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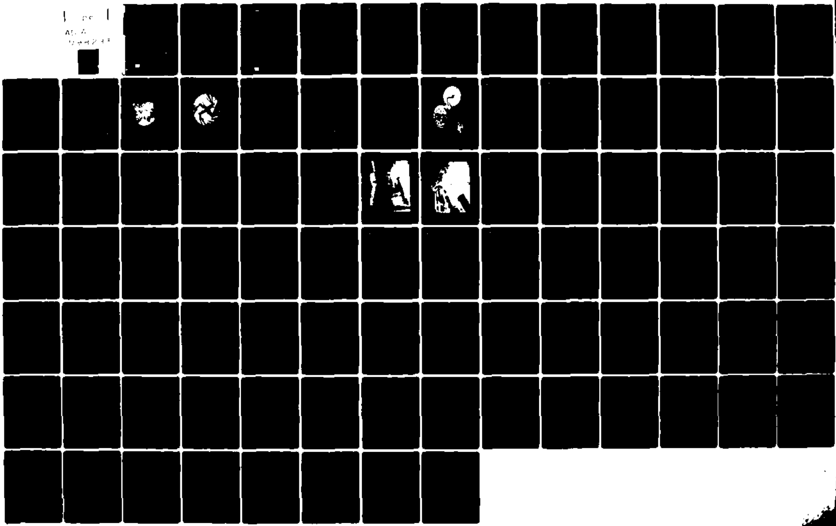

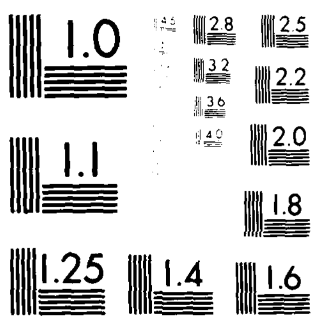

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WR34-8 PERFORMANCE IMPROVEMENT PROGRAM

THE WR34-8 GAS TURBINE COMPRESSOR TEST

CONTRACT NO. DAAK 70-80-C0129

D. BEST AND R. HONN
WILLIAMS RESEARCH CORPORATION
2280 WEST MAPLE ROAD
WALLED LAKE, MICHIGAN 48088

3 APRIL 1981

FINAL REPORT FOR THE COMPRESSOR TEST PHASE

The views, opinions, and/or findings contained in the report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

PREPARED FOR:
US ARMY MOBILITY EQUIPMENT R & D COMMAND
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ELECTROCHEMICAL DIVISION

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Williams Research Corporation

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FINAL REP[redacted]T FOR THE COMPRESSOR TEST PHASE

APPROVED BY: D. Best
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PROGRAM MANAGER

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A rig test was conducted to identify the performance map for the Williams Research Corporation WR34 engine single-stage centrifugal compressor. At the compressor design point, which is at a corrected airflow of 0.538 lbm/sec and speed of 99,050 rpm, an efficiency of 74 percent at a pressure ratio of 4.25:1 was attained. Use of the tested compressor performance in the WR34 engine computer simulation showed that the contractual goal of 27.7 horsepower on a 107°F day at an altitude of 5000 feet can be met.

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PREFACE

This program was authorized under Contract DAAK 70-80-C-0129. The purpose of the program was to establish the present WR34 engine compressor rig test performance as the first step towards both understanding its performance in the engine and to identifying areas in which engine component performance improvements can be made. The applicable DA Project is for future ground power units.

The authors wish to acknowledge contributions made to this program by the following Williams Research Corporation employees:

J. Colyer, for compressor data reduction and analysis.

S. Herridge and F. Kittredge, for directing the compressor test.

I. King, H. Meloy, and D. McCauley, for instrumenting, assembling, and operating the test rig.

D. Dorer and B. Everett, for engine cycle analysis.

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SUMMARY

This test was conducted to establish the performance level of the present Williams Research Corporation WR34 engine single-stage centrifugal compressor. Specific objectives were to:

- Define the compressor performance map from 40 through 115 percent of the design corrected speed
- Determine the performance of each of the compressor components so that potential improvements could be identified
- Ascertain if the compressor would enable the engine to satisfy a requirement of 27.7 horsepower at an inlet temperature of 107°F at an altitude of 5000 feet.

Compressor rig testing demonstrated a compressor design point stage performance of 74 percent efficiency and 4.25:1 pressure ratio at 0.538 lbm/sec corrected airflow. Test data indicated that the relatively thick impeller blades, which were designed with a state-of-the-art castable thickness distribution, result in higher than anticipated levels of impeller loss and restrict flow range. Cycle analysis using the tested compressor performance showed that the WR34 engine can meet the goal of 27.7 horsepower on a 107°F day at an altitude of 5000 feet.

SECTION 1

INTRODUCTION

This report summarizes the rig testing of the single stage centrifugal compressor that is incorporated in the Williams Research Corporation WR34 Engine. The primary purpose of the compressor rig test was to define the performance of the new Williams designed backswept centrifugal compressor; this design being an improvement over the current WR34 engine radial compressor. This establishes a baseline from which compressor performance improvements can be identified and engine cycle analysis can be conducted. The test rig utilized engine compressor hardware which was representative of production quality to ensure that an accurate assessment of engine compressor performance was made.

The compressor rig test program was conducted in the existing small compressor test cell at WRC. Thorough instrumentation was used to gather data required to establish overall compressor performance and identify the performance of each of the compressor components.

The compressor performance data was used in the WR34 engine simulation computer model. This was done to ascertain whether the engine could satisfy a contractural requirement of 27.7 horsepower on a 107°F day at an altitude of 5000 feet.

SECTION 2

INVESTIGATION

The primary program objective was to conduct a compressor rig test to establish the baseline performance of the present WR34 engine single-stage centrifugal compressor. In addition, it was required that the WR34 engine cycle be evaluated using the compressor rig test data. The program consisted of investigating the areas discussed in Sections 2.1 through 2.4.

2.1 COMPRESSOR DESIGN

The design of the WR34 single-stage centrifugal compressor was done by WRC prior to the inception of this contract. The compressor was designed to be a minimal risk configuration both structurally and aerodynamically. The conservative design approach was taken due to a necessity to minimize development effort. The compressor design was oriented toward low-cost producibility, reliability, and ruggedness as well as towards good performance. This was in keeping with the applications envisioned for the WR34 engine. Figure 1 presents a cross-section of the WR34 engine.

The impeller was designed to be accurately cast consistently using proven state-of-the-art casting techniques. This resulted in relatively thick impeller blades which enhance its ruggedness. The impeller is shown in Figure 2.

The rugged, low-cost theme is also present in the radial diffuser. The vane design is similar to ones that have proven to be easily machined and relatively insensitive to leading edge erosion damage and its effect on engine performance. The diffuser was designed to accept bolts through the vanes that are used for engine assembly. The diffuser is portrayed in Figure 3.

In addition to the structural conservatism, the aerodynamic design also reflected a low risk approach. Impeller splitter blades were not considered. Only proven aerodynamic design parameters were incorporated in the design of the inlet, impeller, and radial vane-island diffuser. Aerodynamic and geometric parameters of note are presented in Table I.

2.2 COMPRESSOR TEST RIG DESIGN

This task resulted in the test rig design shown in Figure 4. The test rig utilized the main housing, impeller, and diffuser from the WR34 engine to form the bulk of the compressor flowpath. Figure 5 portrays the compressor flowpath hardware from the engine. The WR34 engine thrust bearing and a shaft modified to mate with an existing high-speed gearbox were the other engine components incor-

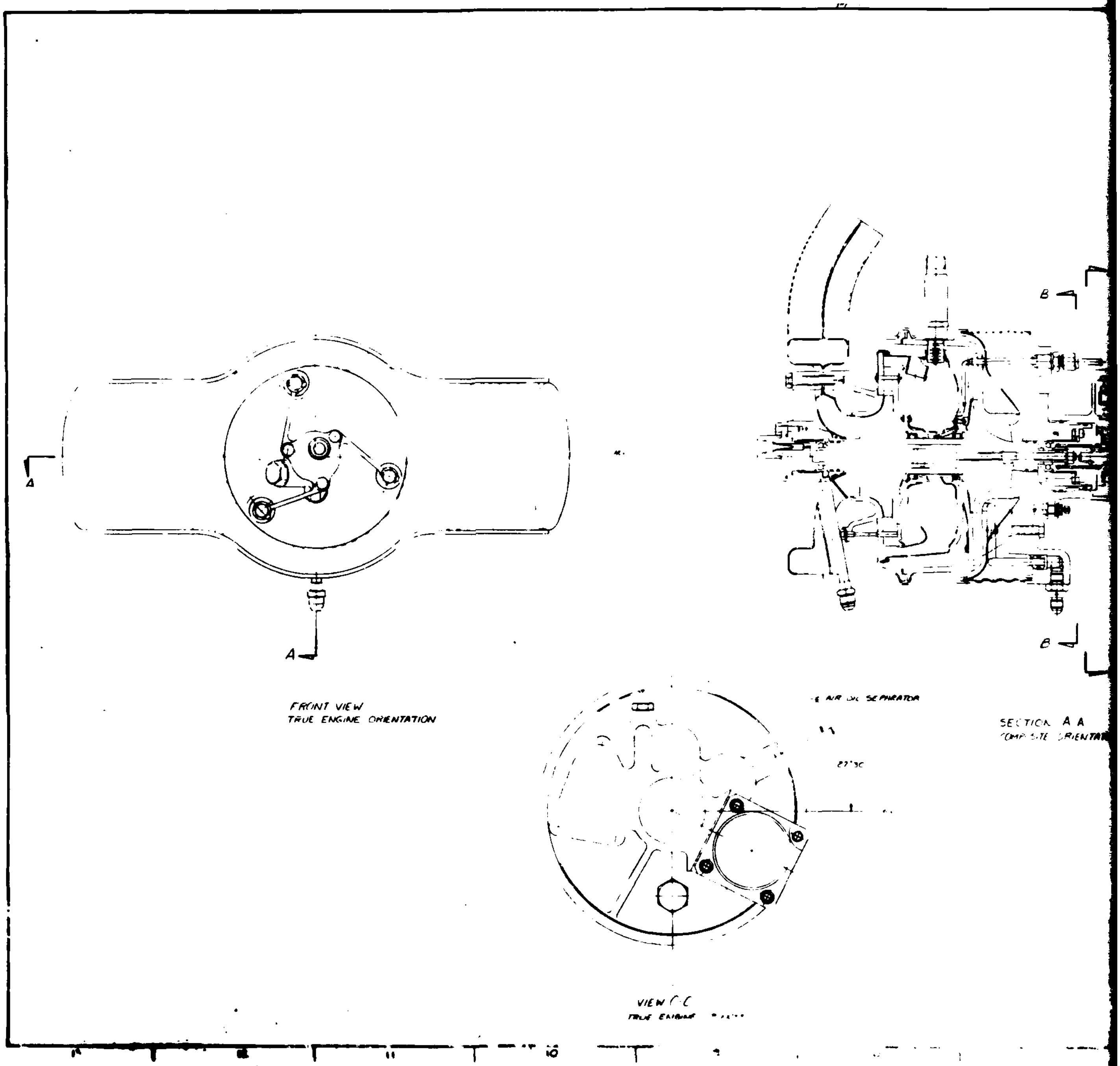
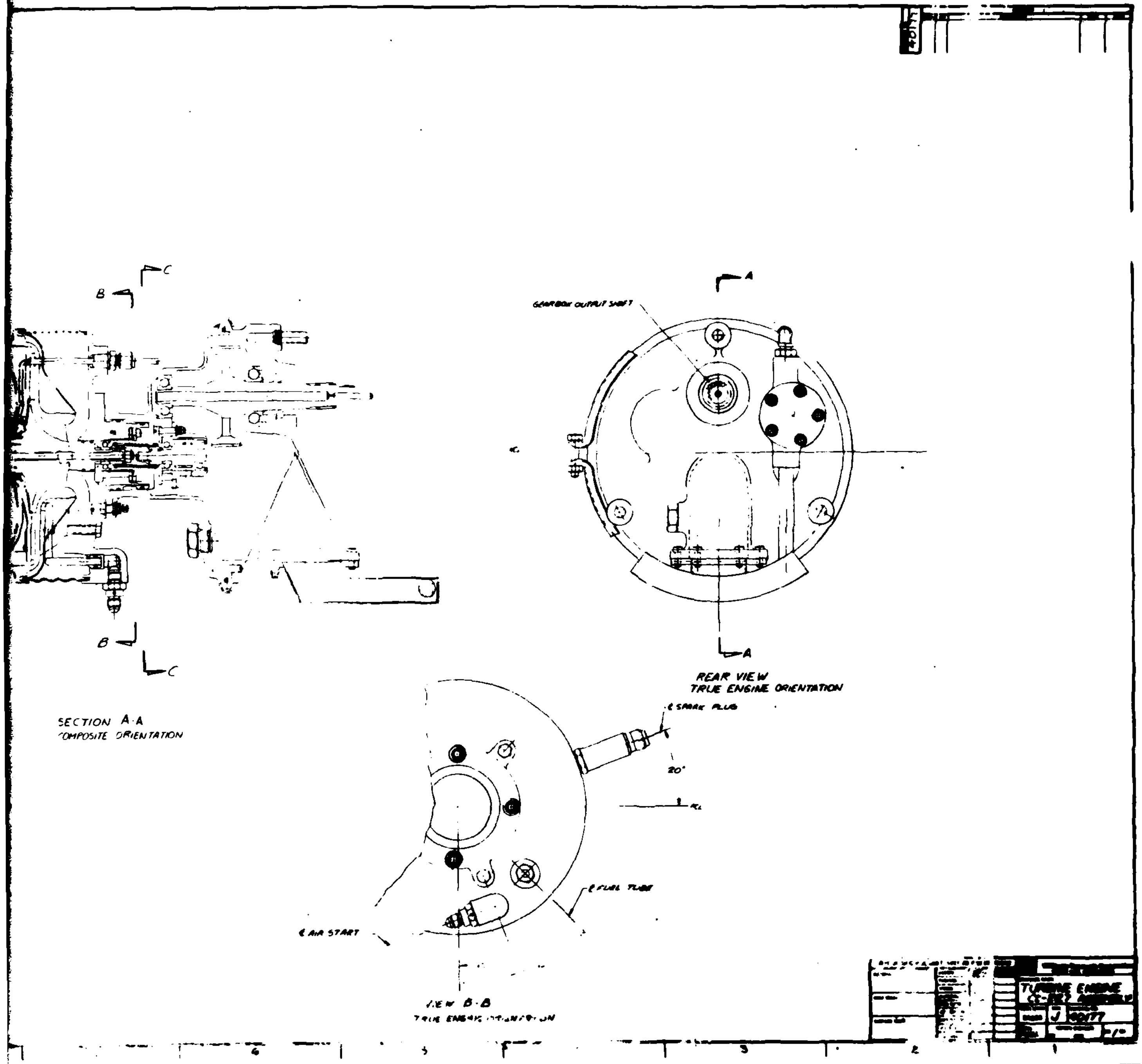


Figure 1. Layout of WR34-15X Engine


GEARBOX OUTPUT SHAFT
REAR VIEW
TRUE ENGINE ORIENTATION
SECTION A-A
COMPOSITE ORIENTATION
℄ SPARK PLUG
20°
℄ FUEL TUBE
℄ AIR START
VIEW B-B
TURBINE ENGINE
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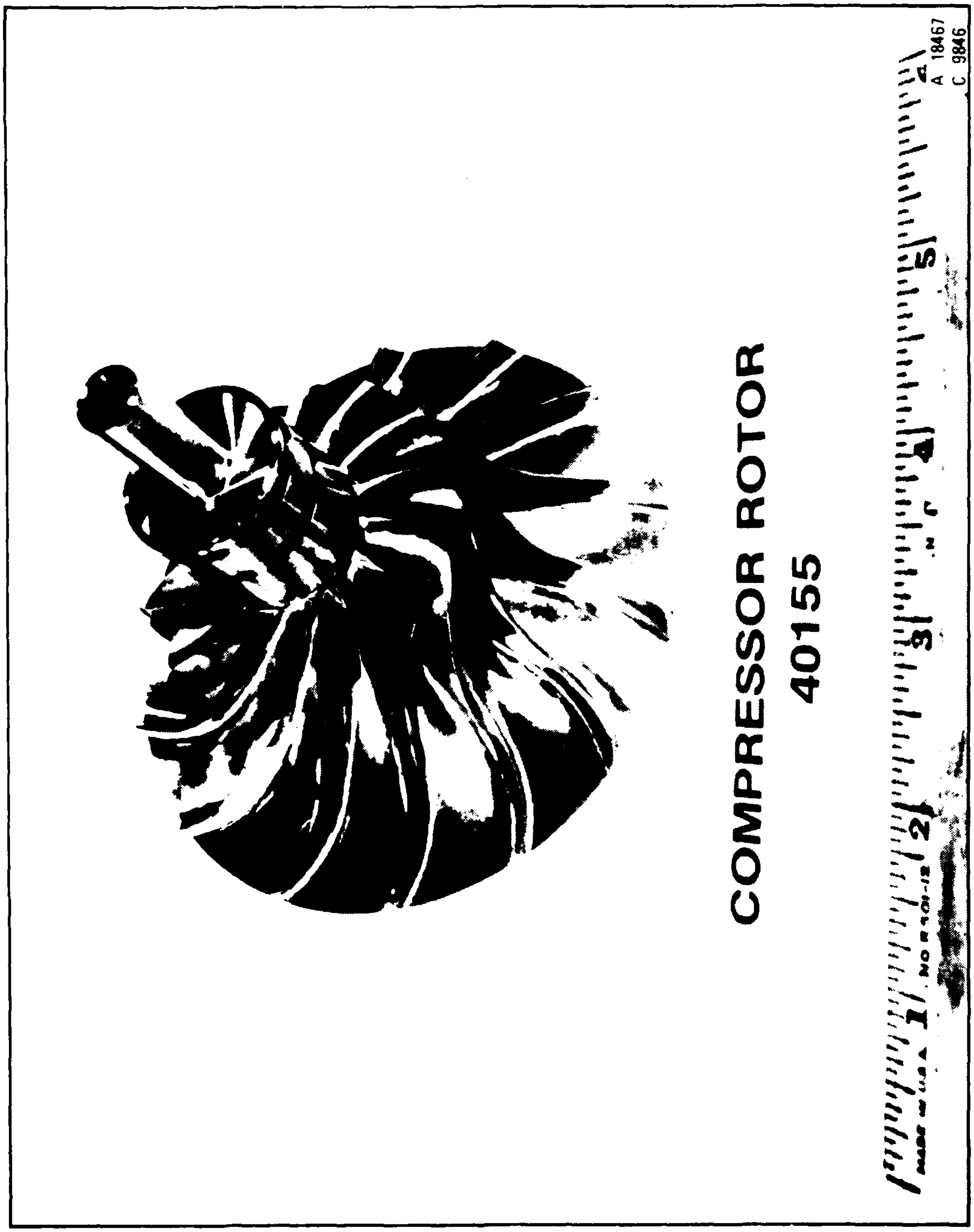


Figure 2. Photograph of Impeller

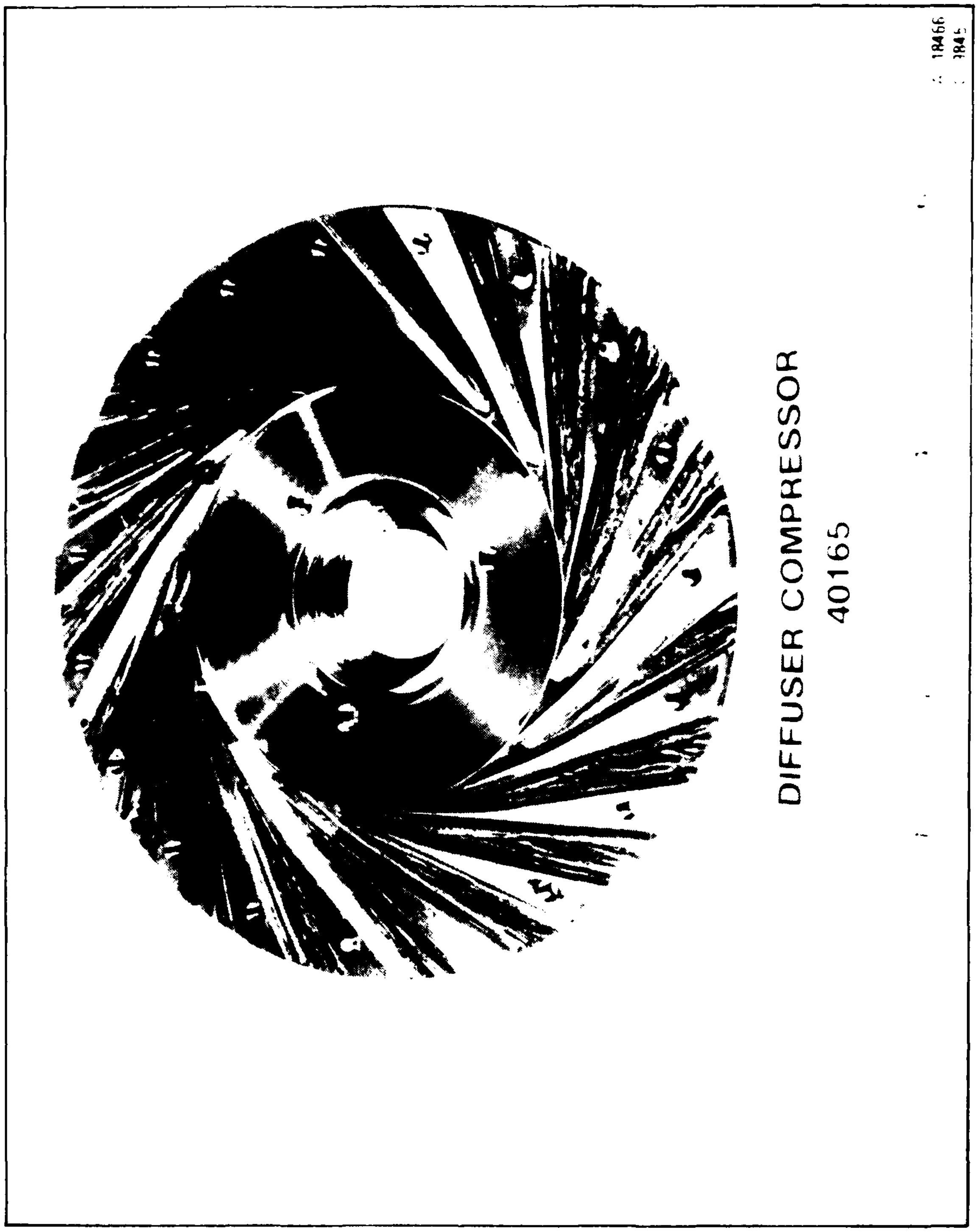


Figure 3. Photograph of Vaned Diffuser

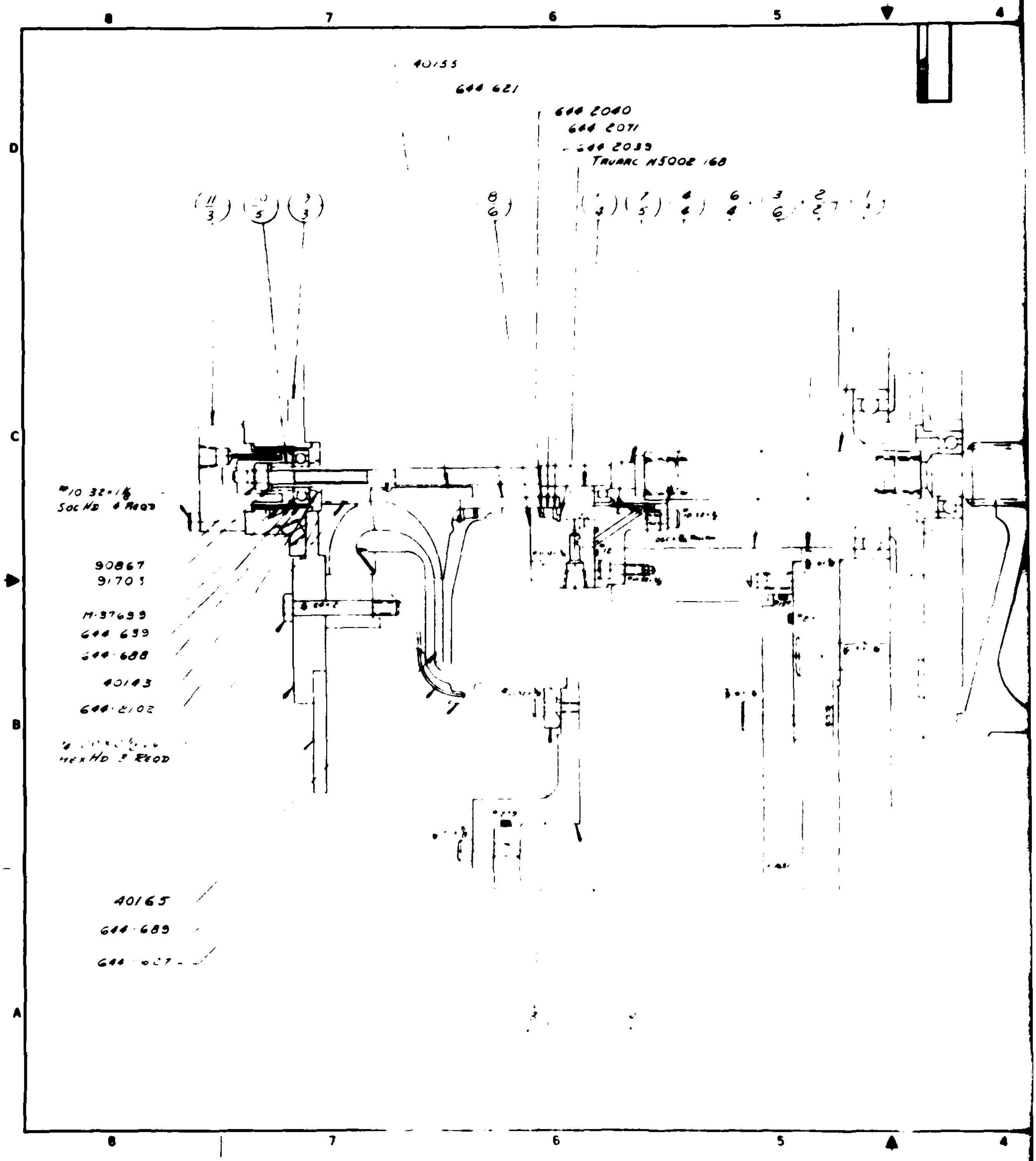
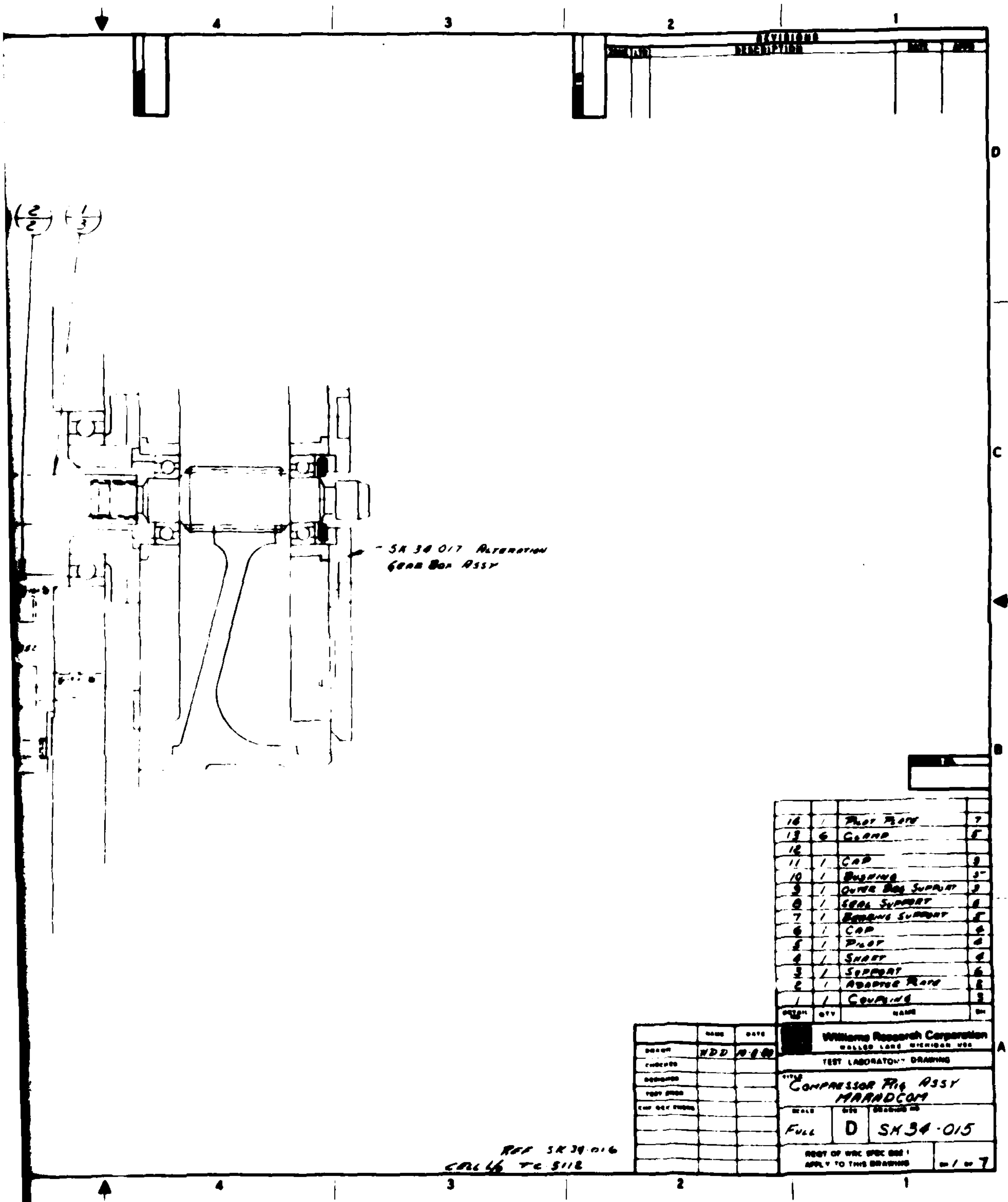


Figure 4. Layout of Test Rig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OUTER BRG SUPPORT
SEAL SUPPORT
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TEST LABORATORY DRAWING
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TABLE I. WR34 COMPRESSOR DESIGN PARAMETERS

Stage Pressure Ratio (inlet total to stage exit total)	3.862-4.25
Stage Pressure Ratio (inlet total to stage exit static)	3.757-4.15
Stage Efficiency (total-to-total)	0.749-0.740
Stage Efficiency (total-to-static)	0.730-0.721
Stage Temperature Rise ($\Delta T/T$)	0.625
Corrected Flow (lbm/sec)	0.538
Corrected Speed (rpm)	99,050
Number of Impeller Blades	14
Inducer Hub Radius (inches)	0.479
Inducer Edge of Blade Radius (inches)	1.056
Inducer Hub Normal Thickness (inches)	0.051
Inducer Edge of Blade Normal Thickness (inches)	0.020
Impeller Exit Radius (inches)	1.921
Impeller Exit Blade Width (inches)	0.147
Impeller Exit Hub Normal Thickness (inches)	0.081
Impeller Exit Shroud Normal Thickness (inches)	0.020
Impeller Exit Angle (degrees)	37.97
Impeller Rake Angle (degrees)	30.0
Number of Diffuser Vanes	19
Vaned Diffuser Leading Edge Radius (inches)	2.017
Vaned Diffuser Leading Edge Thickness (inches)	0.015
Vaned Diffuser Passage Height (inches)	0.150
Vaned Diffuser Trailing Edge Radius (inches)	3.510
Vaned Diffuser Trailing Edge Thickness (inches)	0.378
Compressor Exit Outer Radius (inches)	3.721
Compressor Exit Inner Radius (inches)	3.571

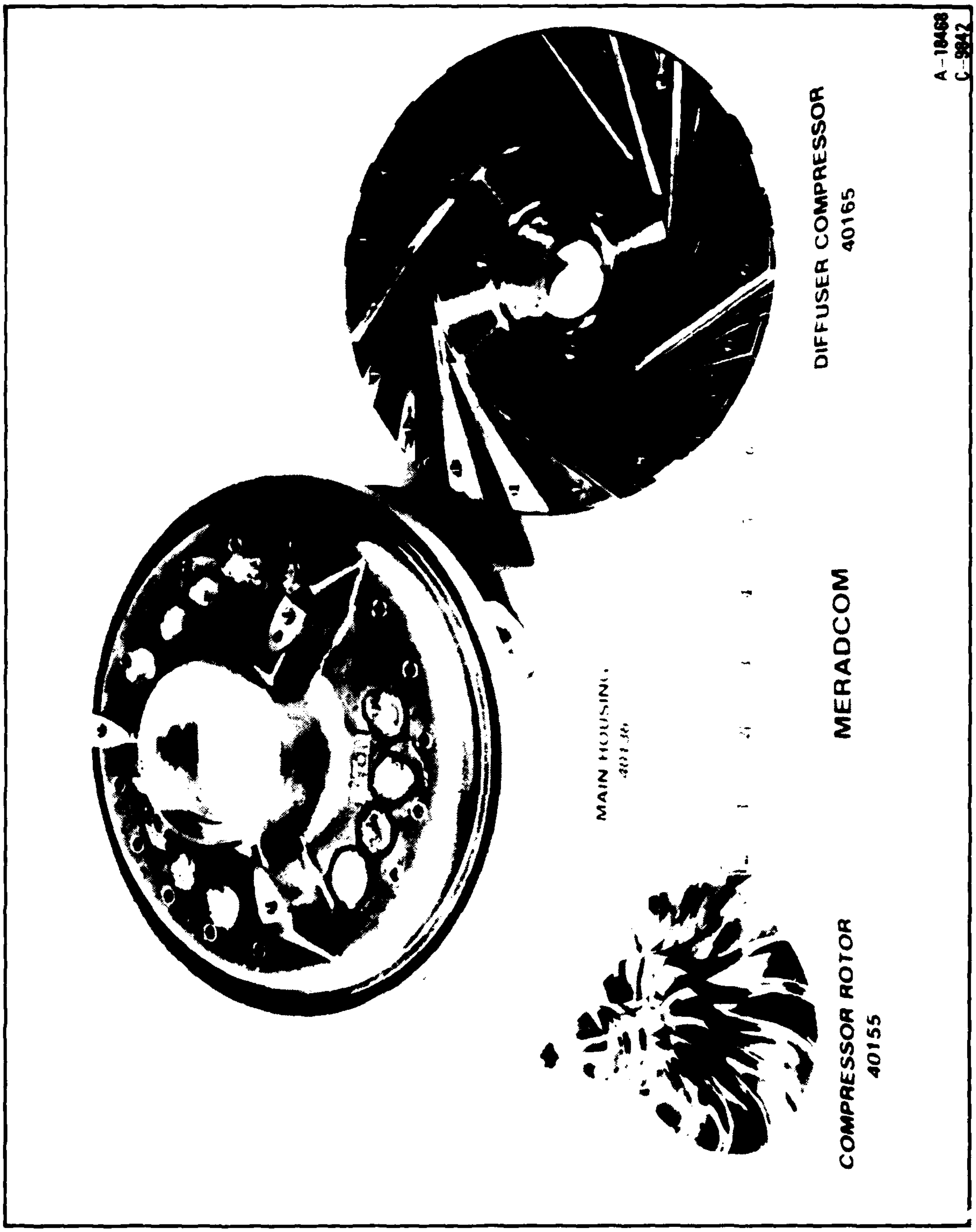


Figure 5. Photograph of Main Housing, Impeller, and Vaned Diffuser

porated into the test rig. This enables the test rig to readily accept and test engine compressor hardware if engine diagnostic testing is required.

An impeller thrust analysis utilizing the WRC centrifugal compressor thrust analysis computer program, which has been correlated against available data including the WRC F107 cruise missile turbofan engine, was used to calculate thrust bearing loads. The thrust bearing was judged to be satisfactory for the projected compressor test duty cycle.

Stress and vibration analysis of both the impeller and diffuser, which were conducted during the design of the compressor, and thus prior to this contract, indicated compressor test rig operation would be satisfactory at all desired speeds. As the analyses were run to satisfy more rigorous conditions than would occur during the compressor rig test, the compressor operation in the rig was considered safe.

2.3 TEST RIG FABRICATION AND ASSEMBLY

2.3.1 Test Rig Fabrication

The test rig was fabricated in accordance with test rig drawings.

2.3.2 Impeller Fabrication

The impeller, though designed to be cast, was fabricated using WRC's in-house impeller machining facility to shorten the hardware schedule. The impeller was machined out of 15-5 Ph stainless steel. The blades were cut on a pantograph machine with the other finish machine work done in the experimental machine shop.

Careful finished machining of the impeller produced a nearly nominal part. This was verified by thorough inspection of the impeller blades on a ten to one optical comparator. The worst blade discrepancy found was 0.001 inches on the suction surface of the blades in the region of the impeller transition from axial to radial.

2.3.3 Impeller Stationery Shroud Fabrication

A WR34 engine main housing casting was machined to form the shroud side inlet contour into the impeller, the impeller stationary shroud, the sealing wall for the vaned diffuser, and the outer wall of the bend downstream of the diffuser vanes. The machining utilized existing WR34 engine detail drawings and tooling. All machining was done at Williams Research. An inspection of the contours on a ten to one optical comparator showed the worst discrepancy to be 0.002 inches which occurred in the inlet.

2.3.4 Vaned Diffuser Fabrication

The vane-island diffuser vanes were cut out of 17-4 PH stainless steel using WRC's pantograph machining facility. All other machining was done in the corporation's experimental shop. No noticeable discrepancies between the vanes and the nominal ten times size vane template were observed during inspection.

2.3.5 Test Rig Static Pressure Tap Machining

All static pressure taps used in the compressor testing were located analytically by WRC's compressor personnel. They were subsequently accurately milled into the WR34 engine main housing. This insured accurate location of all static pressures.

2.3.6 Test Rig Pressure and Temperature Rake Fabrication

All pressure and temperature rakes incorporated into the test rig were designed and built by WRC. Sketches of the inlet total pressure and temperature rakes are shown in Figures 6 and 7 respectively. Exit total pressure and temperature rake sketches are shown in Figures 8 and 9 respectively.

2.3.7 Test Rig Assembly

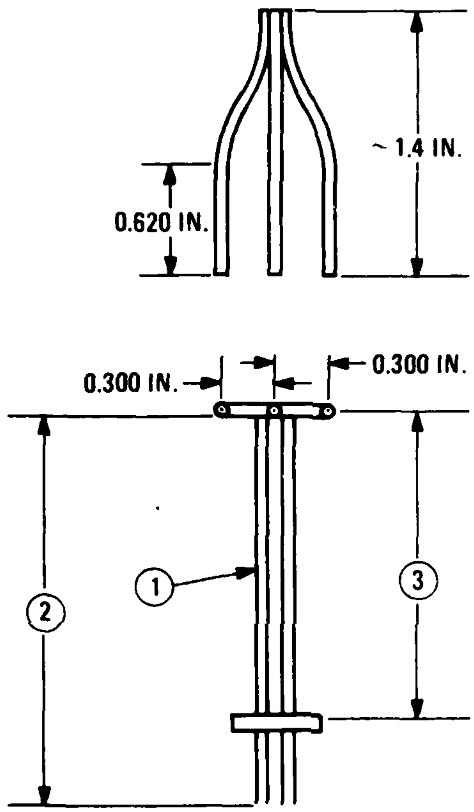
Instrumentation was first installed in the individual test rig parts. The test rig was then assembled according to the build instructions. The impeller and shaft were dynamically balanced. All critical build dimensions were recorded. The test rig, after assembly, was installed in the test cell.

2.4 COMPRESSOR TESTING

2.4.1 Compressor Test Cell Description

The test was run in the existing WRC centrifugal compressor test cell. A sketch of the test set-up is shown in Figure 10. Ambient air is drawn through a roof top mounted air filter into a plenum directly below. The air then enters an ASME bellmouth where inlet total temperature and pressure and static pressure at the nozzle throat are measured. The flow then passes through an uninsulated 9-inch diameter cylindrical duct followed by a right-angle bend of circular cross section. Air exits from the bend through a short section of 8-inch diameter duct to the inlet plenum. Total pressure and temperature are measured at this location. The air then enters the test section, is compressed, and enters a large insulated discharge plenum, where total temperature and pressure and static pressure are measured. The air leaves the discharge plenum through two insulated opposed discharge plenum headers. The flow then merges into one larger duct which guides it to the discharge throttling valves. There are two electrically operated throttling valves--a main valve and a vernier valve. The vernier valve permits

I. TOTAL PRESSURE AT STAGE INLET
(3 RAKES REQUIRED)



NOTES:

1. ALL TUBING PREFERABLY 0.040 INCH O.D. BUT MAKE NO BIGGER THAN 0.062 INCH O.D.
2. MAKE THE TUBE LENGTH 4 FEET OR MORE.
3. RAKE IMMERSION DEPTH DOWN TO MOUNTING PAD SHOULD BE SUCH THAT RAKES ARE EQUALLY SPACED ACROSS THE PASSAGE WITH RAKES SEPARATED BY 120 DEGREES FROM EACH OTHER. RAKES SHOULD BE MOUNTED ON GEARBOX HOUSING USING EXISTING SCREWS.

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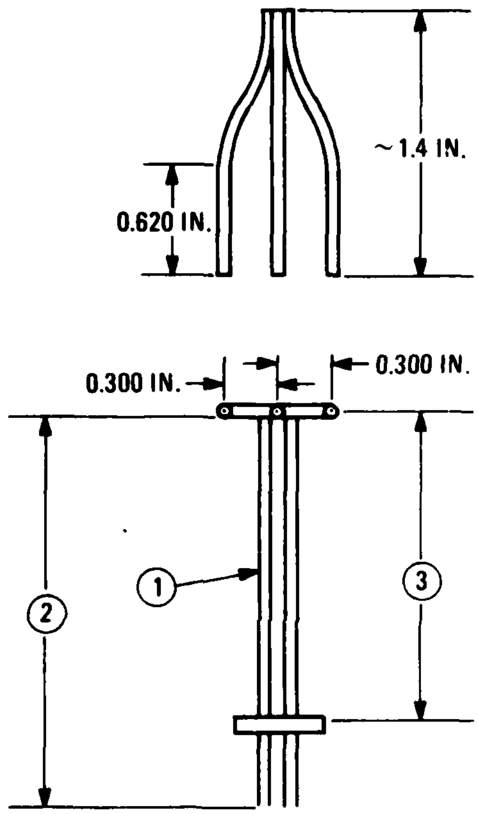
Figure 6. Sketch of Inlet Total Pressure Rake

II. TOTAL TEMPERATURE AT STAGE INLET
(3 RAKES REQUIRED)



NOTES:

1. ALL TUBING SHOULD BE 0.062 INCH O.D. USING CHROMEL/ALUMEL THERMOCOUPLE MATERIAL IN AN ASPIRATED CONFIGURATION.
2. MAKE THE TUBE LENGTH 4 FEET OR MORE.
3. RAKE IMMERSION DEPTH DOWN TO MOUNTING PAD SHOULD BE SUCH THAT RAKES ARE EQUALLY SPACED ACROSS THE PASSAGE WITH RAKES SEPARATED BY 120 DEGREES FROM EACH OTHER. RAKES SHOULD BE MOUNTED ON GEARBOX HOUSING USING EXISTING SCREWS.

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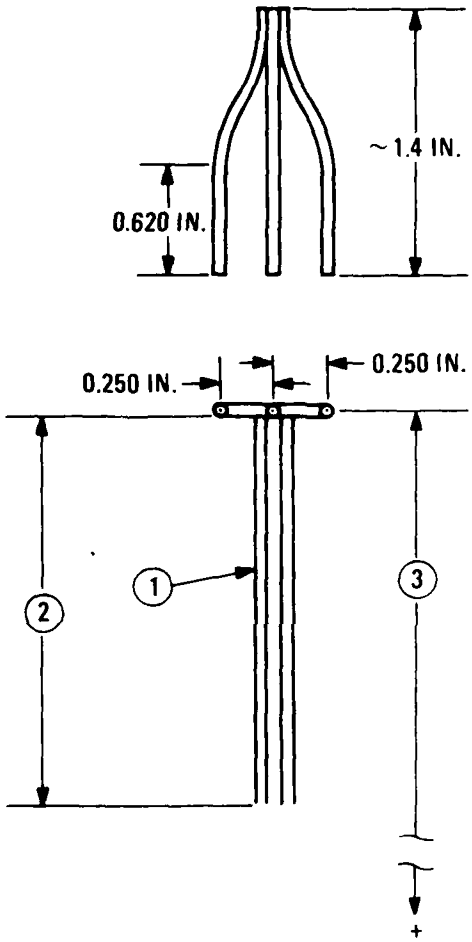
Figure 7. Sketch at Inlet Temperature Rake

III. TOTAL PRESSURE AT STAGE EXIT
(4 RAKES REQUIRED)



NOTES:

(1) ALL TUBING PREFERABLY 0.040 INCH O.D. BUT MAKE NO BIGGER THAN 0.062 INCH O.D.

(2) MAKE THE TUBING LENGTH 4 FEET OR MORE.

(3) RAKE IMMERSION RADIUS OF 3.647 INCHES IS FROM THE TEST RIG CENTERLINE TO ELEMENT CENTERLINE. THE RADIUS TOLERANCE IS ± 0.005 INCH. NOTE THAT THE RAKE HAS TO BE SET AT 50.557 DEGREES FROM THE RIG CENTERLINE TO MATCH THE PREDICTED FLOW ANGLE.

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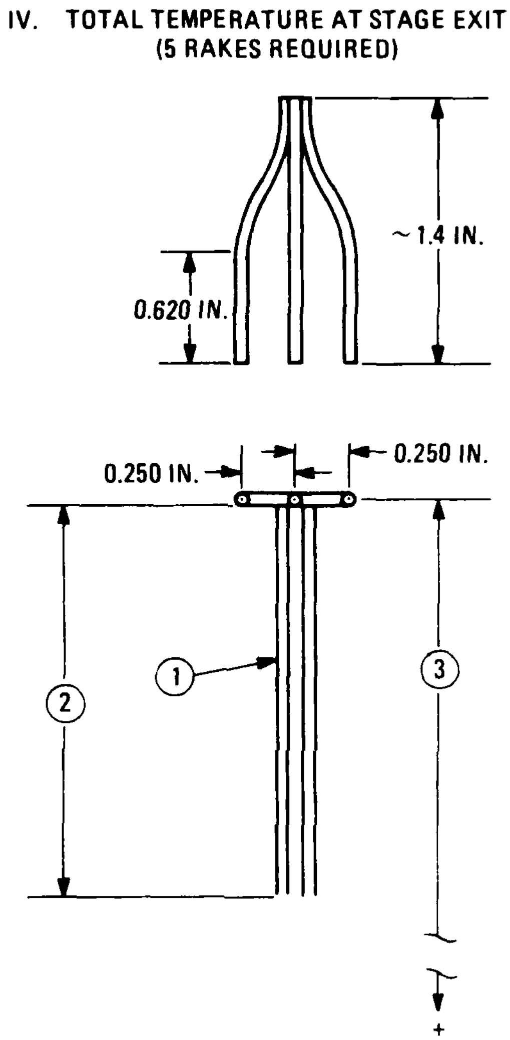
Figure 8. Sketch of Exit Total Pressure Rake



NOTES:

1. ALL TUBING SHOULD BE 0.062 INCH O.D. USING CHROMEL/ALUMEL THERMOCOUPLE MATERIAL IN AN ASPIRATED CONFIGURATION.
2. MAKE THE TUBE LENGTH 4 FEET OR MORE.
3. RAKE IMMERSION RADIUS OF 3.647 INCHES IS FROM THE TEST RIG CENTERLINE TO ELEMENT CENTERLINE. THE RADIUS TOLERANCE IS ± 0.005 INCH. NOTE THAT THE RAKE HAS TO BE SET AT 50.557 DEGREES FROM THE RIG CENTERLINE TO MATCH THE PREDICTED FLOW ANGLE.

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Figure 9. Sketch of Exit Temperature Rake

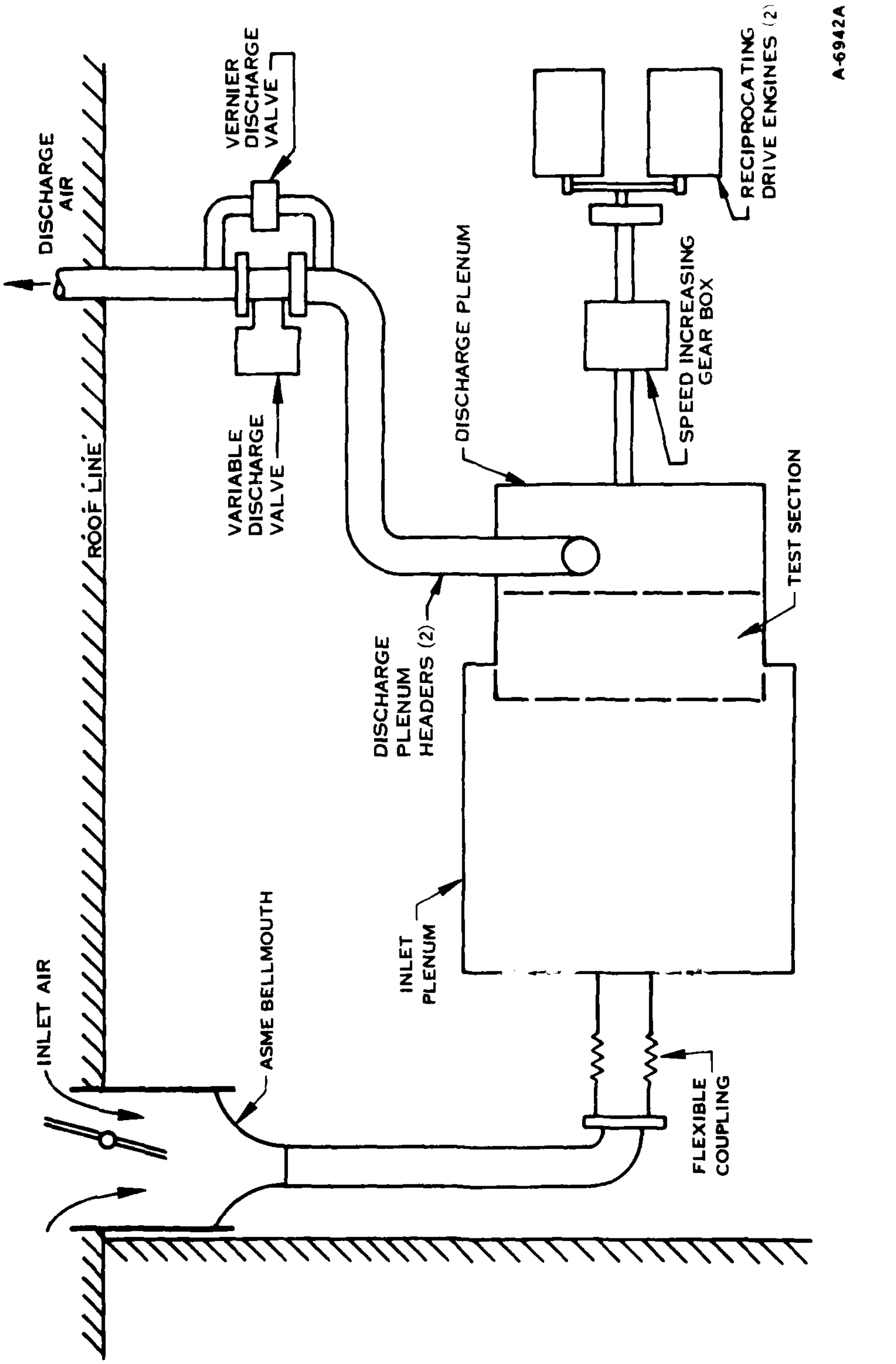


Figure 10. Schematic of WRC Centrifugal Compressor Test Cell (A-1)

the fine adjustments necessary when operating near the compressor surge line. From this point, the flow discharges to the atmosphere.

Compressor drive power is provided by two coupled 413 cubic inch Chrysler industrial engines developing a total of 340 horsepower working through hydraulic clutches and a speed-increasing gearbox. A pressurized labyrinth seal in the gearbox prevents lubricating oil from entering the test section.

2.4.2 Compressor Test Equipment

The equipment used in the compressor rig test is presented in Table II.

2.4.3 Test Data Parameters Recorded

The compressor was instrumented to obtain an overall performance map. In addition, sufficient instrumentation was installed to identify the impeller and vaned diffuser performance characteristics. Compressor performance instrumentation that was installed in the test rig is presented in Table III and portrayed in Figure 11. Bearing temperatures, compressor rotational speed, and other mechanical data, along with the ASME bellmouth temperature and pressure data, were recorded manually. All other performance parameters were recorded on the digital automatic data acquisition system (ADAS).

The ADAS system assigns each parameter a unique channel number and the data is recorded using that identification. The channel number assignments are recognized by the WRC centrifugal compressor data reduction program, which then converts this data into a usable form. A real time display of selected pressure and temperature data was used during the testing which enabled the analyst to quickly check compressor performance.

2.4.4 Test Procedure

After the test rig was partially instrumented, assembled, and installed in the test cell, a mechanical check of the test rig was made (Build 1). Speeds run were at 40, 50, 60, 70, 80, 90 and 100 percent of design corrected speed (99,050). Initially, Regal 20W oil was used in the gearbox lubrication system. Considerable oil foaming occurred preventing proper oil scavenging, resulting in a rapid increase in bearing temperatures and vibrations. The Regal 20W oil was drained and replaced with Texamatic A oil. Also, another oil scavenge pump was connected into the lubrication system. Proper oil circulation throughout the gearbox and compressor test rig resulted. However, a large amount of oil was lost through the discharge plenum chamber and also collected around the inlet to the compressor rotor inside the inlet plenum chamber. Heat transfer from the gearbox and discharge plenum chamber to the compressor main housing was rather high. After approximately 100 minutes

TABLE II. MERADCOM WR34 CENTRIFUGAL COMPRESSOR RIG TEST EQUIPMENT REQUIRED

Inlet ASME Bellmouth

- 4-inch diameter

Plumbing Between the Inlet Bellmouth and Inlet Plenum

Inlet Plenum

Centrifugal Compressor Test Rig Assembly

- Main Housing
- Steel 38° backward curved impeller
- Aluminum impeller stationary shroud
- Steel vane island diffuser

Discharge Plenum

Discharge Plumbing and Valving

Compressor Drive System

- Two Chrysler 413 cubic inch engines
- Speed-increasing gearbox

Test Rig Vibration Meter

Howell Automatic Data Acquisition System (ADAS)

- Digital data acquisition
- 100 pressures available on four scanivalves
- 50 temperatures available

TABLE III. MERADCOM WR34 CENTRIFUGAL COMPRESSOR RIG TEST SUMMARY OF INSTRUMENTATION

INSTRUMENTATION LOCATION/TYPE	QUANTITY
ASME BELLMOUTH	
Delta Pressure	1
Total Temperature	3
INLET PLENUM	
Total Pressure	4
Total Temperature	4
COMPRESSOR INLET	
Total Pressure Rakes, 3-element	3
Total Temperature Rakes, 3-element	3
Static Pressure, Shroud	4
IMPELLER STATIONARY SHROUD	
Static Pressure	12
Static Pressure, Impeller Exit	6
VANED DIFFUSER	
Static Pressure	18
COMPRESSOR EXIT	
Total Pressure Rakes, 3-element	4
Total Temperature Rakes, 3-element	5
DISCHARGE PLENUM	
Static Pressure	3

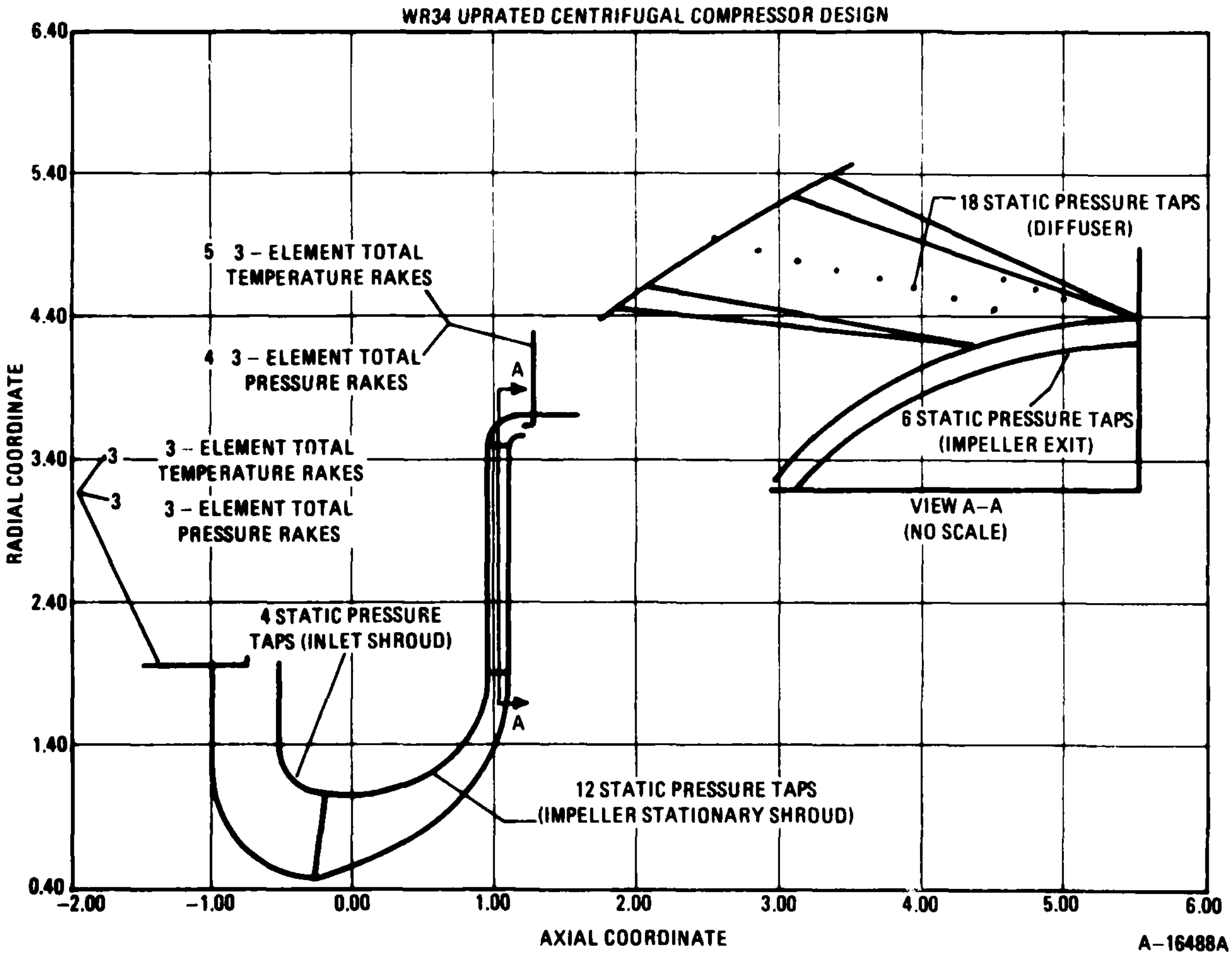


Figure 11. Meradcom WR34 Centrifugal Compressor Instrumentation Locations

running time, the front rig bearing temperature and vibration increased rapidly. Immediate shutdown of the compressor test rig was necessary.

No damage was done to the compressor test rig. The front ball bearing separater had fractured, causing the bearing failure. Compressor rotor front face clearance was determined by measuring the rub tabs installed on the impeller stationery shroud which equalled 0.011 to 0.013 inches.

Prior to Build 2, several alterations were made to the test rig. Provisions were made on the oil seals including a collar separating the diffuser from the rear rig bearing to prevent the oil leakage. The improved oil seals and a supply of 4 to 6 psi guard air pressure to the collar were adequate to prevent the oil leakage. Also, a heat shield was placed on the discharge plenum chamber to prevent heat transfer to the compressor main housing.

All instrumentation was completed for the performance run (Build 2) and installed at the compressor inlet, compressor shroud, and diffuser exit. Also, 0.006 inches was removed from the shim on the compressor rotor stack-up assembly to obtain the required 0.005 to 0.007 inch front face running clearance. A new front rig ball bearing was included on assembly. The compressor test rig was assembled, Build 2, and installed in Cell A-1. Figures 12 and 13 show the test rig installed in the test cell.

On December 19, 1980 the compressor test rig was run at 40, 60 and 80 percent of design corrected speed (99,050 rpm). Wide open, choke, surge, and three points between wide open and surge were recorded. Operation of the compressor test rig was good with no apparent oil leakage or mechanical problems.

On December 20, 1980 the compressor test rig was run beginning at 50 percent of design corrected speed (99,050 rpm). Data points at wide open, choke, surge, and three points in between wide open and surge were recorded. Guard air pressure was maintained at 4 to 6 psi to prevent any major oil leakage. Operation of the compressor test rig continued successfully. The compressor test rig was then accelerated to speeds of 60, 70, 80, 90, 95 and 100 percent of design corrected speed (99,050 rpm). Data for wide open, choke, surge, and three points in between wide open and surge were obtained at all speed lines.

As the compressor test rig was accelerated to 105,000 rpm (105 percent corrected speed), mechanical problems began with the front rig ball bearing. Data at wide open and choke were recorded.

Vibrations began to increase, with an unusual rumbling noise coming from the compressor rig. Therefore, the compressor test rig was immediately shut down.

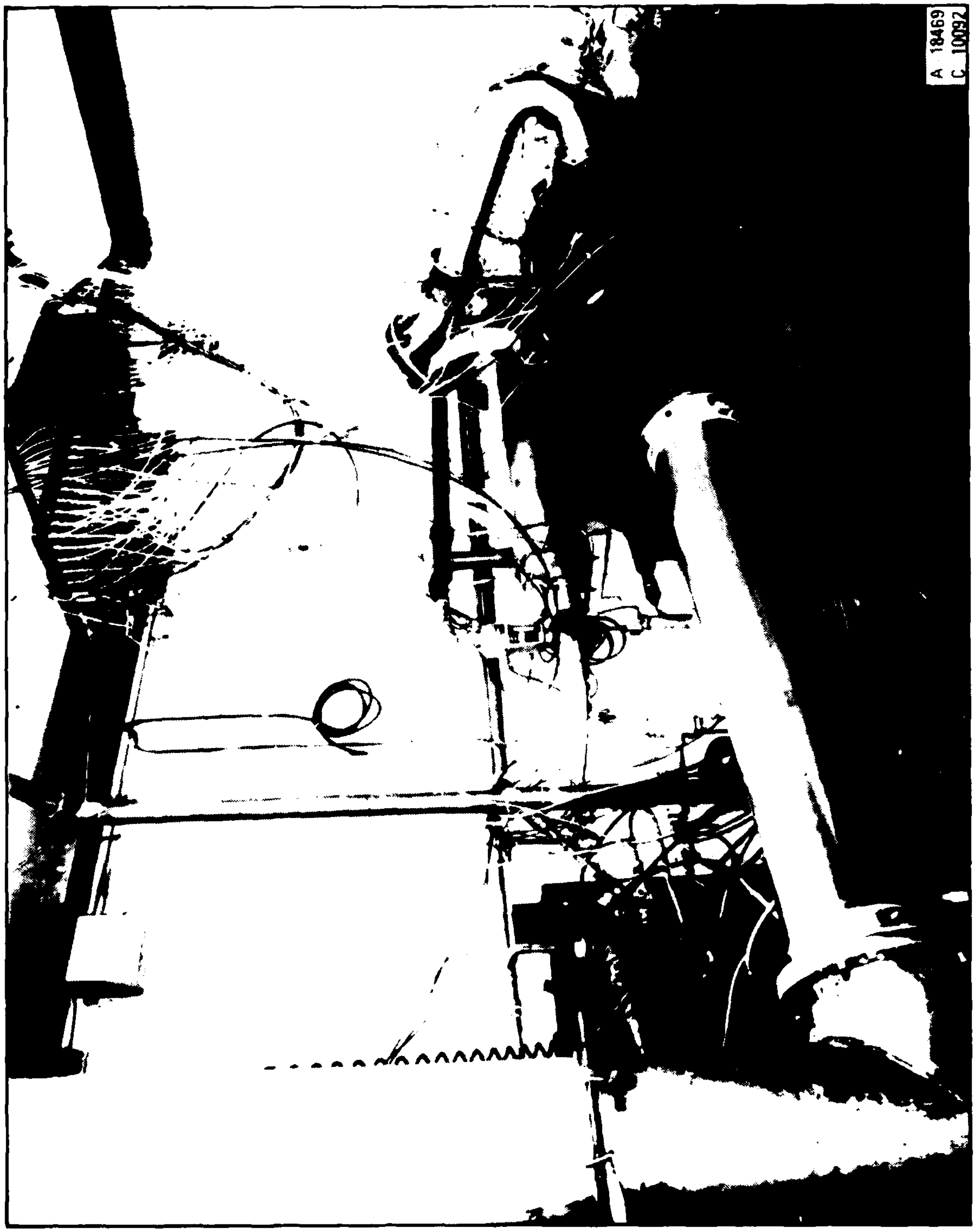


Figure 12. Photograph of Test Cell with Test Rig Installed

Figure 13. Photograph of Test Rig Installed in Test Cell

Vibration pick up #3 had come loose from the gearbox and was remounted. The compressor test rig rotated freely and was allowed to cool for 15 minutes, then restarted. All vibrations were checked at various speed lines as the compressor rig was accelerated to 105,000 rpm (105 percent corrected speed).

Data points at wide open and choke were recorded. As surge was attempted the vibrations increased along with a rapid increase in the front rig bearing temperature. Also, a loud whine was audible. Again, the compressor rig was immediately shut down. The run down appeared normal with no unusual sounds or physical problems.

On disassembly of the compressor test rig, it was found that the compressor rotor had slightly rubbed the main housing front face. One of the three rub tabs were lost. Through measuring the other two rub tabs, the final front face clearance was equal to 0.005 → 0.006 inches (design intent).

Examining the front rig ball bearing indicated that the steel ball separater had fractured, almost leading to a complete bearing failure. Other compressor rig hardware including instrumentation was not damaged.

The original intent was to collect data at 105, 110, and 115 percent of design corrected speed in addition to the data that was collected. However, due to funding limitations, the mechanical problem on Build 2 terminated the testing.

SECTION 3

DISCUSSION OF TEST RESULTS

3.1 COMPRESSOR TEST RESULTS AND DISCUSSION

The raw data was reduced using the WRC centrifugal compressor data reduction computer program. Appendix A contains the test log pages, manually recorded data sheets, data reduction program output at the design point, and a summary sheet from the data reduction program presenting compressor parameters of note for all significant data gathered during rig testing.

The overall stage performance, consisting of total pressure ratio, total-to-total efficiency, and temperature rise, is shown in Figures 14, 15 and 16 respectively. The design point goals are shown on each plot as a point of reference. Stage performance was calculated based on total temperature and pressure at the inlet and total temperature and pressure at the bend exit prior to dumping into the discharge plenum. As the inlet measuring station was upstream of the start of the radial inflow inlet, all inlet loss is charged to the compressor. In the same vein, the stage exit measuring station accounted for all losses in the compressor including those in the exit bend. All efficiencies were calculated using enthalpy tables which ensured that an accurate assessment of compressor performance was made.

Table IV presents a comparison of selected compressor parameters at the design point between the projected values and the test data. As is shown in Table IV, impeller axial and radial clearances at the design point for the test data were in agreement with the design intent. Therefore, clearance was not a factor in the differences between projected and tested parameter values.

As is readily observable from Table IV, the compressor pressure ratio and temperature rise are noticeably different than the design intent. Compressor temperature rise is 10 percent higher than the design intent. Compressor pressure ratio (total-to-total) is 9.6 percent above the design intent. The net result of this unexpectedly high energy addition is a 0.9 point lower efficiency than projected. The reason(s) for the larger than expected energy addition are unclear from the data gathered to date. Basically, two temperature anomalies were observed when the data was reduced.

The primary anomaly, the 10 percent high temperature rise, is not explainable at this time. Figure 17 presents the impeller slip

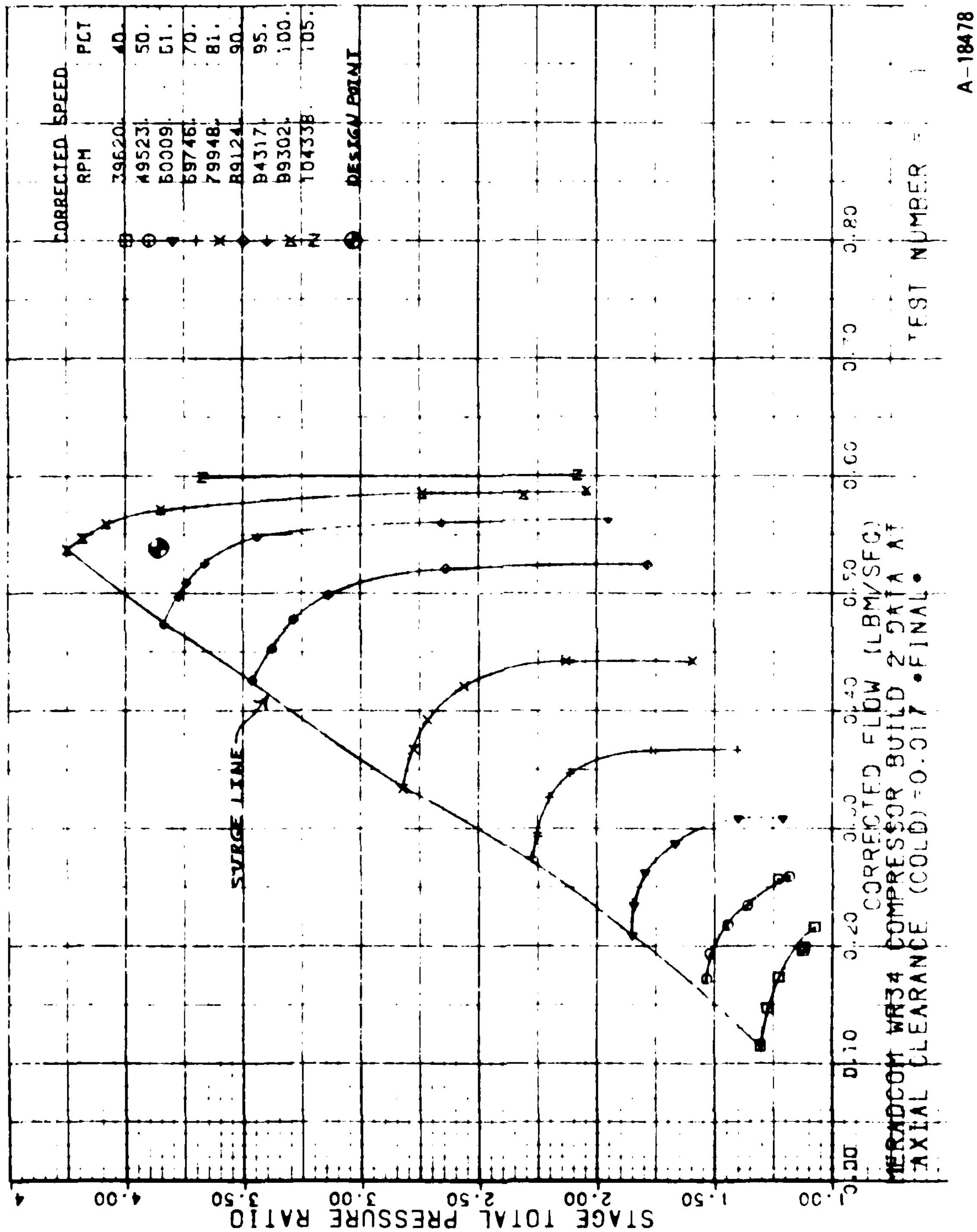


Figure 14. Stage Total Pressure Ratio versus Corrected Airflow

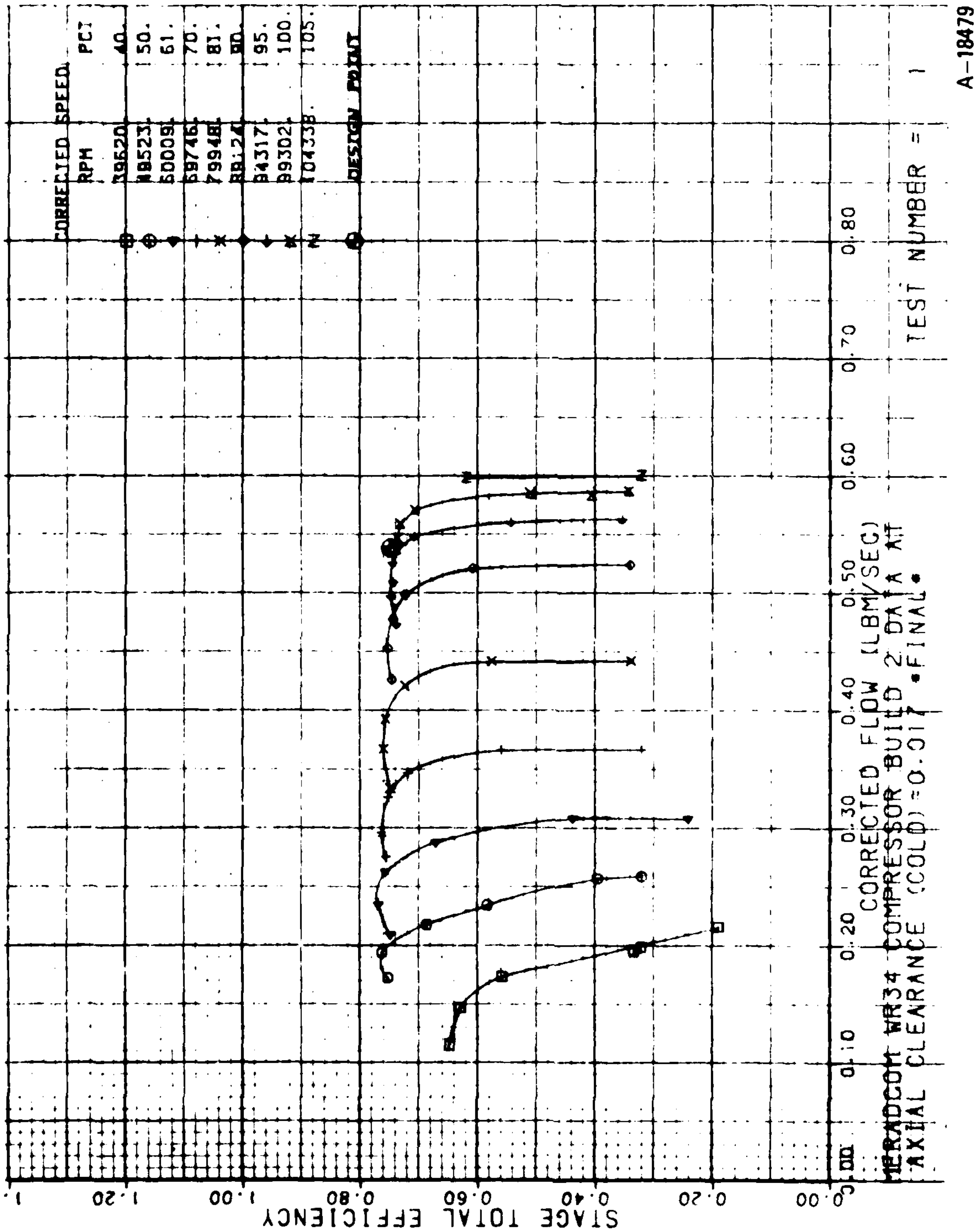


Figure 15. Stage Total-to-Total Efficiency versus Corrected Airflow

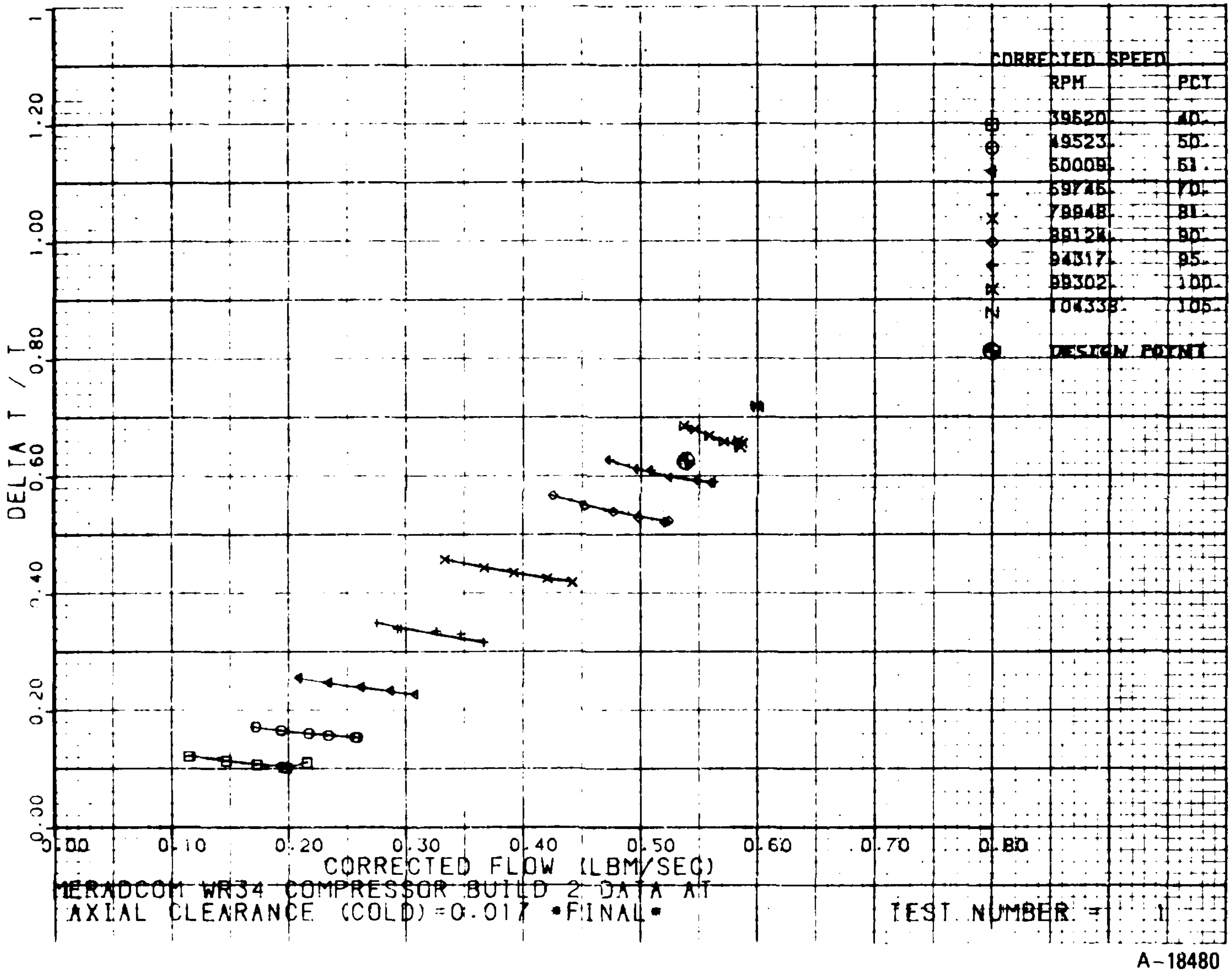
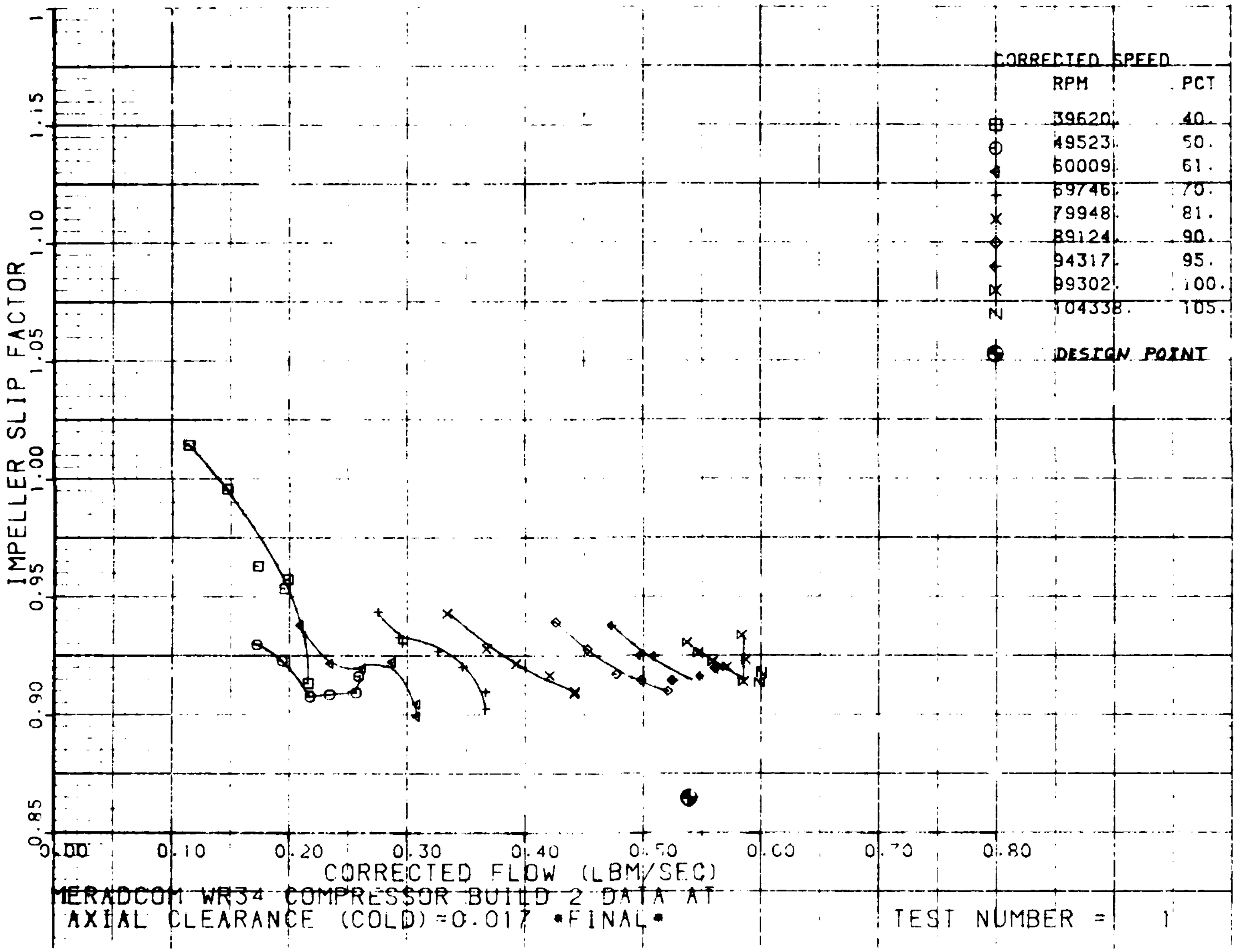


Figure 16. Stage Temperature Rise versus Corrected Airflow

TABLE IV. MERADCOM WR34 COMPRESSOR DESIGN POINT COMPARISON OF PREDICTED VERSUS RIG TEST DATA

	PROGRAM GOAL	DATA
Corrected Airflow (lbm/sec)	0.538	0.538
Corrected Speed (rpm)	99,050	98,999
Pressure Ratio (inlet total to stage exit total)	3.862	4.252
Efficiency (inlet total to stage exit total), percent	74.9	74.0
Pressure Ratio (inlet total to stage exit static)	3.757	4.119
Efficiency (inlet total to stage exit static), percent	73.0	72.0
Temperature Rise ($\Delta T/T$)	0.625	0.688
Stage Exit Mach Number	0.200	0.215
Axial Running Clearance (inches)	0.005	0.0055
Radial Running Clearance (inches)	0.007	0.007



A-18481

Figure 17. Impeller Slip Factor versus Corrected Airflow

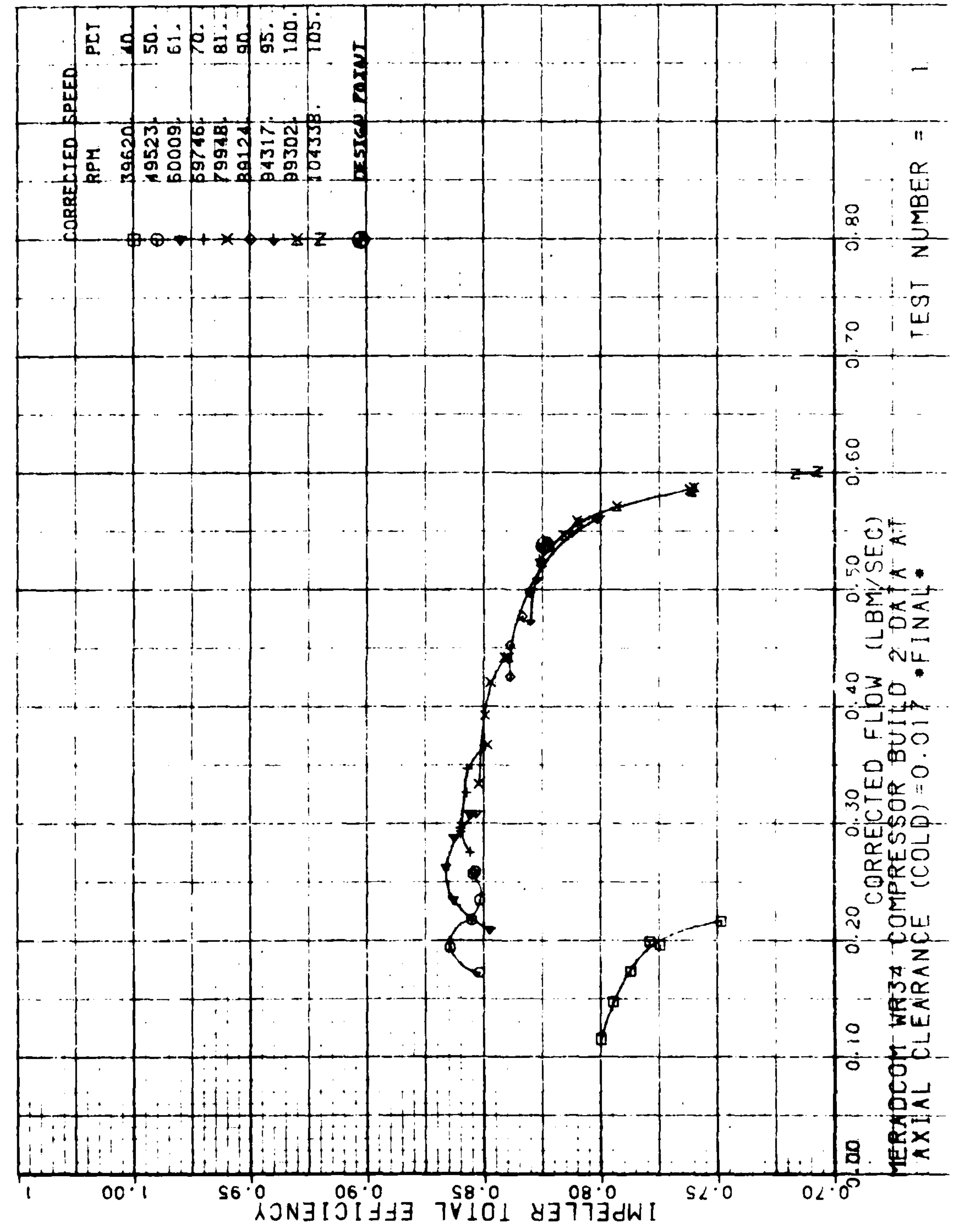
factor calculated at all test data points. Note the substantially higher values then would be expected from correlations. Several possible hypotheses could explain the higher than expected slip factor. One explanation is that compressor discharge air was getting past a carbon seal and leaking into the impeller back cavity, thus inserting previously compressed air at the impeller exit. An alternate explanation is that low momentum fluid at the impeller exit was recirculating back into the impeller, thus increasing its temperature level.

The secondary temperature anomaly was also of concern. From the data presented in Appendix A at the compressor design point, it was observed that a temperature spread of 14.29°F exists on the compressor exit thermocouples. It would be expected that they would read much more uniformly. Possibly the close proximity of the main housing, which was aluminum and therefore conducted heat readily from the gearbox, to the thermocouples at the compressor exit caused the temperature spread. The close proximity of the thermocouples to the main housing was caused by the very small passage height at the stage exit. Although the temperature problems are unexplained at this time, some very positive results did come from the testing.

Both the impeller and diffuser performance were only slightly short of their performance goal at the design point. As this was the first rig test of the compressor, the results are very encouraging and portend improved compressor performance with further compressor development. The impeller performance was synthesized from measured airflow, measured speed, measured stage inlet and exit temperatures, measured impeller exit static pressures, and an effective area at the impeller exit. Diffuser static pressure recovery was then calculated based on the synthesized impeller performance and the measured stage exit static pressure. Impeller performance, which is presented in Figures 18 and 19. The impeller design point measured static pressure distribution along the stationery shroud, shown in Figure 20, compares reasonably well with the prediction. Diffuser recovery also compares closely to the prediction.

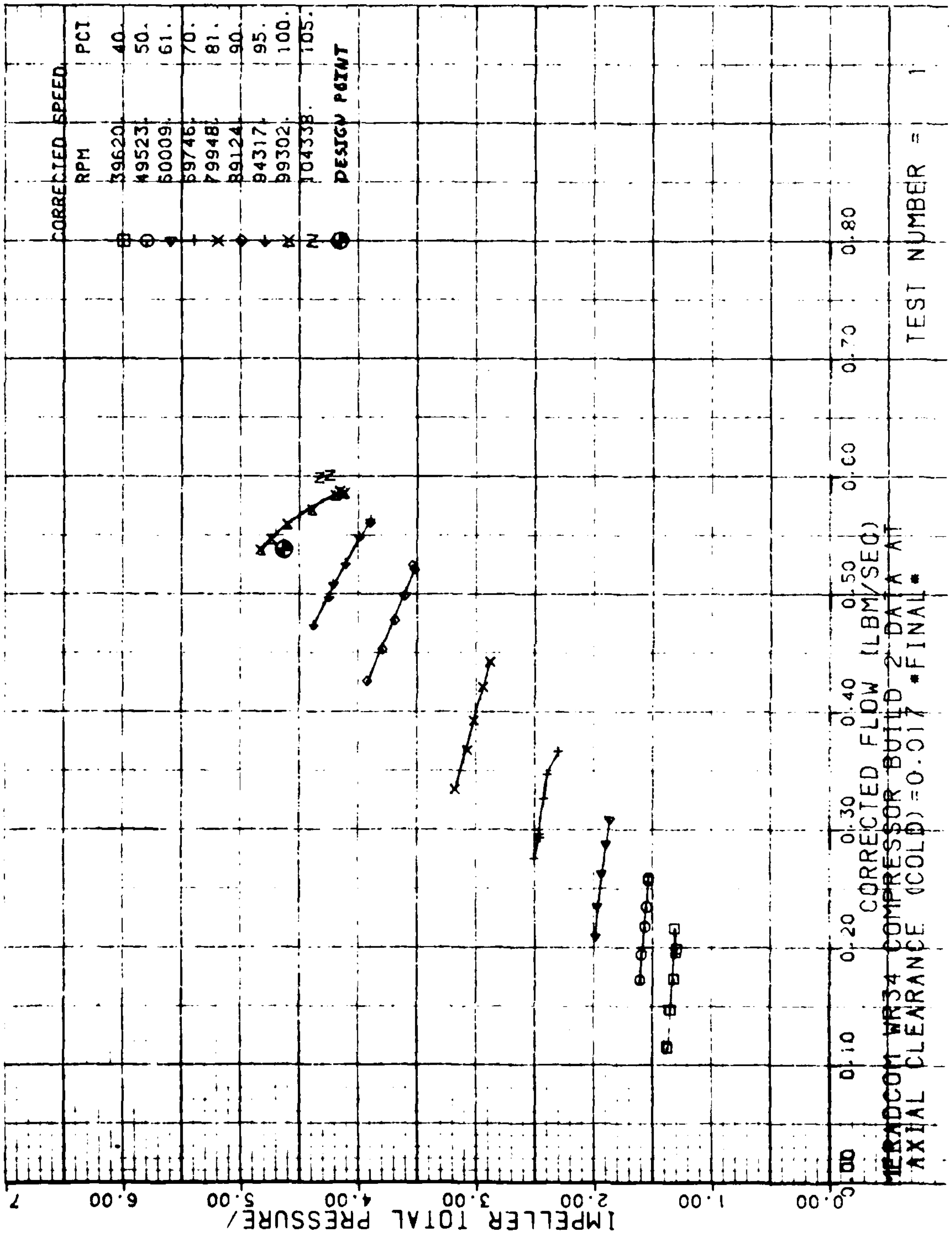
The diffuser static pressure recovery, calculated from the test data at the compressor design point, is 68.7 percent. Figure 21 presents the diffuser static pressure recovery for all valid test data points.

Figure 22 presents the calculated impeller exit absolute flow angle variation with corrected airflow and speed for all valid test data points. It is an output of the impeller calculation. Note the relatively constant value of swirl angle at compressor choke (minimum value of angle along each speed line). This, coupled with the absence of a sharp compressor temperature rise



A-18482

Figure 18. Impeller Total-to-Total Efficiency versus Corrected Airflow



A-18483

Figure 19. Impeller Total-to-Total Pressure Ratio versus Corrected Airflow

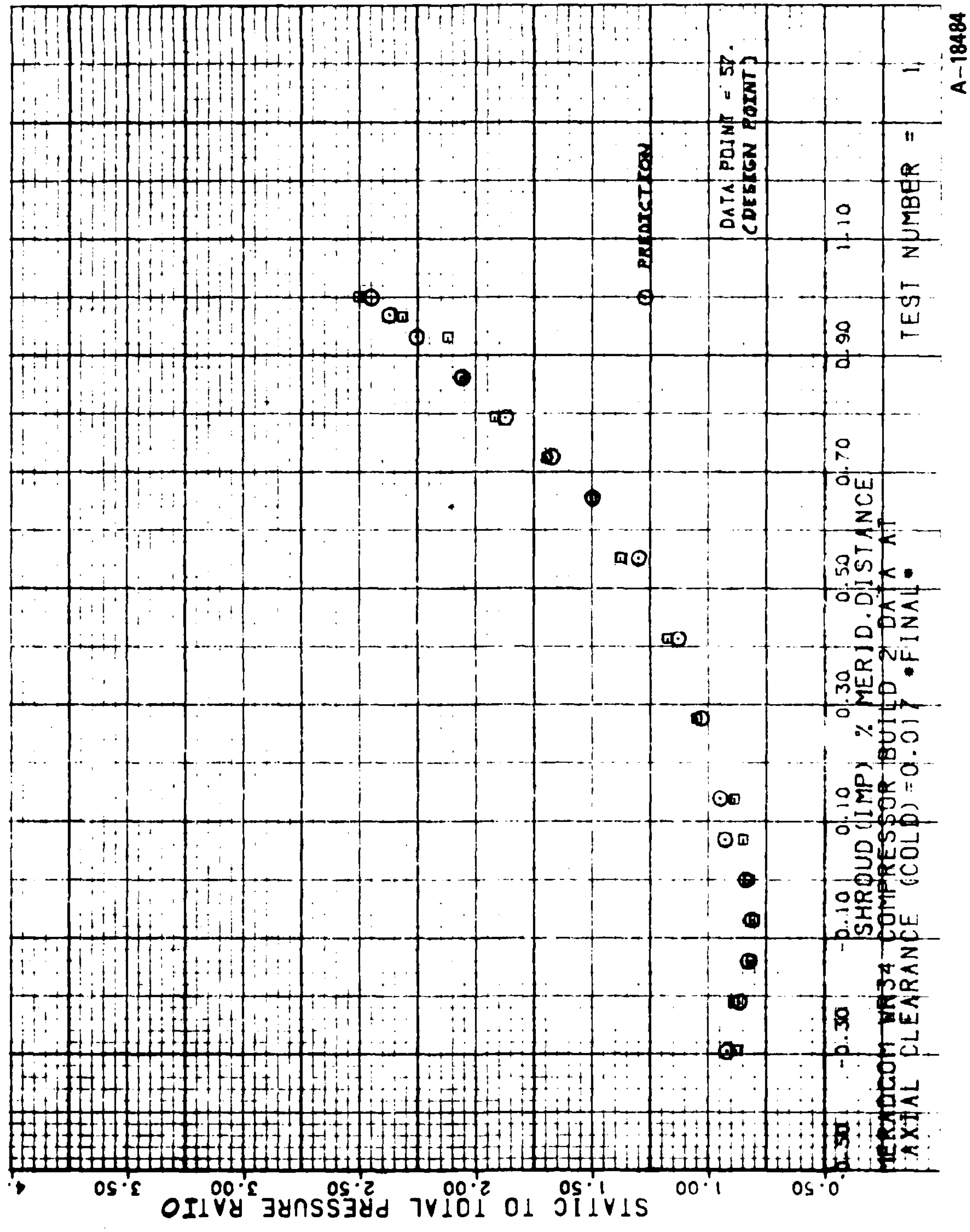


Figure 20. Impeller Shroud Static Pressure Distribution at the Design Point

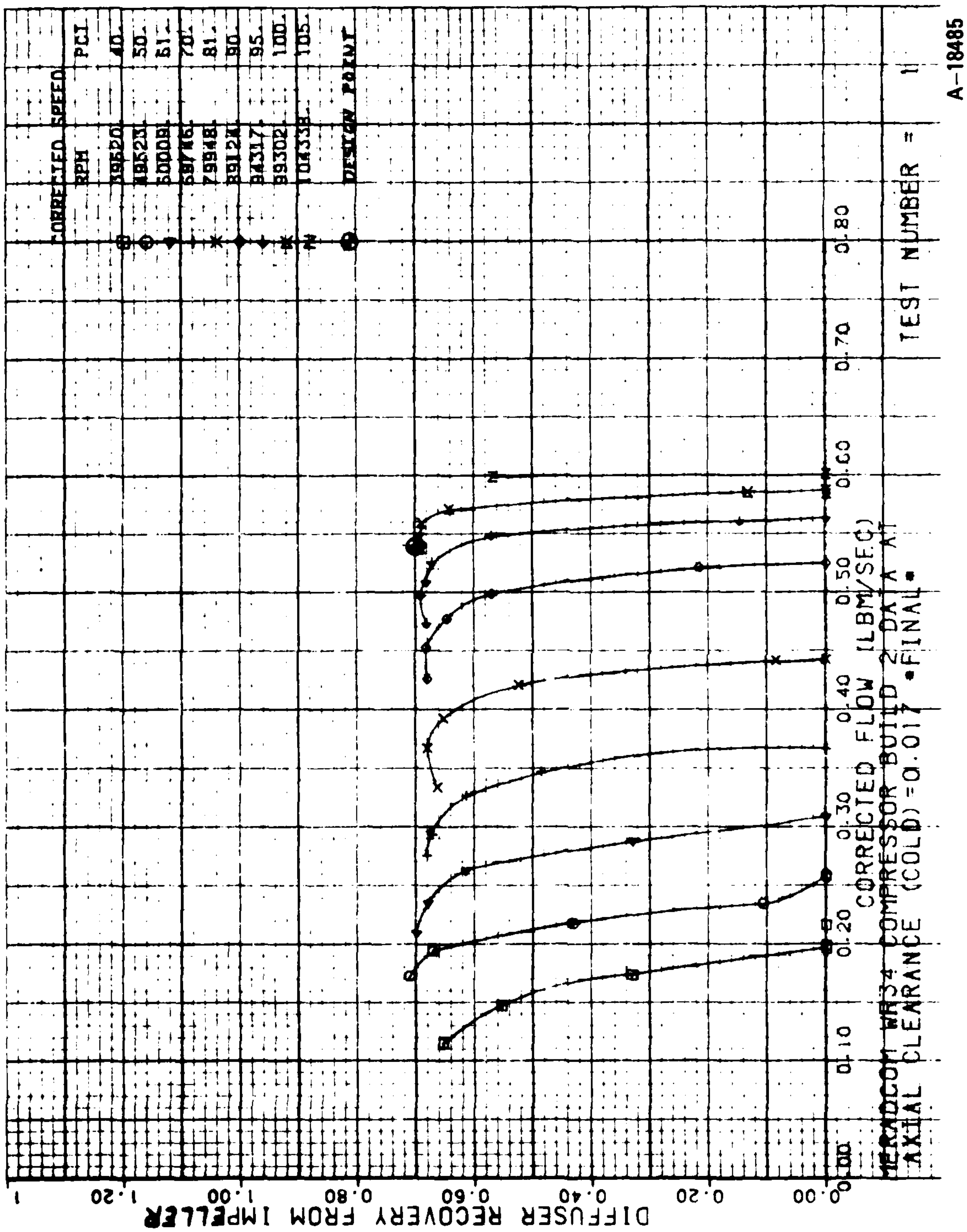


Figure 21. Diffuser Static Pressure Recovery Coefficient from the Impeller

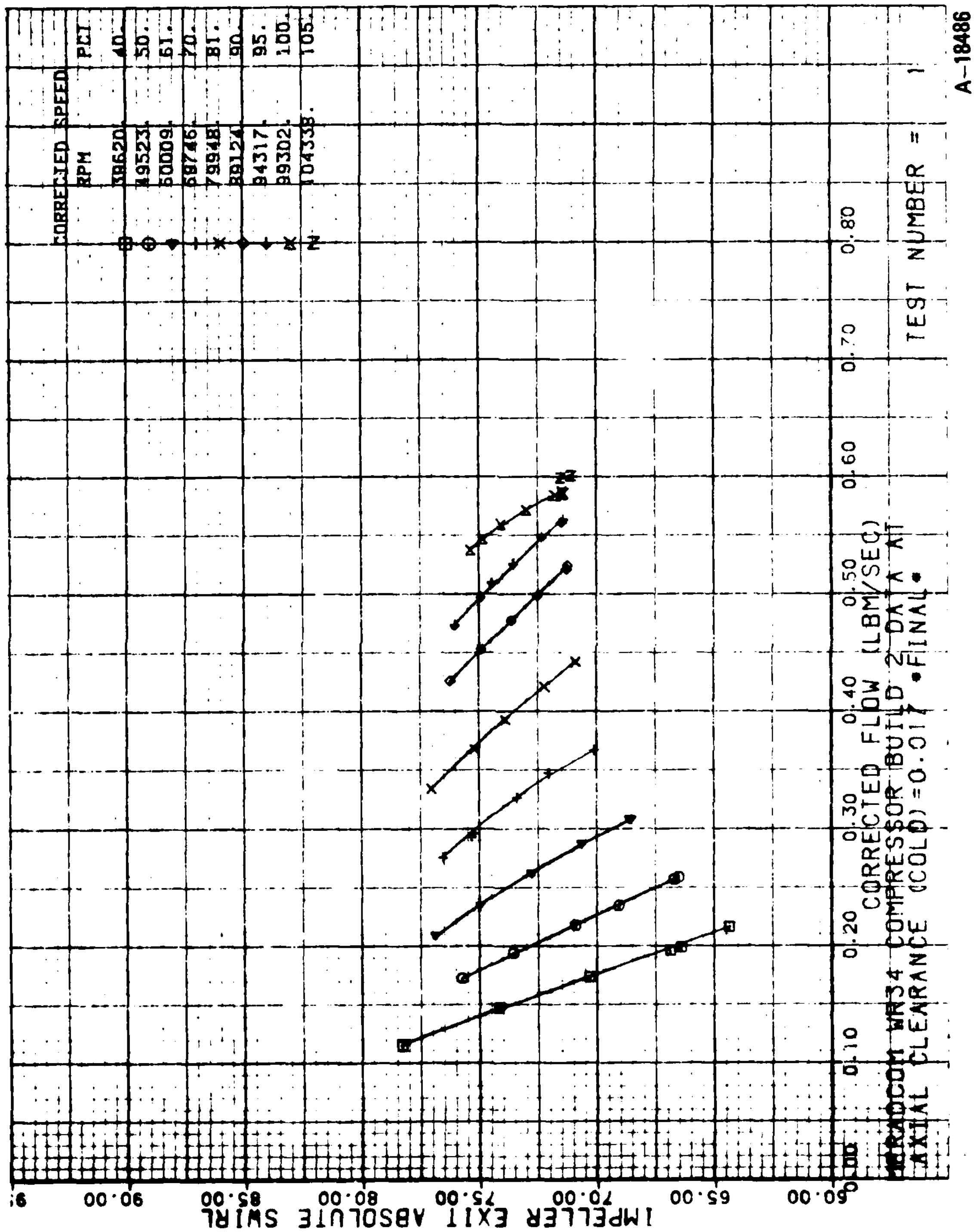


Figure 22. Impeller Exit Absolute Swirl Angle versus Corrected Airflow

reduction at compressor choke from Figure 16, indicates the diffuser controlled choke at corrected speeds above 80 percent of design corrected speed. However, the varying swirl angle at surge (maximum value of angle along each speedline) indicates that the impeller may control surge. A possible explanation for this phenomena is that, at the surge value of impeller incidence, the relatively thick impeller blades form a shock structure that triggers impeller surge. Further testing is required to verify which component, the impeller or diffuser, controls surge.

3.2 CYCLE ANALYSIS RESULTS

The true test of the adequacy of the tested WR34 compressor performance was whether it properly matched with the remainder of the engine. Therefore, the unaltered WR34 test data was input to the WR34 engine computer simulation. The engine achieved the desired output of 35 horsepower with a turbine inlet temperature of 1868°F and a specific fuel consumption of 1.14. In addition, the contract requirement of 27.7 horsepower on a 107°F day at an altitude of 5000 feet was also satisfactorily demonstrated. However, it should be noted that if the horsepower requirement were reduced to approximately 20.1 (approximately 15 KVA), with the same temperature and altitude conditions, turbine life should increase by more than 1,000 hours. Although higher compressor efficiency is desirable, the tested compressor is more than adequate to operate the WR34 engine. Table V presents a summary of the engine cycle.

TABLE V. ENGINE PERFORMANCE CYCLE WR34-8

		ENGINE (WR34-8)	ENGINE (WR34-8)
	T_{AMB} – °F	59	107
	P_{AMB} – PSIA	14.696	12.22
	HP_{OUT}	35.0	27.7
	SFC – LB/(HP·HR)	1.097	1.135
	TIT – °F	1710	1868
	N – RPM	100000	100000
	W_N – LB/SEC	0.550	0.407
INLET	$(\Delta P/P_T)_{INLET}$	0.01	0.010
	ΔT_{INLET}	10	10
COMP.	$W\sqrt{\theta}/\delta$ – LB/SEC	0.555	0.5157
	$N/\sqrt{\theta}$ – RPM	99050.	94838.
	P_R	3.921	3.631
	ΔT	353.3	353.4
	η	0.710	0.717
BURNER	$(W\sqrt{T_T}/P_T)_{IN}$	0.2835	0.2794
	$(\Delta P/P_T)$	0.030	0.030
	f/a	0.0196	0.0217
	η	0.995	0.995
	F.H.V. – BTU/LB	18400	18400
TURB	$(W\sqrt{T_T}/P_T)_{IN}$	0.4674	0.4657
	P_R	3.72	3.454
	$\eta_{TOTAL\text{-}STATIC}$	0.788	0.79
	$(N/\sqrt{T_T})_{IN}$	2146	2072
EXH	$(\Delta P/P_T$STATIC - AMB.	0.01	0.010
PAR. LOSSES	BEARING FRI-HP	1.05	1.05
	η_{GB}	0.97	0.97
	% LEAKAGE	1.00	1.0

A-155048

SECTION 4

CONCLUSIONS

The WR34 compressor, which was designed to withstand army ground power engine operating environment, has shown to perform adequately in combination with the other existing engine components based on the compressor rig test data. The compressor features a relatively thick bladed impeller design that enables it to be reliably cast using state-of-the-art techniques. The diffuser uses the proven vane-island design machined from 304 stainless steel which is inexpensive to fabricate and resistant to erosion effects on the diffuser performance. The goal of this compressor and diffuser design choice was to keep the WR34 engine fabrication inexpensive without compromises to performance and engine life.

From the data obtained during the initial rig test of the WR34 compressor it is apparent that, while further testing could result in a more detailed understanding of the compressor, the existing results are more than aedquate for the WR34 engine.

Cycle analysis using the compressor rig test data, has verified that the engine can meet the contract specification of 27.7 horsepower on a 107°F day at an altitude of 5,000 feet. As previously noted the reduction of the horsepower to 20.1 will add over 1,000 hours to the life of the turbine. The combined rugged design and excellent performance demonstrated during compressor rig tests indicates the next logical step would be the operating evaluation. Thus, keeping to the WR34 Performance Improvement Program Schedule, Proposal 8125L.

SECTION 5

RECOMMENDATIONS

To verify that the tested compressor performance is consistent with its operation in the engine, and to ensure that the engine computer simulation is a correct representation of engine performance, it is recommended that a WR34 engine be thoroughly instrumented and tested. Instrumentation on the compressor would be a representative sample of what was used during rig testing to allow a direct comparison between engine and rig performance. This testing would be conducted using existing WR34 engine testing facilities at Williams Research. Test data to verify the predicted performance of all the engine components would be obtained and would provide insight into any possible differences between test rig and engine compressor performance.

Rig and engine data on the compressor would then be compared to determine if any change to the compressor is needed to better satisfy engine operation. At this point, the WR34 compressor could be rig tested again and a determination of why it was 10 percent high on temperature rise made. This would be done by running the impeller without the diffuser being present (vaneless space only test) to establish the impeller flow range and temperature rise. If the impeller surges where the stage test did at compressor design speed, a flow stability problem in the impeller would exist and a recontour of the present impeller in the exit region (material off the impeller shroud side) to reduce impeller internal velocity diffusion would be conducted. The main housing would then be metal sprayed and recountoured to match the impeller. The recontoured impeller would then be tested in the vaneless space test configuration. Based on the results of this rig testing, further modifications to the impeller would be identified. Assuming that the impeller operates properly, a new vaned diffuser design and fabrication would be undertaken and a full compressor stage rig test would be conducted. This recommended course of action would result in an effective compressor development program.

Based on the results of the engine testing, modifications to components other than the compressor would also be identified. Improvements could then confidently be made to the WR34 engine.

APPENDIX A

COMPRESSOR RIG TEST DATA

EVENTS AND COMMENTS (continuation) p8/

Model: WR 34 496
S. Herridge
MERADCOM
#1
12-6-80
Mechanical Check-Run
Compressor Test Rig

12/5/80 Start Comp Rig 16:40 accelerate up to N ≅ 25000 RPM. Mechanical check-run is good. Slight error in temp readouts inlet @ ASME nozzle. Check tc's 1,2 & 3
Shut Rig down 16:50

12/6/80 Amb Temp = 74.0 °F
Barometer = 29.36 in Hg
Note Vib #2 Sensitivity = 10

Start 8:06 accelerate ⇒ N = 40 000 RPM
no mechanical problems continue running
instrumentation check is good

D.P. #1 8:12 N = 40510 RPM record data
accelerate to 50% N no problems

D.P. #2 8:16 N = 50200 RPM record data
no mechanical problems continue running
accelerate to N = 60%

D.P. #3 8:23 N = 60000 RPM record data
oil Scavenge temps @ front & rear rig Brgs have increased 100°F & 150°F respectively
accelerate to 70% N

D.P. #4 8:28 N = 71000 RPM record data
Rig oil scavenge temps slight increase to front 110°F & 175°F
accelerate to 80% N

EVENTS AND COMMENTS (continuation) pg 2

4090 (6-79)

ENGINE MODEL WR 34 496 ENGINEER S. Herridge
SERIAL NO. MERADCOM COMPLETION DATE
BUILD NO. MECHANIC
CHANGE NO. INSPECTOR
STARTING DATE 12-6-80 ENGINEER APPROVAL
TEST OBJECTIVE MERADCOM Mechanical Check Run Compressor Test Rig

D.P. #5 8:34 N = 80750 RPM record data
Oil Scavenge temps front ≅ 100°F ; Rear 220°F
8:36 decelerate rig & change ASME ~~exhaust~~ inlet nozzle ΔP ~~to larger size~~ water to ~~20~~ U-tube
Deceleration sounds good no mechanical problems

Idle at N = 28000 RPM let front & rear rig Brgs cool

8:43 Shut rig down run down sounds good
slight oil leakage from rig → vent 6/R
Change Vib #2 sensitivity to 20.6
CONVERT ASME NOZZLE MANOMETER TO 50" U TUBE with [illegible] H_2O
Run time = 37 minutes
Note heat transfer from c/B & Discharge Plenum appears to affecting Rig Rear Brg Temp

9:26 Start Rig gradually accelerate up to N = 80000 RPM repeat D.P. #5
Note Vib #1 begins ~~[illegible]~~ @ 2.00 G's than tapers off as N increases. Idle @ 33000 RPM add oil to rig

9:31 accelerate rig to 80% N continued operation sounds good - no mechanical problems

EVENTS AND COMMENTS (continuation) pg 3

Engine Model: WR 34 496
Serial No: MERADCOM
Build No: #1
Date: 12-6-80
Engineer: Steve Herridge
Engineering Approval:
Objective: Mechanical Check Run
Compressor Test Rig

EVENTS AND COMMENTS

9:36 D.P. #6 N = 80760 RPM record data
no mechanical or physical problems rig sounds
good accelerate to 90% N

9:42 D.P. #7 N = 90350 RPM record data
Vib #1 = 4.3 slight loss in oil
(oil vapor)
accel to 100% N

9:47 D.P. #8 N = 100,012 RPM
Vib #1 6.5 → 7.8 6's

losing oil out exhaust stack
9:49 Decelerate Rig Vib's begin to decrease
with speed. Oil pressure to rig held
at 44 psi
As oil temp @ Front & Rear Rig Brgs
increased so did Vib Front 6.5 → 8.0 6's
Rear 3.8 → 4.5 6's

9:52 Disengage clutch ~~[illegible]~~ shut rig down
Run down sounds good no apparent problems
Mechanical Check is good accept for Oil leakage problem
Run time = 26 minutes

Add oil 1 qt +

10:03 Start Rig accelerate ~~gradually~~ steadily to
100% N. Oil pressure to rig 44 psi
Oven head temp From 100°F ; Rear 180°F
Accelerate steadily to N = 100 000 RPM

EVENTS AND COMMENTS (continuation) pg 4

WR34 496 — Steve Herridge
MERADCOM
#1
12-6-80
MEchanical Check Run — Compressor Test Rig

attempt N = 100 000 RPM ; oil pressure inlet to rig = 44 psi Rig temp
Front Brg = 150°F ; Rear Brg 300°F
Vib #1 = 4.5 → 5.0 G's
Vib #2 = 3.0 → 3.5 G's spiked @ 7 G's

10:13 Rig shut down automatic trip
run down is good. No apparent problems
accept for major oil leakage out rig.

10:16 Start Rig accel to N = 100 000 RPM

10:20 Rig Shut Down automatic trip, air in lubrication system; scavenge pump out?
scavenge pump is ok. Regal 20W oil is foaming to much to prevent proper scavenging from G/B. Therefore oil pressure to Comp Rig drops causing "automatic trip shut down"

10:05 → 10:13 8 min
10:16 → 10:20 4 min } = 12.0 min run time

Drain Regal 20 W oil and completely refill system with Texamatic A oil

12:30 Start Comp Rig ; run @ N = 34 000 RPM warm-up accelerate to N = 100 000 RPM

12:35 Shut down oil pressure drop
Add auxiliary oil scavenge pump to increase oil scavenge

EVENTS AND COMMENTS (continuation)

pg 5

MODEL	ENGINEER
SERIAL NO.	COMPLETION DATE
NO.	MECHANIC
CHANGE NO.	INSPECTOR
DATE	ENGINEER APPROVAL

TEST OBJECTIVE

EVENTS AND COMMENTS

13:20 Start rig accelerate to 35000 RPM idle for warm-up. Accelerate to 100000 RPM. Stabilize at 100000 RPM

13:30 DP #9 N = 100090 RPM record data Vib #1 3.5 → 4.5 G's. Close exhaust valve to obtain partial choke conditions

13:33 D.P. #10 N = 100020 RPM record data sudden Increase in Vib #1 3.5 → 8.0 G's high squeal sound from rig

13:35 Declutch Shut rig down for inspection run down sounds good. Much Oil vapor found in cell. Disassemble Rig

Oil found inside Inlet Plenum Chamber
Excess heat build-up around Discharge Plenum
Shaft coupling bottomed out on spline drive
Outer Ring on Brg - Slight rotation
Front Rig Brg - Ball Separator came apart causing non-uniform spacing of balls

Comp Rotor - not damage
Main Hsg - not damage
Front face CLR = 0.011 → 0.013 in

Total Run Time = 111 minutes
Total Starts = 7

TITLE: MERADCOM Bld #1

COMMENTS: Compressor Test
Hand Data Hook-Up

TEST NO. 496
PAGE 2 OF 3
DATA SHEET 1A
DATE 6 DAY 12 MO. 80

		A-1 Boom Pos [redacted]	1	2	3	4	5	6
	N1 [RPM] (high speed)	#1	40680	50130	59960	70400	80850	80940
	N2 [RPM] (C/E internal)	#2	40700	50450	60110	70200	80820	80100
	Start Time		8:06					9:06
	Stop Time						8:43	
	Total Run Time						37 min	
G's	Vib #1 front Rig Brg	1	1.2	0.8	1.1	1.0	1.5	1.5
G's	Vib #2 Rear Rig Brg	2	0.4	0.5	0.6	1.0	2.2	1.0
G's	Vib #3	3	0.0	0.0	0.0	0.2	0.1	0.0
CE [°F]	T front Rig Brg	overhead ①	90	100	100	110	100	100
CE [°F]	T front Rig Brg	4	104	113	120.3	125.9	133.2	131.7
CE [°F]	T [illegible] Rig Brg	overhead ②	90	100	150	195	220	210
* CE [°F]	T [illegible]	—	—	—	—	—	—	—
* CE [°F]	T [illegible] High speed Rig	—	—	—	—	—	—	—
CE [°F]	T Oil Return → Rig	3	75.3	81.6	82.0	92.2	96.7	92.7
CC [°F]	T ASME Nozzle	5	48.9	46.6	45.2	45.2	45.5	47.1
CC [°F]	T Inlet Pipe	6	56.4	54.5	55.8	54.0	53.0	57.1
CC [°F]	T Inlet Pipe	7	51.8	50.7	53.6	46.1	46.8	46.9
[in H2O]	P ASME Nozzle	WALL	3.55	5.5	7.13	10.75	15.5	5.8
[psi]	P Oil Press to Comp Rig	PANEL	42	42	42	42	43	43
	Initial Face CLR	0.020						
	Final Face CLR	0.011 // 0.01						

* ADAS

TITLE: MERADCOM CH #1

COMMENTS: Compressor Test
Hand Data Hook-Up

TEST NO. 4?6
PAGE 2 OF 3
DATA SHEET 7 B
DATE DAY 12 MO. 80 YR.

		A-1 Boom Pos [redacted]	7	8	9	10		
	N1 [RPM] (mag. pick-up)	#1	90910	100300	100670	100280		
	N2 [RPM] (elec. ...)	#2	90920	100400	10070	100200		
	Start Time				13:30			
	Stop Time			9:52		13:35		
	Total Run Time			26 min		5 min		
G's	Vib #1	1	4.3	6.5	3.5	3.5		
G's	Vib #2	2	1.4	3.8	1.5	1.5		
G's	Vib #3	3	0.2	1.2	0.5	0.5		
CA [°F]	T front Rig Brg	overhead ①	100	140				
[°F]	T front Rig Brg	4	193.4	162.0	174.6			
CA [°F]	T rear Rig Brg	overhead ②	280	300				
* CA [°F]	T C/A High Speed Brg	—						
* CA [°F]	T C/A High Speed Brg	—						
CA [°F]	T Oil Return → Rig	3	103.8	115.1	100.7			
CC [°F]	T ASME Nozzle	5	46.7	46.3	46.4			
CC [°F]	T Inlet Pipe	6	47.0	47.0	45.9			
CC [°F]	T Inlet Pipe	7	48.0	47.1	45.1			
[" H2O]	P ASME Nozzle	U tube	20.4	25.8	25.2	24.8		
[psi]	P Oil Press to Comp. Rig	Panel	44	44	44	44		
	Initial Fuel ...							
	Final Fuel ...							

ADAS read-out

TITLE: *MERADCOM B/d #1*

COMMENTS: *Compressor Test*

Hand Data Hook-Up

TEST NO. *496*

PAGE *3* OF *3*

DATA SHEET *2A*

DATE *6* DAY *12* MO. *80* YR.

		A-1 Boom Pos						
		[redacted]	1	2	3	4	5	6
	Start Time							
	Stop Time							
	Total Run Time							
Eng #1	Water Temp [°F]	1						
Eng #1	Gen Amps							
Eng #1	Oil Press							
Eng #2	Water Temp [°F]	2	169	160	168	168	165	165
Eng #2	Gen Amps			6	4	4	4	4
Eng #2	Oil Press			42	48	48	50	55
[°F]	Amb Temp	74.0	74.0					
[in Hg]	Barometer	29.26	29.26					
	% Rel Humidity							

TITLE: MERADCOM Bld # 1

COMMENTS: Compressor Test

Hand Data Hook-Up

TEST NO. 49'

PAGE 3 OF 3

DATA SHEET 2B

DATE ___ DAY 12 MO. 80 YR.

	A-1 Boom Pos						
	[redacted]	7	8	9.	10.		
Start Time							
Stop Time							
Total Run Time							
Eng #1 Water Temp [°F]							
Eng #1 Gen Amps							
Eng #1 Oil Press							
Eng #2 Water Temp [°F]	2	170.9	168.5	164	168		
Eng #2 Gen Amps		4	4	6	6		
Eng #2 Oil Press		53	55	55	55		
[°F] Amb Temp	74	76	—				
[Hg] Barometer		29.35	—				
% Rel Humidity							

EVENTS AND COMMENTS (continuation)

pg 1

4000 (8-70)

ENGINE MODEL: NERADCOM TEST
SERIAL NO.
BUILD NO: 2
CHARGE NO
STARTING DATE: 12-19-80
TEST OBJECTIVE: Compressor Test

Rid # 2

ENGINEER: S.H. R. F.H. K. E.
COMPLETION DATE: 12-20-80
MECHANIC
INSPECTOR
ENGINEER APPROVAL

LAST READ	EVENTS AND COMMENTS
15.00	START ENGINE – WARM UP
15:34	RIG ENGAGED
15:38	ACCEL TO 40 K R.P.M.
15:42	DATA PT. #1
15:45	SET TO CHOKE
15:58	DATA PT. #2
16:00	SET TO SURGE
16:04	DATA PT. 3
16:05	SET TO S+1
16:09	DATA #4
16:	SET TO S+2
16:11	DATA #5
16:13	SET TO S+3
16:15	DATA #6
16:18	ACCEL TO 60 K
16:19	DATA PT 7 W.O.
16:21	SET TO CHOKE
16:22	DATA PT. 8
16:29	SET TO SURGE
16:30	DATA PT. #9
16:32	SET TO S+1
16:33	DATA PT. #10
16:35	SET TO S+2
16:36	DATA PT. 11
16:37	SET TO S+3
16:38	DATA PT. #12
16:40	ACCEL TO 80 K
16:43	DATA PT. #13
16:44	SET TO CHOKE
16:46	DATA PT. # 14
16:49	SHUT DOWN run time = 75 min

EVENTS AND COMMENTS (continuation)

P2

4090 (6-79)

ENGINE MODEL MERADCOM TEST
SERIAL NO
BUILD NO 2
CHARGE NO
STARTING DATE 12-19-80
TEST OBJECTIVE COMP. TEST

ENGINEER [illegible]
COMPLETION DATE 12-30-80
MECHANIC
INSPECTOR
ENGINEER APPROVAL

LAST READ	EVENTS AND COMMENTS
	Start Engine 11:00
	engine stall 11:200 restart
	Rig Start 11:20 accelerate to N = 50000 RPM
	let temp stabilize: ASME Nozzle temps
	do not stabilize accelerate to 70000 RPM
	10°F spread over temp range still remains.
	decelerate to 50000 RPM ; 48600 RPM mechanical
	D.P #17 W.O. 11:45
D.P.#18	11:49 choke N ≅ 48860 RPM
D.P.#19	11:55 surge N ≅ 48930 RPM
D.P#20	12:00 St1 ΔP = 3.0 N ≅ 48800 RPM
D.P#21	12:04 St2 ΔP = 3.8 N ≅ 48600 RPM
D.P.#22	12:06 St3 ΔP = 4.4 N ≅ 48600 RPM
	Accelerate to 60000 RPM ; 58,500 RPM mechanical
D.P.#23	12:09 W.O. ΔP = 7.6 N ≅ 58800 RPM
D.P.#24	12:11 choke ΔP = 7.6 N ≅ 58500 RPM
D.P.#25	12:17 surge ΔP = 3.5 N ≅ 58600 RPM
DP# 26	12:19 St1 ΔP = 4.4 N ≅ 58600 RPM
DP# 27	12:22 St2 ΔP = 5.5 N ≅ 58700 RPM
DP#28	12:27 St3 ΔP = 6.6 N ≅ 58600 RPM
	Accelerate to 70000 RPM ; 68400 RPM mechanical
D.P.#29	12:32 W.O. ΔP = 10.7 N = 68400 RPM
DP# 30	12:36 choke ΔP = 10.6 N = 68500 RPM
DP# 31	12:44 surge ΔP = 6.0 N = 68700 RPM
DP#32	12:48 Surge +1 ΔP = 6.8 N = 68700 RPM
* D.P. 33	12:50 Surge +1 ΔP = 6.8 N = 68700 RPM
D.P. 34	12:55 Surge +2 ΔP = 8.4 N = 68400 RPM
D.P. 35	12:58 Surge +3 ΔP = 7.5 N = 68500 RPM

* note: increase Guard Air 4→6 psi

EVE[illegible] pg 3

2

[illegible] MERADCOM	s.Herridge
[illegible]	[illegible] DATE 12-20-80
[illegible] NO. 2	MECHANIC
[illegible] NO.	INSPECTOR
[illegible]TING DATE 12-19-80	ENGINEER APPROVAL

[illegible] OBJECTIVE Compressor Test

EVENTS AND COMMENTS

Accelerate To 80000 RPM ; 77300 RPM mechanical

D.P. #36	13:04	W.O.	ΔP = 15.4	N ≅ 77500 RPM
D.P. #37	13:09	choke	ΔP = 15.3	N ≅ 77600 RPM
DP #38	13:16	Surge	ΔP = 8.8	N ≅ 77650 RPM
DP #39	13:23	Surg +1	ΔP = 10.6	N ≅ 77500 RPM
DP # 40	13:29	Surg +2	ΔP = 12.1	N ≅ 77500 RPM
DP # 41	13:32	SURGE + 3	ΔP = 13.9	N = 77500 RPM

ACCEL TO 90000 RPM 86800 mechanical

DP#42	13:38	W.O.	ΔP = 21.3	N = 86700 RPM
DP#43	13:43	choke	ΔP = 21.1	N = 86640 RPM
DP#44	13:48	surge	ΔP = 14.2	N = 86900 RPM
DP#45	13:51	surge +1	ΔP = 16.0	N = 86540 RPM
DP#46	13:54	surg +2	ΔP = 17.8	N = 86700 RPM
DP#47	13:57	Surge +3	ΔP = 19.3	N = 86590 RPM

Accelerate → 95000 RPM , 91600 RPM mechanical

DP#48	14:03	W.O.	ΔP = 24.5	N = 91600 RPM
DP#49	14:08	choke	ΔP = 24.3	N = 91640 RPM
DP#50	14:11	Surge	ΔP = 17.4	N = 91670 RPM
DP#51	14:16	surge +1	ΔP = 19.1	N = 91580 RPM
DP #52	14:19	Surge +2	ΔP = 20.1	N = 91540 RPM
DP #53	14:22	surge +3	ΔP = 21.3	N = 91650 RPM
DP #54	14:24	Surge +4	ΔP = 23.2	N = 91670 RPM

EVENTS AND COMMENTS (continuation)

3

P2 4

MODEL: AERADCOM	ENGINEER: S. Herridge
	COMPLETION DATE: 12-20-80
BUILD NO.: 2	MECHANIC:
CHANGE NO.:	INSPECTOR:
STARTING DATE: 12-19-80	ENGINEER APPROVAL:
OBJECTIVE: Compressor Test	

EVENTS AND COMMENTS

Accelerate to 100000 96500 RPM mechanical

D.P. 55	14:30	W.O.	ΔP = 26.5	N = 96680 RPM
D.P. 56	14:32	choke	ΔP = 26.3	N = 96500 RPM
DP 57	14:40	Surge	ΔP = 22.1	N = 96600 RPM
DP 58	14:42	Surge +1	ΔP = 23.0	N = 96600 RPM
DP 59	14:45	Surge +2	ΔP = 24.0	N = 96400 RPM
DP 60	14:47	Surge +3	ΔP = 25.0	N = 96500 RPM
DP 61	14:50	Surge +4	ΔP = 26.1	N = 96500 RPM

accelerate to 105% N 101300 RPM mech

DP 62	14:54	W.O.	ΔP = 22.6	N = 101400 RPM
		choke	ΔP =	N = 101300 RPM

declutch 14:57 shut down due to unusual noise, Vib #3 was loose from G/B Hsg. Clutch on #1 Eng was slightly warm. Remount Vib #3 by bolting to G/B.

15:50 Restart Engine

D.P. #63 Zero Point

16:00 Engage Clutch start compressor Rig

Check Vib pick ups at various speed line.

EVENTS ... (continued) pg 5

4

MERADCOM — S. Herridge — 12-20-80

2

12-19-80

Compressor Test

	EVENTS AND COMMENTS
DP 64	16:10 W.O. ΔP = 27.7 N = 101250 RPM
DP 65	16:14 choke ΔP = 27.5 N = 101250 RPM
	16:15 declutch shut-down: loud whine; Vib #1 increased to 5.8 G's G/B High Speed shaft Brg temp increased rapidly to 250°F. Also oil return to rig increased in temp. Front rig Brg temp increased rapidly.

TITLE: MERADCOM Bld # 2

COMMENTS: Compressor Test
Hand Data Hook-Up

TEST NO. 496
PAGE 1 OF 12
DATA SHEET A
DATE ___ DAY 12 MO. 80 YR.

T BC $ 82 21.8

Data Pt.

Units	Parameter	PROBE NO	1	2	3	4	5	6
			W.O	CHOKE	SURGE	S+1	S+2	
	N1 [RPM] high speed		39970	38400	38300	38500	38600	38400
	N2 [RPM] G/B internal		40010	38200	38400	38200	38600	38700
	Start Time	15:34						
	Stop Time							
	Data Pt. Time		15:43	15:53	16:04	16:09	16:11	16:13
	Total Run Time							
G's	Vib #1 front Rig Brg		1.0	0.5	0.6	0.6	0.6	0.5
G's	Vib #2 Rear Rig Brg		0.5	0.5	0.5	0.5	0.5	0.5
G's	Vib #3 G/B surface		2.0	2.5	2.6	2.3	2.8	2.5
cc [°F]	T front rig brg	over head ①	100	100	100	100	100	95
cc [°F]	T rear rig brg	over head ②	80	85	95	95	95	95
cc [°F]	T oil return → rig	3	75.3	81.5	78	78.8	79.3	79.7
cc [°F]	T front rig brg	4	80.0	82	89.6	91	87	90.1
cc [°F]	T ASME Nozzle	5	15.3	15	15.3	14.6	14.1	14.4
cc [°F]	T ASME Nozzle	6	14.2	14	14.2	13.6	13.5	13.7
cc [°F]	G/B Brg Temp front	7	121.3	130	130.6	131	131.1	131.2
cc [°F]	G/B Brg Temp rear	8	109.8	122	122	122.7	123.1	123.6
[in H2O]	ΔP ASME Nozzle	well	3.9	3.3	1.1	1.8	2.5	3.2
[psi]	P oil press → Comp Rig	U Tube gauge	44	44	40	44	44	44
	Initial Face CLR							
	Final Face CLR							

COMMENTS: [illegible]

2

TEST NO. [illegible]
[illegible] 2 [illegible] 12
DATA SHEET A
DATE 19 12 80

	PROBE NO	7 W.O.	8	9 SURGE	10 S+1	11	12
N [RPM] high speed		57	578	576	577	576	572
[RPM] [illegible]		57	576	576	575	575	572
Start Time							
Stop Time							
Data Pt Time		16:19	16:22	16:29	16:31	16:34	16:39
Total Run Time							
#1 front [illegible] brg		0.6	0.4	0.4	0.4	0.4	0.3
#2 rear [illegible] brg		0.5	0.5	0.6	0.5	0.5	0.5
#3 G/B [illegible]		2.6	2.5	2.5	2.3	2.0	2.1
[°F] T front rig brg	[illegible]	125	125	130	130	135	135
[°F] T rear rig brg	[illegible]	110	110	115	115	125	125
[°F] T oil return → rig	3	98.0	86	89.9	91.4	92.4	93.5
[°F] T [illegible] rig [illegible]	4	13[illegible]	97.0	126.5	130.5	132.7	140.9
[illegible] [illegible] E [illegible]	5	13.0	12.9	13.6	13.0	13.2	12.9
[illegible] [illegible] ME Nozzle	6	12.9	12.9	13.0	12.6	12.8	12.6
[°F] G/B [illegible] Temp [illegible]	7	160.7	164.6	168.4	169.6	170.5	170.9
[°F] G/B brg Temp [illegible]	1	147.6	152.2	155.5	156.4	157.4	157.8
[illegible] [illegible] E [illegible]	[illegible]	7.5	7.2	3.4	4.4	5.5	6.5
[illegible]	[illegible]	44	44	44	44	44	44
[illegible]							
Initial Face [illegible]							
Final Face CLR							

TITLE: [illegible] [illegible]

TEST NO. 496
PAGE 3 OF 12
DATA SHEET A
DATE 19 / 12 / 80 (DAY / MO. / YR.)

COMMENTS: Compressor Test
Hand Data Hook-Up

3

Data Pt.

		PROBE NO.	13	14	15	16	5	6
	N [RPM] high spe[illegible]		7629	760				
			763	760				
	[illegible]							
	Start Time							
	St[illegible]							
	[illegible]		16:42	16:				
	Total [illegible]							
	Vib #1 [illegible]		1.0	0.7				
	Vib #2 [illegible]		0.6	0.6				
	Vib #3 [illegible]		2.1	1.7				
[°F]	T front rig brg	overhead	200	200				
[°F]	T rear rig brg	overhead	200	190				
[°F]	T oil return rig	3	94.7	95.2				
[°F]	T [illegible] rig brg	4	167.3	167.2				
[°F]	T ASME Nozzle	5	14.6	12.6				
[°F]	T ASME Nozzle	6	13.2	12.9				
[°F]	[illegible] Temp [illegible]	7	206.5	208.3				
[°F]	[illegible] Temp [illegible]	8	188.9	190.3				
cc [°F]	ASME Nozzle	9						
	[illegible] ASME Nozzle		13.2	14.0				
	[illegible]		44	45				
	[illegible]							
	[illegible]							
	[illegible]							

ADAS 0 POINT

TITLE: MERADCOM Bld. # 2

COMMENTS: Compressor Test

Hand Data Hook-Up

DATA PT. 16

50%

TEST NO. 476

PAGE 4 OF 12

DATA SHEET A

DATE 20 / 12 / 80 (DAY / MO. / YR.)

		~~O POINT~~ Data Pt.	17	18	19	20	21	22
			W.O.	CHOKE	S	S+1	S+2	S+3
	N [illegible] high speed		48680	48854	48840	48820	48871	48870
	N [illegible]		48740	48846	48862	48880	48880	48866
	Start Time		11:25					
	Stop Time							
	Data Pt. Time		11:45	11:50	11:55	12:00	12:04	12:05
	Total [illegible] Time							
6's	[illegible] front [illegible] brg		0.2	0.2	0.2	0.2	0.2	0.2
G's	[illegible] #2 [illegible] brg		0.5	0.3	0.3	0.3	0.3	0.3
[illegible]	[illegible]		0	0	0	0	0	0
[illegible]	T front rig brg	over hood	110	105	105	105	105	105
[illegible]	T rear rig brg	over hood	110	110	110	110	110	110
[illegible]	T oil return → rig	3	89.3	85.2	84.4	84.9	85.5	85.9
[illegible]	T [illegible] rig brg	4	103.6	102.5	103.5	104.1	103.6	103.0
[illegible]	T ASME Nozzle	5	30.5	29.1	35.5	32.6	31.0	29.8
[illegible]	T ASME Nozzle	6	42.8	41.0	46.0	36.6	38.7	41.0
[illegible]	[illegible] Temp [illegible]	7	155.5	154.5	153.6	153.6	153.7	153.7
[illegible]	[illegible] Temp [illegible]	8	143.7	142.5	141.9	141.8	141.8	141.9
cc [°F]	T ASME NOZZLE	9	38.5	36.0	36.0	36.0	36.2	37.0
[illegible]	[illegible]	[illegible]	5.4	5.3	2.4	3.0	3.8	4.4
	[illegible]		44	44	44	44	44	44
	T [illegible] Fuel [illegible]							
	[illegible]							

TITLE: MERDP CM [illegible]

TEST NO. 476

PAGE 5 OF 12

COMMENTS: Compressor [illegible]

DATA SHEET A

60%

20 . 12 . 80 (MO. YR.)

			W.O.	CHOKE	[illegible]S	S+1	S+2	S+3
			23	24	25	26	27	28
	[illegible]		58880	58850	58882	58890	58780	58540
	[illegible]		58878	58859	58894	58897	58800	58500
	[illegible] Time		—	—	—	—	—	—
	[illegible] Time							
	[illegible] Time		12:09	12:11	12:16	12:18	12:23	12:27
	[illegible] Time							
	[illegible]		0.2	0.2	0.2	0.2	0.2	0.2
	[illegible] #2 [illegible]		0.3	0.3	0.3	0.3	0.3	0.3
	[illegible] #3 C/C [illegible]		0	0	0.1	0.0	0	0
	T [illegible]	[illegible]	120	120	125	125	125	125
	T [illegible]	[illegible]	140	140	143	145	145	145
	T [illegible]	3	88.0	89.4	91.8	92.8	94.0	[illegible]
	T [illegible]	4	108.5	108.3	113.0	113.5	113.2	[illegible]
	T ASME Nozzle	5	29.7	28.0	29.9	28.0	29.8	[illegible]
	T ASME Nozzle	6	40.0	40.0	40.8	36.1	39.0	[illegible]
	C/C Brg Temp [illegible]	7	169.0	170.6	172.8	173.8	174.7	[illegible]
	C/C Brg Temp [illegible]	8	155.3	156.6	158.9	159.7	160.6	[illegible]
cc (°F)	T ASME NOZZLE	9	32.6	35.7	35.0	37.0	36.5	[illegible]
	ΔP ASME Nozzle	[illegible]	7.6	7.6	3.5	4.4	5.5	6.6
	[illegible] → [illegible]	[illegible]	44	44	[illegible]	44	[illegible]	[illegible]

Initial [illegible]

Final [illegible]

[illegible] 6 12

[illegible] A

[illegible] 20 12 80

70%

		W.0 29	CHOKE 30	S 31	S+1 32	S+1 33	S+2 34
[illegible]		68600	68800	68750	68680	68750	68390
[illegible]		68590	68790	68810	68650	68710	68400
[illegible]		—	—	—	—	—	—
[illegible]							
[illegible] Time		12:32	12:37	12:44	12:47	12:51	12:65
[illegible]							
[illegible]		0.8	0.8	0.7	0.5	0.5	0.5
[illegible]		0.4	0.4	0.7	0.6	0.6	0.6
[illegible]		0	0	0	0	0	0
[illegible]	1	135	135	140	130	140	140
[illegible]	2	190	190	200	205	205	200
[illegible]	3	93.9	94.4	97.4	98.3	99.8	100.1
[illegible]	4	118.6	118.6	123.5	124.0	127.8	121.6
[illegible] ASME Nozzle	5	30.9	28.9	29.2	29.6	24.6	24.1
T ASME Nozzle	6	44.9	39.0	35.9	40.5	23.2	23.6
[illegible]	7	195.4	197.7	199.6	200.2	195.2	196.0
[illegible]	8	178.1	179.8	181.6	182.1	182.1	182.7
cc (°F) T ASME NOZZLE	9	38.5	30.5	33.6	32.1	23.9	23.2
ΔP ASME Nozzle		10.7	10.6	6.0	6.8	6.8	8.4
P oil press		45	45	45	45	45	45

7 12 A

20 12 80

		70% S+3 35	80% W.O. 36	CHOKE 37	SURGE 38	S+1 39	S+2 40
		68500	77770	77650	77600	77710	77650
		68495	77775	77590	77580	77670	77640
		12:58	13:03	13:09	13:15	13:24	13:29
		0.5	0.6	0.6	0.6	0.6	0.6
		0.6	0.6	0.4	0.5	0.5	0.5
		0	0	0	0	0	0
	1	130	140	140	150	150	150
	2	180	210	210	210	230	230
	3	101.4	103.2	101.8	103.0	105.8	107.1
	4	121.8	125.0	124.5	129.0	130.2	130.5
	5	23.8	25.1	21.5	23.1	23.0	22.5
	6	22.5	24.2	21.1	21.7	22.0	21.9
	7	196.4	214.7	217.1	217.8	219.4	220.1
	8	183.1	198.3	201.7	202.4	203.8	203.1
cc (°F) T ASME NOZZLE	9	22.6	23.0	21.0	21.9	22.1	22.2
		9.5	15.4	15.3	8.8	10.6	12.1
		45	45	46	46	46	46

8 12

20 12 80

90%

		S+3 41	W.O 42	CHOKE 43	SURGE 44	S+1 45	S+2 46
[illegible]		77606	86800	86670	86900	86670	86880
[illegible]		77640	86700	86640	86830	86660	86800
[illegible] Time		—	—	—	—		
[illegible] Time							
[illegible] Time		13:32	13:38	13:43	13:48	13:52	13:54
[illegible] Time							
[illegible]		0.6	1.2	1.2	1.1	1.1	1.1
[illegible]		0.5	0.6	0.6	0.6	0.6	0.6
[illegible]		0	0	0	0	0	0
[illegible]	1	140	150	150	170	160	161
[illegible]	2	230	270	270	290	280	280
[illegible]	3	100.2	108.9	108.3	110.6	111.8	113.1
[illegible]	4	130.7	134.9	135.8	139.0	139.6	138.0
[illegible]	5	22.7	22.5	22.4	22.7	22.8	22.7
[illegible]	6	22.0	21.8	22.1	22.2	21.8	22.1
[illegible]	7	220.8	239.9	240.5	241.6	242.0	242.8
[illegible]	8	203.8	220.6	221.5	222.1	222.2	222.8
cc (°F) T ASME NOZZLE	9	[illegible]	22.0	22.4	22.4	22.2	22.6
[illegible]		13.9	21.3	21.1	14.2	16.0	17.7
[illegible]		46	46	46	46	48	48

9 12

20 12 80

		90%		95%			
		S+3	W.O	CHOKE	S	S+1	S+2
		47	48	49	50	51	52
[illegible]		86670	91690	91560	91750	91700	91610
[illegible]		86662	91640	91540	91700	91630	91620
Start Time							
[illegible] Time							
[illegible] Time		13:57	14:02	14:05	14:12	14:16	14:19
[illegible] Time							
[illegible]		1.0	2.2	2.3	1.5	1.5	1.6
[illegible]		0.6	1.0	1.1	0.9	0.7	0.6
[illegible]		0	0	0	0	0	0
	1	160	160	160	173	175	175
	2	280	290	300	305	305	305
[illegible]	3	114.0	116.8	119.4	118.3	116.3	116.4
[illegible]	4	137.8	141.3	142.5	145.2	144.7	147.3
[illegible]	5	22.4	21.2	22.0	21.6	21.2	20.9
[illegible]	6	21.9	20.8	21.4	21.3	20.8	20.8
[illegible] Temp	7	243.1	253.2	254.5	254.8	254.3	254.4
[illegible] Temp	8	223.1	233.6	236.0	236.0	235.5	235.5
(°F) T ASME NOZZLE	9	22.0	20.5	21.2	21.2	20.6	22.9
[illegible]		19.3	24.6	24.3	18.4	19.1	20.1
[illegible]		48	48	48	48	48	48

10

10 12

20 12 80

95% → | 100%

		S+3	S+4	W.O.	CHOKE	S	S+(
		53	54	55	56	57	58
[illegible]		91700	91710	96610	96570	96600	96650
[illegible]		91600	91700	96600	96560	96600	96600
[illegible]		—	—	—	—	—	—
[illegible]							
[illegible] Time		14:22	14:25	14:29	14:32	14:39	14:43
[illegible]							
[illegible]		1.8	1.8	2.1	2.3	2.0	2.0
[illegible]		0.6	0.6	1.0	1.1	1.3	1.8
[illegible]		0	0	0.1	0.1	0.1	0.1
[illegible]	1	160	150	160	160	170	160
[illegible]	2	310	300	320	320	340	340
[illegible]	3	117.4	117.9	120.8	122.9	125.8	124.8
[illegible]	4	143.0	141.5	146.6	145.0	149.6	150.0
[illegible]	5	21.4	21.6	20.7	20.8	21.2	22.2
[illegible]	6	21.1	21.2	20.8	20.9	20.6	22.4
[illegible]	7	254.6	255.0	265.2	267.6	268.0	267.8
[illegible]	8	236.0	236.2	246.6	247.9	249.3	249.8
CC (°F) T ASME NOZZLE	9	21.0	20.2	20.6	20.8	20.1	21.0
[illegible]		21.3	23.2	26.5	26.3	22.2	23.0
		48	48	48	48	48	48

11 12 A

20 12 80

		100 %			105 %	
		St 2 59	St 3 60	St 4 61	W.O 62	CHOKE ~~63~~ S 63
[illegible]		96410	96310	96450	10154	101
[illegible]		96400	96300	96390	10150	101
		—	—	—	—	—
[illegible]						14:57
[illegible]		14:46	14:48	14:50	14:54	~~14:55~~
[illegible]		2.0	2.2	2.4	3.1	
[illegible]		0.9	0.5	1.0	1.9	
[illegible]		0.1	0.1	0.2	0.3	
[illegible]	1	160	160	160	160	
[illegible]	2	335	330	325	340	
[illegible]	3	122.9	122.2	122.0	124.0	
[illegible]	4	147.5	147.4	147.8	149.6	
[illegible]	5	20.8	21.1	21.0	20.5	
[illegible]	6	20.9	20.9	20.9	20.3	
[illegible]	7	268.0	266.9	266.6	274.9	
[illegible]	8	248.8	247.4	248.2	255.7	
(°F) T ASME NOZZLE	9	20.2	21.2	20.5	19.7	
[illegible]		24.0	25.0	26.1	27.6	2.
[illegible]		48	48	48	48	48

SHUT DOWN TO CHECK RIG

ZERO POINT

12 12
A
20 12 80

12

105%

		W.O. 64	CHOKE 65
		101350	101570
		101300	101532
		16:00	
			16:15
		16:11	16:14
		2.2	2.2
		1.1	1.1
		1.8	1.8
	1	160	1
	2	280	2
	3	112.9	119.8
	4	140.7	210
	5	20.1	
	6	20.2	2.
	7	263.0	268.0
	8	263.6	
cc (°F) T ASME NOZZLE	9	20.0	2.
		27.7	27.5
		46	47

TITLE: MERADCOM Bld # 2

COMMENTS: Compressor Test
Hand Data Hook-Up

TEST NO. 496
PAGE 1 OF 2
DATA SHEET B
DATE 19 (DAY) 12 (MO.) 80 (YR.)
20 - 12 - 80

		Start	D.P. #1 W.O.	D.P. #7 W.O.	D.P. #13 W.O.	D.P. 17 W.O.	D.P. 23 W.O.	D.P. #29 W.O.
		[redacted]						
	N_1 [RPM] (high speed)		40900	57600	76600		58,650	68600
	N_1 [RPM] (6/R internal)		40600	57400	76600		58850	68,700
	Start Time Eng	15:20						
	Stop Time							
	Total Run Time							
Eng #	Water Temp [°F]	118.3	154.1	161.7	162.8	160.4	167.5	168.4
Eng #	Gen Amps	6	5	5	5	2	3	3
Eng #	Oil Press	62	45	50	50	44	48	50
[°F]	Amb Temp	71	—	—		74		
[in Hg]	Barometer	29.50	—	—		29.69		
	% Rel Humidity							

TITLE: MERADCOM Bld # 2 TEST NO. 446

COMMENTS: Compressor Test PAGE 2 OF 2

Fixed Data Hook-Up DATA SHEET B

DATE 20 DAY 12 MO. 80 YR.

	PROBE NO	D.P. 36 W.O.	D.P. 42 WO	DP 48 W.O.	DP 55 W.O.	DP 62 W.O.	DP 64 W.O.
N [RPM] (high sp.		77500		916200	96500	101300	101300
N [RPM] (Counter		77600		917500	96500	101400	101300
Start Time							
Stop Time							
Total Run Time							
Water Temp [°F]		161.5	171.6	169.3	170.3	171.1	168.0
Gen Amps		3	2	3	3	3	3
Oil Press		50	50	50	50	52	52
Amb Temp							
Barometer							
Rel Humidity							

WILLIAMS RESEARCH CORPORATION CENTRIFUGAL COMPRESSOR TEST RIG DATA REDUCTION

MERADCOM WR34 COMPRESSOR THIRD RUN AT AXIAL CLEARANCE (COLD)=0.017 FOR DATA — DATE RUN : 02/15/81
TEST DATE 12 20 80 — TEST NO 1 — TIME RUN : 15.2505

CONSTANTS USED INSIDE THE PROGRAM INCLUDING INPUT VALUES AND STORED CONSTANTS

COMPRESSOR GEOMETRIC PARAMETERS IN INCHES

INDUCER HUB RADIUS	=0.4790
INDUCER EDGE OF BLADE RADIUS	=1.0560
IMPELLER EXIT RADIUS	=1.9205
IMPELLER EXIT PASSAGE HEIGHT	=0.1540
VANED DIFFUSER LEADING EDGE RADIUS	=2.0170
VANED DIFFUSER LEADING EDGE PASSAGE HEIGHT	=0.1500
VANED DIFFUSER THROAT WIDTH	=0.2043
VANED DIFFUSER THROAT PASSAGE HEIGHT	=0.1500
VANED DIFFUSER EXIT RADIUS	=3.5100
VANED DIFFUSER EXIT PASSAGE HEIGHT	=0.1500
OUTSIDE RADIUS AT DESWIRL VANE LEADING EDGE	=0.
INSIDE RADIUS AT DESWIRL VANE LEADING EDGE	=0.
OUTSIDE RADIUS AT DESWIRL VANE TRAILING EDGE	=0.
INSIDE RADIUS AT DESWIRL VANE TRAILING EDGE	=0.
OUTSIDE RADIUS AT STAGE EXIT	=3.7210
INSIDE RADIUS AT STAGE EXIT	=3.5710
NUMBER OF BLADES AT THE IMPELLER LEADING EDGE	= 14
NUMBER OF BLADES AT THE IMPELLER EXIT	= 14
IMPELLER BACKWARD CURVATURE ANGLE	=37.973
NUMBER OF VANES AT VANED DIFFUSER LEADING EDGE	= 19
NUMBER OF VANES AT VANED DIFFUSER TRAILING EDGE	= 19

COMPRESSOR AERODYNAMIC PARAMETERS

COMPRESSOR INLET EFFECTIVE AREA (PERCENT)	=0.9800
IMPELLER INDUCER EFFECTIVE AREA (PERCENT)	=0.9800
IMPELLER EXIT EFFECTIVE AREA (PERCENT)	=0.9000
VANED DIFFUSER LEADING EFFECTIVE AREA (PERCENT)	=0.9600
VANED DIFFUSER THROAT EFFECTIVE AREA (PERCENT)	=0.9600
VANED DIFFUSER EXIT EFFECTIVE AREA (PERCENT)	=0.9000
DESWIRL VANE LEADING EDGE EFFECTIVE AREA (PERCENT)	=0.9000
DESWIRL VANE TRAILING EDGE EFFECTIVE AREA (PERCENT)	=0.9000
COMPRESSOR EXIT EFFECTIVE AREA (PERCENT)	=0.9000

CONSTANTS AND CONVERSION FACTORS

COMPRESSOR DESIGN CORRECTED SPEED	= 99050.0
SPEED COUNT CONVERSION FACTOR	= 1.00000
BELLMOUTH DIAMETER	= 2.0125
BELLMOUTH EFFECTIVE AREA COEFFICIENT (PERCENT)	= 0.9900
GAS CONSTANT	= 53.3450
GRAVITATIONAL CONSTANT	= 32.1740
CONVERSION FROM INCHES OF MERCURY TO PSI	= 0.4911600
CONVERSION FROM INCHES OF MERRIAM 295 TO MERCURY	= 0.2169110
CONVERSION FROM INCHES OF WATER TO MERCURY	= 0.0735200

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**WILLIAMS RESEARCH CORPORATION CENTRIFUGAL COMPRESSOR TEST RIG DATA REDUCTION**

MERADCOM WR34 COMPRESSOR THIRD RUN AT AXIAL CLEARANCE (COLD)=0.017 FOR DATA          DATE RUN : 02/15/81
 TEST DAT.  12 20   80                                 TEST NO    1                  TIME RUN :  15.2505

PROGRAM OPTIONS UTILIZED

            COMPRESSOR INLET CALCULATION                 = YES
            INDUCER LEADING EDGE CALCULATION             = YES
            INDUCER TOTAL TEMPERATURE DATA               = NO
            INDUCER ANGLE DATA INPUT                     = NO
            INDUCER PSOUTER INPUT ONLY                   = YES
            IMPELLER SHROUD AND EXIT CALCULATION         = YES
            VANELESS SPACE CALCULATION                   = NO
            VANED DIFFUSER CALCULATION                   = YES
            BEND CALCULATION                             = NO
            DESWIRL VANE CALCULATION                     = NO
            STAGE EXIT CALCULATION                       = YES
            EFFICIENCY BASED ON ENTHALPY                 = YES
            WORK FACTOR IS INPUT                         = NO
            PERFORMANCE CORRECTED FOR HUMIDITY           = NO
            PERFORMANCE CORRECTED FOR REYNOLDS NO.       = YES
            ROTOR ONLY TEST                              = NO

SUMMARY OF NUMBER OF INPUT TEMPERATURE AND PRESSURE PARAMETERS

            NUMBER OF INLET BELLMOUTH TEMPERATURE ELEMENTS                                                  = 3
            NUMBER OF INLET PIPE OR TANK TOTAL PRESSURE ELEMENTS                                            = 4
            NUMBER OF INLET PIPE OR TANK TOTAL TEMPERATURE ELEMENTS                                         = 4
            NUMBER OF TOTAL PRESSURE ELEMENTS AT OR NEAR THE START OF THE COMPRESSOR INLET                  = 9
            NUMBER OF TOTAL TEMPERATURE ELEMENTS AT OR NEAR THE START OF THE COMPRESSOR INLET               = 9
            NUMBER OF STATIC PRESSURES ON THE OUTSIDE WALL AT OR NEAR THE START OF THE COMPRESSOR INLET     = 4
            NUMBER OF STATIC PRESSURES ON THE INSIDE WALL AT OR NEAR THE START OF THE COMPRESSOR INLET      = 0
            NUMBER OF TOTAL PRESSURE ELEMENTS AT OR NEAR THE IMPELLER INDUCER LEADING EDGE                  = 0
            NUMBER OF TOTAL TEMPERATURE ELEMENTS AT OR NEAR THE IMPELLER INDUCER LEADING EDGE               = 0
            NUMBER OF STATIC PRESSURES ON THE OUTSIDE WALL AT OR NEAR THE IMPELLER INDUCER LEADING EDGE     = 1
            NUMBER OF STATIC PRESSURES ON THE INSIDE WALL AT OR NEAR THE IMPELLER INDUCER LEADING EDGE      = 0
            NUMBER OF SINGLE TAP STATIC PRESSURE LOCATIONS ON THE IMPELLER SHROUD                           =16
            NUMBER OF MULTIPLE TAP STATIC PRESSURE LOCATIONS ON THE IMPELLER SHROUD                         = 1
            NUMBER OF IMPELLER BACK CAVITY TOTAL TEMPERATURE ELEMENTS                                       = 0
            NUMBER OF STATIC PRESSURE TAPS IN THE VANELESS SPACE BETWEEN THE IMPELLER AND DIFFUSER          = 0
            NUMBER OF STATIC PRESSURE TAPS AT THE VANED DIFFUSER LEADING EDGE                               = 4
            NUMBER OF TOTAL PRESSURE ELEMENTS AT THE VANED DIFFUSER THROAT                                  = 0
            NUMBER OF STATIC PRESSURE TAPS AT THE VANED DIFFUSER THROAT                                     = 3
            NUMBER OF STATIC PRESSURE TAPS AT THE VANED DIFFUSER EXIT                                       = 3
            NUMBER OF VANED DIFFUSER STATIC PRESSURES TO BE PLOTTED ON THE VANE LAYOUT                      =18
            NUMBER OF STATIC PRESSURE TAPS IN THE BEND DOWNSTREAM OF THE VANED DIFFUSER                     = 0
            NUMBER OF STATIC PRESSURE TAPS AT THE DESWIRL VANE LEADING EDGE                                 = 0
            NUMBER OF STATIC PRESSURE TAPS AT THE DESWIRL VANE TRAILING EDGE                                = 0
            NUMBER OF TOTAL PRESSURE ELEMENTS AT THE STAGE EXIT                                             =12
            NUMBER OF TOTAL TEMPERATURE ELEMENTS AT THE STAGE EXIT                                          =15
            NUMBER OF STATIC PRESSURE TAPS AT THE STAGE EXIT                                                = 0
            NUMBER OF STATIC PRESSURE TAPS IN THE COMPRESSOR DISCHARGE PLENUM                               = 3
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**WILLIAMS RESEARCH CORPORATION CENTRIFUGAL COMPRESSOR TEST RIG DATA REDUCTION**

MERADCOM WR34 COMPRESSOR THIRD RUN AT AXIAL CLEARANCE (COLD)=0.017 FOR DATA      DATE RUN : 02/15/81
 TEST DATE  12 20  80                          TEST NO   1                      TIME RUN :  15.2505

MEASURING FLUID USED FOR PRESSURE PARAMETERS

          INLET PIPE OR TANK MEASUREMENT                                                  =PSIG
          COMPRESSOR INLET MEASUREMENT                                                    =PSIG
          OUTSIDE WALL STATIC PRESSURE AT COMPRESSOR INLET MEASUREMENT                    =PSIG
          INSIDE WALL STATIC PRESSURE AT COMPRESSOR INLET MEASUREMENT                     =PSIG
          TOTAL PRESSURE AT INDUCER INLET MEASUREMENT                                     =PSIG
          OUTSIDE WALL STATIC PRESSURE AT IMPELLER INDUCER LEADING EDGE MEASUREMENT       =PSIG
          INSIDE WALL STATIC PRESSURE AT IMPELLER INDUCER LEADING EDGE MEASUREMENT        =PSIG
          IMPELLER SHROUD SINGLE STATIC TAP LOCATION MEASUREMENT                          =PSIG
          IMPELLER SHROUD MULTIPLE STATIC TAP LOCATION MEASUREMENT                        =PSIG
          VANELESS SPACE STATIC PRESSURE MEASUREMENT                                      =PSIG
          VANED DIFFUSER LEADING EDGE STATIC PRESSURE MEASUREMENT                         =PSIG
          VANED DIFFUSER THROAT TOTAL PRESSURE MEASUREMENT                                =PSIG
          VANED DIFFUSER THROAT STATIC PRESSURE MEASUREMENT                               =PSIG
          VANED DIFFUSER EXIT STATIC PRESSURE MEASUREMENT                                 =PSIG
          VANED DIFFUSER STATIC PRESSURES THAT ARE PLOTTED MEASUREMENT                    =PSIG
          BEND DOWNSTREAM OF VANED DIFFUSER STATIC PRESSURE MEASUREMENT                   =PSIG
          DESWIRL VANE LEADING EDGE STATIC PRESSURE MEASUREMENT                           =PSIG
          DESWIRL VANE TRAILING EDGE STATIC PRESSURE MEASUREMENT                          =PSIG
          STAGE EXIT TOTAL PRESSURE MEASUREMENT                                           =PSIG
          STAGE EXIT STATIC PRESSURE MEASUREMENT                                          =PSIG
          COMPRESSOR DISCHARGE PLENUM STATIC PRESSURE MEASUREMENT                         =PSIG


NOTE.....COMPRESSOR INLET TOTAL PRESSURE WILL BE USED AS THE INLET TOTAL PRESSURE IN CALCULATIONS (PTINL)

NOTE.....COMPRESSOR INLET TOTAL TEMPERATURE WILL BE USED AS THE INLET TOTAL TEMPERATURE IN CALCULATIONS (TTINL)

WARNING.....EXIT TOTAL PRESSURE TO BE USED IN CALCULATIONS IS NOT SPECIFIED. PTSTGE WILL BE DEFAULTED TO

WARNING.....EXIT STATIC PRESSURE TO BE USED IN CALCULATIONS IS NOT SPECIFIED  PSPLEN WILL BE DEFAULTED TO

WARNING.....EXIT TOTAL TEMPERATURE TO BE USED IN CALCULATIONS IS NOT SPECIFIED. TTSTGE WILL BE DEFAULTED TO
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WILLIAMS RESEARCH CORPORATION CENTRIFUGAL COMPRESSOR TEST RIG DATA REDUCTION

MERADCOM WR34 COMPRESSOR THIRD RUN AT AXIAL CLEARANCE (COLD)=0.017 FOR DATA   DATE RUN : 02/15/81
DATA POINT 57 TEST DATE 12 20 80   TEST NO 1   TIME RUN : 15.2505

TEMPERATURES AS INPUT IN DEGREES FARENHEIT WITH AVERAGES IN DEGREES RANKINE

ASME NOZZLE (TBELL)	TANK OR INLET PIPE (TTANK)	COMPRESSOR INLET (TTINL)	INDUCER LEADING EDGE (TTIND)	STAGE EXIT (TTSTGE)	IMPELLER BACK CAVITY (TTBACK)
21.200	38.703	32.266	0.	369.631	0.
20.600	0.	32.376	0.	369.192	0.
20.100	35.750	32.820	0.	365.674	0.
0.	36.448	34.483	0.	365.454	0.
0.	0.	35.038	0.	370.730	0.
0.	0.	0.	0.	373.149	0.
	0.	35.925	0.	375.128	
	0.	34.927	0.	379.744	
	0.	35.481	0.	374.468	
	0.	0.	0.	0.	
	0.	0.	0.	382.822	
	0.	0.	0.	377.326	
				377.986	
				378.645	
				373.149	
				0.	
				0.	
				0.	
				0.	
				0.	
				0.	
				0.	
				0.	
				0.	
480.321	496.655	493.852	0.	833.481	

WILLIAMS RESEARCH CORPORATION CENTRIFUGAL COMPRESSOR TEST RIG DATA REDUCTION

MERADCOM WR34 COMPRESSOR THIRD RUN AT AXIAL CLEARANCE (COLD)=0.017 FOR DATA
DATA POINT 57 TEST DATE 12 20 80 TEST NO 1

DATE RUN : 02/15/81
TIME RUN : 15.2505

PRESSURES AS INPUT IN INCHES OF WATER, MERRIAM 295 FLUID, MERCURY AND PSIG WITH AVERAGES IN PSIA

TANK OR INLET PIPE (PTANK)	COMP. INLET TOTAL (PTINL)	INLET OD STATIC (PSODINL)	INLET ID STATIC (PSIDINL)	INDUCER L.E. TOTAL (PTIND)	INDUCER L.E. OD STATIC (PSODIND)	INDUCER L.E. ID STATIC (PSIDIND)	SHROUD SINGLE TAP STATIC (PSS)	SHROUD SINGLE TAP STATIC (PSS)	SHROUD MULTI. TAP STATIC (PSM)	SHROUD MULTI. TAP STATIC (PSM)	VANELESS SPACE STATIC (PSVNLS)
-0.580	-0.594	-2.229	0.	0.	-2.965	0.	-2.229	12.247	23.534	0.	0.
-0.593	-0.594	-2.083	0.	0.	0.	0.	-2.083	14.323	18.849	0.	0.
-0.593	-0.594	-3.134	0.	0.	0.	0.	-3.134	15.081	19.833	0.	0.
-0.593	-0.593	-3.299	0.	0.	0.	0.	-3.299	17.780	17.744	0.	0.
0.	-0.593	0.	0.	0.	0.	0.	-2.965	0.	18.544	0.	0.
0.	-0.593	0.	0.	0.	0.	0.	-2.608	0.	24.102	0.	0.
0.	-0.593			0.			-2.076	0.	0.	0.	
0.	-0.593			0.			0.182	0.	0.	0.	
0.	-0.593			0.			1.896	0.	0.	0.	
0.	0.			0.			4.710	0.	0.	0.	
0.	0.			0.			6.495	0.	0.	0.	
0.	0.			0.			9.167	0.	0.	0.	
13.933	13.929	11.836	0.	0.	11.557	0.					

REFERENCE PRESSURES

PIPE OR TANK (RPTANK)	INLET TOTAL (RPTINL)	INLET OD STATIC (RPSODINL)	INLET ID STATIC (RPSIDINL)	INDUCER TOTAL (RPTIND)	INDUCER OD STATIC (RPSODIND)	INDUCER ID STATIC (RPSIDIND)	SHROUD SINGLE TAP (RPSSNG)	SHROUD MULTI. TAP (RPSMUL)	VANELESS STATIC (RPSVNLS)
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

DIFFUSER L.E. STATIC (PSDFLE)	DIFFUSER THROAT TOTAL (PTDFTH)	DIFFUSER THROAT STATIC (PSDFTH)	DIFFUSER EXIT STATIC (PSDFTE)	DIFFUSER PLOTTED STATIC (PSDFPLT)	DIFFUSER PLOTTED STATIC (PSDFPLT)	DIFFUSER EXIT BEND STATIC (PSBEND)	DESWIRL VANE L.E. STATIC (PSDSWLI)	DESWIRL VANE T.E. STATIC (PSDSWLE)	STAGE EXIT TOTAL (PTSTGE)	STAGE EXIT STATIC (PSSTGE)	DISCHARGE PLENUM STATIC (PSPLEN)
19.875	0.	33.203	43.400	19.875	0.	0.	0.	0.	45.512	0.	42.752
22.319	0.	33.881	43.168	22.874	0.	0.	0.	0.	44.938	0.	42.765
26.845	0.	33.325	42.911	27.791	0.	0.	0.	0.	43.827	0.	43.032
31.407	0.	0.	0.	33.203	0.	0.	0.	0.	44.352	0.	0.
0.	0.	0.	0.	22.319	0.	0.	0.	0.	44.511	0.	0.
0.	0.	0.	0.	26.845	0.	0.	0.	0.	44.719	0.	0.
				31.407	0.				43.815		
				33.881	0.				44.938		
				33.325	0.				44.499		
				38.478	0.				45.317		
				40.005	0.				45.341		
				41.617	0.				0.		
				42.081	0.						
				42.496	0.						
				42.838	0.						
				43.400	0.						
				43.168	0.						
				42.911	0.						
39.634	0.	47.992	57.682				0.	0.	59.229	0.	57.372

REFERENCE PRESSURES

DIFFUSER LE STATIC (RPSDFLE)	DIFFUSER THRT TOT (RPTDFTH)	DIFFUSER THRT STAT (RPSDFTH)	DIFFUSER EXIT STAT (RPSDFTE)	DIFFUSER PLT STAT (RPSDFPLT)	DIFFUSER BEND STAT (RPSBEND)	DESWIRL LE STATIC (RPSDSWLI)	DESWIRL TE STATIC (RPSDSWLE)	STAGE EXIT TOT (RPTSTGE)	STAGE EXIT STAT (RPSSTGE)	DISCHARGE PLEN STAT (RPSPLEN)
0.	.	0.	.	.	0.	0.	0.	0.	0.	0.

WILLIAMS RESEARCH CORPORATION CENTRIFUGAL COMPRESSOR TEST RIG DATA REDUCTION

MERADCOM WR34 COMPRESSOR THIRD RUN AT AXIAL CLEARANCE (COLD)=0.017 FOR DATA   DATE RUN : 02/15/81
DATA POINT 57 TEST DATE 12 20 80   TEST NO 1   TIME RUN : 15.2505

PERFORMANCE OUTPUT DATA

UNCORRECTED BAROMETER (IN. HG)	=29.690
CORRECTED AMBIENT PRESSURE (PSIA)	=14.522
AMBIENT TEMPERATURE (FARENHEIT)	=74.000
DELTA P NOZZLE (IN. H2O)	=22.200
NOZZLE AREA (INCHES ** 2)	= 3.149
RPM COUNTS	= 96600.00

MEASURED STAGE OVERALL PERFORMANCE

CORRECTED SPEED (RPM)	PERCENT DESIGN CORRECTED SPEED	CORRECTED FLOW (LBM/SEC)	FLOW SQRT THETA	FLOW DELTA	Q INLET FLOW (LBM/SEC)	STATIC/TOTAL PRESSURE RATIO (PSPLEN/PTINL)	TOTAL/TOTAL PRESSURE RATIO (PTSTGE/PTINL)
98999.19	99.9	0.5377	0.97577	0.94781	0.7882	4.1189	4.2522

DELTA T / T (TTSTGE-TTINL/ TTINL)	Z WORK FACTOR	STATIC/ TOTAL EFFICIENCY	TOTAL/ TOTAL EFFICIENCY	EXIT MACH NUMBER
0.68771	0.78270	0.7200	0.7398	0.2145

STAGE OVERALL PERFORMANCE CORRECTED FOR REYNOLDS NUMBER

NOTE.....TEST DATA REYNOLDS NUMBER IS BASED ON THE AVERAGE PRESSURE AND TEMPERATURE AT THE INDUCER LEADING EDGE (PTIND AND TTIND)

REYNOLDS NUMBER BASED ON TEST DATA	REYNOLDS NUMBER BASED ON STANDARD DAY
0.342E 07	0.339E 07

CORRECTED SPEED (RPM)	PERCENT DESIGN CORRECTED SPEED	CORRECTED FLOW (LBM/SEC)	FLOW SQRT THETA	FLOW DELTA	Q INLET FLOW (LBM/SEC)	STATIC/TOTAL PRESSURE RATIO (PSPLEN/PTINL)	TOTAL/TOTAL PRESSURE RATIO (PTSTGE/PTINL)
98999.19	99.9	0.5377	0.97577	0.94781	0.7882	4.1165	4.2499

DELTA T / T (TTSTGE-TTINL/ TTINL)	Z WORK FACTOR	STATIC/ TOTAL EFFICIENCY	TOTAL/ TOTAL EFFICIENCY	EXIT MACH NUMBER
0.68771	0.78270	0.7196	0.7394	0.2147

WILLIAMS RESEARCH CORPORATION CENTRIFUGAL COMPRESSOR TEST RIG DATA REDUCTION

WERAL CM WR74 COMPRESSOR THIRD RUN AT AXIAL CLEARANCE (COLD)=0.017 FOR DATA
DATA POINT 57 TEST DATE 12 20 80 - TEST NO 1

DATE RUN : 02/15/81
TIME RUN : 15.2505

COMPRESSOR INLET CALCULATION

NOTE.....AVERAGE TOTAL PRESSURE USED IN THE CALCULATION IS FROM THE COMPRESSOR INLET STATION (PTINL)

NOTE.....AVERAGE TOTAL TEMPERATURE USED IN THE CALCULATION IS FROM THE COMPRESSOR INLET STATION (TTINL)

INPUT PARAMETERS FOR THE COMPRESSOR INLET CALCULATION

NUMBER OF TOTAL PRESSURE RAKES	= 3
NUMBER OF TOTAL TEMPERATURE RAKES	= 3
OUTER (SHROUD) WALL RADIUS (INCHES)	= 1.400
OUTER (SHROUD) WALL AXIAL COORDINATE(Z) (INCHES)	=-0.533
INNER (HUB) WALL RADIUS (INCHES)	= 1.400
INNER (HUB) WALL AXIAL COORDINATE (INCHES)	=-1.004

RAKE ELEMENT DATA AVERAGED AT EACH AXIAL IMMERSION

Z (INCHES)	TOTAL PRESSURE (PSIA)	Z (INCHES)	TOTAL TEMPERATURE (DEGREES RANKINE)
-1.004	13.928	-1.004	492.175
-0.769	13.930	-0.769	494.448
-0.533	13.930	-0.533	495.132

RMS MERIDIONAL VELOCITY AND MACH NUMBER FROM FLOW FUNCTION USING INPUT AERODYNAMIC BLOCKAGE FACTOR =0.980

MERIDIONAL VELOCITY (FEET / SECOND)	MERIDIONAL MACH NUMBER
249.912	0.2306

OUTER WALL VELOCITY AND MACH NUMBER FROM MEASURED STATIC PRESSURE, MEASURED TOTAL PRESSURE, AND MEASURED TOTAL TEMPERATURE

STATIC NUMBER	STATIC PRESSURE (PSIA)	STATIC PRESSURE/ TOTAL PRESSURE	MERIDIONAL VELOCITY (FT/SEC)	MERIDIONAL MACH NUMBER
1	12.294	0.8824	457.126	0.4265
2	12.432	0.8928	435.486	0.4057
3	11.388	0.8174	577.083	0.5444
4	11.223	0.8055	597.034	0.5644

WILLIAMS RESEARCH CORPORATION CENTRIFUGAL COMPRESSOR TEST RIG DATA REDUCTION

MERADCOM WRC COMPRESSOR THIRD RUN AT AXIAL CLEARANCE (COLD)=0.017 FOR DATA — DATE RUN : 02/15/81
DATA POINT 57 TEST DATE 12 20 80 — TEST NO 1 — TIME RUN : 15.2505

IMPELLER INDUCER LEADING EDGE CALCULATION

NOTE.....AVERAGE TOTAL PRESSURE USED IN THE CALCULATION IS FROM THE COMPRESSOR INLET STATION (PTINL)

NOTE.....AVERAGE TOTAL TEMPERATURE USED IN THE CALCULATION IS FROM THE COMPRESSOR INLET STATION (TTINL)

INPUT PARAMETERS FOR THE IMPELLER INDUCER LEADING EDGE CALCULATION

NUMBER OF TOTAL PRESSURE RAKES = 0
NUMBER OF TOTAL TEMPERATURE RAKES = 0
NUMBER OF INPUT AIR ANGLES = 0
OUTER (SHROUD) WALL RADIUS (INCHES) = 1.056
INNER (HUB) WALL RADIUS (INCHES) = 0.479

RMS MERIDIONAL VELOCITY AND MACH NUMBER FROM FLOW FUNCTION USING INPUT AERODYNAMIC BLOCKAGE FACTOR =0.980

MERIDIONAL VELOCITY (FEET / SECOND)	MERIDIONAL MACH NUMBER
386.114	0.3589

OUTER WALL VELOCITY AND MACH NUMBER FROM MEASURED STATIC PRESSURE, AVERAGE TOTAL PRESSURE, AND AVERAGE TOTAL TEMPERATURE

STATIC NUMBER	STATIC PRESSURE (PSIA)	STATIC PRESSURE/ TOTAL PRESSURE	MERIDIONAL VELOCITY (FT/SEC)	MERIDIONAL MACH NUMBER
1	11.557	0.8295	556.179	0.5236

CALCULATED PARAMETERS AT THE IMPELLER INDUCER LEADING EDGE

RMS			OUTER WALL				INNER WALL			
RELATIVE VELOCITY (FT/SEC)	RELATIVE AIR ANGLE (DEGREES)	RELATIVE MACH NUMBER	RELATIVE VELOCITY (FT/SEC)	RELATIVE AIR ANGLE (DEGREES)	RELATIVE MACH NUMBER	MERIDIONAL VEL. RATIO TO RMS	RELATIVE VELOCITY (FT/SEC)	RELATIVE AIR ANGLE (DEGREES)	RELATIVE MACH NUMBER	MERIDIONAL VEL. RATIO TO RMS
791.731	60.8115	0.7352	1049.663	58.0037	0.9881	1.4405	0.	0.	0.	0.

WILLIAMS RESEARCH CORPORATION CENTRIFUGAL COMPRESSOR TEST RIG DATA REDUCTION

MERADCOM WR34 COMPRESSOR THIRD RUN AT AXIAL CLEARANCE (COLD)=0.017 FOR DATA
DATA POINT 57 TEST DATE 12 20 80 TEST NO 1

DATE RUN : 02/15/81
TIME RUN : 15.2505

IMPELLER SHROUD AND EXIT PARAMETERS

NOTE.....COMPRESSOR INLET TOTAL PRESSURE WILL BE USED AS THE INLET TOTAL PRESSURE IN CALCULATIONS (PTINL)

IMPELLER SHROUD STATIC / TOTAL PRESSURE RATIO VERSUS PERCENT MERIDIONAL DISTANCE

LOCATION NUMBER	PERCENT MERIDIONAL DISTANCE	STATIC/ INLET TOTAL PRESSURE/	LOCATION NUMBER	PERCENT MERIDIONAL DISTANCE	STATIC/ INLET TOTAL PRESSURE/	LOCATION NUMBER	PERCENT MERIDIONAL DISTANCE	STATIC/ INLET TOTAL PRESSURE/
1	-0.293	0.883	10	0.552	1.381	19	0.	0.
2	-0.209	0.893	11	0.655	1.509	20	0.	0.
3	-0.139	0.818	12	0.724	1.701	21	0.	0.
4	-0.068	0.806	13	0.793	1.922	22	0.	0.
5	0.	0.830	14	0.862	2.071	23	0.	0.
6	0.069	0.855	15	0.931	2.125	24	0.	0.
7	0.138	0.894	16	0.966	2.319	25	0.	0.
8	0.276	1.056	17	1.000	2.510	26	0.	0.
9	0.414	1.179	18	0.	0.	27	0.	0.

IMPELLER EXIT PERFORMANCE USING STAGE EXIT MEASURED TEMPERATURE

STATIC PRESSURE RATIO (PSIMPEX/PTINL)	TOTAL PRESSURE RATIO (PTIMPEX/PTINL)	TOTAL/ TOTAL EFFICIENCY	ABSOLUTE MACH NUMBER	ABSOLUTE AIR ANGLE FROM RADIAL (DEGREES)	SLIP FACTOR	RADIAL VELOCITY (FT/SEC)	ABSOLUTE VELOCITY (FT/SEC)	RELATIVE VELOCITY (FT/SEC)	RELATIVE VELOCITY RATIO (WIMPEX/WINDOD)
2.5094	4.8377	0.8217	1.0181	75.3882	0.9310	330.350	1309.513	482.598	0.4598

RELATIVE AIR ANGLE FROM RADIAL (DEGREES)	DEVIATION (DEGREES)	VANELESS SPACE AND DIFFUSER STATIC PRESSURE RECOVERY(CP) (PSDLEN-PSIMPEX)/(PTIMPEX-PSIMPEX)	VANELESS SPACE AND DIFFUSER OMEGA BAR (PTSTGE-PTIMPEX)/(PTIMPEX-PSIMPEX)
46.9[illegible]2	8.829	0.6912	0.2515

WILLIAMS RESEARCH CORPORATION

CENTRIFUGAL COMPRESSOR TEST RIG DATA REDUCTION SUMMARY

MERADCOM WR34 COMPRESSOR THIRD RUN AT AXIAL CLEARANCE (COLD)=0.017 FOR DATA

DATE RUN : 02/15/81
TIME RUN : 15.2505

TEST NUMBER 1 TEST DATE 12 20 80

DATA PT	PERCENT SPEED	CORRECTED SPEED	CORRECTED FLOW	STAGE TOT/TOT PRESS/	STAGE TOT/STAT PRESS/	STAGE DELTA T/ T	STAGE Z	STAGE EFFIC. TOT/TOT	STAGE EFFIC. TOT/STAT	IMPELLER TOT/TOT PRESS/	IMPELLER TOT/STAT PRESS/	IMPELLER EFFIC. TOT/TOT	DIFF. CPR	DIFF. OMEGA BAR
1	41.8	41377.6	0.217	1.077	1.005	0.1121	0.6811	0.1922	0.0133	1.326	1.151	0.7490	-0.836	1.423
2	40.0	39628.9	0.199	1.121	1.074	0.1027	0.7224	0.3228	0.2014	1.309	1.135	0.7795	-0.353	1.085
3	39.9	39509.9	0.115	1.308	1.310	0.1228	0.8722	0.6492	0.6531	1.388	1.161	0.8005	0.654	0.355
4	39.9	39531.8	0.148	1.278	1.267	0.1151	0.8164	0.6307	0.6092	1.358	1.154	0.7953	0.594	0.395
5	40.2	39841.6	0.174	1.230	1.209	0.1088	0.7595	0.5597	0.5137	1.333	1.148	0.7879	0.333	0.558
6	40.3	39873.8	0.196	1.127	1.083	0.1041	0.7242	0.3352	0.2215	1.312	1.136	0.7751	-0.305	1.052
17	50.0	49522.8	0.259	1.186	1.079	0.1548	0.6996	0.3220	0.1420	1.545	1.264	0.8541	-0.660	1.280
18	50.2	49697.0	0.257	1.233	1.137	0.1552	0.6971	0.3972	0.2402	1.547	1.267	0.8551	-0.465	1.121
19	50.0	49484.1	0.173	1.537	1.527	0.1733	0.7856	0.7538	0.7410	1.620	1.296	0.8525	0.711	0.256
20	49.8	49363.0	0.194	1.523	1.504	0.1672	0.7618	0.7634	0.7386	1.605	1.296	0.8649	0.672	0.265
21	50.1	49632.0	0.218	1.447	1.410	0.1619	0.7294	0.6880	0.6363	1.575	1.283	0.8558	0.433	0.437
22	50.1	49598.2	0.235	1.364	1.304	0.1585	0.7152	0.5846	0.4973	1.559	1.273	0.8522	0.108	0.683
23	60.6	60009.0	0.309	1.209	1.096	0.2290	0.7054	0.2437	0.1164	1.869	1.418	0.8537	-0.714	1.464
24	60.5	59884.6	0.309	1.400	1.250	0.2290	0.7092	0.4397	0.2876	1.873	1.419	0.8568	-0.372	1.044
25	60.2	59665.9	0.209	1.854	1.833	0.2570	0.8018	0.7498	0.7346	1.996	1.454	0.8481	0.700	0.261
26	60.4	59790.6	0.235	1.848	1.813	0.2489	0.7731	0.7697	0.7437	1.978	1.462	0.8633	0.681	0.252
27	60.2	59645.2	0.263	1.801	1.755	0.2412	0.7529	0.7578	0.7219	1.945	1.451	0.8666	0.616	0.292
28	60.0	59464.7	0.288	1.670	1.590	0.2346	0.7368	0.6720	0.6030	1.908	1.432	0.8630	0.331	0.500
29	70.4	69746.2	0.367	1.407	1.164	0.3171	0.7243	0.3227	0.1396	2.309	1.605	0.8502	-0.627	1.281
30	70.6	69953.4	0.367	1.774	1.596	0.3168	0.7196	0.5606	0.4502	2.307	1.608	0.8499	-0.016	0.762
31	70.3	69659.5	0.275	2.282	2.242	0.3504	0.8028	0.7569	0.7385	2.510	1.668	0.8564	0.681	0.271
32	70.2	69536.1	0.293	2.253	2.202	0.3411	0.7842	0.7641	0.7398	2.465	1.661	0.8601	0.672	0.263
33	70.3	69657.6	0.296	2.256	2.206	0.3410	0.7812	0.7659	0.7421	2.465	1.663	0.8604	0.677	0.260
34	70.7	70015.9	0.326	2.207	2.133	0.3366	0.7630	0.7524	0.7163	2.433	1.652	0.8578	0.615	0.290
35	70.9	70220.0	0.347	2.117	2.015	0.3316	0.7471	0.7196	0.6672	2.404	1.644	0.8577	0.488	0.378
36	80.7	79948.4	0.443	1.598	1.173	0.4202	0.7306	0.3403	0.1108	2.888	1.837	0.8402	-0.632	1.228
37	80.6	79872.9	0.442	2.137	1.927	0.4189	0.7301	0.5769	0.4908	2.884	1.837	0.8417	0.086	0.714
38	80.3	79567.5	0.334	2.827	2.764	0.4593	0.8069	0.7504	0.7317	3.189	1.928	0.8526	0.663	0.287
39	80.4	79649.0	0.368	2.780	2.700	0.4446	0.7794	0.7609	0.7361	3.075	1.900	0.8488	0.681	0.251
40	80.5	79691.6	0.393	2.722	2.628	0.4361	0.7635	0.7575	0.7271	3.022	1.888	0.8498	0.653	0.265
41	80.4	79671.7	0.421	2.569	2.433	0.4261	0.7463	0.7242	0.6769	2.949	1.862	0.8476	0.525	0.350
42	90.0	89123.7	0.525	1.787	1.238	0.5255	0.7365	0.3420	0.1194	3.545	2.075	0.8257	-0.569	1.196
43	89.9	89076.1	0.521	2.643	2.391	0.5231	0.7339	0.6096	0.5385	3.529	2.075	0.8260	0.217	0.609
44	89.9	89094.5	0.426	3.465	3.377	0.5680	0.7969	0.7470	0.7287	3.933	2.196	0.8391	0.680	0.269
45	89.7	88857.5	0.453	3.381	3.283	0.5508	0.7767	0.7526	0.7311	3.800	2.166	0.8394	0.684	0.256
46	90.0	89112.8	0.478	3.286	3.149	0.5409	0.7583	0.7452	0.7141	3.699	2.139	0.8342	0.648	0.265
47	89.8	88992.7	0.499	3.139	2.967	0.5316	0.7471	0.7244	0.6828	3.613	2.106	0.8308	0.571	0.314
48	95.2	94317.5	0.564	1.955	1.278	0.5916	0.7410	0.3552	0.1222	3.906	2.177	0.8007	-0.520	1.129
49	95.0	94124.6	0.561	2.663	2.433	0.5901	0.7420	0.5446	0.4878	3.903	2.178	0.8021	0.148	0.719
50	94.9	94010.3	0.474	3.837	3.742	0.6295	0.7939	0.7399	0.7234	4.390	2.351	0.8307	0.682	0.271
51	94.8	93939.3	0.498	3.775	3.663	0.6136	0.7749	0.7482	0.7279	4.257	2.327	0.8308	0.692	0.249
52	95.0	94049.1	0.509	3.742	3.616	0.6117	0.7705	0.7449	0.7217	4.222	2.312	0.8279	0.683	0.251
53	94.9	93996.0	0.526	3.664	3.517	0.5994	0.7558	0.7456	0.7176	4.115	2.288	0.8267	0.673	0.247
54	95.1	94183.9	0.549	3.441	3.239	0.5947	0.7468	0.7085	0.6678	3.999	2.229	0.8130	0.571	0.315
55	100.3	99302.0	0.588	2.048	1.307	0.6578	0.7442	0.3436	0.1202	4.166	2.218	0.7607	-0.467	1.087
56	100.1	99197.4	0.586	2.745	2.475	0.6508	0.7375	0.5109	0.4515	4.125	2.219	0.7625	0.135	0.724
57	99.9	98999.2	0.538	4.252	4.119	0.6877	0.7827	0.7398	0.7200	4.838	2.510	0.8217	0.691	0.252
58	100.0	99049.0	0.547	4.185	4.046	0.6815	0.7747	0.7366	0.7156	4.742	2.479	0.8162	0.693	0.246
59	99.8	98848.9	0.560	4.085	3.933	0.6709	0.7657	0.7330	0.7092	4.609	2.433	0.8106	0.689	0.241
60	99.7	98732.5	0.572	3.854	3.665	0.6600	0.7549	0.7082	0.6767	4.400	2.344	0.7937	0.643	0.266
61	99.9	99000.0	0.584	2.316	1.723	0.6616	0.7532	0.4073	0.2525	4.202	2.217	0.7616	-0.249	0.950
62	105.3	104338.3	0.601	2.085	1.329	0.7191	0.7376	0.3225	0.1169	4.255	2.187	0.7077	-0.415	1.049
64	105.3	104311.0	0.601	2.087	1.316	0.7181	0.7369	0.3235	0.1128	4.249	2.186	0.7079	-0.422	1.048
65	105.4	104438.0	0.599	3.678	3.436	0.7217	0.7383	0.6202	0.5818	4.343	2.237	0.7173	0.569	0.316