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Research and Development Division

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MTI 79TR51

PHASE 2 - PERFORMANCE TEST REPORT
HELIUM CIRCULATORS

MASTER

Prepared for:

Union Carbide Corporation,
Nuclear Division

April 1979

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MECHANICAL TECHNOLOGY INCORPORATED
968 Albany-Shaker Road
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TECHNICAL REPORT

PHASE 2 PERFORMANCE TEST REPORT HELIUM CIRCULATORS

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INTRODUCTION

The subject prototype helium circulator was completed November 15, 1978 at the Latham facility of Mechanical Technology Incorporated (MTI). Installation in the test loop was completed on January 19, 1979 with preliminary debugging testing with nitrogen completed on February 16, 1979.

The performance testing and 100-hour shakedown testing was completed on March 30, 1979. Motor testing was completed on April 4, 1979. Post test disassembly and inspection was completed by April 6, 1979.

The conduct and analysis of this performance and shakedown testing together with the motor tests are reported herein.

OBJECTIVE

The object of this test was to accomplish the following:

1. Demonstrate satisfactory aerodynamic performance and prepare compressor characteristic maps.
2. Demonstrate satisfactory mechanical performance, rotor and bearing stability over the complete operating range.
3. Demonstrate the ability of the circulator to withstand a sudden depressurization while operating at maximum speed and 1500 psi discharge pressure.
4. Conduct a 100-hour shakedown test at design-point operating conditions with gas sampling every 25 hours, including 10 starts and stops.
5. Demonstrate satisfactory motor performance.
6. Provide overall operating data.

More explicit requirements of the test objectives and methods are given in the following related reports.

Design Study Report MTI 76TR15

Test Procedure Part 1 MTI EA 79-3 (Circulator)

Test Procedure Part 2 MTI EA 79-3 (Motor)

SUMMARY

Test Authority

Contract No. ORNL/Sub/76250/2 and its amendments represented the authority for this test.

Test Specification

This test was conducted in accordance with ORNL specification No. M-11590-RB-001-S-5 issue dated November 11, 1974 and its amendments.

Test Unit

The prototype helium circulator was assembled at MTI Latham facility to specification PL 316 J03 group 1. All component parts were measured prior to assembly and critical selected parts at disassembly following completion of the test.

Test Facility

The entire performance and qualification test was carried out at MTI Latham facility using a closed test loop to specification 316 E 105 (MTI) and instrumentation to specification 316 E 100 (MTI).

CONCLUSIONS

The circulator successfully completed all specified tests without incident. Design performance was achieved at less than 0.9 design speed, indicating ample margin for uprating. The motor winding temperatures were stable at 178°F below maximum limit indicating a substantial margin of safety and/or capacity for uprating. Several depressurization tests were conducted. At no time did the thrust bearing film thickness fall below 0.00015 inch, indicating a considerable margin of safety in this mode of operation. An overall circulator energy efficiency at design point of 58.4 percent was realized.

The acceleration time from zero to 3000 rpm could not be measured as the strip chart recorder would not record under 2500 rpm. Observation indicated that zero to 3000 rpm was achieved almost instantaneously. The touch down speed was recorded as 450 to 500 rpm by observing the rpm indicator and the oscilloscopes. This indicates that minimal contact occurs during either start-up or shutdown, emphasizing the ability of the circulator to make an unlimited number of starts and stops.

It was found that electrical interference from the power supply almost completely obliterated the traces on the oscilloscopes monitoring thrust bearing film thicknesses and shaft motion. It is essential that adequate filters be used in conjunction with the oscilloscopes and that all motor power supply leads are enclosed in grounded conduit.

Erratic behavior of the servo optic power supply was evident prior to the start of testing and delayed commencement of acceptance testing.

During testing the circulator almost invariably could not be started immediately after a shutdown unless the circuit breakers in the power supply were turned off and then turned on again. This is not understood and as operation of the power supply is not part of this test specification it is not proposed to go into further detail here. Further information, however, can be extracted from the Daily Log Sheets in Appendix 8.

RECOMMENDATIONS

Evaluate fully and maximize the performance capability of the circulator by:

1. Installing larger power feed throughs thereby increasing the current carrying capacity of this limiting component from 250 to 325 amperes.
2. Enlarging flow area of Valtek loading valve by reducing the diameter of the valve plug to provide an increase in flow volume of 25 percent.
3. Retesting with present vaned diffuser and new power feed through (or present feed through with forced cooling using shop air) up to maximum speed of 24,000 rpm (less slip) and maximum flow limited by motor winding temperature.
4. Repeating 3 above but with vaneless diffuser.
5. Evaluating by test maximum rate of safe depressurization.

1.0 DESCRIPTION OF CIRCULATOR

A complete description of the circulator design, construction and specified performance is given in MTI Design Study Report 76TR15.

2.0 METHOD OF TEST

Full details of the method of testing and instrumentation used is given in MTI report Test Procedure Helium Circulators Parts 1 and 2.

Calibration of Instrumentation

(General Electric Schenectady Instrument Services)

All instrumentation used to measure performance of the circulator was calibrated by the General Electric Schenectady Instrument Services (GESIS) and is traceable to the National Bureau of Standards (NBS).

Certificates of calibration are attached to this section of this report.

- a. Prior to test dated February 20-21, 1979.
- b. Post Test dated April 9-10, 1979.

Calibration of Instrumentation (MTI)

Calibration of the instrumentation used with the 8-channel Gould-Brush Recorder was carried out by Dale Springstead at MTI and is traceable to NBS. This is located at the end of this section, following the certificates of calibration.

Helium Gas Sampling

A tank truck containing 40,000 scfm of helium was supplied by Liquid Carbonic based in New Jersey. A sample of the helium from the tank truck was taken by Liquid Carbonic and the analysis is attached to this section.

During the 100-hour shakedown testing, samples of gas were extracted from the motor cavity every 24 hours. In addition, at the conclusion of the test a further sample was taken direct from the tank truck as a check on Liquid Carbonic's analysis. The results of these analyses are attached to this section.

The sampling procedure is given on the attached instruction sheet.

2.1 Calibration of Instrumentation

(General Electric Schenectady Instrument Services)

APPARATUS

SERVICE

DIVISION

GENERAL ELECTRIC COMPANY, ONE RIVER ROAD, SCHENECTADY, NEW YORK 12345
Phone (518) 385-2211

February 26, 1979

Mr. Denis Dominy
Mechanical Technology Incorporated
968 Albany-Shaker Road
Latham, N.Y. 12110

Dear Mr. Dominy:

Following are the results of instrument calibration at your facility on February 20th and 21st, 1979.

HEISE GAGE C-72796

STD. PSIG	0.0	300.0	600.0	900.0	1200.0	1800.0	2000.0
Heise PSIG	0.0	299.6	598.6	898.4	1197.3	1796.2	1996.0

HEISE GAGE C-72793

STD. PSIG	0.0	300.0	600.0	900.0	1200.0	1800.0	2000.0
Heise PSIG	0.0	300.0	600.0	899.8	1199.8	1799.6	1999.6

HEISE GAGE C-72792

STD. PSIG	0.0	300.0	600.0	900.0	1200.0	1800.0	2000.0
Heise PSIG	0.0	299.0	599.0	898.0	1198.2	1798.8	1999.0

HEISE GAGE C-72795

STD. PSIG	0.0	300.0	600.0	900.0	1200.0	1800.0	2000.0
Heise PSIG	0.0	298.0	598.0	896.8	1197.4	1797.2	1997.0

HEISE GAGE C-72794

STD. PSIG	0.0	300.0	600.0	900.0	1200.0	1800.0	2000.0
Heise PSIG	0.0	299.4	598.6	898.2	1198.0	1797.2	1996.0

HEISE GAGE C-72797

STD. PSIG	0.0	300.0	600.0	900.0	1200.0	1800.0	2000.0
Heise PSIG	0.0	299.4	599.6	900.0	1200.0	1800.2	2000.0

AFTER ADJUSTMENT

All Heise Gages were calibrated with a water dead weight tester. After calibration, each gage was purged with dry nitrogen.

The Barton differential pressure indicators and validyne transducers were zeroed with the high and low ports vented to atmosphere. Next, 1300 PSIG of dry nitrogen was applied across each transducer and differential pressure indicator. Zero shift checks were then made with the following results: DP-P₁ 8 - +.01 PSI Shift, DP-P₁ 5- +.01 PSI Shift. All other units had no zero shift.

Calibration of all differential pressure indicators and transducers were next accomplished. Results are as follows:

BARTON D.P. INDICATOR PI-II

STD. IN. H ₂ O	0.0	20.0	40.0	60.0	80.0	99.0
Barton In. H ₂ O	0.0	20.7	41.0	60.8	80.9	100.0

BARTON D.P. INDICATOR PI -1

STD. PSIG	0.000	10.000	20.000	30.000	39.000
Barton PSIG	0.000	10.033	20.000	30.000	39.066

BARTON D.P. INDICATOR PI-2

STD. PSIG	0.000	10.000	20.000	30.000	39.000
Barton PSIG	0.000	9.967	20.000	30.165	39.165

BARTON D.P. INDICATOR PI-3

STD. PSIG	0.000	10.000	20.000	30.000	39.000
Barton PSIG	0.000	9.934	19.967	30.066	39.033

BARTON D.P. INDICATOR PI-4

STD. PSIG	0.000	10.000	20.000	30.000	39.000
Barton PSIG	0.000	10.033	20.000	30.330	39.330

VALIDYNE TRANSDUCER PR₁

STD. PSIG	0.000	10.000	20.000	30.000	40.000
Validyne D.C. Volts	+0.00	1.95	3.92	5.92	7.99

ADJUSTED ZERO AND SPAN.

VALIDYNE TRANSDUCER PR₂

STD. PSIG	0.000	5.000	10.000	15.000	20.000
Validyne D.C. Volts	0.00	2.42	4.92	7.44	9.99

ADJUSTED ZERO AND SPAN

VALIDYNE TRANSDUCER PR1 -STATIC PRESSURE

STD PSIG	0.00	250.00	500.00	750.00	1000.00	1250.00	1500.00
Validyne D.C. Volts	0.00	1.70	3.36	5.01	6.67	8.34	10.04

ADJUSTED ZERO AND SPAN

VALIDYNE TRANSDUCER PR2 - STATIC PRESSURE

STD. PSIG 0.00 250.00 500.00 750.00 1000.00 1250.00 1500.00
Validyne D.C. Volts 0.00 1.65 3.29 4.95 6.61 8.30 10.00

BARTON D.P. INDICATOR PI - 9

STD. IN. H₂O 0.00 10.00 20.00 30.00 40.00 49.00
Barton IN. H₂O 0.00 10.40 20.50 30.45 40.55 49.75

BARTON D.P. INDICATOR PI -6

STD. IN. H₂O 0.00 10.00 20.00 30.00 40.00 49.00
Barton IN. H₂O 0.00 10.40 20.25 30.10 40.50 49.55

BARTON D.P. INDICATOR PI -8

STD. IN. H₂O 0.00 2.00 4.00 6.00 8.00 9.00 9.50
Barton IN. H₂O +0.01 2.26 4.33 6.22 8.21 9.29 9.80

BARTON D.P. INDICATOR PI-5

STD. IN. H₂O 0.00 2.00 4.00 6.00 8.00 9.00 9.50
Barton IN. H₂O +0.01 2.30 4.32 6.22 8.21 9.29 9.80

BARTON D.P. INDICATOR PI -7

STD. IN. H₂O 0.0 50.0 100.0 150.0 200.0 250.0 300.0 349.0
Barton IN. H₂O 0.0 50.0 100.0 150.0 199.5 250.0 300.0 349.5

BARTON D.P. INDICATOR PI -10

STD. IN. H₂O 0.0 50.0 100.0 150.0 200.0 250.0 349.0
Barton IN. H₂O 0.0 50.0 100.0 150.0 199.5 248.5 349.0

Following are calibration checks on Barton differential indicators P₁₈, P₁₉, P₁₅ and P₁₆ after five minutes wait.

BARTON D.P. INDICATOR PI -6

STD. IN. H₂O 0.00 10.00 20.00 30.00 40.00 49.00
Barton IN. H₂O 0.00 10.10 20.15 30.10 40.20 49.50

BARTON D.P. INDICATOR PI - 9

STD. INC. H₂O 0.00 10.00 20.00 30.00 40.00 49.00
Barton IN. H₂O 0.00 10.40 20.45 30.45 40.45 49.60

BARTON D.P. INDICATOR PI -5

STD. IN. H₂O 0.00 2.00 4.00 6.00 8.00 9.00 9.50

Barton IN. H₂O +0.01 2.18 4.20 6.27 8.21 9.20 9.78

BARTON D.P. INDICATOR PI -8

STD. INC. H₂O 0.00 2.00 4.00 6.00 8.00 9.00 9.50

Barton IN. H₂O +0.02 2.14 4.20 6.23 8.20 9.20 9.79

Standards 0301, 0215, 0338 and 0049 which were used for the calibrations, are compared to Company Standards, which are referenced to the National Bureau of Standards.

Sincerely yours,

Stanley Karpinski
Stanley Karpinski

SR. Tech.

SCHENECTADY INSTRUMENTATION SERVICES

(A/C 518) 385-9281

cc O. Vitillo
W. Emigh

GENERAL ELECTRIC CO., BLDG. 28, ROOM 500, SCHENECTADY, NEW YORK 12345

SCHENECTADY
INSTRUMENTATION
AND COMMUNICATION
EQUIPMENT SERVICE

April 11, 1979

Mr. Denis Dominy
Mechanical Technology Incorporated
968 Albany-Shaker Road
Latham, NY 12110

Dear Mr. Dominy:

Following are the results of instrument calibration at your facility on April 10 and April 11, 1979.

HEISE GAGE C-72796

STD. PSIG	0.0 300.0 600.0 900.0 1200.0 1800.0 2000.0
Heise PSIG	0.0 299.8 598.4 898.0 1196.8 1795.6 1995.0

HEISE GAGE C-72793

STD. PSIG	0.0 300.0 600.0 900.0 1200.0 1800.0 2000.0
Heise PSIG	0.0 300.6 600.2 900.0 1199.8 1799.4 1999.6

HEISE GAGE C-72792

STD. PSIG	0.0 300.0 600.0 900.0 1200.0 1800.0 2000.0
Heise PSIG	0.0 299.4 599.2 898.0 1198.0 1798.0 1998.2

HEISE GAGE C-72795

STD. PSIG	0.0 300.0 600.0 900.0 1200.0 1800.0 2000.0
Heise PSIG	0.0 298.6 598.8 897.6 1198.2 1797.4 1997.0

HEISE GAGE C-72794

STD. PSIG	0.0 300.0 600.0 900.0 1200.0 1800.0 2000.0
Heise PSIG	0.0 299.0 597.4 897.2 1197.6 1796.4 1995.2

HEISE GAGE C-72797

STD. PSIG	0.0 300.0 600.0 900.0 1200.0 1800.0 2000.0
Heise PSIG	0.0 299.4 599.6 900.0 1200.0 1800.0 1999.0

All Heise Gages were calibrated with a water dead weight tester. After calibration, each gage was purged with dry nitrogen.

The Barton differential pressure indicators and validyne transducers were zeroed with the high and low ports vented to atmosphere. Next, 1300 PSIG of dry nitrogen was applied across each transducer and differential pressure indicator. Zero shift checks were then made with the following results: DP P_1 6 + .066 PSI Shift. All other units had no zero shift.

Calibration of all differential pressure indicators and transducers were next accomplished. Results are as follows:

BARTON D.P. INDICATOR PI-11

STD. IN.	H ₂ O	0.0	20.0	40.0	60.0	80.0	99.0
Barton Inc. H ₂ O		0.0	20.8	40.9	60.7	80.7	100.0

BARTON D.P. INDICATOR PI-1

STD. PSIG	0.000	10.000	20.000	30.000	39.000
Barton PSIG	0.000	10.165	20.067	30.067	39.221

BARTON D.P. INDICATOR PI-2

STD. PSIG	0.000	10.000	20.000	30.000	39.000
Barton PSIG	0.000	9.967	20.000	30.067	39.067

BARTON D.P. INDICATOR PI-3

STD. PSIG	0.000	10.000	20.000	30.000	39.000
Barton PSIG	0.000	9.967	19.967	30.000	39.000

BARTON D.P. INDICATOR PI-4

STD. PSIG	0.000	10.000	20.000	30.000	39.000
Barton PSIG	0.000	10.033	20.165	30.330	39.198

VALIDYNE TRANSDUCER PR₁

STD. PSIG	0.000	10.000	20.000	30.000	40.000
Validyne	+.067	2.00	3.98	5.97	8.03
D.C. Volts					

ADJUSTED ZERO AND SPAN.

VALIDYNE TRANSDUCER PR₂

STD. PSIG	0.000	5.000	10.000	15.000	20.000
Validyne	+.008	2.37	4.82	7.34	9.95
D.C. Volts					

ADJUSTED ZERO AND SPAN.

VALIDYNE TRANSDUCER PRI-STATIC PRESSURE

STD. PSIG 0.00 250.00 500.00 750.00 1000.00 1250.00 1500.00
Validyne +.027 1.76 3.41 5.06 6.70 8.36 10.06
D.C. Volts
ADJUSTED ZERO AND SPAN

VALIDYNE TRANSDUCER PR2-STATIC PRESSURE

STD. PSIG 0.00 250.00 500.00 750.00 1000.00 1250.00 1500.00
Validyne +.062 1.71 3.34 4.97 6.62 8.28 9.96
D.C. Volts

BARTON D.P. INDICATOR PI-9

STD. IN. H₂O 0.00 10.00 20.00 30.00 40.00 49.00
Barton In. H₂O 0.00 10.35 20.45 30.45 40.50 49.65

BARTON D.P. INDICATOR PI-6

STD. In. H₂O 0.00 10.00 20.00 30.00 40.00 49.00
Barton In. H₂O 0.00 10.50 20.50 30.50 40.50 49.50

BARTON D.P. INDICATOR PI-8

STD. In. H₂O 0.00 2.00 4.00 6.00 8.00 9.00 9.50
Barton In. H₂O 0.00 2.10 4.13 6.11 8.21 9.20 9.70

BARTON D.P. INDICATOR PI-5

STD. In. H₂O 0.00 2.00 4.00 6.00 8.00 9.00 9.50
Barton In. H₂O 0.00 2.12 4.19 6.20 8.21 9.29 9.77

BARTON D.P. INDICATOR PI-7

STD. In. H₂O 0.00 50.0 100.0 150.0 200.0 250.0 300.0 349.0
Barton In. H₂O 0.0 50.0 101.0 150.5 200.5 250.5 300.5 349.5

BARTON D.P. INDICATOR PI-10

STD. In. H₂O 0.0 50.0 100.0 150.0 200.0 250.0 300.0 349.0
Barton In. H₂O 0.0 50.0 100.0 150.5 199.5 248.0 297.0 348.0

Standards 0301, 0215, 0338 and 0049 which were used for the calibration, are compared to Company Standards, which are referenced to the National Bureau of Standards.

Sincerely yours,

Stanley Karpinski
Stanley Karpinski
SR. Tech.
SCHENECTADY INSTRUMENTATION SERVICES
(A/C 518) 385-9281

cc: O. Vitillo
W. Emigh

SAMPLING PROCEDURE - ORNL 100 Hr. TEST

Repeat every 24 hours

1. One Liter Stainless Steel containers are good for 245 psi. They are fitted with pressure gages and flow meters.
2. Connect to sampling valve on circulator via regulator.
3. Flowmeter connected to outlet of container with valve.
4. Leave coupling between circulator valve and container loose. Keep valves closed on either openings of container.
5. Allow Helium to leak out through loose union on container inlet for five (5) minutes. Tighten union. Close union.
6. Open Inlet Valves to container until pressure reaches 20/30 psi. Open outlet valve. Allow gas to flow at rate of 2 liters/min. for five (5) minutes.
7. Close Outlet Valve. Allow pressure to reach 100 psi. Close inlet valve. Purge down to 20/30 psi. Repeat three times.
8. Fill container to 100 psi using procedures 6 and 7 above
9. Label containers with data and time.
10. Ship to Golob Labs via U.P.S. or by Federal Express. The former gives a three day turnaround. The latter overnight. (Through Purchasing)

ATTENTION

Fred Golob
46 Industrial Park Road
Berkeley Heights, N.J. 07922
(201) 464-3331

Ref. MTI Purchase Order No. 902-04007

NOTE:

Five containers are available. The first is to sample gas direct from tank trailer via piping, hose, valves, cooling coil and regulator which should be thoroughly purged prior to sampling per five above.

DGD/sb

2.2 Calibration of Instrumentation

(Mechanical Technology Incorporated)

CALIBRATION CHECKLIST

SECTION A

1. CALIBRATING ACTIVITY
Metrology Laboratory

CHL

2. SUBMITTING ACTIVITY

RED

3. TEST INSTRUMENT
(Name of Item Calibrated)

RECORDER
T/C AMPLIFIER

4. MANUFACTURER

GUILD

5. MODEL NUMBER
(Commercial or Military)

481
13-4715-4X
TYPE K

6. SERIAL NUMBER

D39570

6.1 WORK ORDER NO.

7. REASON FOR SUBMISSION

CERTIFICATION/CALIBRATION
CROSSCHECK

FAILURE FROM DAMAGE OR ABUSE
OPERATIONAL FAILURE

1
2
3
4

8. CUSTOMER CONTROL #

9. SERVICING CYCLE (MONTHS)

CERTIFICATION/CALIBRATION
CROSSCHECK

6

10. CALIBRATION PROCEDURE

MANUAL
APPLY SIGNALS

SECTION B

1. CALIBRATION TECHNICIAN

DHMS

2. TEST DATE

3-15-79

3. CONDITION RECEIVED

WITHIN TOLERANCE
OUTSIDE TOLERANCE

Explain Below
in "Remarks"

1
2

TEMPERATURE
HUMIDITY

75
%

4. CONDITION RETURNED

WITHIN TOLERANCE
OUTSIDE TOLERANCE

Explain Below
in "Remarks"

1
2

5. SERVICING LABEL AFFIXED

3-15-79

CERTIFICATION/CALIBRATION
CROSSCHECK

LIMITED USE
REJECT

Explain Below
in "Remarks"

1
2
3
4

6. NEXT SERVICING DATE

CERTIFICATION/CALIBRATION
CROSSCHECK

9-15-79

TEST EQUIPMENT USED FOR CALIBRATION

MODEL #	CONTROL #	DATE DUE CAL	MODEL #	CONTROL #	DATE DUE CAL
ROTERMAN	9023	5-31-79			
FID 6572		7-5-79			

REMARKS

SECTION C

3.1 - SET UP 8 AMPLIFIER CHANNELS FOR
CORRECT GAIN FACTORS FOR TRANSIENT
RECORDING.

GUILD 481 IS BEING RECENT

QA FINAL INSPECTION APPROVED

[Signature]

35210

2.3 Helium Gas Sampling

Gollob Analytical Service

MOLININI GOLLOB, INC.

47 INDUSTRIAL ROAD, BERKELEY HEIGHTS, NEW JERSEY 07922 • TEL. (201) 464-3331

TO: Mr. D. Dominy
Mechanical Technology Inc.
968 Albany Shaker Road
Latham, New Ycrk 12110

G.A.S. REPORT No. 43081
Date Reported: 4/12/79
Date Requested: 4/4/79
P. O. No. 902-04007

MATERIAL SUBMITTED: 5 (Five) F Bulbs

INFORMATION REQUESTED: Mass Spectrometry-Gas Chromatography Analyses

NOTEBOOK REFERENCE: 575 pages 5 - 7, HB 551 pages 51-56

RESULT OF INVESTIGATION

<u>Sample Identification: F-11</u>	<u>F-86</u>	<u>F-94</u>	<u>F-65</u>	<u>F-134</u>	
<u>Constituents</u>	<u>Concentration % by Volume</u>				
Nitrogen	0.0093	0.011	0.0068	0.0086	0.0093
Oxygen	ND 0.0001	0.0008	ND 0.0001	0.0016	0.0004
Argon	ND 0.0001	ND 0.0001	ND 0.0001	ND 0.0001	ND 0.0001
Carbon Dioxide	0.0004	0.0005	0.0005	ND 0.0001	0.0004
Hydrogen	0.0003	0.0006	0.0010	ND 0.0002	0.0009
Helium	99+	99+	99+	99+	99+
Neon	0.0012	0.0012	0.0011	0.0011	0.0012
Water	0.0020	0.0020	0.0030	0.0007	0.0030
Total Hydrocarbons as Methane	0.0015	0.0008	0.0018	ND 0.00001	0.0017
Unknown*	0.0015	0.0017	0.0013	0.0015	0.0010

ND=none detected, less than

*Molecular weight about 120.

These samples were scanned from mass 2 through mass 150 and no other constituents were detected. The detection threshold for most constituents is 0.0002%.

cc:M.H. Burton
t 41779

By

GOLLOB ANALYTICAL SERVICE

LIQUID CARBONIC

Subsidiary of Houston Natural Gas Corporation

SPECIALTY GAS and CHEMICAL PRODUCTS

CERTIFICATE OF ANALYSISTo: Medical Tech. Inc.Date: March 14, 1979968 Albany Shaker Rd.

Ref. # _____

Latham, NY

Cust. P.O. # _____

Product Helium TrailerCyl. Serial
No.Cyl. Serial
No.Cyl. Serial
No.

Trailer # 3132

<u>Components</u>	<u>Requested</u>	<u>Actual</u>	<u>Actual</u>	<u>Actual</u>
Oxygen		14ppm		
Nitrogen		34ppm		
T.H.C.		N.D. .5ppm		
Moisture		N.D. 3ppm		
Helium		99.995+%		

N.D. = NONDETECTABLE, LESS THAN

Cyl. Volume _____

CGA Valve No. _____

Total Cyl. Pressure _____

Method of Analysis:

Specific Oxygen Analyzer, Total

HYD

rocarbons Analyzer, Specific
sture Analyzer, Gas Chromatography.Certified By: Ron Schulz - Chemist

2-17

It is recommended the above cylinders not be depleted
below 50 psig unless otherwise indicated.

3.0 TEST PERSONNEL

All testing was conducted by MTI personnel from the Latham and New Karner Road facilities. Data recording was conducted manually with transient tests recorded on an 8-channel strip chart recorder, all in accordance with MTI Report EA-79-3 Parts 1 and 2. Representatives of ORNL witnessed the majority of the circulator aerodynamic, mechanical and transient testing.

4.0 ANALYSIS OF RESULTS

4.1 Compressor Characteristics

Data reduction of the compressor characteristics was done by computer and the relevant output is given in Appendices 3 and 4; test data sheets are located in Appendix 5. To illustrate equations, method used and corrections to specified design-point conditions, one test point from each of the 1300 and 1500 psi discharge pressure runs is given below.

4.2 Power Consumed

To obtain an overall assessment of the power consumed by the circulator and the distribution of losses, three different methods were used:

A. Aerodynamic Horsepower

This can be calculated from the measured gas flow and head together with an assumption for compressor efficiency and a further assumption for parasitic losses which are assumed to vary from the calculated value by an amount inversely proportional to speed³.

B. Shaft Output Power

This can be calculated from the kW input meter using a motor efficiency taken from actual motor test data.

C. Shaft Output Power (Alternate Method)

This can also be calculated from actual readings of the phase voltage and current, and by using values for motor efficiency and power factor taken from actual motor test results.

In the following examples the variation of power factor and motor efficiency were taken from the motor test results given in MTI Report 76TR15. These results are plotted in Figure 4.2-1 so that these two values can be interpolated at intermediate values of speed and kW inputs. The values actually used for the data reduction are tabulated in Table 4.2-1. Also shown in this table are the corrections used for voltage measurements which are necessary due to internal

Fig. 4.2-1 Motor Characteristics Relationship Between kW Input, Power Factor, Motor Efficiency and Speed. Curves Based on Motor Test Report in MIT 76TR15 Design Study Report.

TABLE 4.2-1

RELATIONSHIP BETWEEN: rpm, kW, POWER FACTOR,
MOTOR EFFICIENCY AND VOLTAGE CORRECTION

	Test No.	rpm	kW	P.F.	Motor η	Volts
1300 psig	47	21,144	153.1	.85	.87	-20
	48	21,153	141.7	.85	.86	-20
	49	21,153	127.0	.842	.85	-20
	50	21,156	112.8	.83	.83	-20
	51	14,099	44.8	.73	.78	-14.7
	52	14,083	34.1	.65	.73	-14.7
	53	14,100	36.2	.66	.74	-14.7
	54	14,100	41.2	.71	.76	-14.7
	55	7,031	6.1	.3	.34	-7.3
	56	7,058	5.0	.11	.11	-7.3
	57	7,055	5.4	.12	.12	-7.3
	58	7,060	5.7	.3	.34	-7.3
	59	3,002	.7	.02	.02	-3.1
	60	3,000	.7	.02	.02	-3.1
	61	3,000	.7	.02	.02	-3.1
	62	3,000	.8	.02	.02	-3.1
1500 psig	64	21,143	142.5	.85	.87	-20
	65	21,142	145.5	.85	.87	-20
	66	21,134	155.9	.85	.87	-20
	67	21,130	174.4	.85	.87	-20
	68	14,105	51.8	.76	.81	-14.7
	69	14,124	38.7	.66	.74	-14.7
	70	14,096	42.4	.71	.76	-14.7
	71	14,088	47.6	.75	.79	-14.7
	72	7,055	7.5	.33	.37	-7.3
	73	7,052	6.5	.3	.34	-7.3
	74	7,068	5.6	.12	.12	-7.3
	75	3,000	.7	.02	.02	-3.1
	76	3,070	.7	.02	.02	-3.1
	77	3,025	.8	.02	.02	-3.1
	78	3,000	.7	.02	.02	-3.1

NOTE: rpm, kW, P.F., Motor Efficiency, taken from Curve in Figure 4.2-1 which was prepared from motor test data in MTI Report No. 76TR15 voltage correction taken from Curve in Figure 4.2-2.

voltage drops within the power supply. These are assumed to vary linearly with speed and are shown in Figure 4.2-2. (Correction given by manufacturer of power supply.)

The volt and ampere meters supplied with the power supply were not used for this series of tests due to their doubtful accuracy and nonlinearity when used with the nonsinusoidal wave form generated by this power supply. The voltage was measured at the dc Bus with a Hewlett-Packard 3465B voltmeter, using a multiplier of 0.78 to arrive at the relative ac voltage.

The ac current was measured in one phase by using a 300 to 5 ampere current transformer and a 0.2 ohm-precision, 100-watt resistor. The resulting ac voltage was measured using a Cimron DMM-15, true rms reading voltmeter. When multiplied by a factor of 300, this voltage reading gave a current reading in amperes.

The analyzed performance data are shown in curve form in Figure 4.2-3 for 1300 psi, 650°F and in Figure 4.2-4 for 1500 psi, 650°F.

Speed lines corresponding to 0.9 of design speed, 0.6 of design speed, 0.3 of design speed and 3000 rpm were tested from surge point at minimum flow to maximum flow as determined by the loading valve. Maximum flow achieved exceeded the design point by 1.6 percent. Also plotted for each of the above speed lines was a measure of the input power in kW. (See Tables 4.2-2, 4.2-3 and 4.2-4.)

4.3 Record of Testing

- A. During this test period the circulator logged a total of 152 hours 41 minutes and accumulated 59 stops and starts.
- B. A summary and Index of Test Run Numbers are given in Appendix 1.
- C. Record of shaft orbits and thrust bearing film thicknesses are given in Appendix 2.
- D. Test data sheets are given in Appendix 6.
- E. Record of transient tests is contained in Appendix 7.
- F. Record of daily log sheets is given in Appendix 8.

Fig. 4.2-2 Voltage Correction Chart

1300 psi Discharge Pressure; 650°F Discharge Temperature

Fig. 4.2-3 Helium Circulator Performance - CFTL Loop Each Circulator (1300 psi)

Fig. 4.2-4 Helium Circulator Performance - CFTL Loop Each Circulator (1500 psi)

TABLE 4.2-2

EQUATIONS USED FOR REDUCING TEST DATA

Run No. Date Time

rpm =

$$\rho_{\text{DENSITY ORIFICE}} = .373 \frac{P_{\text{ORIFICE}}^{(1)}}{T_{\text{ORIFICE}}^{(2)}}$$

$$\rho_{\text{DENSITY COMP. INLET}} = .373 \frac{P_{\text{COMP INLET}}^{(3)}}{T_{\text{COMP INLET}}^{(4)}}$$

$$\rho_{\text{DENSITY MEAN}} = .373 \frac{P_{\text{MEAN}}^{(5)}}{T_{\text{MEAN}}^{(7)}}$$

$$\frac{\text{ACTUAL ft}^3}{\text{sec}} = \sqrt{\Delta P_{\text{ORIFICE}}^{(11)} \times \frac{T_{\text{ORIFICE}}^{(2)}}{P_{\text{ORIFICE}}^{(1)}}} \times .9921$$

$$\frac{\text{ACTUAL ft}^3}{\text{sec}} \text{ CORRECTED} = \frac{\text{ACTUAL ft}^3}{\text{sec}} \times \frac{\rho_{\text{DENSITY ORIFICE}}}{\rho_{\text{DENSITY DESIGN}}}$$

$$\text{HEAD} = \frac{\Delta P_{\text{CIRC}}^{(8)} \times 144}{\rho_{\text{DENSITY MEAN}}}$$

$$\text{HEAD} = \frac{\partial}{\partial - 1} R(T_{\text{COMP INLET}}^{(4)}) \left[\left(\frac{P_{\text{COMP OUTLET}}^{(9)}}{P_{\text{COMP INLET}}^{(10 \text{ or } 3)}} \right)^{\frac{\partial - 1}{\partial}} - 1 \right]$$

$$\text{hp}_{\text{aero}} = \frac{\frac{\text{ACTUAL ft}^3}{\text{sec}} \times \rho_{\text{DENSITY ORIFICE}} \times \text{HEAD} \times \text{P.L.}}{550 \times \eta_c}$$

$$\text{hp}_{\text{out}} = \frac{\text{kW} \times \eta_{\text{MOTOR}}}{.746}$$

$$\text{hp}_{\text{out}} = \frac{(\text{VOLTS} \times .78) \times (\text{AMPS} \times 300) \times \sqrt{3} \times \text{P.F.} \times \eta_{\text{MOTOR}}}{746}$$

$$(1) P_{\text{ORIFICE}} = \text{AVERAGE} + 14.7$$

$$(2) T_{\text{ORIFICE}} = \text{AVERAGE} + 460$$

$$(3) P_{\text{COMP INLET}} = \text{AVERAGE} + 14.7$$

$$(4) T_{\text{COMP INLET}} = \text{AVERAGE} + 460$$

$$(5) P_{\text{MEAN}} = \frac{P_{\text{COMP INLET}}^{(3)} + P_{\text{COMP OUT}}}{2}$$

$$(6) T_{\text{COMP OUT}} = \text{AVERAGE} + 460$$

$$(7) T_{\text{MEAN}} = \frac{T_{\text{COMP INLET}}^{(4)} + T_{\text{COMP OUT}}^{(6)}}{2}$$

$$(8) \Delta P_{\text{CIRC}} = \text{AVERAGE} + \text{NOTHING}$$

$$(9) P_{\text{COMP OUTLET}} = P_{\text{COMP INLET}} + \Delta P_{\text{CIRC}}$$

$$(10) P_{\text{COMP INLET}} = (3) \text{ above}$$

$$(11) \Delta P_{\text{ORIFICE}} = \text{AVERAGE} + \text{NIL}$$

$$\frac{\partial}{\partial - 1} = 2.587$$

$$\frac{\partial - 1}{\partial} = .3865$$

$$R = 386.25$$

$$\text{P.L.} = 1.04 \times \left[1 + \left(1.1863 - 1 \times \frac{\text{rpm}}{23,500} \right)^3 \right]$$

$$\text{P.F.} = \text{See Table No. 4.2-1}$$

$$\eta_{\text{MOTOR}} = \text{See Table No. 4.2-1}$$

$$\rho_{\text{DENSITY DESIGN}} = .4373 \text{ for } 1300 \text{ psi, } 650^\circ\text{F}$$

$$\rho_{\text{DENSITY DESIGN}} = .508 \text{ for } 1500 \text{ psi, } 650^\circ\text{F}$$

TABLE 4.2-3

SAMPLE CALCULATION USING DATA FROM TEST RUN NUMBER 47

Run No. 47 Date 3-19-79 Time 13.25
rpm = 21,144

$$\rho_{DO} = .373 \times \frac{1332.2}{1101.1} = .4513$$

$$\rho_{DCI} = .373 \times \frac{1305.2}{1101} = .4422$$

$$\rho_{DM} = .373 \times \frac{1319.4}{1106.04} = .44495$$

$$acfs = \sqrt{305 \times \frac{1101.1}{1332.2}} \times .9921 = 15.752$$

$$acfs_{CORR} = 15.752 \times \frac{.4513}{.4373} = 16.256$$

$$Head = \frac{28.35 \times 144}{.44495} = 9174.96$$

$$Head = 2.587 \times 386.25 \times 1101 \left[\left(\frac{1333.55}{1305.2} \right)^{.3865} - 1 \right]$$

$$= 9175.04$$

$$hp_{aero} = \frac{15.752 \times .4513 \times 9175.04 \times \overbrace{1.04 \times 1.1358}^{1.1813}}{550 \times .80}$$

$$= 175.071 \quad (\text{Design} = 175.6)$$

$$hp_{out} = \frac{153.1 \times .87}{0.746} = 178.55$$

$$hp_{out} = \frac{(596.7 \times .78) - 20 \times (.9145 \times 300) \times \sqrt{3} \times .85 \times .87}{746}$$

$$= \frac{445.4 \times 274.35 \times 1.732 \times .85 \times .87}{746}$$

$$= 209.8$$

$$P_O = 1317.5 + 14.7 = 1332.2$$

$$T_O = 641.1 + 460 = 1101.1$$

$$P_{CI} = 1290.5 + 14.7 = 1305.2$$

$$T_{CI} = 641 + 460 = 1101$$

$$P_M = \frac{1305.2 + 1333.55}{2}$$

$$T_{OUT} = 651.075 + 460 = 1111.075$$

$$T_{MEAN} = \frac{1101 + 1111.075}{2} = 1106.08$$

$$\Delta P_{CIRC} = 28.35$$

$$\Delta P_{ORIFICE} = 305$$

$$P_{CO} = 28.35 + 1305.2 = 1333.5$$

$$P_{CI} = 1305.2$$

$$\rho_{DESIGN} = .4373$$

TABLE 4.2-4

SAMPLE CALCULATION USING DATA FROM TEST RUN NUMBER 67

Run No. 67 Date 3-20-79 Time 10.00

$$\rho_0 = .373 \times \frac{1534.2}{1106.2} = .5173$$

$$\rho_{CI} = .373 \times \frac{1502.2}{1105.8} = .5067$$

$$\rho_M = .373 \times \frac{1518.4}{1111} = .50977$$

$$acfs = \sqrt{350 \times \frac{1106.2}{1534.2}} \times .9921 = 15.76$$

$$acfs_{CORR} = 15.76 \times \frac{.5173}{.508} = 16.04 \quad (x60 = 962.9)$$

$$Head = \frac{32.35 \times 144}{.50977} = 9138$$

$$Head = 2.587 \times 386.25 \times 1105.8 \left[\frac{1534.55^{.3865}}{1502.2} - 1 \right]$$

$$= 9136.75$$

$$hp_{aero} = \frac{15.76 \times .5173 \times 9136.75 \times 1.04 \times 1.1358}{550 \times .8}$$

$$= 109.97$$

$$hp_{out} = \frac{174.9 \times .87}{0.746} = 203.97$$

$$hp_{out} = \frac{[(589.2 \times .78) - 20] \times 1.03864 \times 300 \times \sqrt{3} \times .85 \times .87}{746}$$

$$= 235.16$$

$$P_0 = 1319.5 + 14.7 = 1534.2$$

$$T_U = 646.2 + 460 = 1106.2$$

$$P_{CI} = 1487.5 + 14.7 = 1502.2$$

$$T_{CI} = 645.8 + 460 = 1105.8$$

$$P_M = \frac{1502.2 + 1534.6}{2} = 1518.4$$

$$T_{out} = 656 + 460 = 1116.0$$

$$T_{MEAN} = 1111$$

$$\Delta P_{CIRC} = 32.35$$

$$\Delta P_{ORIFICE} = 350$$

$$P_{CO} = 1502.2 + 32.35 = 1534.55$$

$$P_{CI} = 1502.2$$

$$\rho_{DESIGN} = .508$$

4.4 Motor Test Report

by Herb Short

Union Carbide Drive Motor Performance Tests

Several tests were performed on the Helium Circulator Test Loop Drive Motor to determine circuit constants, operating capabilities, efficiency, and other acceptance criteria. These tests were conducted on April 2 through April 4, 1979 and included the following:

- (1) Miscellaneous electrical tests to determine the stator winding resistances and insulation resistances; the accuracy with which the resistance-temperature characteristic of the copper stator windings tracked the temperatures indicated by three thermocouples (T/C 9, 10 and 11) embedded in the motor windings, and; the presence of shaft current or electromagnetic imbalance.
- (2) A performance test at no-load with the motor running at 3600, 8000, 12,000, 16,000, 20,000, and 23,500 revolutions-per-minute (rpm).
- (3) A performance test at full-load with the motor running at 3000, 7050, 11,000, 14,100, 18,800, 21,150, and 23,500 rpm.
- (4) A simulated locked-rotor test at a reduced frequency and corresponding motor voltage for the purpose of comparing the input voltage, line current, power, and torque with predicted values from a previous motor analysis.

MISCELLANEOUS ELECTRICAL TESTS

Information concerning the stator winding insulation resistance was taken (in accordance with IEEE standard 43-1974) in the following manner: the three lengths of 4/0 jumper cable leading from the stator windings to the motor terminal board, were disconnected, separated from one another, and positioned so that they were ungrounded. Using a Biddle megohmmeter, MTI S/N 9593, on the 500 Vdc setting, readings were taken of the insulation resistance from one phase to another. All three readings were "infinite" ohms, exceeding the minimum allowable value of 2(rated kilovolts +1) megohms, or 2.92 megohms at 40°C. The ambient temperature during these measurements (as determined by taking the average of the three embedded thermocouple readings) was 24.3°C.

While the stator winding leads were disconnected, measurements were made of the stator winding resistances using an NLS MX-1 digital voltmeter, MTI S/N 9018, which was capable of reading milohms of resistance. The schematic and the appropriate equations for obtaining the individual phase resistances are shown below. The data and calculated values are tabulated in Table I.

$$R1 = \frac{Ra - Rb + Rc}{2}$$

$$R2 = \frac{Ra + Rb - Rc}{2}$$

$$R3 = \frac{Rc + Rb - Ra}{2}$$

Tt	Ra	Rb	Rc	R1	R2	R3
24.32 °C	.011Ω	.012Ω	.012Ω	.0055Ω	.0055Ω	.0065Ω

Table I : Stator Winding Resistance

For the operational tests, it was necessary to measure such parameters as line-to-line voltage, line current, frequency, power input (in watts), and motor revolutions-per-minute as accurately as possible. Due to the nonsinusoidal character of the three phase power supply, and the fact that voltage, current, and power levels were of interest at low frequencies (approximately 3 to 10 hertz) as well as the rated 400 hertz value, it was mandatory that all transducers and associated instruments be capable of responding accurately to a stepped wave form that could be varied from dc to 400 hertz.

A Servo-Optics panel mounted Analogic Digital display provided the readout for power input in kilowatts. Two Ohio Semitronics DC Watt Transducers, Model PC-8-5-02, were installed inside the panel utilizing two of the three phases for the "two wattmeter" method of obtaining total three phase power.

Their dc milliamper outputs were summed and converted to a suitable dc voltage for the panel meter input. The system accuracy was ± 1 percent of the full scale product of voltage and current.

As the reliability of the panel mounted 0-500 ac ammeter and 0-500 voltmeter was questionable, supportive calibration checks using other instrumentation methods were performed. The 300:5 turns ratio of a precision 600/300/150:5 ampere current transformer (R.B. Annis "A" frame split-core) was installed around one of the power lines in the panel; a 0.2 ohm ± 0.1 percent, 100-watt Dale resistor served as the load. Line current proportional to this load voltage was then measured with a Cimron Digital Multimeter, DMM-51, MTI S/N 23885. With the motor leads reconnected, a no-load run was made to obtain a comparison of panel meter versus the Cimron meter current readings. These are listed in Table II. As noted, the panel meter indications were consistently an average of 20 amperes below actual values. Consequently, as no-load and full-load line current data were taken directly from the panel meter, a correction factor of +20 amperes has been made in the appropriate table to show true line current values.

<u>rpm</u>	<u>I Line Panel</u>	<u>I Line</u>	<u>Difference</u>
5,000	155	175.95	20.95
8,000	110	130.15	20.15
10,000	92	112.8	20.8
14,000	74	93.66	19.66
16,000	79	98.61	19.61
Average			20.23 Amperes

* 1 line Cimron = $\frac{300 \text{ Amperes full scale}}{(0.2 \Omega) (5 \text{ Amperes Full Scale})} \times \text{V}_{ac} \text{ Cimron}$

Table II: Line Current Panel Meter Correction

Similarly, other means were employed to measure the true line-to-line voltage. As the power supply generated a stepped dc, three-phase voltage from a floating dc bus voltage (460 volts ac line-to-line at a 600 volts dc bus potential, or numerically, $V_{ac} = .78 V_{dc}$), a Hewlett-Packard Digital Voltmeter, model 3465B, MTI S/N 9025, was used to measure the dc bus voltage directly. The voltmeter was carefully placed so that it was insulated from ground potential.

For comparison purposes, an additional voltmeter (the Cimron DMM51) was connected to the secondary windings of a Sangamo Type T-6A 4:1 precision potential transformer (S/N 7764312), whose primary windings were connected in parallel with one of the phases at the drive motor terminal board. In this manner, the true rms line-to-line voltage could be compared to both the dc bus voltage and the Servo-Optics panel meter readings. As is evident from the line-to-line voltage data recorded in subsequent no-load and full-load operations, (Tables III and V) significant differences occurred between each of the three readings. Since the panel meter accuracy was questionable, having no record of calibration, it was used merely as an approximation when varying the drive frequency to obtain certain operating rpm's. The difference between the dc bus voltage readings and the equivalent Cimron ac line-to-line voltage readings can be attributed to line and contact losses, as well as fluctuations in the $0.78 \frac{V_{ac}}{V_{dc \text{ bus}}}$ ratio factor over the operating range of the power unit. As measurements of power and line current were obtained upstream of the line loss, all calculations were done utilizing the line-to-line voltage data measured by the Hewlett-Packard meter, i.e., dc bus voltage $\times 0.78 = V_{ac \text{ rms, line-to-line}}$.

FULL-LOAD TESTS

With the motor leads reconnected, conditions were readied for operating the drive motor at full load over a normal horsepower range. While monitoring the stator winding temperature as indicated by thermocouples 9, 10, and 11 to insure that the temperature rise remained within 50 percent and 100 percent of the rated temperature rise of the machine, the machine's speed was gradually increased to its rated value of 23,500 rpm.

Measurements of line-to-line voltage, line current, power input, frequency, and motor rpm were recorded, from which the following parameters were calculated:

$$1) \text{ Power, volt amperes} = \sqrt{3}(V_{\text{line-to-line}})(I_{\text{line}})$$

$$2) \text{ Power factor, pf} = \frac{P, \text{ volt-amperes}}{P, \text{ watts}}$$

$$3) \text{ Horsepower, hp} = \frac{P, \text{ watts}}{746}$$

This information is listed in Table III. Figure I illustrates the relationship motor horsepower and power factor have with respect to motor rpm. Figure II indicates how line-to-line current varied with motor rpm.

DC Bus Voltage X 0.78	V _{L-L} Panel	V _{L-L} Motor Term. Board	I _L , Cor- rected	Power, Watts	Power, Volt - Amperes	Freq. Hertz	Power Factor	Speed rpm	Horsepower
456.53	423	441.2	382	213,000	302,060	400	.705	23,500	285.5
464.1	434	454.4	278	153,000	223,469	363	.684	21,150	205.1
379.55	348	366.6	234	104,700	153,832	326	.681	18,800	140.3
277.68	253	269.0	160	45,200	76,953	245	.587	14,100	60.6
218.63	180	210.0	122	21,500	46,199	188	.465	11,000	28.8
138.06	115	131.2	104	5,800	24,869	123	.233	7,050	7.8
76.67	52	69.6	132	800	17,529	62	.046	3,000	1.1

Table III. Full-Load Operation

Temperature of Stator Windings = 245°F

Fig. I Power Factor and Horsepower Versus Motor Speed
4/9/79 HS

792345

Fig. II V_{L-L} , Power, and I_L Versus Motor rpm
4/11/79 HS

792346

It should be noted that to run the drive motor at the rated speed of 23,500 rpm involved a significant increase in line current, as the dc bus voltage limitation of approximately 600 volts could not be exceeded.

WINDING RESISTANCE VERSUS STATOR TEMPERATURE DECAY TESTS

A test of stator temperature decay versus stator resistance was taken in accordance with Section 5.6.4 of IEEE Standard 112-1978. Immediately following the full-load motor test, while the stator winding temperature was at a maximum value of 246°F (cooling water being circulated at a 12 gpm rate), motor leads "R1" and "R2" were disconnected, the NLS MX-1 digital volt-ohmmeter reconnected, and winding resistance "Ra" measurements taken periodically as the temperature decayed to ambient. These resistance values were then translated into temperature using the equation,

$$T_{cal} = T_r + \left(\frac{R_a - R_r}{R_r} \right) (T_r + 234.5)$$

In this instance, R_r is the reference value of winding resistance, 0.011 ohms, as measured at ambient temperature T_r , of 24.3°C. Thermocouples 9, 10 and 11 were again used to obtain an average temperature reading. The results are tabulated in Table IV and shown graphically in Figure III.

Fig. III R_a Versus Temperature.
 R_a Versus Elapsed Time
4/9/79 HS

792344

Ra <u>Ω</u>	Tcal* <u>°C</u>	T/C 9 <u>°C</u>	T/C 10 <u>°C</u>	T/C 11 <u>°C</u>	T ave <u>°C</u>	Elapsed Time
						Since Shutdown (Minutes)
.0145	106.6	118.6	116.4	117.3	117.4	2
.014	94.9	96.9	80.0	104.1	93.7	3
.0135	83.1	89.4	75.6	100	88.3	5
.013	71.4	71.9	57.9	85.4	71.7	13
.0125	59.6	57.7	45.8	72.4	58.6	25
.012	47.8	44.4	35.1	58.9	46.1	48
.0115	36.1	34.1	27.0	50.8	37.2	90
.011	24.3	24.5	24.4	25.7	24.9	180

$$* Tcal = 24.3^{\circ}C + 258.8 \left(\frac{Ra - .011}{.011} \right)$$

Table IV: Stator Winding Resistance Versus Stator Temperature

It was impossible to take the first resistance reading any sooner than two minutes after shutdown because of:

- 1) the slow coastdown rate of the motor
- 2) the time needed to disassemble the motor lead connections and attach the volt meter
- 3) the high residual voltage which remained in the system due to slowly discharging capacitors.

NO-LOAD TESTS

Following cooldown, the motor leads were reconnected and preparations made for running the motor at various speeds under no-load conditions. The helium loop pressure was reduced to 3-5 psi; cooling water continued to circulate through the cooling water piping and stator cooling jacket. Line-to-line voltage, line current, motor rpm, power input, and line frequency were recorded at various no-load speeds. These data have been entered in Table V.

By knowing approximately what the windage and friction losses are, it is possible to calculate the developed mechanical torque from these data.

The sum of the friction, windage, and stator core losses can be extrapolated from a curve of no-load power (watts) versus no-load voltage. This plot is illustrated in Figure IV and represents the method described in Section 4.6.2 of IEEE Standard 112-1978 for determining motor losses. The intercept shows that at zero no-load voltage, the friction and windage, or rotational, losses are approximately 1200 watts. From this information, torque can be calculated using the equation:

$$\text{Torque} = \frac{\text{Power Input} - P_{\text{rotational losses}} \text{ lb}_f \text{ in}}{2\pi (\text{rpm}) (.1130)}$$

Since,

$$P_{\text{rotational}} = P_{\text{friction}} + P_{\text{windage}}$$

and

$$P_{\text{input}} = 3I_o^2 r_l + P_{\text{core loss}} + P_{\text{rotational}}$$

it is possible to determine $P_{\text{rotational}}$ and $P_{\text{core loss}}$ for each data point. This information is included in Table V.

792347

Fig. IV Power Input Versus Voltage_{Line-to-Line}
4/9/79 HS

TABLE V
Determine No-Load Torque

rpm	V _{line-to-line}			Corrected I line	Frequency, hertz	P _{input} , watts	Stator* copper loss, watts	P _{core**} loss, watts	Torque*** lb _f -in.
	dc bus	Panel	At Motor						
3,600	101.17	75	94.52	163	67	1,500	598	-----	6
8,000	206.47	174	196.48	140	140	2,500	441	859	13
12,000	244.06	212	237.88	100	200	2,900	225	1,475	12
16,000	312.16	290	309.32	100	268	5,100	225	3,675	20
20,000	413.01	392	412.28	109	337	9,000	267	7,533	33
23,500	474.16	466	476.50	108	395	12,000	262	10,538	39

* Stator copper loss = $3 I_{line}^2 r_1$

Stator temperature = $246^{\circ}\text{F} = 119^{\circ}\text{C}$

$r_1 = .0075\Omega$ at operating temperature

$P_{rotational} = 1250$ watts from curve, Figure IV

** $P_{core\ loss} = P_{input} - 3 I_{line}^2 r_1 - P_{rotational}$

*** Torque = $\frac{P_{input} - P_{rotational}}{2\pi (rpm) (.1130)}$

Locked-Rotor Tests

Due to assembled configuration of the drive motor, it was not feasible to attach mechanical restraints to the shaft in order to obtain a locked-rotor condition. However, satisfactory data were obtained by simulating a locked-rotor situation through the application of single phase power of approximately 57.5 volts/50 hertz between two of the machine line terminals. In this instance, the line current will be approximately 86 percent and the power input approximately 50 percent of the corresponding values obtained with polyphase power.

Phase lead "R1" was disconnected at the motor terminal board. To observe the line current properly, since the panel meter only indicated 500 amperes full scale and a value greater than 600 amperes was anticipated, the Cimron DMM 51 voltmeter was connected to the Sangamo 300:5A current transformer and 0.2 Ω resistor circuit as before (during panel ammeter calibration checks). Readings of frequency, line-to-line voltage, line current, and input power were taken quickly (within ten seconds) to insure that the machine temperatures did not exceed rated temperature rise plus 40°C. The data are listed in Table VI, below.

1 $\emptyset$ Power Input	3 $\emptyset$ Power Input	V line-to-line (dc bus)	Frequency	1 $\emptyset$ I line	3 $\emptyset$ I line
24,500	49,000	53.6	50 Hz	693 amps	806 amps
Temperature, initial		Temperature, final		R_1 At T_f	
24.4°C		57.2°C		.00625 Ω	

Table VI: Locked-Rotor Test

From this information a value can be derived for the locked-rotor torque unique to these conditions. Torque may be calculated in accordance with section 4.8.2 of IEEE Standard 112-1978 and the equation.

$$\text{Torque} = \frac{\kappa C (P_{\text{input}} - P_{\text{stator losses}} - P_{\text{core losses}})}{\eta_s}$$

where κ is a constant $= 7,043 \text{ lb}_f \text{ ft}$

C is a reduction factor varying between 0.9 and 1.0 to account for nonfundamental losses

n_s is synchronous speed in rpm = 3000 for 50 Hz

Assuming C is 0.95 the equation becomes:

$$\text{Torque} = .00223(P_{\text{input}} - P_{\text{stator losses}} - P_{\text{core losses}})$$

Employing values obtained from no-load operation, we have

$$\text{Torque} = .00223[49,000 - 3 (806)^2 (.00625) - 10,600] = 58.649$$

Referring to the December, 1976 Design Study Report:

Helium Circulators, MTI 76TR15, the value of locked-rotor torque should be approximately 40 to 60 $\text{lb}_f\text{-ft}$, which lends credibility to this calculated value. Note that the value of core loss is an estimate based on core losses experienced during full-load operation and derived from the graphical determination of the friction and windage losses. This figure, which represents rather intangible hysteresis and eddy current losses, seemed a reasonable value for this operating condition.

SHAFT CURRENT AND ELECTROMAGNETIC BALANCE MEASUREMENTS

Any irregularities in the magnetic circuit, and hence, any electromagnetic force which may cause a current to flow through the motor shaft, bearings, bearing supports, and machine framework, were detected in the following manner: the drive motor was removed from the pressure vessel, but left in position on the withdrawal rails; copper "spring contact" assemblies were then constructed as shown in the diagram of Figure V. The supports for each arrangement were insulated from ground, and adjusted to maintain adequate contact tension between the flat end of the shaft and the copper springs. All circuit connections, loose leads, and hardware which could loosen from motor vibrations were tightened and captivated. The Cimron DMM51 voltmeter was then connected between the two shaft contacts. With the machine running at rated speed and voltage, the following data were taken (see Table VII):

Fig. V Contact Spring Arrangement for Measuring Open-Circuit Shaft Voltage

792340

<u>Voltage,</u> <u>line-to-line</u>	<u>I line</u>	<u>Frequency</u>	<u>Power Input</u>	<u>Speed</u>	<u>Measured Shaft</u> <u>Voltage</u>
	amperes	hertz	watts	rpm	
460	125	392	46,000	23,500	0.20 to 0.91

Table VII: Shaft Open Circuit Voltage Measurements

Since during rotation, the rotor rides on "cushioned" gas bearings, and assuming no deformities in the bearings or shaft, no circulating of shaft currents should be detected. The fact that the open circuit shaft voltage varied between 0.2 and 0.91 volts rms while the machine was running at rated speed and voltage is perhaps due to:

- 1) the variations in magnetic flux distribution,
- 2) the mechanical versus electrical winding positions,
- 3) the nonuniformities in compositions,

Also, variations in shaft insulation that occurred during rotor rotation, and the probability that the hexagonally-shaped shaft ends did not permit constant spring contact while rotating may have introduced discontinuities in the readings. It is interesting to note that when the motor was brought down in speed, the range of open circuit voltage, V_{oc} , did not vary significantly from what has been recorded.

Analysis of Motor Performance

As directed by Section 18.12 of the MTI Design Study Report 76TR15, the motor performance analysis was made in accordance with Method (F) of IEEE Standard 112-1978. Forms F_1 , F_2 and F_3 were used for recording and analyzing the data and have been included in the Appendix of this report. Circuit constants pertinent to an analysis using the equivalent circuit techniques were obtained from tests on the pre-production motor as reported in Appendix IV of MTI 76TR15.

Table VIII lists circuit constants corresponding to desired test speeds of the motor used in the Design Study Report and are based on values obtained graphically from Appendix IV of this report (for a constant V/Hz ratio of 1.15.)

Speed, rpm	Slip, rpm	Frequency, hertz	R ₁ , Ω	R ₂ , Ω	$\frac{1}{R_3}$, ohms	L ₁ , henrys	L _m , henrys	R _m , Ω
3,000	600	60	.0089	.0090	41.0	.000067	.00020	2.9
7,050	150	120	.0089	.0063	13.0	.000067	.00050	6.2
12,000	~ 100	~ 200	.0089	.0064	8.6	.000067	.00072	9.5
16,000	80	268	.0089	.0087	7.0	.000067	.00092	15.0
20,000	220	337	.0089	.0071	25.0	.000067	.00035	18.0
23,500	500	400	.0089	.0083	36.0	.000067	.00022	19.0

TABLE VIII: CIRCUIT CONSTANTS DETERMINED GRAPHICALLY FROM PREVIOUS MOTOR RUNS

Beginning with Form F-1, an operating condition of 460 volts, line-to-line, 400 hertz frequency, and a speed of 23,500 rpm (slip of 500 rpm) is considered. Equations (1), (2), and (3) of Form F-1 are then solved in iterative fashion until stable values of x_1 and x_m are obtained within 0.1 percent. Assumptions were first made as follows:

$$\frac{x_1}{x_2} = 1; \frac{x_1}{x_m} = 0.3, \text{ and } x_1 = 0.03 \text{ ohms.}$$

Using values of powers, voltages, and currents obtained through the previously mentioned tests, solutions of Equations (1) through (9) were arrived at. These values of circuit constants are recorded on Form F-2, Appendix A-8. Similar procedures were followed for the 20,000, 16,000 and 12,000 rpm no-load test data; calculations are entered on Form F-2, Appendices A-6, A-4, and A-2, respectively.

Evaluation of the locked-rotor test data and the no-load data for four speeds (23,500, 20,000, 16,000 and 12,000 rpm with slips of 500, 220, 80 and approximately 100 rpm, respectively) resulted in the following values for L_1 and L_m :

Speed, rpm	Slip, rpm	Frequency, hertz	L_1 , henrys	L_1 , henrys Graphical Prediction	L_m , henrys	L_m , henrys Graphical Prediction
23,500	500	400	.000062	.000067	.00096	.00020
20,000	220	337	.000062	.000067	.00098	.00040
16,000	80	268	.000062	.000067	.00101	.00092
12,000	~ 100	~ 200	.000062	.000067	.00100	.00072

TABLE IX: A COMPARISON OF PREDICTED AND CALCULATED VALUES OF L_1 AND L_m

The pre-operational value of the stator leakage inductance, L_1 , obtained from Section 3 of the Design Study Report, closely approximated the calculated value of L_1 using these latest test data. However, the predicted stator magnetizing inductance, L_m , was noticeably smaller for high values of slip than the calculated L_m at similar slips. This difference became significantly smaller as the slip approached zero.

Table X is a comparison of important parameters obtained through Method F-3 calculations (Appendices A-3, A-5, A-7 and A-9 for selected no-load motor speeds of 12,000, 16,000, 20,000 and 23,500 rpm, respectively, and similar parameters actually measured during full-load operation, or obtained graphically from Figure II, which is based on the full load data.

Although the calculated efficiencies appear to be quite respectable for all four operating points, it is doubtful how accurate they truly are. The observed values for the 12,000 and 23,500 rpm speeds are within 6 percent of the calculated values, which would indicate that for these two conditions, fairly reliable data points were taken, especially with respect to shaft rpm and frequency, and consequently, slip. This is evidently not true for the 16,000 and 20,000 rpm data points, where substantial error has been introduced in the calculated values. As stated in IEEE Standard 112-1978, for motor performance analysis in accordance with Method F, "accurate prediction of machine characteristics by the equivalent circuit will depend upon the closeness by which r_2 represents the actual rotor resistance....". Since the value of " r_2/s " weighs heavily in the beginning calculations of Form F-3, incorrectly measured values of per unit slip, s , and the rotor resistance, r_2 , would, by themselves, introduce considerable error in the solutions.

Based on the 12,000 and 23,500 rpm comparisons, it is correct to say that, given, or taking, correct no-load and locked-rotor data and making reasonable assumptions with regard to certain intangible motor losses, the Method F calculations will provide a fair assessment of motor performance at a variety of per unit slips and operating ranges.

Table X: A Comparison of Predicted Motor Performance
Using Method F Analysis, With Actual Operating
Values

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Speed rpm	Power Input, watts		Power Factor		Horsepower		Calculated Efficiency, %
	Calculated	Observed	Calculated	Observed	Calculated	Observed	
12,000	29,112	31,000	0.577	0.51	32.56	34	83.4%
16,000	31,054	65,000	0.4706	0.64	34.43	80	82.71%
20,000	122,466	140,000	0.7394	0.69	147.8	173	90.1%
23,500	224,707	213,000	0.7958	0.705	277.66	285.5	92.18%

Form F-1

Method F: Equivalent Circuit Nomenclature and Equations for Determining Machine Constants

NOTE: Unless otherwise noted, all impedances, admittances, and voltages are per phase for two-phase motors and per phase wye for three-phase motors. Powers and volt-amperes are per complete motor.

Nomenclature

V	= phase voltage, volts
f	= frequency, hertz
I_1	= line or stator current, amperes
I_2	= rotor current, amperes
s	= slip in per unit of synchronous speed
m	= number of phases
r_1	= stator resistance corrected to specified temperature t_s , ohms
r_1'	= stator resistance at temperature during no load test, ohms
r_1''	= stator resistance at temperature during impedance test, ohms
r_2	= rotor resistance referred to stator at specified temperature t_s , ohms
r_2''	= rotor resistance referred to stator at temperature during impedance test, ohms
x_1	= stator leakage reactance, ohms
x_2	= rotor leakage reactance referred to stator, ohms
x_M	= magnetizing reactance, ohms
b_M	= magnetizing susceptance, ohms ⁻¹
r_{fe}	= core resistance, ohms
g_{fe}	= core conductance, ohms ⁻¹
VAR	= reactance volt-ampere, vars
W	= power, watts
W_h	= core loss, watts
W_f	= friction and windage loss, watts
W_{LL}	= stray-load loss, watts = $LL_s + LL_r$

Subscripts:

L	= quantities pertaining to impedance test
o	= quantities pertaining to no-load test or operation

NOTES:

(1) For three-phase motors, the per phase wye stator resistance is one-half of the terminal to terminal resistance.

(2) Design A, B, C, and D motors are defined in the National Electrical Manufacturers Association Motor and Generator Standards, MG-1

Procedure

A relationship between x_1 and x_2 must be assumed. When design details are available, use the calculated ratio $\left(\frac{x_1}{x_2}\right)$

otherwise use:

$\left(\frac{x_1}{x_2}\right) = 1.0$ for Design A motors, Design D motors, and wound-rotor motors

$\left(\frac{x_1}{x_2}\right) = 0.67$ for Design B motors

$\left(\frac{x_1}{x_2}\right) = 0.43$ for Design C motors

$$VAR = \sqrt{(mVI_1)^2 - W^2}$$

$$x_M = \frac{mV_o^2}{VAR_o \cdot mI_{1o}^2 x_1} \left(\frac{1}{1 + \frac{x_1}{x_M}} \right)^2 \quad (1)$$

$$x_{1L} = \frac{VAR_L}{mI_{1L}^2 \left(1 + \frac{x_1}{x_2} + \frac{x_1}{x_M} \right) \left(\frac{x_1}{x_2} + \frac{x_1}{x_M} \right)} \quad (2)$$

$$x_1 = \frac{f}{f_L} x_{1L} \quad (3)$$

Equations (1), (2), and (3) may be solved as follows:

1) Solve Eq (1) for x_M , assuming a value of $\frac{x_1}{x_M}$.

2) Solve Eq (2) for x_{1L} , using x_M from Step 1).

3) Solve Eq (3) for x_1 .

4) Solve Eq (1) for x_M , using x_1 from Step 3).

5) Continue iteration solution until stable values of x_1 and x_M are obtained within 0.1 percent.

$$b_M = \frac{1}{x_M} \quad (4)$$

$$x_2 = \frac{x_1}{\left(\frac{x_1}{x_2}\right)} \quad (5)$$

$$W_h = W_o - W_f - mI_{1o}^2 r_1 \quad (6)$$

Determine W_f per 4.6.2

$$g_{fe} = \frac{W_h}{mV_o^2} \left(1 + \frac{x_1}{x_M} \right)^2 \quad (7)$$

$$r_{fe} = \frac{1}{g_{fe}} \quad (8)$$

$$r_2'' = \left[\left(\frac{W_L}{mI_{1L}^2} - r_1'' \right) \left(1 + \frac{x_2}{x_1} \cdot \frac{x_1}{x_M} \right)^2 - \left(\frac{x_2}{x_1} \right)^2 (x_{1L}^2 g_{fe}) \right] \quad (9)$$

Form F-2
Method F: Induction Motor Characteristics

APPENDIX A-2

Motor Serial No. _____ Model No. _____
Type _____ Horsepower 185 Voltage 460 Synchronous Speed 2400 Frequency 400 Phases 3
Squirrel-Cage
Induction

Summary of Tests

No Load		Impedance Data at <u>50</u> Hz (f_L)		
Line Current, amperes I_o	Power Input, watts W_o	Line volts V_L	Line Current, amperes I	Power Input, watts W
<u>100</u>	<u>2900</u>	<u>53.59</u>	<u>806</u>	<u>49,000</u>

Constants

$$\begin{aligned}
 V &= \underline{135.7} \text{ (volts) (per phase)} & x_2 &= \underline{0.018} \text{ (ohms)} \\
 r_1 &= \underline{0.0056} \text{ (ohms)} & (x_1 + x_2) &= \underline{0.156} \text{ (ohms)} \\
 r_2 &= \underline{0.01548} \text{ (ohms)} & b_M &= \underline{0.1492} \text{ (mhos)} \\
 r_{fe} &= \underline{17.68} \text{ (ohms)} & b_{fe} &= \underline{0.05656} \text{ (mhos)} \\
 x_1 &= \underline{0.078} \text{ (ohms)} & W_f &= \underline{1200} \text{ (watts)} \\
 & & W_h &= \underline{1522} \text{ (watts)}
 \end{aligned}$$

$$W_{LL}' = \underline{690} * \text{ (watts) at } I_L = \underline{90.69} \text{ (amperes)}$$

*See 4.3.4.4.1 and 4.3.4.4.2.

$$W_{LL}' \approx 0.5\% \text{ OF RATED HORSEPOWER}$$

VALUES AT FREQUENCY OF APPROXIMATELY 200
MOTOR RPM = 12000
ASSUMED SLIP OF 100RPM

Summary of Characteristics

Load, percent of rated	0	25	50	75	100	125
Horsepower						
Speed, r/min						
Line Current, amperes						
Efficiency, percent						
Power Factor, percent						

INDUCTION MOTORS AND GENERATORS

IEEE
Std 112-1978Form F-3
Method F: Solution of Equivalent Circuit

APPENDIX A-3

Squirrel cage induction
Type _____ Motor Serial No. _____ Model No. _____
Horsepower 185 Voltage 460 Synchronous Speed 2400 Frequency 400 m=Phases 3

Before starting calculations, fill in following items, obtained from previous tests.

$r_1 = 0.01548$ V = phase volts 135.7 $I_t = 90.69$ and $W_{LL} = 690$ from Form F-2
also all the items below which are marked with an asterisk.

Assume a value of s corresponding to expected full-load speed for full-load point and proportional values for other loads. For motor operation s is positive, as are all other numeric values below. Numbers in () represent item numbers.

Assumed
slip of 100

Item	Description	1	2	3	4	5	6	7	8
1	$s = \text{slip, per unit}$	0.0083							
2	r_1/s	1.8651							
* 3	x_1	0.078							
4	$Z_1^2 = (2)^2 + (3)^2$	3.4845							
5	$g_1 = (2)/(4)$	0.5353							
* 6	g_{fe}	0.05656							
7	$g = (5) + (6)$	0.5918							
8	$-b_1 = (3)/(4)$	0.02238							
* 9	$-b_M =$	0.7492							
10	$-b = (8) + (9)$	0.77158							
11	$Y^2 = (7)^2 + (10)^2$	0.9456							
12	$r_g = (7)/(11)$	0.6259							
* 13	$r_1 = \text{resistance per phase}$	0.0056							
14	$r = (12) + (13)$	0.63147							
15	$x_g = (10)/(11)$	0.8160							
* 16	$x_1 =$	0.078							
17	$x = (15) + (16)$	0.8940							
18	$Z = \sqrt{(14)^2 + (17)^2}$	1.0945							
19	$I_1 = V/(18)$	123.97							
20	$I_2 = I_1 / \sqrt{(4) \times (11)}$	68.29							
21	watts Input = $m \times (19)^2 \times (14)$	29112							
22	Sec. Input = $m \times (20)^2 \times (2)$	28094							
23	Stator $I^2R = m \times (19)^2 \times (13)$	258.17							
24	Core Loss = $m \times (19)^2 \times (6)/(11)$	2757.5							
25	Sec. $I^2R = (1) \times (22)$	216.6							
26	Friction and Windage Loss	1200							
27	$W_{LL} = W_{LL} \times [(20)/I_2]^2$	371.2							
28	Losses = Items (23) through (27)	4873.5							
29	watts Output = $(21) - (28)$	24288.5							
30	Eff. (%) = $100 \times [(29)/(21)]$	83.4							
31	PF (%) = $100 \times (14)/(18)$	57.7							
32	hp Output = $(29)/746$	32.56							
33	Speed = $[1 - (1)] \times \text{Sync. speed}$	12000							
34	Torque = $K_T \times (29)/(33)$	14.26							

For torque in	$K_T =$
lbf.ft	7.043
ozf.ft	112.69
newton-meters	9.549

Form F-2
Method F: Induction Motor Characteristics

APPENDIX A-4

Motor Serial No. _____ Model No. _____
Type _____ Horsepower 185 Voltage 460 Synchronous Speed 2400 Frequency 400 Phases 3
Squirrel Cage
Induction

Summary of Tests

No Load		Impedance Data at <u>50</u> Hz (f_L)		
Line Current, amperes I_o	Power Input, watts W_o	Line volts V_L	Line Current, amperes I	Power Input, watts W
<u>100</u>	<u>5100</u>	<u>53.59</u>	<u>806</u>	<u>49000</u>

Constants

$$\begin{aligned}
 V &= \underline{184.75} \text{ (volts) (per phase)} & x_2 &= \underline{0.1045} \text{ (ohms)} \\
 r_1 &= \underline{0.0056} \text{ (ohms)} & (x_1 + x_2) &= \underline{0.2090} \text{ (ohms)} \\
 r_2 &= \underline{0.01676} \text{ (ohms)} & b_M &= \underline{0.5859} \text{ (mhos)} \\
 r_{fo} &= \underline{23.186} \text{ (ohms)} & R_{fo} &= \underline{0.0431} \text{ (mhos)} \\
 x_1 &= \underline{0.1045} \text{ (ohms)} & W_f &= \underline{1200} \text{ (watts)} \\
 & & W_h &= \underline{3732} \text{ (watts)}
 \end{aligned}$$

$$W_{t,l} = \underline{690} * \text{ (watts) at } I_t = \underline{173.21} \text{ (amperes)}$$

*See 4.3.4.4.1 and 4.3.4.4.2.

VALUES AT 16000 RPM
FREQ OF 268 Hz.
SLIP OF 80 (APPROXIMATELY)

Summary of Characteristics

Load, percent of rated	0	25	50	75	100	125
Horsepower						
Speed, r/min						
Line Current, amperes						
Efficiency, percent						
Power Factor, percent						

Form F-3
Method F: Solution of Equivalent Circuit

APPENDIX A-5

squirrel cage induction
Type _____ Motor Serial No. _____ Model No. _____
Horsepower 185 Voltage 460 Synchronous Speed 2400 Frequency 400 m=Phases 3

Before starting calculations, fill in following items, obtained from previous tests.

$r_1 =$ 0.01676 $V =$ phase volts 184.75 $I_t =$ 173.21 and $W_{LL} =$ 690 from Form F-2

also all the items below which are marked with an asterisk.

Assume a value of s corresponding to expected full-load speed for full-load point and proportional values for other loads. For motor operation s is positive, as are all other numeric values below. Numbers in () represent item numbers.

Slip = $\frac{80}{RPM}$

Item	Description	1	2	3	4	5	6	7	8
1	$s = \text{slip, per unit}$	0.005							
2	r_1/s	3.352							
* 3	x_2	0.1045							
4	$Z_2^2 = (2)^2 + (3)^2$	11.247							
5	$g_2 = (2)/(4)$	0.2980							
* 6	g_{fe}	0.0431							
7	$g = (5) + (6)$	0.3411							
8	$-b_2 = (3)/(4)$	0.0093							
* 9	$-b_M =$	0.5857							
10	$-b = (8) + (9)$	0.5952							
11	$Y^2 = (7)^2 + (10)^2$	0.4706							
12	$r_g = (7)/(11)$	0.7248							
* 13	$r_1 = \text{resistance per phase}$	0.0056							
14	$r = (12) + (13)$	0.7304							
15	$x_g = (10)/(11)$	1.2648							
* 16	$x_1 =$	0.1045							
17	$x = (15) + (16)$	1.3693							
18	$Z = \sqrt{(14)^2 + (17)^2}$	1.5519							
19	$I_t = V/(18)$	119.05							
20	$I_1 = I_t / \sqrt{(4) \times (11)}$	25.10							
21	watts Input = $m \times (19)^2 \times (14)$	3105.4							
22	Sec. Input = $m \times (20)^2 \times (2)$	6335.4							
23	Stator $P_R = m \times (19)^2 \times (13)$	238.1							
24	Core Loss = $m \times (19)^2 \times (6)/(11)$	3894.1							
25	Sec. $P_R = (1) \times (22)$	31.68							
26	Friction and Windage Loss	1200							
27	$W_{LL} = W_{LL} \times [(20)/I_t]^2$	6.76							
28	Losses = Items (23) through (27)	5370.6							
29	watts Output = $(21) - (28)$	25683.4							
30	Eff. (%) = $100 \times [1 - (28)/(21)]$	82.71							
31	PF (%) = $100 \times (14)/(18)$	47.06							
32	hp Output = $(29)/746$	34.43							
33	Speed = $[1 - (1)] \times \text{Sync. speed}$	1600							
34	Torque = $K_T \times (29)/(33)$	11.31							

For torque in	$K_T =$
lbf-ft	7.043 ✓
ozf-ft	112.69
newton-meters	9.549

Form F-2
Method F: Induction Motor Characteristics

APPENDIX A-6

Motor Serial No _____ Model No _____
Type _____ Horsepower 185 Voltage 460 Synchronous Speed 2400 Frequency 400 Phases 3
Squirrel Cage
Induction

Summary of Tests

No Load		Impedance Data at <u>50</u> Hz (I_L)		
Line Current, amperes I_o	Power Input, watts W_o	Line volts V_L	Line Current, amperes I	Power Input, watts W
<u>109</u>	<u>9000</u>	<u>53.59</u>	<u>806</u>	<u>49,000</u>

Constants

$$\begin{aligned}
 V &= \underline{259.81} \text{ (volts) (per phase)} & x_2 &= \underline{0.13151} \text{ (ohms)} \\
 r_1 &= \underline{0.0036} \text{ (ohms)} & (x_1 + x_2) &= \underline{0.26302} \text{ (ohms)} \\
 r_2 &= \underline{0.01669} \text{ (ohms)} & b_M &= \underline{0.48244} \text{ (mhos)} \\
 r_{fo} &= \underline{19.846} \text{ (ohms)} & g_{fe} &= \underline{0.05039} \text{ (mhos)} \\
 x_1 &= \underline{0.13151} \text{ (ohms)} & W_f &= \underline{1200} \text{ (watts)} \\
 & & W_h &= \underline{7600} \text{ (watts)}
 \end{aligned}$$

$$W_{LL} = \underline{670} * \text{ (watts) at } I_L = \underline{253.56} \text{ (amperes)}$$

*See 4.3.4.4.1 and 4.3.4.4.2.

FREQ = 337
APM = 20,000
SLIP = 220

Summary of Characteristics

Load, percent of rated	0	25	50	75	100	125
Horsepower						
Speed, r/min						
Line Current, amperes						
Efficiency, percent						
Power Factor, percent						

INDUCTION MOTORS AND GENERATORS

Form F-3

APPENDIX A-7

Method F: Solution of Equivalent Circuit

Type Squirrel Cage Induction Motor Serial No. _____ Model No. _____
 Horsepower 185 Voltage 460 Synchronous Speed 2400 Frequency 400 m=Phases 3

Before starting calculations, fill in following items, obtained from previous tests.

$r_1 = 0.01669$ V = phase volts 258.81 $I_t = 253.56$ and $W_{LL} = 690$ WATTS from Form F-2
 also all the items below which are marked with an asterisk.

Assume a value of s corresponding to expected full-load speed for full-load point and proportional values for other loads. For motor operation s is positive, as are all other numeric values below. Numbers in () represent item numbers.

$slip = \frac{220}{2400}$

Item	Description	1	2	3	4	5	6	7	8
1	$s = \text{slip, per unit}$	0.0109							
2	r_1/s	153.08							
* 3	x_1	0.13151							
4	$Z^2 = (2)^2 + (3)^2$	7.3606							
5	$g_1 = (2)/(4)$	0.6485							
* 6	g_{fe}	0.05039							
7	$g = (5) + (6)$	0.6989							
8	$-b_1 = (3)/(4)$	0.05571							
* 9	$-b_M =$	0.48244							
10	$-b = (8) + (9)$	0.538							
11	$Y^2 = (7)^2 + (10)^2$	0.7785							
12	$r_g = (7)/(11)$	0.8985							
* 13	$r_1 = \text{resistance per phase}$	0.0056							
14	$r = (12) + (13)$	0.9041							
15	$x_g = (10)/(11)$	0.69165							
* 16	$x_1 =$	0.13151							
17	$x = (15) + (16)$	0.82316							
18	$Z = \sqrt{(14)^2 + (17)^2}$	1.2227							
19	$I_1 = V/(18)$	212.49							
20	$I_2 = I_1 / \sqrt{(4) \times (11)}$	156.81							
21	watts Input = $m \times (19)^2 \times (14)$	122466							
22	Sec. Input = $m \times (20)^2 \times (2)$	112924							
23	Stator $I^2R = m \times (19)^2 \times (13)$	758.6							
24	Core Loss = $m \times (19)^2 \times (6)/(11)$	877.5							
25	Sec. $I^2R = (1) \times (22)$	1231							
26	Friction and Windage Loss	1200							
27	$W_{LL} = W_{LL} \times [(20)/I_t]^2$	264							
28	Losses = Items (23) through (27)	12229.5							
29	watts Output = (21) - (28)	110238							
30	Eff. (%) = $100 \times [1 - (28)/(21)]$	90.01							
31	PF (%) = $100 \times (14)/(18)$	73.94							
32	hp Output = (29)/746	147.8							
33	Speed = $[1 - (1)] \times \text{Sync. speed}$	2000							
34	Torque = $K_T \times (29)/(33)$	38.82							

For torque in	$K_T =$
lb-ft	7.043 ✓
oz-ft	112.69
newton-meters	9.549

Form F-2
Method F: Induction Motor Characteristics

APPENDIX A-8

Motor Serial No _____ Model No _____
Type _____ Horsepower 185 Voltage 460 Synchronous Speed 2400 Frequency 400 Phases 3
Squirrel Cage
Induction

Summary of Tests

No Load		Impedance Data at <u>50</u> Hz (f_L)		
Line Current, amperes I_0	Power Input, watts W_0	Line volts V_L	Line Current, amperes I	Power Input, watts W
<u>108</u>	<u>12000</u>	<u>53.59</u>	<u>806</u>	<u>49,000</u>

Constants

$$\begin{aligned}
 V &= \underline{273.76} \text{ (volts) (per phase)} & x_1 &= \underline{0.1562} \text{ (ohms)} \\
 r_1 &= \underline{0.0056} \text{ (ohms)} & (x_1 + x_2) &= \underline{0.3124} \text{ (ohms)} \\
 r_2 &= \underline{0.0166} \text{ (ohms)} & b_m &= \underline{74158} \text{ (mhos)} \\
 r_{fe} &= \underline{18.71} \text{ (ohms)} & g_{fe} &= \underline{0.0534} \text{ (mhos)} \\
 x_1 &= \underline{0.1562} \text{ (ohms)} & W_f &= \underline{1200} \text{ (watts)} \\
 & & W_h &= \underline{10600} \text{ (watts)}
 \end{aligned}$$

$$W_{LL}' = \underline{690} * \text{ (watts) at } I_t = \underline{366.4} \text{ (amperes)}$$

*See 4.3.4.4.1 and 4.3.4.4.2.

$$I_t = \sqrt{I_1^2 - I_0^2} = \sqrt{(382)^2 - (108)^2} = \underline{366.4}$$

VALUES AT RATED FREQ = 400Hz
SLIP OF 500
RPM = 23,500

Summary of Characteristics

Load, percent of rated	0	25	50	75	100	125
Horsepower						
Speed, r/min						
Line Current, amperes						
Efficiency, percent						
Power Factor, percent						

Form F-3
Method F: Solution of Equivalent Circuit

APPENDIX A-9

Type Squirrel cage induction Motor Serial No. _____ Model No. _____
 Horsepower 185 Voltage 460 Synchronous Speed 2400 Frequency 400 m=Phases 3

Before starting calculations, fill in following items, obtained from previous tests.

$r_1 = .01664$ V = phase volts 278.76 I_t 366.4 and W_{LL} 690 watts from Form F-2
 also all the items below which are marked with an asterisk.

Assume a value of s corresponding to expected full-load speed for full-load point and proportional values for other loads. For motor operation s is positive, as are all other numeric values below. Numbers in () represent item numbers.

Item	Description	1	2	3	4	5	6	7	8
1	s =slip, per unit	.0208							
2	r_1/s	0.8							
* 3	x_1	0.1562							
4	$Z_1^2 = (2)^2 + (3)^2$	0.6644							
5	$g_1 = (2)/(4)$	1.2041							
* 6	g_{fe}	0.0534							
7	$g = (5) + (6)$	1.2545							
8	$-b_1 = (3)/(4)$	0.2351							
* 9	$-b_M =$	0.4158							
10	$-b = (8) + (9)$	0.6509							
11	$Y^2 = (7)^2 + (10)^2$	1.997							
12	$r_g = (7)/(11)$	0.6281							
* 13	r_1 = resistance per phase	0.0056							
14	$r = (12) + (13)$	0.6337							
15	$x_g = (10)/(11)$	0.3259							
* 16	$x_1 =$	0.1562							
17	$x = (15) + (16)$	0.4821							
18	$Z = \sqrt{(14)^2 + (17)^2}$	0.7963							
19	$I_1 = V/(18)$	343.8							
20	$I_2 = I_1 / \sqrt{(4) \times (11)}$	298.5							
21	watts Input = $m \times (19)^2 \times (14)$	224,707							
22	Sec. Input = $m \times (20)^2 \times (2)$	213,845							
23	Stator $P_R = m \times (19)^2 \times (13)$	1986							
24	Core Loss = $m \times (19)^2 \times (6)/(11)$	9482							
25	Sec. $P_R = (1) \times (22)$	4448							
26	Friction and Windage Loss	1200							
27	$W_{LL} = W_{LL} \times [(20)/I_t]^2$	458							
28	Losses = Items (23) through (27)	17,574							
29	watts Output = (21) - (28)	207,133							
30	Eff. (%) = $100 \times [1 - (28)/(21)]$	92.18							
31	PF (%) = $100 \times (14)/(18)$	79.58							
32	hp Output = (29)/746	277.66							
33	Speed = $[1 - (1)] \times \text{Sync. speed}$	23,500							
34	Torque = $K_T \times (29)/(33)$	62.08							

For torque in	$K_T =$
lbf-ft	7.043
ozf-ft	113.69
newton-meters	9.549

$$\text{Slip, pu.} = \frac{n_s - n}{n_s}$$

4.5 Heat Soak Back Test

Test run numbers 29 to 33 document the heat soak back tests to the motor windings. The motor winding temperatures are sensed by three chromel alumel thermocouples placed within the stator coils during manufacture of the stator coils.

The test run numbers 29 to 33 recorded the heat soak back with the motor cooling water circulating at 14.5 gpm. The circulator was operating at full speed and gas temperature was fully stabilized. The stop button was activated and readings taken. The results are plotted and shown in Figure 4.5-1. It is clear that the motor winding temperatures drop rapidly in the first 20 minutes from an initial full speed and load temperature of 275°F. The highest reading thermocouples dropped in this time span to 190°F and thereafter more gradually to 133°F after 60 minutes.

Also shown in Figure 4.5-1 are the average readings of two thermocouples placed at 3 and 12 o'clock at the pressure vessel dome, mid vessel, vessel flange and vessel cover.

Test run numbers 34 to 42 document the heat soak back to the motor windings as for the previous test, except that the cooling water was turned off.

The test results are shown in Figure 4.5-2. The dotted lines indicate the readings from the water inlet and outlet thermocouples, and can be disregarded for the following reasons. The water outlet from the circulator consisted of a run of approximately 8 feet of 3/4 in. flexible hose run horizontally which joined a vertical plastic pipe 1 1/2 in. in diameter by 4 ft 6 in. long. This same size pipe continued in a horizontal run for approximately 40 feet, and then ran down vertically to a drain.

Soon after the circulator was stopped, the water in the system could be heard boiling, with steam issuing into the outside drain. In order to create a more severe test condition the water in the 4 ft 6 in. of vertical piping was drained. The water inlet and outlet thermocouples therefore were measuring the temperature of any remaining vapor within the water inlet and outlet pipes. Figure 4.5-2 shows that the highest reading motor winding thermocouple increased from 255°F

Fig. 4.5-1 Heat Soak Back to Motor Windings
Test Run Numbers 29 to 33

792341

Fig. 4.5-2 Heat Soak Back to Motor Windings
Test Run Numbers 34 to 42

792342

to a maximum of 270°F after 80 minutes and then very slowly started to fall.

In order to prevent boiling of the water within the pressure vessel in the event of a cooling water failure it is proposed during the follow-on testing to install a 30 to 50 gallon header tank on the outlet of the cooling water system. An automatic valve connecting the header tank to the water inlet in the event of water supply pressure failure will be installed thereby creating a thermo syphon system.

4.6 Post Test Inspection

Summary

Inspection of the circulator after acceptance testing showed it to be in excellent condition with two minor exceptions:

- Outgassing from the motor windings as evidenced by plating out on the cold surfaces of the motor cavity.
- Galling of the sliding hydraulic seal rings at the compressor inlet.

Neither of these two occurrences appeared to affect the operation of the circulator in any deleterious manner.

4.6.1 Detailed Inspection

4.6.1.1 Rotor and Journal Bearings. The fan-end journal bearing is in excellent condition. There is a narrow (approximately 1/16 in. wide) highly polished band around the periphery at mid length, opposite the pivot pin location on the tilting pads. At both ends of the journal bearing, but off the chrome oxide surface, there is a heavy coat of a damp appearing foreign substance with the consistency of a black dust. This coating of foreign matter on the inboard end extends up onto the larger diameter of the rotor.

The compressor-end journal bearing is also in excellent condition. This also has a narrow polished band (approximately 1/8 in. wide) around the periphery of the journal bearing at mid length and opposite the pivot pin location on the tilting pads. This end does not have the same damp appearance as the opposite end; only a light coating of black dust exists. The cooling holes drilled into this end show a coating of dark dust and show a directional pattern around the outlet holes.

4.6.1.2 Compressor-End Tilting Pad Bearings. Viewed from the impeller, the top pad has minor scratches in addition to a small polished spot opposite the pivot. This area extends both ways circumferentially as a 1/8 in. wide mark for over half the radius. The lower right pad also shows some slight scratches and polish marks and covers only the trailing half of the bearing surface. The lower left pad also shows a small polished area opposite the pivot location

1/8 in. wide x 3/8 in. long extending on either side, again only on the trailing half of the bearing. The capacitance probes and leads appeared to be in good condition.

4.6.1.3 Fan-End Tilting Pad Bearings. Looking from the fan, the top pad is unmarked except for a slight polished spot opposite the pivot. The lower right pad shows some slight scratch marks on the trailing half of the bearing but only on the outboard half. This pad also shows a polished area opposite the pivot - approximately 1/16 in. x 3/16 in. long. The lower left pad shows scratches in the same location as in the previous pad only this is a little more pronounced and covers three-quarters of the width of the trailing half of the bearing. The capacitance probes and speed pickups appeared to be in good condition. The defective capacitance probe reported in the testing was traced to a short circuit in the Microdot connector which has now been replaced.

The tilting pad bearing pivots show a narrow polished band across the ball about 1/8 in. wide x 3/8 in. long with a 1/8 in. untouched spot in the center of the band length, which would appear to indicate that there is a flat spot on the end of the pivot ball. The pivot sockets on the tilting pads show a corresponding polished area.

4.6.1.4 Impeller. There is normal heat discoloration on the inlet side. All three labyrinth seal surfaces appear to be untouched and in original condition without any signs of touching. The inboard side of the impeller shows a fairly uniform, heavy coating of black dust.

4.6.1.5 Thrust Runner/Fan. This is unmarked and in excellent condition. The fan side shows dust discoloration.

4.6.1.6 Thrust Bearing (Static). This also is in excellent condition. The only visible marks are apparent in the center (uncoated) aluminum hub where the two capacitance thrust film probes are located. The marks are those which were not completely removed and were generated by a rub which occurred during the assembly stage. The original drawing did not allow for a slight relief in this area which has now been incorporated in the final manufacturing drawing.

4.6.1.7 Reverse Thrust Bearing (Static). The reverse thrust or "bumper" bearing shows slight polish marks around the inboard edge. These four areas are about 1/8 in. to 3/16 in. wide and extend 3/4 in. to 1 in. around the inner circumference. This polish probably occurred during assembly when the rotor was barred round by hand to set and check clearances. The thermo-couple lead wire insulation is frayed through in two places. The lead routing will be changed to eliminate this upon reassembly. The corresponding rotating reverse thrust bearing on the rotor shaft is in excellent condition with slight polish marks around the inner circumference.

4.6.1.8 Heat Insulator. The heat insulating assembly is part of the compressor backplate and was not disassembled. The ceramic insulator which is a captive part of this assembly shows a hairline crack at one point. This is of no concern as it is merely a stress relieving crack. A saw cut could be added to the design drawing for cosmetic purposes but is not recommended.

4.6.1.9 Labyrinth Seals. Both rotating and stationary seals show no signs of rubbing and are in excellent condition.

4.6.1.10 Backplate. The side on which the depressurization reed valves are located is heat discolored which is quite normal.

4.6.1.11 Reed Valve Assembly. Heat discolored as would be expected together with a light coating of dust.

4.6.1.12 Compressor Inlet Cone. The cone is heat discolored as would be expected. There are signs of severe galling between the two hydraulic seal rings and the inlet cone. The mechanism by which this occurred is not clear. It is recommended, however, that the seal ring groove depth be increased by 0.010 inch after which the seal rings can be either silver plated or impregnated with molybdenum disulfide. This is a hot chemical process which disperses MoS_2 into the metal enabling it to withstand high temperatures up to a red heat.

4.6.1.13 Diffuser. This is unmarked except for inherent heat discoloration.

4.6.1.14 Motor Windings and Related Subassembly. The motor stator windings appeared to be quite normal. The motor lead wires however showed some discoloration at the connector end. The copper stands were still quite flexible as was the insulation. It is recommended that a clamp type connector, such as a Burndy QIKLUG type QDA, be used in the future in place of the present screw connector particularly if the limit of the motor power is to be ascertained. During these high power tests, it is recommended that thermocouples be placed at the connector end of the motor lead wire and at one position where the motor lead wire is attached to the motor stator windings.

However, inside the cavity, adjacent to the heat exchanger at the compressor end and located at the bottom, was a coating of what appears to be a tacky varnish deposit.

The fan end of the motor housing i.e., the cold end, shows no signs of a tacky varnish; only a light coating of dust is present.

Both cooling water inlet and outlet tubes have a coating of varnish, mostly on the water inlet side which is the coolest.

It would appear from these observations that some outgassing from the motor windings has taken place and plated itself on the cold parts of the motor cavity. As the motor winding insulation was vacuum baked, this should not have occurred; some revision and/or closer inspection of this operation in the future is recommended.

4.6.2 Post Test Dimensional Check

After completion of the acceptance test, critical components such as bearings, rotor, impeller seals, etc. were measured, and these measurements compared to the dimensions recorded during initial assembly.

Three dimensional comparisons are tabulated and attached to this section. No significant changes in any critical dimensions were observed. Small differences are due to inherent differences in the measuring instruments used and in the skill of the cognizant inspector.

4.7 Dimensional Inspection

10 April 1979

UNION CARBIDE CIRCULATOR

Dimensions Before and After
152-Hour Run with 59 Starts and Stops

Backplate Seal Assy. Dwg. 316D72

	<u>Before</u>	<u>After</u>
Seal Ring 316B73 I.D.	2.090	2.091
Seal Ring 316B19P1	2.751	2.750
Seal Ring 316B19P2	6.281	6.279
Seal Ring 316B19P3	5.001	5.000
Impeller Assembly	316E16	No Change
Labyrinth Seal	2.740	2.740
Labyrinth Seal	6.2654	6.2655
Labyrinth Seal	4.9835	4.984
Impeller O.D.	7.3040	7.304
Impeller Pilot O.D.	1.0641	1.0643
Impeller Pilot I.D.	1.0625	1.0628
Shaft Seal (316D43)	2.065	2.065
Fan - Flatness	.0001	.0001/.0002
Pilot O.D.	.6258	.6250
Thrust Brg. - Flatness	.00005	.0001/.00015

10 APRIL 1979

TILTING PADS

2A

4-10-79

6-1-78

A	4.1254	4.1253
B	4.1254	4.1253
C	4.1254	4.1253

2B

A	4.1254	4.1253
B	4.1254	4.1253
C	4.1254	4.1253

2C

A	4.1254	4.1253
B	4.1254	4.1253
C	4.1254	4.1253

1A

A	4.1254	4.1254
B	4.1254	4.1254
C	4.1254	4.1254

1B

A	4.1254	4.1254
B	4.1254	4.1254
C	4.1253	4.1254

A	4.1254	4.1254
B	4.1254	4.1254
C	4.1254	4.1254

Tilting
Pad

10 APRIL 1979

ROTOR DIMENSIONS

4.8 Zygo Inspection

A zygo black light inspection of the impeller showed an indication at the base of one impeller vane. It extended almost right across the vane thickness and about 3/16 in. along the vane in the direction of gas flow. See Figure 4.8-1.

A microscopic examination showed that a fold in the material generated by the action of the milling cutter caused the zygo indication of a possible defect. The suspected area was polished out and rezygloed. This completely removed the indication.

Fig. 4.8-1 Location of Zygo Indication at Base of Impeller Vane 792343

4.9 Photographic Record of Post Test Component Parts

Fig. 4.9-1 Motor Rotor and Journal Bearings

Fig. 4.9-2 Compressor-End Tilting Pad Bearings
Loaded Side

Fig. 4.9-3 Compressor-End Tilting Pad Bearings
Pivot Side

4-60

Fig. 4.9-4 Fan-End Tilting Pad Bearings
Loaded Side

Fig. 4.9-5 Fan-End Tilting Pad Bearings
Pivot Side

Fig. 4.9-6 Compressor Impeller
Gas Inlet Side

Fig. 4.9-7 Compressor Impeller - Rear View
Showing: Labyrinth Seals and Balance Piston

4-64

Fig. 4.9-8 Thrust Bearing Surface Rotating Member

Fig. 4.9-9 Thrust Runner - Cooling Fan Side

Fig. 4.9-10 Thrust Bearing Assembly - Loaded Side
Static Member Showing Gimbal Ring;
Pivots and Three Capacitance Probes

Fig. 4.9-11 Thrust Bearing Assembly - Unloaded Side
Static Member Showing Gimbal Ring;
Pivots and Three Capacitance Probes and One
Thermocouple

Fig. 4.9-12 Fan-End Bearing Housing Assembly
Showing: Tilting Pad Pivots; Top
Pad Flexure Spring; Two Speed
Pickups; and Two Capacitance Probes

Fig. 4.9-13 Fan-End Bearing Housing
Showing: Cooling Gas Deflector

Fig. 4.9-14 Compressor-End Bearing Housing Assembly
Showing: Tilting Pad Pivots; Top Pad
Flexure Spring and Two Capacitance Probes

Fig. 4.9-15 Vaned Diffuser

Fig. 4.9-16 Compressor Backplate/Heat Shield Assembly
Showing: Labyrinth Seals and Three Reed
Valves (one removed)

Fig. 4.9-17 Compressor Backplate/Heat Shield Assembly - Motor Side

Fig. 4.9-18 Reed Valve

Fig. 4.9-19 Motor Stator and Heat Exchanger Assembly - Fan End

Fig. 4.9-20 Motor Stator and Heat Exchanger Assembly - Compressor End

Fig. 4.9-21 Compressor Inlet Assembly - Outer Side
Showing: Balance Piston Bleed Gas Holes
and Labyrinth Seal

Fig. 4.9-22 Compressor Inlet Assembly - Impeller Side
Showing: Labyrinth Seal and Balance Piston
Bleed Holes

Fig. 4.9-23 Compressor Inlet Cone
Showing: Galled and Stuck Seal Rings

Fig. 4.9-24 Pressure Vessel Cover
Showing: Power Feed Through; Capacitance
Probe Feed Through and Thermo-
couple Feed Through

Fig. 4.9-25 Pressure Vessel Cavity

APPENDIX 1

SUMMARY AND INDEX OF TEST RUN NUMBERS

SUMMARY AND INDEX OF TEST RUN NUMBERS - February 26 through March 26

(See Appendix 6 for the test data sheets)

<u>Run Nos.</u>	<u>Description</u>
1 - 15	Debugging tests using Nitrogen.
16	Rotor bearing orbits and thrust film thicknesses. Photographic records were taken of traces. Speed = 21,140 rpm Discharge Pressure = 1300 psig Discharge Temperature 647°F Loading valve fully open
17	Run on second critical speed. Unit speed varied 1000 rpm above and below calculated critical speed of 10,616 rpm. No sign of any instability was noticed. Photographic records were taken of traces. Speed = 10,608 rpm - held for 10 minutes Discharge pressure = 1234 psig Discharge temperature = 583°F Loading valve fully open
18	Run on first critical speed. Unit speed varied 1000 rpm above and below calculated critical speed of 8317. No sign of any instability was noticed. Photographic records were taken of traces. Speed = 8316 rpm - held for 10 minutes Discharge pressure = 1190.5 psig Discharge Temperature = 554°F Loading valve fully open
19	Surge point at 21,148 rpm (minimum flow)
20	Rotor bearing orbits and thrust film thicknesses. Photographic records were taken of traces. Speed = 21,148 rpm Discharge pressure = 1303 psig Discharge temperature = 644°F Loading valve set near surge point (minimum flow)
21	Run on second critical speed. Unit speed varied 1000 rpm above and below calculated critical speed of 10,616 rpm. No sign of any instability was noticed. Photographic records were taken of traces. Speed = 10,608 rpm - held for 10 minutes Discharge pressure = 1245 psig Discharge temperature = 600°F Loading valve set near surge point (minimum flow)

- 22 Run on first critical speed. Unit speed varied 1000 rpm above and below calculated critical speed of 8317rpm. No sign of instability was noticed. Photographic records were taken of traces.
Speed = 8316 rpm - held for 10 minutes
Discharge pressure = 1210 psig
Discharge temperature = 572°F
Loading valve set near surge point (minimum flow)
- 23 Rotor bearing orbits and thrust film thicknesses. Photographic records were taken of traces.
Speed = 20,185 rpm
Discharge pressure = 1501 psig
Discharge temperature = 653.4°F
Loading valve fully open
- 24 Rotor bearing orbits and thrust film thicknesses. Photographic records were taken of traces.
Speed = 20,219 rpm
Discharge pressure = 1489.6 psig
Discharge temperature = 655.6
Loading valve set near surge point (minimum flow)
- 25 Run on second critical speed. Unit speed varied 1000 rpm above and below calculated critical speed of 10,616 rpm. No sign of any instability was noticed. Photographic records were taken of traces.
Speed = 10,616 rpm - held for 10 minutes
Discharge pressure = 1453.2 psig
Discharge temperature = 613°F
Loading valve set near surge point
- 26 Run on first critical speed. Unit speed varied 1000 rpm above and below calculated critical speed of 8317 rpm. No sign of any instability was noticed. Photographic records were taken of traces.
Speed = 8316 rpm - held for 10 minutes
Discharge pressure = 1378.6
Discharge temperature = 578°F
Loading valve set near surge point (minimum flow)
- 27 Run on first critical speed. Unit speed varied 1000 rpm above and below calculated critical speed of 8317 rpm. No sign of any instability was noticed. Photographic records were taken of traces.
Speed = 8310 rpm - held for 10 minutes
Discharge pressure = 1366.1
Discharge temperature = 554.9°F
Loading valve fully open

- 28 Run on second critical speed. Unit speed varied 1000 rpm above and below calculated critical speed of 10,616 rpm. No sign of any instability was noticed. Photographic records were taken of traces.
Speed = 10,611 rpm
Discharge pressure = 1344.1
Discharge temperature = 536°F
Loading valve fully open
- 29 - 33 Heat soak back to motor windings. Zero unit speed. Cooling water on. Temperature dropped from 269.3 to 134.4°F in 1 hour. No Peaking.
- 34 - 42 Heat soak back to motor windings. Zero unit speed. Cooling water off. Temperature at start 249.4°F peaked at 270.2 after 1 hour 50 minutes.
- 43 One hour test run - design speed
Speed = 23,503 rpm
Discharge pressure = 17.8 psig
Discharge temperature = 612.7°F
Loading valve fully open
- 44 One hour test run - one half design speed
Speed = 11,759 rpm
Discharge pressure = 16.9 psig
Discharge temperature = 558.7°F
Loading valve fully open
- 45 One hour test run - 3000 rpm
Discharge pressure = 14.2 psig
Discharge temperature = 501.3°F
Loading valve fully open
- Note: See test runs nos. 86 to 88 for discharge pressure of zero psig nominal.
- 46 Coast down from 3000 rpm. Activated stop button on power panel at 16.11 hours. Rotor touched down at 16.20 hours at 300 rpm. 9 minutes.
- 47 - 50 Compressor characteristic at 1300 psig; 650°F and 0.9 of design speed. Flow varied from surge point to maximum flow determined by fully open loading valve (i.e. 1% above design flow). 0.9 design speed = 21,150 rpm
- 51 - 54 Compressor characteristics at 1300 psig; 650°F and 0.6 of design speed. Flow varied from surge point to maximum flow determined by fully open loading valve.
0.6 of design speed = 14,100 rpm

- 55 - 58 Compressor characteristics at 1300 psig; 650°F and 0.3 of design speed. Flow varied from surge point to maximum flow determined by fully open loading valve.
0.3 of design speed = 7050 rpm
- 59 - 62 Compressor characteristic at 1300 psig; 650°F and 0.1276 of design speed. Flow varied from surge point to maximum flow determined by fully open loading valve.
0.1276 of design speed = 3000 rpm
- 63 Coast down test from 22,450 rpm: 1300 psig and 650°F. Activated by stop button on power supply panel. Time = 102 seconds to 500 rpm touchdown speed. See strip chart record with corresponding run number.
- 64 - 67 Compressor characteristics at 1500 psig; 650°F and 0.9 of design speed. Flow varied from surge point to maximum flow determined by fully open loading valve. (i.e., 1% above design flow) 0.9 of design speed = 21,150 rpm
- 68 - 71 Compressor characteristic at 1500 psig; 650°F and 0.6 of design speed. Flow varied from surge point to maximum flow determined by fully open loading valve.
0.6 of design speed = 14,100 rpm
- 72 - 74 Compressor characteristic at 1500 psig; 650°F and 0.3 of design speed. Flow varied from surge point to maximum flow determined by fully open loading valve.
0.3 of design speed = 7050 rpm
- 75 - 78 Compressor characteristic at 1500 psig; 650°F and 0.1276 of design speed. Flow varied from surge point to maximum flow determined by fully open loading valve.
0.1276 of design speed = 3000 rpm.
- 79 Coast down test from 22,000 rpm; 1500 psig and 650°F activated by pressing stop button on power supply panel. Time = 97 seconds to 435 rpm touchdown speed. See strip chart record with corresponding run number.
- 80 Static depressurization (zero rpm) from 1500 psi; 650°F. See strip chart record and X - Y chart recorder traces with corresponding run numbers maximum recorded ΔP across motor cavity 3.5 psi.
- 81 Dynamic depressurization from 21,000 rpm, 650°F discharge temperature and 600 psig, pressure. See strip chart record and X - Y chart recorder traces with corresponding run numbers. Maximum recorded ΔP across motor cavity 13.1 psi.

- 82 Dynamic depressurization from 21,000 rpm; 650°F discharge temperature and 800 psig pressure. See strip chart record and X - Y chart recorder traces with corresponding run numbers. Maximum recorded ΔP across motor cavity 16.4 psi.
- 83 Dynamic depressurization from 21,000 rpm; 650°F discharge temperature and 1500 psig pressure. See strip chart record and X - Y chart recorder traces with corresponding run numbers. Maximum recorded ΔP across motor cavity 23.5 psi.
- 84 Dynamic depressurization from 21,000 rpm; 650°F discharge temperature and 1500 psig pressure. See strip chart record and X - Y chart recorder traces with corresponding run numbers. Maximum recorded ΔP across motor cavity 24.1 psi.
- 85 Test no. 85 was repeat of test no. 84 except that the minimum thrust bearing film thicknesses were recorded on the 8-channel recorder.
- 86 One hour test run - operating speed (90% design)
Speed = 21,148 rpm
Discharge pressure = 2 psig
Discharge temperature = 630°F
Loading valve fully open
- 87 One hour test run - one half design speed (50% design)
Speed = 11,750 rpm
Discharge pressure = 1.05 psig
Discharge temperature = 567°F
Loading valve fully open
- 88 - 89 One hour test run - 3000 rpm
Discharge pressure = 1.8 psig
Discharge temperature = 515°F
- 90 - 93 Test run to establish motor stator temperature equilibrium at 750°F discharge temperature; 21,150 rpm; 1326 psig discharge pressure. Motor stator winding temperature stabilized at 257.8°F after 1.5 hours.
- 94 - 98 Test run to establish motor stator temperature equilibrium at 750°F discharge temperature; 21,150 rpm; 1543 psig discharge pressure. Motor stator winding temperature stabilized at 273.4°F after 2 hours.
- 99 - 100 Test run to attempt to obtain lines of constant motor power. It was not possible to maintain constant temperatures and the test was discontinued. Data will be obtained from compressor characteristic tests by interpolation.

The 100-hour test run includes the run numbers 101-202.

- 101 Speed = 21,150 rpm
 Discharge pressure = 808 psig
 Discharge temperature = 252.5°F
 ΔP across circulator = 28.2 psig
 Loading valve fully open
- 102 Speed = 21,155 rpm
 Discharge pressure = 1043 psig
 Discharge temperature = 516°F
 ΔP across circulator = 26.5 psig
- 103 - 114 Speed = 21,151 rpm $\pm$ 2
 Discharge pressure = 1330 - 1314 psig
 Discharge temperature = 655.4°F - 649.1°F
 ΔP across circulator = 28.7 - 28.2 psig
 Load valve fully open
 First Stop and Start at 17.05 hours
 Total running time 10 h 20 min
- 115 - 125 Speed = 21,150 rpm $\pm$ 2
 Discharge pressure = 1330 - 1317 psig
 Discharge temperature = 650.4 - 640°F
 ΔP across circulator = 28.7 - 28.5 psig
 Load valve fully open
 Second Stop and Start at 08.07 hours
 Total running time 22 h 20 min
- 126 - 137 Speed = 21,500 rpm $\pm$ 4
 Discharge pressure = 1336 - 1327 psig
 Discharge Temperature = 653.3 - 650°F
 ΔP across circulator 29.1 - 28.7 psig
 Load valve fully open
 Total running time 34 h 20 min
 First helium sample taken at 13.30 hours
 Third Stop and Start at 16.20 hours
- 138 - 149 Speed = 21,150 rpm $\pm$ 3
 Discharge pressure = 1330 - 1308 psig
 Discharge temperature = 651.7 - 648.6°F
 ΔP across circulator = 28.8 - 28.3 psig
 Fourth Stop and Start at 08.05 hours
 Total running time 46 h 20 min
- 150 - 161 Speed = 21,150 rpm $\pm$ 3
 Discharge pressure = 1334 - 1320 psig
 Discharge temperature = 652.1 - 650.3°F
 ΔP across circulator = 29.0 - 28.7 psig
 Second helium sample taken at 13.10 hours
 Fifth Stop and Start at 16.43 hours
 Total running time 58 h 20 min

162 - 172 Speed = 21,152 rpm $\pm$ 2
 Discharge pressure = 1332 - 1317 psig
 Discharge temperature = 652.9 - 648.6°F
 Δ P across circulator = 29.0 - 28.6 psig
 Sixth Stop and Start at 08.05 hours
 Total running time 70 h 20 min

173 - 184 Speed = 21,150 rpm $\pm$ 3
 Discharge pressure = 1334 - 1352 psig
 Discharge temperature = 652.3 - 650.2°F
 Δ P across circulator = 28.9 - 28.75 psig
 Third helium sample taken at 13.10 hours
 Seventh Stop and Start at 16.20 hours
 Total running time 82 h 20 min

185 - 196 Speed = 21,152 rpm
 Discharge pressure = 1331 - 1327 psig
 Discharge temperature = 652.1 - 649.0°F
 Δ P across circulator = 28.8 - 28.2 psig
 Eighth Stop and Start at 08.20 hours
 Total running time to date 94 h 20 min

197 - 202 Speed = 21,150 rpm $\pm$ 2
 Discharge pressure = 1335 - 1327 psig
 Discharge temperature = 652.6 - 650.3°F
 Δ P across circulator = 28.9 - 28.7 psig
 Ninth Stop and Start at 10.00 hours
 Fourth helium sample taken at 13.05 hours
 Tenth Stop and Start taken at 13.20 hours
 End of 100 hour test run at 14.00 hours

203 Test to establish motor winding temperature at
 1.0 psig helium gas inlet pressure
 Speed = 23,500 rpm
 Discharge pressure = 2.0 psig
 Discharge temperature = 650.3°F
 Δ P across circulator = 0.5 psig

204 Coast down from 23,500 rpm to 402 rpm
 Data taken (run 203) just before the button
 was pressed to coast down
 Coast down time 16 minutes 7 seconds

NOTE: It was not possible to maintain specified temperatures of 650°F and pressures of 1300 psi in all cases due to the low energy input into the gas stream at low circulator speeds.

In addition, the 3.7 kW heaters are insufficient to make up the deficiency.

APPENDIX 2

TRACES OF SHAFT AND BEARING STABILITY TEST RUNS

Run No. 16

Zero →

↑
Zero

Compressor-End Journal Bearing Orbit

Speed = 21,140 rpm
Pressure = 1300 psig
Temperature = 647°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 16

Zero →

↑
Zero

Fan-End Journal Bearing Orbit

Speed = 21,140 rpm
Pressure = 1300 psig
Temperature = 647°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 16

Speed = 21,140 rpm
Pressure = 1300 psig
Temperature = 647°F
Scale = 0.00025"/Div.
Two Traces @ 90°
Maximum Flow

Inboard Thrust Bearing Film Thickness

Run No. 16

Speed = 21,140 rpm
Pressure 1300 psig
Temperature = 647°F
Scale = 0.00025"/Div.
One Trace
Maximum Flow

Outboard Thrust Bearing Film Thickness

Run No. 17

Zero → —

↑
Zero

Compressor-End Journal Bearing Orbit

Second Critical Speed
Speed = 10,608 rpm
Pressure = 1234 psig
Temperature = 583°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 17

Zero → —

↑
Zero

Fan-End Journal Bearing Orbit
(Horizontal Trace Only Working)

Second Critical Speed
Speed = 10,608 rpm
Pressure = 1234 psig
Temperature = 583°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 17

Zero →

Inboard Thrust Bearing Film Thickness

Second Critical Speed
Speed = 10,608 rpm
Pressure = 1234 psig
Temperature = 583°F
Scale = 0.00025"/Div.
Two Traces @ 90°
Maximum Flow

Run No. 17

Zero →

Outboard Thrust Bearing Film Thickness

Second Critical Speed
Speed = 10,608 rpm
Pressure = 1234 psig
Temperature = 583°F
Scale = 0.00025"/Div.
One Trace
Maximum Flow

Run No. 18

Compressor-End Journal Bearing Orbit

First Critical Speed
Speed = 8316 rpm
Pressure = 1190.5 psig
Temperature = 554°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 18

Fan-End Journal Bearing Orbit
(Both Horizontal & Vertical Traces Defective)

First Critical Speed
Speed = 8316 rpm
Pressure = 1190.5 psig
Temperature = 554°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 18

Inboard Thrust Bearing Film Thickness

First Critical Speed
Speed = 8316 rpm
Pressure = 1190.5 psig
Temperature = 554°F
Scale = 0.00025"/Div.
Two Traces @ 90°
Maximum Flow

Run No. 18

Outboard Thrust Bearing Film Thickness

First Critical Speed
Speed = 8316 rpm
Pressure = 1190.5 psig
Temperature = 554°F
Scale = 0.00025"/Div.
One Trace
Maximum Flow

Run No. 20

Speed = 21,148 rpm
Pressure = 1303 psig
Temperature = 644°F
Scale = 0.00025"/Div.
Surge Point Flow

↑
Zero

Compressor-End Journal Bearing Orbit

Run No. 20

Speed = 21,148 rpm
Pressure = 1303 psig
Temperature = 644°F
Scale = 0.00025"/Div.
Surge Point Flow

↑
Zero

Fan-End Journal Bearing Orbit
(Both Horizontal & Vertical Traces Defective)

Run No. 20

Speed = 21,148 rpm
Pressure = 1303 psig
Temperature = 644°F
Scale = 0.00025"/Div.
Two Traces @ 90°
Surge Point Flow

Inboard Thrust Bearing Film Thickness

Run No. 20

Speed = 21,148 rpm
Pressure = 1303 psig
Temperature = 644°F
Scale = 0.00025"/Div.
One Trace
Surge Point Flow

Outboard Thrust Bearing Film Thickness

Run No. 21

Compressor - End Journal Bearing Orbit

Second Critical Speed
Speed = 10,616 rpm
Pressure = 1245 psig
Temperature = 600°F
Scale = 0.00025"/Div.
Surge Point Flow

Run No. 21

Fan-End Journal Bearing Orbit
(Horizontal Trace Only Working)

A2-10

Second Critical Speed
Speed = 10,616 rpm
Pressure = 1245 psig
Temperature = 600°F
Scale = 0.00025"/Div.
Surge Point Flow

Run No. 21

Second Critical Speed
Speed = 10,616 rpm
Pressure = 1245 psig
Temperature = 600°F
Scale = 0.00025"/Div.
Two Traces @ 90°
Surge Point Flow

Inboard Thrust Bearing Film Thickness

Run No. 21

Second Critical Speed
Speed = 10,616 rpm
Pressure = 1245 psig
Temperature = 600°F
Scale = 0.00025"/Div.
One Trace
Surge Point Flow

Outboard Thrust Bearing Film Thickness

Run No. 22

Compressor-End Journal Bearing Orbit

First Critical Speed
Speed = 8316 rpm
Pressure = 1210 psig
Temperature = 572°F
Scale = 0.00025"/Div.
Surge Point Flow

Run No. 22

Fan-End Journal Bearing Orbit
(Horizontal Trace Only Working)

First Critical Speed
Speed = 8316 rpm
Pressure = 1210 psig
Temperature = 572°F
Scale = 0.00025"/Div.
Surge Point Flow

Run No. 22

First Critical Speed
Speed = 8316 rpm
Pressure = 1210 psig
Temperature = 572°F
Scale = 0.00025"/Div.
Two Traces @ 90°
Surge Point

Inboard Thrust Bearing Film Thickness

Run No. 22

First Critical Speed
Speed = 8316 rpm
Pressure = 1210 psig
Temperature = 572°F
Scale = 0.00025"/Div.
One Trace
Surge Point Flow

Outboard Thrust Bearing Film Thickness

A2-13

Run No. 23

Zero →

↑
Zero

Compressor-End Journal Bearing Orbit

Speed = 20,185 rpm
Pressure = 1501 psig
Temperature = 653.4°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 23

Zero →

↑
Zero

Fan-End Journal Bearing Orbit
(Horizontal Trace Only Working)
A2-14

Speed = 20,185 rpm
Pressure = 1501 psig
Temperature = 653.4°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 23

Zero → -

Speed = 20,185 rpm
Pressure = 1501 psig
Temperature = 653.4°F
Two Traces @ 90°
Scale = 0.00025"/Div.
Maximum Flow

Inboard Thrust Bearing Film Thickness

Run No. 23

Zero → -

Speed = 20,185 rpm
Pressure = 1501 psig
Temperature = 653.4°F
One Trace
Scale = 0.00025"/Div.
Maximum Flow

Outboard Thrust Bearing Film Thickness

Run No. 24

Speed = 20,219 rpm
Pressure = 1489.6 psig
Temperature = 655.6°F
Scale = 0.00025"/Div.
Surge Point Flow

↑
Zero

Compressor-End Journal Bearing Orbit

Run No. 24

Speed = 20,219 rpm
Pressure = 1489.6 psig
Temperature = 655.6°F
Scale = 0.00025"/Div.
Surge Point Flow

↑
Zero

Fan-End Journal Bearing Orbit
(Horizontal Trace Only Working)

Run No. 24

Speed = 20,219 rpm
Pressure = 1489.6 psig
Temperature = 655.6°F
Two Traces @ 90°
Scale = 0.00025"/Div.
Surge Point Flow

Inboard Thrust Bearing Film Thickness

Run No. 24

Speed = 20,219 rpm
Pressure = 1489.6 psig
Temperature = 655.6°F
One Trace
Scale = 0.00025"/Div.
Surge Point Flow

Outboard Thrust Bearing Film Thickness

Run No. 25

Zero → -

↑
Zero

Compressor-End Journal Bearing Orbit

Second Critical Speed
Speed = 10,616 rpm
Pressure = 1453.2 psig
Temperature = 613°F
Scale = 0.00025"/Div.
Surge Point Flow

Run No. 25

Zero → -

↑
Zero

Fan-End Journal Bearing Orbit
(Horizontal Trace Only Working)

Second Critical Speed
Speed = 10,616 rpm
Pressure = 1453.2 psig
Temperature = 613°F
Scale = 0.00025"/Div.
Surge Point Flow

Run No. 25

Inboard Thrust Bearing Film Thickness

Second Critical Speed
Speed = 1016 rpm
Pressure = 1453.2 psig
Temperature = 613°F
Two Traces @ 90°
Scale = 0.00025"/Div.
Surge Point Flow

Run No. 25

Outboard Thrust Bearing Film Thickness

Second Critical Speed
Speed = 1016 rpm
Pressure = 1453.2 psig
Temperature = 613°F
One Trace
Scale = 0.00025"/Div.
Surge Point Flow

Run No. 26

Zero →

↑
Zero

Compressor-End Journal Bearing Orbit

First Critical Speed
Speed = 8316 rpm
Pressure = 1378.6 rpm
Temperature = 578°F
Scale = 0.00025"/Div.
Surge Point Flow

Run No. 26

Zero →

↑
Zero

Fan-End Journal Bearing Orbit
(Horizontal Trace Only Working)

First Critical Speed
Speed = 8316 rpm
Pressure = 1378.6 psig
Temperature = 578°F
Scale = 0.00025"/Div.
Surge Point Flow

Run No. 26

First Critical Speed
Speed = 8316 rpm
Pressure = 1378.6 psig
Temperature = 578°F
Two Traces @ 90°
Scale = 0.00025"/Div.
Surge Point Flow

Inboard Thrust Bearing Film Thickness

Run No. 26

First Critical Speed
Speed = 8316 rpm
Pressure = 1378.6 psig
Temperature = 578°F
One Trace
Scale = 0.00025"/Div.
Surge Point Flow

Outboard Thrust Bearing Film Thickness

Run No. 27

Zero → —

↑
Zero

Compressor-End Journal Bearing Orbit

First Critical Speed
Speed = 8310 rpm
Pressure = 1366.1 psig
Temperature = 554.9°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 27

Zero → —

↑
Zero

Fan-End Journal Bearing Orbit
(Horizontal Trace Only Working)

First Critical Speed
Speed = 8310 rpm
Pressure = 1366.1 psig
Temperature = 554.9°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 27

First Critical Speed
Speed = 8310 rpm
Pressure = 1366.1 psig
Temperature = 554.9°F
Two Traces @ 90°
Scale = 0.00025"/Div.
Maximum Flow

Inboard Thrust Bearing Film Thickness

First Critical Speed
Speed = 8310 rpm
Pressure = 1366.1 psig
Temperature = 554.9°F
One Trace
Scale = 0.00025"/Div.
Maximum Flow

Outboard Thrust Bearing Film Thickness

Run No. 28

Compressor-End Journal Bearing Orbit

Second Critical Speed
Speed = 10,611 rpm
Pressure = 1344.1 psig
Temperature = 536°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 28

Fan-End Journal Bearing Orbit
(Horizontal Trace Only Working)

Second Critical Speed
Speed = 10,611 rpm
Pressure = 1344.1 psig
Temperature = 536°F
Scale = 0.00025"/Div.
Maximum Flow

Run No. 28

Zero → —

Second Critical Speed
Speed = 10,611 rpm
Pressure = 1344.1 psig
Temperature = 536.1 °F
Two Traces @ 90°
Scale = 0.00025"/Div.
Maximum Flow

Inboard Thrust Bearing Film Thickness

Run No. 28

Zero → —

Second Critical Speed
Speed = 10,611 rpm
Pressure = 1344.1 psig
Temperature = 536.1 °F
One Trace
Scale = 0.00025"/Div.
Maximum Flow

Outboard Thrust Bearing Film Thickness

APPENDIX 3

COMPUTER ANALYSIS OF TEST DATA
1300 psig AND 650°F
COMPRESSOR CHARACTERISTIC

```

      PROGRAM DEB(INPUT,OUTPUT,TAPES=INPUT,TAPE6=OUTPUT)
1     READ(5,10) IRN,TIME,RPM
      IF (IRN.EQ.0) STCP
10    FORMAT(15,2F10.5)
      READ(5,15) PPOR1,PPOR2,TTOR1,TTOR2,TTOR3,TTOR4
15    FORMAT(6F10.5)
      POR=(PPOR1+PPOR2)/2.*14.7
      TOR=(TTOR1+TTOR2+TTOR3+TTOR4)/4.*460.
      RDO=.373*POR/TOR
      READ(5,20) PPC1,PPC2,PPC3,PPC4
20    FORMAT(4F10.5)
      PCI=(PPC1+PPC2+PPC3+PPC4)/4.*14.7
      READ(5,25) TTC1,TTC2,TTC3,TTC4
25    FORMAT(4F10.5)
      TCI=(TTC1+TTC2+TTC3+TTC4)/4.*460.
      RDCI=.373*PCI/TCI
      READ(5,30) DDP1,DDP2,DDP3,DDP4
30    FORMAT(4F10.5)
      DPC=(DDP1+DDP2+DDP3+DDP4)/4.
      PCO=DPC+PCI
      PM=(PCO+PCI)/2.
      READ(5,35) TTC01,TTC02,TTC03,TTC04
35    FORMAT(4F10.5)
      TCO=(TTC01+TTC02+TTC03+TTC04)/4.*460.
      TM=(TCO+TCI)/2.
      RDM=.373*PM/TM
      READ(5,40) DDP01,DDP02
40    FORMAT(2F10.5)
      DPO=(DDP01+DDP02)/2.
      AF3S=SQRT(DPO*(TOR/POR)).*9921
      ACF3S=AF3S*(RDO/.4373)
      ACF3M=ACF3S*60.
      HEAD=DPC*144./RDM
      HEADA=(2.587*386.25*TCI)*(((PCO/PCI)**.3865)-1.)
      PL=1.04*(1.+(1.1863-1.)*(18PM/23500.))**3)
      HPA=(AF3S*RDO*HEAD*PL)/440.
      READ(5,45) W,AM,V,VP,AMPS,PF
45    FORMAT(6F10.5)
      HPO=W*AM/.746
      AHPO=((W*.78)-VP)*((AMPS*300.)*1.7320*PF*AM/746.
      WRITE(6,100) IRN,TIME,RPM

```

```

100  FORMAT(1H1,10X,"RUN NO = ",I5,10X,"TIME = ",F10.5,10X,"RPM = ",F10
1.2,////)
      WRITE(6,200)
200  FORMAT(10X,"P ORIFICE ",10X,"T ORIFICE ",10X," P INLET ",10X," T
      INLET ")
      WRITE(6,250) POR,TOR,PCI,TCI
250  FORMAT(10X,4(F10.5,10X,))////)
      WRITE(6,300)
300  FORMAT(10X,"D P CIRC ",10X,"P COMP OUT",10X,"P MEAN ",10X,"T
      I COMP OUT",10X," T MEAN ")
      WRITE(6,350) DPC,PCO,PM,TCO,TM
350  FORMAT(10X,5(F10.5,10X,))////)
      WRITE(6,400)
400  FORMAT(10X,"R DEN ORIF",10X,"R DEN C I ",10X,"P DEN MEAN",10X/)
      WRITE(6,450) RDO,RDCI,RDM
450  FORMAT(10X,3(F10.5,10X,))////)
      WRITE(6,500)
500  FORMAT(10X,"AC CU FT/S",10X,"CR CU FT/S",10X,"CR CU FT/M",10X," H
      LEAD ",10X,"AC HEAD ")
      WRITE(6,550) AF3S,ACF3S,ACF3M,HEAD,HEAD4
550  FORMAT(10X,5(F10.4,10X,))////)
      WRITE(6,600)
600  FORMAT(10X,"HP AERO ",10X,"POWER LOSS",10X," HP OUT ",10X,"AC HP
      I OUT ")
      WRITE(6,650) HPA,PL,HPO,AHPO
650  FORMAT(10X,4(F10.5,10X,))////)
      GO TO 1
      END

```

R

RUN NO = 47 TIME = 13.25000 RPM = 21144.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1332.20000	1100.95000	1305.20000	1101.10000	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
28.35000	1333.55000	1319.37500	1111.07500	1106.08750
R DEN ORIF	R DEN C I	P DEN MEAN		
.45135	.44214	.44493		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
15.7509	16.2568	975.4093	9175.4623	9175.8733
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
175.10789	1.18113	178.54826	209.81076	
KW Core = 157.1 x .45135 = 158.0				
.4373				

RUN NO = 48

TIME = 13.35000

RPM = 21153.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1326.70000	1105.15000	1297.70000	1097.25000	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
29.97500	1327.67500	1312.60750	1108.00000	1102.62500
R DEN ORIF	R DEN C I	P DEN MEAN		
.44778	.44114	.44406		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
14.3312	14.6745	880.4722	9720.2926	9719.7408
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
167.45883	1.18131	163.35389	193.80338	
KW COR = 141.7 x .44778 = 145.1				

14373

RUN NO = 49

TIME = 13.45000

RPM = 21153.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1333.20000	1101.67500	1302.20000	1106.25000	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
31.00000	1333.20000	1317.70000	1114.50000	1110.42500
R DEN ORIF	R DEN C I	P DEN MEAN		
.45139	.43907	.44263		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
12.3320	2.7809	766.8539	10085.2818	10097.3854
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
151.51627	1.18131	144.70509	176.82033	
KW CORA = 127.0 * .45139 = 57.31				
4373				

RUN NO = 50

TIME = 14.00000

RPM = 21156.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1331.20000	1100.25000	1301.20000	1106.50000	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
31.10000	1332.30000	1316.75000	1114.70000	1110.60000
R DEN ORIF	R DEN C I	P DEN MEAN		
.45130	.43863	.44224		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
10.2043	10.5309	631.8544	10126.7104	10139.7431
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
125.37293	1.10137	125.50134	156.95387	
KW CORR = 112.8 X .45130 = 116.4				
.4375				

RUN NO = 51

TIME = 14.10000

RPM = 14099.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1308.70000	1107.20000	1296.95000	1108.02500	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
12.57500	1309.52500	1303.23750	1109.85000	1108.93750
R DEN ORIF	R DEN C I	P DEN MEAN		
.44088	.43660	.43835		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
10.5040	10.5901	635.4056	4130.9045	4136.7745
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
47.10338	1.08184	46.84182	54.68755	
$KW_{CORR} = 44.8 \times .44088 = 19.75$				
4373				

RUN NO = 52 TIME = 14.2500 RPM = 14083.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1312.70000	1096.65000	1299.20000	1098.50000	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
14.45000	1313.65000	1306.42500	1098.62500	1098.56250
R DEN ORIF	R DEN C I	P DEN MEAN		
.44648	.44115	.44358		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
6.9356	7.0813	424.8765	4690.9607	4702.5228
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
35.79940	1.08170	33.36863	39.23500	

$$KW_{CORR} = 34.1 \times \frac{.44648}{.6373} = 34.8$$

RUN NO = 53

TIME = 14.4000

RPM = 14100.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1319.20000	1104.02500	1304.95000	1106.02500	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
13.95000	1318.90000	1311.92500	1106.17500	1106.10000
R DEN DRIF	R DEN C I	P DEN MEAN		
.44570	.44009	.44241		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
7.7012	7.8490	470.9428	4540.6001	4551.3621
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
38.41071	1.98185	35.90885	41.52456	
$KW_{CORR} = 36.2 \times .44570 = 16.2$				

RUN NO = 54 TIME = 14.50000 RPM = 14100.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1316.70000	1112.25000	1303.70000	1113.67500	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
13.32500	1317.02500	1310.36250	1114.27500	1113.97500
R DEN ORIF	R DEN C I	P DEN MEAN		
.44156	.43664	.43876		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
9.2090	9.2988	557.9282	4373.2557	4382.3407
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
43.81545	1.08185	41.97319	49.02871	
$KW_{CORR} = 41.2 \times \frac{.44156}{.4373} = 41.6$				

RUN NO = 55 TIME = 15.00000 RPM = 7031.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1292.70000	1106.30000	1288.45000	1110.47500	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
3.17500	1291.62500	1290.03750	1106.75000	1108.61250
R DEN ORIF	R DEN C I	P DEN MEAN		
.43585	.43278	.43404		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
5.1674	5.1532	309.0140	1053.3552	1056.0182
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
5.64963	1.04519	2.78016	3.09385	
KW COR = $6.1 \times .43585 = 6.1$				
.4373				

RUN NO = 56 TIME = 15.2500 RPM = 7058.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1289.70000	1103.30000	1286.45000	1110.97500	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
3.52500	1289.97500	1288.21250	1104.92500	1107.95000
R DEN ORIF	R DEN C I	P DEN MEAN		
.43602	.43191	.43369		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
3.3715	3.3616	201.6975	1170.4300	1174.6819
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
4.10219	1.04525	.73727	.35447	
$KW_{core} = 5.0 \times .43602 = 4.19$ $.4373$				

RUN NO = 57

TIME = 15.3500

RPM = 7055.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1336.70000	1104.75000	1332.95000	1110.82500	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
3.60000	1336.50000	1334.75000	1105.62500	1108.22500
R DEN ORIF	R DEN C I	P DEN MEAN		
.45131	.44759	.44924		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
3.7892	3.9106	234.6353	1153.9425	1157.6820
HP AERC	POWER LOSS	HP OUT	AC HP OUT	
4.70330	1.04524	.86863	.42449	
$KW_{COR} = 5.4 \times .45131 = 5.57$				
4373				

RUN NO = 58 TIME = 15.45000 RPM = 7060.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1336.70000	1108.35000	1333.70000	1113.22500	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
3.52500	1337.22500	1335.46250	1108.67500	1110.95000
R DEN ORIF	R DEN C I	P DEN MEAN		
.44985	.44687	.44838		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
4.5350	4.6651	279.9077	1132.0760	1135.3940
HP AERD	POWER LOSS	HP OUT	AC HP OUT	
5.50248	1.04525	2.59786	3.04457	
$KW_{CORR} = 5.7 \times \frac{.44985}{.4373} = 5.86$				

RUN NO = 59

TIME = 16.05000

RPM = 3002.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1326.70000	1105.37500	1325.45000	1110.05000	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
.62500	1326.07500	1325.76250	1103.52500	1106.78750
R DEN ORIF	R DEN C I	P GEN MEAN		
.44768	.44538	.44680		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
2.1734	2.2250	133.4993	201.4337	202.1207
HP AERO	POWER LCSS	HP OUT	AC HP OUT	
.46502	1.04040	.01877	.00840	
KW CORE = 0.7 x .44768 = 0.72				
.4373				

RUN NO = 60 TIME = 16.15000 RPM = 3000.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1324.70000	1105.25000	1322.95000	1109.20000	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
.72500	1323.67500	1323.31250	1102.22500	1105.71250
R DEN ORIF	R DEN C I	P DEN MEAN		
.44706	.54488	.44640		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
1.8572	1.8986	113.9172	233.8684	234.7177
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
.46080	1.04040	.01877	.00878	
KW CORP = 0.7 x .44706 = 2.72				
4373				

RUN NO = 61 TIME = 16.3000 RPM = 3000.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1320.70000	1105.12500	1319.95000	1110.02500	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
.55000	1320.50000	1320.22500	1100.17500	1105.10000
R DEN ORIF	R DEN C I	P DEN MEAN		
.44576	.44354	.44561		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
1.0890	1.1101	66.6061	177.7338	178.6063
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
.20502	1.04040	.01877	.00903	
KW CORR = 0.7 x .44576 = 0.312				
.4373				

RUN NO = 62 TIME = 16.00000 RPM = 3000.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1315.20000	1105.35000	1313.95000	1110.27500	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
.55000	1314.50000	1314.22500	1098.72500	1104.50000
R DEN ORIF	R DEN C I	P DEN MEAN		
.44381	.44143	.44383		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
.8459	.8585	51.5098	178.4483	179.4622
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
.15931	1.04040	.02145	.00924	
$KU_{CORR} = 0.8 \times \frac{.44381}{.4373} = 0.82$				

APPENDIX 4

COMPUTER ANALYSIS OF TEST DATA
1500 psig AND 650°F
COMPRESSOR CHARACTERISTIC

BATCH UPDATED 03/28/79 TODAY IS 03/30/79

USERS WISHING TO RUN JOBS WHICH HAVE IN EXCESS OF 4 HOURS
WALL CLOCK EXECUTION AND PRINT TIME ARE REQUESTED TO
CONTACT THE OPERATIONS SHIFT MANAGER AT 301-340-3923
PRIOR TO SUBMITTING JOBS TO MAKE SURE THERE ARE NO
SCHEDULING CONFLICTS.

ATTENTION EXPORT 2 USERS . . .

WE ARE STARTING OUR CONVERSION FROM E12 TO INTERCOM
5.0 ON EC2.

THE NEW ROTARY NUMBERS ARE -

2000 BAUD LOCAL	■	(301) 279-5587
2000 BAUD INWATS	■	(800) 638-8971
4800 BAUD LOCAL	■	(301) 279-7708
4800 BAUD INWATS	■	(800) 638-8991

ALL 2000 BPS AND 4800 BPS USERS SHOULD TRY THEIR
TERMINALS ON INTERCOM AND REPORT ANY PROBLEMS TO
GARY RINGOLD AT 301-340-3889 AT THE DATA CENTER.

EFFECTIVE MARCH 5, 1979 THE 279-7708 ROTARY WILL CONSIST
OF 5 LINES AND THE 340-7610 ROTARY WILL BE DECREASED
BY 3 LINES.

FOR ADDITIONAL INFORMATION ON INTERCOM 5.0, SYSBULL 164
CONTAINS COMMAND DIFFERENCES BETWEEN E12 AND INTERCOM 5.0.


```

1      PROGRAM DEB(INPUT,OUTPUT,TAPES=INPUT,TAPE6=OUTPUT)
      1  READ(5,10) IRN,TIME,RPM
      10 IF (IRN.EQ.0) STOP
      15 FORMAT(15,2F10.5)
      5  READ(5,15) PPOR1,PPOR2,TTOR1,TTOR2,TTOR3,TTOR4
      15 FORMAT(6F10.5)
      POR=(PPOR1+PPOR2)/2.*14.7
      TOR=(TTOR1+TTOR2+TTOR3+TTOR4)/4.*460.
      RDO=.373*POR/TOR
      10 READ(5,20) PPC11,PPC12,PPC13,PPC14
      20 FORMAT(4F10.5)
      PCI=(PPC11+PPC12+PPC13+PPC14)/4.*14.7
      READ(5,25) TTC11,TTC12,TTC13,TTC14
      25 FORMAT(4F10.5)
      TCI=(TTC11+TTC12+TTC13+TTC14)/4.*460.
      15 RDCI=.373*PCI/TCI
      READ(5,30) DDPC1,DDPC2,DDPC3,DDPC4
      30 FORMAT(4F10.5)
      DPC=(DDPC1+DDPC2+DDPC3+DDPC4)/4.
      20 PCO=DPC*PCI
      PM=(PCO+PCI)/2.
      READ(5,35) TTCO1,TTCO2,TTCO3,TTCO4
      35 FORMAT(4F10.5)
      TCO=(TTCO1+TTCO2+TTCO3+TTCO4)/4.*460.
      25 TM=(TCO+TCI)/2.
      RDM=.373*PM/TM
      READ(5,40) DDP01,DDP02
      40 FORMAT(2F10.5)
      DPO=(DDP01+DDP02)/2.
      30 AF3S=SQRT(DPO*(TOR/POR))*0.9921
      ACF3S=AF3S*(RDO/.5080)
      ACF3M=ACF3S*60.
      HEAD=DPC*144./ROM
      HEADA=(2.587*386.25*TCI)*(((PCO/PCI)**.3865)-1.)
      35 PL=1.04*(1.+(1.1863-1.)*(RPM/23500.)*3)
      HPA=(AF3S*RDO*HEADA*PL)/440.
      READ(5,45) W,AM,V,VP,AMPS,PF
      45 FORMAT(6F10.5)
      HPO=W*AM/.746
      40 AHPO=((V*.78)-VP)*(AMPS*300.)*1.7320*PF*AM/746.
      WRITE(6,100) IRN,TIME,RPM
      100 FORMAT(1H,10X,"RUN NO = ",15,10X,"TIME = ",F10.5,10X,"RPM = ",F10
      1,2,///)
      WRITE(6,200)
      45 200 FORMAT(10X,"P ORIFICE ",10X,"T ORIFICE ",10X," P INLET ",10X," T
      1 INLET ")
      WRITE(6,250) POR,TOR,PCI,TCI
      250 FORMAT(10X,4(F10.5,10X,))///)
      WRITE(6,300)
      50 300 FORMAT(10X,"D P CIRC ",10X,"P COMP OUT",10X,"P MEAN ",10X,"T
      1 COMP OUT",10X," T MEAN ")
      WRITE(6,350) DPC,PCO,PM,TCO,TM
      350 FORMAT(10X,5(F10.5,10X,))///)
      WRITE(6,400)
      55 400 FORMAT(10X,"R DEN ORIF",10X,"R DEN C I ",10X,"P DEN MEAN",10X/)
      WRITE(6,450) RDO,RDCI,RDM
      450 FORMAT(10X,3(F10.5,10X,))///)

```

```

1      PROGRAM DEB(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      1      READ(5,10) IRN,TIME,RPM
      10      IF (IRN.EQ.0) STOP
      15      FORMAT(15,2F10.5)
      5      READ(5,15) PPOR1,PPOR2,TTOR1,TTOR2,TTOR3,TTOR4
      15      FORMAT(6F10.5)
      POR=(PPOR1+PPOR2)/2.*14.7
      TOR=(TTOR1+TTOR2+TTOR3+TTOR4)/4.*460.
      RDO=.373*POR/TOR
      10      READ(5,20) PPC11,PPC12,PPC13,PPC14
      20      FORMAT(4F10.5)
      PCI=(PPC11+PPC12+PPC13+PPC14)/4.*14.7
      READ(5,25) TTC11,TTC12,TTC13,TTC14
      25      FORMAT(4F10.5)
      TCI=(TTC11+TTC12+TTC13+TTC14)/4.*460.
      RDCI=.373*PCI/TCI
      READ(5,30) DDPC1,DDPC2,DDPC3,DDPC4
      30      FORMAT(4F10.5)
      DPC=(DDPC1+DDPC2+DDPC3+DDPC4)/4.
      PCO=DPC*PCI
      PM=(PCO+PCI)/2.
      READ(5,35) TTCO1,TTCO2,TTCO3,TTCO4
      35      FORMAT(4F10.5)
      TCO=(TTCO1+TTCO2+TTCO3+TTCO4)/4.*460.
      TM=(TCO+TCI)/2.
      25      RDM=.373*PM/TM
      READ(5,40) DDP01,DDP02
      40      FORMAT(2F10.5)
      DPO=(DDP01+DDP02)/2.
      30      AF3S=SQRT(DPO*(TOR/POR))*0.9921
      ACF3S=AF3S*(RDO/.5080)
      ACF3M=ACF3S*60.
      HEAD=DPC*144./RDM
      HEAD0=(2.587*386.25*TCI)*((FCO/PCI)**.3865)-1.)
      35      PL=1.04*(1.+(1.1963-1.)*(RPM/2350.)*.31)
      HPA=(AF3S*RDO*HEAD0*PL)/440.
      READ(5,45) W,AM,VP,AMPS,PF
      45      FORMAT(6F10.5)
      HPO=W*AM/.746
      AMPO=((V*.78)-VP)*(AMPS*300.)*1.7320*PF*AM/746.
      40      WRITE(6,100) IRN,TIME,RPM
      100     FORMAT(1H1,10X,"RUN NO = ",15,10X,"TIME = ",F10.5,10X,"RPM = ",F10.5,10X,"")
      1.2,///)
      WRITE(6,200)
      45      200     FORMAT(10X,"P ORIFICE ",10X,"T ORIFICE ",10X," P INLET ",10X," T INLET ")
      WRITE(6,250) POR,TOR,PCI,TCI
      250     FORMAT(10X,4(F10.5,10X),///)
      WRITE(6,300)
      50      300     FORMAT(10X,"D P CIRC ",10X,"P COMP OUT",10X,"P MEAN ",10X,"T COMP OUT",10X," T MEAN ")
      WRITE(6,350) DPC,PCO,PM,TCO,TM
      350     FORMAT(10X,5(F10.5,10X),///)
      WRITE(6,400)
      55      400     FORMAT(10X,"R DEN ORIF",10X,"R DEN C I ",10X,"P DEN MEAN",10X,/)
      WRITE(6,450) RDO,RDCI,RDM
      450     FORMAT(10X,3(F10.5,10X),///)

```



```

      500 WRITE(6,500)
      500 FORMAT(10X,"AC CU FT/S",10X,"CR CU FT/S",10X,"CR CU FT/M",10X," H
60      LEAD ",10X,"AC HEAD ")
      550 WRITE(6,550) AF3S,ACF3S,ACF3M,HEAD,HEADA
      550 FORMAT(10X,5(F10.4,10X)///)
      600 WRITE(6,600)
      600 FORMAT(10X,"HP AERO ",10X,"POWER LOSS",10X," HP OUT ",10X,"AC HP
65      1 OUT ")
      650 WRITE(6,650) HPA,PL,HPO,AHPO
      650 FORMAT(10X,4(F10.5,10X)///)
      GO TO 1
      END

```

SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
4114 DEB

VARIABLES	SN	TYPE	RELOCATION
4733	ACF3M	REAL	4732 ACF3S
4731	AF3S	REAL	4747 AHPO
4741	AM	REAL	4744 AMPS
4710	DDPC1	REAL	4711 DDPC2
4712	DDPC3	REAL	4713 DDPC4
4726	DDP01	REAL	4727 DDP02
4714	DPC	REAL	4730 DPO
4734	HEAD	REAL	4735 HEADA
4737	HPA	REAL	4746 HPO
4661	IRN	INTEGER	4701 PCI
4715	PCO	REAL	4745 PF
4736	PL	REAL	4716 PH
4672	POR	REAL	4675 PPC11
4676	PPC12	REAL	4677 PPC13
4700	PPC14	REAL	4664 PPOR1
4665	PPOR2	REAL	4707 RDC1
4725	RDM	REAL	4674 RDO
4663	RPM	REAL	4706 TCI
4723	TCO	REAL	4662 TIME
4724	TM	REAL	4673 TOR
4702	TTC11	REAL	4703 TTC12
4704	TTC13	REAL	4705 TTC14
4717	TTC01	REAL	4720 TTC02
4721	TTC03	REAL	4722 TTC04
4666	TTOR1	REAL	4667 TTOR2
4670	TTOR3	REAL	4671 TTOR4
4742	V	REAL	4743 VP
4740	W	REAL	

FILE NAMES
0 INPUT

MODE

2043 OUTPUT

0 TAPES

FMT

2043 TAPE6

FMT

EXTERNALS TYPE ARGS
SQRT REAL 1 LIBRARY

STATEMENT LABELS

4115	1		4312	10	FMT	4327	15	FMT
4341	20	FMT	4353	25	FMT	4365	30	FMT
4377	35	FMT	4407	40	FMT	4423	45	FMT
4433	100	FMT	4446	200	FMT	4466	250	FMT
4474	300	FMT	4516	350	FMT	4524	400	FMT
4541	450	FMT	4547	500	FMT	4571	550	FMT
4577	600	FMT	4616	550	FMT			

STATISTICS

PROGRAM LENGTH	642B	418
BUFFER LENGTH	4106B	2118

FWA OF THE LOAD 101
LWA+1 OF THE LOAD 20114

TRANSFER ADDRESS -- DEB 4215

PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK	ADDRESS	LENGTH	FILE	DATE	PROCSSR	VER	LEVEL	HARDWARE	COMMENTS
DEB	101	4750	LGO	03/30/79	FTN		4.6 433B	666X I	OPT=1
/STP.END/	5051	1							
/FCL.C./	5052	26							
/QB.IO./	5100	132							
QBNTY=	5232	0	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		FCL INITIALIZATION ROUTINE.
COMIO=	5232	64	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		COMMON CODED I/O ROUTINES AND CONSTANTS.
FECMSK=	5316	41	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		INITIALIZE CONSTANTS.
FLTOUT=	5357	311	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		COMMON FLOATING OUTPUT CODE.
FORSYS=	5670	604	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		FORTAN OBJECT LIBRARY UTILITIES.
INCOM=	6474	302	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		COMMON INPUT FORMATTING CODE.
INPC=	6776	160	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		FORMATTED READ FORTAN RECORD.
KODER=	7156	456	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		OUTPUT FORMAT INTERPRETER.
OUTCOM=	7634	154	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		COMMON OUTPUT CODE.
ALOG	10010	73	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		COMPUTE COMMON AND NATURAL LOGARITHMS, OPT=ALL.
EXP	10103	75	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		EXPONENTIAL FUNCTION, E TO POWER X, OPT=ALL.
SQRT	10200	43	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		COMPUTE THE SQUARE ROOT OF X, OPT=ALL.
SYS=1ST	10243	62	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		MATH LIBRARY LINK TO ERROR MESSAGE PROCESSOR.
XTQY=	10325	7	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		REAL TO REAL EXPONENTIATION.
FLTIN=	10334	154	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		COMMON FLOATING INPUT CONVERTER.
FMTAP=	10510	352	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		CRACK APLIST AND FORMAT FOR KODER/KRAKER.
FORUTL=	11062	16	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		FCL MISC. UTILITIES.
GETFIT=	11100	42	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		LOCATE AN FIT GIVEN A FILE NAME.
KRAKER=	11142	406	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		PROCESS FORMATTED FORTAN INPUT.
OUTC=	11550	172	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		FORMATTED WRITE FORTAN RECORD.
SYS=10=	11742	1	SL-FORTRAN	07/05/78	COMPASS	3.	3-433		LINK BETWEEN SYS=10 AND INITIALIZATION CODE.
SYS.RM	11743	37	SL-SYSIO	03/12/75	COMPASS	3.	75010		PROCESS SYSTEM REQUEST.
/CON.RM/	12002	6							
CIO.RM	12010	40	SL-SYSIO	07/06/78	COMPASS	3.	3-433		
/AQB.RM/	12050	10							
MOVE.RM	12060	64	SL-SYSIO	07/06/78	COMPASS	3.	3-433		
MCT.RM	12144	233	SL-SYSIO	07/06/78	COMPASS	3.	3-433		
/JMPS.RM/	12377	11							
/MEMC.RM/	12410	3							
/OPES.FO/	12413	1							
/OPEN.FO/	12414	7							
OPEN.RM	12423	237	SL-SYSIO	07/06/78	COMPASS	3.	3-433		
/TERM.RM/	12662	1							
/PUT.FO/	12663	7							
PUT.SQ	12672	1407	SL-SYSIO	07/06/78	COMPASS	3.	3-433		
WAR.SQ	14301	260	SL-SYSIO	07/06/78	COMPASS	3.	3-433		
/CLSF.FO/	14561	7							
CLSF.RM	14570	22	SL-SYSIO	07/06/78	COMPASS	3.	3-433		
/GET.BT/	14612	5							
BTRT.SQ	14617	115	SL-SYSIO	07/06/78	COMPASS	3.	3-433		
WEOX.SQ	14734	150	SL-SYSIO	07/06/78	COMPASS	3.	3-433		

/SKFL.FO/	15104	7				
SKFL.SQ	15113	51	SL-SYSIO	07/06/78	COMPASS	3. 3-433
ERR.RM	15164	406	SL-SYSIO	07/06/78	COMPASS	3. 3-433
CHWR.SQ	15572	7	SL-SYSIO	07/06/78	COMPASS	3. 3-433
OSUB.RM	15501	71	SL-SYSIO	07/06/78	COMPASS	3. 3-433
OPEN.SQ	15572	257	SL-SYSIO	07/06/78	COMPASS	3. 3-433
OPEX.SQ	16151	14	SL-SYSIO	07/06/78	COMPASS	3. 3-433
/PUT.RT/	16165	11				
RLEQ.RM	16176	42	SL-SYSIO	07/06/78	COMPASS	3. 3-433
CLSF.SQ	16240	134	SL-SYSIO	07/06/78	COMPASS	3. 3-433
/CLSV.FO/	16374	7				
CLSV.SQ	16403	137	SL-SYSIO	07/06/78	COMPASS	3. 3-433
/REW.FO/	16542	7				
REW.SQ	16551	33	SL-SYSIO	07/06/78	COMPASS	3. 3-433
/GET.FO/	16604	7				
/RPAR.XX/	16613	1				
/GET.RT/	16614	11				
GET.SQ	16625	1060	SL-SYSIO	07/06/78	COMPASS	3. 3-433
Z.SQ	17705	101	SL-SYSIO	07/06/78	COMPASS	3. 3-433
FSU.SQ	20006	106	SL-SYSIO	07/06/78	COMPASS	3. 3-433

.327 CP SECONDS

327008 CM STORAGE USED

24 TABLE MOVES

RUN NO = 64 TIME = 9.15000 RPM = 21143.00

P. ORIFICE	T ORIFICE	P INLET	T INLET
1530.20600	1101.90000	1495.45000	1098.30000

D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
35.97500	1531.42500	1513.43750	1108.05000	1103.17500

R DEN ORIF	R DEN C I	P DEN MEAN
.51798	.50788	.51172

AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
10.7978	11.0100	660.5988	10123.5862	10129.5178

HP AERO	POWER LOSS	HP OUT	AC HP OUT
152.08096	1.18111	166.18633	158.31353

KW_{CORR} = $142.5 \times \frac{.51798}{.5080} = 145.29$

RUN NO = 65		TIME = 9.30000		RPM = 21147.00	
P ORIFICE	T ORIFICE	P INLET	T INLET		
1527.20000	1101.37500	1492.20000	1103.27500		
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN	
35.57500	1527.77500	1509.98750	1112.15000	1107.71250	
R DEN ORIF	R DEN C 1	P DEN MEAN			
.51721	.50449	.50846			
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD	
12.2091	12.4306	745.8334	10075.1675	10084.8339	
HP AERO	POWER LOSS	HP OUT	AC HP OUT		
170.95756	1.18119	169.68499	118.54084		
$KW_{CORR} = 145.5 \times \frac{.51721}{.5080} = 148.13$					

RUN NO = 66 TIME = 9.45000 RPM = 21134.00

P ORIFICE	T ORIFICE	P INLET	T INLET
1532.20000	1105.70000	1498.70000	1105.60000

D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
34.45000	1533.15000	1515.92500	1114.75000	1110.17500

R DEN ORIF	R DEN C I	P DEN MEAN
.51688	.50562	.50933

AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
13.8996	14.1424	848.5459	9739.9475	9746.5612

HP AERO	POWER LOSS	HP OUT	AC HP OUT
187.93550	1.18092	181.81367	211.28266

$KW_{LORR} = 155.9 \times .51688 = 158.6$
5080

RUN NO = 67 TIME = 10.00050 RPM = 21130.00

P ORIFICE	T CRIFICE	P INLET	T INLET
1534.20000	1105.70000	1502.20000	1105.77500

D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
32.35000	1534.55000	1518.37500	1115.97500	1110.87500

R DEN ORIF	P DEN C I	P DEN MEAN
.51755	.50672	.50983

AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
15.7568	16.0530	963.1816	9137.2203	9136.5510

HP AERO	POWER LOSS	HP OUT	AC HP OUT
199.95999	1.18084	203.38874	235.16220

KW CORR = 174.4 X .5755 = 17.77
-5080

RUN NO = 68 TIME = 10.10000 RPM = 14105.00

P ORIFICE	T ORIFICE	P INLET	T INLET
1530.20000	1111.37500	1515.45000	1111.95000

D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
14.92500	1530.37500	1522.91250	1113.85000	1112.90000

R DEN ORIF	R DEN C I	P DEN MEAN
.51357	.50835	.51042

AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
10.5263	10.6417	638.5008	4210.6505	4216.6283

HP AERO	POWER LOSS	HP OUT	AC HP OUT
56.04949	1.08189	56.24397	64.49182

KW = $51.8 \times \frac{51357}{5080} = 52.0$

RUN NO = 69		TIME = 10.20000		RPM = 14124.00	
P ORIFICE		T ORIFICE		P INLET	
1515.20000		1105.50300		1497.20000	
				1107.52500	
D P CIRC		P COMP OUT		P MEAN	
16.02500		1513.22500		1505.21250	
				1108.12500	
				1107.82500	
R DEN ORIF		R DEN C I		P DEN MEAN	
.51123		.50424		.50680	
AC CU FT/S		CR CU FT/S		CR CU FT/M	
6.6995		6.7421		404.5269	
				4553.2872	
				4563.1644	
HP AERO		POWER LOSS		HP OUT	
38.43496		1.08206		38.38874	
				42.86009	
$KW_{CORR} = 38.7 \times \frac{.5123}{.5080} = 38.95$					

RUN NO = 70 TIME = 10.35000 RPM = 14096.00

P ORIFICE	T ORIFICE	P INLET	T INLET
1520.20000	1183.67500	1503.70000	1114.60000

D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
15.95000	1519.65000	1511.67500	1115.37500	1114.98750

R DEN ORIF	R DEN C I	P DEN MEAN
.47703	.50321	.50571

AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
8.3687	7.8585	471.5104	4541.7781	4551.1965

HP AERO	POWER LOSS	HP OUT	AC HP OUT
44.67141	1.08181	43.19571	49.83913

$$KW_{CORR} = 42.4 \times \frac{47703}{15080} = 39.82$$

RUN NO = 71 TIME = 10.45000 RPM = 14088.00

P ORIFICE	T ORIFICE	P INLET	T INLET
1512.70000	1109.00000	1496.95000	1109.37500

D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
15.12500	1512.07500	1504.51250	1111.05000	1110.21250

R DEN ORIF	R DEN C I	P DEN MEAN
.50876	.50331	.50547

AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
9.4973	9.5119	570.7126	4308.8300	4315.5887

HP AERO	POWER LOSS	HP OUT	AC HP OUT
51.26744	1.08174	50.40751	58.39760

KW COR = 47.6 X $\frac{50.878}{5080}$ = 47.7

RUN NO = 72 TIME = 10.55000 RPM = 7055.00

P. ORIFICE	T. ORIFICE	P. INLET	T. INLET
1497.70000	1104.67500	1493.95000	1109.10000

D P CIRC	P. COMP. OUT	P. MEAN	T. COMP. OUT	T. MEAN
3.77500	1497.72500	1495.83750	1105.85000	1107.47500

R. DEN. ORIF	R. DEN. C. I	P. DEN. MEAN
.50571	.50243	.50380

AC. CU. FT/S	CR. CU. FT/S	CR. CU. FT/M	HEAD	AC. HEAD
5.1828	5.1594	309.5621	1078.9967	1081.5080

HP. AERO	POWER LOSS	HP. OUT	AC. HP. OUT
6.73371	1.04524	3.71984	3.74325

KW CORR = $7.5 \times \frac{.50571}{.5080} = 7.47$

RUN NO = 73 TIME = 11.10000 RPM = 7052.00

P ORIFICE	T ORIFICE	P INLET	T INLET
1534.70000	1102.62500	1529.45000	1107.37500

D P. CIRC	P. COMP OUT	P. MEAN	T. COMP OUT	T. MEAN
3.97500	1533.42500	1531.43750	1103.07500	1105.22500

R DEN ORIF	R DEN C I	P DEN MEAN
.51916	.51517	.51634

AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
4.3248	4.4199	265.1933	1107.4961	1110.6190

HP AERO	POWER LOSS	HP OUT	AC HP OUT
5.92382	1.04524	2.96247	3.08777

KW CORR = $6.5 \times \frac{.51916}{.5080} = 6.64$

RUN NO = 74		TIME = 11.25000		RPM = 7068.00	
P ORIFICE	T ORIFICE	P INLET	T INLET		
1533.20000	1103.30000	1528.70000	1108.17500		
D. P. CIRC	P COMP. OUT	P MEAN	T COMP OUT	T MEAN	
4.15000	1532.85000	1530.77500	1102.77500	1105.47500	
R DEN ORIF	R DEN C I	P DEN MEAN			
.51834	.51454	.51650			
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD	
3.0286	3.0902	185.4126	1157.0159	1160.8800	
HP AERO	POWER LOSS	HP OUT	AC HP OUT		
4.32928	1.04527	.90080	.42723		
$KW_{CORR} = 5.6 \times \frac{.51834}{.5080} = 5.71$					

RUN NO = 75 TIME = 11.4500 RPM = 3000.00

P ORIFICE	T ORIFICE	P INLET	T INLET
1529.20000	1109.25000	1527.70000	1111.47500

D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
.90000	1529.60000	1528.15000	1105.75000	1108.61250

R DEN ORIF	R DEN C I	F DEN MEAN
.51468	.51268	.51416

AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
2.1615	2.1900	131.3971	252.0635	252.8367

HP AERO	POWER LOSS	HP OUT	AC HP OUT
.66510	1.04040	.01877	.00806

KW COR = $0.7 \times \frac{.51468}{.5080} = 0.709$

RUN NO = 76 TIME = 11.55000 RPM = 3020.00

P. ORIFICE	T ORIFICE	P INLET	T INLET
1518.70000	1103.92500	1516.70000	1108.52500

D P CIRC	P COMP. OUT	P MEAN	T COMP. OUT	T MEAN
.80000	1517.50000	1517.10000	1101.32500	1104.92500

R. DEN ORIF	R. DEN C I	P DEN MEAN
.51315	.51034	.51214

AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
1.8618	1.8807	112.8405	224.9377	225.7771

HP AERO	POWER LOSS	HP OUT	AC HP OUT
.51005	1.04041	.01877	.00834

$KW_{corr} = 17 \times \frac{.5135}{5080} = 0.708$

RUN NO	77	TIME	12.10000	RPM	3025.00
P ORIFICE	T ORIFICE	P INLET	T INLET		
1538.20000	1103.10000	1536.20000	1112.85000		
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN	
.85000	1137.05000	1536.62500	1105.30000	1109.07500	
R DEN ORIF	R DEN C I	P DEN MEAN			
.51778	.51490	.51679			
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD	
1.5122	1.5413	92.4770	236.8458	237.7653	
HP AERO	POWER LOSS	HP OUT	AC HP OUT		
.44020	1.04041	.02145	.00871		
$KW_{COR} = 0.8 \times .51778 = 0.4142$					

RUN NO = 78 TIME = 12.20000 RPM = 3000.00

P ORIFICE	T ORIFICE	P INLET	T INLET	
1524.70000	1100.50000	1522.70000	1105.80000	
D P CIRC	P COMP OUT	P MEAN	T COMP OUT	T MEAN
.57500	1523.27500	1522.98750	1096.62500	1101.21250
R DEN ORIF	R DEN C I	P DEN MEAN		
.51678	.51363	.51586		
AC CU FT/S	CR CU FT/S	CR CU FT/M	HEAD	AC HEAD
1.2852	1.3074	78.4441	160.5079	161.2480
HP AERO	POWER LOSS	HP OUT	AC HP OUT	
.25323	1.04040	.01877	.00890	

KW CORR = $0.7 \times \frac{51678}{5080} = 0.71$

```

ECZ  ECZ  SCOPE 3.4.3  406F.314  03/28/79
14.09.38.DEB50JQ FROM /ZT
14.09.38.ISIP, INPUT .00000008 IODBS, ***/ZT, DC= 00.
14.09.38.DEB5,T10,P4.
14.09.41.USER(B000188.)
14.09.41.ATTENTION - YOUR PASSWORD IS UNCHANGED
14.09.41.FOR 60 DAYS.
14.09.42.PROJECT(*976*)
14.09.47.ACCH, B0001, *976*
14.09.47.FTN.
14.09.54. .202 CP SECONDS COMPIATION TIME
14.09.54.LDSET(PRESET=ZERO)
14.09.54.LGO(IPL=999999)
14.10.01. STOP
14.10.01.ATTACH,COST.
14.10.01.PFN IS
14.10.01.COST
14.10.02.PF CYCLE NO. = 001
14.10.05.COST.
14.10.05.*****
14.10.05.= COST = $ 3.34913867187498 E+000
14.10.05.*****
14.10.05. EXIT
14.10.05.ISOP, OUTPUT .00000029 IODBS, ***/ZT, DC= 40.
14.10.06.ISEQ, ENTERED QUEUE 14.09.35 79089
14.10.06.ISSN, 22.090 EXECUTION TIME
14.10.06.MS 7168 MCROS 0 MAX USED)
14.10.06.CPA .821 SEC.
14.10.06.IO 21.258 SEC.
14.10.06.CM 200.896 KWS.
14.10.06.ISSN, 3.881 TOTAL SBLUS NON-APPLICATION
14.10.07.PP 13.326 SEC. DATE 03/30/79
14.10.07.EJ END OF JOB, ZT

```


APPENDIX 5
POWER LIMITING CURVES

POWER LIMITING CURVES

These curves provide parameters to assist in preventing overloading of the motor, or ancillary electrical equipment when the circulator is operated under varying pressure, temperature, speed and flow conditions.

As it is impractical with the test loop available to obtain these limiting operational parameters by test, the Power Limiting curves given in this section are calculated using actual test values to establish generalized overall efficiency values to enable the computation to be carried out. The large number of variables involved makes it impractical to carry out a rigorous computation and the method to be described is considered adequate for the purpose intended.

Two different sets of limit curves are given. The first is using the motor power law which gives the relationship - motor input power available proportional to $\frac{\text{rpm}_2}{\text{rpm}_1}$. This is considered to be the true case as it utilizes the maximum motor power available at a given speed.

The second is using the fan law which gives the relationship compressor power required is proportional to $(\frac{\text{rpm}_2}{\text{rpm}_1})^3$. It will be noted by studying the curves that the pressure versus temperature versus speed versus flow curve for 1300 psi and 21,150 rpm is identical for both sets of curves. The variations shown are to be found above and below this speed line and are due to the proportionality relationships previously stated.

As a starting point, these curves are based on the compressor characteristics plotted from the actual test data for the 1500 psi test at speeds of 21,150, 14,100, 7050 and 3000 rpm. Also, the interpolated and extrapolated curves for speeds of 23,500, 18,800, 16,450, 11,750, 9400 and 4700 rpm are used.

The maximum kW input power recorded during the test was for run no. 67. The actual measured power was 174.4 kW. Corrected for density at inlt to the compressor, this came to 177.7 kW. This corrected value will be the value used to calculate the motor power for each speed line. Reference to the computer analysis for test run no. 67 shows that the motor shaft power amounted to $203.389 \times \frac{.51755}{.5080} = 207.2$ horsepower which is almost exactly the design condition power.

Based on the relationship that power input $\propto \frac{\text{rpm}}{\text{rpm}} \frac{2}{1}$, the following is obtained:

POWER INPUT kW $\propto$ N (MOTOR CAPABILITY)

		CALCULATED VALUE	TEST VALUE
kW at 21,150 rpm	=		177.7
kW at 23,500 rpm	= $\frac{23,500}{21,150} \times 177.7$	= 197.4	
kW at 18,800 rpm	= $\frac{18,800}{21,150} \times 177.7$	= 157.95	
kW at 16,450 rpm	= $\frac{16,450}{21,150} \times 177.7$	= 138.2	
kW at 14,100 rpm	= $\frac{14,100}{21,150} \times 177.7$	= 118.5	52.0
kW at 11,750 rpm	= $\frac{11,750}{21,150} \times 177.7$	= 98.72	
kW at 9,400 rpm	= $\frac{9,400}{21,150} \times 177.7$	= 78.98	
kW at 7,050 rpm	= $\frac{7,050}{21,150} \times 177.7$	= 59.23	7.47
kW at 4,700 rpm	= $\frac{4,700}{21,150} \times 177.7$	= 39.5	
kW at 3,000 rpm	= $\frac{3,000}{21,150} \times 177.7$	= 25.2	.82

A value of overall efficiency = η_{overall} which is assumed to be constant for each speed line but variable for each different speed line is calculated. Using the values observed during the testing for 1300 and 1500 psig characteristics a generalized efficiency curve of η_{overall} versus speed rpm can be plotted as shown in Figure A5-1 on page A5-6, from equation(e) on the following page.

$$a. \quad \text{hp}_{\text{gas}} = \frac{\frac{\text{acfm}}{60} \times .373 \frac{P}{T} \times \text{HEAD}}{550 \times \eta_{\text{comp.}} \times \eta_{\text{parasitic}}}$$

$$b. \quad \text{hp}_{\text{out of motor}} = \frac{\text{kW} \times \eta_{\text{motor}}}{0.746}$$

$$c. \quad \frac{kW \times \eta_M}{0.746} = \frac{acfm \times .373 \times P \times HEAD}{60 \times T \times \eta_c \times \eta_p \times 550}$$

$$d. \quad \text{Then } kW = \frac{acfm \times .373 \times P \times HEAD \times .746}{60 \times T \times \eta_c \times \eta_p \times \eta_M \times 550}$$

$$\text{Say } \eta_{\text{overall}} = \eta_c \times \eta_p \times \eta_M$$

$$e. \quad \text{Then } \eta_{\text{overall}} = \frac{acfm \times .373 \times P \times HEAD \times .746}{kW \times 60 \times T \times 550}$$

$$f. \quad \text{Also temperature } T = \frac{acfm \times .373 \times P \times HEAD \times .746}{kW \times 60 \times \eta_o \times 550}$$

Using the mean value of η_o defined by the single approximated curve and from the compressor characteristic curve of head versus acfm and using equation no. 6 values of temperature versus acfm are calculated for each speed line by selecting values of acfm which best fit the characteristic. About five or six values are sufficient. By substituting various values of P discharge i.e. 1500, 1300, 1100, 900, 700 psi a family of curves is constructed comprising speed lines of 1.0, .9, .8, .7 and .6 times rpm for each selected value of discharge pressure. These curves are shown in Figures A5-2 through A5-6 on pages A5-7 through A5-11.

By reading horizontally at constant values of discharge temperature, lines of constant temperature versus speed versus acfm can be drawn on the generalized compressor map, as shown in Figures A5-7 through A5-11 on pages A5-12 through A5-16.

Similarly a family of curves can be made for the condition $kW \propto \text{rpm}^3$ which is the condition actually encountered during the compressor test. Values of actual test kW input versus calculated compressor power are shown for references as follows:

$$\text{POWER INPUT } kW \propto N^3 \text{ (COMPRESSOR DEMAND)}$$

		CALCULATED VALUE	TEST VALUE
kW at 21,150 rpm	=		177.7
kW at 23,500 rpm	=	$\left(\frac{23,500}{21,150}\right)^3 \times 177.7$	= 243.75

kW at 18,800 rpm	=	$\left(\frac{18,800}{21,150}\right)^3$	x 177.7	=	124.8	
kW at 16,450 rpm	=	$\left(\frac{16,450}{21,150}\right)^3$	x 177.7	=	83.61	
kW at 14,100 rpm	=	$\left(\frac{14,100}{21,150}\right)^3$	x 177.7	=	52.65	52.0
kW at 11,750 rpm	=	$\left(\frac{11,750}{21,150}\right)^3$	x 177.7	=	30.47	
kW at 9,400 rpm	=	$\left(\frac{9,400}{21,150}\right)^3$	x 177.7	=	15.6	
kW at 7,050 rpm	=	$\left(\frac{7,050}{21,150}\right)^3$	x 177.7	=	6.58	7.47
kW at 4,700 rpm	=	$\left(\frac{4,700}{21,150}\right)^3$	x 177.7	=	1.95	
kW at 3,000 rpm	=	$\left(\frac{3,000}{21,150}\right)^3$	x 177.7	=	.51	.82

This family of curves is attached as Figures A5-12 through A5-16, and A5-17 through A5-21 on pages A5-18 through A5-26.

Fig. A5-1 Helium Circulator Overall Efficiency versus Speed

792089

Fig. A5-2 Helium Circulator - CFTL Loop
(kW $\propto$ rpm, 1500 psi)

Fig. A5-3 Helium Circulator - CFTL Loop
(kW $\propto$ rpm, 1300 psi)

Fig. A5-4 Helium Circulator - CFTL Loop
(kW $\propto$ rpm, 1100 psi)

792099

Fig. A5-5 Helium Circulator - CFTL Loop
(kW $\propto$ rpm, 900 psi)

792098

Fig. A5-6 Helium Circulator - CFTL Loop
(kW $\propto$ rpm, 700 psi)

POWER LIMITING CURVES

Helium Circulator Performance - CFTL Loop
Each Circulator

Fig. A5-7 kW Input Versus Discharge Temperature °F
(kW = rpm, 1500 psi Discharge Pressure)

POWER LIMITING CURVES

Helium Circulator Performance - CFTL Loop
Each Circulator

Fig. A5-8 kW Input Versus Discharge Temperature °F
(kW = rpm, 1300 psi Discharge Pressure)

POWER LIMITING CURVES

Helium Circulator Performance - CFTL Loop
Each Circulator

Fig. A5-9 kW Input Versus Discharge Temperature °F
(kW = rpm, 1100 psi Discharge Pressure)

POWER LIMITING CURVES

Helium Circulator Performance - CFTL Loop
Each Circulator

Fig. A5-10 kW Input Versus Discharge Temperature °F
(kW = rpm, 900 psi Discharge Pressure)

POWER LIMITING CURVES

Helium Circulator Performance - CFTL Loop
Each Circulator

Fig. A5-11 kW Input Versus Discharge Temperature °F
(kW = rpm, 700 psi Discharge Pressure)

Fig. A5-12 Helium Circulator - CFTL Loop
(kW $\propto$ rpm³, 1500 psi)

Fig. A5-13 Helium Circulator - CFTL Loop
(kW $\propto$ rpm³, 1300 psi)

Fig. A5-14 Helium Circulator - CFTL Loop
(kW $\propto$ rpm³, 1100 psi)

Fig. A5-15 Helium Circulator - CFTL Loop
(kW $\propto$ rpm³, 900 psi)

Fig. A5-16 Helium Circulator - CFTL Loop
(kW $\propto$ rpm³, 700 psi)

POWER LIMITING CURVES
Helium Circulator Performance - CFTL Loop
Each Circulator

Fig. A5-17 kW Input versus Discharge Temperature °F
(kW $\propto$ rpm³, 1500-psi Discharge Pressure)

POWER LIMITING CURVES

Helium Circulator Performance - CFTL Loop
Each Circulator

Fig. A5-18 kW Input Versus Discharge Temperature °F
(kW = rpm³, 1300 psi Discharge Pressure)

POWER LIMITING CURVES

Helium Circulator Performance - CFTL Loop
Each Circulator

Fig. A5-19 kW Input Versus Discharge Temperature °F
(kW $\propto$ rpm³, 1100 psi Discharge Pressure)

POWER LIMITING CURVES

Helium Circulator Performance - CFTL Loop
Each Circulator

Fig. A5-20 kW Input Versus Discharge Temperature °F
(kW = rpm³, 900 psi Discharge Pressure)

POWER LIMITING CURVES

Helium Circulator Performance - CFTL Loop
Each Circulator

Fig. A5-21 kW Input Versus Discharge Temperature °F
(kW $\propto$ rpm, 700 psi Discharge Pressure)

APPENDIX 6

TEST SHEETS

FEB 26 to Feb 26

Nitrogen

TIME	2-26	3-16											24	26	28	
RUN NO	1	2		3	4	5	6		7	8	9	10		11	12	13
SPEED RPM	12000	12000		11758	11760	11751	11752		18812	18807	18803	?		21148	21147	21145
MOTOR AMPS	90					92	90		140	140	120	125		180	150	212
MOTOR VOLTS	290					273	273		400	400	400	400		395	400	399
POWER FACTOR	1.2	2.0				1.58	1.58		3.12	3.15	3.15	3.15		3.50	3.52	3.50
MOTOR WATTS	766	26		2												
THRUST FILM MILS												14.6				
THRUST FILM MILS																
THRUST FILM MILS																
COMP BEARING MILS																
FAN BEARING MILS																
COOLING WATER FLOW RATE																
AP PSIG CIRC	6.0	6.0		6.5	6.5	6.6	6.6		15.44	15.6	15.9	15.7		18.5	19.0	19.3
AP PSIG CIRC				6.25	6.3	6.5	6.4		15.22	15.4	15.7	15.5				
AP PSIG CIRC				6.25	6.3	6.4	6.3		15.2	15.4	15.8	15.5				
AP PSIG CIRC				6.5	6.5	6.6	6.6		15.5	15.7	16.1	15.7		18.7	19.0	
P ₁ INLET PSIG	42	44	4	47	48	49	50		52	57.0	60.0	63.0		55	58	47
P ₂ INLET PSIG	46	49		45	51	52	53		55	60.0	64.0	66.0		58	60	
P ₃ INLET PSIG	42	44		47	48	48	49		52	56.0	58.0	62.0		54	55	
P ₄ INLET PSIG	46	44		48	49	49	50		53	57.0	60.0	63.0		56	59	
P OUTLET PSIG																
P OUTLET PSIG																
P OUTLET PSIG																
P ₅ ORIFICE PSIG	44	46		49	51	52	53		53	69.0	72.0	75.0		70	72	62
P ₆ ORIFICE PSIG	48	49		53	56	56	57		67	73.0	76.0	79.0		72	76	
AP ORIFICE "W.G."	41.5	47.5		53	43.3	34.6	25.2		12.5	112	81	62		148	70	192
AP ORIFICE "W.G."				53	43.5	33.5	25.8		12.5	108	80	61		145	68	
AP I-V PSI	400	31.0		33	35	40	40		49.2	51	54.8	55.8		46	53	
1 COMP TEMP IN °F	119.3			100.5	116.5	127.9	136.0		220.9	268.9	296.7	327.7		285.5	321.8	
2 COMP TEMP IN °F	120.2			101.9	117.7				220.6							
3 COMP TEMP IN °F	120.6			102.3	117.9				225.3							
4 COMP TEMP IN °F	120.7			102.3	118.0				225.5							
5 COMP TEMP OUT °F	133.7			116.0	131.2	142.4	150.7		259.1	304.4	332.8	361.8		332.8	365.2	
6 COMP TEMP OUT °F	134.4			116.4	131.7				260.8							
7 COMP TEMP OUT °F	134.4			116.4	131.6				261							
8 COMP TEMP OUT °F	134.6			116.6	131.9				261.8							
9 MOTOR WINDINGS °F	88.2			92.4	95.2	96.4	97.6		136.9	144.6	165.1	164		141.9	155.5	
10 MOTOR WINDINGS °F	85.3			89.2	91.9				129.9							
11 MOTOR WINDINGS °F	86.2			90.5	93.1				131.5							
12 THRUST °F	74.3			75.9	77.2	78.2	78.6		98.8	102.9	106.9	110.9		105	113	
13 FAN BEARING °F	87.5			90.8	93.4	94.8	95.9		135.0	145.5	157.8	158.2		146.8	160.5	
14 COMP BEARING °F	98.3			101.6	104.5	105.8	106.8		153	163.5	168.7	174.1		165.4	179.7	
15 T ORIFICE °F	124.1			106.5	122.3	122.6	121.6		238.9	255.1	312.2	341.4		305.7	338.9	
16 T ORIFICE °F	125.2			106.7	122.4				239.4					306	340.5	
17 T ORIFICE °F	125.3			106.8	122.5				239.7					306	341.1	
18 T ORIFICE °F	125.4			106.8	122.6				240					306	341.5	
19 H ₂ O IN °F	39.3			40.1	60.0	39.9	60.0		60	60	60	60		40	40	
20 H ₂ O OUT °F	44.1			47.3	61.6	65.7	65.7		50	51.4	52.1	53.1		50.3	52.3	
COMP TEMP IN °F ①	123.3	161.6		104.2	119.3	129.8	137.6		230.6	276.2	302.5	332.6		230	155.4	
COMP TEMP OUT °F 2	136.8	155		117.9	132.5	143.0	151.1		264.5	305.9	337.0	367.3		376	201.5	
T ORIFICE °F 3	127.0	145.4		107.8	123.0	133.6	141.5		2110.8	286.2	312.9	342.9		343	169.3	
21 TEMP INLET DOME 12 O'C				96.3	109.8											
22 TEMP INLET DOME 3 O'C				97.5	110.7											
23 TEMP M.D. VESSEL 12 O'C				97.3	77.9											
24 TEMP M.D. VESSEL 3 O'C				76.7	77.0											
25 TEMP VESSEL FLANGE 12 O'C				72.5	72.5											
26 TEMP VESSEL FLANGE 3 O'C				71.8	71.9											
27 TEMP BLIND FLANGE 12 O'C				72.0	71.9											
28 TEMP BLIND FLANGE 3 O'C				71.7	71.7											

Släkt

TIME	8:25	9:05	9:25	9:45	9:50
RUN NO	14	15	—	—	—
SPEED RPM	21604	21628	21656	21601	21601
MOTOR AMPS	235	225	192	260	260
MOTOR VOLTS	435	445	448	435	435
POWER FACTOR HZ	365	365	368		
MOTOR WATTS KW	143	137	106.9	160	160
THRUST FILM MILS	1.0	1.5	1.1		
THRUST FILM MILS	1.0	1.5	1.1		
THRUST FILM MILS	1.0	1.5	1.1		
COMP BEARING MILS <i>on li</i>	3 ¹⁰	3 ¹⁰	3 ¹⁰		
FAN BEARING MILS	3 ¹⁰	3 ¹⁰	3 ¹⁰		
COOLING WATER FLOW RATE	7	12	12		
ΔP PSIG CIRC	27	25	27.8	29.0	29.0
ΔP PSIG CIRC	27	25	28.0		
ΔP PSIG CIRC	27	25	27.9		
ΔP PSIG CIRC	27	25	28.2		
P INLET PSIG	712	1015	1080	1270	1272
P INLET PSIG	714	1020	1083		
P INLET PSIG	716	1019	1002		
P INLET PSIG	717	1019	100.3		
P OUTLET PSIG					
P OUTLET PSIG					
P OUTLET PSIG					
P OUTLET PSIG					
P ORIFICE PSIG	744	1020	1024	1296	1300
P ORIFICE PSIG	744	1038	1030		1300
ΔP ORIFICE "W.G."	300	270	126	325	320
ΔP ORIFICE "W.G."	290	270	125		320
ΔP I-V PSI	73	15	36	20	20
COMP TEMP IN °F	247	594.4	551.3	633	650
COMP TEMP IN °F					
COMP TEMP IN °F					
COMP TEMP IN °F					
COMP TEMP OUT °F	257.3	601.9	561.6	662	
COMP TEMP OUT °F					
COMP TEMP OUT °F					
COMP TEMP OUT °F					
MOTOR WINDINGS °F	124.2	190.6	199.2	222	226
MOTOR WINDINGS °F					
MOTOR WINDINGS °F					
THRUST °F	92	119	124.6		
FAN BEARING °F	124	192.4	201.6		
COMP BEARING °F	131	192.4	205.7		
T ORIFICE °F				651	
T ORIFICE °F					
T ORIFICE °F	276	603	546.1		
T ORIFICE °F	277	604	554.9		
H ₂ O IN °F	46	32.8	39.3		
H ₂ O OUT °F	57.7	60.9	61.1		
COMP TEMP IN °F	247	605.6	546.4	652	650
COMP TEMP OUT °F	258	612.3	558.1	665	666
T ORIFICE °F	277	607.0	544.3	654	650
TEMP INLET DOME 12 0°C					
TEMP INLET DOME 3 0°C					
TEMP M.D. VESSEL 12 0°C					
TEMP M.D. VESSEL 3 0°C					
TEMP VESSEL FLANGE 12 0°C					
TEMP VESSEL FLANGE 3 0°C					
TEMP BLIND FLANGE 12 0°C					
TEMP BLIND FLANGE 3 0°C					

TIME	10:50	11:05	11:20	11:45	12:05	12:22	12:45	13:00	13:10	13:22	13:35	13:45	14:00	14:10	14:22	14:35	14:45
RUN NO	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
SPEED RPM	21140	10608	8316	21128	21149	10619	8319	20185	20219	10616	8316	8310	10611				
MOTOR AMPS	252	102	88		197	93	83	273	214	98	86	83	103				
MOTOR VOLTS	436	182	136		442	192	138	396	399	182	138	135	190				
POWER FACTOR	42	358	182	140	358	184	147	342	342	183	145	192	178				
MOTOR WATTS KW	152	19.7	9.5		115	15.2	7.2	152.1	118.4	17.7	8.5	10.7	22.1				
THRUST FILM MILS	1.1	1.1	8/10		1/2	.8	3/4	.85	1/2	3/4	3/4	3/4	3/4				
THRUST FILM MILS	1.1	1.1	8/10		1/2	.8	3/4	.85	1/2	3/4	3/4	3/4	3/4				
THRUST FILM MILS	1.1	1.1	8/10		.8	.8	3/4	.85	3/4	.85	3/4	3/4	3/4				
COMP BEARING MILS	1.5	.006	1.2		1.5	7/10	.5	1.5	1.5	1.7	.5	.5	3/4				
FAN BEARING MILS	2	—	—		—	1.1	7/10	2	2	1.0	.75	.7	.8				
COOLING WATER FLOW RATE	13	13	13		13	13	13	15	15	15	15	15	15				
1	AP PSIG CIRC	28	7.2	4.5		31	8	5	29.3	32.6	9.2	5.6	5.1	5.2			
2	AP PSIG CIRC	28.2	7.1	4.3		31.2	7.7	4.8	29.5	33	9.0	5.5	4.9	8.1			
3	AP PSIG CIRC	28.2	7.1	4.2		31.1	7.7	4.8	29.4	32.8	9.0	5.5	4.9	8.1			
4	AP PSIG CIRC	28.3	7.3	4.5		31.3	8.0	5	29.6	33.1	9.2	5.7	5.1	8.2			
1	P INLET PSIG	1271	1224	1186		1272	1238	1205	1472	1457	1444	1373	1361	1334			
2	P INLET PSIG	1276	1225	1188	1260	1278	1240	1208	1476	1461	1445	1396	1362	1336			
3	P INLET PSIG	1273	1227	1188		1276	1240	1208	1474	1461	1445	1396	1363	1338			
4	P INLET PSIG	1274	1226	1188		1276	1240	1208	1476	1462	1445	1396	1362	1337			
	P OUTLET PSIG	113	110	104		111	107	104	134	133	124	117	111	106			
	P OUTLET PSIG	199	151	125		199	150	135	220	212	170	150	140	135			
	P OUTLET PSIG																
	P OUTLET PSIG																
5	P ORIFICE PSIG	1298	1228	1189		1303	1248	1208	1497	1489	1449	1396	1362	1338			
6	P ORIFICE PSIG	1300	1238	1195		1309	1249	1215	1504	1496	1456	1403	1369	1347			
7	AP ORIFICE "W.G."	304	77	44.7	123	136	32.3	20.0	32.2	160	388	258	53.0	86			
8	AP ORIFICE "W.G."	301	74	44.8	123	135	32.5	20.0	319	158	390	240	52.0	87			
9	AP I-V PSI	110	30.8	21.0		110	43.2	28.2	110	110	64.8	40.2	36.2	68.5			
1	COMP TEMP IN °F	638.6	584.7	555.6		642.9	605.2	580.0	644.1	640.0	617.5	586.6	561.0	536.3			
2	COMP TEMP IN °F	638.9	583.8	554.5		642.1	604.0	578.8	643.9	640.6	616.5	584.3	560.2	537.7			
3	COMP TEMP IN °F	638.3	583.5	553.7		641.4	603.6	578.2	643.8	640.9	614.5	584.0	559.3	537.5			
4	COMP TEMP IN °F	638.9	583.4	553.3		641.1	603.4	577.9	643.7	641.0	614.2	583.5	559.0	537.2			
5	COMP TEMP OUT °F	646.5	583.1	551.6		647.4	601.6	574.8	650.6	646.4	612.9	580.4	556.9	536.0			
6	COMP TEMP OUT °F	647.4	583.7	552.0		647.9	602.1	575.3	651.5	647.7	613.3	580.9	557.4	536.4			
7	COMP TEMP OUT °F	648.0	586.2	552.6		648.3	602.8	575.8	652.3	648.8	613.9	581.5	557.8	537.0			
8	COMP TEMP OUT °F	647.4	583.4	551.5		647.3	601.8	574.8	651.5	648.5	612.9	580.4	556.9	536.2			
9	MOTOR WINDINGS °F	236.9	185.0	156.7		248.4	193.3	168.6	277.4	269.0	237.4	184.7	170.1	169.2			
10	MOTOR WINDINGS °F	234.0	181.3	153.2		246.0	189.8	165.2	269.2	263.4	213.3	180.8	166.4	165.8			
11	MOTOR WINDINGS °F	235.2	181.3	153.1		246.6	189.7	165.1	270.8	266.2	213.2	180.6	166.5	166.4			
12	THRUST °F	149.3	120.5	102.2		159.8	129.8	119.6	169.2	168.0	141.9	125.3	122.2	124.8			
13	FAN BEARING °F	238.6	186.5	160.0		252.8	195.9	172.4	273.5	271.3	218.8	187.8	173.6	172.2			
14	COMP BEARING °F	242.8	185.3	157.9		255.2	194.3	169.8	276.4	273.1	216.8	185.1	170.9	170.4			
15	T ORIFICE °F	—	—	—		—	—	—	—	—	809	—	—	534.8			
16	T ORIFICE °F	638.4	583.9	549.0		635.2	599.5	573.3	643.6	647.4	605.4	578.5	555.2	534.5			
17	T ORIFICE °F	639.0	580.3	549.4		635.5	599.9	573.7	644.4	648.3	605.6	578.9	555.6	535.1			
18	T ORIFICE °F	638.9	580	549.0		635.0	599.5	573.3	644.2	648.1	605.5	578.6	555.2	534.7			
19	H ₂ O IN °F	39.3	39.3	39.6		39.1	39.2	39.2	39.7	39.1	39.1	40.1	39.7	40.1			
20	H ₂ O OUT °F	67.0	56.3	52.8		67.6	56.9	53.4	67.6	67.1	57.2	54.7	52.9	53.9			
21	COMP TEMP IN °F	640.1	580.7	550.4		636.6	601.5	575.6	646.0	650.3	607.2	580.8	556.9	536.1			
22	COMP TEMP OUT °F	648.8	580.6	548.8	638	644.2	600.0	572.2	653.4	655.6	605.7	578.0	554.9	535.0			
23	T ORIFICE °F	639.1	578.9	548.2		634.1	599.0	572.8	644.9	650.3	604.8	578.1	554.7	534.5			
24	TEMP INLET DOME 12 °C	622.9	571.5	539.6		621.5	589.5	564.9	626.4	620.3	595.9	569.6	544.4	521.4			
25	TEMP INLET DOME 3 °C	644.8	590.8	557.7		643.4	609.7	584.2	649.0	649.1	616.6	587.5	563.2	539.3			
26	TEMP M.D. VESSEL 12 °C	141.7	132.8	123.5		148.7	139.6	131.2	160.8	160.8	148.5	139.4	131.9	126.8			
27	TEMP M.D. VESSEL 3 °C	216.6	204.1	180.0		231.1	216.4	195.5	260.1	261.0	238.2	214.7	194.5	180.0			
28	TEMP VESSEL FLANGE 12 °C	140.3	158.9	159.4		167.7	179.9	178.4	213.0	216.1	210.5	201.4	187.6	175.0			
29	TEMP VESSEL FLANGE 3 °C	139.9	158.9	158.7		166.1	179.0	177.1	210.4	213.3	214.5	208.0	197.6	184.2			
30	TEMP BLIND FLANGE 12 °C	92.9	106.2	114.2		125.9	133.3	137.1	162.3	162.3	162.4	169.8	168.6	164.6			
31	TEMP BLIND FLANGE 3 °C	99.0	115.4	124.8		138.0	147.2	151.4	182.1	187.3	191.1	191.9	190.2	196.0			

TIME	1515	1530	1545	1600	1615	1630	1645	1650	1655	1700	1705	1710	1715	1720	1725	1730	1735	1740	1745	1750	1755	1800	1805	1810	1815	1820	1825	1830	1835	1840	1845	1850	1855
RUN NO	29	30	31	32	33	34	35	36	37	38	39	40	41	42																			
SPEED RPM	HEAT	SOAK			WATER	ON		14.8	GPM																								
MOTOR AMPS																																	
MOTOR VOLTS																																	
POWER FACTOR																																	
MOTOR WATTS																																	
THRUST FILM MILS																																	
THRUST FILM MILS																																	
THRUST FILM MILS																																	
COMP BEARING MILS																																	
FAN BEARING MILS																																	
COOLING WATER FLOW RATE																																	
AP PSIG CIRC																																	
AP PSIG CIRC																																	
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P ORIFICE PSIG																																	
AP ORIFICE "W.G."																																	
AP ORIFICE "W.G."																																	
AP I-V PST																																	
COMP TEMP IN °F																																	
COMP TEMP IN °F																																	
COMP TEMP IN °F																																	
COMP TEMP IN °F																																	
COMP TEMP OUT °F	649.3	587.4	543.1	515.4	492.9	646.7	563.7	526.4	502	483	470	455	440	426																			
COMP TEMP OUT °F	649.9	585.0	544.2	518.0	495.4	647.8	565.3	526.7	504	485	470	456	439	427																			
COMP TEMP OUT °F	650.5	587.2	544.5	518.0	495.0	648.8	565	526.7	504	486	477	456	441	428																			
COMP TEMP OUT °F	649.7	582.9	544.1	518.0	494.4	648.4	560	526.3	504	486	472	457	441	428																			
MOTOR WINDINGS °F	271.5	174.7	139.6	121.2	108.8	254.5	227.2	224	240	245	247.7	250	251.7	252.4																			
MOTOR WINDINGS °F	268.0	146.9	116.8	101.6	91.9	251.1	219.7	216.7	230	234	231	234.5	241	242																			
MOTOR WINDINGS °F	269.3	200.4	167.4	148.3	134.4	252.2	249.9	248.4	263	267	269	270.1	270.2	269.8																			
THRUST °F																																	
FAN BEARING °F																																	
COMP BEARING °F																																	
T ORIFICE °F																																	
T ORIFICE °F																																	
T ORIFICE °F																																	
T ORIFICE °F																																	
H ₂ O IN °F	39.1	38.9	39.0	38.7	39.8	38.8	46.3	53.6	58.6	62	65	68	70	72																			
H ₂ O OUT °F	67.6	45.1	44.0	43.1	43.5	65.4	178.9	158.9	113	93	85	80	78	79																			
COMP TEMP IN °F																																	
COMP TEMP OUT °F																																	
T ORIFICE °F																																	
TEMP INLET DOME 12 O'C	626.0	619.4	603.4	590.3	558.0	623.2	612.7	591	577	541	522	501	482	466																			
TEMP INLET DOME 3 O'C	649.0	637.9	614.5	583.8	549.8	646.2	629.8	599	570	542	521	500	479	463																			
TEMP M.D. VESSEL 12 O'C	158.2	155.3	152.5	149.2	144.0	150.1	159.2	167	171	174	175	174	173	172																			
TEMP M.D. VESSEL 3 O'C	247.7	231.1	205.9	182.3	162.4	228.3	224.8	224	226	228	229	231	231	232																			
TEMP VESSEL FLANGE 12 O'C	183.0	197.9	195.6	191.1	184.0	166.1	186.6	190.4	195	200	202	205	207	208																			
TEMP VESSEL FLANGE 3 O'C	184.7	194.3	192.0	185.6	176.3	170.8	181.4	182.1	182	184	185	186	188	189																			
TEMP BLIND FLANGE 12 O'C	156.2	158.0	158.0	156.3	152.8	146.1	148.3	154.1	160	167	172	177	180	182																			
TEMP BLIND FLANGE 3 O'C	175.4	177.6	178.7	176.8	172.1	161.8	164.7	166.7	168	169	170	172	173	175																			

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TIME	1325	1335	1345	1400	1410	1425	1440	1450	1500	1525	1535	1545	1605	1615	1630	17:00
RUN NO	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
SPEED RPM	21144	21151	21153	21156	14099	14093	14100	14100	7021	7059	7055	7060	3002	3000	3000	3000
MOTOR AMPS X300	91450	95560	78626	7250	52255	45196	41555	49605	33126	32165	32270	32637	44307	42418	43250	4357
MOTOR VOLTS X.72	596.7	596.0	601.4	600.9	356.9	255.6	255.0	256.6	177.9	177	177.4	177.7	97.6	99.2	100.0	101.5
POWER FACTOR	358	358	358	358	243	242	242	240	122	122	123	122	55	56	55	58
MOTOR WATTS KW	153.1	141.7	127.0	112.9	44.9	34.1	36.2	41.2	6.1	5.0	5.4	5.7	.7	.7	.7	.8
THRUST FILM MILS 0.6	.8	.75	.7	.6	.8	.65	.65	.75	.75	.7	.7	.75	.7	.65	.65	.7
THRUST FILM MILS	.8	3/4	.7	.6	.8	.65	.65	.75	.75	.7	3/4	.75	.7	.65	.65	.7
THRUST FILM MILS	.9	.85	.8	.8	.9	.75	.8	.8	.7	.65	.65	.7	.55	.5	.5	.5
COMP BEARING MILS	1.8	1.75	1.7	1.7	1.1	1.25	1.25	1.2	.75	.6	.6	.65	.3	.3	.35	.3
FAN BEARING MILS	2.0	2.0	2.0	2.0	1.4	1.4	1.45	1.45	.75	.75	.75	.75	.5	.5	.5	.5
COOLING WATER FLOW RATE	14	14	14	14	14	14	9	9	9	5	5	5	5	5	5	5
AP PSIG CIRC	28.2	29.8	30.3	30.9	12.6	14	14	12.4	3.2	3.5	3.6	3.5	.6	.7	.6	.6
AP PSIG CIRC	28.4	30.1	31.1	31.2	12.5	14.8	13.6	13.2	3.1	3.4	3.4	3.5	.6	.7	.5	.5
AP PSIG CIRC	28.2	29.9	30.9	31.0	12.5	14.8	13.3	13.2	3.1	3.6	3.5	3.5	.6	.7	.5	.5
AP PSIG CIRC	28.6	30.1	31.2	31.3	12.7	14.2	14.2	13.5	3.3	3.6	3.7	3.6	.7	.8	.6	.6
P INLET PSIG	125.9	128.2	128.6	128.6	128.1	128.3	128.9	128.8	127.4	127.2	131.8	131.9	131.0	130.8	130.5	129.9
P INLET PSIG	125.9	128.2	128.6	128.6	128.1	128.4	128.9	128.8	127.3	127.1	131.6	131.7	130.9	130.6	130.3	129.8
P INLET PSIG	129.2	129.4	129.9	129.7	128.3	128.6	129.1	129.0	127.4	127.2	132.0	132.0	131.2	131.0	130.6	130.0
P INLET PSIG	129.2	128.4	128.9	128.7	128.4	128.5	129.2	129.0	127.4	127.2	131.9	132.0	131.2	130.9	130.7	130.0
P-OUTLET PSIG		134	133	130	127	119	114	111	108	105	104	103	102	101	100	100
P-OUTLET PSIG Fan Thrust		2.11	2.10	2.00	1.80	1.60	1.65	1.65	1.50	1.55	1.55	1.55	1.55	1.55	1.60	1.55
P-OUTLET PSIG = $\Delta P + P_{ic}$																
P-OUTLET PSIG = $\Delta P + P_{ic}$																
P ORIFICE PSIG	131.8	131.2	131.1	131.6	129.4	129.9	130.5	130.2	127.8	127.5	132.1	132.2	131.2	131.0	130.6	130.1
P ORIFICE PSIG	131.7	131.2	131.9	131.7	129.4	129.9	130.4	130.2	127.9	127.5	132.3	132.2	131.2	131.0	130.6	130.0
AP ORIFICE "W.G."	307	232	189	128	133	60	73	102	31.6	13.4	17.6	25.2	5.8	4.2	1.45	.9
AP ORIFICE "W.G."	303	249	188	124	132	57	71	102	31.8	13.6	17.7	25.2	5.72	4.2	1.4	.83
AP - V PSI	87	97	102	100	36.2	54	60	52.8	17.5	21	20.2	19	4.5	5.0	4.5	5.0
COMP TEMP IN °F	641.5	637.1	647.2	647.7	648.5	639.2	646.7	654.1	651.4	652.3	651.8	654.2	651.2	650.1	651.0	651.6
COMP TEMP IN °F	641.3	637.2	646.4	646.7	648.1	638.6	646.2	653.8	650.5	651.3	651.0	652.4	650.1	649.3	650.1	650.6
COMP TEMP IN °F	641.2	637.3	646.0	646.1	647.9	638.3	645.8	653.6	650.2	650.4	650.5	652.8	649.6	648.8	649.7	649.6
COMP TEMP IN °F	640.4	637.4	645.4	645.5	647.6	637.9	645.4	653.2	649.8	649.9	650.0	652.5	649.3	648.6	649.3	649.3
COMP TEMP OUT °F	650.1	646.4	653.9	654.1	649.0	637.8	645.4	653.4	646.1	644.4	645.0	648.1	642.9	641.6	639.7	638.2
COMP TEMP OUT °F	650.9	647.6	654.4	654.6	649.5	638.4	645.9	654.0	646.4	644.6	645.3	648.3	643.1	642.0	639.8	638.4
COMP TEMP OUT °F	651.5	648.7	655.0	655.0	650.3	639.1	646.6	654.7	647.1	645.2	646.1	649.0	643.9	642.5	640.5	639.1
COMP TEMP OUT °F	651.8	649.3	655.1	655.1	650.6	639.2	646.8	655.0	647.4	645.5	646.1	649.3	644.2	642.8	640.7	639.2
MOTOR WINDINGS °F	230.2	249.1	246.7	242.8	211.7	193.9	199.2	204.6	192.5	200.6	206.1	203.4	195.5	197.6	204.4	197.0
MOTOR WINDINGS °F	246.7	245.7	243.4	237.7	208.1	190.8	196.6	201.6	189.1	197.5	202.7	200.1	190.5	192.7	194.7	191.5
MOTOR WINDINGS °F	248.7	247.1	244.4	240.7	208.9	191.5	197.0	202.0	189.2	197.9	202.7	200.1	190.5	192.7	194.7	191.5
THRUST °F	153.9	153.3	152.7	153.3	140.2	133.9	139.9	140.9	136.1	136.1	143.0	141.8	136.2	136.5	137.7	136.4
FAN BEARING °F	250.2	249.9	248.2	245.2	213.4	196.9	202.3	206.7	199.7	201.6	206.1	204.8	196.8	198.9	200.7	198.0
COMP BEARING °F	254.1	253.5	254.4	248.0	219.2	196.3	201.8	205.4	193.0	200.0	204.7	202.4	196.5	198.9	200.4	197.6
T ORIFICE °F	640.5	643.9	642.3	640.3	646.9	639.5	643.8	651.9	646.2	644.0	644.8	649.3	645.3	645.1	645.1	645.3
T ORIFICE °F	640.5	644.5	642.1	639.9	646.7	635.1	643.6	651.8	645.9	645.1	644.5	648.0	645.0	644.8	644.7	644.9
T ORIFICE °F	641.8	646.4	649.7	649.1	648.0	636.3	644.9	653.1	647.0	644.1	645.5	649.1	646.1	646.1	645.9	646.1
T ORIFICE °F	641.0	645.8	640.6	639.7	647.3	635.4	643.9	652.2	646.1	641.0	644.2	648.0	645.1	645.0	644.8	645.1
H ₂ O IN °F	39.5	40.6	40.4	40.0	39.9	39.6	39.9	39.9	40.1	40.0	40.2	40.0	40.5	40.6	40.7	40.6
H ₂ O OUT °F	67.4	67.5	67.2	66.6	60.5	58.4	66.6	67.6	62.0	62.5	78.2	77.9	69.6	70.4	70.1	69.9
COMP TEMP IN °F	643.1	647.0	642.7	641.7	649.3	637.7	646.2	654.3	649.7	647.0	646.8	649.9	648.4	648.2	648.6	649.1
COMP TEMP OUT °F	652.4	653.2	651.9	650.8	650.8	637.9	646.1	654.7	645.2	642.1	641.7	645.8	642.0	640.8	638.0	635.9
T ORIFICE °F	641.9	646.1	640.8	638.3	638.1	636.0	644.6	653.0	646.2	644.4	643.8	647.3	645.3	645.2	645.0	645.1
TEMP INLET DOME 12 0'C	626.5	623.8	627.8	629.5	626.8	617.4	623.0	627.7	626.7	623.9	623.3	625.7	623.2	621.9	622.7	622.6
TEMP INLET DOME 3 0'C	649.1	646.7	650.3	651.9	649.3	639.4	645.3	650.0	649.2	646.0	645.4	647.9	645.2	644.1	645.0	644.9
TEMP M.D. VESSEL 12 0'C	154.7	155.4	155.3	154.5	148.7	139.9	139.6	140.2	138.6	139.9	140.9	141.1	138.7	138.0	139.6	139.2
TEMP M.D. VESSEL 3 0'C	239.2	240.0	239.0	236.8	227.7	203.6	200.9	201.0	198.7	198.9	200.1	200.8	197.3	194.3	197.3	196.9
TEMP VESSEL FLANGE 12 0'C	200.3	196.9	202.8	202.7	202.7	194.7	186.3	182.6	191.0	173.6	171.9	171.4	172.6	171.0	169.5	169.2
TEMP VESSEL FLANGE 3 0'C	199.5	201.9	202.9	203.5	201.7	193.2	185.8	182.4	190.1	172.6	170.8	171.1	171.1	167.5	167.6	167.3
TEMP BLIND FLANGE 12 0'C	154.6	160.6	162.5	163.9	165.3	164.4	161.9	160.2	158.0	153.9	150.2	149.0	148.3	146.9	146.0	144.8
TEMP BLIND FLANGE 3 0'C	172.0	179.3	181.7	184.2	185.4	185.1	181.9	180.1	177.9	172.7	168.6	166.9	165.5	164.5	162.9	161.6

TIME	09:15	09:30	09:45	10:00	10:10	10:20	10:35	10:45	10:55	11:10	11:25	11:45	11:55	12:10	12:20
RUN NO	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
SPEED RPM	2114.3	2114.7	2114.2	2113.0	14.105	14.124	14.090	14.078	2.055	2.058	2.068	3.000	3.020	3.025	3.000
MOTOR AMPS x300	69243	51932	72400	03364	58791	47754	50910	53761	33561	33179	32477	40304	31168	44069	44294
MOTOR VOLTS x.79	5944	5938	588.7	589.2	557.5	557.1	556.1	356.3	172.5	172.3	172.4	96.0	92.2	99.3	99.4
POWER FACTOR	355	358	358	358	241	241	241	241	124	121	121	52	52	52.0	52.0
MOTOR WATTS KW.	142.5	145.5	155.9	174.4	51.8	38.7	42.4	47.6	7.5	6.5	5.6	.7	.7	.8	.7
THRUST FILM MILS	1.6	1.5	.7	.75	.85	.7	.7	.75	.8	.75	.75	.75	.75	.75	.7
THRUST FILM MILS	.6	.65	.7	.75	.85	.7	.7	.75	.8	.75	.75	.75	.75	.75	.7
THRUST FILM MILS	.9	.95	1.0	1.0	.85	.8	.85	.9	.75	.75	.75	.7	.6	.6	.8
COMP BEARING MILS	1.6	1.5	1.5	1.5	1.0	1.0	1.0	1.1	.5	.4	.5	.3	.3	.35	.3
PAN BEARING MILS	2.0	2.0	2.0	2.0	1.5	1.4	1.4	1.4	.75	.7	.7	.3	.4	.4	.4
COOLING WATER FLOW RATE	15	15	15	15	5	5	5	5	5	5	5	5	5	5	5
1 AP PSIG CIRC	35.7	35.4	34.3	32.2	14.9	16.0	15.9	15.1	8.8	9.1	11.3	.9	.8	.9	.6
2 AP PSIG CIRC	36.1	35.7	34.5	32.4	14.9	16.0	15.9	15.1	3.8	4.0	4.0	.9	.8	.8	.5
3 AP PSIG CIRC	35.4	35.5	34.4	32.3	14.9	16.0	15.9	15.0	3.6	3.9	4.0	.8	.7	.7	.4
4 AP PSIG CIRC	36.2	35.7	34.6	32.5	15.0	16.1	16.1	15.3	3.9	3.9	4.3	1.0	.9	1.0	.8
1 P INLET PSIG	1480	1479	1484	1488	1500	1482	1489	1482	1471	1515	1514	1512	1501	1521	1508
2 P INLET PSIG	1490	1476	1493	1487	1499	1481	1498	1481	1477	1513	1512	1512	1501	1520	1506
3 P INLET PSIG	1482	1478	1485	1487	1502	1484	1490	1483	1479	1516	1515	1514	1503	1523	1509
4 P INLET PSIG	1481	1478	1484	1488	1502	1482	1489	1483	1480	1515	1515	1514	1503	1522	1509
P-OUTLET PSIG	109	113	117	122	119	115	111	109	106	103	102	102	101	101	101
P-OUTLET PSIG	185	195	205	185	175	180	185	182	175	180	180	180	180	180	180
P OUTLET PSIG															
P OUTLET PSIG															
5 P ORIFICE PSIG	1515	1512	1517	1519	1515	1500	1506	1498	1483	1520	1518	1515	1504	1524	1510
6 P ORIFICE PSIG	1516	1513	1518	1520	1516	1501	1505	1498	1482	1520	1519	1518	1508	1523	1510
7 AP ORIFICE "W.G." (1.6.5)	166	211	272	350	155	65	92	125	37.0	46.4	12.9	6.5	4.35	3.25	2.35
8 AP ORIFICE "W.G." (1.6.5)	163	209	272	350	155	60	90	125	37.0	46.5	13.0	6.6	4.39	3.20	2.3
9 AP I-V PSI	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1 COMP TEMP IN °F	633.8	644.8	645.8	645.9	651.2	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4
2 COMP TEMP IN °F	638.4	643.0	645.7	645.8	651.2	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4
3 COMP TEMP IN °F	638.0	642.8	645.5	645.7	651.2	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4
4 COMP TEMP IN °F	637.9	642.5	645.4	645.7	651.2	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4	647.4
5 COMP TEMP OUT °F	647.0	651.3	654.4	654.9	659.9	647.4	654.5	650.1	645.2	644.5	642.2	645.1	640.7	644.8	636.1
6 COMP TEMP OUT °F	647.6	651.8	654.8	655.5	659.6	647.4	655.0	650.6	645.5	644.7	642.4	645.4	641.0	644.9	636.3
7 COMP TEMP OUT °F	648.6	652.6	655.6	656.6	654.3	648.6	655.8	651.6	646.1	645.5	643.1	646.1	641.6	645.5	636.9
8 COMP TEMP OUT °F	649.0	652.9	656.0	656.9	654.6	649.9	656.2	651.9	646.5	645.6	643.1	646.2	642.0	646.0	637.2
9 MOTOR WINDINGS °F	236.5	242.4	248.0	253.0	257.1	218.0	218.5	210.5	199.5	205.4	209.8	204.1	198.8	204.1	187.8
10 MOTOR WINDINGS °F	234.8	240.6	245.6	250.2	254.6	210.9	216.1	208.5	196.4	202.3	206.7	199.9	191.7	195.7	183.4
11 MOTOR WINDINGS °F	235.6	241.7	246.7	251.8	256.0	211.2	216.5	209.0	196.0	202.5	206.6	200.7	192.8	196.6	184.7
12 THRUST °F	145.4	146.9	149.9	152.2	145.9	142.1	144.3	139.7	138.1	141.4	145.0	139.7	136.6	137.2	133.5
13 PAN BEARING °F	239.9	245.5	249.4	253.1	257.5	216.3	220.8	217.3	201.3	207.2	211.5	205.1	198.7	201.6	191.4
14 COMP BEARING °F	243.1	248.8	253.0	257.4	261.7	216.1	220.8	215.3	200.1	205.7	210.3	205.2	197.8	201.2	189.8
15 T ORIFICE °F	640.0	641.0	645.2	646.6	651.0	648.1	652.0	647.5	644.5	648.8	643.3	647.7	643.7	648.0	640.3
16 T ORIFICE °F	641.3	641.0	645.1	646.6	650.5	645.1	652.5	647.5	644.3	648.9	643.9	647.6	643.6	647.7	640.2
17 T ORIFICE °F	643.4	642.2	646.6	648.1	652.2	648.8	653.1	650.1	645.4	648.9	644.0	648.8	644.1	649.0	648.5
18 T ORIFICE °F	642.9	641.3	645.9	647.4	651.1	648.8	653.2	648.3	644.5	648.9	643.0	647.8	643.7	647.7	640.9
19 H ₂ O IN °F	39.7	39.7	39.8	39.8	39.9	40.1	40.2	40.3	40.2	40.3	40.3	40.2	40.2	40.0	40.1
20 H ₂ O OUT °F	65.0	65.4	66.0	66.4	66.8	67.4	67.8	68.2	68.7	69.1	69.5	69.9	70.3	70.7	71.1
1 COMP TEMP IN °F	644.9	644.1	647.6	649.2	653.1	649.5	655.1	651.2	647.9	643.4	645.9	650.5	647.2	651.2	644.9
2 COMP TEMP OUT °F	652.2	652.1	656.6	658.5	662.6	649.1	655.6	652.3	644.1	639.6	640.6	644.5	640.4	644.9	635.7
3 T ORIFICE °F	644.8	641.6	646.5	648.3	651.9	645.9	653.7	651.1	644.4	640.9	643.0	647.8	644.0	647.9	640.8
21 TEMP INLET DOME 12 °C	64.67	62.68	62.88	63.08	62.68	62.61	62.90	62.69	62.67	62.33	62.23	62.45	62.39	62.64	62.24
22 TEMP INLET DOME 3 °C	64.96	64.96	65.17	65.37	64.96	64.96	65.18	64.96	64.91	64.91	64.91	64.91	64.91	64.91	64.91
23 TEMP M.D. VESSEL 12 °C	144.1	147.9	150.2	152.5	147.5	142.5	143.0	142.0	140.1	139.7	142.1	140.0	138.9	139.2	138.9
24 TEMP M.D. VESSEL 3 °C	222.1	230.7	235.5	237.2	229.8	220.0	215.9	213.0	209.1	203.8	207.9	202.7	199.5	200.1	197.6
25 TEMP VESSEL FLANGE 12 °C	166.7	170.9	178.6	184.4	191.4	190.3	183.8	182.4	182.4	178.9	176.0	176.3	175.6	174.5	174.2
26 TEMP VESSEL FLANGE 3 °C	60.2	70.2	78.0	83.6	91.4	100.2	107.2	116.3	124.4	129.7	135.8	141.5	147.5	153.0	157.8
27 TEMP BLIND FLANGE 12 °C	68.6	115.8	122.6	127.9	132.9	142.5	147.4	148.6	150.3	151.2	150.2	149.9	149.2	147.2	148.9
28 TEMP BLIND FLANGE 3 °C	118.1	127.7	135.8	142.3	151.8	159.5	164.6	166.2	167.2	168.2	167.6	167.0	166.5	165.3	164.7

TIME	14:00	15:00	16:00	16:50	17:50
RUN NO	86	87	88	89	
SPEED RPM	2,148	11,750	3,000	3,000	
MOTOR AMPS $\times 300$	4,009.6	5,367.8	4,712.0	4,832.2	
MOTOR VOLTS $\times .78$	589.5	320.1	105.0	105.9	
POWER FACTOR $\times .72$	357	200.0	59.0	55	
MOTOR WATTS KW	7.9	2.7	.7	.8	
THRUST FILM MILS $\times .3$	1.3	1.5	.75	.7	
THRUST FILM MILS	1.5	1.7	.8	.8	
THRUST FILM MILS	1.35	1.7	.5	.5	
COMP BEARING MILS	.9	.5	.3	.3	
FAN BEARING MILS	1.7	1.3	.9	.8	
COOLING WATER FLOW RATE	72	62	62	62	
AP PSIG CIRC	4	.2	.1	-	
AP PSIG CIRC	4	.1	.1	-	
AP PSIG CIRC	3	.1	.1	-	
AP PSIG CIRC	4	.2	.1	-	
P INLET PSIG	10	1	2	2	
P INLET PSIG	20	1	1	1	
P INLET PSIG	1.0	1	2	1	
P INLET PSIG	3	2	2	2	
P OUTLET PSIG	102	99	95	94	
P OUTLET PSIG	155	170	120	125	
P OUTLET PSIG					
P OUTLET PSIG					
P ORIFICE PSIG	2	2	2	1	
P ORIFICE PSIG	2	1	1	1	
AP ORIFICE "W.G."	3.35	1.1	.09	.1	
AP ORIFICE "W.G."	3.32	1.0	.09	.1	
AP I-V PSI	1	.5	-	-	
COMP TEMP IN °F	642.9	572.5	575.6	576.2	
COMP TEMP IN °F	640.6	562.4	525.8	517.2	
COMP TEMP IN °F	639.7	566.2	524.3	515.2	
COMP TEMP IN °F	640.1	566.9	526.2	518.0	
COMP TEMP OUT °F	630.0	567.1	514.2	484.5	
COMP TEMP OUT °F	629.9	565.5	512.3	484.1	
COMP TEMP OUT °F	630.8	566.8	515.9	487.2	
COMP TEMP OUT °F	631.4	567.9	515.5	488.2	
MOTOR WINDINGS °F	216.9	220.5	165.6	141.8	
MOTOR WINDINGS °F	207.5	212.0	163.9	137.8	
MOTOR WINDINGS °F	206.6	210.3	165.6	132.5	
THRUST °F	139.9	121.3	104.2	96.8	
FAN BEARING °F	240.7	192.1	179.6	132.5	
COMP BEARING °F	244.8	261.1	194.3	188.0	
T ORIFICE °F	631.1	553.5	504.2	477.5	
T ORIFICE °F	630.7	553.2	503.9	477.7	
T ORIFICE °F	633.1	554.4	505.3	479.1	
T ORIFICE °F	631.4	553.9	505.0	477.6	
H ₂ O IN °F	41.0	41.3	41.3	41.3	
H ₂ O OUT °F	73.5	72.2	66.6	61.2	
COMP TEMP IN °F	641.0	568.9	528.9	519.8	
COMP TEMP OUT °F	631.4	566.5	515.4	485.6	
T ORIFICE °F	630.7	553.7	504.0	477.2	
TEMP INLET DOME 12 O'C	622.4	565.6	516.2	477.6	
TEMP INLET DOME 3 O'C	611.44	526.0	535.3	507.8	
TEMP M.D. VESSEL 12 O'C	147.9	133.8	124.3	112.4	
TEMP M.D. VESSEL 3 O'C	219.6	188.6	170.5	158.2	
TEMP VESSEL FLANGE 12 O'C	142.9	129.3	116.7	108.6	
TEMP VESSEL FLANGE 3 O'C	186.9	166.7	142.4	135.3	
TEMP BLIND FLANGE 12 O'C	149.9	145.4	131.2	120.5	
TEMP BLIND FLANGE 3 O'C	168.6	163.3	148.0	136.5	

TIME	09:25	09:55	10:25	10:55		11:15	11:45	12:15	12:45	13:15		14:20					
RUN NO	90	91	92	93		94	95	96	97	98		99	100				
SPEED RPM	21150	21150	21150	21150		21147	21149	21149	21142	21149		21154					
MOTOR AMPS $\times 300$	84715	84392	86098	85504		953	92288	92349	92150	90903							
MOTOR VOLTS $\times 70$	5458	593.4	592.9	596.0		591.6	591.4	589.2	589.7	590.2							
POWER FACTOR $\times 72$	358	358	355	350		360	350	360	360	360							
MOTOR WATTS KW	144.5	142.0	142.1	141.5		160.6	160.5	160.0	160.0	159.5		114.7	114.7				
THRUST FILM MILS 0.8	3/4	.75	.25	.75		.75	.75	.7	.7	.75							
THRUST FILM MILS	3/4	.75	.75	.75		.75	.75	.7	.75	.75							
THRUST FILM MILS	1.15	1.15	1.1	1.15		1.15	1.15	1.1	1.1	1.0							
COMP BEARING MILS	1.9	1.8	1.4	1.8		1.5	1.5	1.5	1.5	1.5							
FAN BEARING MILS	1.9	2.0	2.0	2.0		2.1	2.1	2.0	2.0	2.1							
COOLING WATER FLOW RATE	13	13	13	13		13	13	13	13	13							
AP PSIG CIRC	26.4	26.2	26.3	26.2		31.2	31.1	31.0	31.0	31.1		32					
AP PSIG CIRC	26.4	26.5	26.5	26.3		31.3	31.3	31.3	31.2	31.2							
AP PSIG CIRC	26.5	26.3	26.3	26.3		31.2	31.2	31.2	31.1	31.1							
AP PSIG CIRC	26.7	26.7	26.6	26.5		31.8	31.6	31.4	31.4	31.3							
P INLET PSIG	1296	1297	1286	1277		1509	1503	1508	1505	1498							
P INLET PSIG	1296	1300	1289	1280		1511	1505	1511	1509	1500							
P INLET PSIG	1297	1301	1290	1279		1511	1505	1510	1510	1501							
P INLET PSIG	1298	1301	1290	1280		1513	1505	1510	1510	1502							
P-OUTLET-PSIG CONDUNIT °F	109	119	125	139		135	140	144	146	147							
P-OUTLET-PSIG PRESS THRU °F	190	210	230	220		150	140	140	140	140							
P OUTLET PSIG																	
P OUTLET PSIG																	
P ORIFICE PSIG	1322	1326	1315	1304		1343	1536	1539	1540	1530							
P ORIFICE PSIG	1323	1326	1315	1304		1549	1536	1539	1542	1533							
AP ORIFICE "W.G."	283	283	285	280.2		310	303	306	305	305							
AP ORIFICE "W.G."	282	281	282	280.5		305	305	302	302	303							
AP I-V PSI	76	65.5	63	62		85	84	82	80.5	78							
COMP TEMP IN °F	7384	741.6	755.5	742.9		749.1	740.8	736.1	751.4	737.0							
COMP TEMP IN °F	739.9	741.0	750.6	749.9		748.8	740.5	736.0	751.0	736.8							
COMP TEMP IN °F	740.2	740.4	753.9	742.5		748.9	740.4	736.5	750.6	736.6							
COMP TEMP IN °F	740.6	740.1	753.1	742.0		748.1	740.1	736.8	750.2	736.3							
COMP TEMP OUT °F	747.9	748.6	764.7	752.3		757.7	749.9	745.7	758.1	745.1							
COMP TEMP OUT °F	748.9	749.1	760.3	755.8		758.9	749.4	747.1	758.7	745.7							
COMP TEMP OUT °F	750.3	742.9	760.3	756.4		757.9	750.4	748.9	759.3	746.7							
COMP TEMP OUT °F	750.7	742.9	760.2	756.6		758.0	750.5	749.9	759.4	746.9							
MOTOR WINDINGS °F	239.9	251.8	236.9	252.8		266.5	275.0	274.3	274.5	274.7							
MOTOR WINDINGS °F	237.9	250.2	234.3	255.0		263.7	272.2	271.2	271.4	271.5							
MOTOR WINDINGS °F	239.0	251.5	255.7	256.3		265.4	273.8	272.8	273.1	273.4							
THRUST °F	157.7	164.8	167.9	168.3		173.3	177.3	177.6	178.7	178.9							
FAN BEARING °F	243.1	255.3	239.4	259.7		248.1	276.0	275.0	275.4	275.3							
COMP BEARING °F	246.5	258.8	262.8	263.0		271.5	279.6	278.7	279.1	279.1							
T ORIFICE °F	743.8	725.5	744.3	742.5		745.9	738.4	747.9	745.6	734.4							
T ORIFICE °F	745.3	735.5	743.7	742.9		745.8	738.1	749.3	745.3	734.1							
T ORIFICE °F	746.4	736.8	744.7	742.6		746.7	739.3	753.9	746.4	735.5							
T ORIFICE °F	745.2	725.3	743.3	741.5		745.7	738.5	753.6	745.3	734.6							
H ₂ O IN °F	40.3	40.4	40.5	40.4		40.9	40.7	40.8	40.5	40.5							
H ₂ O OUT °F	68.1	68.9	70.4	70.3		73.0	74.3	74.0	74.0	73.9							
COMP TEMP IN °F	746.1	732.8	744.6	742.3		746.9	740.4	734.1	747.1	732.7		468.0					
COMP TEMP OUT °F	753.6	746.9	753.3	752.3		755.8	749.6	761.9	756.0	745.9		478.0					
T ORIFICE °F	743.2	735.7	741.9	741.2		745.2	738.7	751.9	745.2	735.2		462.2					
TEMP INLET DOME 12 O'C	716.8	722.4	728.8	724.0		722.3	724.3	722.4	726.2	719.4							
TEMP INLET DOME 3 O'C	713.8	722.9	754.2	749.5		752.5	750.5	749.9	753.0	745.9							
TEMP M.D. VESSEL 12 O'C	145.2	154.4	158.8	160.1		163.3	168.3	168.5	167.9	167.8							
TEMP M.D. VESSEL 3 O'C	223.4	232.5	248.7	250.2		253.7	264.7	264.4	264.3	264.9							
TEMP VESSEL FLANGE 12 O'C	117.1	132.9	151.6	150.4		159.2	166.0	167.9	170.1	170.7							
TEMP VESSEL FLANGE 3 O'C	145.3	180.1	198.2	200.6		210.1	217.9	223.2	225.5	225.5							
TEMP BLIND FLANGE 12 O'C	93.0	112.9	143.9	158.4		164.4	171.9	170.9	181.9	182.8							
TEMP BLIND FLANGE 3 O'C	100.7	131.9	159.6	176.7		154.1	182.2	192.0	195.3	196.9							

CIRCULATOR TEST

UNIT NO: 1

DATE: 26 MAR 197

START TIME: 8:35 AM

START 100 HR RUN.

(2)

TIME	0840	0900	0940	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	
RUN NO	101	102	103	104	105	106	107	108	109	110	111	112	113	114	
SPEED RPM	21,150	21,150	21,157	21,157	21,151	21,150	21,150	21,150	21,151	21,150	21,149	21,150	21,151	21,151	
MOTOR TEMPS CONDUNIT °F			121	123	139	144	145	145	146	146	147	144	145	145	
MOTOR TEMPS PAYS TRU °F			230	230	235	235	235	240	240	240	240	240	245	240	
POWER FACTOR															
MOTOR WATTS K.W.	146.3	140.4	155.2	154	152.2	152.0	154.0	153.9	151.6	152.6	153.8	152.0	153.0	153.5	
THRUST FILM MILS OUTRAMP	0.8	0.95	1.15	1.25	1.25	1.25	1.25	1.23	1.23	1.23	1.23	0.8	0.8	0.8	
THRUST FILM MILS	.7	.9	1.00	1.00	1.02	1.12	1.12	1.10	1.10	1.10	1.10	0.8	0.8	0.8	
THRUST FILM MILS	.7	.9	1.00	1.00	1.12	1.12	1.12	1.10	1.10	1.10	1.10	0.8	0.8	0.8	
COMP BEARING MILS	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.75	1.75	1.75	
FAN BEARING MILS	1.6	1.7	2.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.25	2.25	2.25	
COOLING WATER FLOW RATE	12	12	12	12	13	13	13	13	14	14	14	14	14	14	
AP PSIG CIRC	1	28.2	26.5	28.7	28.7	28.2	28.2	28.7	28.7	28.3	28.5	28.8	28.5	28.5	
AP PSIG CIRC															
AP PSIG CIRC															
AP PSIG CIRC															
P INLET PSIG	1	753	1015	1302	1304	1286	1285	1307	1300	1289	1289	1303	1284	1297	1302
P INLET PSIG															
P INLET PSIG															
P INLET PSIG															
P OUTLET PSIG															
P OUTLET PSIG															
P OUTLET PSIG															
P OUTLET PSIG															
P ORIFICE PSIG	5	808	1043	1333	1333	1315	1314	1336	1327	1317	1318	1330	1313	1324	1329
P ORIFICE PSIG															
AP ORIFICE "W.G."	7	310	287	312	312	310	315	315	312	307	310	312	307	308	310
AP ORIFICE "W.G."															
AP I-V PSI	11		77	75.0	70.0	68.5	63.0	67.0	62.5	63.0	64.0	74.0	72.0	71.7	
COMP TEMP IN °F															
COMP TEMP IN °F															
COMP TEMP IN °F															
COMP TEMP IN °F															
COMP TEMP OUT °F															
COMP TEMP OUT °F															
COMP TEMP OUT °F															
COMP TEMP OUT °F															
MOTOR WINDINGS °F	9	120	177.3	234.2	244.5	247.3	248.4	248.5	240.0	246.2	247.2	248.4	250.3	249.5	250.3
MOTOR WINDINGS °F	10	117.7	174.7	231.6	241.4	244.1	244.7	244.7	244.4	242.5	243.1	244.1	244.0	245.2	245.0
MOTOR WINDINGS °F	11	119	176.0	233.0	242.8	245.6	246.3	246.6	246.0	244.3	244.7	246.0	247.7	246.9	246.7
THRUST °F															
FAN BEARING °F															
COMP BEARING °F															
T ORIFICE °F															
T ORIFICE °F															
T ORIFICE °F															
T ORIFICE °F															
H ₂ O IN °F	19	41.3	40.9	41.0	41.1	41.3	41.0	41.2	41.3	42.0	41.8	41.0	42.0	42.0	42.0
H ₂ O OUT °F	20	51.3	59.7	68.3	70.0	70.1	69.8	68.4	68.4	68.3	68.2	67.9	69.2	69.0	68.8
COMP TEMP IN °F	1	244.5	505	644.2	645.4	642.0	641.6	641.2	640.3	639.4	640.9	643.9	642.9	645.4	645.8
COMP TEMP OUT °F	2	252.5	518	653.3	654.9	651.6	651.1	650.7	649.9	649.1	650.5	653.5	652.4	655.0	655.4
T ORIFICE °F	3	246.3	511	643.3	644.2	640.9	640.3	640.0	639.1	638.2	639.7	642.8	641.8	644.2	644.7
TEMP INLET DOME 12 0°C															
TEMP INLET DOME 3 0°C															
TEMP M.D. VESSEL 12 0°C															
TEMP M.D. VESSEL 3 0°C															
TEMP VESSEL FLANGE 12 0°C															
TEMP VESSEL FLANGE 3 0°C															
TEMP BLIND FLANGE 12 0°C															
TEMP BLIND FLANGE 3 0°C															

TOTAL RUN TIME 10 HRS 20 MIN

AT RATED LOAD

1st STOP
STARTSTOPPED & STARTED
17:05
Reset Scope 20:05
When Stopped

A6-13

(3)

TIME	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000			
RUN NO	126	127	128	129	130	131	132	133	134	135	136	137		2 nd Stop	
SPEED RPM	21,150	21,150	21,150	21,149	21,152	21,154	21,150	21,150	21,150	21,150	21,150	21,147		3 rd Stop	
MOTOR AMPS condenser F	144	145	146	145	146	144	144	145	137	141	141	142		2 nd Start	
MOTOR VOLTS phase 1	240	240	240	240	240	240	240	240	260	260	255	238			
POWER FACTOR									REPLACED TEMP. READ-OUT						
MOTOR WATTS	153.7	153.8	153.5	153.7	153.8	154.1	154.4	153.9	153.6	153.6	153.5	153.3		3 rd Stop	
THRUST FILM MILS condenser	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8		3 rd Start	
THRUST FILM MILS	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8		2 nd Stop	
THRUST FILM MILS	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8		2 nd Start	
COMP BEARING MILS	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.80		16.20	
FAN BEARING MILS	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25			
COOLING WATER FLOW RATE	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5			
AP PSIG CIRC	28.8	29.8	28.7	28.7	28.8	28.8	28.9	28.8	28.7	28.8	28.7	29.1			
AP PSIG CIRC															
AP PSIG CIRC															
AP PSIG CIRC															
P INLET PSIG	1300	1301	1300	1303	1303	1305	1308	1302	1300	1299	1298	1320			
P INLET PSIG															
P INLET PSIG															
P INLET PSIG															
P OUTLET PSIG															
P OUTLET PSIG															
P OUTLET PSIG															
P OUTLET PSIG															
P OUTLET PSIG															
P ORIFICE PSIG	5	1327	1329	1327	1331	1331	1334	1336	1331	1327	1327	1326	1327		
P ORIFICE PSIG															
AP ORIFICE "W.G."	7	312	313	312	313	313	315	314	312	312	312	312	315		
AP ORIFICE "W.G."															
AP I-V PSI	11	76.5	74.7	73.0	71.5	71.2	70.0	72.0	69.9	81.0	76.0	74.0	75.9		
COMP TEMP IN °F															
COMP TEMP IN °F															
COMP TEMP IN °F															
COMP TEMP IN °F															
COMP TEMP OUT °F															
COMP TEMP OUT °F															
COMP TEMP OUT °F															
COMP TEMP OUT °F															
MOTOR WINDINGS °F	9	250.5	250.2	250.3	249.5	240.7	248.5	248.9	248.6	247.5	249.5	249.4	250.9		
MOTOR WINDINGS °F	10	246.4	246.0	246.0	245.2	245.1	244.5	244.9	244.5	243.4	245.5	245.2	246.6		
MOTOR WINDINGS °F	11	248.1	247.8	247.6	246.7	246.6	246.0	246.6	246.2	245.1	247.1	247.0	248.2		
THRUST °F															
FAN BEARING °F															
COMP BEARING °F															
T ORIFICE °F															
T ORIFICE °F															
T ORIFICE °F															
T ORIFICE °F															
H ₂ O IN °F	19	41.1	40.6	41.2	40.5	40.7	40.9	41.5	40.7	40.7	41.6	41.5	41.6		
H ₂ O OUT °F	20	68.5	68.0	68.7	67.7	67.5	67.6	68.3	67.7	67.6	68.6	68.6	68.8		
COMP TEMP IN °F	1	641.4	642.4	643.7	642.7	643.8	642.3	642.2	641.3	640.0	641.0	640.9	643.7		
COMP TEMP OUT °F	2	650.9	651.9	653.3	652.2	653.3	651.8	651.7	650.9	649.5	650.4	650.4	653.2		
T ORIFICE °F	3	640.2	641.2	642.6	641.5	642.6	641.1	641.0	640.1	638.8	639.8	639.7	642.5		
TEMP INLET DOME 12 0'C															
TEMP INLET DOME 3 0'C															
TEMP M.D. VESSEL 12 0'C															
TEMP M.D. VESSEL 3 0'C															
TEMP VESSEL FLANGE 12 0'C															
TEMP VESSEL FLANGE 3 0'C															
TEMP BLIND FLANGE 12 0'C															
TEMP BLIND FLANGE 3 0'C															

TOTAL RUN TIME 34 HRS 20 MIN

(4)

TIME	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800						
RUN NO	138	139	140	141	142	143	144	145	146	147	148	149						
SPEED RPM	2150	2150	2147	2149	2145	2145	2144	2144	2144	2147	2148	2147						
MOTOR WATTS	143	143	143	143	141	142	141	141	141	141	141	142						
MOTOR WATTS PASS-THRU °F	260	260	260	260	260	260	260	260	260	260	260	260						
POWER FACTOR																		
MOTOR WATTS	153.5	151.2	152.0	151.6	151.2	151.4	151.9	151.1	152.2	154.2	151.9	151.8						
THRUST FILM MILS	.85	.85	.85	.85	.95	.85	.6	.6	.6	.6	.6	.6						
THRUST FILM MILS	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7						
THRUST FILM MILS	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7						
COMP BEARING MILS	1.8	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75						
FAN BEARING MILS	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1						
COOLING WATER FLOW RATE	13.5	14	14	14	14	14	14	14	14	14	14	14						
AP PSIG CIRC	28.7	28.3	28.8	28.5	28.2	28.4	28.4	28.4	28.3	28.8	28.8	28.5						
AP PSIG CIRC																		
AP PSIG CIRC																		
AP PSIG CIRC																		
P INLET PSIG	1299	1279	1301	1284	1300	1300	1302	1302	1300	1302	1301	1286						
P INLET PSIG																		
P INLET PSIG																		
P INLET PSIG																		
P OUTLET PSIG	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200						
P OUTLET PSIG	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200						
P OUTLET PSIG	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200						
P OUTLET PSIG	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200						
P ORIFICE PSIG	1318	1306	1314	1313	1317	1314	1328	1330	1328	1328	1330	1315						
P ORIFICE PSIG																		
AP ORIFICE "W.G." 7	312	307	313	308	312	312	312	312	312	313	313	307						
AP ORIFICE "W.G."																		
AP I-V PSI	72	70	70	68.5	69	69.5	68	65.5	67	66.5	66	65						
COMP TEMP IN °F																		
COMP TEMP IN °F																		
COMP TEMP IN °F																		
COMP TEMP IN °F																		
COMP TEMP OUT °F																		
COMP TEMP OUT °F																		
COMP TEMP OUT °F																		
COMP TEMP OUT °F																		
MOTOR WINDINGS °F	250.9	248.0	247.7	248.3	247.8	248.3	247.5	246.6	247.0	245.6	245.6	246.0						
MOTOR WINDINGS °F	245.6	243.0	242.9	243.4	243.6	243.3	243.2	241.3	241.8	241.3	241.4	241.6						
MOTOR WINDINGS °F	247.3	244.6	244.7	245.2	244.1	245.0	244.8	242.8	243.3	243.0	243.1	243.3						
THRUST °F																		
FAN BEARING °F																		
COMP BEARING °F																		
T ORIFICE °F																		
T ORIFICE °F																		
T ORIFICE °F																		
T ORIFICE °F																		
H ₂ O IN °F	41.5	41.6	41.5	41.4	41.1	41.4	41.3	41.2	41.1	41.2	41.2	41.1						
H ₂ O OUT °F	68.6	68.2	68.3	68.2	67.9	67.6	67.6	65.4	65.7	65.7	66.0	66.0						
COMP TEMP IN °F	641.0	641.0	640.3	640.1	639.0	641.5	642.5	641.7	641.3	639.6	640.8	642.1						
COMP TEMP OUT °F	650.6	650.6	649.9	649.7	648.6	651.0	652.2	649.2	650.9	649.1	650.3	651.7						
T ORIFICE °F	639.6	639.6	639.2	639.9	637.7	640.7	641.7	639.5	640.2	639.4	639.3	641.0						
TEMP INLET DOME 12 °C																		
TEMP INLET DOME 3 °C																		
TEMP M.D. VESSEL 12 °C																		
TEMP M.D. VESSEL 3 °C																		
TEMP VESSEL FLANGE 12 °C																		
TEMP VESSEL FLANGE 3 °C																		
TEMP BLIND FLANGE 12 °C																		
TEMP BLIND FLANGE 3 °C																		

TOTAL RUN TIME 46 HRS 20 MIN

(5)

UNIT NO:

DATE: 23 MAR 79

START TIME:

TIME	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	4TH STOP START
RUN NO	150	151	152	153	154	155	156	157	158	159	160	161	00805 HRS
SPEED RPM	21,149	21,151	21,149	21,152	21,152	21,150	21,150	21,149	21,151	21,151	21,149	21,150	RESET ZEROS
MOTOR AMPS	140	140	142	144	145	145	145	145	142	143	144	144	ON SCOPES
MOTOR VOLTS	260	260	265	265	265	265	265	260	260	260	260	265	#2 H ₂ SAMPLE
POWER FACTOR													@ 1310 HRS
MOTOR WATTS	153.8	153.6	153.9	153.8	151.6	152.8	153.1	151.4	152.0	152.6	152.8	153.5	
THRUST FILM MILS	0.90	0.90	0.90	0.90	0.90	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
THRUST FILM MILS	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	
THRUST FILM MILS	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	SWITCHED TO
COMP BEARING MILS	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	NEW H ₂ BOTTLE
FAN BEARING MILS	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	@ 1430 HRS
COOLING WATER FLOW RATE	14.5	15.0	14.9	14.0	14.0	13.5	14.0	14.0	14.0	14.0	14.0	14.0	
AP PSIG CIRC	28.7	28.8	28.8	28.8	28.5	28.7	28.7	29.0	29.0	28.7	28.7	28.7	5TH STOP START
AP PSIG CIRC													@ 1643 HRS
AP PSIG CIRC													CHECKED SCOPE
AP PSIG CIRC													ZEROS
P INLET PSIG	1303	1300	1305	1304	1283	1300	1298	1312	1300	1296	1298	1303	
P INLET PSIG													
P INLET PSIG													
P INLET PSIG													
P OUTLET PSIG	1287-1303	1287-1303	1286-1304	1286-1304	1282-1303	1282-1303	1285-1304	1283-1313		1280-1302	1282-1305	1281-1303	
P OUTLET PSIG	1287-1303	1287-1303	1286-1304	1286-1304	1282-1303	1282-1303	1285-1304	1283-1313		1280-1302	1282-1305	1281-1303	
P OUTLET PSIG	1287-1303	1287-1303	1286-1304	1286-1304	1282-1303	1282-1303	1285-1304	1283-1313		1280-1302	1282-1305	1281-1303	
P OUTLET PSIG	1287-1303	1287-1303	1286-1304	1286-1304	1282-1303	1282-1303	1285-1304	1283-1313		1280-1302	1282-1305	1281-1303	
P ORIFICE PSIG	1321	1329	1334	1333	1313	1328	1328	1341	1320	1325	1328	1331	
P ORIFICE PSIG													
AP ORIFICE "W.G."	312	313	313	313	307	312	312	314	315	311	311	312	
AP ORIFICE "W.G."													
AP I-V PSI	76	74.7	74.7	74.5	71	72.5	70.5	71.5	76.0	75.5	74	73.2	
COMP TEMP IN °F													
COMP TEMP IN °F													
COMP TEMP IN °F													
COMP TEMP IN °F													
COMP TEMP OUT °F													
COMP TEMP OUT °F													
COMP TEMP OUT °F													
COMP TEMP OUT °F													
MOTOR WINDINGS °F	248.7	248.6	250.4	250.4	249.2	249.6	248.8	249.4	248.8	250.6	250.7	250.1	
MOTOR WINDINGS °F	244.3	244.4	246.1	246.0	249.7	245.4	244.5	244.9	244.4	246.2	246.2	245.7	
MOTOR WINDINGS °F	245.9	246.0	247.7	247.6	246.5	247.0	246.2	246.8	246.0	247.8	248.0	247.3	
THRUST °F													
FAN BEARING °F													
COMP BEARING °F													
T ORIFICE °F													
T ORIFICE °F													
T ORIFICE °F													
T ORIFICE °F													
H ₂ O IN °F	40.3	40.5	40.8	40.5	41.0	40.7	42.0	41.4	40.9	41.9	41.9	41.3	
H ₂ O OUT °F	65.7	66.0	68.2	68.0	69.1	68.8	68.7	68.0	67.4	68.7	69.0	67.9	
COMP TEMP IN °F	641.9	640.9	642.6	642.1	641.6	642.8	641.6	642.5	642.8	642.8	642.4	641.2	
COMP TEMP OUT °F	651.4	650.3	652.1	651.7	651.1	651.7	651.1	652.1	652.4	652.1	651.9	650.7	
T ORIFICE °F	640.7	639.7	641.5	641.0	640.5	641.0	640.2	640.4	640.9	640.4	640.3	639.1	
TEMP INLET DOME 12 °C													
TEMP INLET DOME 3 °C													
TEMP H.D. VESSEL 12 °C													
TEMP H.D. VESSEL 3 °C													
TEMP VESSEL FLANGE 12 °C													
TEMP VESSEL FLANGE 3 °C													
TEMP BLIND FLANGE 12 °C													
TEMP BLIND FLANGE 3 °C													

TOTAL RUN TIME 58 HRS 20 MIN

(6)

TIME	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800						
RUN NO	162	163	164	165	166	167	168	169	170	171	172		SWITCHED TO					
SPEED RPM	21152	21148	21147	21150	21148	21150	21149	21154	21154	21155	21154	21152	NEW He Bottle					
CONDUIT °F	143	141	143	143	143	141	140	140	140	139	140		0200 HRS					
PASS-THRU °F	260	260	260	260	260	260	260	260	260	260	260							
POWER FACTOR																		
MOTOR WATTS	1510	1540	1536	1536	1540	1513	1520	1540	1519	1510	1524	1530						
THRUST FILM MILS		.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85						
THRUST FILM MILS	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75						
THRUST FILM MILS	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75						
COMP BEARING MILS	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75						
FAN BEARING MILS	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1						
COOLING WATER FLOW RATE	14	14	14	14	14	14	14	14	14	14	14	14						
AP PSIG CIRC 1	28.9	28.9	28.8	28.8	28.6	28.8	28.8	28.8	28.8	29.0	28.6	28.7						
AP PSIG CIRC																		
AP PSIG CIRC																		
AP PSIG CIRC																		
P INLET PSIG 1	1300	1304	1305	1300	1300	1300	1300	1300	1300	1304	1293	1299						
P INLET PSIG																		
P INLET PSIG																		
P INLET PSIG																		
P INLET PSIG	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300						
P OUTLET PSIG	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300						
P OUTLET PSIG	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300						
P OUTLET PSIG	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300						
P OUTLET PSIG	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300	5051-1300						
P ORIFICE PSIG 5	1317	1321	1328	1329	1328	1330	1328	1328	1330	1332	1323	1329						
P ORIFICE PSIG																		
AP ORIFICE "W.G." 7	312	314	313	313	313	313	313	315	315	314	314	312						
AP ORIFICE "W.G."																		
AP I-V PSI 11	72.5	72.2	72	72.0	72.0	71.5	72.5	72.5	72.0	72.5	72.0	72.0						
COMP TEMP IN °F																		
COMP TEMP IN °F																		
COMP TEMP IN °F																		
COMP TEMP IN °F																		
COMP TEMP OUT °F																		
COMP TEMP OUT °F																		
COMP TEMP OUT °F																		
COMP TEMP OUT °F																		
MOTOR WINDINGS °F 9	249.6	249.3	249.1	248.3	248.0	248.0	247.1	246.6	246.4	246.7	247.3	247.6						
MOTOR WINDINGS °F 10	244.4	244.6	244.3	243.7	243.5	243.5	242.8	242.3	242.2	242.7	243.2	243.1						
MOTOR WINDINGS °F 11	246.0	246.2	246.0	245.5	245.1	245.2	243.9	244.0	243.9	244.1	245.0	244.9						
THRUST °F																		
FAN BEARING °F																		
COMP BEARING °F																		
T ORIFICE °F																		
T ORIFICE °F																		
T ORIFICE °F																		
T ORIFICE °F																		
H ₂ O IN °F 19	41.9	41.9	41.8	41.6	41.2	41.8	41.8	41.7	41.6	41.7	41.9	40.9						
H ₂ O OUT °F 20	68.0	68.2	67.9	67.6	67.6	67.7	67.8	67.3	67.0	67.6	67.9	67.3						
COMP TEMP IN °F 1	640.4	640.9	639.9	640.4	639.7	639.0	639.5	639.9	640.6	639.5	641.6	643.4						
COMP TEMP OUT °F 2	649.9	650.5	649.5	649.9	649.4	648.6	649.2	649.4	650.2	649.1	651.2	652.9						
T ORIFICE °F 3 (15)	638.5	638.7	638.0	638.5	638.0	637.1	637.7	638.0	638.7	638.0	641.7	641.5						
TEMP INLET DOME 12 °C																		
TEMP INLET DOME 3 °C																		
TEMP M.D. VESSEL 12 °C																		
TEMP M.D. VESSEL 3 °C																		
TEMP VESSEL FLANGE 12 °C																		
TEMP VESSEL FLANGE 3 °C																		
TEMP BLIND FLANGE 12 °C																		
TEMP BLIND FLANGE 3 °C																		

(7)

UNIT NO: 1

DATE: 29 MAR 1979

START TIME:

TIME	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000				
RUN NO	173	174	175	176	177	178	179	180	181	182	183	184				
SPEED RPM	21151	21149	21149	21150	21149	21149	21151	21160	21149	21150	21150	21150	#6 STOP & START			
MOTOR AMPS	138	140	141	140	140	141	145	143	140	141	142	141	@ 0805			
MOTOR VOLTS	260	265	265	265	260	265	265	265	260	260	260	260	#3 He SAMPLE			
POWER FACTOR													@ 13.10			
MOTOR WATTS	153.3	153.6	153.3	153.6	153.5	152.7	153.6	153.9	153.8	154.0	153.7	153.8				
THRUST FILM MILS	0.87	0.87	0.87	0.90	0.95	0.95	0.95	0.95	0.95	1.00	1.00	1.00				
THRUST FILM MILS	0.75	0.75	0.75	0.80	0.85	0.85	0.85	0.85	0.85	0.87	0.87	0.87	SWITCHED TO NEW			
THRUST FILM MILS	0.75	0.75	0.75	0.80	0.85	0.85	0.85	0.85	0.85	0.87	0.87	0.87	He BOTTLES			
COMP BEARING MILS	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	@ 1330			
FAN BEARING MILS	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20				
COOLING WATER FLOW RATE	14	14	14	14	14	14	14	14	14	14	14	14				
AP PSIG CIRC	28.75	28.8	28.8	28.8	28.8	28.7	28.8	28.8	28.8	28.9	28.8	28.8	#7 STOP & START			
AP PSIG CIRC																
AP PSIG CIRC																
AP PSIG CIRC																
P INLET PSIG	1297	1303	1302	1302	1303	1296	1303	1304	1304	1304	1303	1303				
P INLET PSIG																
P INLET PSIG																
P INLET PSIG																
P OUTLET PSIG																
P OUTLET PSIG																
P OUTLET PSIG																
P OUTLET PSIG																
P ORIFICE PSIG	1326	1333	1332	1331	1331	1325	1332	1333	1334	1333	1331	1332				
P ORIFICE PSIG																
AP ORIFICE "W.G." 7	312	312	312	312	312	310	311	312	312	312	312	312				
AP ORIFICE "W.G." 11	75.7	74.7	73.5	73.0	73.0	72.5	72.5	72.5	75.0	74.2	74.0	74.0				
COMP TEMP IN °F																
COMP TEMP IN °F																
COMP TEMP IN °F																
COMP TEMP IN °F																
COMP TEMP OUT °F																
COMP TEMP OUT °F																
COMP TEMP OUT °F																
COMP TEMP OUT °F																
MOTOR WINDINGS °F 9	249.5	250.0	249.3	248.7	249.2	248.8	248.3	248.1	248.4	249.0	249.3	249.7				
MOTOR WINDINGS °F 10	245.0	245.4	245.0	244.4	244.8	244.4	244.1	243.8	244.2	244.7	245.3	245.3				
MOTOR WINDINGS °F 11	246.6	247.1	246.7	246.0	246.5	246.2	245.7	245.4	245.8	246.5	247.0	247.0				
THRUST °F																
FAN BEARING °F																
COMP BEARING °F																
T ORIFICE °F																
T ORIFICE °F																
T ORIFICE °F																
T ORIFICE °F																
H ₂ O IN °F 19	40.7	40.7	40.7	40.7	40.7	40.7	40.3	40.8	41.0	42.0	42.0	42.0				
H ₂ O OUT °F 20	67.5	67.4	67.3	67.2	67.3	67.0	66.9	67.2	67.3	68.0	68.7	68.5				
COMP TEMP IN °F 1	640.8	642.2	642.3	642.3	642.5	642.4	642.9	642.1	642.4	640.7	642.1	642.3				
COMP TEMP OUT °F 2	650.3	651.8	651.8	651.8	652.0	651.9	652.3	651.6	651.8	650.2	651.7	651.9				
T ORIFICE °F 3 (15)	638.9	644.3	640.3	640.3	640.6	640.3	640.8	640.1	640.3	638.8	640.2	640.2				
TEMP INLET DOME 12 °C																
TEMP INLET DOME 3 °C																
TEMP M.D. VESSEL 12 °C																
TEMP M.D. VESSEL 3 °C																
TEMP VESSEL FLANGE 12 °C																
TEMP VESSEL FLANGE 3 °C																
TEMP BLIND FLANGE 12 °C																
TEMP BLIND FLANGE 3 °C																

TOTAL RUN TIME 82 MINS 20 MIN

TIME	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800				
RUN NO	185	186	187	188	189	190	191	192	193	194	195	196				
SPEED RPM	21154	21151	21150	21153	21151	21152	21152	21150	21152	21150	21150	21152				
CONDUIT °F	143	143	144	144	145	145	145	145	145	145	145	146				
PASS-THRU °F	260	260	260	260	260	260	260	260	260	260	260	260				
POWER FACTOR																
MOTOR WATTS	151.5	152.4	153.9	151.1	151.4	151.6	151.0	151.2	151.0	151.9	151.8	152.0				
THRUST FILM MILS OUTWARD	.85	.80	.80	.80	.8	.8	.8	.8	.8	.8	.8	.8				
THRUST FILM MILS	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75				
THRUST FILM MILS	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75				
COMP BEARING MILS	1.8	1.75	1.75	1.75	1.73	1.75	1.75	1.75	1.75	1.75	1.75	1.75				
FAN BEARING MILS	2.2	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1				
COOLING WATER FLOW RATE	14	14	14	14	14	14	14	14	14	14	14	14				
AP PSIG CIRC 1	28.8	28.6	28.5	28.5	28.3	28.3	28.2	28.3	28.2	28.5	28.4	28.8				
AP PSIG CIRC																
AP PSIG CIRC																
AP PSIG CIRC																
P INLET PSIG 1	1300	1292	1303	1300	1320	1303	1299	1300	1302	1302	1303	1300				
P INLET PSIG																
P INLET PSIG																
P INLET PSIG																
P OUTLET PSIG	1285		1303	1290	1300	1285	1289	1285	1302	1284	1282	1286				
P OUTLET PSIG	1285		1303	1290	1300	1285	1289	1285	1302	1284	1282	1286				
P OUTLET PSIG	1285		1303	1290	1300	1285	1289	1285	1302	1284	1282	1286				
P OUTLET PSIG	1285		1303	1290	1300	1285	1289	1285	1302	1284	1282	1286				
P OUTLET PSIG	1285		1303	1290	1300	1285	1289	1285	1302	1284	1282	1286				
P ORIFICE PSIG 5	1329	1320	1330	1328	1328	1331	1327	1329	1330	1330	1330	1328				
P ORIFICE PSIG																
AP ORIFICE "W.G." 7	312	308	312	312	312	312	308	312	307	308	312	312				
AP ORIFICE "W.G."																
AP I-V PSI 11	71.3	72	72	74	73	72	71.5	73.5	72.0	72.5	72.5	74				
COMP TEMP IN °F																
COMP TEMP IN °F																
COMP TEMP IN °F																
COMP TEMP IN °F																
COMP TEMP OUT °F																
COMP TEMP OUT °F																
COMP TEMP OUT °F																
COMP TEMP OUT °F																
MOTOR WINDINGS °F 9	248.6	249.5	248.6	249.3	248.8	248.3	248.9	247.0	246.7	247.3	247.2	247.8				
MOTOR WINDINGS °F 10	244.2	245.1	244.2	244.7	244.4	244.1	244.9	247.6	242.1	242.8	243.0	243.1				
MOTOR WINDINGS °F 11	246.0	246.7	246.0	246.6	246.0	245.7	244.1	244.4	243.9	244.4	244.6	245.1				
THRUST °F																
FAN BEARING °F																
COMP BEARING °F																
T ORIFICE °F																
T ORIFICE °F																
T ORIFICE °F																
T ORIFICE °F																
H ₂ O IN °F 19	42.0	42.2	42.2	42.1	42.2	42.1	42.1	42.1	42.1	42.1	42.2	42.4				
H ₂ O OUT °F 20	68.3	68.8	68.6	68.4	68.4	68.0	67.7	67.7	67.6	67.9	68.5	67.8				
COMP TEMP IN °F 1	637.5	642.4	640.7	641.5	639.9	639.9	640.7	640.7	640.3	639.4	640.8	641.5				
COMP TEMP OUT °F 2	649.0	651.8	650.2	651.0	649.4	649.4	650.3	650.3	649.9	649.0	649.9	652.1				
T ORIFICE °F 3 (15)	637.5	640.3	638.8	639.4	637.9	637.7	637.2	638.7	638.1	637.5	638.2	639.4				
TEMP INLET DOME 12 0°C																
TEMP INLET DOME 3 0°C																
TEMP M.D. VESSEL 12 0°C																
TEMP M.D. VESSEL 3 0°C																
TEMP VESSEL FLANGE 12 0°C																
TEMP VESSEL FLANGE 3 0°C																
TEMP BLIND FLANGE 12 0°C																
TEMP BLIND FLANGE 3 0°C																

TOTAL RUN TIME 94 HRS 20 MIN

[illegible]

rec'd - 16 m 7 dec 23 500 402

APPENDIX 7

TRANSIENT TEST TRACES
8-CHANNEL GOULD-BRUSH RECORDER

3-30-79
DMS.

Depressurization Test

Test No. 81, 600 psi, 21,000 rpm

Test No. 80, 1500 psi, Zero rpm

Residual Motor
Cavity Pressures

Speed 1/2"/sec

#1 1/2" = 1 psi

1424 hr

1 Second

1 psi

A7-5

A7-8

0 -

Depressurization Test
21,000 rpm
800 psi
Test No. 82

3/20/79
Dmb

Speed 1/2" per sec
1/2" per psi

1 psi

Residual Motor
Cavity Pressure

1 Second

#3

3-20-79
Dm

Depressurization Test
2,100 rpm
1,200 psi
Test No. 83

Speed 1/2" per sec
Amplitude 2 psi/1/2"

A7-10

2 psi

Residual Motor
Cavity Pressure

1 Second

#4

A7-11

Depressurization Test
21,000 rpm
1,500 psi
Test No. 84

3/21/79
Dms

Speed 1/2" per sec
Amplitude 2 psi per 1/2"

A7-12

Residual Motor
Cavity Pressure

1 Second

2 psi

DEPRESSURIZATION TEST

TEST NO 84 - 3-21-79

0 - - - RO - - - M

INITIAL FILM

1500 PSI

2100 RPM

25 m/m/SEC

1 SEC

0.00025" / DIVISION

0.00025" / DIVISION

- O - ZERO FILM

INITIAL FILM

St. Denny

techni rite ELECTRONICS INC.

DEPRESSURIZATION FROM 21,000 rpm

1500 psi

TEST NO. 85 3-21-75

1 sec

791698

APPENDIX 8

EXTRACT FROM DAILY LOG BOOK
COVERING TEST PERIOD
NOVEMBER 15, 1978 to APRIL 6, 1979

15 Nov. 1978 After reassembling Thrust Brg. (P11) and Fan (P15) and Torquing til bolt nut. Checked with plastic feeler gauges the squareness of Fan to Thrust Brg., a .004 feeler goes in all around, snug. Installed Housing (P47), Spacer (P50), Spacer Bore (P36) and Laminated Shim (P40). The clearance between Housing and Fan set for .018" (print calls for .010 - .020).

With all capacitance probes and speed pick-up connected to Wayne Kerr distance meters and to scopes.

2.35 pm Started rotating up to about 6,000 R.P.M. According to the journal scopes the shaft appears to be riding rather high towards the top pad.

2.45 Shut down. Reset top pads to give approx. .0015" - .002" clearance. Inlet labyrinth seal clearance checked, a .005" feeler can be inserted all around, it is slightly tighter at about 2.00 o'clock (looking at impeller end).

3.47 Start and up to 3,555 R.P.M. Increasing speed very slowly, checking speed counter.

- 3.50 5,140 R.P.M.
- 3.51 6,250
- 3.52 8,000
- 3.53 Slowing to stop.

Readjusting Impeller end bearing to bring shaft to center of labyrinth, dropped approx. .003"

4.13 Start and increasing speed
4.14 9,300 R.P.M.
4.15 11,000
4.16 Slowing down
The rotor stops rotating from approx. 1000 R.P.M.

4.20 Start & increased speed to 11,300 R.P.M. then down to stop.

(2)

16-24 Nov '78 R. Christie & R. Vedder working on unit as follows —

checked S. Malenowski on Journal film thickness, said O.K. to bend flexure .003", also said that diametrical clearance should be .0009 — .0014". Reset clearance on both ends to .0009 — .001".

Installed dial indicator on compressor end pivot screw. Ran up to 15,000 R.P.M. Found that flexure moved .0015" — .002". Seems O.K. Found machine hard to start. Disassembled, cleaned all bearings using bobbin, Reassembled — starts O.K.

Dropped comp. pads so that shaft rested on labyrinth, Found that we had total labyrinth clearance (4 laby.) of .010" — .012". Raised shaft .003" off labyrinth and reset journal dia. clearance to .0009" — .001". Ran to 15,000 R.P.M., all O.K.

Tried to clean up noisy journal probe signals on scopes. Found that grounding all instruments and circulator got rid of most of the spikes.

27 Nov '78 Ran machine to 24,000 R.P.M. Looks good — orbits .0003" — .0004" except for noisy probes at various speeds, intermittent. D. Springstead will check for loose components in probes.

28 Nov '78 Check for loose components, could find no problems. Replaced Probes and ran machine again. One Fan Journal Probe showed vibration at 1200 R.P.M. and one Compressor Journal Probe showed vibration at 13,500 R.P.M. Ran machine to 22,000 R.P.M., saw some slight vibration on probes. Brought to 0 R.P.M., tried to restart but COULD NOT. Power supply problem.

29 Nov '78 Was in touch with Evans of Servo-Optics. He suggested several possibilities. By the end of the day it was determined that the power supply, NOT the motor, was at fault. The starting current was unbalanced on the three phases, $\phi 1 - 280A$, $\phi 2 - 180A$, $\phi 3 - 280A$.

30 Nov. Called H. Young of Union Carbide and he agreed that M.T.I. should NOT continue to trouble shoot. Union Carbide and Servo-Optics will resolve the problem.

1 DEC '78 D. Springstead & D. Ladue checked further into the problem per instructions of Tom Hudson (Union Carbide). Tried starting several times. Heavy vibration in circulator. With Pot set at 1.5 (60m) starting current reads as follows $1\phi - 280Amps$, $2\phi - 180Amps$, $3\phi - 280Amps$. After much digging D. Springstead found the problem to be a bad Optoisolator on gate drive board assembly 0780-000 Pt A1. This was replaced and the circulator was started & ran O.K. Noise problem on probe traces still evident.

12/4/78 Besides the intermittent probe noise, the continual spikes on the probe traces that come from the power source are making the orbits impossible to analyze. Various filtering systems were tried but none improved the scope picture sufficiently. A TE 600 Wayne-Kerr system will now be tried, as this is what Union Carbide will be using.

- 5 DEC '78 T.E. 600 borrowed from Lajace in N.K.R. and installed. Ran circulator and power supply noise is worse. Again, filtering signal helped, but not enough. D. Springstead has ordered FERRITE beads to put on instrument leads to damp transient spikes.
- 6 DEC '78 D. Springstead tried more filtering on instrument leads but still not effective enough. Appraised both Tom Hudson of Monobide and Bob Evans of Servo-Optics of the problem.
- 7 DEC. D. Springstead working on filtering problem, he went to Ferroxcube Corporation & picked up FERRITE BEADS to go around power leads. Hope to reduce large voltage spikes out of power supply that have been effecting scope displays.
- 8 DEC. Installed beads on power outlet leads. This, with the commercial filter gives a readable trace on scopes. D. Springstead will design and build seven (7) small filters to complete the filtering of each probe output.
- 11 DEC. With prototype breadboard filter in place, machine was run and the scope trace was of acceptable quality. He will now build and package the 7 filters.
- 12-15 DEC. Installed REED valves (P19) (P20) and Support Ring (P12) and made ready for assembly into pressure vessel. Incidentally the total weight of circulator & support ring is 1100 lbs. While attempting to attach (P12), found that two (2) of the helicoils in (P12) were bad (it had come from Buelher like this, only it had been forgotten to replace the coils). This meant the whole thing had to be taken apart again, then removing and replacing the coils.
- While attempting to install the above circulator, support

King assembly to the pressure vessel between flange on
the support bracket 316 E 123 it was found that the
distance between P.V. and flange was too short by
about 9"

Removed support bracket and put it to T.B.I. shot
where it was modified as follows: - But shot in
top to allow an eye-bolt to be attached in clearance
flange, drilled & tapped 3 jack screw holes in Ring so that
flange can be pushed out of position, drilled and tapped
holes so that the two back tension screws bearing on
be moved 12 1/2" clear to flange end, this will allow
the support bracket to be moved far enough away from
the pressure vessel to allow circulation with its protruding
cooling water tubes to be installed on its flange

Measure - installing fittings in deck for pressure measurement
lines. Three fittings and 1/4 STD. ST. tubing will eventually
be welded together at the deck end.
But, bent and about 40 deg the line to fitting at the
inletmost end. The line cannot be welded at 40 deg
specially into one piece all the way because all joints
and transducers will have to be calibrated periodically
and there must be at least one disconnect in each
line.
Made and assembled a header with the necessary valves
to connect gas bottles and gases when collecting.

Started to install miniature flashing glands for T.C.'s
into deck in readiness for welding when it was discovered
that the holes in the glands were .053" dia. while the
T.C. stems were .062" dia. All glands were then drilled
out to .063" dia. and will be installed as time permits.

The inlet and valve part of the 4" VALVE valve
arrived ~~today~~, but before it could be installed in
the horizontal position (the book suggests it should
be in a vertical position) a support bracket that
will not sustain movement must be made.
The T.B.I. shot is now modifying the plate T-bar for
this purpose. This valve assembly weighs about 400 lbs.

(6)

hence the need for supports.

18-22 Dec. Installed control section of VALTEK 4" valve into Loop. The support bracket consists of 2 T-bar uprights, a cross piece on top with a suspended load spring attachment (left over from loop supports) and a turnbuckle.

Installed Impeller Inlet Adapter (P7) and two (2) piston ring seals (P733).

Had 2 guide studs made to facilitate mating of lower and circulator to Pressure Vessel.

27-28 Dec. The gap between butt ends of the Seal Rings (P733) is approximately .027", which should be O.K.

3" conduit has been run from lower supply to the box alongside the Pressure Vessel.

Attempted to install circulator into Pressure Vessel, found that the additional 1100 lbs. overhung weight on the Support Bracket has caused the Bracket to tilt down so that it will not enter the vessel.

Installed ^{additional} one .025" steel shim (total 3) under each of the two pillow block bearings at flange end of assembly bracket hoping it will compensate for the additional overhung load.

ACTUAL MEASUREMENTS:-

PRESSURE VESSEL I.D. = 19.752"

SUPPORT RING O.D. = $\frac{19.747}{19.750}$

1979

(7)

2 Jan '79. Spread a thin film of Prussian blue on the I.D. of Pr. 6 where it will mate with piston ring seals Pr 33, this is to find out exactly where the rings will seat when the circulator is installed.

Tried to install circulator, found that it would not enter all the way, misses by about $\frac{3}{4}$ " of an inch.

Pulled circulator out, found that piston rings had been hanging too low out of grooves and had jammed against end of Pr 6. The rings are bent and will have to be straightened out again.

Removed the piston rings, attempted again to install the circulator again, it still will not enter. Backed off up the ramp.

Checked I.D. measurements of pressure vessel and O.D. of Support Ring fit to check for out-of-roundness. Found some out-of-roundness but the overall clearance is only .002 - .004". The printer indicates that the clearance should be from .002 - .012".

Another problem — the cover (in the bracket) is slightly cocked or the whole bracket is — the flange & vessel faces are about .020" open at top and about .030" at the far (wall) side. This probably can be corrected by loosening the bolts attaching bracket to pillow block bearings and twisting bracket, if there is enough clearance in the bolt holes.

Another problem appears to be that the cover is slightly out of rotation, this means that the bolt holes in the cover don't exactly line up with the studs in the vessel, the studs will enter but may damage the threads.

but down on the diameter of the two alignment pins, they appear to be rubbing hard on the bracket holes.

(8)

1-2-79 (contd.) Sent Support Ring (P.2) to shop (T.B.I) and had O.D. of pilot fit (where it enters the pressure vessel) reduced
ECN to give a clearance of approximately .010 in diameter.

Support Bracket - 316 E 123 sent to shop, two $1\frac{1}{8}$ holes opened up to 4 dia. to allow a nut and socket wrench to be used to bolt flange into position
ECN before withdrawing assembly bracket up the ramp. At the same time the other holes were opened up and/or elongated to allow for the rotational misalignment.

1-4-79 Received Support Ring back from shop and installed
1-8-79 it on circulator.

Installed Stop-Start and Speed Control switches on instrument panel.

Installed Pressure Transducers in back of instrument panel.

Installed $\frac{3}{4}$ VALTEK in dump line.

Received Support Bracket from shop and mounted it on ramp.

1-9-79 Spent some time adjusting shims under Support Bracket to get it to the right height. Attached circulator to flange.

Ran the above assembly down the ramp and into the vessel, no apparent hitches, pulled it back out of the vessel.

Installed Impeller Inlet Adapter (P.7), made up a couple of different styles of ring expanders with the hope that perhaps they would hold the Seal Rings (P.33) in a more central position while attempting to slide the Back Plate Seal Assembly (P.6) (attached to circulator) into position. Found out that ring expanders cannot be used, the ring grooves are not deep enough.

Ran the circulator back down the ramp, no problems. Pulled it back out, installed piston ring seals (2) (P.33) and put some Prussian Blue on the outer diameter of rings.

Installed the large Seal Rings (P.22).

Ran the circulator down once more, everything appears to have entered nicely.

Meantime a spring hanger is required to support the $\frac{3}{4}$ VALTEK dump valve. Purchasing says 4-8 weeks delivery time, so it was decided to build a hanger here, that is now in progress.

1-10-79 Pulled circulator back up the ramp, the bluing shows exactly how far the Piston Seal Ring (P.33) penetrate into Back Plate Seal Assembly (P.6) as shown opposite. The large seal rings (P.22) appear to have fitted in perfectly.

With the Circulator attached to Bracket on ramp, power leads, capacitance leads etc. attached.

Ran at various speeds to check out instrumentation and bearing orbits.

Now that the main power lines from power supply to circulator are inside the conduit the interference with scope signals etc. has been cut drastically, now an orbit can be clearly seen.

D. Springstead made and installed Low Pass (400~) filter in output of Wayne Kerr systems and this also helped clear up the signals.

Installed circulator into Pressure Vessel, ran at various speeds up to about 23,000 R.P.M. — outside the vessel the noise is bad, about 96-98 D.B.

Inside the vessel it cannot be heard over the noise of the power supply until it reaches nearly full speed. and the scope signals are now good.

The gaskets (P.45) under the Reed Valve assembly had been forgotten so the cover was unbolted and the circulator withdrawn from P.V.

When the 1100lb. circulator load is off the Assembly Bracket the Cover O.D. (attached to P.V.) is too low to enter the Bracket I.D., so the overhead crane has to be used to lift cover

$\frac{1}{16}$ - $\frac{1}{8}$ after loosening the large nuts, so that bolts will enter. Apparently the overhung load tends to tip the Bracket forward and downward towards the P.V. This will put an upward pull on the two rear pillow block bearings which they may not have been designed to take. There does not appear much that can be done to correct this except maybe install an additional pair of pillow block bearings.

Examined inside of P.V., found some metal chips, dirt and a small piece of Teflon tape. Inside the Inlet Adapter (P46) was also found some metal chips and dirt.

Installed gaskets (P45) under Reed Valve assemblies. Cleaned P.V. and Inlet Adapter.

Installed circulator back into P.V. and torqued the large closure nuts to 500 ft. lbs. Installed 3 Rosemount Temperature pickups into loop. Meantime a $1\frac{1}{4}$ " PVC pipe line has been installed to drain cooling water from circulator to the nearest floor drain, which is in the hallway outside of the test area.

Two T.B.I. welders are here tip-welding the various threaded fittings to the loop, they are also attaching various hanging supports brackets to the crane rails etc.

The above mentioned electronic is being replaced by D. Springstead.

A spring loaded suspension fixture has been installed to support the $\frac{3}{4}$ " VALTEK dump valve.

23-7-24

T.C. extension leads (23) are being made also (7) capacitance probe extension leads.

A 4-way solenoid valve has been installed on $\frac{3}{4}$ " VALTEK dump valve and piped so that valve will only open when switch on instrument panel is turned to "ON". Installed ~~an~~ an additional $\frac{1}{4}$ " copper line connected thru a check valve to the "Dump" valve, this line will be

connected to a nitrogen bottle and will only come into play when & if the Joy compressor (shop air supply) should stop unexpectedly.

Installed control valve and gauge on instrument panel to operate the 4" VALTEK load control valve remotely.

24-25th Connected shop air and pressurized Loop & Pressure Vessel to approximately 100 PSI (shop air press.) to check for leaks using "Snoop".

Leaks :- Main P.V. Box between faces.

Outlet from vessel — 2 T.C. $\frac{1}{16}$ NPT welds

Inlet to vessel — 3 - $\frac{1}{16}$ NPT THREADED Swagelok fittings.

— 3 T.C. $\frac{1}{16}$ NPT WELDED.

— 1 T.C. fitting broken.

Amper area — 1 T.C. fitting welded thread.

All fittings threaded or brazed at back of instrument panel appear to be O.K. at this pressure.

One pair of flanges on 4" VALTEK valve leak & bolts were tightened. The welders have experimented with different wire hoping to find one where the weld will not crack. They have tried to stop the leaks with little or no success.

On closer inspection it was found that the Swagelok fittings $\frac{1}{16}$ NPT male connectors were not made of stainless steel & this alone can cause welding cracks.

Ordered replacement STAINLESS STEEL fittings.

But off, drilled out and retapped ~~the~~ all 12 T.C. fittings. While this was being done the Loop was under about 15 P.S.I. air pressure to prevent any dirt or chips entering the Loop.

23-

The new stainless steel Swegelok fittings were installed in Loop and welded into place.

Some of the fittings still leak at about 100 p.s.i. air. The same flanges on Valtex 4" load valve still leak.

Meantime, T.C. leads were made and are being connected from Loop & P.V. to instruments on panel.

T.C.'s have been installed in circulator cooling water inlet (at flowmeter) and outlet, leads are being made for these two places.

The leaking Swegelok fittings were rewelded and are now reported as being leak tight.

After D. Doming talked with the VALTEK valve people in Provo, Utah the 4" valve was removed from Loop and has been taken apart (partially) so that when the new gasket (looks like Flex-o-Tallic) arrives it can be installed immediately. When the valve was taken apart, a long sliver of metal fell out — this ~~was~~ had been peeled off the fit at assembly and could possibly have kept the two faces apart and prevented the gasket being compressed sufficiently.

The new electrical box arrived and has been installed on the cover. Three large holes had to be cut into back plate before installation — they had been forgotten on the drawing. With this box in place it is very difficult to torque the large nuts holding the cover, there is just enough room to swing the torque wrench.

Wk. of 5th Feb. Installed heating cables around O.D. of Loop, from the beginning of the straight surface section to pressure vessel and from outlet of P.V. to beginning of cooling duct. Cemented heating cables in place using ZESTON INC., GRADE Z-10 Heat Transfer compound and baked for about 12 hours at 250°F.

Next insulating material (Johns-Manville Lava Blanket, Refractory Fiber) was wrapped 2" thick around O.D. of loop and taped in place. The only places left uncovered are where it will have to be leak-checked after the leaks on the two VALTEK valves have been stopped.

4" VALTEK valve, leaking at lower housing gasket, was removed from Loop and dismantled. Valtek people sent us two (2) replacement gaskets for each joint. Installed new gasket and put valve back into Loop. Raising shop air up to 100 p.s.i.g. — valve still leaks.

Removed valve again from Loop — Had a cast iron lap made and using diamond paste lapped bottom of gasket groove and its mating face — this is a slow process.

Wk. of 12th Connected cooling water hoses to and from the pressure vessel. The flow meter reading appears to be in error. Removed flowmeter and took it apart, it was quite dirty inside. Reassembled and tried again with a second flow meter in the line — still reading very low. Removed and dismantled — found that a small snap-ring on the inner stem had apparently rusted thru and disintegrated. Put in a new snap-ring and installed flow meter back into cooling system. Now the flow meter checks out with the 2nd meter.

Continued lapping 4" Valtek valve parts, now both faces looking at gasket are flat and have a grey mate finish. Assembled valve back into Loop and checked for leaks — using 100 p.s.i.g. shop air pressure.

The 4" and 3/4" Valtek valves both leak at approximately the same position on both valves.

Removed both valves from system and on to workbench.

The dump valve (3" Valtel) appeared to leak past the seat. The valve stem lock nut was adjusted so that "plug head" would enter into valve seat a few thousandths more.

Reassembled valve back into Loop taking particular care that "body bonnet flange" was tightened down squarely on to valve body.

The load valve (4" Valtel) still leaks at lowest housing gasket as before. Called the Valtel people and they will send us a new set of a different type of gasket.

Meantime a blank flange was installed under the "bonnet" flange and the Loop was filled with Nitrogen up to about 150 P.S.I.G. The dump valve is now leak tight at the bonnet flange and past the plug.

During this time D. Springstead has done some preliminary calibration of Validyne pressure transducers and he changed a diaphragm on one of them. He has kept one set of data, we have another.

We have had T.B.I. run a liquid penetrant inspection (ZYGO) on area of Housing in which gasket sits and on mating area of Bonnet. They have given us a piece of paper which states that "NO DEFECTS NOTED". So now we will have to wait for the new gaskets which apparently have gone astray in transit.

A new blank flange, made out of 1" thick carbon steel, has been installed over the 4" Valtel body and two (2) bottles of Nitrogen have been fed into Loop, this gives a pressure of 350 P.S.I.G. At least one leak at a welded joint has shown up.

Opened dump valve, using electric switch and checked pressure drop — From 700 down to 600 P.S.I.G. = 1 second.

Received from Valtel (16th Feb.) 2 new gaskets #16493-868-eco. Installed one new gasket.

"C" Ring. I.D. = 23.020"

O.D. = 23.664"

W. = .635"

16 FEB. 79 Received new "C" Ring, accompanied by 3 copies of certification.

Installed 4" VALTEK valve ^{back} ~~into~~ Loop.

Ran another pressure check on Loop using Nitrogen at 760 P.S.I.G.

One of the Rosemount T.C. fittings appears to be leaking up from the inside of the tube, around the wires. There are also a few small leaks thru' T.C. packing glands.

20 FEB.

Removed the leaking Rosemount T.C. — found that the weld holding the tube to the 1/2" pipe fitting had cracked. Removed the other two Rosemounts to check, found that one other weld had cracked.

Silver brazed all three welds and reinstalled back into Loop. One of the pressure tap welds were also leaking — peened this over using hammer & punch, will weld it later.

G. E. Instrument people here to calibrate pressure gauges, ΔP gauges and Pressure Transducers. Had to make some ^{temporary} changes in the tubing so that gauges could be connected to suit the G. E. people.

Leak checking Loop tonight using Nitrogen to 1500 P.S.I.G.

At 18.30 HRS. Nitrogen pressure in Loop was 1330 P.S.I.G.

21 FEB

At 08.00 HRS. pressure was 1300 P.S.I.G.

There are several very small leaks showing up under "Snooty". It was decided to blow down the Loop thru' dump valve. Connected a pressure transducer across Pressure Vessel to attempt to record on a chart the ΔP across the vessel and find out how the Reed Valves react while dumping the gas.

NO ΔP was recorded during the 30 secs. it took to dump pressure — maybe a transducer with a 5 lb. diaphragm should have been used instead of a 500 lb diaphragm.

An attempt will now be made to stop the slight leak at the Valtex valve main flange by making certain

26th 6 Starts & Stops Total Running time 73 minutes approx.

27th 1 Start & Stop Running time 15 min approx.

that the flange is tightened down squarely.
The G.C. people finished calibrating the gauges etc..

The last few sections of the Loop are now being insulated and the welders will be here today or tomorrow to weld the one fitting still leaking.

23 FEB. 79

The one leaky fitting and two small areas of $\frac{1}{4}$ O.D. tubing which had been burned while welding previously, have now been rewelded.

The remaining bare sections of the Loop are now being insulated.

26 FEB.

Charged Loop system to between 45 and 50 P.S.I.G. Nitrogen. Made a number of starts and stops, checking instruments etc.. as shown opposite page.

27 FEB.

Made only one start & stop today.

Apparently the cooling air ductwork is rather noisy when the fan is running. An attempt has been made to bring the noise level down by inserting threaded rod through the ductwork at various points and tightening up the nuts on either side, hopefully this will stiffen the ducts.

28 FEB.

Cut off a metal bar which had been welded to the 2" dump line & to the vertical loop support. This had been initially put up to support the dump line but is now thought to be unnecessary now that there is a support from the floor.

#12 T.C. (Thrust Bearing) is giving erratic readings, checked leads to Fluke readout, they and the instrument appear to be O.K. May be something wrong with the T.C. itself.

One Magnetic Speed Pick-up (LEFT) is not operating properly switched to the (RIGHT) pick-up and everything now appears to be O.K.

D. Springstead is checking wattmeter.

4" VALTEK LOAD VALVE
SEAT RETAINER REWORK.

INCREASE .095"
RADIALLY ALL
ROUND

gsk
02/27/79

During the last run it was discovered that for a given speed pressure etc., the flow was not up to what it should be, so the 4" VALTEK load valve was removed from the body in the Loop and the SEAT RETAINER was reworked as shown in sketch attached to opposite page.
Valve reinstalled back into Loop.

3-1-79 Connected vacuum pump and pulled Loop down to 480 microns
Charged system with Helium to 140 p.s.i.g.

2 starts Started unit 9.15 - off 9.30 am. up to 11750 R.P.M.
On 14.42 Off 14.43 hrs.

(16 mins.)

3-2-79 Started and stopped a number of times for a total of
47 mins. and 8 starts. Speeds varied up to 21,000 R.P.M.

(47 mins)

8 starts All the above starts and stops have been connected
with attempts to calibrate and or adjust instrumentation
on the Servo-Optics power supply.

3-5-79 Pressure checked system, using helium, up to 400 p.s.i.g.
Found that screw fittings on the Blower Cover were leaking,
as shown opposite. Took all fittings apart, thoroughly
cleaned and then had them TIG welded together.

Pressurized system to 400 p.s.i.g. there is now only one
very small leak where the fitting 'tree' joins the pipe from
the pressure vessel.

At 16.30 hours pressure in system was 400 p.s.i.g.

3-6-79 At 8.00 hours pressure in system was 399 p.s.i.g. and
the small leak noted before seems to have dried up.

Increased Loop press. to approximately 600 p.s.i.g.

Ran rig up to approx. 21,000 R.P.M., Howard Black & D.
Springstead taking electrical data from Power Supply
where there appears to be some problems.

2 MARCH '79

TO DATE

HOURS CIRC. HAS RUN.

Nº OF STARTS

1 hr. 28 min.

17

Attempted to start circulator — no movement at all.
 Started to remove circulator from pressure vessel.

7 MARCH

Dismantled circulator on bench. All bearings: —
 Tilting pads, Thrust Brg. etc. in very good condition
 only a few dirt scratches on all of them, with one
 exception — the fan end journal has a narrow (about
 1/8" wide) brightly polished band around the circumference
 which appears to be in line with where the bearing
 pivot pins would be. Also each bearing pin shows a
 small polished spot, probably 1/16" wide x 1/8" long, directly
 thru' each pad from the pivot socket.

On the back of each pad, in the socket where the pivot
 pin presses there should be a continuous polished line.
 In all of these tilting pads there is a break in the
 polished line, which would seem to indicate that
 there is a small flat spot on the end of each ball.

All Chrome Oxide bearing surfaces were thoroughly cleaned
 using COBEN (contains TRICHLOROMETHANE)

With the exception of the Thrust Brg., all the bearing
 surfaces — Journals, Tilting Pads and Thrust Runner (fan)
 were then sprayed (using an air brush) with a thin
 coating (.0005" — .0007") of SOLID FILM LUBRICANT called
 SURF-KOTE M-1284 made by Hohman Co..

Parts were left to dry for about 30 mins for ease of handling
 then baked in the oven at 325°F. for approximately 1 hour.
 The rotor was too long for our oven and had to be taken
 to Wiltfless Co. and put in one of their ovens.

Also the Thrust Brg. T.C. was checked in the oven against
 another T.C. and a dial thermometer and found to be
 accurate within 4°-5°F.

After the baked parts had cooled to room temp. they were
 hand polished using first Scotch Brite cloth, then cheese
 cloth and finishing with a Nylon cloth. The final thickness
 of the Surf-Kote is probably in the neighborhood of
 .0002" — .0004" .

9 MARCH Installed Tilting Pads into Fan End Brg. Housing which had remained in unit.

Installed Pads back into Impeller End Brg. Housing.

Installed Rotor into Stator and Fan End Housing then Installed Impeller End Housing.

Installed both tie-bolts into Rotor.

Adjusted Tilting pads at Fan End Housing by attaching a dial indicator to end of shaft and sweeping around around fit for holding Thrust Brg. in position. The shaft is set just about dead center in the housing at this ~~end~~ end.

Moving to the Impeller End of the Rotor, the pads were backed off and the shaft moved up & down to find how large the clearance is inside the labyrinth seals, there is .007" - .008" between top of journal & I.D. of seal. The shaft was now set at about .001" below the center line (to allow for lift when rotating).

The top pads both ends were next brought down to touch the journals, then backed off .001".

Installed Impeller on rotor - tie-bolt ^(P78) torqued to give a stretch of .005"

Installed Thrust Brg. assembly, centered around end of shaft.

Installed Thrust Runner (Fan), torqued to 90 ins. lbs.

Rotor end play is .004" - .005"

There is a slight problem with the Silver plated 10-32 screws used to hold (P6) in place. They are hex. socket heads and the heads are apparently soft, consequently the hex's are becoming rounded and it's becoming difficult to remove screws — have ordered another dozen screws.

Received new 'Omni' face seal from Calif.

Received one new magnetic speed pick-up.

284

9⁰⁰ 7. check of signal at (12) & (16) on PCI

(E) 16 to 6 (bus voltage)	(V _d) 12 to 6 (control)	Pot	Vac panel - normal	
+ 0.916	0.013			← sig. on, but stop of!
- 8.02	- 2.44	1.5		
- 8.1	- 4.40	3.0	270	"
- 8.12	- 7.3	5.0	270	"
- 8.1	- 8.77	6.0	270	"
- 9.57	- 10.24	7.0	319	"
- 11.00	- 11.68	8.0	380	"
- 11.83	- 12.49	9.0	420	"
- 12.12	- 12.51	10.0	410	"
- 11.91	- 12.50	9.5	415	"

9³⁰ 5) check of signal at (13) on dc bus voltage isolator

V₍₁₃₎ V_{dc bus} Pot V_{ac panel}

not a dc voltage

357 1.5

voltage feedback isolator bad

6) switches input (1) to (2) & (5) to (6) on dc bus voltage isolator

V₍₁₅₎ V_{dc bus} Pot V_{ac panel}
 - 1.8 0 0 0
 - 11.8 6.4 1.5 485

7) shielded input (6) & (7) out (5) to (4)

good channel	$V_{(4)}$	$V_{dc \text{ amp}}$	V_{ac}	$V_{ac \text{ panel}}$	stop off no load
	0.02	+ 013.2	0		
	-4.8	355	1.5	260	
	-4.89	359	3.0	270	
	-4.89	359	5.0	270	
	-4.98	366	6.0	272	
	-5.81	429	7.0	325	
	-6.64	523	8.0	398	
	-7.10	585	9.0	448	←
	-7.13	582	10.0	450	

want 350 Hz @ 590 volts dc

$$\frac{460 \text{ ac}}{.78} = 590 \text{ V}_{dc}$$

$$8.75 \text{ v}_{ac} = 350 \text{ Hz}$$

$$V/\text{Hz} \approx = \frac{460}{350} = 1.3$$

$$V/\text{Hz}_{dc} = \frac{590}{350} = 1.68$$

need to increase feed back voltage

∴ decrease feed back resistor, now 316 Ω

$$\left(\frac{7.13}{.8} \right) (316) = 281 \Omega$$

 $\rightarrow 277.5$

8) change voltage feedback resistor from 316Ω to 277Ω

V_{dc}	V_{ac}	V_{rms}	Pot.	Hz
-4.29	357	265	1.5	60
-4.33	360	270	3.0	120
-4.33	360	270	5.0	200
-4.99	417	312	6.0	240
-5.82	489	370	7.0	280
-6.63	621	475	8.0	320

277 Ω voltage feedback resistor too small
(note didn't consider $50k$ in series)

appear to be two ways to make setting
for 350 Hz @ 460V_{ac} or 590V_{dc}

1) adjust voltage feedback resistor
or adjust V_{Hz} pot

9) changed dc bus voltage feedback

9) V_{14}

	$V_{dc \text{ bus}}$	$V_{re \text{ panel}}$	Pot	HZ
cont.	-4.72	356	260	1.5 60
	-4.77	360	270	3.0 120
	-4.77	360	270	5.0 200
	-4.99	377	280	6.0 240
	-5.81	442	335	7.0 280
	-6.64	540	410	8.0 320
	-7.04	601	460	9.5 340
↑	-7.11	602	4	9.0

limited

10) with Pot on 8.75, set V/HZ to get $V_{dc} = 590$

-4.87	367	280	1.5	1.5 60
-4.90	369.7	280	3.0	120
-4.88	368.7	280	5.0	200
-4.85	366	260	6.0	240
-5.52	419	315	7.0	280
-6.13	490	370	8.0	320
-6.69	548	415	8.5	340
-6.89	592	450	8.75	350
-7.09	604	460	9.0	360

↑ limited

conclude UFPS operating okay no load
and get 460V @ 350 HZ

Remaking 3 short leads from Wayne Kerr's so that machine can be run on bench, also 3 short power leads are being made for the same reason.

9 MARCH

Meanwhile Tom Hudson (from Union Carbide), D. LaDue & D. Springstead are checking into the Power Supply control system and making some changes.

During the day a number of starts & stops on unit were made so that they could check various things as they went along.

At 5:00 pm the helium pressure in the Loop was approx. 630 p.s.i.g.

10 MARCH SAT.

D. Springstead and Tom Hudson of Union Carbide worked on Power Supply.

12 MARCH

Started unit for a few minutes to check power supply rework — appears to be O.K.

Started unit at 8:20 AM, at 8:25 AM speed 21,604 RPM. Data taken at various temperatures and loads.

After running for some time the Loop pressure gradually crept up from 610 p.s.i.g. to between 900 - 1000 p.s.i.g. and temperature climbed to about 600°F.

Meantime the ΔP across the vessel gradually dropped from about 75" W.C. to about 15" W.C. as the Loop pressure & temperature gradually increased, also during this time the scopes show that the gap between Thrust Brg. and Thrust Runner (Fan) was gradually widening, if it had increased much more there was a possibility of it going unstable.

The Loop pressure was eventually increased from about 1000 p.s.i.g. to 1300 p.s.i.g. using high pressure helium from the trailer outside.

The VALTEK load valve was ~~was~~ closed a little to increase the load, this tended to reduce the Thrust film thickness a little.

Shut down at 9:50 AM

Immediately after shut down an attempt was made to measure temperature of one of the three power supply pass-thrus.

Running
Time
90 mins.

Starts 2

($\frac{3}{8}$ " DIA Cu RODS) — the hand held Pyrometer was destroyed by a static charge remaining in the system.
 Blew three (3) 700 V 400 Amp. Amp Fuses (Type SHAWMUT A 70 P 400) in Power Supply. Replaced.

Tried to start — O.K.

13th-14th Removed unit from pressure vessel.

Repaired T.C. pass thru' on inside of cover (1 spade terminal had broken off).

Replaced one Magnetic speed pick-up (the other was erratic) — gap set at .006"

The RIGHT Fan End Journal capacitance probe had cut out just before shut down, so probe was removed, found that groove in tip had filled with black dust from the journal bearings. This dust has been cleaned out, probe checked and reinstalled — gap set at .0074"

Installed unit into vessel, connected all power, capacitance and T.C. leads.

Before connecting helium hose to vessel the line was blown out as usual, now there appears to be some brown dust coming thru'. It was decided to blow out the brass pipe line from the trailer to the test area using steam.

After some trouble the steam generator was finally made to operate and the pipe line was blown out using plain water — no detergent. Immediately afterwards the line was blown dry using helium.

Then the system was charged up to approx. 400 p.s.i.g. with helium and the unit kicked over to find out if everything was operating properly.

Installed T.C. on one of the main power line pass-thrus into pressure vessel and connected it to a separate readout.

- 15 MARCH Started unit rotating at 9.30 am. & increased slowly to 21,150 R.P.M.
 Room temp. 66°F.
 Power pass-thru 64°F Conduit T.C. on power line 65°F.
 Loop heater on at 10.10 am.
 ΔP across vessel motor cavity 80" W.C.
 Omni seal leaks slightly.
 At 10.20 am ΔP_v is 65" W.C.
- 10.30 Rm. 74°F, Pass-thru 145°F, Conduit 87°F
 ΔP_v 63.5" W.C. Loop pressure at Circ. Inlet 1050 p.s.i.g.
 Data taken.
- 10.45 Loop heater OFF. Temp. 638°F.
- 11.00 Rm. 81°F, Pass-thru 190°F, Conduit 111°F.
 ΔP_v 100" W.C. + Loop press. Inlet 1275 p.s.i.g.
- 11.10 Lost signal from Fan End J.B.
 Reducing speed to run critical speed tests.
 Heaters ON.
- 11.30 Heaters OFF. Increasing Speed.
- 11.45 Speed 21,130 R.P.M. While reducing flow (partially closing VALTEK load valve), a approximately 123" WC ($\frac{\Delta P}{7}$) the unit seemed to go into surge condition momentarily. Immediately increased flow and this condition disappeared.
- 11.50 Increased flow.
 Fan ON Heaters OFF.
 Fan end J.B. capacitance signal intermittent one side.
- 12.00 Room 77°F, Power pass-thru 176°F, Conduit 111°F.
- 12.07 Reducing speed for next set of tests.
- 13.30 Fan ON Heat ON.
 Pressure increased in system to 1471 p.s.i.g., 19827 R.P.M.
 Rm. 77°F, Pass-thru 215°F, Conduit 125°F
 Just found out that Pass-thru readout reads 25° low so actual temp. would be 240°F.
- 14.30 hrs. Rm. 77°F, Pass thru. 175°F, Conduit 113°F.
- 15.15 Shut down - end of this part of test.
- 16.15 Heat Soak Back test with cooling water on.
- 16.20 Attempted to start - N.G. Turned the power supply switches on and off a couple of times, then the unit started rotating.

16.30 hr. Journal bearings orbits rather large as was the thrust bearing runout, probably caused by the rotor warping thru' sitting in one position soaking up heat — after a few minutes running both J.B. orbits & Thrust film thickness returned to near normal.

16.45 Rm. 77°F, Pass-thru' 220°F, Conduit 98°F.

Loop 1473 p.s.i.g. — Speed 19,565 R.P.M.

16.55 Shut down for Heat Soak Back test, this time with cooling water shut off.

RUNNING TIME FOR 3/15/79 8 hours. Starts & Stops 2.

16 MARCH 11.10 am. Start and up to 3,570 R.P.M.

Ramped speed down very quickly by hand, very fast stop — $1\frac{1}{2}$ secs.

Started again, up to 3570 R.P.M.

Hit stop button — very fast stop again $\frac{3}{5}$ second.

Both above stops recorded on chart paper.

11.17 Start and up to 5000 R.P.M.

Hit stop button — stop in $\frac{3}{5}$ second.

11.21 Start and up to 7500 R.P.M. — Hit stop button

Roughly 2500 R.P.M./sec. ramp down speed.

Rotor appears to drop off to a stop from 1000-1200 R.P.M.

11.35 Start — up to 10,000 R.P.M.

Hit stop button — stop in $2\frac{3}{5}$ seconds approx.

11.41 Start, and increased to 19,644 R.P.M.

Biv. Inlet at 860 p.s.i.g. ΔP_v 100+ "W.C.

Power pass-thru' 105°F, Conduit 73°F, Loop 657°F.

1300 hr. Rm 87°F, Pass-thru' 225°F, Conduit 114°F,

Biv. Inlet 1333 p.s.i.g. ΔP_v 100+ "W.C., Speed 20,000 R.P.M.

*1307 hr. Shut Down. Dumped press. down to 100 p.s.i.g. —

Using $\frac{1}{4}$ " needle valve at Biv. Inlet bled press. down to 17 p.s.i.g. 1320 hr. started rotating again.

Heater ON Loop all this time since 1300 hr. Now OFF Increasing speed slowly.

1410 hr. ΔP_v 1.5 "W.C. Rm. 80°F. Pass-thru' 160°F, Conduit 100°F
Even with the Loop heaters on it is now impossible to maintain temp. at 650°F, it is now down to 580°F.
Reduced speed to 11,750 R.P.M. to repeat above tests.

To summarize today's running : $\longrightarrow$ 19 MARCH '79

Ran compressor characteristics at speeds of .9, .6, .3 and .12 of 23,500 R.P.M.

Temperature controlled at higher speeds by fan and cooling water.

At lower speeds temperature controlled by speeding up to .9, then reducing speed to desired value and taking data.

1510 hrs. Reduced to 3000 R.P.M. to repeat the above tests.

ΔP_v 0.5 "W.C., Rm. 77°F, Pass. thru' 140°F, Conduit 91°F.

1605 hrs. 3000 R.P.M. ΔP_v 0.5 "W.C., Rm. 77°F, Pass. thru' 135°F,

Conduit 90°F, Circ. Inlet 12 p.s.i.g.

1610 hrs. Increased speed to 5000 R.P.M.

1611 hrs. Hit Power Supply STOP button and coasted down.

1620 hrs. Touch down at approx. 560 R.P.M.

1621 Started cooling fan — cooling water at 12 G.P.M.
cooling system down for weekend.

Running Time 4 hrs 40 mins.

Coasting Down Time 9 mins.

Starts & Stops 6.

TOM HUDSON

HARRY YOUNG

AL GRINDELL

19 MARCH Union Carbide representatives here today →

This morning there was only a few p.s.i.g. helium in Loop.

Replaced #7 T.C. (comp. outlet.)

Charged Loop to 630 p.s.i.g. helium

9.10 hours. Started unit rotating — up to 20,941 R.P.M.

Pressure in Loop increased as temperature increased, up to 1100 p.s.i.g.

At about 10.10 am Loop press. increased (from trailer) to 1280 p.s.i.g. Temp. in Loop now 650°F.

10.45 hrs. Shut down — having great difficulty controlling Loop temperature. Cooling Fan Drive — removed large belt sheave and replaced the original sheave to increase fan speed.

11.50 Started unit and gradually increased to 21,100 R.P.M.
Comp. outlet 655°F.

1300 hrs — 21,148 R.P.M., Loop at comp. outlet 658°F,
 $\frac{PI}{I}$ is 1247 p.s.i.g. ΔP_v 84.5 "W.C. Pass. thru' 240°F.
Conduit 127°F.

1355 hours — Intentionally surged unit — Loop 650°F, 1280 p.s.i.g.
at 21,156 R.P.M. Unit moves into and out of surge with no apparent problems.

1700 hrs. Shut down

1705 — Restarted and ran two (2) coast-down tests.

Running Time 6 hrs 45 mins.

Starts & Stops 4

When dumping from 1200 p.s.i.g and 21,000 RPM. ~~the~~
 the INBOARD Thrust probes appeared to indicate
 that the film thickness was momentarily near
 zero. Unit will have to be removed from
 vessel to examine Reed Valves after some more
 tests are completed.

20 MARCH. Started rotating at 8.00 am — up to 21,000 R.P.M.
 Loop-approx. 695 p.s.i.g. Bringing system up to
 operating conditions

Running compressor maps similar to yesterday's run, only
 this time at system pressure of 1500 p.s.i.g.

13.11 hours — Shut down

Made up some stainless steel tubing as shown opposite
~~B~~ and connected an X-Y recorder into the system
 to measure the ΔP across the circulator while dumping
 the pressure from various levels and speeds.

14.15 Started and advanced up to 19,600 R.P.M.

14.20 Shut down

Using the new transducer and the X-Y platter recorded
 the ΔP across vessel while dumping the helium.

Dumped from 1500 p.s.i.g. and 650°F.

Time to dump approximately 23.5 secs.

Reed valves appeared to open at 3.2 p.s.i.g.

Recharged system to 600 p.s.i.g.

14.33 Started and increased to 21,000 R.P.M.

Dumped pressure from 600 p.s.i.g. and 650°F.

Recorded data.

14.41 Shut down.

Recharged system to 800 p.s.i.g. and 650°F.

14.56 Started — up to 20,997 R.P.M. & 650°F.

15.09. Dumped pressure — recorded data.

15.10 Shut down

15.25 — 15.10 Repeated above — this time dumping from 1200 p.s.i.g.

Tom Hudson and Dale Springstead are now working on
 power supply system.

Made a number of starts and stops while Tom Hudson and
 D. Springstead work on, and check out, anti-reverse-rotation
 equipment — no. of starts & stops 6 or 7.

Total running time 6 hrs 3 min. approx.

No. of starts & stops 12

TOTAL RUNNING TIME SINCE BRC'S SPRAYED WITH
SURF-KOTE

34 HOURS 7 MINS

Nº STARTS 34

21 MARCH 7.50 AM Made 2 or 3 starts to check out the anti-rotation equipment.

7.52 AM Running at 7480 R.P.M., 20 p.s.i.g. in Loop at 150°F.

8.00 Stop.

8.03 Start and on up to 8300 R.P.M.

8.04 Stop.

Making adjustments on anti-rotation equipment.

Tom Hudson doing the work with D. Springsted.

Made 2 more starts and stops, lost power — now Tom Hudson & D. Springsted removed the anti-rotation equipment.

The Thrust Brg. traces on scopes are now being connected to a recorder chart.

Charged system to 700 p.s.i.g.

9.04 AM Started and increased to 21,000 R.P.M., heating system.

10.30 — 19,409 R.P.M., Inlet gas 647°F., Circ. inlet 1460 p.s.i.g.
 ΔP_v 83" W.C.

10.41 21,500 R.P.M.

10.42 Dumped pressure in Loop, all data recorded.

10.44 Reduced speed to 8000 R.P.M. approx.

Increased again to approx. 18000 R.P.M.

Charging system to 1500 p.s.i.g.

12.14 Dumped pressure and recorded data.

12.15 Shut down.

12.17 Started up again momentarily to check if it would start. — O.K.

12.20 Stopped to again install anti-rotation equipment.
Made four (4) starts to check out equipment.

1310 Started rotating.

1354 Stopped — Dumped pressure down to about 15 p.s.i.g.

Used $\frac{1}{4}$ " bleed valve to further reduce to 2 p.s.i.g. on $\frac{PI}{I}$.

1358 Started again and up to 21,000 R.P.M.

1400 Beginning of 1-hour run at 2 p.s.i.g. and 21,147 R.P.M.

1500 Reduced to 11,750 R.P.M. at 572.6°F (compressor outlet)
and 2 p.s.i.g.

1600 Reduced to 3,000 R.P.M. and 528°F. and 2 p.s.i.g.

1700 Shut down.

Running Time 7 hrs. 9 mins. — Starts - 8.

22 MARCH Total running time since Bys sprayed with
SURF-KOTE

$$\begin{array}{r} 34 \text{ HRS } 7 \text{ mins} \\ 6 \quad 25 \\ \hline = 40 \text{ HRS. } 32 \text{ mins.} \end{array}$$

$$\begin{array}{r} \text{Total number of Starts} - 34 \\ 3 \\ \hline = 37 \end{array}$$

(27)

24 March 79 Switched Loop heater on at 7.40 AM. Shooting for 750°F.

8.20 AM Made a couple of starts to check instruments, then increased speed to about 11,000 R.P.M. + 1300 p.s.i.g.

High temperature test runs follow. Data taken.

11.15 Increased to 1500 p.s.i.g. and 21,150 R.P.M. + 750°F.

Data taken after motor temperatures stabilized.

13.20 Reduced speed to 10,000 R.P.M., increased cooling air and water flow to "cool down" the system.

Reduced loop pressure to ~~1,100~~ 1,100 p.s.i.g.

14.45 Shut down.

running time
6 hrs 25 min

starts
3

- 26 MARCH 79 Pressure has dropped over the weekend to approx. 180 p.s.i.g.
 Bringing system up to 655 p.s.i.g. from tank trailer outside
 STARTING 100 HOUR SHAKEDOWN TEST.
- 8.35 Started rotating — up to 21,153 R.P.M.
 Cooling water set at 10 G.P.M.
- 9.25 Added Helium to bring system up to 1300 p.s.i.g.
 The Cooling Air Fan is now controlled by an automatic ON-OFF switch which should make it a more uniform temperature. Now running with both heating coils & fan ON together, this way the temp. is held constant at 650°F.
- 11.05 Apparently we have a leak somewhere in the system. Added Helium from trailer to compensate.
- 12.50 " " to raise press. from 1265 p.s.i.g. to 1307 p.s.i.g.
- 13.55 " " 1285 to 1300 p.s.i.g.
- 14.30 Room temp. now up to 84°F.
- 15.07 Added Helium 1278 — 1300 p.s.i.g.
 R. Christie climbed up on roof to check exhaust pipe from Dump Valve — no signs of any leak thru valve.
- 16.30 Added Helium 1278 — 1305 p.s.i.g.
- * 17.05 Reduced speed and stopped circulator, this is the 1st STOP & START of the 10 required during this 100 hour test. Started again immediately and resumed test at 21,150 R.P.M. Reset zeros on Thrust & J.B. scopes while stopped.
- 18.35 Added Helium 1275 — 1300 p.s.i.g.
- 19.35 " " 1280 — 1303
- 21.00 " " 1278 — 1326
- 22.05 Switched to bottle of He (1300 p.s.i. to full)
- 23.00 Added Helium 1277 — 1299 p.s.i.g.
- 24.00 " " 1280 — 1302
- 27 MARCH 01.00 " " 1284 — 1301
- 02.00 " " 1280 — 1301
- 03.00 " " 1284 — 1300
- 04.00 " " 1284 — 1300
- 05.00 " " 1284 — 1301
- 06.00 " " 1284 — 1300
- 07.00 " " 1284 — 1303 " Pass-thru temp. gauge
- * 08.07 STOP & START IMMEDIATELY for 2nd STOP. shorted out.
- 08.18 Added Helium 1280 — 1302 p.s.i.g.
- 09.45 " " 1284 — 1302

SAMPLING PROCEDURE - ORNL 100 Hr. TEST

Repeat every 24 hours

1. One Liter Stainless Steel containers are good for 245 psi. They are fitted with pressure gages and flow meters.
2. Connect to sampling valve on circulator via regulator.
3. Flowmeter connected to outlet of container with valve.
4. Leave coupling between circulator valve and container loose. Keep valves closed on either openings of container.
5. Allow Helium to leak out then loose union on container inlet for five (5) minutes. Close valve. Tighten union.
6. Open Inlet Valves to container until pressure reaches 20/30 psi. Open outlet valve. Allow gas to flow at rate of 2 liters/min. for five (5) minutes.
7. Close Outlet Valve. Allow pressure to reach 100 psi. Close inlet valve. Purge down to 20/30 psi. Repeat three times.
8. Fill container to 100 psi using procedures 6 and 7 above
9. Label containers with data and time.
10. Ship to Golob Labs via U.P.S. or by Federal Express. The former gives a three day turnaround. The latter overnight. (Through Purchasing)

ATTENTION

Fred Golob
46 Industrial Park Road
Berkeley Heights, N.J. 07922
(201) 464-3331

Ref. MTI Purchase Order No. 902-04007

NOTE:

Five containers are available. The first is to sample gas direct from tank trailer via piping, hose, valves, cooling coil and regulator which should be thoroughly purged prior to sampling per five above.

27, MARCH 79 CONTD.

1050 Added H_2 — 1284 to 1300 p.s.i.g.

1120 Switched to a new bottle H_2 on trailer (1300 p.s.i. to Full)

1140 Added H_2 1284 — 1300 p.s.i.g.

1245 " " 1285 — 1305 "

* 1330 1st Helium sample Taken from pressure vessel.

1340 Added Helium 1230 — 1307 p.s.i.g.

Had a bad leakage problem in the cooling air system, the aluminum rivets holding the flexible section between fan & duct started to break — replaced rivets, this time steel rivets used. just too much vibration.

1450 Added H_2 1285 — 1308 p.s.i.g.

1555 " " 1290 — 1303 "

* 1620 Reduced speed and stopped circulator — **STOP #3**.

Changed the temp. readout which was being used to measure Temp. of a power line pass-thru — The original had shorted out. 1625 Start and increased to 21,150 R.P.M. To continue 100 hour test.

1647 Added Helium 1285 — 1302 p.s.i.g.

1752 " " 1283 — 1300 "

1850 " " 1286 — 1300 "

2200 " " 1279 — 1300 "

2300 " " 1282 — 1300 "

2400 " " 1284 — 1297 " Switched bottles on

28 MARCH 0100 " " 1280 — 1299 " Trailer.

0800 Approx. every hour as shown above a small quantity H_2 has to be added to the system — this is recorded on the data sheets.

* 0805 Reduced speed and shut down for the **4th STOP & START**.

Had to make 3 attempts before unit would restart, there is apparently something wrong in the Power Supply system, this is NOT the first time this has happened.

0807 RESTARTED and resumed normal speed 21,150 R.P.M. & 650°F.

1310 #2 H_2 SAMPLE TAKEN — this takes about 15 mins. to complete.

Then added gas to bring system up to 1300 p.s.i.g. as recorded on data.

1430 Switched to new full Helium bottle.

* 1500 Lost #3 ROSEMOUNT T.C. which reads downstream of orifice, will now use FLUKE #15 readout to substitute.

1643 #5 STOP & START. Had to make three or four attempts before unit would start up again — trouble seems to be in Power Supply, had to turn all switches off then on again several times.

9 MARCH 79 2100 HRS — Outboard Thrust Scope out, replaced with spare unit.

9 MARCH 0200 — Switched to full helium bottle.

0805 #6 STOP — because of previous problems restarting, this time all switches on Power Supply were turned OFF, then ON again before attempting to restart. Unit started right up.

Shipped to Betmaseal Inc., New Lebanon — one set of tooling for manufacture of Pass-thruts — to be returned on completion of order. Also sent high pressure regulator.

0938 Added Helium as required to maintain operating pressure in approx. The same quantities as on preceding days.

1310 #3 HELIUM SAMPLE TAKEN.

* 1330 Switched to new Helium bottle on trailer.

1620 #7 STOP & START Unit started at 2nd attempt, it may be that we should wait a couple of minutes each time before attempting to restart, give the voltage time to decay down. Helium added to system as required, to maintain pressure at approx. 1300 P.S.I., during the night, as recorded on data sheets.

2115 Switched to new Helium bottle.

30th MARCH 0820 — #8 STOP & START Made 2 or 3 attempts to restart — N.G., then turned Power Supply switches OFF, then ON, then unit started normally.

1000 — #9 STOP & START No problem starting this time.

1120 — Switched to a new bottle of Helium.

Adding Helium every hour as required to maintain pressure, record kept on data sheets.

1305 — #4 HELIUM SAMPLE TAKEN. Recharged system.

1320 — #10 STOP & START. No problem restarting.

1400 — Last set of data taken for the 100 hour test.

* 1422 Reduced speed and stopped.

Dumped pressure by hand switch.

* 1423 Restarted and increased to 23,500 R.P.M. at atmospheric press.

1426 Hit STOP button on Power Supply to COAST to a stop.

All necessary data being recorded on Brush recorder.

1447 Unit stopped rotating from 402 R.P.M.

ACTUAL COAST DOWN TIME 16 MINS. 7 SECS. 23,500 - 402 R.P.M.

30 MARCH 1979 TOTAL RUNNING TIME SINCE BEARINGS

WERE SPRAYED WITH SURF-KOTE TO DATE.

141 HOURS 44 MINS.

TOTAL NUMBER OF STARTS = 48

30 MARCH (CONT'D) Charged system up to 330 p.s.i.g. Helium.

1444 - Started rotating - up to 10,837 R.P.M. to cool system down. Heaters OFF, Fan on FULL, Cooling water @ 15 G.P.M.

1540 - Shut everything down, temperatures about 200°F. & below.

2 APRIL '79 System pressure had dropped over the weekend from 330 p.s.i.g. to 8 p.s.i.g.

Charged system up to 600 p.s.i.g.

Herb Short and Dale Springstead getting instrumentation together to run DRIVE MOTOR TESTS. as per REPORT #EA-79-3

0910 Start rotating at approx. 3500 R.P.M. Cooling at 10 G.P.M., Conduit 88°F, Pass-thru 75°F, Heaters ON.

1.45 start Increased to ~~21~~ 11,500 R.P.M. bringing outlet temp. to 650°F.

10.25 Comp. outlet temp. 650°F, bringing system pressure up from 1000 to 1300 p.s.i.g. from trailer.

10.55 Reduced to stop so that H. Short can make some instrument changes

1058 started and increased to 21,150 R.P.M.

Herb Short taking data at the following speeds.

1117 Increased to 23,500 R.P.M., 660°F., 1300 p.s.i.g.

1121 Reduced to 21,150 R.P.M., 665°F., 1307 p.s.i.g.

1127 " " 14,100 " 639°F., 1284 "

1132 " " 7,050 " 618°F., 1263 "

1142 " " 3,000 " 589°F., 1225 "

2.45 start 1150 Increased to 8,000 " To maintain system temp. during lunch hour.

1250 Increased to 18,800 R.P.M. to allow system to stabilize for next test.

1255 Added He 1164 - 1233 p.s.i.g. DATA taken.

1310 Increased to 21,150 R.P.M., 631°F & 1270 p.s.i.g.

1340 Added He 1287 - 1312 p.s.i.g. DATA.

1352 Reduced to stop. Heat OFF.

TODAYS RUNNING TIME

1 hour	45 min
2	54
<hr/>	
4 hours	39 mins

1	Start
2	
<hr/>	
2	STARTS
3	

2 APRIL 79. System pressure had dropped to 8 p.s.i.g. ($\frac{P_1}{T}$) over weekend.

Charged system to 600 p.s.i.g.

Herb Short and Dale Springstead getting instrumentation together to run DRIVE MOTOR TESTS — REPORT #EA-79-3

09:10 Started rotating. Comp. outlet 590°F., cooling water 56 P.M.

1 shut down Conduit 68°F., Pass-thru 75°F. Heaters ON.

1 Start. Running at 11,500 R.P.M. to bring system temperature to 650°F.

1025 Comp. outlet now 650°F., started to bring system pressure up from 1100 to 1300 p.s.i.g. from the trailer.

1055 Reduced speed and stopped so that H. Short can make some instrumentation changes

1058 Started and increased slowly to 21,150 R.P.M.

H. Short taking data at the following speeds:—

1117 Increased to 23,500 R.P.M., 660°F., 1300 p.s.i.g.

1121 Reduced to 21,150 R.P.M., 665°F., 1307

1127 " " 14,100 " 639°F., 1284

1132 " " 7,050 " 618°F., 1263

1142 " " 3,000 " 589°F., 1225

1150 Increased to 8,000 R.P.M. to maintain system temperatures during lunch period.

1250 Increased to 18,800 R.P.M. to stabilize for next tests.

2 hrs 54 min 1255 Added He, from 1164 — 1233 p.s.i.g. DATA TAKEN

1 Start. 1310 Increased to 21,150 R.P.M., 631°F., 1270 p.s.i.g.

1340 Added He, 1287 — 1310 p.s.i.g. DATA.

1352 Reduced to Stop.

Heat burning turned off.

1447 Started and increased to 5570 R.P.M. — This run is to cool system and unit.

1530 Shut down — compressor outlet 241°F.

#5 HELIUM SAMPLE TAKEN — FROM TRAILER.

Today's running time

Starts

1 hour 34 min

5

3 APRIL '79

NO LOAD TESTS.

Damped system pressure from 550 to 10 P.S.I.-g.

0845 Start and increased to 11,260 R.P.M.

0854 - 12000 R.P.M. Loop 7.0 P.S.I.-g. DATA TAKEN

0900 - 8000 " " booring at 12 G.P.M. "

0906 - 3600 " " " "

29 min 0908 - 16,000 " " " "

1 Start 0911 - 20,000 " " " "

0913 - 23,500 " " " "

— 0914 - Shut down.

Getting ready to run 'LOCKED ROTOR' tests

1 Start Attempted to start motor in single phase conditions, cannot run as it is over 500 Amps line current, Shut Down immediately.

— Installed new Cimaron ammeter in line.

0942 - Started long enough for H. Shot to take readings.

1 Start Reconnected the third power lead.

1004 Started - 3600 RPM. NO LOAD.

Running calibration - CIMARON TO PANEL METER.

1 hr 2 min 1105 - 8,000 R.P.M.

1107 - 10,000 "

1 Start 1108 - 14,000 "

1109 - 16,000 "

— The unit suddenly and for no apparent reason slowed down and was manually switched off.

3 min 1112 Restarted with no troubles - increased to 5000 RPM.

1 Start 1115 Stop - finished of meter calibration

These tests are complete so unit will now be removed from pressure vessel.

AS OF 4 APRIL 1973.

TOTAL TIME RUN & NUMBER OF STARTS SINCE
BEARINGS WERE SPRAYED WITH SURF-KOTE.

152 HRS 41 MINS

59 STARTS.

4 APRIL 79 Removed unit from pressure vessel.

Reconnected power leads and speed pick-up lead.
Made and installed two brackets with copper springs making contact with both ends of rotor. With the two ends connected to a meter the short will take SHAFT CURRENT TEST readings.

10.50 Started and increased speed to 23,516 R.P.M.

5 min
1 Start DATA TAKEN

10.55 STOP

The unit is now being dismantled.

5 APRIL 79 CIRCULATOR IS APART FOR INSPECTION.

Found one (1) bad capacitance probe lead - RIGHT SIDE FAN END J.B. - this is being replaced.

Oil (?) deposits - Inside the Motor Housing (P4) 316E17, Impeller end, there is a thin coating of what appears to be oil or varnish and some black dirt spots - probable cause - outgassing from varnish (?) on windings.

The Fan end of the housing - which is the cool end - shows no signs of oily deposits, only a very light coat of dry dust.

Both cooling water inlet & outlet tubes have a coating of varnish, for want of a better word - mostly on the inlet which is the colder tube. This coating smells much more than the windings. The O.D. of both tubes will have to be sanded where the packing glands sit, both are scratched up.

ROTOR - Fan end J.B. in very good condition except that there is a narrow (approx. 1/16 wide) highly polished band around the circumference at mid-length - opposite the pivot pin location on the tilting pads. At both ends of the J.B. but off the Chrome Oxide there is a heavy coat of damp appearing foreign substance or black dust, this coating on the inboard end extends up on to the larger diameter of the rotor.

LOOKING AT END
OF PIVOT BALL.

ONTO IMPELLER END J.B. is also in excellent condition, but this also has a narrow polished band (about $\frac{1}{8}$ " wide) around circumference at mid-length and opposite pivot-pin location on tilting pad. This end does not have the same oily appearing film as the other end, only a light coating of dark dust. The cooling holes drilled into this end show a coating of dark dust and show a directional pattern around the outlet holes.

IMPELLER — Heat discolored on inlet side (outboard side). All three labyrinth seals appear to be untouched and in perfect condition, no signs of any rubbing. Inboard side shows a uniform fairly heavy coating of black dust.

COMPRESSOR END TILTING PADS — Looking from Impeller — Top Pad has a couple of dirt scratches plus a small polished spot opposite the pivot, this area extends both ways circumferentially as a $\frac{1}{8}$ " wide scuffed mark for better than half the radius.

Lower Right Pad — some light dirt scratches, polished spot etc. as in previous pad except that light scuffed area covers only the trailing half of the bearing.

Lower Left Pad — small polished area opposite pivot $\frac{1}{8} \times \frac{3}{8}$ long extending in scuffed area on either side, these only on trailing half of bearing, otherwise pad in excellent condition.

FAN END TILTING PADS — Looking from Fan — Top Pad unmasked except for a slight polish spot opposite side from pivot.

Lower Right Pad shows some scratch marks on the trailing half of the bearing, but only only on the outboard half.

This one also shows polished area opposite pivot $\frac{1}{16} \times \frac{3}{16}$ long. Lower Left Pad shows scratches in same location as in previous pad, only this is a little more pronounced and covers $\frac{3}{4}$ of width of trailing half of bearing.

Both capacitance probes and speed pick-ups appear to be in good condition.

PIVOTS — Show a narrow polished band across the ball about $\frac{1}{8}$ " wide $\times$ $\frac{3}{8}$ " long with an $\frac{1}{8}$ " untouched spot in the center of the band length, which would appear to indicate that there is a small flat spot on end of pivot. Otherwise all pivots are in good condition.

PIVOT SOCKETS ON TILTING PADS show a corresponding polished area as on pivots

CONT'D

THRUST RUNNER (FAN) Unscratched and in excellent condition, the Fan side shows dust discoloration. This will be checked to see if flatness has changed.

THRUST BEARING is also in excellent condition, the only marks are scratches in center uncoated aluminum area where the inboard capacitance probes are, and they are there from an original sub, before the center section of the Fan was undercut.

BUMP bearing shows slight polish marks around inboard edge, these 4 areas are about $\frac{1}{8}$ - $\frac{3}{16}$ " wide and extend $\frac{3}{4}$ " - 1" around inner circumference. The T.C. lead is in bad shape, insulation is frayed through in two (2) places.

The corresponding bearing on end of shaft is in excellent condition with a very light polished area around the inner diameter.

HEAT INSULATOR (P 26) which has not been dismantled yet shows a crack running across outer edge.

LABRYNTH SEALS — all seals, both male & female parts show no signs of rubbing and are in excellent condition, all will be measured later and checked against original inspection reports.

BACK PLATE — REED VALVE SIDE is heat discolored, otherwise clean.

REED VALVE ASSY. — heat discolored and outside of fingers have a coating of black dust on last $\frac{1}{2}$ inch. The inboard or sealing face of reed has some traces of leakage as indicated by dark streaks.

DIFFUSER — Heat discolored, otherwise appears to be in good shape.

END RING — 316 D20 — Heat discolored. Inside, where taper meets ring bore there are several fairly deep scratches with picked up metal at the inboard end of some of them.

Had to remove Impeller Inlet Adapter (P 7), both piston rings (P 33) badly grooved across rubbing surfaces. Both rings were stuck and had to be pried out. The gap between butts approx. .023" - .024" and side clearance where a feeler can get in is only .0025".