secondary splitters would normally be required, loading was reduced by back turning. This load was, in turn, picked up in the knee of the impeller, where solidity is still high, by overturning. The tangential turning angle schedule is shown in Figure 12. The values were basically chosen for the shroud, while hub values result from the need for the vane itself to be essentially radially oriented for stress reasons, except for the latter portion of the flow path. In the 80-to-90% position of the flow path, the hub angles were held to zero. The result is that the back-curved impeller can be machined to a lesser diameter to make a radial bladed impeller of approximately the same pressure ratio output. (That is, there is very little blade loading in the last 8% of the blading.)

DIFFUSER DESIGN

A pipe-type diffuser was chosen for the design. The basic changes featured, as compared with the RC-1, are in the choice of diffuser inlet-to-impeller tip radius ratio and in departure from a constant-width vaneless space.

The effect of radius ratio on vaneless space loss, diffuser inlet Mach number, and efficiency to the diffuser exit (Mach No. = 0.35) is shown in Figure 13. Diffuser pressure recovery is held at a constant value of 0.70, and vaneless space loss is from the CCP analysis. Although the vaneless space loss increases with radius ratio, the reduced diffuser inlet velocity allows somewhat greater pressure to be developed at the diffuser exit and, therefore, better compressor efficiency. However, insufficient data have been available at the higher values of radius ratio to establish complete confidence in that design regime. In reality, diffuser pressure recovery may vary with radius ratio. The radius ratio for the RC-2 was chosen to be 1.13, comparable with a reworked RC-1 configuration.

Figure 12. Impeller vane angle schedule.

Figure 13. Vaneless diffuser.

To reduce the boundary layer buildup on the vaneless space walls, the width was reduced in proportion to radius change. Thus, the physical area was maintained constant with radius up to the radius where the pipe ridges are encountered.

Geometrical relationships among the many variables involved dictate the exact dimensions used. A constant width was used from the constant area section to the diffuser throat. Thus, the throat diameter is identical to the final width in the constant area section. The throat width is set by choke requirements. Figure 14 shows the trend of the dimensional requirements. A choice of 27 pipes in the diffuser was made. The variable width section terminates at the pipe centerline tangency radius, and thus does not enter the pipe ridge zone.

The throat area was chosen to provide a 2% margin to choke. The area is further adjusted to allow for losses and blockage totaling 8%, according to Figure 15, which was taken from Morris and Kenny.¹²

¹² Morris, R. E., and Kenny, D. P. High-Pressure Ratio Centrifugal Compressors for Small Gas Turbine Engines. Report No. 6, 31st Meeting of the Propulsion and Energetics Panel of AGARD, Ottawa, Canada. June 1968.

Figure 14. Vaneless diffuser geometry for fixed throat.

Figure 15. Pipe diffuser throat blockage factor.

The diffuser exit Mach number is designed to be 0.35. Diffuser geometry was chosen primarily by reference to high Mach number data from two-dimensional diffusers as discussed by Runstadler and Dean.³ A cross plot of data taken from that report³ is shown in Figure 16. Performance and geometry for two area ratios are shown plotted against blockage. The blockage at choke of the RC-1 has been computed to be 3.5%, assuming a one-dimensional throat flow. However, this blockage definition is not compatible with the Figure 16 blockage definition. One to two percent apparently must be added to the 3.5% in order to use these data from Runstadler and Dean.³

The area ratio was chosen as 2.15. The diffuser length was based on a length-to-inlet radius ratio of 11.5.

As on the original design, there was no attempt made to convert the diffuser exit velocity to a higher pressure. It was recognized that there is, in general, a requirement in engine use for a lower compressor exit Mach number. The performance of a secondary diffuser is conservatively estimated when data are presented to a lower level of Mach number. A value of static pressure recovery of 0.30 to a Mach number of 0.15 was assumed for performance calculation.

The diffuser design parameters are presented in Table 3.

Figure 16. Plane wall diffuser performance.

TABLE 3. DIFFUSER DESIGN PARAMETERS.

Vaneless space		
Exit radius (leading edge), in.		4.773
Width at inlet, in.		0.336
Final width, in.		0.3125
Radius at final width (tangency), in.		4.5484
Total pressure loss, %		2.9
Diffuser		
Number of pipes		27
Throat diameter, in.		0.3125
Total throat area, in. ²		2.07089
Leading-edge wedge angle, deg		8.7
Leading-edge mean angle from tangential, deg		16.4
Diffuser exit/throat area ratio		2.15
Diffuser exit radius, in.		6.018
Length to inlet radius ratio		11.5
Included cone angle, deg		4.6
Inlet Mach number		1.00
Exit Mach number		0.35
Static pressure recovery coefficient		0.70
Total pressure drop, %		6.6

PERFORMANCE

The compressor performance was computed by means of the performance prediction calculation CCP.

In actual compressor rig operation, overall performance was measured at the diffuser exit. Design Mach number was 0.35. A conservative static pressure recovery of 0.30 was used as an assessment of probable collector and diffusion loss to a Mach number of 0.15. Performance numbers were quoted both at diffuser exit and after allowing for the previously mentioned loss for further diffusion.

The performance details are given in Table 4; the pressure ratio shown is the originally computed value of 8.3 at an efficiency of 0.807 (total-to-total at a Mach number of 0.15) and a flow rate of 4.2 lbm/sec. Later computations with a different slip factor formulation slightly modified these original design numbers to a pressure ratio of 8.5 and an efficiency of 0.805 at a Mach number of 0.15. These modified design numbers are those quoted in the proposal which led to the contract work reported herein.

TABLE 4. DESIGN PERFORMANCE.

	<u>Original design value</u>		<u>Value quoted in contract (Table 9)</u>	
Flow rate, lbm/sec	4.2		4.2	
Shaft speed, rpm	56,000		56,000	
Specific speed	85		85	
Pressure ratio and efficiency developed	<u>R_c</u>	<u>η</u>	<u>R_c</u>	<u>η</u>
Impeller exit	9.67	0.884	9.777	0.8895
Diffuser leading edge	9.30	0.864	9.54	0.869
Diffuser exit	8.68	0.829	8.857	0.825
Adjusted to Mach number = 0.15	8.32	0.807	8.5	0.805

MECHANICAL DESIGN

The mechanical design effort consisted of that required to validate the integrity of the new parts and to adapt the new design to the existing rig. Thus, certain parts were new as necessary for dimensional adaptation. The major design effort, however, was the stress and vibration analysis and accommodation of results into the rotating parts.

The rig layout may be seen in Figure 17. Air is taken from a 30-in. -diameter inlet plenum by an inlet bell. Between the inlet bell and the impeller, inlet guide vanes are cantilever mounted from the outer wall. The inlet guide vanes are adjustable in angle. The inlet bell structure contains four struts supporting an inner body and results in an annular flow path forward of the impeller. This construction was used to provide a location for installing a shaft-driven strain gage signal transfer device. This provides the structural capability for acquiring stress and vibration data from the impeller, should it appear necessary.

The inlet ducting as previously discussed is unmodified from the RC-1 for the new design, except for an adaptor that fills in a gap in the hub flow path.

The impeller is, of course, a new design. The covering shroud also is new. The existing RC-1 shroud could have been reworked to accommodate the new impeller, but it was retained to continue testing the RC-1 design. The diffuser also is a new design. The diffuser and shroud are mounted on the main support, which is unchanged except for minor rework.

As on the RC-1, the shaft is integral with the impeller. Detailed rotor dynamic analysis of the system showed that use of the existing bearings and bearing support system would produce excessive radial excursions of the coupling end of the shaft at the new design speed. To avoid this, that end of the shaft required a larger diameter, which, in turn, forced the use of a larger diameter bearing. Thus, a new bearing housing was required.

The rotor dynamic analysis is reported by R. Trent.¹³ The report states that, while vibratory response is expected to be within acceptable limits, a soft mount for the front bearing should be considered. Therefore, sufficient design effort was accomplished to ensure that the initial hardware could be reworked to provide controlled mount flexibility in the event it should be required.

The impeller design was subjected to a vibration analysis as reported by L. Burns.¹⁴ Natural frequencies of the primary vane, splitter vane, and wheel were computed. Certain potential vibratory modes were identified. However, it is believed that excitation forces for these points do not exist to sufficient degree to warrant concern.

A stress analysis was made on the titanium impeller, and reported by M. Clute.¹⁵ Stresses were computed and are quoted at 7% overspeed. Maximum steady-state stress in the vanes of 54,000 psi occurs in the inducer section of the primary vane. A value of 52,000 psi occurs at an intermediate meridional position on the primary vane. Splitter vane stresses do not exceed these values. No significant level of stress was computed in the region of the back-curved tip section.

With an assumed 15,000-psi vibratory stress for 10^7 cycles, this titanium material can sustain a steady-state load of 76,000 psi.

The maximum wheel stress, 74,000 psi, occurs at the rear face near the hub. The wheel has no bore. The ultimate tensile strength of the material at 200°F is 119,000 psi.

¹³Trent, R. Dynamic Analysis RC-2 Compressor Rotor Case System. Engineering Department Report TDR AX.0220-016, Detroit Diesel Allison Division, General Motors. June 1972.

¹⁴Burns, L. Vibration Analysis of the RC-2 Impeller. Engineering Department Report TDR AX.0201-037, Detroit Diesel Allison Division, General Motors. July 1972.

¹⁵Clute, M. Stress Analysis of the RC-2 Impeller. Engineering Department Report TDR AX.0201-036, Detroit Diesel Allison Division, General Motors. July 1972.

Figure 17. Compressor rig layout.

A

Figure 17. Compressor rig layout.

B

C

These wheel and blade stresses were arrived at with an anticipated thermal pattern imposed as reported by Colborn.¹⁶ Final wheel stress values are given in Figures 18 and 19.

Figure 18. RC-2 impeller radial stress.

Figure 19. RC-2 impeller tangential stress.

¹⁶Colborn, J. H. Temperature Distributions in the RC-2 Impeller. Engineering Department Report TDR AX.0201-035, Detroit Diesel Allison Division, General Motors. May 1972.

III. COMPRESSOR TESTS

The RC-2 compressor was tested and modified to determine the degree of validity of the performance analysis previously described. The first, or baseline, test was run with the compressor "as designed," and at two inlet guide vane settings other than the design setting. This build of the compressor is designated RC-2.5. RC-2.1 through RC-2.4 were short rig mechanical check runs necessitated by initial rotor whip and vibration difficulties. Instrumentation checks were also obtained during these tests. The tests resulted in the addition of six rear bearing stiffening struts.

The second test, RC-2.6, was run with the inlet guide vanes twisted $+8$ deg at the hub and -8 deg at the tip, and with the diffuser plated so as to decrease the throat area by 4%. These compressor modifications were made as a result of the analysis of the RC-2.5 data, which indicated:

- Impeller exit hub-to-shroud total pressure and angle profiles were weak on the shroud side.
- Inducer was starting to choke earlier than the diffuser at design speed.

The third test, RC-2.7, was run with the RC-2.6 hardware, except that the impeller tip diameter was reduced by 7.5%, so the exducer was essentially radial rather than bent back. The radial space between the impeller tip and the original diffuser was reworked to result in a constant-width vaneless space up to the original vaneless space inlet (see Figure 20). This impeller modification was suggested by the very rapid blade curvature in the original exducer design, which apparently resulted in a deviation of the airflow from the blade pressure surface, as evidenced in RC-2.5 and RC-2.6 by the higher than predicted work output of the rotor.

Figure 20. RC-2.7 configuration.

INSTRUMENTATION

The compressor was instrumented in such a manner that the intrastage losses could be deduced as accurately as possible. Additional instrumentation was added as the test program progressed and certain areas of concern emerged.

RC-2.5 Instrumentation

Inlet Station

The compressor's inlet total temperature and pressure were measured upstream of the inlet in a large (36-in.-diameter) plenum. The instrumentation consisted of four static pressure taps and four total temperature probes.

Inducer Inlet

Three static pressure taps were distributed circumferentially at each of the following locations:

- On the shroud, before the inlet guide vanes
- On the hub, before the inlet guide vanes
- On the shroud, after the inlet guide vanes
- On the hub, after the inlet guide vanes

In addition, a six-element boundary layer rake was located on the hub behind the inlet guide vanes.

Impeller Shroud

Two rows of eleven static pressure taps each were distributed along the impeller cover. The two rows were separated circumferentially by 125 deg. Three additional taps were distributed circumferentially at the radius of the last pressure tap of the two rows.

Vaneless Space

The vaneless space instrumentation included:

- Eleven static pressure taps were distributed along the presumed flow path from the impeller tip to the diffuser throat, on each of the hub and shroud sides of the diffuser.
- Four static pressure taps were distributed circumferentially to span one diffuser passage at a radius 3% outboard of the original impeller tip radius, on each of the hub and shroud sides of the diffuser.
- Four static pressure taps were distributed circumferentially to span one diffuser passage at a radius 7.7% outboard of the original impeller tip radius (the "tangency" radius of the pipe diffuser), on each of the hub and shroud sides of the diffuser.

- Three total pressure probes were imbedded in the leading edge of the diffuser, one at the apex of the leading edge, and one on either side of the apex. The apex total pressure probe consistently read a value lower than the maximum diffuser outlet total pressure, thus indicating that this probe was operating at some significant incidence to the flow, so this pressure was discounted.

Diffuser Inlet Throat

Seven static pressure taps were located in the throat of the diffuser. The taps were located 45 deg apart around the circular throat, as shown in Figure 21.

In addition, a static pressure tap was located 0.10 in. ahead of and 0.10 in. behind the throat on the shroud side of the diffuser.

Diffuser Passage

One static pressure tap was located on each of the hub and shroud sidewalls of the diffuser, one-half the distance between the diffuser's throat and exit plane.

Diffuser Exit Plane

Three static pressure taps were located at the diffuser outlet: one on the pressure surface, one on the hub side, and one on the shroud side of the diffuser.

Two 3-element and two 2-element total pressure rakes were located at the diffuser exit. The location of the diffuser exit instrumentation is shown in Figure 22.

Figure 21. Throat pressure taps.

x Total pressures (or temperatures)

• Static

Note: Each passage contains only two or three probes: Pattern shown is a superposition of all the instrumentation in one passage.

Figure 22. Diffuser exit plane instrumentation.

An identical arrangement with thermocouples instead of pressure rakes was also included at the diffuser exit. No more than one of the rakes was positioned at any diffuser passage exit. Thus there were rakes positioned behind eight of the twenty-seven diffuser passages.

Collector Outlet

Three 3-element thermocouple rakes were located at the collector outlet in the pattern indicated in Figure 23.

Impeller Outlet Traverse Data

Two specially designed total pressure probes were used to traverse the vaneless space at a radius 7.7% outboard of the impeller tip radius (i. e., at the diffuser "tangency" radius). These probes were located 180 deg apart, so they were one-half passage apart with respect to a diffuser passage. The probes were steel cylinders of 0.032 in. dia, with a single 0.007-in. -dia sensing hole. These probes were yawed at each axial traverse station until the maximum pressure reading was obtained and recorded. The probes were then yawed in one direction until a suitable lower pressure was obtained, and this yaw angle was recorded. The probes were then rotated in the opposite direction until this last pressure was duplicated, and the angle was recorded again. The measured flow angle was taken to be the average of the two last recorded angles. However, the angle level was modified in the data reduction program to match continuity, thus accounting for zero point calibration errors and circumferential angle variations. In addition, two special thermocouple probes were subsequently substituted for these pressure

Figure 23. Collector outlet instrumentation.

probes and used to obtain the flow total temperature distribution at the same two locations as the total pressure traverses. These temperature probes consisted of steel cylinders of 0.032 in. outer diameter, with two 0.015-in. -dia holes 17 deg apart and axially displaced by 0.032 in. A thermocouple was located halfway between these two holes. The thermocouple was formed by laser-welding two 0.001-in. -dia wires (iron and constantan) together. No attempt was made to modify the readings of these probes for recovery factor and wire correction effects. The traverse data were deleted from the 17-deg inlet guide vane test of RC-2.5 for economic reasons.

RC-2.6 Instrumentation

The RC-2.6 compressor test included all the instrumentation described for the RC-2.5 test, except that no temperature traverses were obtained.

RC-2.7 Instrumentation

The RC-2.7 compressor test included all the instrumentation described for the RC-2.5 test, except that no temperature traverses were obtained.

Additional instrumentation was provided the compressor for this test in the region of the impeller tip, the diffuser throat, and the collector exit as follows:

- The impeller tip additional instrumentation consisted of five static pressure taps distributed circumferentially to span one diffuser passage (i.e., 13.33 deg) at the new impeller outlet radius of 3.91 in.
- The diffuser inlet throat additional instrumentation consisted of:
 - Seven static pressure taps 0.08 in. apart, with the center one at the throat and the others along the pipe centerline on the shroud side
 - Four static pressure taps duplicating the one 0.08 in. upstream of the throat in four other passages
 - Three special removable total pressure probes located 0.05 in. behind the throat along the pipe centerline. These total pressure probes were removable and could be replaced by "blanks" (see Figure 24).
- The added instrumentation at the collector exit consisted of a single total pressure probe and a single static pressure tap.

Figure 24. Removable throat total pressure probe (left).

Performance Measurements

The compressor's performance was defined in terms of airflow rate, pressure ratio, speed, and efficiency. The compressor performance is shown later.

The airflow rate was measured by means of an ASME square-edge orifice plate and was corrected to standard conditions. This orifice meter was calibrated and shown to conform to the ASME standards¹⁷ and had an accuracy of $\pm 1/2\%$ of the flow.

The compressor's pressure ratio was the ratio of the arithmetic average of the measured diffuser exit total pressure to the arithmetic average of the measured inlet pressure. This measurement has an accuracy of better than $\pm 1/4\%$. The quoted compressor efficiency was the true adiabatic efficiency (i.e., calculated from the enthalpy tables rather than using a constant specific heat ratio). The efficiency calculated using a constant $\gamma = 1.4$ would be higher than the true value by about 1% at a pressure ratio of 8:1.

$$\begin{aligned}\eta_{\text{adiabatic}} &= \frac{(H_2 - H_1)_{\text{ideal}}}{(H_2 - H_1)_{\text{actual}}} \\ &= \frac{H_{2 \text{ ideal}} - H_1}{H_{2 \text{ actual}} - H_1}\end{aligned}$$

The ideal enthalpy rise $H_{2 \text{ ideal}} - H_1$ was obtained for the achieved pressure ratio from the gas tables in Reference 18; the actual enthalpy rise $H_{2 \text{ actual}} - H_1$ was obtained from the measured arithmetic average temperatures at the inlet and the collector outlet. To ensure that no heat was lost between the diffuser exit and the collector exit, the entire compressor was wrapped in fiberglass insulation. The diffuser exit temperatures were not used to calculate efficiencies because of the large and varied thermocouple recovery corrections required at the diffuser exit, where the transverse Mach number gradients are very large. However, the corrected temperature measurements taken at the diffuser exit do in fact agree fairly closely with those taken at the collector exit.

The accuracy of the efficiency measurement is approximately $\pm 1/2\%$ at design speed.

The speed of rotation at the compressor is measured by a digital tachometer mounted on the control panel in the test stand. The accuracy of this instrument is better than $\pm 1/10$ of 1% of the reading.

¹⁷ Flow Measurement. ASME Power Test Code Committee, ASME, New York. 1959.

¹⁸ Keenan, J. H., and Kaye, J. Gas Tables. John Wiley and Sons, Inc., New York. 1961.

RC-2.5 BASELINE TEST

The RC-2.5 compressor was tested for performance with 17, 25, and 33 deg inlet guide vane settings. Yaw/pressure and yaw/temperature traverses of the impeller outlet flow were performed at the 25 and 33 deg inlet guide vane settings. These traverses could be executed for choked flow conditions only, as the compressor surged prematurely with the probes installed. The impeller and diffuser are shown in Figures 25 and 26.

Figure 25. RC-2 impeller (RC-2.5 and RC-2.6 configuration).

Figure 26. RC-2 diffuser.

The test period was 24 September 1973 to 4 October 1973. The reading numbers were 266 to 460. A configuration summary follows:

<u>Configuration</u>	<u>Baseline RC-2.5 ("as designed")</u>
Impeller	P/N EX-106488
Diffuser	P/N EX-106583 27 Pipe
IGV assy	P/N EX-99257
Collector	P/N EX-99270
Cover	P/N EX-106582
Impeller tip	Cold clearance: 0.035 in.

Compressor Performance Data

Compressor performance maps for each of the three inlet guide vane settings are presented in Figures 27 through 35. The efficiency and pressure ratio plotted in these figures are based on total pressure measurements at the diffuser exit and total temperature measurements at the collector exit.

Figure 27. RC-2.5 performance—25 deg IGV setting.

Figure 28. RC-2.5 performance—25 deg IGV setting.

Figure 29. RC-2.5 performance—25 deg IGV setting.

Figure 30. RC-2.5 performance—33 deg IGV setting.

Figure 31. RC-2.5 performance—33 deg IGV setting.

Figure 32. RC-2.5 performance—33 deg IGV setting.

Figure 33. RC-2.5 performance—17 deg IGV setting.

Figure 34. RC-2.5 performance—17 deg IGV setting.

Figure 35. RC-2.5 performance—17 deg IGV setting.

Impeller Outlet Flow Distribution Data

Two traversing yaw/pressure probes were installed after the completion of the performance tests at 25 and 33 deg inlet guide vane settings. Five traverse points were taken between the hub and the shroud of the compressor, and both the flow total pressure and angle were obtained. The traverse data were obtained for a choked flow condition only because the presence of the probes was found to cause the compressor to surge as soon as the flow decreased from its choke value. Inasmuch as these probes did affect the compressor performance, all performance data were obtained prior to installation of these probes.

Following these pressure surveys, the two temperature probes were installed in the place of the pressure probes and the traverse was repeated.

Figures 36 through 40 show the impeller outlet total pressure distribution, total temperature distribution, and a typical flow angle distribution for both the 25 and 33 deg IGV settings.

Figure 36. Total pressure distribution at impeller discharge, inlet guide vane setting 25 deg.

Figure 37. Total pressure distribution at impeller discharge, inlet guide vane setting 33 deg.

Figure 38. Total temperature distribution at impeller discharge, inlet guide vane setting 25 deg.

Figure 39. Total temperature distribution at impeller discharge, inlet guide vane setting 33 deg.

Figure 40. Typical flow angle distribution at impeller discharge (90% corrected speed).

Table 6 is a reduction of the yaw/pressure traverse data obtained by the Traverse Data Reduction program. The nomenclature for this computer output is defined in Table 5.

**TABLE 5. TRAVERSE DATA REDUCTION PROGRAM NOMENCLATURE
FOR TABLES 6, 7, AND 8.**

1st Line: Title

Lines 3-14: Input data obtained from the RC-2.5 run numbers identified in the title

Lines 17-21: Total pressure at probe 1 (PT1), psia; axial traverse location (Z1), in.; flow angle at probe 1 (ALPH1), deg.; total pressure at probe 2 (PT2), psia; axial traverse location (Z2), in.; and flow angle at probe 2 (ALPH2), deg

Note: Probe 1 is identified as INLET STATION PROBE, and probe 2 as LEADING EDGE STATION PROBE.

Line 24: Iteration Count (I)

Averaged total pressure at probe 1 (PT1B)

Averaged flow angle at probe 1 (ALP1)

Averaged static pressure at tangency circle, from first reading number (Choke) (P1)

Averaged Mach number at probe 1 (M1)

Averaged Mach number at diffuser exit, from second reading number (break point) (M2)

Static Pressure Recovery from probe 1 to diffuser exit
($CP = (P2 - P1) / (PT1 - P1)$)

Line 26: Averaged total pressure at diffuser exit, from second reading number (break point) (PT2B)

Diffuser exit blockage, as fraction of diffuser exit area (BLOCK)

Airflow corrected to conditions at probe 1 (WAC)

Actual to theoretical flow rate ratio at choke,

$$W/WMAX = WA / (.532 A^* PT1 \sqrt{T T1})$$

where A^* is the diffuser throat area, and $TT1$ is the total temperature

Total pressure loss $DPT/PT1 = (PT1B - PT2B) / PT1B$

Diffuser exit static pressure from second reading number (break point) (P2)

Airflow rate, lbm/sec (WA)

Ratio of diffuser throat area to normal flow area at probe 1 ($A^*/A1$)

Line 29: Same as line 24, except that probe 2 replaces probe 1, and the static pressure P1 is obtained from the second (break point) reading number.

Line 31: Same as line 26, except that probe 2 replaces probe 1.

TABLE 6. YAW/PRESSURE DATA REDUCTION—RC-2.5.

RC2.5, 25 DEG IGV, 70 PRCNT SPD, INPUT DATA FOLLOWS				RDG 331, AND BREAK PT RDG 279			
5	31.7610	29.4510	31.5920	32.6700	45.4000	829.0001	1.9850
	31.4530	29.4510	31.7150	32.6930			
215.4000	55.3000	261.3000	101.4000				
0.0000	47.0000	201.0000	409.0000	0.0000	50.0000	247.0000	338.0000
0.0000	52.4000	169.0000	478.0000	0.0000	56.5000	217.0000	414.0000
0.0000	55.0000	136.0000	513.0001	0.0000	59.5000	187.0000	527.0001
0.0000	56.3000	102.0000	539.0001	0.0000	60.2000	153.0000	490.0000
0.0000	51.0000	64.0000	533.0001	0.0000	54.0000	110.0000	493.0000
52.1000	0.1770	52.8000	0.3541	53.2000	0.3541	51.1300	0.3541
49.6300	0.3541	52.3000	0.7082	48.3000	0.7082	48.6000	0.7082
48.8000	0.7082						
0.0000	0.0000	0.0000	0.0000				
INLET STATION PROBE				LEADING EDGE STATION PROBE			
PT1	Z1	ALPH1		PTLE	ZLE	ALPHLE	
47.0000	0.0280	-10.9799		50.0000	0.0278	-26.2799	
52.4000	0.0904	1.4400		56.5000	0.0863	-12.5999	
55.0000	0.1548	7.7399		59.5000	0.1448	7.7399	
56.3000	0.2211	12.4200		60.2000	0.2111	1.0799	
51.0000	0.2952	11.3400		54.0000	0.2950	1.6199	

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
5	54.0470	12.9318	31.3540	0.9174	0.3989	0.6189	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
50.6621	0.2413	0.6829	0.9598	0.0626	45.4000	1.9850	1.0361

LEADING EDGE DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
7	58.8421	11.7908	31.3119	0.9937	0.3989	0.5117	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
50.6621	0.2413	0.6273	0.8816	0.1390	45.4000	1.9850	1.1347

RC 2.5, 25 DEG IGV, 85 PRCNT SPD, CHOKE RDG 334, AND BREAK PT RDG 312

INPUT DATA FOLLOWS							
5	44.9400	38.6100	43.1400	47.2900	72.1000	960.2000	2.9460
	44.2000	37.8000	43.4000	47.0000			
215.4000	55.3000	261.3000	101.4000				
0.0000	77.0000	201.0000	419.0000	0.0000	77.5000	247.0000	355.0000
0.0000	85.5000	169.0000	476.0000	0.0000	87.8000	217.0000	441.0000
0.0000	91.2000	136.0000	515.0001	0.0000	92.5000	187.0000	476.0000
0.0000	93.4000	102.0000	552.0001	0.0000	93.0000	153.0000	486.0000
0.0000	81.5000	64.0000	546.0001	0.0000	78.0000	110.0000	491.0000
83.3000	0.1770	84.6000	0.3541	84.7000	0.3541	81.3000	0.3541
79.8000	0.3541	83.1000	0.7082	76.5000	0.7082	74.3000	0.7082
78.1000	0.7082						
0.0000	0.0000	0.0000	0.0000				
INLET STATION PROBE				LEADING EDGE STATION PROBE			
PT1	Z1	ALPH1		PTLE	ZLE	ALPHLE	
77.0000	0.0280	-10.7999		77.5000	0.0278	-23.2199	
85.5000	0.0904	1.0799		87.8000	0.0863	-7.7399	
91.2000	0.1548	8.1000		92.5000	0.1448	-1.4400	
93.4000	0.2211	14.7599		93.0000	0.2111	0.3600	
81.5000	0.2952	13.6799		78.0000	0.2950	1.2599	

TABLE 6. (CONT)

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
5	88.6841	12.6809	39.15	1.1325	0.4031	0.6601	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
80.6411	0.2452	0.6648	0.9341	0.0906	72.1000	2.9460	1.0562

LEADING EDGE DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
7	88.5079	12.5859	42.8624	1.0728	0.4031	0.6405	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
80.6411	0.2452	0.6661	0.9361	0.0888	72.1000	2.9460	1.0641

RC 2.5 25 DEG IGV.90 PRCNT SPD, CHOKE RDG 343, AND BREAK PT RDG 292
INPUT DATA FOLLOWS

5	48.4400	42.0000	46.2500	52.8000	74.4000	1001.6000	3.2780
	49.7000	42.2000	46.4000	52.8000			
21	0.0000	55.3000	261.0000	101.4000			
	0.0000	92.0000	201.0000	396.0000	0.0000	86.5000	247.0000
	0.0000	103.0000	169.0000	474.0000	0.0000	96.2000	217.0000
	0.0000	109.0000	136.0000	521.0001	0.0000	101.5000	187.0000
	0.0000	110.0000	102.0000	560.0001	0.0000	100.8000	153.0000
	0.0000	97.8000	64.0000	551.0001	0.0000	85.0000	110.0000
90	90.9000	0.1770	91.9000	0.3541	90.1000	0.3541	88.6000
86	86.5000	0.3541	86.5000	0.7082	79.8000	0.7082	81.3000
84	84.1000	0.7082					0.3541
	0.0000	0.0000	0.0000	0.0000			0.7082

INLET STATION PROBE

PT1	Z1	ALPH1
92.0000	0.0273	-13.3199
103.0000	0.0896	0.7200
109.0000	0.1540	9.1800
110.0000	0.2203	16.2000
97.8000	0.2944	14.5799

LEADING EDGE STATION PROBE

PTLE	ZLE	ALPHLE
86.5000	0.0273	-18.7200
96.2000	0.0858	-8.2800
101.5000	0.1443	-2.1599
100.8000	0.2106	1.6199
85.0000	0.2944	-1.7999

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
6	106.2073	12.0551	47.0055	1.1450	0.4598	0.4627	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
86.0063	0.2746	0.6308	0.8866	0.1902	74.4000	3.2780	1.1102

LEADING EDGE DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
6	96.1033	13.1589	47.5557	1.0550	0.4598	0.5529	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
86.0063	0.2746	0.6972	0.9798	0.1050	74.4000	3.2780	1.0185

TABLE 6. (CONT)

RC295 25 DEG IGV, 100 PRCNT SPD, CHOKE RDG 339, AND BREAK PT RDG 301

INPUT DATA FOLLOWS

5	58.8000	50.2000	54.6000	55.3000	101.0000	1102.8501	3.8730
	59.4000	50.0000	54.6000	56.3000			
	215.0000	55.3000	261.0000	101.4000			
	109.0000	109.0000	201.0000	408.0000	0.0000	110.0000	247.0000 323.0000
	109.0000	123.0000	169.0000	518.0001	0.0000	123.0000	217.0000 448.0000
	0.0000	132.0000	136.0000	563.0001	0.0000	131.0000	187.0000 527.0001
	0.0000	136.0000	102.0000	565.0001	0.0000	131.0000	153.0000 563.0001
	0.0000	114.0000	64.0000	500.0000	0.0000	110.0000	110.0000 460.0000
	116.4000	0.1770	121.4000	0.3541	118.2000	0.3541	113.1000 0.3541
	113.1000	0.3541	120.3000	0.7082	106.2000	0.7082	106.0000 0.7082
	110.7000	0.7082					
	0.0000	0.0000	0.0000	0.0000			

INLET STATION PROBE

LEADING EDGE STATION PROBE

PT1	Z1	ALPH1	PTLE	ZLE	ALPHLE
109.0000	0.0273	-11.1599	110.0000	0.0273	-28.9799
123.0000	0.0896	8.6399	123.0000	0.0858	-6.4799
132.0000	0.1540	16.7400	131.0000	0.1443	7.7399
136.0000	0.2203	17.0999	131.0000	0.2106	14.2199
114.0000	0.2944	5.3999	110.0000	0.2944	-4.3199

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP
6	129.8408	12.3485	54.5900	1.1851	0.4240	0.6167

PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
114.2947	0.2794	0.6398	0.8991	0.1197	101.0000	3.8730	1.0842

LEADING EDGE DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP
8	128.3320	12.3989	56.1546	1.1540	0.4240	0.6213

PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
114.2947	0.2794	0.6473	0.9097	0.1093	101.0000	3.8730	1.0799

RC2,5, 33 DEG IGV, 70 PRCNT SPD, CHOKE RDG 394, AND BREAK PT RDG 360

INPUT DATA FOLLOWS

5	31.4800	29.4900	30.6900	32.5900	44.6000	817.1000	2.0230
	31.5700	29.4900	31.5300	32.6000			
	215.4000	55.3000	261.3000	101.4000			
	0.0000	49.0000	201.0000	438.0000	0.0000	44.0000	247.0000 353.0000
	0.0000	53.0000	169.0000	483.0000	0.0000	52.5000	217.0000 477.0000
	0.0000	56.0000	136.0000	523.0001	0.0000	55.0000	187.0000 513.0001
	0.0000	56.5000	102.0000	543.0001	0.0000	56.0000	152.0000 535.0001
	0.0000	50.0000	64.0000	507.0000	0.0000	51.0000	110.0000 518.0001
	51.8500	0.1770	52.8200	0.3541	53.2000	0.3541	50.9000 0.3541
	49.1000	0.3541	51.8000	0.7082	47.8000	0.7082	46.1000 0.7082
	44.4000	0.7082					
	0.0000	0.0000	0.0000	0.0000			

INLET STATION PROBE

LEADING EDGE STATION PROBE

PT1	Z1	ALPH1	PTLE	ZLE	ALPHLE
49.0000	0.0280	-5.7600	44.0000	0.0278	-23.5799
53.0000	0.0504	2.3400	52.5000	0.0863	-1.2599
56.0000	0.1548	9.5399	55.0000	0.1448	5.2200
56.5000	0.2211	13.1399	56.0000	0.2111	9.1800
50.0000	0.2952	6.6599	51.0000	0.2950	6.1199

TABLE 6. (CONT)
INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
5	54.0933	13.0580	31.0494	0.9270	0.4263	0.5880	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
50.5370	0.2704	0.6904	0.9703	0.0657	44.6000	2.0230	1.0262

LEADING EDGE DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
8	54.7472	12.8926	31.2827	0.9311	0.4263	0.5675	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
50.5370	0.2704	0.6822	0.9587	0.0769	44.6000	2.0230	1.0392

RC 2.5, 33 DEG IGV, 80 PRCT SPD, CHOKE RDG 398 AND BREAK PT RDG 366

INPUT DATA FOLLOWS

5	38.8000	34.3000	38.3000	41.0000	58.2000	900.0001	2.5700
	38.9000	34.5000	38.7000	41.2000			
215.4000	55.3000	261.3000	101.4000				
0.0000	67.0000	201.0000	459.0000	0.0000	66.0000	247.0000	413.0000
0.0000	74.0000	169.0000	486.0000	0.0000	76.0000	217.0000	470.0000
0.0000	77.0000	136.0000	521.0001	0.0000	80.5000	187.0000	509.0000
0.0000	76.8000	102.0000	542.0001	0.0000	80.7000	153.0000	524.0001
0.0000	57.0000	64.0000	435.0000	0.0000	71.5000	110.0000	523.0001
69.6000	0.1770	70.6000	0.3541	70.6000	0.3541	67.8000	0.3541
65.5000	0.3541	67.8000	0.7082	62.6000	0.7082	59.9000	0.7082
60.1000	0.7082						
0.0000	0.0000	0.0000	0.0000				

INLET STATION PROBE

PT1	Z1	ALPH1
67.0000	0.0280	-1.9799
74.0000	0.0904	2.8800
77.0000	0.1548	9.1800
76.8000	0.2211	12.9599
57.0000	0.2952	-6.2999

LEADING EDGE STATION PROBE

PTLE	ZLE	ALPHLE
66.0000	0.0278	-12.7799
76.0000	0.0863	-2.5199
80.5000	0.1448	4.5000
80.0000	0.2111	7.1999
71.5000	0.2950	7.0199

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
5	73.0926	12.8229	38.0190	1.0132	0.4338	0.5753	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
66.2359	0.2679	0.6812	0.9574	0.0938	58.2000	2.5700	1.0447

LEADING EDGE DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
8	77.1701	12.1620	38.2377	1.0539	0.4338	0.5127	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
66.2359	0.2679	0.6452	0.9068	0.1416	58.2000	2.5700	1.1006

RC2.5 33 DEG IGV, 90 PERCENT SPD, CHOKE, RDG 401

INPUT DATA FOLLOWS

5	47.0650	40.0800	43.7770	50.3840	50.0000	994.0001	3.1690
	46.5760	40.0800	44.7160	51.1070			
215.4000	55.3000	261.3000	101.4000				
0.0000	87.0000	247.0000	395.0000	0.0000	84.0000	201.0000	404.0000
0.0000	94.0000	217.0000	460.0000	0.0000	96.0000	169.0000	464.0000
0.0000	100.0000	187.0000	503.0000	0.0000	103.0000	136.0000	510.0000

TABLE 6. (CONT)

0.0000	98.0000	153.0000	531.0001	0.0000	104.0000	102.0000	529.0001
0.0000	91.0000	110.0000	472.0000	0.0000	91.0000	64.0000	510.0000
84.5000	0.1770	85.7860	0.3541	83.2830	0.3541	82.1680	0.3514
80.1100	0.3541	76.0660	0.7082	73.5250	0.7082	69.2790	0.7082
76.2050	0.7082						
0.0000	0.0000	0.0000	0.0000				

INLET STATION PROBE

LEADING EDGE STATION PROBE

PT1	Z1	ALPH1	PTLE	ZLE	ALPHLE
87.0000	-0.0616	-13.5000	84.0000	0.1175	-14.3999
94.0000	-0.0031	-1.799	96.0000	0.1799	-3.5999
100.0000	0.0553	5.9399	103.0000	0.2443	4.6800
98.0000	0.1216	10.9799	104.0000	0.3106	8.1000
91.0000	0.2055	0.3600	91.0000	0.3847	4.6800

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
4	95.5370	12.8065	44.8928	1.0973	0.8175	0.1008	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
77.5662	0.4394	0.6754	0.9492	0.1881	50.0000	3.1690	1.0461

LEADING EDGE DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
7	101.4961	12.1301	45.3663	1.1372	0.8175	0.0825	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
77.5662	0.4394	0.6357	0.8935	0.2357	50.0000	3.1690	1.1034

RC2.5 33 DEG IGV, 100 PRCT SPD, RDG 404-CHOKE, AND 389 -BREAK PT

INPUT DATA FOLLOWS

5	53.1000	46.6400	49.4900	54.0000	96.6000	1097.2001	3.6490
	0.0000	0.0000	0.0000	0.0000			
215.0000	55.3000	261.0000	101.4000				
	0.0000	103.0000	201.0000	389.0000	0.0000	0.0000	0.0000
	0.0000	118.0000	169.0000	457.0000	0.0000	0.0000	0.0000
	0.0000	128.0000	136.0000	555.0001	0.0000	0.0000	0.0000
	0.0000	130.0000	102.0000	534.0001	0.0000	0.0000	0.0000
	0.0000	108.0000	64.0000	511.0000	0.0000	0.0000	0.0000
111.2000	0.1770	115.4000	0.3541	111.0000	0.3541	107.7000	0.3541
108.5000	0.3541	114.8000	0.7082	101.4000	0.7082	101.1000	0.7082
105.4000	0.7082						
0.0000	0.0000	0.0000	0.0000				

INLET STATION PROBE

LEADING EDGE STATION PROBE

PT1	Z1	ALPH1	PTLE	ZLE	ALPHLE
103.0000	0.0273	-14.5799	0.0000	0.5089	-87.1199
118.0000	0.0896	-2.3400	0.0000	0.5089	-87.1199
128.0000	0.1540	15.2999	0.0000	0.5089	-87.1199
130.0000	0.2203	11.5200	0.0000	0.5089	-87.1199
108.0000	0.2944	7.3799	0.0000	0.5089	-87.1199

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
5	124.4537	12.2121	50.2532	1.2160	0.4166	0.6246	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
108.8595	0.2791	0.6272	0.8815	0.1253	96.6000	3.6490	1.0961

The progression of the flow from the tangency circle to the diffuser leading edge was calculated by the Radial Vaneless Space program. The flow angle and Mach number variation with radius calculated by this program for the 100% speed data at 25 deg inlet guide vane setting are shown in Figure 41. These curves show that the diffuser is operating at approximately one deg of incidence even in this choke flow condition. The calculated total pressure loss in the vaneless space agrees closely with the loss indicated by the difference in total pressure measurements between the traverse station and the diffuser leading edge.

Rig Mechanical Operation

The mechanical operation of the compressor rig itself was uneventful. However, vibrations in the steam turbine drive train were great enough to prohibit running in the neighborhood of 95% speed.

Six compressor rear bearing support struts were added for this build, with a view to reducing the vibration levels previously recorded on the RC-1 and RC-2 rigs. This configuration exhibited maximum rear bearing vibration levels of 2.25 in./sec compared to 3.6 in./sec in the previous build (RC-2.2). Rotor whip did not exceed 6 mils.

Figure 41. Distribution of Mach number and flow angle in vaneless diffuser.

RC-2.6 FIRST MODIFICATION TEST

The RC-2.6 compressor was modified from the original design by twisting the inlet guide vanes +8 deg at the hub and -8 deg at the tip, and plating the diffuser flow path 0.003 in. The modified compressor was tested for performance, and then yaw/pressure data was obtained in the manner described in the RC-2.5 Baseline Test Report at the 25 deg IGV setting.

The test period was 29 and 30 January 1974. The reading numbers were 461 to 552. A configuration summary follows:

<u>Configuration</u>	<u>Modified RC-2 compressor</u>
Impeller	P/N EX-106488
Diffuser	P/N EX-106583-1 Plated 27 Pipe
IGV assy	P/N EX-99257-1 Twisted
Collector	P/N EX-99270
Cover	P/N EX-106582
Impeller tip	Cold clearance: 0.035 in.

Compressor Performance Data

The modified compressor performance is shown in Figures 42, 43, and 44. The measuring stations and methods were identical to those described in the RC-2.5 Baseline Test Report. The rig was insulated in the same manner as was RC-2.5.

Impeller Outlet Flow Distribution Data

The two total pressure/yaw probes described in the RC-2.5 Baseline Test subsection were used to obtain traverse data in the manner described previously.

Figures 45 and 46 show, respectively, the impeller outlet total pressure distribution and typical flow angle distributions.

Table 7 is a reduction of the yaw/pressure traverse data obtained by the Traverse Data Reduction program. The nomenclature for this computer output is defined in Table 5.

Rig Mechanical Operation

The mechanical operation of the rig itself was uneventful. However, vibrations in the steam turbine drive train were great enough to prohibit running at 85% speed. Data were obtained at 86% speed since the vibration level there was acceptable.

Figure 42. RC-2.6 performance.

Figure 43. RC-2.6 performance.

Figure 44. RC-2.6 performance.

Figure 45. Impeller outlet total pressure distribution.

Figure 46. Flow angle at impeller discharge.

TABLE 7. YAW/PRESSURE DATA REDUCTION—RC-2.6.

RC 2.6 • 70 PRCNT SPEED RDG 544							
INPUT DATA FOLLOWS							
5	33.1890	31.1980	32.7270	33.1510	42.6075	794.5700	2.0150
	32.8970	31.9950	31.9930	33.1510			
	215.4000	55.3000	261.3000	101.4000			
	0.0000	26.5000	201.0000	494.0000	0.0000	47.1000	247.0000
	0.0000	53.0000	169.0000	501.5000	0.0000	54.0000	217.0000
	0.0000	55.2000	136.0000	572.0001	0.0000	56.1000	187.0000
	0.0000	54.9000	102.0000	580.0001	0.0000	56.1000	153.0000
	0.0000	45.0000	64.0000	525.5001	0.0000	48.0000	110.0000
	51.4500	0.1770	50.7680	0.3541	51.9520	0.3541	49.9850
	48.0160	0.3541	47.9780	0.7082	45.4930	0.7082	43.0430
	46.7530	0.7082					0.7082
	0.0000	0.0000	0.0000	0.0000			
INLET STATION PROBE				LEADING EDGE STATION PROBE			
	PT1	Z1	ALPH1		PTLE	ZLE	ALPHLE
	26.5000	0.0280	4.3199		47.1000	0.0278	-21.2399
	53.0000	0.0904	5.6700		54.0000	0.0863	-11.1599
	55.2000	0.1548	18.3600		56.1000	0.1448	-6.6599
	54.9000	0.2211	19.7999		56.1000	0.2111	-2.3400
	45.0000	0.2952	9.9899		48.0000	0.2950	-10.5299
INLET STATION DATA ON AVERAGE BASIS							
I	PT1B	ALP1	P1	M1	M2	CP	
6	51.7647	13.9223	32.4629	0.8444	0.4304	0.5255	
	PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA
	48.3934	0.2373	0.7086	1.0353	0.0651	42.6075	2.0150
							A*/A1
							0.9451
LEADING EDGE DATA ON AVERAGE BASIS							
I	PT1B	ALP1	P1	M1	M2	CP	
5	53.6357	13.3109	32.5056	0.8770	0.4304	0.4780	
	PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA
	48.3934	0.2373	0.6839	0.9992	0.0977	42.6075	2.0150
							A*/A1
							0.9877

RC 2.6 • 80 PRCNT SPEED • RDG 547							
INPUT DATA FOLLOWS							
5	42.6100	38.6620	41.4680	42.6300	59.3000	873.2200	2.6200
	41.9690	40.0970	39.7520	42.6300			
	215.4000	55.3000	261.3000	101.4000			
	0.0000	37.2000	201.0000	424.0000	0.0000	64.2000	247.0000
	0.0000	75.0000	169.0000	535.0001	0.0000	75.5000	217.0000
	0.0000	77.0000	136.0000	569.0001	0.0000	78.1000	187.0000
	0.0000	75.5000	102.0000	578.0001	0.0000	77.1000	153.0000
	0.0000	59.4000	64.0000	517.5001	0.0000	63.1000	110.0000
	71.0000	0.1770	70.8080	0.3541	72.0900	0.3541	66.9470
	66.4570	0.3541	67.3080	0.7082	63.3810	0.7082	59.5940
	64.9510	0.7082					0.7082
	0.0000	0.0000	0.0000	0.0000			
INLET STATION PROBE				LEADING EDGE STATION PROBE			
	PT1	Z1	ALPH1		PTLE	ZLE	ALPHLE
	37.2000	0.0280	-8.2800		64.2000	0.0278	-24.8400
	75.0000	0.0904	11.6999		75.5000	0.0863	-12.9599
	77.0000	0.1548	17.8199		78.1000	0.1448	-8.4599
	75.5000	0.2211	19.4399		77.1000	0.2111	-4.2299
	59.4000	0.2952	8.5499		63.1000	0.2950	-12.5100

TABLE 7. (CONT)
INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP		
7	73.0763	13.1695	41.1068	0.9451	0.4261	0.5690		
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1	
67.1864	0.2453	0.5842	0.9997	0.0806	59.3000	2.6200	0.9981	

LEADING EDGE DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP		
5	73.7850	13.0306	41.0991	0.9538	0.4261	0.5568		
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1	
67.1864	0.2453	0.6777	0.9901	0.0894	59.3000	2.6200	1.0086	

RC 2.6 , 90 PRCNT SPEED , RDG 550 AND BREAK PT. RDG. 504 CORRECTED
INPUT DATA FOLLOWS

5	53.6290	46.3230	51.3190	53.4890	83.4900	959.6700	3.3220	
	52.9580	49.0670	48.9540	53.4890				
	215.4000	55.3000	261.3000	101.4000				
	0.0000	51.9000	201.0000	442.0000	0.0000	86.4000	247.0000	337.5000
	0.0000	100.5000	169.0000	529.5001	0.0000	100.3000	217.0000	406.5000
	0.0000	102.5000	136.0000	564.5001	0.0000	103.0000	187.0000	434.0000
	0.0000	100.2000	102.0000	588.0001	0.0000	102.2000	153.0000	458.5000
	0.0000	78.9000	64.0000	527.5001	0.0000	86.0000	110.0000	417.0000
	97.8300	0.1770	98.2890	0.3541	97.6800	0.3541	95.2760	0.3541
	93.4100	0.3541	93.9300	0.7082	89.0220	0.7082	84.8800	0.7082
	91.6400	0.7820						
	0.0000	0.0000	0.0000	0.0000				

INLET STATION PROBE

LEADING EDGE STATION PROBE

PT1	Z1	ALPH1		PTLE	ZLE	ALPHLE
51.9000	0.0280	-5.0399		86.4000	0.0278	-26.3699
100.5000	0.0904	10.7099		100.3000	0.0863	-13.9499
102.5000	0.1548	17.0099		103.0000	0.1448	-9.0000
100.2000	0.2211	21.2399		102.2000	0.2111	-4.5900
78.9000	0.2952	10.3500		86.0000	0.2950	-12.0599

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP		
7	96.5595	13.2148	50.7612	1.0041	0.4029	0.7146		
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1	
93.3690	0.2450	0.6883	1.0056	0.0330	83.4900	3.3220	0.9947	

LEADING EDGE DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP		
5	98.1946	12.9926	51.0766	1.0132	0.4029	0.6879		
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1	
93.3690	0.2450	0.6769	0.9889	0.0491	83.4900	3.3220	1.0115	

TABLE 7. (CONT)

RC 2.6 , 100 PRCNT SPEED, RDG. 552 AND BREAK PT RDG 513 CORRECTED							
INPUT DATA FOLLOWS.							
5	63.9940	54.3740	59.1560	56.7090	99.8700	1053.8801	3.9330
	64.1710	58.7210	58.2490	56.7090			
	215.4000	55.3000	261.2000	101.4000			
	0.0000	72.0000	201.0000	479.0000	0.0000	104.0000	247.0000
	0.0000	130.5000	169.0000	523.0001	0.0000	122.5000	217.0000
	0.0000	133.0000	136.0000	593.0001	0.0000	130.5000	187.0000
	0.0000	130.0000	102.0000	589.0001	0.0000	129.0000	153.0000
	0.0000	102.0000	64.0000	508.0000	0.0000	102.5000	110.0000
	120.4000	0.1770	121.6800	0.3541	121.6300	0.3541	116.1800
	115.7200	0.3541	115.4400	0.7082	108.2440	0.7082	105.8700
	113.6900	0.7820					0.7082
	0.0000	0.0000	0.0000	0.0000			
INLET STATION PROBE				LEADING EDGE STATION PROBE			
	PT1	Z1	ALPH1		PTLE	ZLE	ALPHLE
	72.0000	0.0280	1.6199		104.0000	0.0278	-32.0400
	130.5000	0.0904	9.5399		122.5000	0.0863	-16.5600
	133.0000	0.1548	22.1399		130.5000	0.1448	-12.9599
	130.0000	0.2211	21.4199		129.0000	0.2111	-4.5000
	112.0000	0.2952	6.8399		102.5000	0.2950	-14.3999
INLET STATION DATA ON AVERAGE BASIS							
	I	PT1B	ALP1	P1	M1	M2	CP
	7	125.3422	12.7351	58.2386	1.1064	0.4505	0.6204
	PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA
	114.7942	0.3024	0.6579	0.9612	0.0841	99.8700	3.9330
							A*/A1
							1.0216
LEADING EDGE DATA ON AVERAGE BASIS							
	I	PT1B	ALP1	P1	M1	M2	CP
	5	122.8547	12.9376	59.4180	1.0738	0.4505	0.6376
	PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA
	114.7942	0.3024	0.6712	0.9806	0.0656	99.8700	3.9330
							A*/A1
							1.0157

RC-2.7 FINAL TEST

The RC-2.7 compressor was modified from the RC-2.6 configuration by cutting off the outside 7.5% of the rotor (from the original radius of 4.224 in. to the new radius of 3.91 in.). The impeller blade exit angle is now 5 deg from radial at the hub and zero deg (radial) at the shroud, instead of the original 35 deg at the hub and 30 deg at the shroud. The modified impeller is shown in Figure 47. This compressor was tested for performance, and then yaw/pressure data were obtained in the manner described in the RC-2.5 Baseline Test Report.

Figure 47. Modified Impeller—RC-2.7 configuration.

The test period was 4 through 10 April 1974. The reading numbers were 553 to 635. A configuration summary follows.

Configuration — Baseline compressor with the following modifications:

- Diffuser plated as in RC-2.6
 - Inlet guide vanes twisted as in RC-2.6
 - Rotor cut down 7.5% radially
Impeller:	P/N EX-106488-1 Cut down
Diffuser:	P/N EX-106583-1 Plated
IGV assy:	P/N EX-99257-1 Twisted
Collector:	P/N EX-99270
Cover:	P/N EX-106582
Impeller tip:	Cold clearance: 0.022 in.

Compressor Performance Data

The modified compressor performance is shown in Figures 48, 49, and 50. The measuring stations and methods were identical to those described in the RC-2.5 Baseline Test subsection. The rig was insulated in the same manner as were RC-2.5 and RC-2.6.

Figure 48. RC-2.7 performance.

Figure 49. RC-2.7 performance.

Figure 50. RC-2.7 performance.

New Instrumentation

The RC-2.7 compressor test included all the instrumentation described for the RC-2.5 test, except that no temperature traverses were obtained. Additional instrumentation was provided the compressor for this test in the region of the impeller tip, the diffuser throat, and the collector exit as previously discussed under RC-2.7 Instrumentation. The three removable throat total pressure probes were removed after completion of the initial part of the test and were replaced by the "blanks," and the 86% and 100% design speed lines were repeated to check the effect of the probes on the flow. The comparison at 86% speed is not quite straightforward, however, because the impeller rubbed the shroud at 100% speed, thus removing material from the shroud, and increasing the clearance when the 86% speed was repeated as compared to the original clearance. The main effect of the throat probes at 100% speed was to decrease the efficiency by less than 0.3%.

Impeller Outlet Flow Distribution Data

The two total pressure/yaw probes described in the RC-2.5 Baseline Test subsection were used to obtain traverse data in the manner described previously. Because of the reduced impeller radius, these probes were 16.5% outboard of the impeller, instead of 7.7% as in the previous tests.

Some difficulty was experienced in yawing probe 2, so only partial data were obtained with that unit. The problem was caused by a mechanical bind in the actuator mechanism.

Figures 51 and 52 show, respectively, the impeller outlet total pressure distribution and a typical flow angle distribution.

Table 8 is a reduction of the yaw/pressure traverse data obtained by the Traverse Data Reduction program. The nomenclature for this computer output has been defined in Table 5.

Rig Mechanical Operation

The mechanical operation of the compressor rig itself was uneventful. However, vibrations in the steam turbine drive train were great enough to prohibit running at 85% speed. Data were obtained at 86% speed instead. The lower of the two drive turbines was replaced during this test because its vibrations exceeded normal limits at 90% speed. No further problems were encountered after installation of the new turbine.

After teardown of the compressor rig, evidence was observed of a light rub between the rotor exducer and the shroud. This slight contact was anticipated in view of the low tip clearance used in the buildup.

Figure 51. Impeller outlet total pressure profile.

Figure 52. Impeller outlet flow angle profile.

TABLE 8. YAW/PRESSURE DATA REDUCTION—RC-2.7.

RC 2.7 701 SPEED, RDG 627

INPUT DATA FOLLOWS

5	32.1960	30.6450	31.9440	33.0610	40.8000	784.3400	1.8640
	32.0320	31.2200	31.5230	32.3700			
	215.4000	55.3000	261.3000	101.4000			
	0.0000	39.8000	201.0000	436.5000	0.0000	44.5000	247.0000
	0.0000	46.8000	169.0000	495.0000	0.0000	47.5000	217.0000
	0.0000	50.4000	136.0000	565.0001	0.0000	51.2000	187.0000
	0.0000	50.8000	102.0000	569.5001	0.0000	50.5000	153.0000
	0.0000	45.0000	64.0000	539.0001	0.0000	45.0000	110.0000
	47.9460	0.1770	46.9350	0.3541	49.3110	0.3541	48.0440
	45.4960	0.3541	42.8950	0.7082	41.9440	0.7082	42.5860
	44.3270	0.7028					0.7082
	0.0000	0.0000	0.0000	0.0000			

INLET STATION PROBE

LEADING EDGE STATION PROBE

PT1	Z1	ALPH1	PTLE	ZLE	ALPHLE
39.8000	0.0280	-6.0299	44.5000	0.0278	-7.6499
46.8000	0.0904	4.5000	47.5000	0.0863	-2.2500
50.4000	0.1548	17.0999	51.2000	0.1448	5.2200
50.8000	0.2211	17.9099	50.5000	0.2111	3.6899
45.0000	0.2952	12.4200	45.0000	0.2950	-1.7999

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP
6	48.7784	13.7786	31.9473	0.8016	0.3930	0.5259

PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
45.3845	0.1959	0.6912	1.0098	0.0695	40.8000	1.8640	0.9548

LEADING EDGE DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP
7	48.5907	13.8257	31.7833	0.8029	0.3930	0.5364

PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
45.3845	0.1959	0.6939	1.0137	0.0659	40.8000	1.8640	0.9516

RC 2.7 79.73 SPEED, RDG 630

INPUT DATA FOLLOWS

5	39.7970	37.2260	39.4990	41.3770	51.4000	870.2900	2.3890
	39.4550	38.0650	38.7880	40.1540			
	215.4000	55.3000	261.3000	101.4000			
	0.0000	52.9000	201.0000	476.5000	0.0000	0.0000	0.0000
	0.0000	64.3000	169.0000	533.5001	0.0000	0.0000	0.0000
	0.0000	59.6000	136.0000	575.5001	0.0000	0.0000	0.0000
	0.0000	68.7000	102.0000	572.5001	0.0000	0.0000	0.0000
	0.0000	58.5000	64.0000	514.5001	0.0000	0.0000	0.0000
	60.3600	0.1770	59.1400	0.3541	61.1900	0.3541	59.4040
	59.7310	0.3541	53.8340	0.7082	53.2040	0.7082	54.3860
	57.4380	0.7028					0.7082
	0.0000	0.0000	0.0000	0.0000			

INLET STATION PROBE

LEADING EDGE STATION PROBE

PT1	Z1	ALPH1	PTLE	ZLE	ALPHLE
52.9000	0.0280	1.1700	0.0000	0.5095	-87.1199
64.3000	0.0904	11.4300	0.0000	0.5095	-87.1199
69.6000	0.1548	18.9899	0.0000	0.5095	-87.1199
68.7000	0.2211	18.4500	0.0000	0.5095	-87.1199
58.5000	0.2952	8.0100	0.0000	0.5095	-87.1199

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP
6	65.6673	13.4688	39.4500	0.8852	0.4022	0.4558

PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
57.4599	0.1586	0.6931	1.0127	0.1249	51.4000	2.3890	0.9763

TABLE 8. (CONT)

RC2.7 89.79 (SPEED . RDG.632

INPUT DATA FOLLOWS

5	50.7200	48.1090	48.7590	51.4150	71.9000	950.2800	3.0470
	51.9580	46.9420	50.4540	54.0100			
	215.4000	55.3000	261.3000	101.4000			
	0.0000	73.8000	201.0000	483.5000	0.0000	0.0000	0.0000
	0.0000	92.1000	169.0000	549.5001	0.0000	0.0000	0.0000
	0.0000	95.5000	136.0000	568.0001	0.0000	0.0000	0.0000
	0.0000	92.5000	102.0000	558.0001	0.0000	0.0000	0.0000
	0.0000	76.1000	64.0000	505.0000	0.0000	0.0000	0.0000
	85.5810	0.1770	83.8690	0.3541	86.8750	0.3541	83.8620
	81.7310	0.2541	74.8990	0.7082	73.9180	0.7082	0.0000
	0.0000	0.7028					0.7082
	0.0000	0.0000	0.0000	0.0000			

INLET STATION PROBE

LEADING EDGE STATION PROBE

PT1	Z1	ALPH1	PTLE	ZLE	ALPHLE
73.8070	0.0280	2.4299	0.0000	0.5095	-87.1199
92.1000	0.0904	14.3099	0.0000	0.5095	-87.1199
95.5000	0.1548	17.6399	0.0000	0.5095	-87.1199
92.5000	0.2211	15.8399	0.0000	0.5095	-87.1199
76.1000	0.2952	6.2999	0.0000	0.5095	-97.1199

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
6	89.7259	12.9954	49.7365	0.9581	0.4276	0.5542	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
81.5354	0.2477	0.6761	0.9878	0.0912	71.9000	70	1.0112

RC 2.7 .100(SPEED. RDG 635

FIXED STATION 3

INPUT DATA FOLLOWS

5	63.3210	56.6020	58.1000	63.8730	93.5600	1044.5300	3.7370
	63.9340	54.6680	60.8550	66.4910			
	215.4000	55.3000	261.3000	101.4000			
	0.0000	98.0000	201.0000	446.5000	0.0000	0.0000	0.0000
	0.0000	111.0000	169.0000	505.0000	0.0000	0.0000	0.0000
	0.0000	124.0000	136.0000	586.0001	0.0000	0.0000	0.0000
	0.0000	119.5000	102.0000	576.5001	0.0000	0.0000	0.0000
	0.0000	99.0000	64.0000	523.0001	0.0000	0.0000	0.0000
	110.7400	0.1770	106.7600	0.3541	112.9480	0.3541	109.5970
	106.5450	0.3541	97.7920	0.7082	96.2360	0.7082	97.9420
	103.5530	0.7028					0.7082
	0.0000	0.0000	0.0000	0.0000			

INLET STATION PROBE

LEADING EDGE STATION PROBE

PT1	Z1	ALPH1	PTLE	ZLE	ALPHLE
98.0000	0.0280	-4.2299	0.0000	0.5095	-87.1199
111.0000	0.0904	6.2999	0.0000	0.5095	-87.1199
124.0000	0.1548	20.8800	0.0000	0.5095	-87.1199
119.5000	0.2211	19.1699	0.0000	0.5095	-87.1199
99.0000	0.2952	9.5399	0.0000	0.5095	-87.1199

INLET STATION DATA ON AVERAGE BASIS

I	PT1B	ALP1	P1	M1	M2	CP	
6	116.1180	12.8929	60.4002	1.0132	0.3994	0.5951	
PT2B	BLOCK	WAC	W/WMAX	DPT/PT1	P2	WA	A*/A1
104.4340	0.2022	0.6717	0.9814	0.1006	93.5600	3.7370	1.0191

IV. COMPARISON OF THEORY AND EXPERIMENT

The test data obtained for the RC-2.5, -2.6, and -2.7 compressor builds were analyzed and compared with the CCP calculation predictions. The calculation was then rerun with different values of some of the input parameters in order to "match" the test data. The data matching procedure was used to diagnose the compressor and to recommend modifications for the subsequent tests.

DATA ANALYSIS

The compressor test data were analyzed to obtain the intrastage performance parameters. A short discussion of each of the measurements and its analysis follows. For comparison purposes, all pressure values were nondimensionalized by dividing by the compressor inlet (pitot) pressure.

DIFFUSER VANELESS SPACE

Inlet Static Pressure

This is the arithmetic average of eight static pressure taps distributed circumferentially so as to span one diffuser passage at a radius 3% outboard of the original impeller and 11.3% outboard of the modified impeller used in the RC-2.7 test. Half the taps were located on the hub side of the compressor, and the other half on the shroud side.

Traverse Station Static Pressure

This is the arithmetic average of eight static pressure taps distributed as previously stated, except that they were located at a radius 7.7% outboard of the original impeller and 16.5% outboard of the RC-2.7 impeller.

Traverse Station Total Pressure

The "raw" value of this parameter is calculated from the data obtained in choke and as described in the RC-2.5 Test subsection.

A correction was then made to the raw value to reflect the value which the traverse data would have yielded had the compressor been capable of stable operation at other than choked flow conditions with the traversing probes in place. The correction is performed by multiplying the raw value of the traverse pressure by the ratio of the maximum diffuser exit pressure at the operating point in question to the same pressure at the "break" point at that speed. The value of the break point pressure is illustrated in Figure 53. In the case of RC-2.7, the value

of the throat total pressure readings could be substituted for the maximum diffuser exit pressure; this method would give a result differing by less than 0.2% from the method actually used. The value of the traverse total pressure obtained in this manner is used in the calculation of the pressure ratio, Mach number, and efficiency to the traverse stations of Tables 9, 10, 11, and 12 shown later in this section.

The method of obtaining the operating point traverse total pressure clearly involves the assumption that only minor (and negligible) profile changes occur at the traversing station as the compressor is loaded. Some substantiation for this assumption has been presented by S. Baghdadi.¹⁰

The Diffuser Leading-Edge Static Pressure

The value of this parameter is obtained by averaging the readings of four static pressure taps. Two of these pressure taps are located on the hub and two on the shroud side of the compressor as illustrated in Figure 54. Because of the very large pressure gradients in this region, the value of the leading-edge pressure obtained in this manner is felt to be accurate only to within $\pm 5\%$.

Figure 53. Diffuser exit peak total pressure ratio—"Break Point".

¹⁰ Baghdadi, S. A Study of Vaned Radial Diffusers Using Swirling Transonic Flow Produced by a Vortex Nozzle. PhD. Thesis, Purdue University, Lafayette, Indiana. December 1973.

The Diffuser Leading-Edge Total Pressure

The diffuser leading-edge centerline total pressure read lower than the maximum diffuser exit static pressure throughout the RC-2 program. The other two leading-edge total pressure probes, which were in place and intact only for the RC-2.5 test, appeared to read a realistic value. The average reading of these two probes was used in Table 2. These probes were damaged in the plating process used to decrease the throat area for the RC-2.6 tests and were not used.

The Diffuser Throat Static Pressure

The value of this parameter is obtained by arithmetically averaging the readings of the static pressure taps distributed around the diffuser throat as shown in Figure 21. All seven of the tap readings were used in the RC-2.6 data analysis; in the case of RC-2.5 and -2.7, however one of the taps was disregarded in the averaging as it read suspiciously high.

The Diffuser Throat Total Pressure

Diffuser throat total pressure data were obtained only for the RC-2.7 test, as previously discussed. The arithmetic average of the readings of the three probes located at the centerline of the three different diffuser passages was used* to obtain the diffuser throat centerline total pressure. The value of the area-averaged (or "one-dimensional") throat total pressure was then computed by multiplying the centerline total pressure by the blockage factor obtained from a one-dimensional continuity calculation at the throat. This is the throat total pressure listed in Table 11.

Impeller Tip Static Pressure

The RC-2.5 and -2.6 builds did not have static pressure taps exactly at the impeller tip radius. It was therefore necessary to interpolate the impeller tip static pressure value from the radial static pressure distribution measured along the shroud and in the diffuser. The arithmetic average of the five taps 4% radially inboard and the eight taps 3% radially outboard of the impeller tip were included in that distribution.

In the case of RC-2.7, the arithmetic average of the five taps located at the new impeller tip radius was used as the impeller tip static pressure.

*All three centerline probes read within 1% of the average value.

Figure 54. Leading-edge static pressure tap location.

APPLICATION OF CCP TO THE RC-2 COMPRESSOR

RC-2.5

Table 9 compares the predicted and measured values of the intrastage and overall compressor performance parameters. The predicted value of the rotor work, $\Delta H/H$, is seen to be low by 6.6% compared with the measured value. Two factors are of importance in understanding this significant discrepancy. First, the CCP calculation had only recently been modified to account for back-curved exducer blading at the time of the original prediction, and no substantial background for this type of compressor had been acquired. Second, the back-curved section of the RC-2 impeller is an unusual, "no work" section added to the tip of a basically radial design. This approach led to rapid curvature changes in the exducer which, according to the analysis of the test data, resulted in flow separation along the exducer pressure surfaces. (The slip factor works out to be greater than unity if the actual metal angle of 32.5 deg at the rotor exit is used.) The analysis of the test data indicates that, in actuality, the maximum justifiable value of the effective blade exit angle is 28 deg.

Figure 55 compares the original slip factor prediction to the most recent computations used in predicting the slip factor for RC-2.7 as a function of the rotor exit blade angle. The most recent theory produces a much higher value of the slip factor than did the original theory.

Table 9 shows that the CCP calculation was within 1% of the test data in its computation of the pressure ratio and flow rate, but that the calculated efficiency was 4.5% higher than the measurement.

TABLE 9. COMPARISON OF PREDICTED AND MEASURED VALUES—RC-2.5.

	<u>Calculated</u>	<u>Measured</u>
Impeller		
η traverse	0.863	0.834
η adiabatic	0.890	
η hydraulic	0.940	
η mixed	0.864	
$\Delta H/U^2/Jg$	0.763	
$C\theta/U$	0.780	
Impeller tip static pressure	3.716	3.640
Vaneless space		
Inlet (1.03 R/R _{IT})		
P_s/P_{T1}	4.290	4.028
P_T/P_{T1}	9.777	
M	1.150	
Traverse station (1.077 R/R _{IT})		
P_s/P_T	4.600	4.306
P_T/P_{T1}	9.750	9.995
M	1.094	1.166
Diffuser		
Leading edge		
P_s/P_{T1}	4.895	4.231
P_T/P_{T1}	9.542	9.468
M	1.025	1.138
Throat		
P_s/P_{T1}		5.781
Exit		
P_T/P_{T1}	8.357	8.883
P_s/P_{T1}	8.138	8.018
M	0.350	0.385
C_{PLE} -exit	0.700	0.723
C_{p traverse-exit	0.687	0.653
Overall compressor (to diffuser exit)		
$\Delta H/H$	1.048	1.117
$W a_c$	4.184	4.230
η	0.825	0.781
R_c	8.857	8.883

Figure 55. Variation of slip factor with exducer blade angle.

RC-2.6

The RC-2.5 test data indicated that the diffuser inlet flow profile was weak on the shroud side and that the inducer was choking at the maximum flow at design speed. For RC-2.6, the first of these problems was attacked by twisting the inlet guide vanes— -3 deg (open) at the tip, $+8$ deg (closed) at the hub—in such a manner as to strengthen the shroud flow by redistributing the work at the impeller outlet. The second problem was tackled by plating the diffuser to reduce the throat area by 3% .

The data obtained during the RC-2.6 tests are plotted together with the a priori (predicted) CCP calculations in Figures 56 and 57.

The a priori input to the CCP calculation involved a variation in the impeller axial blockage input with speed which was similar to that deduced from the RC-2.5 a posteriori analysis. The change in the "flow quality" mode which was input for the 70% speed line was likewise anticipated from the RC-2.5 data analysis. Figure 56 shows that the CCP calculation successfully predicted the test data at all speeds except 100% .

To match the 100% speed test data a posteriori, the value of the impeller exit axial blockage was increased over the value used a priori, and the diffuser choking coefficient was modified. In addition, the flow quality mode of the rotor was changed from Mode 1 to Mode 3, indicating

Figure 56. Predicted and measured performance—RC-2.6.

Figure 57. Predicted and measured performance—RC-2.6.

a degraded rotor performance. These changes result from the fact that the RC-2.6 rotor with the twisted IGV's behaved similarly to the RC-2.5, 33 deg IGV setting instead of similarly to the 17 deg setting as anticipated. In other words, it would appear that the hub value of the IGV setting dominated over the tip value.

Table 10 compares the a priori calculated and measured values of the intrastage and overall performance parameters of RC-2.6 near the design point. This table shows that the calculation was within 0.1% of the measured pressure ratio, but was 1.5% high in efficiency and 6.6% high in flow.

TABLE 10. COMPARISON OF PREDICTED AND MEASURED VALUES—RC-2.6

	Calculated	Measured
Impeller		
η_{traverse}	0.864	0.821
$\eta_{\text{adiabatic}}$	0.885	
$\eta_{\text{hydraulic}}$	0.926	
η_{mixed}	0.852	
$\Delta H/U^2/Jg$	0.811	
C_{θ}/U	0.836	
Impeller tip static pressure	3.959	3.930
Vaneless space		
Inlet (1.03 R/R _{IT})	4.320	4.398
P_s/P_{T1}	10.760	
P_T/P_{T1}	1.210	
M		
Traverse station (1.077 R/R _{IT})		
P_s/P_{T1}	1.690	4.582
P_T/P_{T1}	10.333	9.996
M	1.142	1.118
Diffuser		
Leading edge		
P_s/P_{T1}	4.984	4.630
P_T/P_{T1}	10.306	
M	1.074	
Throat		
P_s/P_{T1}	5.421	6.284
Exit		
P_T/P_{T1}	9.173	9.169
P_s/P_{T1}	8.425	8.368
M	0.350	0.364
$C_{PI \text{ E-exit}}$	0.618	
$C_{P \text{ traverse-exit}}$	0.640	0.699
Overall compressor (to diffuser exit)		
$\Delta H/H$	1.112	1.135
$W a_c$	4.460	4.184
η	79.460	78.000
R_c	9.173	9.169

RC-2.7

The analysis of the RC-2.5 and -2.6 data indicated that the rotor outlet flow deviated (i.e., was separated) from the pressure surface in an unusual manner. This deviation was ascribed to the rapid curvature used in the exducer design, so the back-curved portion of the exducer had to be removed to remedy the situation. This modification entailed the insertion of an extended vaneless space to replace the outboard 8% of the rotor which was removed, so the diffuser leading edge was now 22% outboard of the rotor tip.

The predicted and measured values of the RC-2.7 performance (both overall and intrastage) near the design point are shown in Table 11. The calculated value of the mass flow in Table 11 is that which yielded the maximum overall efficiency. However, the program showed very little variation of the overall efficiency with flow rate, so the a priori calculated performance at the increased flow rate differed significantly from the value shown in Table 11 only with respect to the diffuser throat static pressure and Mach number. The calculation is seen to be high by 3.6% in flow, 0.7% in efficiency, and 1.78% in pressure ratio.

The adjustment required to "match" the calculation to the test data consisted of varying the diffuser choking coefficient; this change lowered the pressure and shifted the compressor's choke flow to a lower value. The resulting map is compared to the test data in Figures 58 and 59. The only aerodynamic program input which is varied with speed is the diffuser choking coefficient. If an average value of this coefficient were used*, the maximum deviation from the data resulting would be $\pm 1\%$ in efficiency and $\pm 2\%$ in pressure ratio. The computer runs used to produce Figures 58 and 59 are shown in the Appendix, together with the input-output nomenclature. The compressor running clearance, which is included in the rotor hub to shroud dimension BH, is input, and varies with rotor rpm.

Figure 58. Measured and matched performance—RC-2.7.

Figure 59. Measured and matched performance—RC-2.7.

*Obviously, until a more accurate diffuser choking relationship is found, the a priori or design mode of the program will use such a constant coefficient.

TABLE 11. COMPARISON OF PREDICTED AND MEASURED VALUES—RC-2.7.

	<u>Calculated</u>	<u>Measured</u>
Impeller		
η traverse	0.866	0.820
η adiabatic	0.898	
η hydraulic	0.940	
η mixed	0.853	
$\Delta H/U^2/Jg$	0.879	
C_θ/U		
Impeller tip static pressure	3.166	3.300
Vaneless space		
Inlet (1.116 R/R _{IT})		
P_s/P	4.225	4.500
P_T/P_{T1}	9.424	
M	1.135	
Traverse station (1.168 R/R _{IT})		
P_s/P_{T1}	4.535	4.605
P_T/P_{T1}	9.436	8.639
M	1.079	0.992
Diffuser		
Leading edge		
P_s/P_{T1}	4.825	4.583
P_T/P_{T1}	9.230	
M	1.009	
Throat		
P_T/P_{T1}	8.880	8.490
P_s/P_{T1}	5.030	5.137
Exit		
P_T/P_{T1}	8.334	8.188
P_s/P_{T1}	7.657	7.473
M	0.350	0.364
$C_{pLE-exit}$	0.641	
$C_{pTraverse-exit}$	0.637	0.708
Overall compressor (to diffuser exit)		
$\Delta H/H$	1.041	1.042
$W a_c$	4.200	4.058
η	0.800	0.793
R_c	8.334	8.188

DISCUSSION

Tables 9, 10, and 11 may be interpreted to indicate that the CCP program has difficulty in separating the subcomponent performance. The reason for this may be the very complex relationship between the impeller and the diffuser.* Table 12 lists the measured subcomponent efficiencies of the various RC-2 configurations. The pressure ratio at the traverse station for the 17 deg IGV setting of RC-2.5 was not measured, and is deduced by comparing the leading-edge total pressures to those of the 25 and 33 deg IGV settings of this build. Table 12 indicates that, when the IGV's were twisted, the impeller efficiency was reduced and the diffuser's pressure recovery coefficient increased. This increase in the diffuser performance can be at least partly traced to the improvement in the impeller outlet flow profile which in turn can be traced to the work redistribution effect of twisting the inlet guide vanes. Since improving the flow profile into the diffuser was the motivation for twisting the inlet guide vanes, this result was expected. Unfortunately, the loss in impeller efficiency was not expected. The explanation for the decrease in impeller performance in going from RC-2.5 (25 deg IGV) to RC-2.6 cannot be explained solely in terms of an increased inducer tip Mach number, for the RC-2.5, 17 deg IGV build, which has the highest impeller efficiency listed in Table 12, also has the highest inducer tip Mach number. In fact, the only parameter that separates the higher efficiency impellers (RC-2.5, IGV=17 deg and IGV=25 deg) from the lower efficiency impellers (RC-2.5, IGV=33 deg, RC-2.6 and RC-2.7) is the hub value of the inlet guide vane setting, which was 33 deg for the lower efficiency rotors and 17 and 25 deg for the high efficiency rotors. The differences in rotor efficiencies can thus be tentatively attributed to a sensitivity to the inducer inlet flow incidence profile.

TABLE 12. INTRASTAGE EFFICIENCIES OF VARIOUS RC-2 CONFIGURATIONS.

	RC-2.5			RC-2.6	RC-2.7
	<u>IGV = 17</u>	<u>IGV = 25</u>	<u>IGV = 33</u>	<u>IGV = 25</u>	<u>IGV = 25</u>
Impeller					
Inducer tip Mach No.	1.220	1.112	1.034	1.218	1.191
$R_{ctraverse}$	10.431	9.995	9.541	9.996	8.639
$\eta_{traverse}$	0.840	0.834	0.823	0.821	0.820
$M_{traverse}$	1.170	1.166	1.181	1.118	0.992
Diffuser					
$C_{ptraverse-exit}$	0.643	0.653	0.651	0.699	0.708
$R_{c exit}$	9.187	8.883	8.399	9.169	8.188
M_{exit}	0.383	0.385	0.376	0.364	0.364
Overall					
η	0.780	0.781	0.767	0.780	0.793

*The vaneless space up to the traversing station is considered to be part of the impeller, since this is the performance measuring station closest to the rotor.

It is important to note that the "impeller" efficiencies listed in Table 12 actually include losses up to the traverse station. Thus, the actual impeller efficiency (not including vaneless space losses) must have increased in RC-2.7 as compared to RC-2.6, because the traverse station is 13% outboard of the impeller in the former case and only 7.7% in the latter.* This is important because it implies that the removal of the bent back section of the rotor decreased the rotor losses, thus lending credibility to the theory that the exducer pressure surface was separated in RC-2.5 and RC-2.6. In fact, the a posteriori CCP calculations show the rotor loss to have decreased from 50.9% of the total losses in RC-2.6 to only 38.4% in RC-2.7.

The RC-2.7 compressor showed an efficiency improvement of 1.3% in spite of the fact that the diffuser leading edge was 22% outboard of the modified impeller. If the current design practices at DDA and elsewhere can be used as a guide (ref: D. P. Kenny², an ASME publication,⁶ and D. P. Kenny²⁰), the RC-2.7 radius ratio is excessive—the optimum radius ratios used vary from 5% to 13% for high-pressure-ratio machines. Thus, a further efficiency improvement may be realized if the modified rotor were tested with a new, rematched, smaller radius ratio diffuser. However, the magnitude of the improvement is difficult to assess without recourse to a performance prediction calculation (such as CCP) which takes into account both the decreased losses due to the lower leading-edge Mach number and the increased "frictional" loss because of the large vaneless space radius ratio. Contrary to expectations, the CCP calculation does not show a performance decrement in the case of this particular diffuser as the leading-edge radius ratio is increased from 1.13 to 1.22. Because of the lack of sufficient test data at the higher radius ratios, only a specific test can confirm the CCP prediction in this regard.

*Obviously, this comment assumes that the losses in the vaneless space are proportional to the extent of the vaneless space.

²⁰Kenny, D. P. A Comparison of the Predicted and Measured Performance of High Pressure Ratio Centrifugal Compressor Diffusers. ASME Paper No. 72-GT-54, 1972.

V. CONCLUSIONS

1. The CCP calculation successfully predicted the flow and pressure ratio, but it did not accurately predict the efficiency measured in the first test of the RC-2 compressor because of the unusual exducer blading used in this design. Indications are that the flow was separated from the pressure surface at the rotor exit. Certain "flow quality" parameters, which are input to the calculation, had to be adjusted to account for the deviation of the flow from the blade pressure surface.
2. Once a machine has been tested, the CCP calculation can be used to deduce the appropriate "flow quality" parameters, and thus helps point out the weaknesses in the rotor design.
3. Once the calculation has been matched to the data at design point, the entire map can be reproduced by varying only one aerodynamic coefficient in the case of the radial rotor (RC-2.7) and three coefficients in the case of a back-curved rotor (RC-2.6 and RC-2.5). In no case are coefficients varied along a given speed line.
4. The CCP calculation will not predict "bumps" in surge lines as were measured in the case of RC-2.5 and RC-2.6. The predicted surge line will be nearly straight, as was measured for RC-2.7.
5. The CCP calculation fairly accurately predicts the effects of minor modifications to the compressor.
6. Both the rotor and the diffuser were sensitive to the flow profile at their respective inlets.

VI. RECOMMENDATIONS

1. The diffuser loss models used in the CCP calculation should be updated to take into account the recent data of References 3 and 4.
2. An effort should be directed toward finding a relationship between the impeller "flow quality" and the blading distribution; in particular, a relationship is required that would express the rotor "flow quality" in terms of the gradients in the impeller blade angle distribution and certain diffuser parameters. Such a relationship would obviate the necessity for inputting the "flow quality" into the calculation.
3. The RC-2.7 rotor should be equipped with a properly matched diffuser, and tested for performance to ascertain the compressor's true potential.

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APPENDIX CENTRIFUGAL COMPRESSOR PERFORMANCE PROGRAM

Input

TRIG	Choking flow coefficient acting directly on Δq_{ri} (Normally for no choking = 1.0)
DELSF	Perturbation on slip factor; used only for study
CC	Coefficient acting on $(M_{RIT} - M_{RIC})$ where M_{RIT} = Inlet shroud rel Mach No. M_{RIC} = Critical rel Mach No.
C3	Coefficient determining the dependence (explicit) of secondary recirculation losses on inlet flow coefficient (0 = no dependence)
C1	Not used
C5	Coefficient acting on $\text{abs}(M_1 - M_{ICR})$, i.e., $(M_T - CMT)$
C6	Inducer tip coefficient
TRIGR	Scale parameter on the overall diffuser loss from LE to $M = 0.15$ (collector)
D1	Inducer inlet hub diameter—ft
D1/D2	Inducer hub/tip ratio
N	RPM
W	Mass flow—lb/sec
D3	Impeller tip diameter—ft
ALPHA	Effective IGV exit angle—deg
IGV	Loss parameter. 0 = no losses. If equal to ALPHA = guide vane correlation losses. If any other number correlation is off by (ALPHA - IGV).
BH	Impeller blade tip width including shroud clearance—ft
BFI	Optional parameter used in conjunction with TRIGR for study only
BLH	Impeller exit wall blockage factor
BLM	Impeller exit metal blockage factor
BLTH	Impeller exit wake blockage factor
RR	Radius ratio of vaneless space
VRATD	Parameter entering a diffusion factor calculation—not used
CPA	Diffuser incidence coefficient
C2	Not used
No. of blades	Impeller tip blade number
AD	Total diffuser throat area—ft ²
BH2	Gap width at diffuser LE—ft
UD	Match or design point speed—ft/sec
PHIPD	Match or design point flow coefficient
WD	Fixed parameter in diffuser calculation—universal

ALPS	Diffuser LE mean blade angle from tangential—deg
C7	Diffuser parameter acting on $C_D P_{DLE}/PTTHT V_S M_{DLE}$ curve
C8	Coefficient entering equation of blockage influence in the impeller on secondary losses
C9	First-order incidence coefficient for diffuser. Same value for all pipes
C10	Diffuser incidence parameter describing the transition from subsonic to supersonic
C11	Universal factor on friction formula in the vaneless space
C12	Factor entering calculation for negative incidence loss on inducer
C13	Factor entering calculation for inducer tip incidence effect on wall blockage
RNMCR	Inducer tip relative critical Mach No. 0.87 is the state-of-the-art number
CMT	Critical absolute inlet Mach No. acting on IGV and inducer

Output

POP	Rotor inlet total head pressure after IGV losses—lb/ft ²
PRTTE	Total/total pressure rise inducer tip to exducer tip in the rotor (before mixing)
HE	Euler head = U^2/gJ
W/A	Flux entering rotor with fixed standard 0.985 blockage factor—lb/ft ²
MT	Absolute inducer inlet Mach No., max when there are no IGV
GG	$(1 + \frac{\gamma-1}{2} MT^2)$
RHOS	Static density—lb/ft ³
MAX	Axial component of MT
PHI	V_{axial} (referring to MT)/ $U_{(impeller\ exit\ tip)}$ = flow factor
AI	Sonic speed at MT—ft/sec
VT	Absolute velocity at MT—ft/sec
CTHT	Tangential velocity at inducer RMS—ft/sec
BETAG	Gas angle at inducer tip—deg
PHIP	Inducer inlet flow coefficient V_{ABS}/U_{RMS}
First column of subprints (Without incidence)	Gives top column $C_D \times P_{DLE}/TTHRT$
(With incidence)	Bottom column $C_D \times P_{DLE}/TTHRT$
The remaining subprints are calculation check points.	
URMS	Inducer speed at RMS—ft/sec

PF	Prewirl factor at U_{RMS} normalized to HE
PSI	Rotor overall total/total pressure coefficient related to PRTTE
EFFH	Rotor isentropic efficiency just before dump
DQ	Internal loss coefficient normalized to HE
RNMIT	Rel inducer inlet tip Mach No.
TO4	Total discharge temp of diffuser—°R
TO3D	Total temperature dumped at impeller tip—°R
TO3	Total temperature at impeller tip before dump—°F
PO3	Total pressure at impeller tip—lb/ft ²
U	Speed at impeller tip—ft/sec
DRMS	Inducer RMS diameter—ft
EPS	D3/DRMS
CSF	Slip factor at impeller tip
PRDLE	Pressure ratio total/total diffuser LE
CPT35	Diffuser static recovery throat to exit ($M = 0.35$)
RC 35	Pressure ratio total/total at diffuser exit ($M = 0.35$) to ambient
ET 35	Overall compressor efficiency total/total at discharge ($M = 0.35$)
DP 35	$\left(\frac{\Delta P_T}{P_T}\right)_{0.35}$ from diffuser LE to exit
DPQ	$\frac{\Delta P \text{ (static)}}{q_{LE}}$ from diffuser LE to throat
PSTH	Static pressure ratio at throat as referred to ambient
ETS	Total-to-static efficiency based on given collector dump loss
NS	Specific speed
RCS	Pressure ratio diffuser exit static to ambient
MEXIT	Correlated guess as an iteration helper to calculate MDEX
MDLE	Mach number at diffuser LE
DQX	External loss coefficient normalized to HE
TRF	Rotor work coefficient — enthalpy rise across impeller normalized to ambient stagnation enthalpy
EFFI	Impeller adiabatic efficiency (unmixed) including IGV losses
DPOP	Total pressure loss in vaneless space normalized to impeller tip total head pressure
PSLE	Static pressure ratio at diffuser LE normalized to ambient
DIBF	Blockage factor in vaneless space at BH2 (not including metal)
EFFM	Rotor efficiency after mixing at diffuser LE (includes vaneless space loss)
MG	Mach No. in rotor just before dump
mDEX	Mach No. (dumped)
DP'D	$\Delta P_0/P_0$ (dump loss)
ALPHD	Mean gas angle from tangential as dumped—deg

ALPLE	Gas angle at diffuser LE—deg
A*/A	Adiabatic efficiency diffuser LE to throat
ET15	Overall stage efficiency to M = 0.15
VTH ₄	Whirl at diffuser LE—ft/sec
VR	Radial velocity at discharge to rotor—ft/sec
MTHR	Throat Mach No.
BTHR	Throat blockage factor
RDP _{TH}	$\Delta P_T/P_{T(LE)}$ from LE to throat
POEXIT	Pressure ratio referred to ambient at M = 0.15
RDPEX	$\Delta P_T/P_{T(LE \text{ to } 0.15 \text{ M})}$
CCPA	Static pressure recovery coefficient LE to M = 0.15

PERMANENT DATA

GAMMA	1.4 at standard inlet conditions; varies with conditions at compressor outlet
CP	0.24 Btu/(lb°R) at standard inlet conditions; conditions at compressor outlet
H ₀	124.03 Btu
RHOST	0.07651 lb/ft ³
PO	2116 lb/ft ²
TO	518.7°R
BF2	wheel throat (at inducer) blockage factor = 0.9
BETAM	Not used
C30	Not used
C31	Iteration step size
C32	Iteration step size
TMw	Iteration limit
C4	Enters collector dump formula for static efficiency

CCP program RC-2.7 output data is listed in Table A-1.

TABLE A-1.CCP PROGRAM RC-2.7 OUTPUT DATA

CENT COMP INLET CALC RC-2.7 100

DATA							
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850F 02	0.1500E 01
N1	01/02	N	W	D3	ALPHA	IGV	NH
0.2000E 00	0.4630E 00	0.5590E 05	0.4115E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.2942E-01
RFT	RLH	RLH	BLTH	RR	VRATD	CPA	C2
0.0	0.8500F 00	0.9400E 00	0.7300F 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0
NO OF BLADES	AD	RH2	UD	PHIPD	WD	ALPS	C7
0.3200E 02	0.1410E-01	0.2600E-01	0.1910F 04	0.6250E 00	0.9950F 00	0.1640E 02	0.1030E 01
C8	C9	C10	C11	C12	C13	RNHCP	CMT
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700F 00	0.5440E 00
RESULTS							
PDP	PATTE	HE	W/A	MT	GG	RHOS	MAX
0.2087E 04	0.9855F 01	0.1459E 03	0.3629E 02	0.5565E 00	0.1042E 01	0.6491E-01	0.5160F 00
PHI	AI	VT	CTMT	RETAG	PHIP		
0.2925E 00	0.1083E 04	0.6029E 03	0.2259E 03	0.6175F 02	0.6110E 00		
0.9456	0.9772	0.8856	0.7236	0.3296	0.6003		
0.9318	0.9734	0.8956	0.7236	0.3296	0.6003		
*** CHOKE ***							

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

URMS	PF	PSI	EFFH	NQ	RNMIT	Y04	Y03D		
0.3867E 03	0.6101F-01	0.7843E 00	0.9302E 00	0.5887E-01	0.1090E 01	0.1048E 04	0.1037E 04		
Y03	P03	U	NRMS	EPS	CSF	PRDLF	CPT35		
0.1024E 04	0.2057E 05	0.1911F 04	0.3366E 00	0.1937E 01	0.9042E 00	0.9003F 01	0.6982E 00		
RC35	ET35	DP35	DPQ	PSTM	ETS	NS	RCS		
0.8065E 01	0.7859E 00	0.1043F 00	-0.4685F-01	0.4570E 01	0.7306F 00	0.9251F 02	-0.7171F 01		
WEXIT	WOLF	DOX	TRE	FFFI	DPQP	PSLE	DIOF		
0.1276E 01	0.1005E 01	0.4083E-01	0.8843F 00	0.8872E 00	0.7966E-01	0.4726E 01	0.6306E 00		
EFFIM	MG	WDEX	DPIN	ALPHD	ALPLE	AS/A	ET15		
0.8401E 00	0.1306F 01	0.1310E 01	0.2030F-01	0.1500E 02	0.1870F 02	-0.4440E 01	0.7583E 00		
VTM4	V2	WTHD	RTMF	ROPTH	POEXIT	RDPXY	CCPA		
0.1681E 04	0.6974F 03	0.9989F 00	0.9711F 00	0.4040F-01	0.7626E 01	0.1529F 00	0.6274E 00		

TABLE A-1 (CONT)

CENT COMP INLET CALC PC-2.7 100

DATA											
TRIG	0.1000E 01	0.0	0.2000E 01	0.1000E 01	0.5000E-02	C5	0.2500E 01	0.5850E 02	TRIGR	0.1500E 01	
01	0.2000E 00	0.4633E 00	0.5597E 00	0.4107E 01	0.6520E 00	ALPHA	0.2700E 02	IGV	0.2942E-01	BH	
REF	0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	VRATD	0.6000E 00	CPA	0.1000E-01	C2	
NO OF BLADES	0.3200E 02	0.1410E-01	0.2600E-01	0.1918E 04	0.6250E 00	W	0.0950E 00	ALPS	0.1640E 02	C7	
CR	0.1050E 01	0.1500E 00	0.1000E 01	0.6500E-01	0.4500E-01	C12	0.5000E-01	RNMCP	0.8700E 00	CMT	
RESULTS											
POP	0.2087E 04	0.0854E 01	0.1459E 03	0.3621E 02	0.5548E 00	GG	0.1062E 01	RHDS	0.6497E-01	MAX	
PHI	0.2916E 00	0.1084E 04	0.6011E 03	0.2252E 03	0.6183E 02	PHIP	0.6093E 00				
0.9456	0.9711	0.9862	0.7225	0.0327	1.0030						
0.9323	0.9731	0.9862	0.7225	0.0327	1.0000						
URMS	0.9866E 03	0.6093E-01	0.7846E 00	0.9302E 00	0.5897E-01	RNMIT	0.1090E 01	TO4	0.1048E 04	TO3D	
TO3	0.1024E 04	0.2058E 05	0.1011E 04	0.3366E 00	0.1937E 01	CSF	0.9044E 00	PROLE	0.9005E 01	CPT35	
PC35	0.8095E 01	0.7876E 00	0.1011E 00	0.3085E-01	0.4833E 01	ETS	0.7177E 00	NS	0.9342E 02	RCS	
NEXIT	0.1276E 01	0.1005E 01	0.4054E-01	0.0845E 00	0.8872E 00	NPOP	0.7979E-01	PSLF	0.4730E 01	DIBF	
EFFIM	0.8400E 00	0.1386E 01	0.1310E 01	0.2933E-01	0.1596E 02	ALPDE	0.1866E 02	A*/A	0.3527E 00	ETIS	
VTH4	0.1693E 04	0.6865E 03	0.9521E 00	0.9697E 00	0.3849E-01	RDPH	0.7672E 01	RDPEX	0.1480E 00	CCPA	

TABLE A-1 (CONT)

CENT COMP INLET CALC PC-2.7 100

DATA									
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR		
0.1000E 01	0.0	0.2300E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01		
Q1	Q1/D2	N	W	D3	ALPHA	IGV	BW		
0.2000E 00	0.4630E 00	0.5500E 05	0.4000E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.2942E-01		
BFI	RLM	RLM	RLTH	RR	VRATD	CPA	C2		
0.0	0.4500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0		
NO OF BLADES	AG	AM2	UD	PHIPD	WD	ALPS	C7		
0.3200E 02	0.1410E-01	0.2600E-01	0.1319E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1030E 01		
CA	CO	C10	C11	C12	C13	RNMCP	CMT		
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00		
RESULTS									
POP	PRTF	WE	W/A	MT	GG	QWTS	MAX		
0.2088E 04	0.9891E 01	0.1459E 03	0.3587E 02	0.5463E 00	0.1060E 01	0.6529E-01	0.5065E 00		
PHI	AI	VT	CTHT	BETAG	PHIP				
0.2475E 00	0.1045E 04	0.5925E 03	0.2220E 03	0.6225E 02	0.6005E 00				
0.9450	0.9697	0.7164	0.0478	1.0030					
0.9342	0.9719	0.8887	0.5946	1.0000					
UPMS	PF	PSI	EFFH	DO	RNMIT	TD4	TD3D		
0.9866E 03	0.5996E-01	0.7862E 00	0.9302E 00	0.5899E-01	0.1088E 01	0.1050E 04	0.1038E 04		
TD3	PD3	U	DRMS	EPS	CSF	PROLE	CPT35		
0.1025E 04	0.2066E 05	0.1911E 04	0.3366E 00	0.1937E 01	0.9052E 00	0.9035E 01	0.6450E 00		
RC35	ET35	DP35	DPQ	PSTH	ETS	NS	RCS		
0.8190E 01	0.7915E 00	0.9350E-01	0.1781E 00	0.5349E 01	0.7539E 00	0.8943E 02	0.7590E 01		
WEXIT	MOLF	NOX	TAF	EFFI	DPOD	PSLF	DIBF		
0.1276E 01	0.1004E 01	0.4147E-01	0.8967E 00	0.5867E 00	0.8050E-01	0.4752E 01	0.6287E 00		
EFFIM	WG	WDEX	DPD	ALPHD	ALPLE	A*/A	ET15		
0.8356E 00	0.1384E 01	0.1304E 01	0.2942E-01	0.1567E 02	0.1849E 02	0.7685E 00	0.7670E 00		
VTM4	VP	WTHR	RTHR	ROPTH	POEXIT	RDPX	CCPA		
0.1684E 04	0.6804E 03	0.8661E 00	0.9474E 00	0.3427E-01	0.7796E 01	0.1371E 00	0.6475E 00		

CENT	COMP	INLET	CALC	RC-2.7	100
100	100	100	100	100	100

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TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 100

DATA							
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01
O1	D1/D2	N	M	D3	ALPHA	IGV	BH
0.2000E 00	0.4630F 00	0.5595E 05	0.4018E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.2942E-01
RF1	RLM	RLM	BLTH	RR	VRATO	CPA	C2
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0
PO OF BLADES	AN	RH2	UD	PHIPD	WD	ALPS	C7
0.3200E 02	0.1410F-01	0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1030E 01
C8	C9	C10	C11	C12	C13	RNMCR	CMT
0.1050E 01	0.1500F 00	0.1900E 01	0.6500F-01	0.4500F-01	0.5000E-01	0.8700E 00	0.5440E 00
RESULTS							
PDP	PRTTE	ME	W/A	MT	GG	RHOS	MAX
0.2090E 04	0.9871E 01	0.1457E 03	0.3543E 02	0.5359E 00	0.1057E 01	0.6568E-01	0.4969E 00
PHI	A1	VT	CTHT	BETAG	PHIP		
0.2824F 00	0.1086F 04	0.5818E 03	0.2179F 03	0.6276E 02	0.5900E 00		
0.9661	0.9671	0.8920	0.7097	0.0675	1.0000		
0.9354	0.9711	0.8920	0.5918	1.0000	1.0000		
LRMS	PF	PSI	EFFH	DQ	RNMIT	TO4	TO3D
0.9861E 03	0.5890E-01	0.7861E 00	0.9279E 00	0.6111E-01	0.1085E 01	0.1051E 04	0.1039E 04
YN3	PN3	U	DRMS	EPS	CSF	PROLF	CPT35
0.1076F 04	0.2063E 05	0.1910E 04	0.3366E 00	0.1937E 01	0.9061E 00	0.9013E 01	0.6240E 00
RC35	ET35	DP35	DPQ	PSTH	ETS	NS	RCS
0.8201E 01	0.7907E 00	0.9007E-01	0.2445F 00	0.5566E 01	0.7562E 00	0.8851E 02	0.7648E 01
MEXIT	MDLF	DOX	TRF	EFFI	DPOP	PSLE	DIBF
0.1276E 01	0.1002F 01	0.4199E-01	0.8892E 00	0.8841E 00	0.8160E-01	0.4749F 01	0.6277E 00
EFFIM	MG	MPFX	DPTD	ALPHD	ALPLE	A0/A	ETIS
0.8368E 00	0.1383F 01	0.1306F 01	0.2093E-01	0.1542E 02	0.1934E 02	0.8261E 00	0.7672E 00
VTM4	VR	MTMR	RTMR	RDPTH	POEXIT	RDPEX	CCPA
0.1684E 04	0.6769E 03	0.8278E 00	0.9667F 00	0.3197E-01	0.7821E 01	0.1322E 00	0.6535E 00

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 90

DATA											
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR				
0.1000F 01	0.0	0.2000F 01	0.1200F 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01				
0.2000E 00	0.4630E 00	N	W	D3	ALPHA	IGV	BM				
0.0	0.4500F 00	BLM	BLTH	RR	VRATD	CPA	C2				
NO OF BLADES	AD	RM2	UN	PHIPD	WD	ALPS	C7				
0.3200F 02	0.1410E-01	0.2600F-01	0.1914E 04	0.6250E 00	0.0950E 00	0.1640E 02	0.1050E 01				
0.1050E 01	C9	C10	C11	C12	C13	RNMCP	CMT				
0.1500F 00	0.1900F 01	0.6500E-01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00				
RESULTS											
POP	PRTFE	ME	W/A	MT	GG	RHNS	MAX				
0.2101E 04	0.7047F 01	0.1184E 03	0.2911E 02	0.4087E 00	0.1033E 01	0.6994E-01	0.3790E 00				
PHI	AI	VT	CTMT	BETAG	PHIP						
0.2417E 00	0.1098E 04	0.4489E 03	0.1681E 03	0.6684E 02	0.5049E 00						
0.9733	0.5667	0.9269	0.7309	0.5156	1.0000						
*** CHOKE ***											
0.5693	0.9888	0.9269	0.7309	0.5156	1.0000						
*** CHOKE ***											
URMS	PF	PSI	EFFH	DQ	RNMIT	T04	T03D				
0.3890E 03	0.5041F-01	0.7823E 00	0.9173E 00	0.7053E-01	0.9634E 00	0.9584E 03	0.9473E 03				
T03	P03	U	DRMS	EPS	CSF	PRDLE	CPT35				
0.9356E 03	0.1480E 05	0.1722E 04	0.3366E 00	0.1937E 01	0.9032E 00	0.6572E 01	0.7439E 00				
RC35	ET35	DP35	DPO	PSTH	ETS	NS	RCS				
0.6180E 01	0.7959E 00	0.5963E-01	-0.1259F 00	0.3440E 01	0.1547E 00	0.2754F 03	0.1546E 01				
MEXT	MDLE	DOX	TRF	EFFI	DPOP	PSLE	D10F				
0.1229F 01	0.9375F 00	0.4776F-01	0.9006E 00	0.8687E 00	0.6448E-01	0.3725F 01	0.6602E 00				
EFFIM	MG	MODEX	DPTD	ALPHD	ALPLE	A*/A	ET15				
0.8286E 00	0.1261F 01	0.1205E 01	0.1949E-01	0.1529E 02	0.1884E 02	0.1298E 01	0.7651E 00				
VTH4	VR	MTNR	BTHR	RDPTH	POEXT	RDPKX	CCPA				
0.1516E 04	0.5724E 03	0.9919E 00	0.9866E 00	0.1849E-01	0.5847E 01	0.1104E 00	0.6857E 00				

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 90

DATA							
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01
O1	D1/D2	N	W	D3	ALPHA	IGV	8H
0.2000E 00	0.4630E 00	0.5043E 05	0.3261E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3010E-01
BFI	BLH	BLM	BLTH	HR	VRATL	CPA	C2
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0
NO OF BLADES	AD	RH2	UD	PHIPD	WD	ALPS	C7
0.3200E 02	0.1410E-01	0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1050E 01
C8	C9	C10	C11	C12	C13	RNMCR	CMT
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00
RESULTS							
POP	PRTE	HE	W/A	MT	GG	RHOS	MAX
0.2101E 04	0.7040E 01	0.1184E 03	0.2475E 02	0.4025E 00	0.1032E 01	0.7012E-01	0.3732E 00
PHI	AI	VT	CTMT	BETAG	PHIP		
0.2382E 00	0.1099E 04	0.4423E 03	0.1657E 03	0.6719E 02	0.4976E 00		
0.9734	0.9866	0.9285	0.5558	1.0000			
0.9684	0.9880	0.9285	0.5358	1.0000			
*** CHOKE ***							
URMS	PF	PSI	EFFH	DQ	RMMIT	TD4	TD3D
0.8888E 03	0.4968E-01	0.7821E 00	0.9155E 00	0.7222E-01	0.9627E 00	0.9592E 03	0.9480E 03
TO3	PO3	U	DRMS	EPS	CSF	PRDLE	CPT35
0.9361E 03	0.1479E 05	0.1722E 04	0.3366E 00	0.1937E 01	0.9040E 00	0.6563E 01	0.7462E 00
RC35	ET35	NP35	DPO	PSTH	ETS	NS	RCS
0.6171E 01	0.7936E 00	0.5975E-01	-0.1401E 00	0.3406E 01	0.7925E 00	0.8036E 02	-0.6136E 01
MEXIT	MOLE	DOX	TRF	EFFI	DROP	PSLE	DIBF
0.1229E 01	0.9367E 00	0.4827E-01	0.9026E 00	0.8665E 00	0.6523E-01	0.3727E 01	0.6572E 00
EFFIM	MG	MDEX	NPYD	ALPHD	ALPLE	A*/A	ET15
0.8262E 00	0.1240E 01	0.1704E 01	0.1974E-01	0.1509E 02	0.1873E 02	0.1259E 01	0.7626E 00
VTH4	VR	MTHR	BTHR	ROPTH	POEXIT	ROPEX	CCPA
0.1517E 04	0.5655E 03	0.9992E 00	0.5867E 00	0.1854E-01	0.5835E 01	0.1109E 00	0.6851E 00

TABLE A-1 (CONT)

CENT COMP INFLT CALC RC-2.7 90

DATA									
TRIG	DFLSF	CC	C3	C1	C5	C6	TRIGR		
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01		
D1	N1/D2	N	M	D3	ALPHA	IGV	BH		
0.2000F 00	0.4630F 00	0.5044E 05	0.3213F 01	0.6520F 00	0.2200F 02	0.2200F 02	0.3010F-01		
RF1	RLM	RLM	ALTM	RR	VRATO	CPA	C2		
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000F-01	0.0		
NO OF BLADES	AD	BH2	UC	PHIPD	WD	ALPS	C7		
0.3200E 02	0.1410F-01	0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640F 02	0.1050E 01		
C8	C9	C10	C11	C12	C13	RHWCR	CMT		
0.1050E 01	0.1500F 00	0.1900E 01	0.6500F-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00		
RESULTS									
POP	PRTTF	ME	W/A	MT	GG	RHDS	MAX		
0.2102E 04	0.7042E 01	0.1184E 03	0.2633E 02	0.3952E 00	0.1031E 01	0.7033E-01	0.3664E 00		
PHI	AI	VT	CTHT	BETAG	PHIP				
0.2339E 00	0.1099F 04	0.4344E 03	0.1627E 03	0.6762E 02	0.4887E 00				
0.9735	0.9867	0.9306	0.7173	0.5658	1.0000				
0.9686	0.9869	0.9306	0.7173	0.5658	1.0000				
URMS	PF	PSI	EFFH	DQ	RHMIT	T04	T030		
0.8890E 03	0.4879E-01	0.7818E 00	0.9131E 00	0.7445E-01	0.9623E 00	0.9607E 03	0.9493E 03		
T03	P03	U	DPMS	EPS	CSF	PRDLE	CPT35		
0.9373E 03	0.1480F 05	0.1722E 04	0.3366E 00	0.1937E 01	0.9050E 00	0.6559E 01	0.7055E 00		
RC35	ET35	DP35	DPO	PSTH	ETS	NS	RCS		
0.6196E 01	0.7937E 00	0.5529E-01	0.6817E-01	0.3883E 01	0.7449E 00	0.8287E 02	0.5718E 01		
MEXIT	MDLF	DOX	TRF	EFFI	DPOP	PSLE	DIBF		
0.1229E 01	0.9340E 00	0.4890E-01	0.9052E 00	0.8637E 00	0.6630E-01	0.3727E 01	0.6533E 00		
EFFIM	MC	MDX	DPTD	ALPHD	ALPLE	A0/A	ETIS		
0.8231E 00	0.1260F 01	0.1703E 01	0.2014E-01	0.1483E 02	0.1859E 02	0.7090E 00	0.7654E 00		
VTM4	VR	MTMR	BTHR	RDPTH	POCKIT	ROPEX	CCPA		
0.1518E 04	0.5664E 03	0.8833E 00	0.5849E 00	0.1653E-01	0.5873E 01	0.1015E 00	0.6943E 00		

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 90

DATA									
TRIG	DELSE	CC	C3	C1	C5	C6	TRIGR		
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01		
D1	D1/D2	N	W	D3	ALPHA	IGV	BM		
0.2000E 00	0.4630E 00	0.5040E 05	0.3126E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3010E-01		
BFI	RLM	RLM	BLTH	RR	VRATD	CPA	C2		
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0		
NO OF BLANKS	AP	RM2	UD	PHIPD	WD	ALPS	C7		
0.3200E 02	0.1410E-01	0.2600E-01	0.1011E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1050E 01		
C8	C9	LO	CL1	CL2	CL3	RNMCR	CMT		
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00		
RESULTS									
POP	PRTTF	HE	W/A	MT	GG	RHOS	MAX		
0.2102E 04	0.7018E 01	0.1182E 03	0.2756E 02	0.3821E 00	0.1029E 01	0.7070E-01	0.3543E 00		
PHI	AI	VT	CTHT	BETAG	PHIP				
0.2266E 00	0.1100E 04	0.4205E 03	0.1575E 03	0.6836E 02	0.4734E 00				
0.9737	0.9849	0.7043	0.6191	1.0000					
0.9691	0.9859	0.7043	0.6191	1.0000					
URMS	PF	PSI	EFFH	DO	RNMIT	T04	T03D		
0.8883E 03	0.4726E-01	0.7814E 00	0.9091E 30	0.7809E-01	0.9603E 00	0.9620E 03	0.9504E 03		
T03	P03	U	NRMS	EPS	CSF	PRDLE	CPT35		
0.9381E 03	0.1475E 05	0.1721E 04	0.3366E 00	0.1937E 01	0.9068E 00	0.6528E 01	0.6665E 00		
RC35	FT35	DP35	DPO	PSTH	ETS	NS	RCS		
0.4185E 01	0.7897E 00	0.5260E-01	0.2079E 00	0.4190E 01	0.7527E 00	0.8118E 02	0.5782E 01		
MEKIT	MDLF	DOX	TRF	EFFI	DPNP	PSLE	DIBF		
0.1230E 01	0.9343E 00	0.5006E-01	0.9096E 00	0.8591E 00	0.6804E-01	0.3718E 01	0.6462E 00		
FFFIW	MG	MDEX	DPTN	ALPHD	ALPLF	AP/A	ET15		
0.8179E 00	0.1259E 01	0.1200E 01	0.2075E-01	0.1438E 02	0.1818E 02	0.8870E 00	0.7641E 00		
VTM4	VR	MTM9	ATHR	RQPTH	POEXIT	RDPXY	CCPA		
0.1519E 04	0.5606E 03	0.9070E 00	0.9837E 00	0.1483E-01	0.5904E 01	0.9558E-01	0.6992E 00		

TABLE A-1 (CONT)

CENT CCMP INLET CALC RC-2.7 90

DATA									
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR		
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01		
01	D1/D2	N	W	D3	ALPHA	IGV	BM		
0.2000E 00	0.4633E 00	0.5041E 05	0.3113E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3010E-01		
BF1	RLM	RLM	RLTH	RR	VRATD	CPA	C2		
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0		
NO OF BLADES	AN	RM2	UD	PHIPD	WD	ALPS	C7		
0.3200E 02	0.1410E-01	0.2400E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1050E 01		
C8	C9	C10	C11	C12	C13	RNMCR	CMT		
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00		
RESULTS									
POP	ORTTF	HE	W/A	MT	GC	RHOS	MAX		
0.2102E 04	0.7027E 01	0.1183E 03	0.2745E 02	0.3802E 00	0.1029E 01	0.7076E-01	0.3525E 00		
PH1	AI	VT	CTMT	RETAG	PHIP				
0.2254E 00	0.1101E 04	0.4184E 03	0.1567E 03	0.6847E 02	0.4709E 00				
0.9737	0.9837	0.7018	0.6267	1.0000					
0.9692	0.9858	0.7018	0.6267	1.0000					
URMS	PF	PSI	EFFH	DQ	RNMIT	TD4	TD3D		
0.8845E 03	0.4702E-01	0.7813E 00	0.9084E 00	0.7878E-01	0.9606E 00	0.9626E 03	0.9510E 03		
TD3	PD3	U	DRMS	EPS	CSF	PRDLE	CPT35		
0.9386E 03	0.1476E 05	0.1721E 04	0.3366E 00	0.1937E 01	0.9071E 00	0.6529E 01	0.6599E 00		
RC35	ET35	DP35	DPQ	PSTH	ETS	NS	ACS		
0.6188E 01	0.7889E 00	0.5234E-01	0.2276E 00	0.4235E 01	0.7525E 00	0.8096E 02	0.5791E 01		
MEXIT	MDLF	DOX	TRF	EEFI	DPOP	PSLE	DIBF		
0.1230E 01	0.9341E 00	0.5024E-01	0.9103E 00	0.8583E 00	0.6843E-01	0.3718E 01	0.6450E 00		
EFFIM	MG	WDEK	OPTD	ALPHD	ALPLE	AA/A	ETIS		
0.9170E 00	0.1259E 01	0.1200E 01	0.2091E-01	0.1430E 02	0.1834E 02	0.8966E 00	0.7636E 00		
VTM4	VR	MTMD	ATHR	RDPTH	POEXIT	ROPFY	CCPA		
0.1520E 04	0.5600E 03	0.7965E 00	0.9836E 00	0.1459E-01	0.5910E 01	0.9486E-01	0.6997E 00		

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 96

DATA											
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR				
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01				
01	01/02	N	W	03	ALPHA	IGV	BM				
0.2000E 00	0.4630E 00	0.4815E 05	0.2980E 01	0.6520E 00	0.2230E 02	0.2200E 02	0.3020E-01				
BFI	BLW	PLM	BLTH	RR	VRATD	CPA	C2				
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0				
N7 OF BLADES	AD	RM2	UD	PHIPD	WD	ALPS	C7				
0.3200E 02	0.1410E-01	0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1049E 01				
C8	C9	C10	C11	C12	C13	RNMCR	CMY				
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00				
RESULTS											
POP	PRTE	HE	W/A	MT	GG	RLOS	MAX				
0.2103E 04	0.6177E 01	0.1079E 03	0.2629E 02	0.3609E 00	0.1026E 01	0.7120E-01	0.3346E 00				
PHI	AI	VT	CTMT	BETAG	PHIP						
0.2243E 00	0.1102E 04	0.3977E 03	0.1490E 03	0.6858E 02	0.4687E 00						
0.9753	0.9836	0.9359	0.7363	0.7461	0.9800						
*** CHNKE ***	0.9359	0.7383	0.7461	0.5404	0.9800						
*** CHNKE ***	0.9359	0.7383	0.7461	0.5404	0.9800						
URMS	PF	PSI	EFFH	DQ	RNMIT	T04	T03D				
0.8486E 03	0.4679E-01	0.7844E 00	0.9169E 00	0.7112E-01	0.9162E 00	0.9226E 03	0.9118E 03				
T03	PN3	U	DRMS	EPS	CSF	PROLE	CPT35				
0.9004E 03	0.1299E 05	0.1644E 04	0.3366E 00	0.1937E 01	0.9023E 00	0.5799E 01	0.7472E 00				
RC35	ET35	DP35	DPQ	PSTH	ETS	NS	RCS				
0.5469E 01	0.7946E 00	0.5675E-01	-0.1856E 00	0.3037E 01	0.2305E-01	0.1112E 04	0.1065E 01				
MEXIT	MDLE	DOX	TRF	EFFI	DPOP	PSLE	DIBF				
0.1209E 01	0.9074E 00	0.5083E-01	0.9063E 00	0.8654E 00	0.5897E-01	0.3401E 01	0.6639E 00				
EFFIM	MG	MDEX	DPTD	ALPHD	ALPLE	AS/A	ETIS				
0.8271E 00	0.1209E 01	0.1141E 01	0.1604E-01	0.1503E 02	0.1890E 02	0.1177E 01	0.7621E 00				
VTM4	VR	MTMR	8TMR	RDPTH	POEXIT	ROPEX	CCPA				
0.1446E 04	0.5273E 03	0.9926E 00	0.9876E 00	0.1707E-01	0.5173E 01	0.1077E 00	0.6775E 00				

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 RA

DATA									
TRIG	DELSE	CC	C3	C1	C5	C6	TRIGR		
0.1000F 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850F 02	0.1500E 01		
01	0.1/D2	N	W	D3	ALPHA	IGV	BH		
0.2000E 00	0.4630F 00	0.4821E 05	0.2939E 01	0.6520F 00	0.2200F 02	0.2200F 02	0.3020E-01		
RFI	RLM	RLM	BLTH	RR	VRAID	CPA	C2		
0.0	0.9503E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0		
NO OF BLADES	AN	BM2	UD	PHIPD	WD	ALPS	C7		
0.3200E 02	0.1410E-01	0.2600E-01	0.1919E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1049E 01		
CR	C9	C10	C11	C12	C13	RNMCR	CMT		
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00		
RESULTS									
POP	PRTE	PE	W/A	MT	GG	RWOS	MAX		
0.2103E 04	0.6199E 01	0.1082E 03	0.2592E 02	0.3549E 00	0.1025E 01	0.7144E-01	0.3290E 00		
PHI	AI	VT	CTHT	BETAG	PHIP				
0.2204E 00	0.1103E 04	0.3913E 03	0.1466E 03	0.6898E 02	0.4604E 00				
0.9751	0.9076	0.9374	0.7301	0.8034	0.5363				
0.9707	0.9885	0.9374	0.7301	0.8034	0.5363				
URMS	PF	PSI	EFFH	DQ	RNHIT	T04	T03D		
0.8497E 03	0.4557E-01	0.7842F 00	0.9146E 00	0.7319E-01	0.9171F 00	0.9251E 03	0.9139F 03		
T03	P03	U	NRMS	EPS	CSF	PROLE	CPT35		
0.9022E 03	0.1304F 05	0.1646E 04	0.3366E 00	0.1937E 01	0.9033E 00	0.5813E 01	0.7360E 00		
RC35	FT35	OP35	DPQ	PSTH	ETS	NS	RCS		
0.5489E 01	0.7919E 00	0.5572E-01	-0.1213E 00	0.3171E 01	0.6999E 00	0.8501E 02	0.4676E 01		
HEXIT	MDLF	X	TRF	EFFI	DPOP	PSLE	DIBF		
0.1210E 01	0.9074E 00	0.5210E-01	0.9005E 00	0.8622E 00	0.6009E-01	0.3409E 01	0.6578E 00		
EFFIM	MG	MDFX	DPID	ALPHD	ALPLE	AS/A	ET15		
0.9236E 00	0.1209E 01	0.1160E 01	0.1639E-01	0.1476E 02	0.1879E 02	0.1297E 01	0.7605E 00		
VTM4	VR	WTHR	ATHR	RDPH	POEXIT	ROPEX	CCPA		
0.1449E 04	0.5245F 03	0.9576E 00	0.9871E 00	0.1660E-01	0.5201E 01	0.1052E 00	0.6798E 00		

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 86

DATA									
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR		
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.650E 02	0.1500E 01		
D1	D1/D2	N	W	D3	ALPHA	IGV	BH		
0.2000E 00	0.4633E 00	0.4817E 05	0.2923E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3020E-01		
RFI	RLH	RLM	RLTH	RR	VRATD	CFA	C2		
0.0	0.9500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0		
NO OF BLADES	AD	RM2	UD	PHIPD	WD	ALPS	C7		
0.3200E 02	0.1410E-01	0.2600E-01	0.1919E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1049E 01		
C8	C9	C10	C11	C12	C13	RMCR	CMT		
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.3700E 00	0.5440E 00		
RESULTS									
PUMP	PRTTE	WE	W/A	MT	GG	RHOS	MAX		
0.2103E 04	0.4193E 01	0.1080E 03	0.2577E 02	0.3526E 00	0.1025E 01	0.7150E-01	0.3269E 00		
PHI	AI	VT	CTHT	BETAG	PHIP				
0.2192E 00	0.1103E 04	0.3088E 03	0.1456E 03	0.6910E 02	0.4580E 00				
0.9753	0.5871	0.7287	0.8215	0.9998					
0.9707	0.9883	0.7287	0.8215	0.9998					
URMS	PF	PSI	EFFH	DO	RNMIT	TO4	TO3D		
0.8430E 03	0.4572E-01	0.7842E 00	0.9142E 00	0.7363E-01	0.9162E 00	0.9247E 03	0.9135E 03		
TO3	PQ3	U	DRMS	EPS	CSF	PROLE	CPT35		
0.9017E 03	0.1301E 05	0.1644E 04	0.3366E 00	0.1937E 01	0.9035E 00	0.5797E 01	0.7255E 00		
RC35	ET35	DP35	DPQ	PSTH	ETS	MS	RCS		
0.5481E 01	0.7917E 00	0.5461E-01	-0.6615E-01	0.3273E 01	0.7321E 00	0.8195E 02	0.4943E 01		
WFXIT	MDLE	DOX	TRF	EFFI	DPNP	PSLE	D18F		
0.1210E 01	0.9067E 00	0.5244E-01	0.9103E 00	0.8615E 00	0.6020E-01	0.3403E 01	0.6566E 00		
FFFI4	MS	WDEY	DPD	ALPHD	ALPLE	AO/A	ET15		
0.4228E 00	0.1209E 01	0.1159E 01	0.1640E-01	0.1471E 02	0.1876E 02	0.1716E 01	0.7612E 00		
VT44	VR	MTHP	ATHR	RDPHT	POFXT	RDPFX	CCPA		
0.1448E 04	0.5231E 03	0.9272E 00	0.9866E 00	0.1611E-01	0.5201E 01	0.1028E 00	0.6819E 00		

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 R6

DATA											
TRIG	DELSE	CC	C3	C1	C5	C6	TRIGR				
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01				
N1	N1/N2	N	W	D3	ALPHA	IGV	BM				
0.2000E 00	0.4630E 00	0.4874E 05	0.2870E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3020E-01				
RFI	RLW	RLW	BLTH	RR	VRATD	CPA	C2				
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0				
NO OF BLADES	AD	RH2	UD	PHIPD	WD	ALPS	C7				
0.3200E 02	0.1410E-01	0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1049E 01				
CR	C9	CLN	CL1	CL2	CL3	RNMCR	CMT				
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00				
RESULTS											
PMP	PRTTF	MF	W/A	MT	GG	RHOS	MAX				
0.2104E 04	0.6200E 01	0.1383E 03	0.2531E 02	0.3451E 00	0.1024E 01	0.7169E-01	0.3200E 00				
PHI	AI	VT	CTHT	BETAG	PHIP						
0.2144E 00	0.1103E 04	0.3807E 03	0.1426E 03	0.6959E 02	0.4478E 00						
0.9753	0.5866	0.9399	0.7182	0.8522	1.0000						
0.9708	0.9873	0.9399	0.7182	0.8582	1.0000						
IRMS	PF	PSI	EFFH	DQ	RNMIT	T04	T03D				
0.8502E 03	0.4471E-01	0.7839E 00	0.9113E 00	0.7627E-01	0.9172E 00	0.9273E 03	0.9159E 03				
T03	P03	U	DRMS	EPS	CSF	PROLE	CPT35				
0.9039E 03	0.1306E 05	0.1647E 04	0.3366E 00	0.1937E 01	0.9049E 00	0.5811E 01	0.6874E 00				
RC35	FT35	DP35	DPQ	PSTH	ETS	NS	RCS				
0.5514E 01	0.7901E 00	0.5124E-01	0.1044E 00	0.3616E 01	0.7490E 00	0.7955E 02	0.5135E 01				
WEXIT	WOLE	DOX	TRF	EFFI	DPOP	PSLF	DIBF				
0.1211E 01	0.9067E 00	0.5330E-01	0.9135E 00	0.8582E 00	0.6165E-01	0.3411E 01	0.6496E 00				
FEELW	WG	WDEX	NPTD	ALPHD	ALPLF	A0/A	ET15				
0.8189E 00	0.1200E 01	0.1159E 01	0.1688E-01	0.1436E 02	0.1859E 02	0.7974E 00	0.7623E 00				
VTH4	VR	MTWR	RTHR	RDPTH	POEXIT	RDPYX	CCPA				
0.1452E 04	0.5199E 03	0.8378E 00	0.9952E 00	0.1456E-01	0.5256E 01	0.9566E-01	0.6894E 00				

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 RO

DATA											
TRIG	0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5950E 02	0.1500E 01	TRIGR	0.1500E 01	
D1	0.2000E 00	0.4630E 00	0.4483E 05	0.2520E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3040E-01	BH		
RFI	0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0	C2		
NO OF BLADES	0.3200E 02	0.1410E-01	0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1035E 01	C7		
CA	0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00	CMT		
RESULTS											
POP	0.2105E 04	0.5120E 01	0.9355E 02	0.2227E 02	0.2982E 00	0.1018E 01	0.7283E-01	0.2755E 00	MAX		
PHI	0.1959E 00	0.1107E 04	0.3300E 03	0.1236E 03	0.7104E 02	0.4176E 00					
*** CHOKE ***	0.9653E-01	0.9441	0.7480	1.1815	0.5089	0.9540					
0.9599	0.9454	0.9441	0.7489	1.1815	0.5089	0.9540					
*** CHOKE ***											
URMS	0.7901E 03	0.4170E-01	0.7883E 00	0.9176E 00	0.7083E-01	0.6508E 00	0.8734E 03	0.8628E 03	T03D		
T03	0.8517E 03	0.1078E 05	0.1530E 04	0.3366E 00	0.1937E 01	0.9009E 00	0.4842E 01	0.7331E 00	CPT35		
RC35	0.4504E 01	0.7799E 00	0.6979E-01	0.3001E 00	0.2521E 01	0.3908E-01	0.7082E 03	0.1097E 01	RCS		
MEXIT	0.1141E 01	0.4608E 00	0.5692E-01	0.9160E 00	0.8606E 00	0.5193E-01	0.2986E 01	0.6634E 00	DIBF		
EFFIM	0.8241E 00	0.1131E 01	0.1093E 01	0.1172E-01	0.1447E 02	0.1886E 02	0.1160E 01	0.7448E 00	ETIS		
VTM4	0.1345E 04	0.4609E 03	0.9920E 00	0.9830E 00	0.2349E-01	0.4261E 01	0.1200E 00	0.6209E 00	CCPA		

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 80

DATA									
TRIG	DELSE	CC	C3	C1	C5	C6	TRIG		
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01		
01	01/02	N	W	D3	ALPHA	IGV	0H		
0.2000E 00	0.4633E 00	0.4483E 05	0.2485E 01	0.6523E 00	0.2200E 02	0.2200E 02	0.3040E-01		
BFI	BLM	OLM	RLTH	RR	VRATD	CPA	C2		
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0		
NO OF BLADES	AD	RH2	UN	PHIPD	WJ	ALPS	C7		
0.3200E 02	0.1410E-01	0.2600E-01	0.1919E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1035E 01		
CR	C9	C10	C11	C12	C13	RNMCR	CMT		
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00		
RESULTS									
POP	PRITE	HE	W/A	MT	GG	RHOS	MAX		
0.2105E 04	0.5120E 01	0.9355E 02	0.2191E 02	0.2928E 00	0.1017E 01	0.7292E-01	0.2715E 00		
PHI	AI	VT	CTMT	RETAG	PHIP				
0.1963E 00	0.1107E 04	0.3241E 03	0.1214E 03	0.7139E 02	0.4102E 00				
0.9654	0.9830	0.7420	0.9450	0.5047	0.9693				
0.9596	0.9837	0.7420	0.9450	0.5047	0.9693				
URMS	PF	PSI	EFTH	DQ	RNMIT	TO4	Y03D		
0.7901E 03	0.4095E-01	0.7983E 00	0.9158E 00	0.7249E-01	0.8508E 00	0.8746E 03	0.8637E 03		
TO3	PJ3	IJ	DRWS	EPS	CSF	PRDLE	CPT35		
0.8523E 03	0.1078E 05	0.1530E 04	0.3366E 00	0.1937E 01	0.9018E 00	0.4839E 01	0.7169E 00		
RC35	ET35	DP35	DPQ	PSTH	ETS	NS	RCS		
0.4509E 01	0.7779E 00	0.5824E-01	-0.2102E 00	0.2661E 01	0.6988E 00	0.8053E 02	0.3972E 01		
MEXIT	MDLF	DOX	TRF	EFFI	DPOP	PSLE	DI0F		
0.1142E 01	0.8600E 00	0.5830E-01	0.9191E 00	0.8577E 00	0.5270E-01	0.2988E 01	0.6584E 00		
EFFTH	MG	MODEX	DPTD	ALPHD	ALPLE	A0/A	ET15		
0.8209E 00	0.1131E 01	0.1092E 01	0.1188E-01	0.1423E 02	0.1877E 02	0.1245E 01	0.7443E 00		
VTM4	VR	MTHR	BTHR	RDPTH	POEXIT	RDPX	CCPA		
0.1345E 04	0.4575E 03	0.9449E 00	0.9818E 00	0.2269E-01	0.4275E 01	0.1165E 00	0.6243E 00		

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 80

DATA									
TRIG	DELSE	CC	C3	C1	C5	C6	TRIGR		
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01		
01	D1/D2	N	W	D3	ALPHA	IGV	BM		
0.2000E 00	0.4430E 00	0.4430E 05	0.2449E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3040E-01		
RFI	RLW	RLM	BLTH	RR	VRAID	CPA	C2		
0.0	0.9500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0		
NO OF BLADES	AD	R42	UN	PHIPD	WD	ALPS	C7		
0.3200E 02	0.1410E-01	0.2600E-01	0.1918E 04	0.6250E 00	0.0950E 00	0.1640E 02	0.1035E 01		
CA	C9	C10	C11	C12	C13	RNMCP	CMT		
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00		
RESULTS									
PMP	PRTFE	ME	W/A	MT	GG	RHOS	MAX		
0.2105E 04	0.5117E 01	0.9351E 02	0.2159E 02	0.2879E 00	0.1017E 01	0.7303E-01	0.2670E 00		
PHI	AT	VT	CTMT	BETAG	PHIP				
0.1932E 00	0.1107E 04	0.2188E 03	0.1194E 03	0.7171E 02	0.4036E 00				
0.9654	0.9818	0.9459	0.7358	0.5011	0.9830				
0.9595	0.9825	0.9459	0.7358	0.5011	0.9830				
IRMS	PF	PSI	EFFM	DO	RNMIT	TO4	TO3D		
0.7499E 03	0.4029E-01	0.7883E 00	0.9142E 00	0.7395E-01	0.8507E 00	0.8755E 03	0.8644E 03		
T03	PQ3	U	GRMS	EPS	CSF	PRDLE	CPT35		
0.9527E 03	0.1077E 05	0.1530E 04	0.3366E 00	0.1937E 01	0.9026E 00	0.4633E 01	0.6854E 00		
RC35	ET35	DP35	DPQ	PSTH	ETS	NS	RCS		
0.4521E 01	0.7775E 00	0.6463E-01	-0.5635E-01	0.2837E 01	0.7296E 00	0.7721E 02	0.4188E 01		
WEXIT	WCE	WDX	T0E	EFFI	DPDP	PSLF	D18F		
0.1142E 01	0.9594E 00	0.5967E-01	0.9270E 00	0.8551E 00	0.5340E-01	0.2944E 01	0.6502E 00		
EFFIM	WG	WDFX	DPTN	ALPHD	ALPLE	A8/A	ET15		
0.4190E 00	0.1130E 01	0.1001E 01	0.1203E-01	0.1402E 02	0.1870E 02	0.3533E 01	0.7464E 00		
VTM4	VR	WTHD	ATHP	RDPTH	PDEXIT	PDPKX	CCPA		
0.1344E 04	0.4545E 03	0.8673E 00	0.9801E 00	0.2100E-01	0.4303E 01	0.1097E 00	0.6326E 00		

TABLE A-1 (CONT)

CENT COMP INLEY CALC PC-2.7 80

DATA									
TRIG	0.1000F 01	DELSE	CC	C3	C1	C5	C6	TRIGR	
		0.0	0.2000F 01	0.1200F 01	0.5000F-02	0.2500F 01	0.5850E 02	0.1500E 01	
C1	0.2000F 00	0.1702	N	W	D3	ALPHA	ICV	BH	
		0.4630F 00	0.4493F 05	0.2417E 01	0.6520F 00	0.2200F 02	0.2700F 02	0.3040E-01	
RFI	0.0	ALH	RLW	RLTH	RR	VRATD	CPA	C2	
		0.8500F 00	0.9400F 00	0.7300F 00	0.1221F 01	0.6000F 00	0.1000F-01	0.0	
NO OF BLADES	0.3200F 02	AD	RA2	UD	PHPD	WD	ALPS	C7	
		0.1410F-01	0.2400F-01	0.1919F 04	0.6250E 00	0.9750E 00	0.1640E 02	0.1035E 01	
CA	0.1050E 01	C9	C10	C11	C12	C13	RNMCB	CMT	
		0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00	
RESULTS									
POP	0.2105E 04	PRTF	WE	W/A	MT	GG	RHNS	MAX	
		0.5120E 01	0.9355F 02	0.2131F 02	0.2839E 00	0.1016F 01	0.7311E-01	0.2632E 00	
DHI	0.1905E 00	AT	VT	CTMT	BETAG	PHIP			
		0.1107F 04	0.3144E 03	0.1178E 03	0.7198E 02	0.3979E 00			
	0.9654	0.9801	0.9467	0.7300	1.3901	0.4979			
	0.9595	0.9814	0.9467	0.7300	1.3901	0.4979			
URMS	0.7901E 03	PF	PSI	EFTH	DO	RNMIT	T04	T03D	
		0.3973E-01	0.7983F 00	0.9129E 00	1.7530E-01	0.8510F 00	0.8766F 03	0.8653E 03	
TC3	0.8534E 03	PN3	U	NRMS	EPS	CSF	PRDLE	CPI35	
		0.1078E 05	0.1530E 04	0.3366F 00	0.1937E 01	0.9034E 00	0.4833E 01	0.6633E 00	
PC35	0.4527E 01	ET35	NP35	DPO	PSTH	ETS	NS	RCS	
		0.7759F 00	0.6335E-01	0.2634E-01	0.3025E 01	0.7322E 00	0.7634E 02	0.4222E 01	
MEXIT	0.1144F 01	MDLE	COY	TRF	EFFI	DPNP	PSLE	N10F	
		0.8592F 00	0.6091E-01	0.9245E 00	0.8527E 00	0.5410E-01	0.2985F 01	0.6443E 00	
EFFIM	0.8153F 03	MG	MDEX	DPTN	ALPHD	ALPLE	A*/A	ET15	
		0.1130F 01	0.1050E 01	0.1218F-01	0.1383E 02	0.1865E 02	0.3997E 00	0.7461E 00	
VTM4	0.1347E 04	VR	WTHR	BTMP	RDPTH	PDEXIT	RDPDX	CCPA	
		0.4521F 03	0.8265E 00	0.9791E 00	0.2002E-01	0.4317E 01	0.1067F 00	0.6355E 00	

TABLE A-1 (CONT)

CENT COMP INLET CALC PC-2.7 90

DATA									
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR		
0.1000E 01	0.0	0.2300E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5800E 02	0.1500E 01		
D1	0.1/02	N	M	D3	ALPHA	IGV	BH		
0.2000E 00	0.4663E 00	0.4402E 05	0.2367E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3040E-01		
BFI	RLM	RLM	RLTH	RR	VRATD	CPA	C2		
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.121E 01	0.6000E 00	0.1000E-01	0.0		
NO OF BLADES	AD	AM2	UD	PHIPD	WD	ALPS	C7		
0.3200E 02	0.1410E-01	0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1035E 01		
C8	C9	C10	C11	C12	C13	RNMCP	CMT		
0.1050E 01	0.1500E 00	0.1900E 01	0.4500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00		
RESULTS									
P/P	PATTF	HE	W/A	MT	GG	RHOS	MAX		
0.2106E 04	0.5117E 01	0.9351E 02	0.2087E 02	0.2774E 00	0.1015E 01	0.7325E-01	0.2572E 00		
PHI	AI	VT	CTHT	RETAG	PHIP				
0.1852E 00	0.1108E 04	0.3073E 03	0.1151E 03	0.7241E 02	0.3891F 00				
0.9655	0.9791	0.9481	0.7209	1.4555	1.0000				
0.4596	0.9809	0.9481	0.7239	1.4555	1.0000				
UPMS	PF	PSI	EFFH	DO	RNMIT	TO4	TO3D		
0.7899E 03	0.3994E-01	0.7403E 00	0.9106E 00	0.7738E-01	0.8509E 00	0.8778E 03	0.8662E 03		
T03	P03	II	DAMS	EPS	CSF	PROLE	CPT35		
0.8540E 03	0.1077E 05	0.1530E 04	0.3366E 00	0.1937E 01	0.9046E 00	0.4826E 01	0.6309E 00		
PC35	FT35	NP35	DPQ	PSTM	ETS	NS	RCS		
0.4524E 01	0.7731E 00	0.6227E-01	0.1239F 00	0.3173F 01	0.7328F 00	0.7531F 02	0.4242E 01		
WEXIT	WULE	POX	TAR	EFFI	DPDP	PSLE	DIRF		
0.1145E 01	0.8555E 00	0.4219E-01	0.9279E 00	0.8496E 00	0.5514E-01	0.2982E 01	0.6358E 00		
EFFIM	WG	WDEX	PTD	ALPHD	ALPLE	A*/A	ET15		
0.8117E 00	0.1130E 01	0.1009E 01	0.1242E-01	0.1354E 02	0.1855E 02	0.7641E 00	0.7450E 00		
VIM4	V4	WTH2	ATHR	ROPTH	POEXIT	RDPEX	CCPA		
0.1348E 04	0.4482E 03	0.7785E 00	0.5779E 00	0.1873E-01	0.4326E 01	0.1035F 00	0.6377E 00		

TABLE A-1 (CONT)

CENT (CMD IN) 17 JUL 68-20.7 85

TEST		REL		DATA			
0.1000E 01	0.2000E 01	0.3000E 01	0.4000E 01	0.5000E-02	C5	C6	TRIGR 01
0.2000E 00	0.4000E 00	0.6000E 00	0.8000E 00	0.9000E 00	ALPHA	IGV	RM
0.3000E 00	0.6000E 00	0.8000E 00	1.0000E 00	0.1221E 01	VRATD	CPA	C2
0.4000E 00	0.8000E 00	1.0000E 00	1.2000E 00	0.1640E 02	WD	ALPS	C7
0.5000E 01	0.1000E 00	0.1500E 00	0.2000E 00	0.3020E 00	C13	RNMCR	CMT
0.6000E 00	0.1500E 00	0.2000E 00	0.2500E 00	0.4024E 01	GG	RMOS	MAX
0.7000E 03	0.3014E-01	0.4024E-01	0.5038E-01	0.6052E-01	PHIP	PRDLE	0.2525E 00
0.8000E 03	0.4024E-01	0.5038E-01	0.6052E-01	0.7066E-01	CSF	NS	0.8672E 03
0.9000E 01	0.5038E-01	0.6052E-01	0.7066E-01	0.8078E-01	ETS	PSLF	CPT35
1.0000E 01	0.6052E-01	0.7066E-01	0.8078E-01	0.9090E-01	DPUP	0.5611E-01	0.6059E 00
1.1000E 01	0.7066E-01	0.8078E-01	0.9090E-01	0.1015E 01	ALPLF	0.8366E 00	0.4256E 01
1.2000E 01	0.8078E-01	0.9090E-01	0.1015E 01	0.1221E 01	POEXIT	0.1012E 00	0.6288E 00
1.3000E 01	0.9090E-01	0.1015E 01	0.1221E 01	0.1427E 00	0.4336E 01	0.1012E 00	0.7439E 00
1.4000E 01	0.1015E 01	0.1221E 01	0.1427E 00	0.1640E 02	0.1012E 00	0.1012E 00	0.6397E 00
1.5000E 01	0.1221E 01	0.1427E 00	0.1640E 02	0.1856E 02	0.1012E 00	0.1012E 00	0.6397E 00
1.6000E 01	0.1427E 00	0.1640E 02	0.1856E 02	0.2072E 02	0.1012E 00	0.1012E 00	0.6397E 00
1.7000E 01	0.1640E 02	0.1856E 02	0.2072E 02	0.2288E 02	0.1012E 00	0.1012E 00	0.6397E 00
1.8000E 01	0.1856E 02	0.2072E 02	0.2288E 02	0.2504E 02	0.1012E 00	0.1012E 00	0.6397E 00
1.9000E 01	0.2072E 02	0.2288E 02	0.2504E 02	0.2720E 02	0.1012E 00	0.1012E 00	0.6397E 00
2.0000E 01	0.2288E 02	0.2504E 02	0.2720E 02	0.2936E 02	0.1012E 00	0.1012E 00	0.6397E 00
2.1000E 01	0.2504E 02	0.2720E 02	0.2936E 02	0.3152E 02	0.1012E 00	0.1012E 00	0.6397E 00
2.2000E 01	0.2720E 02	0.2936E 02	0.3152E 02	0.3368E 02	0.1012E 00	0.1012E 00	0.6397E 00
2.3000E 01	0.2936E 02	0.3152E 02	0.3368E 02	0.3584E 02	0.1012E 00	0.1012E 00	0.6397E 00
2.4000E 01	0.3152E 02	0.3368E 02	0.3584E 02	0.3800E 02	0.1012E 00	0.1012E 00	0.6397E 00
2.5000E 01	0.3368E 02	0.3584E 02	0.3800E 02	0.4016E 02	0.1012E 00	0.1012E 00	0.6397E 00
2.6000E 01	0.3584E 02	0.3800E 02	0.4016E 02	0.4232E 02	0.1012E 00	0.1012E 00	0.6397E 00
2.7000E 01	0.3800E 02	0.4016E 02	0.4232E 02	0.4448E 02	0.1012E 00	0.1012E 00	0.6397E 00
2.8000E 01	0.4016E 02	0.4232E 02	0.4448E 02	0.4664E 02	0.1012E 00	0.1012E 00	0.6397E 00
2.9000E 01	0.4232E 02	0.4448E 02	0.4664E 02	0.4880E 02	0.1012E 00	0.1012E 00	0.6397E 00
3.0000E 01	0.4448E 02	0.4664E 02	0.4880E 02	0.5096E 02	0.1012E 00	0.1012E 00	0.6397E 00
3.1000E 01	0.4664E 02	0.4880E 02	0.5096E 02	0.5312E 02	0.1012E 00	0.1012E 00	0.6397E 00
3.2000E 01	0.4880E 02	0.5096E 02	0.5312E 02	0.5528E 02	0.1012E 00	0.1012E 00	0.6397E 00
3.3000E 01	0.5096E 02	0.5312E 02	0.5528E 02	0.5744E 02	0.1012E 00	0.1012E 00	0.6397E 00
3.4000E 01	0.5312E 02	0.5528E 02	0.5744E 02	0.5960E 02	0.1012E 00	0.1012E 00	0.6397E 00
3.5000E 01	0.5528E 02	0.5744E 02	0.5960E 02	0.6176E 02	0.1012E 00	0.1012E 00	0.6397E 00
3.6000E 01	0.5744E 02	0.5960E 02	0.6176E 02	0.6392E 02	0.1012E 00	0.1012E 00	0.6397E 00
3.7000E 01	0.5960E 02	0.6176E 02	0.6392E 02	0.6608E 02	0.1012E 00	0.1012E 00	0.6397E 00
3.8000E 01	0.6176E 02	0.6392E 02	0.6608E 02	0.6824E 02	0.1012E 00	0.1012E 00	0.6397E 00
3.9000E 01	0.6392E 02	0.6608E 02	0.6824E 02	0.7040E 02	0.1012E 00	0.1012E 00	0.6397E 00
4.0000E 01	0.6608E 02	0.6824E 02	0.7040E 02	0.7256E 02	0.1012E 00	0.1012E 00	0.6397E 00
4.1000E 01	0.6824E 02	0.7040E 02	0.7256E 02	0.7472E 02	0.1012E 00	0.1012E 00	0.6397E 00
4.2000E 01	0.7040E 02	0.7256E 02	0.7472E 02	0.7688E 02	0.1012E 00	0.1012E 00	0.6397E 00
4.3000E 01	0.7256E 02	0.7472E 02	0.7688E 02	0.7904E 02	0.1012E 00	0.1012E 00	0.6397E 00
4.4000E 01	0.7472E 02	0.7688E 02	0.7904E 02	0.8120E 02	0.1012E 00	0.1012E 00	0.6397E 00
4.5000E 01	0.7688E 02	0.7904E 02	0.8120E 02	0.8336E 02	0.1012E 00	0.1012E 00	0.6397E 00
4.6000E 01	0.7904E 02	0.8120E 02	0.8336E 02	0.8552E 02	0.1012E 00	0.1012E 00	0.6397E 00
4.7000E 01	0.8120E 02	0.8336E 02	0.8552E 02	0.8768E 02	0.1012E 00	0.1012E 00	0.6397E 00
4.8000E 01	0.8336E 02	0.8552E 02	0.8768E 02	0.8984E 02	0.1012E 00	0.1012E 00	0.6397E 00
4.9000E 01	0.8552E 02	0.8768E 02	0.8984E 02	0.9199E 02	0.1012E 00	0.1012E 00	0.6397E 00
5.0000E 01	0.8768E 02	0.8984E 02	0.9199E 02	0.9415E 02	0.1012E 00	0.1012E 00	0.6397E 00
5.1000E 01	0.8984E 02	0.9199E 02	0.9415E 02	0.9630E 02	0.1012E 00	0.1012E 00	0.6397E 00
5.2000E 01	0.9199E 02	0.9415E 02	0.9630E 02	0.9846E 02	0.1012E 00	0.1012E 00	0.6397E 00
5.3000E 01	0.9415E 02	0.9630E 02	0.9846E 02	1.0061E 02	0.1012E 00	0.1012E 00	0.6397E 00
5.4000E 01	0.9630E 02	0.9846E 02	1.0061E 02	1.0277E 02	0.1012E 00	0.1012E 00	0.6397E 00
5.5000E 01	0.9846E 02	1.0061E 02	1.0277E 02	1.0492E 02	0.1012E 00	0.1012E 00	0.6397E 00
5.6000E 01	1.0061E 02	1.0277E 02	1.0492E 02	1.0708E 02	0.1012E 00	0.1012E 00	0.6397E 00
5.7000E 01	1.0277E 02	1.0492E 02	1.0708E 02	1.0923E 02	0.1012E 00	0.1012E 00	0.6397E 00
5.8000E 01	1.0492E 02	1.0708E 02	1.0923E 02	1.1139E 02	0.1012E 00	0.1012E 00	0.6397E 00
5.9000E 01	1.0708E 02	1.0923E 02	1.1139E 02	1.1354E 02	0.1012E 00	0.1012E 00	0.6397E 00
6.0000E 01	1.0923E 02	1.1139E 02	1.1354E 02	1.1570E 02	0.1012E 00	0.1012E 00	0.6397E 00
6.1000E 01	1.1139E 02	1.1354E 02	1.1570E 02	1.1785E 02	0.1012E 00	0.1012E 00	0.6397E 00
6.2000E 01	1.1354E 02	1.1570E 02	1.1785E 02	1.1999E 02	0.1012E 00	0.1012E 00	0.6397E 00
6.3000E 01	1.1570E 02	1.1785E 02	1.1999E 02	1.2215E 02	0.1012E 00	0.1012E 00	0.6397E 00
6.4000E 01	1.1785E 02	1.1999E 02	1.2215E 02	1.2429E 02	0.1012E 00	0.1012E 00	0.6397E 00
6.5000E 01	1.1999E 02	1.2215E 02	1.2429E 02	1.2644E 02	0.1012E 00	0.1012E 00	0.6397E 00
6.6000E 01	1.2215E 02	1.2429E 02	1.2644E 02	1.2858E 02	0.1012E 00	0.1012E 00	0.6397E 00
6.7000E 01	1.2429E 02	1.2644E 02	1.2858E 02	1.3073E 02	0.1012E 00	0.1012E 00	0.6397E 00
6.8000E 01	1.2644E 02	1.2858E 02	1.3073E 02	1.3287E 02	0.1012E 00	0.1012E 00	0.6397E 00
6.9000E 01	1.2858E 02	1.3073E 02	1.3287E 02	1.3501E 02	0.1012E 00	0.1012E 00	0.6397E 00
7.0000E 01	1.3073E 02	1.3287E 02	1.3501E 02	1.3716E 02	0.1012E 00	0.1012E 00	0.6397E 00
7.1000E 01	1.3287E 02	1.3501E 02	1.3716E 02	1.3930E 02	0.1012E 00	0.1012E 00	0.6397E 00
7.2000E 01	1.3501E 02	1.3716E 02	1.3930E 02	1.4144E 02	0.1012E 00	0.1012E 00	0.6397E 00
7.3000E 01	1.3716E 02	1.3930E 02	1.4144E 02	1.4358E 02	0.1012E 00	0.1012E 00	0.6397E 00
7.4000E 01	1.3930E 02	1.4144E 02	1.4358E 02	1.4572E 02	0.1012E 00	0.1012E 00	0.6397E 00
7.5000E 01	1.4144E 02	1.4358E 02	1.4572E 02	1.4786E 02	0.1012E 00	0.1012E 00	0.6397E 00
7.6000E 01	1.4358E 02	1.4572E 02	1.4786E 02	1.4999E 02	0.1012E 00	0.1012E 00	0.6397E 00
7.7000E 01	1.4572E 02	1.4786E 02	1.4999E 02	1.5213E 02	0.1012E 00	0.1012E 00	0.6397E 00
7.8000E 01	1.4786E 02	1.4999E 02	1.5213E 02	1.5427E 02	0.1012E 00	0.1012E 00	0.6397E 00
7.9000E 01	1.4999E 02	1.5213E 02	1.5427E 02	1.5640E 02	0.1012E 00	0.1012E 00	0.6397E 00
8.0000E 01	1.5213E 02	1.5427E 02	1.5640E 02	1.5854E 02	0.1012E 00	0.1012E 00	0.6397E 00
8.1000E 01	1.5427E 02	1.5640E 02	1.5854E 02	1.6067E 02	0.1012E 00	0.1012E 00	0.6397E 00
8.2000E 01	1.5640E 02	1.5854E 02	1.6067E 02	1.6281E 02	0.1012E 00	0.1012E 00	0.6397E 00
8.3000E 01	1.5854E 02	1.6067E 02	1.6281E 02	1.6494E 02	0.1012E 00	0.1012E 00	0.6397E 00
8.4000E 01	1.6067E 02	1.6281E 02	1.6494E 02	1.6708E 02	0.1012E 00	0.1012E 00	0.6397E 00
8.5000E 01	1.6281E 02	1.6494E 02	1.6708E 02	1.6921E 02	0.1012E 00	0.1012E 00	0.6397E 00
8.6000E 01	1.6494E 02	1.6708E 02	1.6921E 02	1.7135E 02	0.1012E 00	0.1012E 00	0.6397E 00
8.7000E 01	1.6708E 02	1.6921E 02	1.7135E 02	1.7348E 02	0.1012E 00	0.1012E 00	0.6397E 00
8.8000E 01	1.6921E 02	1.7135E 02	1.7348E 02	1.7562E 02	0.1012E 00	0.1012E 00	0.6397E 00
8.9000E 01	1.7135E 02	1.7348E 02	1.7562E 02	1.7775E 02	0.1012E 00	0.1012E 00	0.6397E 00
9.0000E 01	1.7348E 02	1.7562E 02	1.7775E 02	1.7989E 02	0.1012E 00	0.1012E 00	0.6397E 00
9.1000E 01	1.7562E 02	1.7775E 02	1.7989E 02	1.8202E 02	0.1012E 00	0.1012E 00	0.6397E 00
9.2000E 01	1.7775E 02	1.7989E 02	1.8202E 02	1.8416E 02	0.1012E 00	0.1012E 00	0.6397E 00
9.3000E 01	1.7989E 02	1.8202E 02	1.8416E 02	1.8629E 02	0.1012E 00	0.1012E 00	0.6397E 00
9.4000E 01	1.8202E 02	1.8416E 02	1.8629E 02	1.8843E 02	0.1012E 00	0.1012E 00	0.6397E 00
9.5000E 01	1.8416E 02	1.8629E 02	1.8843E 02	1.9056E 02	0.1012E 00	0.1012E 00	0.6397E 00
9.6000E 01	1.8629E 02	1.8843E 02	1.9056E 02	1.9270E 02	0.1012E 00	0.1012E 00	0.6397E 00
9.7000E 01	1.8843E 02	1.9056E 02	1.9270E 02	1.9483E 02	0.1012E 00	0.1012E 00	0.6397E 00
9.8000E 01	1.9056E 02	1.9270E 02	1.9483E 02	1.9697E 02	0.1012E 00	0.1012E 00	0.6397E 00
9.9000E 01	1.9270E 02	1.9483E 02	1.9697E 02	1.9910E 02	0.1012E 00	0.1012E 00	0.6397E 00
10.0000E 01	1.9483E 02	1.9697E 02	1.9910E 02	2.0124E 02	0.1012E 00	0.1012E 00	0.6397E 00

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 70

DATA														
TRIG	0.1000E 01	0.0	NELSF	CC	0.2000E 01	C3	0.1200F 01	C1	0.5000E-02	C5	C6	0.5850E 02	TRIGR	0.1500E 01
01	0.2000E 00	0.4630F 00	01/02	N	0.3919E 05	W	0.1919F 01	D3	0.6520E 00	ALPHA	IGV	0.2200E 02	BM	0.3080E-01
AFI	0.0	0.8500F 00	RLW	RLW	0.9400E 00	ALTH	0.7300F 00	RR	0.1221E 01	VRATD	CPA	0.1000F-01	C2	0.0
NO OF BLADES	0.3200E 02	0.1410E-01	AD	AM2	0.2600E-01	W	0.1918F 04	PHIPD	0.6250E 00	WD	ALPS	0.1640E 02	C7	0.1033E 01
CA	0.1050E 01	0.1500F 00	C9	C10	0.1900E 01	C11	0.6500F-01	C12	0.4500E-01	C13	RMCGR	0.8700E 00	CMT	0.5440E 00
RESULTS														
PQP	0.2106F 04	0.1722F 01	PRTTF	PE	0.7149E 02	W/A	0.1710F 02	MT	0.2236E 00	GG	RMOS	0.7426E-01	MAX	0.2073E 00
PHI	0.1721E 00	0.1111E 04	AI	VT	0.2493E 03	CTMT	0.5103F 02	RETAG	0.7382E 02	PHIP				
0.9850	0.9852	0.9486	0.7930	1.9886	0.4686	0.8742								
*** CHOKE ***	0.9612	0.9557	0.9486	0.7900	1.9886	0.4686	0.8742							
*** CHOKE ***														

STANDARD FIXUP TAKEN - EXECUTION CONTINUING

URMS	0.6907E 03	PF	0.3590E-01	PSI	0.7907E 00	EFFH	0.9199E 00	DQ	0.6887E-01	RNMIT	0.7437E 00	TD4	0.7936E 03	TD3D	0.7840E 03
TD3	0.7741F 03	PD3	0.7840F 04	U	0.1338E 04	PPMS	0.3366F 00	FPS	0.1937E 01	CSF	0.8956F 00	PRDLE	0.3562E 01	CPT35	0.7364E 00
RC35	0.2318F 01	FT35	0.7684E 00	DP35	0.6833E-01	DPQ	-0.5432E 03	PSTH	0.1845E 01	FTS	0.1143E 00	NS	0.2943E 03	RCS	-0.1229E 01
MFYIT	0.9911E 00	MDLE	0.7757E 00	NOX	0.6629E-01	TRF	0.9259F 00	EFFI	0.8540F 00	DPDP	0.4016E-01	PSLE	0.2393F 01	DIBF	0.6765E 00
EFFIM	0.9199F 00	MG	0.9999F 00	WJEX	0.5752F 00	DPTD	0.6283F-02	ALPHD	0.1407E 02	ALPLE	0.1896F 02	A2/A	0.1094E 01	ET15	0.7266E 00
VT46	0.1169E 04	VR	0.3674F 03	MTWP	0.5969F 00	RTWP	0.9836F 00	RDPTH	0.2277E-01	POEXIT	0.3138E 01	RDPFX	0.1189F 00	CCPA	0.5613F 00

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 70

DATA											
TRIG	0.1000E 01	DELSE	CC	C3	C1	C5	C6	TRIGR	0.1500E 01		
01	0.2000E 00	0.4633E 00	0.3018E 05	W	03	ALPHA	ICV	BW	0.3040E-01		
API	0.0	0.9500E 00	0.0400E 00	ALTM	RR	VRATD	CPA	C2	0.0		
NO OF BLADES	AD		RM2	UIN	PHIPD	W	ALPS	C7	0.1033E 01		
0.3200E 02	0.1410E-01		0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02				
C9	C9		C10	C11	C12	C13	RNMCR	CMT	0.5440E 00		
0.1050E 01	0.1500E 00	0.1900E 01	0.1900E 01	0.4500E-01	0.4500E-01	0.5000E-01	0.8700E 00				
RESULTS											
POP	PRTTF	HE	W/A	MT	GG	RHDS	MAX				
0.2106E 04	0.3720E 01	0.7145E 02	0.1666E 02	0.2174E 00	0.1009E 01	0.7436E-01	0.2016E 00				
PHI	AI	VT	CTMT	RETAG	PHIP						
0.1675E 00	0.1111E 04	0.2416E 03	0.9051E 02	0.7424E 02	0.3499E 00						
0.9459	0.9836	0.9486	0.7814	2.1483	0.4616	0.8957					
0.9606	0.9927	0.9486	0.7814	2.1483	0.4616	0.8957					
UPMS	PF	PSI	FFH	NO	RNMIT	T04	T03D				
0.6905E 03	0.3493E-01	0.7907E 00	0.9174E 00	0.7096E-01	0.7439E 00	0.7949E 03	0.7849E 03				
T03	P03	U	NPMS	EPS	CSF	PROLE	CPT35				
0.7746E 03	0.7836E 04	0.1330E 04	0.3366E 00	0.1937E 01	0.8966E 00	0.3557E 01	0.6834E 00				
RC35	FT35	NP35	NPQ	PSTH	ETS	NS	RCS				
0.3333E 01	0.7681E 00	0.6302E-01	-0.2383E 00	0.2152E 01	0.7123E 00	0.7335E 02	0.3093E 01				
MEXIT	MDLE	NOX	TRF	EFFI	DPOP	PSLE	DIBF				
0.9921E 00	0.7750E 00	0.6907E-01	0.9307E 00	0.8496E 00	0.4099E-01	0.2392E 01	0.6635E 00				
EFFIM	MC	MOEX	DPTD	ALPHD	ALPLE	A6/A	ETIS				
0.8151E 00	0.9989E 00	0.9737E 00	0.6345E-02	0.1374E 02	0.1988E 02	0.1237E 01	0.7314E 00				
VTM4	VP	MTHR	RTHR	RDPTH	POEXIT	ROPEX	CCPA				
0.1169E 04	0.3621E 03	0.8593E 00	0.9804E 00	0.2025E-01	0.3174E 01	0.1078E 00	0.5755E 00				

TABLE A-1 (CONT)

CENT CCMP INLET CALC RC-2.7 70

DATA							
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01
D1	D1/D2	N	M	D3	ALPHA	IGV	BM
0.2000E 00	0.4630E 00	0.3919E 05	0.1845E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3080E-01
RFI	RLM	RLM	RLTM	RR	VRATD	CPA	C2
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0
N OF BLADES	AN	RM2	UD	PHIPD	WD	ALPS	C7
0.3200E 02	0.1410E-01	0.2633E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1440E 02	0.1033E 01
C8	C9	C10	C11	C12	C13	RNMCR	CMT
0.1050E 01	0.1500E 00	0.1900E 01	0.4500E-01	0.4500E-01	0.5300E-01	0.8700E 00	0.5440E 00
RESULTS							
POP	PRTF	HE	W/A	MT	GG	RHDS	MAX
0.2106E 04	0.3722E 01	0.7140E 02	0.1627E 02	0.2121E 00	0.1009E 01	0.7444E-01	0.1966E 00
PHI	AT	VT	CTMT	BFTAG	PHIP		
0.1633E 00	0.1111E 04	0.2357E 03	0.8879E 02	0.7469E 02	0.3413E 00		

STANDARD FIXUP TAKEN, EXECUTION CONTINUING

0.9659	0.9804	0.9436	0.7729	2.3028	0.4555	0.9169					
0.9604	0.9814	0.9486	0.7729	2.3029	0.4555	0.9169					
URMS	PF	PSI	EEFM	DO	RNMIT	T04	T03D				
0.5707E 03	0.3437E-01	0.7907E 00	0.9155E 00	0.7296E-01	0.7444E 00	0.7964E 03	0.7860E 03				
T03	P03	U	DPMS	EPS	CSF	PRPLE	CPT35				
0.7753E 03	0.7843E 04	0.1338E 04	0.3366E 00	0.1937E 01	0.8977E 00	0.3556E 01	0.6433E 00				
RC35	FT35	NO35	NOQ	PSTM	ETS	NS	RCS				
0.3337E 01	0.1644E 00	0.6174E-01	-0.8786E-01	0.2303E 01	0.7156E 00	0.7196E 02	0.3124E 01				
MEKIT	WOLF	NOX	TRF	CFI	DPDP	PSLF	DINF				
0.5936E 00	0.7767E 00	0.7176E-01	0.9354E 00	0.8453E 00	0.4185E-01	0.2392E 01	0.6510E 00				
FFIM	MG	W3EX	ODTD	ALPHD	ALPLE	As/A	ETL5				
0.8104E 00	0.9985E 00	0.9729E 00	0.6435E-02	0.1344E 02	0.1882E 02	0.2009E 01	0.7306E 00				
VTM4	VR	WTHD	ATMP	QDPTH	PREFIX	RDPFX	CCPA				
0.1170E 04	0.3578E 03	0.7939E 00	0.5787E 00	0.1975E-01	0.3187E 01	0.1037E 00	0.5789E 00				

TABLE A-1 (CONT)

CENT COMP INFLT CALC 9C-2.7 70

DATA											
TRIG	0.1000E 01	DELSE	0.2700E 01	C3	0.1700E 01	C1	0.5000E-02	C5	0.2500E 01	C6	TRIGR
0.1000E 01	0.0		0.2700E 01		0.1700E 01		0.5000E-02		0.2500E 01		0.1500E 01
DI	0.2000E 00	0.4630E 00	0.3019E 05	W	0.1904E 01	D3	0.6520E 00	ALPHA	0.2200E 02	IGV	BM
0.2000E 00			0.3019E 05		0.1904E 01		0.6520E 00		0.2200E 02		0.3080E-01
AFI	0.3000E 02	0.1410E-01	0.2600E-01	UD	0.1719E 04	RA	0.1221E 01	VPATD	0.6000E 00	CDA	C2
0.3000E 02			0.2600E-01		0.1719E 04		0.1221E 01		0.6000E 00		0.0
NO OF BLADES	0.1050E 01	0.1500E 00	0.1900E 01	C10	0.6500E-01	C12	0.4500E-01	WD	0.9950E 00	ALPS	C7
0.1050E 01			0.1900E 01		0.6500E-01		0.4500E-01		0.9950E 00		0.1033E 01
								C13	0.5000E-01	RNMCR	CMT
									0.5000E-01		0.5440E 00
RESULTS											
PNP	0.2106E 04	0.3722E 01	0.7149E 02	W/A	0.1591E 02	MT	0.2071E 00	GG	0.1009E 01	RMOS	MAX
0.2106E 04			0.7149E 02		0.1591E 02		0.2071E 00		0.1009E 01		0.1920E 00
PHI	0.1595E 00	0.1112E 04	0.2302E 03	VT	0.8624E 02	8ETAG	0.7506E 02	PHIP	0.3333E 00		
0.1595E 00			0.2302E 03		0.8624E 02		0.7506E 02		0.3333E 00		

STANDARD FIXUP TAKEN, EXECUTION CONTINUING

0.9659 0.9797 0.9487 0.7647 2.4563
 C.9603 C.9805 0.9487 0.7647 2.4563

URMS	0.6907E 03	0.3324E-01	0.7907E 00	PSI	0.9135E 00	NO	0.7484E-01	RMMIT	0.7450E 00	TO4	TO3D
0.6907E 03			0.7907E 00		0.9135E 00		0.7484E-01		0.7450E 00		0.7869E 03
TD3	0.7759E 03	0.7840E 04	0.1338E 04	U	0.3366E 00	EPS	0.1937E 01	CSF	0.8988E 00	PROLE	CPT35
0.7759E 03			0.1338E 04		0.3366E 00		0.1937E 01		0.8988E 00		0.6095E 00
RC35	0.3337E 01	0.7613E 00	0.6090E-01	DP35	0.1427E-01	PSTM	0.2405E 01	ETS	0.7150E 00	MS	RCS
0.3337E 01			0.6090E-01		0.1427E-01		0.2405E 01		0.7150E 00		0.3136E 01
MEFIT	0.9948E 00	0.7743E 00	0.7442E-01	NOX	0.9399E 00	EFFI	0.8412E 00	DPDP	0.4267E-01	PSLE	DIBF
0.9948E 00			0.7442E-01		0.9399E 00		0.8412E 00		0.4267E-01		0.6391E 00
EFFIM	0.8059E 00	0.5980E 00	0.9720E 00	MDX	0.6522E-02	ALPHD	0.1316E 02	ALPLE	0.1878E 02	AS/A	ETLS
0.8059E 00			0.9720E 00		0.6522E-02		0.1316E 02		0.1878E 02		0.7287E 00
UTM4	0.1171E 04	0.3539E 03	0.7494E 00	MTHR	0.9775E 00	RDPTH	0.1766E-01	PNEXIT	0.3195E 01	RDPFY	CCPA
0.1171E 04			0.7494E 00		0.9775E 00		0.1766E-01		0.3195E 01		0.5809E 00

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 70				DATA			
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5450E 02	0.1500E 01
01	01/02	N	M	D3	ALPHA	IGV	BH
0.2000E 00	0.4630E 00	0.3920E 05	0.1738E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3080E-01
AFI	BLM	RLM	RLTH	RR	VRATD	CPA	C2
0.3	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0
NO OF BLADES		RH2	UP	PHIPD	WD	ALPS	C7
0.3200E 02	0.1410E-01	0.2400E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1660E 02	0.1033E 01
CR	C9	C10	C11	C12	C13	RHMC	CMT
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00
RESULTS							
PDP	PDTF	PE	W/A	WT	GC	RHOS	MAX
0.2106E 04	0.3724E 01	0.7153E 02	0.1533E 02	0.1991E 00	0.1008E 01	0.7464E-01	0.1846E 00
PHI	AI	VT	CTMT	RETAG	PHIP		
0.1534E 00	0.1112E 04	0.2214E 03	0.8295E 02	0.7567E 02	0.3205E 00		
IMC2511 SORT NEGATIVE ARGUMENTS=0.7604599E-02							
TRACEBACK RCJTINE CALLED FROM ISN REG. 14 REG. 15 REG. 0 REG. 1							
SORT	52364844	0036AC70	FFFFFEE4	00362980			
MAIN	00016849	013625A8	FD000008	00386FF8			
ENTRY POINT= 013625A8							
STANDARD FIXUP TAKEN, EXECUTION CONTINUING							
0.9659	0.9775	0.9448	0.7503	2.7293	0.4413	0.9729	
0.9601	0.9792	0.9489	0.7503	2.7293	0.4413	0.9729	
IPMS	PF	PST	FEEM	DQ	RNMIT	TD4	TD3D
0.4909E 03	0.3700E-01	0.7906E 00	0.9102E 00	0.7804E-01	0.7460E 00	0.8002E C3	0.7887E 03
TD3	PD3	"	DRMS	EPS	CSF	PRDLE	CPT35
0.7769E 03	0.7845E 04	0.1338E 04	0.3366E 00	0.1937E 01	0.9007E 00	0.3551E 01	0.5566E 00
RC35	FT35	PD35	PDQ	PSTM	ETS	NS	RCS
0.3339E 01	0.1547E 00	0.5959E-01	0.1462E 00	0.2536E 01	0.7120E 00	0.6941E 02	0.3150E 01
MEXIT	MULF	DOX	TRF	EFFI	DPOP	PSLF	DIBF
0.5971E 00	0.7740E 00	0.7916E-01	0.9478E 00	0.8341E 00	0.4415E-01	0.2389E 01	0.6186E 00
EFFIM	WC	WDEX	DPDN	ALPHD	ALPLE	A9/A	ETIS
0.7991E 00	0.3977E 00	0.9708E 00	0.6705E-02	0.1270E 02	0.1973E 02	0.7829E 00	0.7248E 00
VTM4	VP	WTHP	RTMR	RDPTH	POEXIT	RDPFX	CCPA
0.1173E 04	0.3479E 03	0.6922E 00	0.9759E 00	0.1619E-01	0.3206E 01	0.9711E-01	0.5844E 00

IMC9001 EXECUTION TERMINATING DUE TO ERROR COUNT FOR ERROR NUMBER 217

IMC2171 FINCS - END OF DATA SET ON UNIT 5

TABLE A-1 (CONT)

CENT COMP INFLT CALC RC-2.7 60

										Reproduced from best available copy.	
DATA											
TRIG	0.1000E 01	0.0	DELSE	CC	C3	C1	C5	C6	TRIGR		
	0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E 02	0.5000E 02	0.2500E 01	0.5850E 02	0.1500E 01		
D1	0.2000E 00	0.4630E 00	0.3361E 05	0.1545E 01	0.6520E 00	0.6520E 00	ALPHA	IGV	BM		
	0.2000E 00	0.4630E 00	0.3361E 05	0.1545E 01	0.6520E 00	0.6520E 00	0.2200E 02	0.2200E 02	0.3100E 01		
BFI	0.0	0.4500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.1221E 01	VRATD	CPA	C2		
	0.0	0.4500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.1221E 01	0.6000E 00	0.1000E 01	0.0		
NU OF BLADFS	0.3200E 02	0.1410E 01	0.2600E 01	0.1918E 04	0.6250E 00	0.6250E 00	WD	ALPS	C7		
	0.3200E 02	0.1410E 01	0.2600E 01	0.1918E 04	0.6250E 00	0.6250E 00	0.9950E 00	0.1640E 02	0.1046E 01		
CR	0.1050E 01	0.1500E 00	0.1900E 01	0.4500E 01	0.4500E 01	0.4500E 01	C13	RNMCR	CMT		
	0.1050E 01	0.1500E 00	0.1900E 01	0.4500E 01	0.4500E 01	0.4500E 01	0.5000E 01	0.8700E 00	0.5440E 00		
RESULTS											
PDP	0.2107E 04	0.2762E 01	0.5258E 02	0.1342E 02	0.1761E 00	0.1761E 00	GG	PHCS	MAX		
	0.2107E 04	0.2762E 01	0.5258E 02	0.1342E 02	0.1761E 00	0.1761E 00	0.1005E 01	0.7497E 01	0.1633E 00		
PHI	0.1584E 00	0.1113E 04	0.1960E 03	0.7342E 02	0.7518E 02	0.7518E 02	PHIP				
	0.1584E 00	0.1113E 04	0.1960E 03	0.7342E 02	0.7518E 02	0.7518E 02	0.3309E 00				
STANDARD FIXUP TAKEN, EXECUTION CONTINUING											
0.7779	0.0000	0.7541	0.8439	2.7125	0.4483	0.7489					
*** CHOKE ***											
0.9751	0.9907	0.9541	0.8499	2.7125	0.4483	0.7489					
*** CHOKE ***											
STANDARD FIXUP TAKEN, EXECUTION CONTINUING											
URMS	0.5923E 03	0.3303E 01	0.7043E 00	0.9296E 00	0.608E 01	0.608E 01	RNMIT	T04	T03D		
	0.5923E 03	0.3303E 01	0.7043E 00	0.9296E 00	0.608E 01	0.608E 01	0.6383E 00	0.7219E 03	0.7140E 03		
TC3	0.7059E 03	0.5917E 04	0.1147E 04	0.3365E 00	0.1937E 01	0.1937E 01	CSF	PRDLE	CPT35		
	0.7059E 03	0.5917E 04	0.1147E 04	0.3365E 00	0.1937E 01	0.1937E 01	0.4875E 00	0.2670E 01	0.7541E 00		
RC35	0.2532E 01	0.7753E 00	0.5175E 01	-0.8719E 00	0.1393E 01	0.1393E 01	ETS	NS	RCS		
	0.2532E 01	0.7753E 00	0.5175E 01	-0.8719E 00	0.1393E 01	0.1393E 01	0.3180E 00	0.1315E 03	-0.1508E 01		
WEXIT	0.8424E 00	0.4945E 00	0.7345E 01	0.9279E 00	0.8560E 00	0.8560E 00	DPNP	PSLE	DIBF		
	0.8424E 00	0.4945E 00	0.7345E 01	0.9279E 00	0.8560E 00	0.8560E 00	0.2961E 01	0.1952E 01	0.7137E 00		
EEFIM	0.8235E 00	0.8687E 00	0.8535E 00	0.3089E 02	0.1423E 02	0.1423E 02	ALPLE	A*/A	ET15		
	0.8235E 00	0.8687E 00	0.8535E 00	0.3089E 02	0.1423E 02	0.1423E 02	0.1922E 02	0.1043E 01	0.7227E 00		
VTM4	0.9941E 03	0.2971E 03	0.3979E 00	0.9995E 00	0.1459E 01	0.1459E 01	PNEXIT	RDPEV	CCPA		
	0.9941E 03	0.2971E 03	0.3979E 00	0.9995E 00	0.1459E 01	0.1459E 01	0.2395E 01	0.1032E 00	0.5217E 00		

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 60

DATA									
TRIG	0.1000E 01	DELFS	CC	C3	C1	C5	C6	TRIGR	
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01		
01	01/02	N	W	03	ALPHA	IGV	BH		
0.2000E 00	0.4630E 00	0.3359E 05	0.1538E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3100E-01		
3FI	BLM	RLM	RLTH	RR	VRATD	CPA	C2		
0.0	0.9500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0		
NO OF BLADES	AD	RH2	UN	PHIPD	04	ALPS	C7		
0.3200E 02	0.1410E-01	0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1046E 01		
C8	C9	C10	C11	C12	C13	RNMCR	CMT		
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00		
RESULTS									
POP	PRITE	HE	W/A	PT	GG	RHOS	MAX		
0.2107E 04	0.2759E 01	0.5252E 02	0.1356E 02	0.1753E 00	0.1006E 01	0.7498E-01	0.1625E 00		
PMI	AI	VT	CIHT	BETAG	PHIP				
0.1577E 00	0.1113E 04	0.1951E 03	0.7309E 02	0.7724E 02	0.3295E 00				

STANDARD FIXUP TAKEN , EXECUTION CONTINUING
 0.9779 0.9895 0.9540 0.9493 2.7418 0.4472 0.7509
 0.9750 0.9903 0.9540 0.8493 2.7418 0.4472 0.7509
 *** CHECKE ***

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

URMS	PF	PSI	EFFH	DQ	RNMT	TO4	TO30
0.5920E 03	0.3290E-01	0.7942E 00	0.9293E 00	0.6043E-01	0.6380E 00	0.7218E 03	0.7138E 03
TO3	PO3	U	DRMS	EPS	CSF	PRDLE	CPT35
0.7058E 03	0.5811E 04	0.1147E 04	0.2366E 00	0.1937E 01	0.8876E 00	0.2667E 01	0.7543E 00
RC35	ET35	DP35	DPQ	PSTH	ETS	NS	RCS
0.2529E 01	0.7744E 00	0.5193E-01	-0.9765E 00	0.1390E 01	0.4708E 00	0.7497E 02	-0.2262E 01
MEKIT	MDLE	DOX	TRF	EFFI	DPOP	PSLE	DI8F
0.8420E 00	0.6941E 00	0.7393E-01	0.9286E 00	0.8553E 00	0.2966E-01	0.1950E 01	0.7117E 00
EFFIM	MG	MDEX	DPTD	ALPHD	ALPLE	A*/A	ET12
0.8228E 00	0.8681E 00	0.8529E 00	0.3080E-02	0.1419E 02	0.1922E 02	0.1044E 01	0.7218E 00
VT44	VR	MTHR	BTHR	RDPTH	POEXIT	RDPX	CCPA
0.9935E 03	0.2961E 03	0.9989E 00	0.9895E 00	0.1468E-01	0.2391E 01	0.1035E 00	0.5206E 00

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 60

DATA									
TAIG	DELSF	CC	C3	C1	C5	C6	TRIGR		
0.1000E 01	0.0	0.2000E 01	0.1700E 01	0.5000E-02	0.2500E 01	0.5050E 02	0.1500E 01		
D1	D1/D2	N	W	C3	ALPHA	IGV	BH		
0.2000E 00	0.4630E 00	0.3363E 05	0.1504E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3100E-01		
BFI	RLH	RL4	BLTH	RR	VRATD	CPA	C2		
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0		
NO OF PLADFS	AD	RM2	UD	PHIPD	WD	ALPS	C7		
0.3200E 02	0.1410E-01	0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1046E 01		
C8	C9	C10	C11	C12	C13	RNMCR	CMT		
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00		
RESULTS									
PGP	PRTTF	HE	W/A	MT	GG	RHOS	MAX		
0.2107E 04	0.2765E 01	0.5264E 02	0.1326E 02	0.1713E 00	0.1006E 01	0.7503E-01	0.1588E 00		
PHI	AI	VT	CTHT	BETAG	PHIP				
0.1539E 00	0.1113E 04	0.1906E 03	0.7141E 02	0.7562E 02	0.3216E 00				

RESULTS

IHC2511 SQRT NEGATIVE ARGUMENT=-0.3127480E-01

TRACEBACK ROUTINE CALLED FROM ISN REG. 14 REG. 15 REG. 0 REG. 1

SQRT

52328984 0032CC70 FFFFFFFF 003269R0

MAIN

J0016968 013265A8 F0000008 00344AFF8

ENTRY POINT= 013265A8

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

0.9779	0.9895	0.9531	0.8431	2.9114	0.4402	0.7672
0.9747	0.9888	0.9531	0.8431	2.9119	0.4402	0.7679

URMS	PF	PST	EFFH	DQ	RNMIT	TO4	TO3D		
0.5927E 03	0.3211E-01	0.7943E 00	0.9276E 00	0.6196E-01	0.6393E 00	0.7232E 03	0.7150E 03		
TO3	P33	U	NRMS	EPS	CSF	PROLF	CPT35		
0.7066E 03	0.5824E 04	0.1148E 04	0.3366E 00	0.1937E 01	0.8884E 00	0.2671E 01	0.6981E 00		
PC35	ET35	DP35	NPO	PSTH	ETS	NS	RCS		
0.2545E 01	0.7751E 00	0.4729E-01	-0.4748E 00	0.1649E 01	0.7072E 00	0.7091E 02	0.2367E 01		
MEXIT	MDLE	DQX	TAF	EFFI	DPOP	PSLF	DIBF		
0.8438E 00	0.6842E 00	0.7666E-01	0.9329E 00	0.9514E 00	0.3026E-01	0.1953E 01	0.6983E 00		
FFFIM	MG	MDEX	UPTD	ALPHC	ALPLE	A* A	ET15		
0.9185E 00	0.8681E 00	0.8527E 00	0.3089E-02	0.1389E 02	0.1914E 02	0.1080F 01	0.7297E 00		
VT44	VR	MTHR	ATMP	RDPHT	POEXIT	RDPEX	CCPA		
0.5951E 03	0.2917E 03	0.8473E 00	0.9873E 00	0.1278E-01	0.2425E 01	0.9231F-01	0.5366E 00		

TABLE A-1 (CONT)

C*NT CCMP INLET CALC RC-2.7 60

DATA									
TRIG	0.1000E 01	0.0	DELFS	CC	C3	C1	C5	C6	TRIGR
				0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01
D1	0.2000E 00	0.4630F 00	U1/D2	N	W	D3	ALPHA	IGV	BH
				0.3363E 05	0.1469F 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3100E-01
BFI	0.0	0.8500E 00	BLH	BLM	BLTH	RR	VRATO	CPA	C2
				0.9400E 00	0.7300F 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0
NO OF BLADES	0.3200E 02	0.1410E-01	AD	RH2	UD	PHIPD	WD	ALPS	C7
				0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1046E 01
C8	0.1050E 01	C9	C10	C11	C12	C13	C13	RNMCR	CMT
		0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.5000E-01	0.8700E 00	0.5440F 00
RESULTS									
POP	0.2107E 04	PRTTE	HE	W/A	MT	GC	RHOS	MAX	
		0.2760E 01	0.5255E 02	0.1295E 02	0.1671E 00	0.1006E 01	0.7509E-01	0.1550E 00	
PHI	0.1504E 00	VT	CTI	BETAG	PHIP				
		0.1113E 04	0.1861E 03	0.6970E 02	0.7597E 02				
	0.9779	0.9873	0.9524	0.8380	3.0879	0.4341	0.7827		
	0.9746	0.9880	0.9524	0.8380	3.0879	0.4341	0.7827		
URMS	0.5922E 03	PF	PSI	EFFH	DQ	PNMIT	TO4	TO3D	
		0.3137E-01	0.7943E 00	0.9260E 00	0.6344E-01	0.6391E 00	0.7238E 03	0.7152E 03	
TG3	0.7065E 03	PN3	U	DRMS	EPS	CSF	PRDLF	CPT35	
		0.5814E 04	0.1147E 04	0.3366E 00	0.1937E 01	0.8891E 00	0.2666E 01	0.6634E 00	
RC35	0.2542E 01	ET35	DP35	DPQ	PSTH	FTS	NS	RCS	
		0.7717E 00	0.4663E-01	-0.3183E 00	0.1748E 01	0.7105E 00	0.6963E 02	0.2380E 01	
MEXIT	0.8437E 00	MDLE	DOX	TRF	EFFI	DPOP	PSLE	DIBF	
		0.6833E 00	0.7944E-01	0.9371E 00	0.8475E 00	0.3072E-01	0.1951E 01	0.6859E 00	
EFFIM	0.8143E 00	MG	MOEX	DPD	ALPHD	ALPLE	A*/A	ETIS	
		0.8667E 00	0.8511E 00	0.3083E-02	0.1364E 02	0.1908E 02	0.1121E 01	0.7291E 00	
VTM4	0.9946E 03	VR	MTHR	BTHR	RDPTH	POEXIT	RDPEX	CCPA	
		0.2875E 03	0.7986E 00	0.9863E 00	0.1192E-01	0.2429E 01	0.8905E-01	0.5378E 00	

TABLE A-1 (CONT)

(CENT COMP INLET CALC RC-2.7 60

DATA							
TRIG	DELSE	CC	C3	C1	C5	C6	TPICP
C.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01
01	01/02	N	W	03	ALPHA	IGV	BM
0.2000E 00	0.4630E 00	0.3359E 05	0.1358E 01	0.6520E 00	0.2700E 02	0.2700E 02	0.3100E-01
RFI	RLH	PLM	ALTH	PP	VPATD	CPA	C2
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0
NO OF BLADES	AD	RM2	UD	PHIPD	WD	ALPS	C7
0.3200E 02	0.1410E-01	0.2600E-01	0.1918E 04	0.6250E 00	0.9950E 00	0.1640E 02	0.1046E 01
C8	C9	C10	C11	C12	C13	RNMCR	CMT
0.1050E 01	0.1500E 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00
RESULTS							
PDP	PRATE	HE	W/A	MT	GG	RHOS	MAX
0.2107E 04	0.2759E 01	0.5252E 02	0.1197E 02	0.1541E 00	0.1005E 01	0.7524E-01	0.1429E 00
PHI	AI	VT	CTMT	BETAG	PHIP		
0.1388E 00	0.1114E 04	0.1716E 03	0.6430E 02	0.7711E 02	0.2899E 00		

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

0.9779	0.9849	0.9497	0.8174	3.7584	0.4134	0.8402					
0.9743	0.9862	0.9497	0.8174	3.7584	0.4134	0.8402					
URMS	PF	PSI	EFFH	DQ	PNNIT	TD4	TD3D				
0.5920E 03	0.2895E-01	0.7942E 00	0.9205E 00	0.6861E-01	0.6406E 00	0.7271E 03	0.7174E 03				
TD3	PO3	U	RMS	EPS	CSF	PRDLF	CPT35				
0.7079E 03	0.3811E 04	0.1147E 04	0.3366E 00	0.1937E 01	0.8918E 00	0.2660E 01	0.5502E 00				
RC35	ET35	DP35	CPQ	PSTM	ETS	NS	RCS				
0.2541E 01	0.7592E 00	0.4452E-01	0.1654E-01	0.1959E 01	0.7073E 00	0.6639E 02	0.2402E 01				
MEXIT	MDLE	DQA	TRF	EFFI	DPDP	PSLE	DIBF				
0.8460E 00	0.6819E 00	0.9011E-01	0.9330E 00	0.8334E 00	0.3265E-01	0.1948E 01	0.6418E 00				
FFFTM	MG	MDX	DPTC	ALPHD	ALPLE	A/A	ETIS				
0.7991E 00	0.3643E 00	0.8480E 00	0.3105E-02	0.1274E 02	0.1896E 02	0.3510E 00	0.7229E 00				
VTM4	VR	MTHR	BTHR	RDPH	POEXIT	RDPX	CCPA				
0.9957E 03	0.2737E 03	0.6642E 00	0.9840E 00	0.9858E-02	0.2443E 01	0.8137E-01	0.5434E 00				

TABLE A-1 (CONT)

CENT COMP INLET CALC RC-2.7 60

DATA											
TRIG	DELSF	CC	C3	C1	C5	C6	TRIGR				
0.1000E 01	0.0	0.2000E 01	0.1200E 01	0.5000E-02	0.2500E 01	0.5850E 02	0.1500E 01				
D1	D1/D2	N	M	D3	ALPHA	IGV	BM				
0.2000E 00	0.4630E 00	0.3358E 05	0.1277E 01	0.6520E 00	0.2200E 02	0.2200E 02	0.3100E-01				
BFI	BLM	BLM	BLTM	RR	VRATD	CPA	C2				
0.0	0.8500E 00	0.9400E 00	0.7300E 00	0.1221E 01	0.6000E 00	0.1000E-01	0.0				
NO OF BLADES	AD	BH2	UD	PHIPD	WD	ALPS	C7				
0.3200E 02	0.1410E-01	0.2400E-01	0.1918E 04	0.6250E 00	0.5950E 00	0.1640E 02	0.1046E 01				
C8	C9	C10	C11	C12	C13	RNMCR	CMT				
0.1050E 01	0.1500 00	0.1900E 01	0.6500E-01	0.4500E-01	0.5000E-01	0.8700E 00	0.5440E 00				
RESULTS											
POP	PRTF	ME	W/A	MT	GG	RHOS	MAX				
0.2107E 04	0.2757E 01	0.5249E 02	0.1126E 02	0.1447E 00	0.1004E 01	0.7535E-01	0.1341E 00				
PHI	AT	VT	CTMT	BETAG	PHIP						
0.1304E 00	0.1114E 04	0.1612E 03	0.6038E 02	0.7793E 02	0.2723E 00						
STANDARD FIXUP TAKEN , EXECUTION CONTINUING											
			</								

LIST OF SYMBOLS

A	Area
B	Blockage
b	Diffuser axial width
C	Coefficient
C_D	One-dimensional blockage factor = $1-B$
C_p	Specific heat at constant pressure; static pressure recovery
C_θ	Tangential velocity
F_m	$\prod_{i=1}^r f_i$
f_i	Modifier factor
g	Acceleration of gravity
H	Enthalpy
IGV	Inlet guide vane
i	Incidence
J	Mechanical equivalent of heat
M	Mach number
N	Rotor speed, rpm
N_s	Specific speed = $(\sqrt{Q} N) / [J C_p T_0 (R_{cOA})^{(\gamma-1)/(\gamma-1)}]^{3/4}$, rpm ft ^{3/4} /sec ^{1/2}
$N\sqrt{\theta}$	Impeller rpm corrected to standard conditions
P	Pressure (total)
PF	Prewirl factor
P_{LE}	Diffuser leading-edge total pressure
P_{TH}	Diffuser throat total pressure
p	Pressure (static)
Q	Inlet volume rate of flow
q	Energy head, nondimensional by U_2^2/Jg
R	Radius
R_c	Compressor pressure ratio
R_{cOA}	Overall pressure ratio
SF	Slip factor = $1 - (C_\theta + V_{m2} \tan \beta_{b2})/U_2$
T	Temperature
T_T	Total temperature
U	Rotor speed
V_m	Meridional velocity
V_a	Axial velocity
W_{ac}	Rate of airflow corrected to standard conditions
Z	Axial dimension

LIST OF SYMBOLS (cont)

α	Flow angle a. Inducer inlet flow angle measured from the axial direction b. Diffuser inlet flow angle measured from the tangential direction
β	Relative air angle or blade angle
β_b	Impeller blade mean surface angle
γ	Ratio of specific heats
Δ	Differential
ϵ	Surface roughness
η	Efficiency
ϕ	Inlet flow coefficient = V_a/U_{rms}
ψ	Pressure coefficient

Subscripts

C	Compressor
cr	Critical
ext	External
f	Friction
a	Axial
IT	Impeller tip
LE	Diffuser leading edge
OA	Overall
ri	Rotor internal
rms	Root mean square
T	Total or stagnation
Tan	Tangency
Th	Throat
th	Theoretical
0	Inlet total
1	Inlet guide vane inlet station
2	Impeller inlet station
3	Impeller exit station
4	Diffuser inlet station
5	Diffuser leading-edge station
6	Diffuser exit station
θ	Tangential or wake