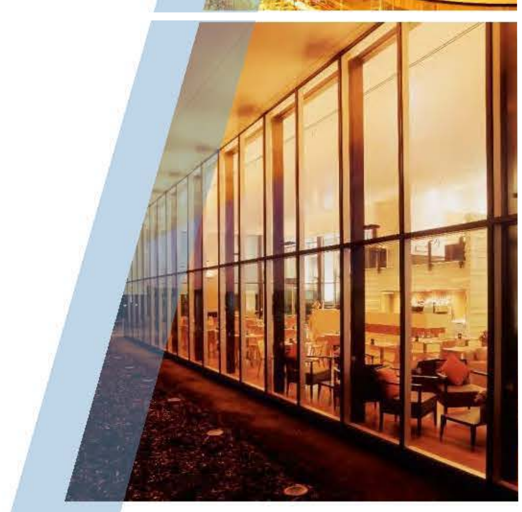


Four-Factor Analysis for Regional Haze Planning in Oklahoma

Cashion Compressor Station
Kingfisher County, Oklahoma
FAC ID 1373

Panhandle Eastern Pipeline Company

Table of Contents

Table Index

Figure Index

Appendix Index

1. Executive Summary

In response to the Oklahoma Department of Environmental Quality (DEQ) letter dated July 1, 2020, GHD Services Inc. (GHD) was retained by Panhandle Eastern Pipeline Co. to prepare a four-factor analysis for the DEQ Regional Haze Second Planning Period Progress Analysis under the Clean Air Act (CAA) and Regional Haze Rule (40 CFR §51.300 to 51.309). As a part of this Progress Analysis, nitrogen oxides (NO_x) emissions were evaluated at the Cashion Compressor Station (Cashion CS) (Site/Facility).

The four-factor analysis is codified in 40 CFR §51.308(d)(1)(i)(A) and is designated as a means for establishing reasonable progress goals towards achieving natural visibility conditions by the year 2064. The four factors to consider are:

1. The costs of compliance
2. The time necessary for compliance
3. The energy and non-air quality environmental impacts of compliance
4. The remaining useful life of any potentially affected sources

The purpose of the four-factor analysis is to identify control measures for reducing emissions that could be used to establish the long-term strategy for attaining state visibility goals. Ramboll US Corporation (Ramboll) produced a study examining the impact of stationary sources of NO_x and SO_2 on each Class I Area in the central region of the United States. DEQ used a method based on this study to determine which sources may have the greatest potential for contributing to visibility impairment at Oklahoma's Class I Area: the Wichita Mountains Wilderness Area. Based on the Ramboll study and DEQ follow-up determinations, DEQ has requested evaluations of potential control measures for NO_x on the following emission units at Cashion CS:

1. U-338 and U-339; Fairbanks Morse 38DS8 MEP-8
2. U-2301 and U-2302; Cooper Quad 12Q155H

The analysis used by DEQ was based on the NOx emissions reported for 2016. As allowed by DEQ, the reported emissions for the Cashion CS were equal to the potential to emit for the Site. Based on the actual emissions from the last 5 years, it appears that this Site does not meet the Four Factor Analysis applicability since the Q/d value is below 5.0. Additionally, by analyzing the wind patterns in the area, the prevailing winds in the area are northerly and southerly. Therefore, emissions from the Cashion CS have a negligible effect on visibility at the Wichita Mountains Wilderness Area since the winds from that direction are very infrequent. Based on these reasons, we believe that any emission reductions made at the Cashion CS would not have a substantive effect in meeting the visibility goals at this Class I Area. Thus, this analysis does not include an economic evaluation of the viable emission controls.

2. Class I Area Impact Analysis

2.1 PSD and TV Permit Evaluations

The nearest Class I area is the Wichita Mountains Wilderness Area, located about 129 km from the Facility. Visibility impacts at this Class I area were evaluated in previous Prevention of Significant Deterioration (PSD) and Title V (TV) permit applications for the Cashion CS. A DEQ memo, dated February 16, 1999, summarizes the visibility evaluation findings:

"The nearest Class I area is the Wichita Mountains Wilderness Area, about 129 km from the facility. The two important tests for impaction on a Class I area are visibility impairment and ambient air quality effect. A significant air quality impact is defined as an ambient concentration increase of 1 $\mu g/m^3$ (24 hour average). No impacts which exceeded this level were modeled beyond 25 km from the source. The protracted transport distance to the nearest Class I area precludes any significant air quality impact from the facility."

In addition, a DEQ memo, dated April 1, 2019, approving the 2018 DEQ Title V renewal permit for the Cashion CS states on page 14: "Ambient air quality standards are not threatened at this site."

2.2 Q/d Analysis

To determine which facilities are subject to the Regional Haze four factor analysis, a Q/d value is calculated using site-wide emissions as tons per year (Q) divided by the distance to the nearest Class I Area in kilometers (d). For the Cashion CS, DEQ used the 2016 Emission Inventory as the baseline NOx emissions, which were reported based on permitted emission factors and hours of operation instead of actual NOx emissions based on the most recent engine test data. Using actual 2016 NOx emissions based on the 2016 engine test results yields a Q/d of 3.6, which is below the Regional Haze selection criteria of 5. By using actual 2016 NOx emissions in the selection evaluation, Cashion CS should have screened out of the four factor analysis requirement.

Additionally, it is projected that a more representative year for future operations at the Cashion CS is 2019. Using 2019 instead of 2016 yields a Q/d of 2.1, which is far below the selection criteria of 5. Based on this information, the Cashion CS should be considered for removal from the four factor analysis requirement. A comparison of annual Q/d values is in Table 2.1 below:

Table 2.1 Annual Q/d Values Comparison

Reporting Year	**Actual** Site-wide Q/d based on recent engine test data	**Reported** Site-wide Q/d based on permitted emission factors
2016	3.6	5.5
2017	4.3	6.0
2018	2.3	4.0
2019	2.1	4.8

NOx engine test data, reported NOx emissions, and a Q/d analysis are presented in Appendix A.

2.3 Air Dispersion Modeling Analysis

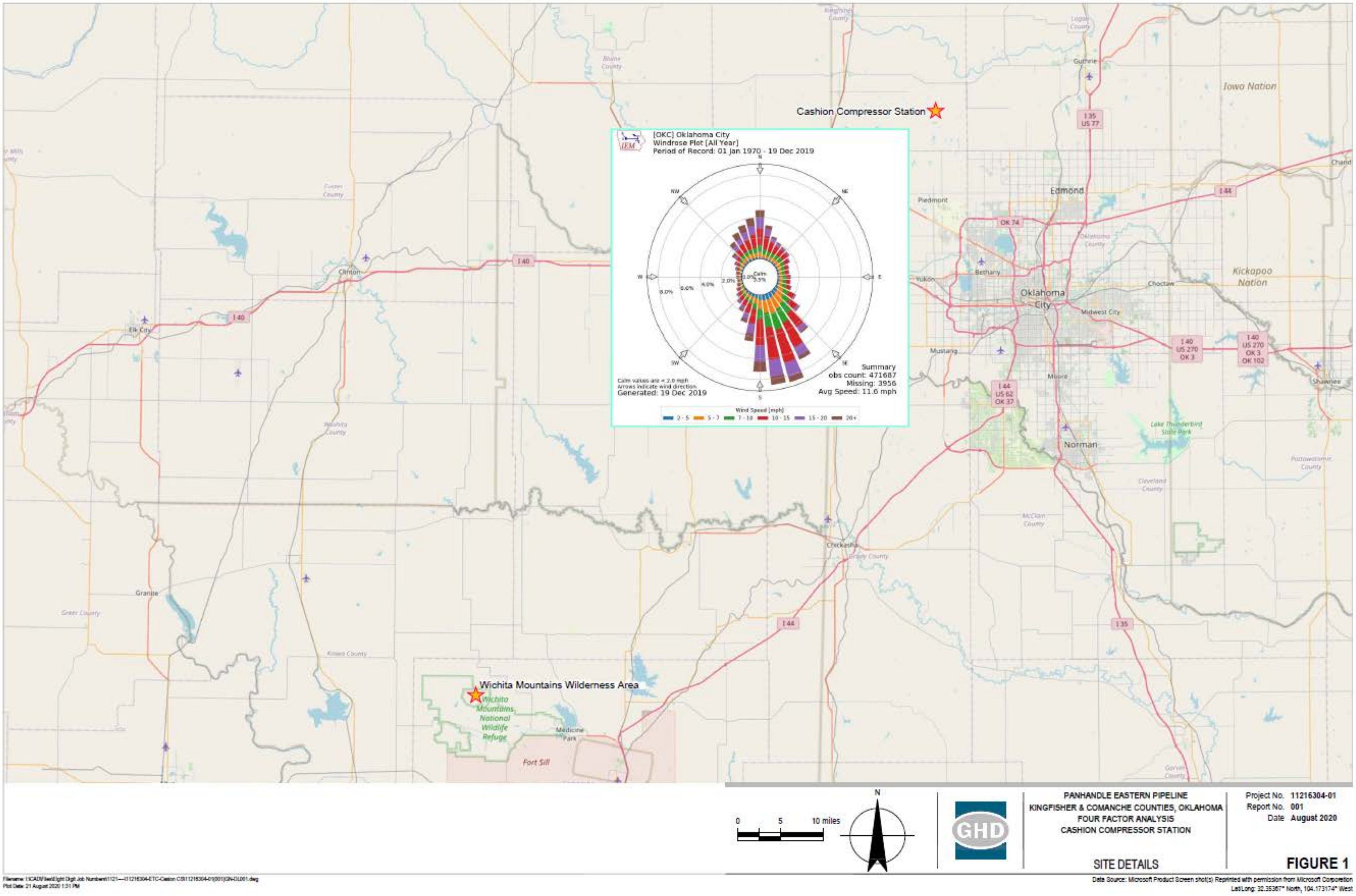
2.3.1 Distance

Previous PSD and TV permit applications (submitted 4/29/1980 and 2/17/1997, respectively) for the Cashion CS included air dispersion modeling to evaluate National Ambient Air Quality Standards (NAAQS) and potential impacts to nearby Class I Areas. The results of this air modeling showed no impacts beyond 25 km from the Facility. The nearest Class I Area, the Wichita Mountains Wilderness Area, is 129 km from the Facility.

2.3.2 Direction

The results from the air modeling also showed the extent of impacts from Facility emission sources were predominantly to the north and south. The nearest Class I Area, the Wichita Mountains Wilderness Area, is approximately 129 km southwest of the Facility. Figure 2.1 depicts the Site and the closest Class I Area with an overlay of the Oklahoma City wind rose from 1970-2019. This wind rose shows that the predominant wind direction in this area is from the north and south. However the Cashion CS Site is located northeast of the Class I Area. Winds blowing from that wind direction happen about 2% of the time. Thus, the emissions from the engines at the Cashion CS are not likely to affect visibility at the Class I Area since the engines would have to be emitting and the wind would have to be blowing from the northeast direction. The probability of both of those events happening at the same time is very low.

Figure 2.1 Wind Rose for the Oklahoma City Airport



3. Four Factor Analysis

3.1 RICE Engine Source Category Description

Cashion CS operates four Reciprocating Internal Combustion Engines (RICE) that are subject to the four-factor analysis. Two engines are 1800 hp Fairbanks Morse 38DS8 MEP-8 compressor engines (Units U-338 and U-339) and the other two engines are 4,500 hp Cooper Quad 12Q155HC compressor engines (Units U-2301 and U-2302). All four RICE engines are natural gas fired, 2-cycle lean burn, and used for transportation of natural gas.

3.2 NOx Emissions and Control Options

3.2.1 NOx Emissions

NO_x is generated from the combustion of natural gas used to power the applicable compressor engines. The exhaust gases are released to the atmosphere through stacks associated with each engine. There are several categories of NO_x formation in combustion processes. The combustion process taking place in RICE predominantly produces thermal NO_x[1], which is formed when nitrogen and oxygen unite during high temperature and high pressure combustion.[2]

3.2.2 Infeasible Control Options Evaluated

A Best Available Control Technology (BACT) evaluation was performed for previous permit applications for the engines at the Cashion CS. The options evaluated are the same that are currently available. These options are deemed infeasible for implementation as described below.

3.2.2.1 Selective Catalytic Reduction (SCR)

Selective catalytic reduction (SCR) is a post-combustion control technology that could be considered a potential control technology for lean burn engines. SCR systems have not been demonstrated to provide proven NO_X reductions over varying load conditions; present significant problems with ammonia slip under varying load conditions; and do not have a proven track record of reliability or durability under typical pipeline operating conditions. For the foregoing reasons, SCR is not a technically practical alternative for engines in natural gas pipeline service.

While SCR has been applied to large boilers and turbines in the power generation industry, its application on new RICE in the gas transmission industry has been rare, and retrofitted applications for existing lean burn RICE had not occurred as of 2014.[4] Additionally, Chapter 2 of the EPA cost manual (updated June 2019) supports the 2014 reference document. According to the EPA cost manual, the only example provided for SCR technology used on a RICE engine occurred in 1994 on a new 1,800 hp diesel-fired engine but not for a natural gas engine. All other examples of SCR applications were for other types of combustion equipment often in industries other than oil & gas.

3.2.2.2 Electric Replacement Engine

Electrical motors require a reliable and substantial supply of electrical power. The Cashion CS is in a remote location where the electrical supply is limited and unreliable. For this reason, the use of electrical motors as an alternate compressor drive unit is considered technically infeasible and impractical.

3.2.3 Feasible Control Option Evaluated

3.2.3.1 LEC Control Option

LEC is a combination of combustion controls in which various engine modifications, upgrades, and tuning methods provide lower emission combustion.

One common upgrade includes increasing the air-to-fuel ratio (AFR) to reduce thermal NO_x formation by diluting combustion gases and lowering peak flame temperature. Upgrades to the AFR controller and turbocharger would be required. Adjusting ignition timing is another modification associated with LEC. This control delays ignition in the power stroke when the chamber is below its maximum pressure. This causes ignition at a lower temperature, thus lowering thermal NO_x formation during combustion. Other LEC options include installing cylinder heads fitted with pre-combustion chambers, larger intercooling applications, enhanced mixing, bypass valves, and increased ignition energy.[3]

These LEC options would have to be evaluated for operational feasibility since they may affect the reliability of the engines.

3.3 Fairbanks Morse Engines (Units U-338 and U-339)

Fairbanks Morse vendors were contacted about quotes for potential LEC upgrades, but none have responded with a willingness or an ability to install LEC upgrades on this model engine at the time of the writing of this report. Previous PSD and TV permit applications (submitted 4/29/1980 and 2/17/1997, respectively) state that “it is not possible to run these engines leaner than their current setting and they are being operated at their minimum emissions point.”

Additionally, the current TV operating permit requires both engines to run no more than approximately 50% of the time, and from 2016 to 2019 both Fairbanks Morse engines only contributed between 7 and 20 % of the total Facility NOx emissions combined.

Since there has not been a vendor identified who is willing and able to perform LEC upgrades, documentation that operation of these engines is already limited to about 50% by the current Facility permit, the relatively small contribution they have to Facility NOx emissions (<20% combined), and documentation that the engines are running at their minimum emissions point, the Fairbanks Morse engines (Units U-338 and U-339) were not evaluated in this four factor analysis.

3.4 Cooper Quad Engines (Units U-2301 and U-2302)

3.4.1 Potential NOx Control Options

Table 3.1 below summarizes potential control technology options:

Table 3.1 Summary of Potential NOx Options

Technology	Description	Feasibility	Performance (% reduction)
Low Emission Combustion (LEC)	Engine tuning improvements to increase combustion efficiency.	Potentially feasible reduction of NOx emission factor for Units 2301 and 2302	70-80%
Selective Catalytic Reduction (SCR)	Exhaust control that converts NO_x to nitrogen and water using ammonia or urea.	**Not technically feasible** based on documented difficulty implementing technology on RICE engines	70-90%[5]
Electric Replacement Engines	Replace natural gas fired engine with electric motor	**Not technically feasible** based on unreliable electricity source at remote site location	100%

3.4.2 Additional Considerations

A four factor analysis is not included in this report since there are complex technical and practical considerations that would need to be evaluated. For example, new LEC upgrades have the potential to limit the range of engine variability under different operating scenarios. In particular, hyper controls have presented issues on the Cooper Quad engines in the past. A detailed evaluation of engine technicalities would be required including a site visit from the LEC vendor to identify what is technically feasible and would not interfere with operations. The field staff at the Cashion CS perform ongoing maintenance on the engines to maximize efficiency and increase reliability. These activities tend to result in lower emissions.

Additionally, we believe that this analysis should not be required since it would have a negligible visibility improvement at the Class I Area. We seek concurrence from DEQ on this assessment.

4. References

1. U.S Environmental Protection Agency (USEPA). *Technical Support Document for Controlling NOx Emissions from Stationary Reciprocating Internal Combustion Engines and Turbines*. March 2007.

2. U.S Environmental Protection Agency (USEPA). *Nitrogen Oxides (NOx), Why and How They Are Controlled.* November 1999.

3. INGAA Foundation, Inc. *Potential Impacts of the Ozone and Particulate Matter NAAQS on Retrofit NOx Control for Natural Gas Transmission and Storage Compressor Drivers*. December 2017.

4. INGAA Foundation, Inc. *Availability and Limitations of NOx Emission Control Resources for Natural Gas-Fired Reciprocating Engine Prime Movers Used in the Interstate Natural Gas Transmission Industry.* July 2014.

5. U.S Environmental Protection Agency (USEPA). *EPA Air Pollution Control Technology Fact Sheet for SCR.*

6. U.S Environmental Protection Agency (USEPA). *EPA Air Pollution Control Cost Manual, 6th Edition*, USEPA Research Triangle Park, NC. January 2002.

7. Northeast States for Coordinated Air Use Management (NESCAUM). *Status Report on NOx Controls for Gas Turbines, Cement Kilns, Industrial Boilers, Internal Combustion Engines*. December 2000.

8. U.S Environmental Protection Agency (USEPA). *Guidance on Regional Haze State Implementation Plans for the Second Implementation Period*. August 20, 2019.

9. Western Regional Air Partnership (WRAP). *Reasonable Progress Source Identification and Analysis Protocol, WRAP Regional Haze Planning Work Group – Control Measures Subcommittee*.

Appendix A

Table 1 – NOx Engine Test Data, Reported Emissions, and Q/d Analysis

Table 1 - NOx Engine Test Data, Reported Emissions, and Q/d Analysis

Cashion Compressor Station - Kingfisher County, Oklahoma

Panhandle Eastern Pipeline Co.

Company ID: 346, Facility ID: 1373

Unit ID	Test Date	Engine Test NOx Emissions (lb/hr)	Permitted NOx Emissions (lb/hr)	Annual Runtime (hrs)	Engine Test NOx Emission Factor (g/hp-hr)	Permitted NOx Emission Factor (g/hp-hr)	Engine Test Annual NOx Emissions (tpy)	Reported Annual NOx Emissions (tpy)
U-2301	5/3/2016	51.745	89.3	6399	5.2	9.0	165.55	286.00
U-2301	3/15/2017	66.858		7979	6.7		266.73	356.00
U-2301	2/16/2018	54.312		5485	5.5		148.95	244.85
U-2301	1/22/2019	48.445		6257	4.9		151.57	279.72
U-2302	5/3/2016	67.462	89.3	7875	6.8	9.0	265.63	351.60
U-2302	3/15/2017	68.631		7188	6.9		246.65	321.00
U-2302	2/16/2018	54.833		4810	5.5		131.88	214.74
U-2302	1/23/2019	50.851		2486	5.1		63.20	110.95
U-338	6/30/2016	15.690	54.77	2283	4.0	13.8	17.91	6.26
U-338	5/24/2017	26.150		1627	6.6		21.27	44.50
U-338	5/16/2018	17.610		1212	4.4		10.67	33.18
U-338	1/23/2019	11.504		4696	2.9		27.01	128.59
U-339	6/30/2016	15.040	54.77	2169	3.8	13.8	16.31	59.40
U-339	5/24/2017	25.040		1941	6.3		24.30	53.10
U-339	5/16/2018	16.810		681	4.2		5.72	18.63
U-339	1/22/2019	13.511		3811	3.4		25.75	104.35

Annual Q/d Comparison

Year	Actual Sitewide Q/d from engine test data	Reported Sitewide Q/d based on permit data
2016	3.6	5.5
2017	4.3	6.0
2018	2.3	4.0
2019	2.1	4.8

Notes:

1. Q = facility sitewide NOx emissions in tons per year (tpy)
2. d = distance from facility to Wichita Mountains Wilderness Area in kilometers (approximately 129 km)
3. Q/d value of 5 was used by Ramboll and DEQ as the threshold for determining facilities subject to the Regional Haze Rule 4 Factor Analysis.

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