COMPLIANCE TEST REPORT
ANR PIPELINE-GOODWELL COMPRESSOR STATION
COMBUSTION EUGDS TURBINE NO.6
COMBUSTION EUGDS TURBINE NO.7

Prepared for:

TC Energy

TC Energy's ANR Pipeline Company
White Cloud, MI

March 22, 2022

Prepared by:

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PREFACE

I, Karl Mast, do hereby certify that the source emissions testing conducted at TC Energy in White Cloud, MI was performed in accordance with the procedures set forth by the United States Environmental Protection Agency, and that the data and results submitted within this report are an exact representation of the testing.

Karl Mast
Test Supervisor

I, Karl Mast, do hereby attest that all work on this project was performed under my direct supervision, and that this report accurately and authentically presents the source emissions testing conducted at ANR Pipeline's Goodwell Compressor Station in White Cloud, MI.

Karl Mast
Test Supervisor

SUMMARY

The compliance testing was performed on the Combustion Turbine No. 6 and Combustion Turbine No. 7 systems in accordance with the requirements of the Title 40, Code of Federal Regulations, Part 60 (40 CFR 60.4320(a). The results of the testing are detailed in the following tables.

NO_x Emission Test Results						
Parameter	**Unit**	**Run 1**	**Run 2**	**Run 3**	**Average**	**Limit**
NO_x ppmvd @ 15% O_2	No. 6	4.9269	4.4276	3.9095	4.4213	25
NO_x ppmvd @ 15% O_2	No. 7	2.3930	2.1640	1.8851	2.1474	25

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1. INTRODUCTION

This report presents the results of the source emissions testing conducted by Environmental Quality Management, Inc. (EQM) for TC Energy's ANR Pipeline (ANR) at Goodwell compressor station, near White Cloud, MI, which is located in Newaygo County.

The primary purpose of this testing program was to conduct emissions testing to determine compliance with operating permit No. MI-ROP-N5576-2021 for Combustion EUGDS Turbine No. 6 and Combustion EUGDS Turbine No. 7 at ANR Pipeline's gas compressor facility.

EQM's responsibility was to conduct the compliance testing for the O2 and NOx emissions rates and perform data reduction for conformance evaluation. ANR Pipeline's responsibility was to maintain process operating parameters and to assist in providing process operating data per compliance test requirements.

The following report provides information pertaining to TC Energy's process operations, and Compliance testing. The Compliance testing conducted on the Combustion Turbine No. 6 was performed on March 22, 2022, from 8:50 A.M. to 9:52 A.M. The Compliance testing conducted on the Combustion Turbine No. 7 was performed on March 22, 2022, from 10:47 A.M. to 11:49 A.M.

The following requirements were specific for the testing program:

1. Equipment calibrations performed and calibration data provided.
2. Three (3) twenty-one (21) -minute, minimum, O_2 and NOx test runs performed at the Combustion Turbine No. 6 and Combustion Turbine No. 7 at maximum achievable load and speed according to pipeline conditions pursuant to EPA, Title 40, Code of Federal Regulations, Part 60, Appendix A.
3. Process manufacturing operations maintained at 100% of capacities and production and fuel consumption rates recorded during the emissions testing periods.
4. All testing and analyses performed in accordance with current EPA test methodologies and analytical procedures for O_2 and NOx emissions determinations.
5. Stratification was found to be less than 0.77% in both turbine exhausts.
6. Diluent corrected stratification test was performed in accordance with Subpart KKKK.

The testing program was approved by and/or coordinated with Tyrah Lydia, TC Energy's ANR Pipeline Company. The emission testing was managed by Karl Mast, Manager, Emission Measurement and Project Manager, EQM. The testing was completed by Zach Hill, Field Activities Lead, EQM. The emission testing was observed Chris Robinson, MEGLE.

2. TEST RESULTS SUMMARY

The compliance testing was performed on the Combustion Turbine No. 6 and Combustion Turbine No. 7 systems in accordance with the requirements of the Title 40, Code of Federal Regulations, Part 60 (40 CFR 60, Appendix A) A summary of the test results is given below:

Table 1. NO_x Emission Test Results

Parameter	Unit	Run 1	Run 2	Run 3	Average	Limit
NO_x ppmvd @ 15% O_2	No. 6	4.9269	4.4276	3.9095	4.4213	25
NO_x ppmvd @ 15% O_2	No. 7	2.3930	2.1640	1.8851	2.1474	25

Based on the information provided above, the Combustion Turbine No. 6 and Combustion Turbine No. 7 met the acceptance criteria during the course of the testing. A complete list of performance parameters for each test run that was performed at the stack sampling locations can be found in Table 2-9.

Additional testing information may be found in Appendix A.

Table 2. Operating Parameters and Ambient Conditions-Turbine No. 6

Run	1	2	3	
Date	03/22/22	03/22/22	03/22/22	
Time	8:50	9:11	9:32	
Engine Operating Conditions	High	High	High	Averages
Unit Horsepower from Control Panel	3,599.0	4,621.0	5,239.0	4,486.3
% Load	45.8	58.8	66.6	57.0
Unit Speed (rpm) CT/GG/GP/Jet	14,830.0	14,810.0	14,796.0	14,812.0
% CT Speed	98.9	98.7	98.6	98.7
Gas Compressor Speed (rpm) PT/Booster	12,386.0	12,296.0	12,276.0	12,319.3
% PT Speed	86.6	86.0	85.8	86.1
Turbine Exhaust Temp T5	1,402.0	1,400.0	1,399.0	1,400.3
Compressor Suction Pressure (PSIG)	275.0	276.0	276.0	275.7
Compressor Suction Temperature (°F)	36.0	36.0	36.0	36.0
Compressor Discharge Pressure (PSIG)	593.0	624.0	627.0	614.7
Compressor Discharge Temperature (°F)	106.0	128.0	140.0	124.7
Compressor Flow (MMSCF/D)	145.0	141.0	140.0	142.0
Heat Rate (BTU(LHV)/HP-hr)	17,236.7155	13,424.5702	11,840.9885	14,167.4247
Ambient Conditions				
Ambient Temperature (°F)	36.00	36.00	37.00	36.33
Barometric Pressure (psi)	14.17	14.18	14.18	14.18
Ambient Relative Humidity (%)	61.00	61.00	59.00	60.33
Absolute Humidity (grains/LB)	19.64	19.64	19.75	19.68

Table 3. Emissions Concentrations, Calculated Mass Emissions, & Calculated Flows- Turbine No. 6

Run	1	2	3	
Date	03/22/22	03/22/22	03/22/22	
Time	8:50	9:11	9:32	
Emissions Concentrations & Calculated Mass Emissions				
NO_x ppm (BIAS Corrected)	4.810	4.330	3.830	4.3233
NO_X LB/HR	1.2455	1.1193	0.9883	1.1177
NO_X (ppm @ 15% O_2)	4.9269	4.4276	3.9095	4.4213
NO_X (ppm @ 15% O_2, ISO)	5.0247	4.5152	3.9746	4.5048
NOx LB/MMBTU	0.0182	0.0163	0.0144	0.0163
NO_X Tons/Year	5.4553	4.9024	4.3288	4.8955
NO_X LB/SCF Fuel	1.92E-05	1.73E-05	1.52E-05	1.72E-05
NO_X LB/MMSCF Fuel	19.2004	17.2544	15.2355	17.2301
% O_2 (BIAS Corrected)	15.140	15.130	15.120	15.1300
Calculated Flows				
Fuel Flow - (SCFM)	1083.3333	1083.3333	1083.3333	1083.3333
Fuel Flow - (SCFH)	65000.00	65000.00	65000.00	65000.00
Exhaust Flow (LB/HR)	142502.2533	142271.6066	141905.7377	142226.5325
Exhaust Flow (SCFM)	37084.7524	37032.5088	36980.4443	37032.5685
Air Flow (SCFM)	34718.0865	34658.4880	34599.0939	34658.5561
Exhaust Flow Method 19 (scfm)	36071.6844	36009.1685	35946.8689	36009.2406
Exhaust Flow Method 19 (lbm/min)	1660.0385	1657.1613	1654.3077	1657.1692
Exhaust Flow Carbon Balance (lbm/min)	2771.8685	2767.2532	2762.6536	2767.2584
Air flow Beshouri (scfm)	36062.4696	36002.4230	35942.5823	36002.4916
BSAC, #/BHP-hr	43.9643	34.1822	30.0984	36.0816
Fuel Flow Measurements				
Fuel Flow From Screen(MSCFH)	65.00	65.00	65.00	65.00
** BASED ON FUEL SPECIFIC DRY F-FACTOR CALCULATION	Run 1	Run 2	Run 3	
* BASED ON CARBON BALANCE (STOICH. + O2)				
- A/F IS TOTAL MASS RATIO				

Table 4. Operating Parameters and Ambient Conditions-Turbine No. 7

Run	1	2	3	
Date	03/22/22	03/22/22	03/22/22	
Time	10:47	11:08	11:29	
Engine Operating Conditions	High	High	High	Averages
Unit Horsepower from Control Panel	6,922.0	6,960.0	6,945.0	6,942.3
% Load	88.0	88.5	88.3	88.3
Unit Speed (rpm) CT/GG/GP/Jet	14,945.0	14,945.0	14,945.0	14,945.0
% CT Speed	99.6	99.6	99.6	99.6
Gas Compressor Speed (rpm) PT/Booster	12,236.0	12,235.0	12,221.0	12,230.7
% PT Speed	85.6	85.6	85.5	85.5
Turbine Exhaust Temp T5	1,384.0	1,385.0	1,388.0	1,385.7
Compressor Suction Pressure (PSIG)	275.0	275.0	276.0	275.3
Compressor Suction Temperature (°F)	37.0	37.0	38.0	37.3
Compressor Discharge Pressure (PSIG)	630.0	638.0	641.0	636.3
Compressor Discharge Temperature (°F)	174.0	176.0	177.0	175.7
Compressor Flow (MMSCF/D)	138.0	137.0	136.0	137.0
Heat Rate (BTU(LHV)/HP-hr)	8,686.2426	8,501.6937	8,520.0559	8,569.3307
Ambient Conditions				
Ambient Temperature (°F)	37.00	38.00	39.00	38.00
Barometric Pressure (psi)	14.20	14.19	14.20	14.20
Ambient Relative Humidity (%)	58.00	62.00	54.00	58.00
Absolute Humidity (grains/LB)	19.39	21.58	19.53	20.17

Table 5. Emissions Concentrations, Calculated Mass Emissions, & Calculated Flows-Turbine No. 7

Run	1	2	3	
Date	03/22/22	03/22/22	03/22/22	
Time	10:47	11:08	11:29	
Emissions Concentrations & Calculated Mass Emissions				
NO_x ppm (BIAS Corrected)	2.320	2.120	1.850	2.0967
NO_X LB/HR	0.5863	0.5218	0.4546	0.5209
NO_X (ppm @ 15% O_2)	2.3930	2.1640	1.8851	2.1474
NO_X (ppm @ 15% O_2, ISO)	2.4294	2.2035	1.9028	2.1786
NOx LB/MMBTU	0.0088	0.0080	0.0069	0.0079
NO_X Tons/Year	2.5681	2.2855	1.9910	2.2815
NO_X LB/SCF Fuel	9.33E-06	8.43E-06	7.35E-06	8.37E-06
NO_X LB/MMSCF Fuel	9.3256	8.4332	7.3465	8.3685
% O_2 (BIAS Corrected)	15.180	15.120	15.110	15.137
Calculated Flows				
Fuel Flow - (SCFM)	1050.00	1033.33	1033.33	1038.8889
Fuel Flow - (SCFH)	63,000	62,000	62,000	62,333.3333
Exhaust Flow (LB/HR)	138,855.8377	135,466.2200	134,856.0183	136,392.6920
Exhaust Flow (SCFM)	36,177.9189	35,303.1159	35,253.6245	35,578.2198
Air Flow (SCFM)	33,882.8984	33,002.2126	32,945.7538	33,276.9549
Exhaust Flow Method 19 (scfm)	35,206.2745	34,287.7827	34,228.5637	34,574.2069
Exhaust Flow Method 19 (lbm/min)	1,620.1774	1,578.1675	1,575.1996	1,591.1815
Exhaust Flow Carbon Balance (lbm/min)	2,704.6287	2,635.1465	2,630.7743	2,656.8498
Air flow Beshouri (scfm)	35,187.6681	34,283.6939	34,226.8106	34,566.0575
BSAC, #/BHP-hr	22.3088	21.6103	21.6199	21.8463
Fuel Flow Measurements				
Fuel Flow From Screen(MSCFH)	63.00	62.00	62.00	62.33
** BASED ON FUEL SPECIFIC DRY F-FACTOR CALCULATION	Run 1	Run 2	Run 3	
* BASED ON CARBON BALANCE (STOICH. + O2)				
- A/F IS TOTAL MASS RATIO				

3. PROCESS DESCRIPTION

TC Energy's ANR Goodwell Compressor Station is located in White Cloud, Michigan and operates two Solar Centaur 60, 7,865 hp and 15,000 rpm, natural gas fired turbines with low NO_x burner for NO_x control labeled EUGDS Turbine 6 (aka 6.1) and EUGDS Turbine 7 (aka 7.2). The plant is located at 6759 East Five Mile Road, White Cloud, MI

The Solar Centaur 60 gas turbine is a simple cycle, natural gas fired, split-shaft turbine. In a simple cycle turbine, filtered atmosphere air is first compressed by the axial flow compressor. The hot compressed air is then fired with natural gas in the combustor. The hot exhaust gases expand through two turbine stages. The gas producer (G.P.) turbine drives the axial flow air while the power turbine (P.T.) drives the centrifugal pipeline compressor. The pipeline gas compressor moves natural gas through the pipeline by compressing it from an initial "suction" state to a more compressed "discharge" state.

The following tables provide a summary of the production rates for the Turbines No. 6 and No. 7 during the test:

Table 6. Turbine No. 6 and No. 7 Brake Horsepower (BHP)

Run No.	Turbine No. 6	Turbine No. 7
1	3,599.0	6,922.0
2	4,621.0	6,960.0
3	5,239.0	6,945.0
Average	4,486.3	6,942.3
Rated BHP	7,865	7,865

Table 7. Turbine No. 6 and No. 7 CT RPM

Run No.	Turbine No. 6	Turbine No. 7
1	14,830.0	14,945.0
2	14,810.0	14,945.0
3	14,796.0	14,945.0
Average	14,812.0	14,945.0
Rated CT RPM	15,000	15,000

Table 8. Unit 6 General Information

General Information

Date:	22-Mar-22
Company:	TC Energy
Station:	Goodwell MI
Unit:	6.1
Engine Type:	Solar Centaur 60

CT Rated RPM:	15000	RPM
PT Rated RPM:	14300	RPM
Rated BHP:	7865	BHP

Permit Limits

	ppm@15%	g/Bhp-Hr	lb/hr	TPY
NOx:	25			
CO:				
VOC:				
H2CO:				

Limits are actuallly listed as average values

Fuel Gas Analysis

Constituent	Mole Percent
Nitrogen	1.123
Carbon Dioxide	0.457
Methane	91.112
Ethane	6.905
Propane	0.363
I-Butane	0.015
N-Butane	0.020
I-Pentane	0.000
N-Pentane	0.000
Hexane +	0.004
Total	100.00

Fuel Meter Type

Enter Type from List Below	2
Orifice Meter (upstream pressure tap):	1
Orifice Meter (downstream pressure tap):	2
Electronic Flow Meter (EFM):	3
Venturi (Nozzle) Meter:	4
Roots Meter w/ Accumulator:	5
Pipe I.D.:	3.068
Orifice I.D.:	1.5

Table 9. Unit 7 General Information

General Information

Date:	22-Mar-22
Company:	TC Energy
Station:	Goodwell MI
Unit:	7.2
Engine Type:	Solar Centaur 60

CT Rated RPM:	15000	RPM
PT Rated RPM:	14300	RPM
Rated BHP:	7865	BHP

Permit Limits

	ppm@15%	g/Bhp-Hr	lb/hr	TPY
NOx:	25			
CO:				
VOC:				
H2CO:				

Limits are actuallly listed as average values

Fuel Gas Analysis

Constituent	Mole Percent
Nitrogen	1.123
Carbon Dioxide	0.457
Methane	91.112
Ethane	6.905
Propane	0.363
I-Butane	0.015
N-Butane	0.020
I-Pentane	0.0004
N-Pentane	0.000
Hexane +	0.004
Total	100.00

Fuel Meter Type

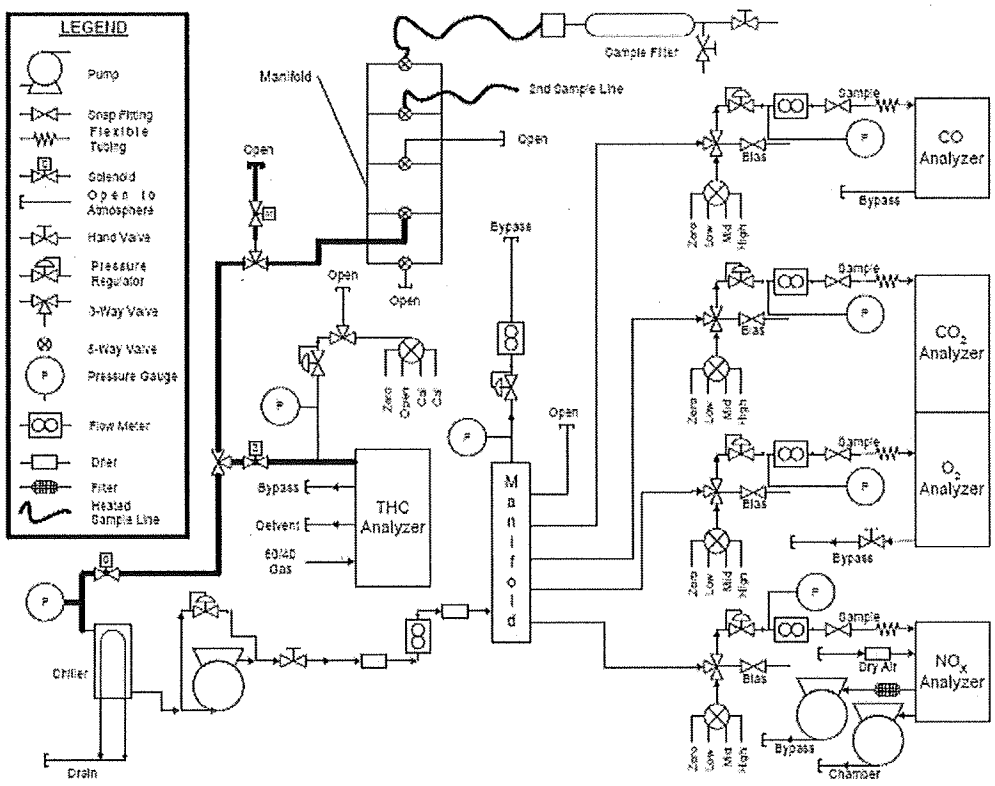
Enter Type from List Below: 2

Orifice Meter (upstream pressure tap):	1
Orifice Meter (downstream pressure tap):	2
Electronic Flow Meter (EFM):	3
Venturi (Nozzle) Meter:	4
Roots Meter w/ Accumulator:	5

Pipe I.D.: 3.068

Orifice I.D.: 1.5

Figure 1. Flow Schematic



Additional Information pertaining to the Fuel Flows may be found in Appendix B.

4. TEST PROCEDURES

EQM and EQM's affiliates and subcontractors use current U.S. EPA accepted testing methodologies in their Air Quality Programs as listed in the U.S. Code of Federal Regulations, Title 40, Part 60, Appendix A. For this testing program, the following specific methodologies were utilized:

- U.S. EPA Method 3A – Determination of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Sources (Instrumental Analyzer Procedure)
- U.S. EPA Method 7E – Determination of Nitrogen Oxides Emissions From Stationary Sources (Instrumental Analyzer Procedure)
- U.S. EPA Method 19– Determination of Volumetric Flow Rate From Stationary Sources

USEPA Methods 3A and 7E were performed at the Exhaust Stack sampling location by continuously extracting a gas sample from the stack through a single point stainless steel sample probe. The extracted sample was pulled through a series of filters to remove any particulate matter. Directly after the probe, the sample was conditioned by a series of refrigeration dryers to remove moisture from the gas stream. After the refrigeration dryers, the sample was transported through a Teflon® line to the analyzers. The flow of the stack gas sample was regulated at a constant rate to minimize drift.

At the start of the day, each monitor was checked for calibration error by introducing zero, mid-range and high-range EPA Protocol 1 gases to the measurement system at a point upstream of the analyzers. In this report, the calibration error test is referred to as instrument calibration. The gas was injected into the sampling valve located at the outlet of the sampling probe. The bias test was conducted before and after each consecutive test run by introducing zero and upscale calibration gases for each monitor. The upscale calibration gases used for each monitor were the high calibration gases.

Measurement System Performance Specifications were as follows:

- Analyzer Calibration Error - Less than +/- 2% of the span of the zero, mid-range and high-range calibration gases.
- Sampling System Bias - Less than +/-5% of the span for the zero, mid-range and high-range calibration gases.
- Zero Drift - Less than +/-3% of the span over the period of each test run.
- Calibration Drift - Less than +/-3% of the span over the period of each set of runs.

Calculations that were used in this testing event for the Units No. 6 and No. 7 are as follows:

Calibration Correction

$$C_{GAS} = (C_R - C_O)\frac{C_{MA}}{C_M - C_O}$$

Where:

C_{GAS}:	Corrected flue gas concentration (ppmvd)
C_R:	Flue gas concentration (ppmvd)
C_O:	Average of initial and final zero checks (ppmvd)
C_M:	Average of initial and final span checks (ppmvd)
C_{MA}:	Actual concentration of span gas (ppmvd)

EPA F-Factor

$$F_d = \frac{\left[(3.64 \cdot H_{Wt\%} \cdot 100) + (1.53 \cdot C_{Wt\%} \cdot 100)\right]}{\frac{GCV}{\rho_{FuelGas}}} \cdot 10^6 + \frac{\left[(0.14 \cdot N_{2Wt\%} \cdot 100) - (0.46 \cdot O_{2Wt\%} \cdot 100)\right]}{\frac{GCV}{\rho_{FuelGas}}} \cdot 10^6$$

Where:

F_d:	Fuel specific F-factor, dscf/MMBtu
$H_{Wt\%}$:	Hydrogen weight percent
$C_{Wt\%}$:	Carbon weight percent
$N_{2Wt\%}$:	Nitrogen weight percent
$O_{2Wt\%}$:	Oxygen weight percent
GCV:	Heating value of the fuel, BTU/dscf
$\rho_{Fuel\ Gas}$:	Density of the fuel gas, lb/scf

NO_x Corrected to 15% O_2

$$Em = NO_X\left(\frac{5.9}{20.9 - \%O_2}\right)$$

Where:

E_m:	Pollutant concentration corrected to 15% O_2, ppm
NO_X:	Pollutant concentration, ppm
$\%O_2$:	Oxygen concentration in percent, measured on a dry basis

5. QUALITY ASSURANCE PROCEDURES

Each reference method presented in the U.S. Code of Federal Regulations details the instrument calibration requirements, sample recovery and analysis, data reduction and verification, types of equipment required, and the appropriate sampling and analytical procedures to ensure maximum performance and accuracy. EQM and EQM's affiliates and subcontractors adhere to the guidelines for quality control set forth by the United States Environmental Protection Agency. These procedures are outlined in the following documents:

- Code of Federal Regulations, Title 40, Part 51
- Code of Federal Regulations, Title 40, Part 60
- Quality Assurance Handbook, Volume 1, EPA 600/9-76-005
- Quality Assurance Handbook, Volume 2, EPA 600/4-77-027a
- Quality Assurance Handbook, Volume 3, EPA 600/4-77-027b

6. CONCLUSIONS

An Emissions Test was conducted on the Turbine 6 and Turbine 7 at TC Energy's ANR Pipeline Company's Goodwell Compressor Station located in White Cloud, MI. The testing was conducted on March 22, 2022.

During the course of the testing, the Turbine 6 and Turbine 7 conformed to the requirements of Code of Federal Regulations, Title 40, Part 60, Appendix A.

The usefulness and/or significance of the emissions values presented in this document as they relate to the compliance status of the Turbine 6 and Turbine 7 emissions shall be determined by others.

For additional information pertaining to the testing program see Appendix E of this report.

A. FIELD TEST DATA