ELLIOTT GROUP
EBARA CORPORATION

Compressor Performance Test Procedure

Recycle Gas Compressor
T-Req: MJ2-0003

KBR
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FOR ENGINEERING USE

THIS DOCUMENT IS:

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ACCEPTANCE DOES NOT RELIEVE SUPPLIER FROM FURNISHING MATERIAL IN CONFORMANCE WITH ORDER. REFER TO SDR-1 FOR FULL DEFINITION OF ACCEPTANCE CONDITIONS.

DISCIPLINE MJ BY MEJ
DATE 29 DEC 11

CERTIFIED FOR CONSTRUCTION

Purchaser: **Mississippi Power Company**
Purchaser's Order No.: **H10-606-043**
User: **Mississippi Power Company**
Shop Order No.: **F128251 / F128252**
Serial No.: **CO1008 / CO2008**
General Order No.: **H11005**

☑ **FOR APPROVAL**
Avoid delay - to: ☐ establish ☑ maintain shipping promise. One approved print must be returned by:
12/29/2011

By: Ivan Donahey
Date: 12/15/2011

☐ **FOR RECORD**
Any requested change of this equipment will result in:
1. Contract price adjustment.
2. Extended shipping promise as this contract is in manufacturing process.

By:
Date:

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Sheet **1** of **21**	

Form 1157 (04/01/05)

Southern Company Generation **Kemper County**
MM98929 0 Unit 1

ELLIOT COMPANY PO: MPC18137-0001
DOC000000058610 Rev: 1
IGCC - GASIFIER - MULTIPAGE - RECYCLE GAS COMPRESSOR - COMPRESSOR

AERODYNAMIC PERFORMANCE TEST PROCEDURE

ELLIOTT COMPANY MODEL 15MB3 CENTRIFUGAL COMPRESSOR

Purchaser:	**Mississippi Power Company**
User:	**Mississippi Power Company**
Elliott Shop Order:	**F105251**
Elliott General Order:	**F128251**

Reported By:

William Hafer

Test Engineering

Rev: 0
Date: October 14, 2011

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I. INTRODUCTION

This procedure is a description of the aerodynamic performance test that will be conducted on compressor F108251 currently being manufactured for Mississippi Power Company. This procedure is in general accordance with ASME PTC10-1997, except as specified herein. In the event of any discrepancy or omission between this procedure and that specification, this procedure will take precedence.

II. TEST DESCRIPTION

The aerodynamic performance test of the compressor will be conducted as an equivalent Type 2 test as defined in the ASME PTC10-1997. The test gas will be Nitrogen and the equivalent test speed is 10188 rpm.

Refer to section IV for details of the compressor performance test conditions and equivalency parameters at the design capacity point.

The assembled compressor will be mounted on a suitable shop test stand. A shop VSD motor will be used to drive the compressor for test. Lube oil for the compressor will be provided by the shop console at the design pressure of 15-18 psig and 120 +/- 5^{o}F. Buffer supply to the gas face seals will be provided by a shop buffer skid. Primary buffer supply will be Nitrogen. All contract bearings and seals will be installed in the compressor for test.

During the performance test, the mechanical operation of the compressor will be monitored by the logging of the following data at 15 minute intervals.

- Time
- Speed
- Lube oil supply pressure and temperature
- Gas seal primary buffer supply pressure and temperature
- Bearing oil throw-off temperatures
- Bearing metal temperatures
- Radial vibration at all four probes
- Axial position

No mechanical guarantees are applicable during the performance test.

For the performance test, the compressor will be connected to a closed gas loop as depicted schematically in Figure 1. The test gas will be purchased in bulk quantities and supplied directly to the gas loop through proper control valve(s). Once the initial purge and fill of the test loop has been completed, gas feed will be maintained to offset normal loop leakage.

The compressor flange and flowmeter piping will be instrumented as described in this procedure. Refer to Section V and Figure 2 for details on the quantity and type of instrumentation.

III. POLICIES AND CODE EXCEPTIONS

Performance test procedures at Elliott Co. are in general accordance with the ASME PTC10-1997 except as noted in this procedure. A complete summary of Code Exceptions is provided in Appendix I.

IV. TEST PARAMETERS AND TEST EQUIVALENCY

1. The aerodynamic performance test for the subject centrifugal compressor is setup as an equivalent Type 2 test as defined in the ASME PTC10-1997.

2. The test equivalency is based on the guarantee condition only, and may not apply to alternate case conditions.

3. Test and design gas thermodynamic properties are based on the Benedict, Webb, and Rubin equations (BWR).

4. Test equivalency is determined as described in the ASME PTC10-1997. Typically, only one of the available inert test gases is suitable for the particular compressor. Once the test gas is selected, the equivalency calculation is performed, per Paragraph 5.3.2 of the PTC10-1997, to determine the test speed that provides volume ratio matching within the limits of Table 3.2 in the code.

   Once the volume ratio requirement is met the remaining equivalency parameters required by Table 3.2 are checked.

   For this compressor's guarantee point the test gas will be Nitrogen, and the equivalent test speed is 10188 rpm.

5. The results of the final equivalency calculations are presented on the following pages.

6. The following equivalency parameters fall outside the limits of Table 3.2 of the PTC10-1997: None.

7. The allowable fluctuations (where relevant) stated in TABLE 3.4 of PTC10-1997 are applicable with the following modifications:

   - Orifice differential pressure fluctuations of 4% are typical.
   - Table 3.4 limits are not applied to points near compressor surge.

SHOP ORDER	F108251
FRAME	15MB3
COMPRESSOR TYPE	CENTRIFUGAL
TYPE OF TEST	2
TEST SPEED (RPM)	10188.
TEST MACH NO.	0.453
ALLOWABLE TEST MACH NO. RANGE	0.302 TO 0.623
REYNOLDS NO. RATIO	0.224
ALLOWABLE REYNOLDS No. RATIO RANGE	0.100 TO 58.805
CAPACITY-SPEED RATIO (% OF DESIGN)	100.0
VOL. RATIO (% OF DESIGN)	99.9

TEST GAS:
GAS PROPERTIES METHOD IS B-W-R 1 GASES MOL WT 28.013
N2 1.00000

GAS PROPERTIES		TEST	DESIGN
INLET:			
COMP FUNC X (SCHULTZ)		0.015	0.044
COMP FUNC Y (SCHULTZ)		1.003	0.998
COMP FACT Z		0.997	0.999
GAS MOL WT		28.01	20.30
SP HEAT	BTU/LB-F	0.250	0.359
SP VOLUME	CUFT/LB	2.102	0.610
VISCOSITY	CP	0.01828	0.01657
DISCHARGE:			
COMP FACT Z		0.999	1.008
SP HEAT	BTU/LB-F	0.251	0.362
SP VOLUME	CUFT/LB	1.614	0.468

PARAMETERS:		TEST	DESIGN
SPEED	RPM	10188.	11937.
SONIC VELOCITY	FPS	1170.	1369.
HORSEPOWER		336.	1863.
EFFICIENCY		0.834	0.838
INLET VOL FLOW	CFM	1479.	1733.
VOLUMETRIC RATIO		1.303	1.304
HEAD	FT-LB/LB	13142.	18119.
WEIGHT FLOW	LB/MIN	704.	2843.
MACHINE RE NO.		0.1219E+07	0.5429E+07
MACH NO.		0.453	0.454
POLYTROPIC EXPONENT M		0.343	0.337
POLYTROPIC EXPONENT N		1.527	1.554
INLET PRESS	PSIA	100.0	465.0
INLET TEMP	R	550.0	536.7
DISCHARGE PRESS	PSIA	149.8	702.0
DISCHARGE TEMP	R	631.7	616.3

V. INSTRUMENTATION FOR PERFORMANCE TESTS

1. Elliott Company employs an automatic measuring and data processing system for compressor performance testing. The basic measurements of pressure, temperature, and speed are collected by the system. The signals from these instruments are transmitted to the computer for conversion to common engineering units. Calculations are then performed to obtain test and design equivalent performance.

2 All pressures will be measured by means of individual transducers for each tap. The transducers are microprocessor based devices which produce a digital output already corrected for results of calibration.

   a. Four separate pressure taps will be read at the inlet flange.

   b. Four separate pressure taps will be read at the discharge flange.

   c. Two separate pressure taps will be read upstream of the flow measuring section.

   d. Two sets of differential pressure taps will be read at the flow measuring section.

3. Temperatures will be measured by Chromel-Alumel thermocouples constructed from premium grade thermocouple wire. Thermocouple output is referenced to a precision UTR. All thermocouples will be verified prior to test.

   a. Four separate temperatures will be read at the inlet flange.

   b. Four separate temperatures will be read at the discharge flange.

   c. Two separate temperatures will be read upstream of the flow measuring section.

4. Speed will be measured by key phasor on either the compressor or driver.

5. The test gas impurity (air) will be monitored throughout the test. The procedure is as follows:

   - Percent oxygen (PO2) in the test loop is determined by means of a Teledyne Model 316RA on-line oxygen analyzer.

   - Air consists of 20.9% oxygen, therefore, the percent air (PA) in the test loop can then be calculated from: PA = (100) (PO2/20.9)

   - The percent air of the test loop is then input to the data reduction program, which adjusts gas properties accordingly.

   - In the case where the test gas is a helium and nitrogen mixture, a Siemens Calomat 6E on-line helium analyzer is also used to directly determine the percentage of helium present in the test gas.

6. Mass flow through the compressor will be determined by a concentric, square-edged orifice plate. The pressure tap configuration will be either D-1/2D or flange taps. Flow equalizers preceding the orifice piping section will be used. Flow section piping and instrumentation follow the requirements of the PTC10 and "Fluid Meters" published by the ASME in 1971.

7. There will be a pressure gauge at each flange and flow section, as well as orifice differential, for visual check. These readings are taken from discreet pressure taps at the same physical location as the computer readings, and are only used for verification of the electronic equipment and control of the test loop.

VI. PERFORMANCE TEST DATA READINGS AND DATA REDUCTION

1. Performance test data acquisition and reduction is conducted by a computer controlled system.

2. Test data scans for each test point are not taken until such time as the compressor is shown to be in equilibrium. Equilibrium is defined as the temperature rise across the compressor not varying more than 1 degree over a five minute period.

3. Once equilibrium is confirmed, three successive scans of all instruments will be taken for each data point and averaged for data reduction. Printed copies of the instrument readings will be available to the test witnesses.

4. Five data points will be taken for the compressor at the equivalent test speed. These points will span the flow range from surge to approximately the maximum flow rate shown on the predicted performance curve applicable to the guarantee point. At least one point will be within 4% of the guarantee point volume flow. Data points will be taken in order of decreasing volume flow; i.e. overload to surge.

5. Surge will be determined by actually surging the compressor. Once the surge location is identified, the compressor will be brought out of surge and the throttle valves reset to provide a stable flow point very near surge. If, however, the flow is reduced to 90% of predicted surge flow, and no surge phenomenon is observed, that flow will be considered to be the surge flow.

6. Basic data reduction of the test performance and the correction to specified (field) speed, suction conditions, and gas analysis will be done on-line via the computer system. Correction to specified conditions is by fan law and Reynolds number correction as shown in the equations in Appendix II.

   A sample of the reduction program output is given in Figure 3. Printed copies of the program output will be supplied to the test witness.

7. A Reynolds Number Correction is applied in the conversion of the test performance to the guarantee condition. The Reynolds Number Correction is described in Paragraph 5.6.3.2 of ASME PTC10-1997.

8. The basic data reduction will provide curves of polytropic head and efficiency versus inlet volume flow for the compressor. At the conclusion of the test, these performance curves will be used as input to a second data analysis program. This second program determines the operating conditions of the overall compressor.

9. The standard mechanical losses from the bearings and seals will be added to the computed gas power to establish the total shaft power required by the compressor at the guarantee point.

10. The following performance curves will be provided in the final report:

    - Head and efficiency vs. inlet volume flow at design speed.
    - Compressor flange pressures and shaft power vs. percent design mass flow at specified pressures.

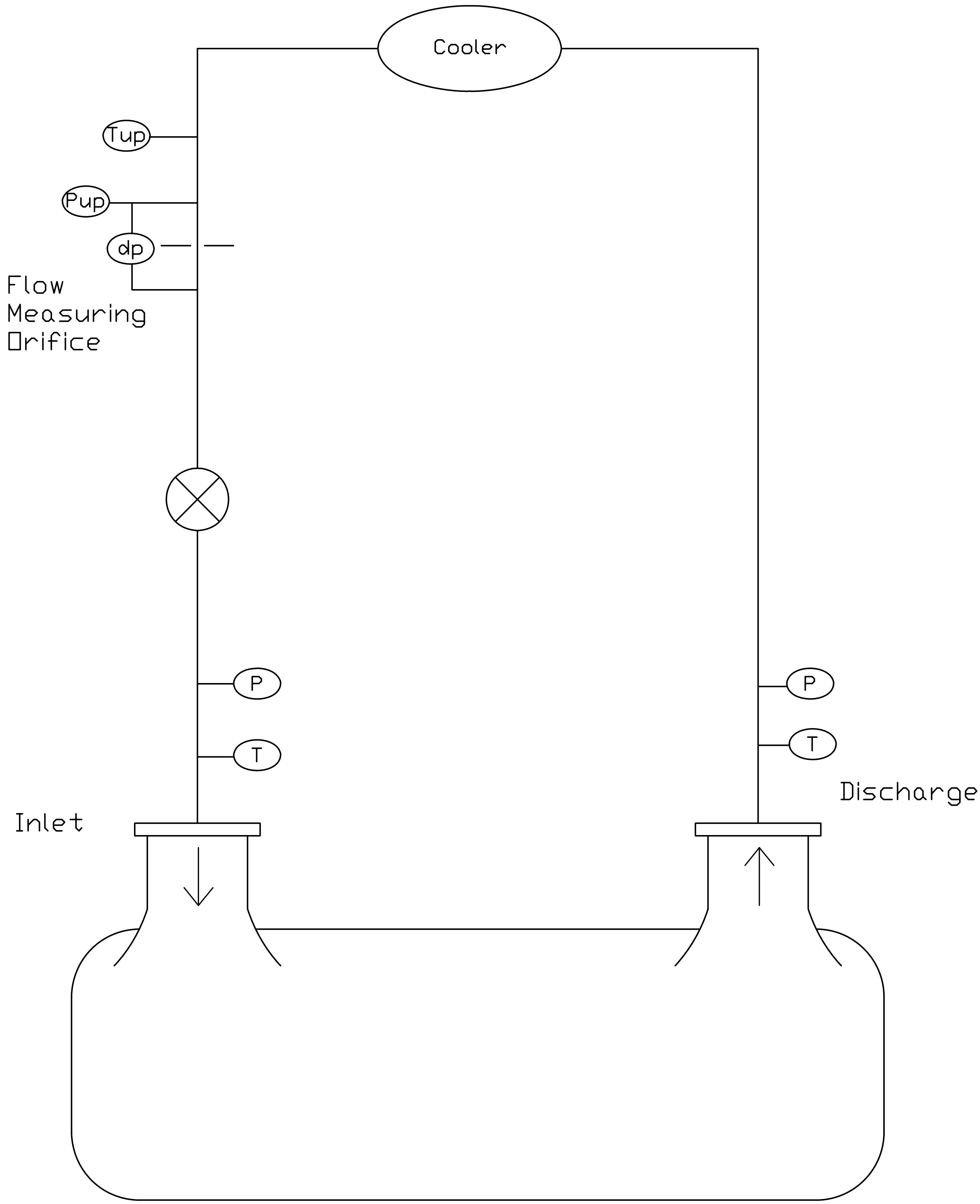
VII. PERFORMANCE GUARANTEES

1. The objective of the performance test is to verify the compressor's ability to provide the required performance at the guarantee field condition within the quoted shaft power tolerance. For this compressor, the guarantee condition is the “Rated” case.

2. Based on the performance test results, corrected to the guarantee condition, the compressor will be capable of handling the guarantee inlet volume flow of 1733 ICFM.

3. At the guarantee capacity the compressor will be able to provide the guarantee discharge pressure of 702 PSIA with the guarantee case inlet conditions of 465 PSIA and 77 ^{O}F.

4. For this fixed speed compressor, the total compressor shaft power required to provide this performance is 1893 HP with tolerances as stated in API 617, 7th Edition, Chapter 2, Paragraph 4.3.3.1.4. This shaft power includes mechanical losses from the bearings and seals of 30 HP. When actual head exceeds required head, and an inlet valve is provided in field operation, suction throttling may be employed to provide the required discharge pressure. Shaft power is then evaluated at the suction throttled condition.



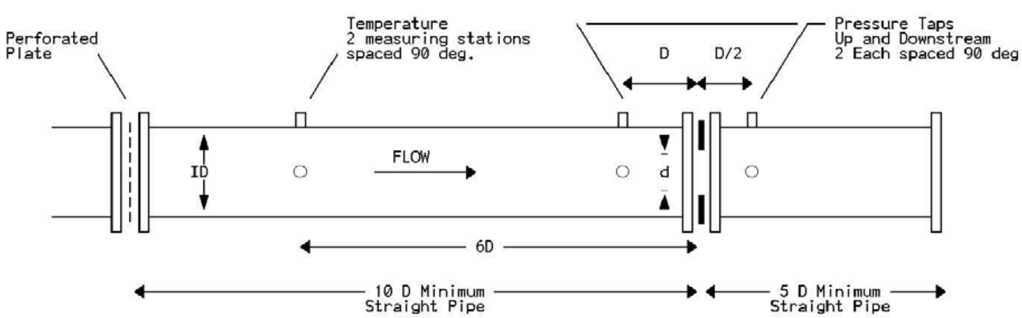
Test Loop Schematic
Shop Order F108251
Figure 1

Figure 2

PERFORMANCE FLOW PIPING INSTRUMENTATION

LINE NO.	D (NOM) INCHES	D (ID) INCHES	d INCHES	BETA (d/D)
1	8	7.981	4.07	0.51

ORIFICE



PERFORMANCE PIPING INSTRUMENTATION

LINE NO.	TYPE	D (NOM) INCHES	LENGTH INCHES
1	Inlet	8	24
2	Discharge	8	24

INLET/SIDELOAD DISCHARGE/EXTRACTION

Sample Data Reduction

```
                 POINT    1.00         SECTION  1 ***

                          RUN CONSTANTS
VISC SP      SP VOL       DIA-1        DIA-2        AREA-1       AREA-2
  0.0071       5.2380      59.2500       0.0000       0.0000       5.1160
NOZ DIA      SPEEDSP      BLADE WD     FLOW MD      PIPE DIA     ORIF DIA
 11.3610    3399.0000       3.4490       0.0000      19.3380      11.3610
IMP1 DIA     REYNOLD      GAS ID       ANUBAR K     ANUBAR d
 51.9600       3.0000      96.0000       0.0000       0.0000
A-UP,TUN     A-GV,INT     A-IMP,MIX    NOZ-CL       CURV
  0.0000       0.0000       0.0000       0.0000       0.0000

                          GAS DATA
GAS PROPERTIES METHOD IS B-W-R      2 GASES   MOL WT  101.332
AIR  0.00957   R134 0.99043

                          TEST DATA
                         INLET     INLET     DISCH     DISCH
                        STATIC     TOTAL    STATIC     TOTAL
PRESSURE         PSIA     4.97      5.01      7.40      7.83
TEMPERATURE         F    89.76     89.92    120.16    121.23
SP VOLUME     CUFT/LB   11.646    11.549     8.234     7.798
SP VOL IDEAL  CUFT/LB                                  7.701
FLOW RATE         CFM           77536.31            52356.79
ENTHALPY       BTU/LB    69.68     69.71     75.85     76.06
ENTHALPY IDEAL BTU/LB                                  74.59
SP HEAT      BTU/LB-F    0.203               0.210
VISCOSITY          CP  0.01256
ENTROPY      BTU/LB-F            0.40232             0.40486

                          ORIFICE DATA   D - D/2 TAPS
UPSTR PRESSURE  PSIA     31.17       FLOW COEF (CF)       0.6445
UPSTR TEMP         F     97.41       THERMAL EXP (FA)     1.0013
UPSTR VOL    CUFT/LB     1.821       Y                    0.7907
UPSTR VISC        CP   0.01283       PRESS RATIO          0.4977
DELTA P         PSIA    15.658       RE               0.9216E+07
ISEN EXPON UP           1.0842       APPROACH FAC (F)     1.0655
WT FLOW       LB/MIN   6083.14       TOTAL LB/MIN        6713.94
SP HEAT     BTU/LB-F     0.211
                          PERFORMANCE
                 PROCESS CALCULATION IS ASME PTC10-1997
*** TEST DATA                        ***  DESIGN EQUIVALENT
SPEED            RPM     2461.       SPEED            RPM     3399.
INLET VOL FLOW   CFM  77536.31       INLET VOL FLOW   CFM 107083.41
HEAD        FT-LB/LB     3823.       HEAD        FT-LB/LB     7360.
EFFICIENCY               0.773       EFFICIENCY               0.781
WORK                     4942.       WORK                     9426.
GAS HP                 1005.33       GAS HP                 5839.58
MACHINE RE NO.      0.1646E+07       MACHINE RE NO.      0.8838E+07
WEIGHT FLOW LB/MIN     6713.94       WEIGHT FLOW   LB/MIN  20443.57
MACH NO.                1.0260       Q/N                     31.504
TOTAL PRESS RATIO       1.5626       H/N**2               0.0006370
TOTAL VOL RATIO         1.4809       RE RATIO                0.1862
POLYTROPIC EXPON        1.1367
ISENTROPIC EXPON        1.1017
FWORK                   1.0006
```

Figure 3
Sample Data Reduction

ELLIOTT COMPANY COMMENTS & EXCEPTIONS TO THE

ASME PTC 10-1997

FOR SHOP PERFORMANCE TESTING

PREPARED BY:

Elliott Company Test Engineering Department

Rev.1

ELLIOTT COMPANY COMMENTS & EXCEPTIONS TO THE ASME PTC 10-1997

SECTION I - OBJECT AND SCOPE

PARAGRAPH 1.6 -

The ASME PTC 10-1997 is the governing code, subject to the comments and exceptions specified herein, for production testing of all multi-stage compressors manufactured by Elliott Company.

SECTION 2 - DEFINITION AND DESCRIPTION OF TERMS

PARAGRAPH 2.1 -

The symbols and units used to denote specific parameters to be measured or computed on test do not duplicate those suggested by code. A complete list of the symbols and their units, used by Elliott Company, is given in our formal test procedure.

PARAGRAPH 2.5.2, 2.7.5 -

Elliott Company will use the ratio q/N (inlet volume flow / speed) in place of flow coefficient.

SECTION 3 - GUIDING PRINCIPLES

PARAGRAPH 3.2 -

Elliott Company shop performance tests are conducted on the following test gases: Air, helium, nitrogen, carbon dioxide, R22, R134, and helium/nitrogen mixtures. For air the gas properties will be determined from Ideal Gas relationships. All other test gases will be considered real and gas properties will be determined by the Elliott Company General Gas Properties Program using the BWR equations, with supporting physical properties taken from the GPSA Handbook, 1972.

PARAGRAPH 3.3.6 (and related 5.5.5) –

Leakage ratio will be evaluated in advance of the test using calculated leakage rates. The test setup will be designed to minimize the difference between the test and specified leakage ratios. Evaluation of volume flow ratios and other equivalency parameters will exclude leakage flows. Leakage flow rates will not be measured on test.

When as a result of the test conditions, losses due to external or interstage leakage and heat transfer will impair an accurate determination of gas horsepower by the standard instrumentation, it will be at the discretion of the Elliott Company to develop suitable means to account for such losses.

PARAGRAPH 3.5 (and related 4.6.11) -

Elliott Company performance for compressors with intermediate streams is based on internal performance. Elliott Company has many years of experience using internal pressure measurements for determination of sectional performance on compressors of this type. Correction from internal to flange pressures is done using well defined nozzle loss coefficients. Note that Para. 4.6.11 does in fact permit use of internal pressure measurements if the sectional performance is defined for internal conditions. Furthermore, with this approach, the volume flow ratio limits stated in para. 3.5.2 and Fig. 3.2 are unnecessary.

PARAGRAPH 3.7.2, 3.7.3 -

Multi-section compressors with external intercoolers will be tested and evaluated on a sectional basis. Every reasonable effort will be made to test all sections at a common speed and still maintain the allowable departure from the specified operating parameters listed in Table 3.2 of the PTC 10-1997. The use of coolers in the performance test loop may not duplicate the field installation, and will be at the discretion of the Elliott Company. Evaluation of the overall compressor(s) performance for the specified design condition will consider the expected pressure drop of the field cooler(s).

PARAGRAPH 3.10 –

Elliott Company normally does not perform a pretest run.

PARAGRAPHS 3.11.1, 3.11.2, 3.11.3 -

Three (3) successive readings of each essential instrument will be considered the standard for shop performance testing at Elliott Company. Duration of time required to complete a set of readings depends on the type of compressor, and the quantity of instrumentation. Requests for additional test readings will be considered only in conjunction with a relaxation of the limits specified in Table 3.4 of the ASME PTC 10-1997.

PARAGRAPH 3.14 -

Raw data as collected by the data acquisition system is made available during the test.

PARAGRAPH 3.11.5 –

Only the guarantee point will be checked for equivalency. All points along a given speed line will be tested at the same equivalent speed. One point will be within +/- 4% of the guarantee volume flow for each section.

PARAGRAPH 3.11.7 –

Elliott Company practice is to demonstrate overload condition for each compressor section within the capabilities of the test setup. The option to demonstrate choke flow may compromise the selection of test loop components, as they are normally sized for optimum performance at the specified operating point.

SECTION 4 - INSTRUMENTS AND METHODS OF MEASUREMENT

PARAGRAPHS 4.3.1,4.3.2,4.3.3 -

For shop performance tests on some (normally high capacity) compressors, Elliott Company test floor limitations may preclude meeting the code requirements for minimum lengths of inlet and discharge piping. The use of flow straighteners and/or equalizers and their design will be at the discretion of the Elliott Company. Elliott Company will continue to locate pressure and temperature taps on the compressor inlets and discharges as defined in ASME PTC 10-1965.

PARAGRAPH 4.6.5, 4.19.2 -

Transducers are calibrated at regular intervals.

PARAGRAPH 4.6.10 -

The barometer will be read and recorded prior to each test point. Instrument temperature will not be recorded.

PARAGRAPH 4.7.3, 4.19.1, 4.19.3 -

Each thermocouple output is checked against a National Institute of Standards and Technology (NIST) instrument at regular intervals.

PARAGRAPH 4.7.7, 4.7.8 -

Use of internal thermocouples and thermocouples mounted on inlet screens may result in variations in excess of 0.5 %.

PARAGRAPH 4.15.3 -

Each thermocouple output is checked against a NIST instrument at regular intervals.

Use of internal thermocouples and thermocouples mounted on inlet screens may result in evidence of nonuniform temperature distribution in excess of 2% of the temperature rise. This is considered normal and will not be remedied by the procedures described.

PARAGRAPH 4.17.1 -

The use of insulation will be at the discretion of the Elliott Company.

PARAGRAPH 4.18.1 –

Mechanical losses are determined from prior testing and are the same values included in the quoted power.

SECTION 5 - COMPUTATION OF RESULTS

PARAGRAPH 5.1 –

Test and corrected performance are presented in terms of inlet volume flow, head and efficiency.

PARAGRAPH 5.4.2.1 –

Each thermocouple output is checked against a NIST instrument at regular intervals. No further correction is applied.

PARAGRAPH 5.6 –

Elliott Company will continue to calculate and present test results in the more practical terms of flow, head and efficiency rather than dimensionless coefficients. This practice is consistent with the sample calculation shown in Appendix C.6 of ASME PTC 10-1997.
A complete listing of the equations used depends on the Type of test and are presented in our formal test procedure and final report.

PARAGRAPH 5.6.4 –

Mechanical losses are determined from prior testing and are the same values included in the quoted power.

PARAGRAPH 5.7 –

Elliott Company concludes from the language of the code that an uncertainty analysis is non-mandatory. Therefore, Elliott Company will not provide an estimate of the test uncertainty. However, instrument tolerances can be provided upon request.

SECTION 6 - REPORT OF TESTS

The final performance test report will include applicable portions of the information shown in para. 6.2 except as amended by the Elliott Company comments to this Code.

ELLIOTT COMPANY PERFORMANCE TEST SET-UP

EQUATIONS USED IN DATA REDUCTION FOR A TYPE 2 PERFORMANCE TEST

I. Mass Flow Rate (Eq. 4, Page 57, PTC 19.5;4-1959) Equation for an orifice

$$W = \left(\frac{359}{60}\right) K \ Fa \ d^2 \ Y \sqrt{HW/v_{up}}$$

$$v_{up} = \frac{ZRT_s}{144P_s}$$

II. Total Conditions are Calculated as Follows:

1. Total Pressure Equation

$$P = P_s + P_V$$

$$P_V = \frac{V^2}{2(gc)(144)(v_s)}$$

Where $V = \frac{Q_s}{60A}$ and $Q_s = v_s W$

2. Total Temperature Equation

$$T = T_s + (1 - C) \ T_V$$

C = Thermocouple Recovery Factor = .65

$$T_V = \frac{V^2}{2(gc)(J)(Cp)}$$

III. Inlet Total Volume Flow

$$Q_t = (W)\ (v)$$

IV. Polytropic Head

1. Volume Exponent

$$n = \ln\left(\frac{P_D}{P_I}\right) / \ln\left(\frac{v_I}{v_D}\right)$$

$$ns = \ln\left(\frac{P_D}{P_I}\right) / \ln\left(\frac{v_I}{v_D'}\right)$$

2. Polytropic Work Factor

$$f = \frac{h_{D'} - h_I}{\left(\frac{ns}{ns-1}\right)\left(P_D v_{D'} - P_I v_I\right)} \times \frac{J}{144}$$

3. Polytropic Head

$$H_p = 144\left(\frac{n}{n-1}\right) f \; P_I v_I \left(\left(\frac{rp}{rv}\right) - 1\right)$$

4. Impeller Blade Tip Velocity

$$U = \frac{N\pi D}{720}$$

5. Polytropic Efficiency

$$\eta_p = \frac{H_p}{\left(h_D - h_I\right)\left(778.16\right)}$$

V. Corrected to Specified Conditions

1. Machine Reynolds Number

Rem = Uw/V*

2. Corrected Efficiency

$$\left(1-\eta_p\right)_{sp} = \left(1-\eta_p\right)_t \left(\frac{RA_{sp}}{RA_t}\right)\left(\frac{RB_{sp}}{RB_t}\right)$$

$$RA = 0.066 + 0.934\left[\frac{\left(4.8 \times 10^6 \times b\right)}{Rem}\right]^{RC}$$

$$RB = \frac{\log\left(0.000125 + \frac{13.67}{Rem}\right)}{\log\left(\varepsilon + \frac{13.67}{Rem}\right)}$$

$$RC = \frac{0.988}{Rem^{0.243}}$$

3. Corrected Head

$$H_{sp} = H_t \left(\frac{\eta_{sp}}{\eta_t}\right) \left(\frac{N_{sp}}{N_t}\right)^2$$

4. Corrected Inlet Capacity

$$Q_{sp} = Q_t \left(\frac{N_{sp}}{N_t}\right)$$

ELLIOTT COMPANY PERFORMANCE TEST SET-UP

NOMENCLATURE

Symbol

A	Area where pressure and temperature are read	ft^2
Cp	Specific heat at constant pressure	BTU/lbm^oF
D	Impeller diameter	Inches
Fa	Thermal expansion factor	
H	Head	ft-lb/lb
HW	Orifice differential pressure	Inches H_2O
J	Mechanical equivalent of heat (778.16)	ft-lbf/BTU
K	Orifice flow coefficient	
N	Speed	rpm
P	Total absolute pressure	PSIA
Q	Total volume flow	ft^3/min
R	Gas constant used in 144 PV = ZRT	ft-lbf/lbm^oR
Rem	Machine Reynolds Number	
T	Total absolute temperature	Degrees Rankine
U	Impeller blade tip velocity	fps
V	Average fluid velocity	fps
V*	Kinematic viscosity	ft^2/sec
W	Weight flow	lb/min
Y	Net expansion factor	
Z	Compressibility function	
b	Tip width of blade	ft
d	Orifice diameter	Inches
f	Polytropic work factor	
h	Enthalpy	BTU/lb
gc	Gravitational constant	lbm ft/lb_f sec^2
rp	Total pressure ratio	
rv	Total volume ratio	
n	Polytropic exponent for a path on the p - v diagram	
ns	Isentropic exponent for a path on the p - v diagram	
v	Total specific volume	
w	Impeller blade tip width	ft
η	Polytropic efficiency	
ε	Surface finish	in

Subscripts

D	Discharge condition
D'	Conditions at discharge pressure and entropy corresponding to inlet
I	Inlet conditions
p	Polytropic
s	Static
sp	Specified
t	Test
up	Orifice upstream condition