BTEC Inc.

Annealing Furnace Oxides of Nitrogen Test Report

A7809

Prepared for:

United States Steel Corporation

Ecorse, Michigan

United States Steel Corporation
Great Lakes Works
No. 1 Quality Drive
Ecorse, Michigan 48229

Project No. 13-4459.00
December 6, 2013

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Executive Summary

BT Environmental Consulting, Inc. (BTEC) was retained by United States Steel Corporation (U. S. Steel) to conduct an evaluation of oxides of nitrogen (NOx) concentrations and emission rates from one exhaust stack serving the Continuous Galvanizing Line (CGL) Annealing Furnace (EGCON-GALV-LINE). The furnace is located at the U. S. Steel facility in Ecorse, Michigan. The evaluation consisted of triplicate 60-minute test runs at the exhaust sampling location.

The results of the emissions test program are summarized by Table E-I.

Table E-1
Test Program Results Summary
Annealing Furnace Exhaust
Test Date: October 24, 2013

Pollutant	Concentration ppmvd	Emission Rate lb/hr	Permit Limit lb/hr
NOx	94.92	8.49	6.6

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1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by United States Steel Corporation (U. S. Steel) to conduct an evaluation of oxides of nitrogen (NOx) concentrations and emission rates from one exhaust stack serving the Continuous Galvanizing Line (CGL) Annealing Furnace (EGCON-GALV-LINE). The furnace is located at the U. S. Steel facility in Ecorse, Michigan. The evaluation consisted of triplicate 60-minute test runs at the exhaust sampling location. The purpose of this report is to document the results of the test program.

AQD has published a guidance document entitled "Format for Submittal of Source Emission Test Plans and Reports" (February 2008). The following is a summary of the emissions test report in the format suggested by the AQD test plan format guide (see Appendix A).

1.a Identification, Location, and Dates of Test

Sampling and analysis for the emission test program was conducted on October 24, 2013 at the U. S. Steel facility in Ecorse, Michigan. The test program included evaluation of volumetric flow rate, and NOx emissions from the annealing furnace.

1.b Purpose of Testing

AQD Permit No. 199600132d requires testing of the EGCON-GALV-LINE exhaust from the selective catalytic reduction (SCR) system serving the Annealing Furnace. NOx emissions were measured.

1.c Source Description

A diagram of the exhaust stack is presented as Figure 1.

1.d Test Program Contact

The contacts for the source are:

Mr. John Bozick
U. S. Steel Environmental
United States Steel Corporation
Great Lakes Works
No. 1 Quality Drive
Ecorse, Michigan 48229
(313) 749-2747

Mr. Todd Wessel
Senior Project Manager
BT Environmental Consulting, Inc.
4949 Fernlee Avenue
Royal Oak, Michigan 48073
Phone (616) 885-4013

1.e Test Personnel

Names and affiliations for personnel who were present during the testing program are summarized by Table 1.

2. Summary of Results

Sections 2.a through 2.d summarize the results of the emissions compliance test program.

2.a Operating Data

Relevant operating data is available in Appendix E.

2.b Applicable Permit

The applicable permit is AQD Permit No. 199600132d.

2.c Results

The overall results of the emission test program are summarized by Table 2 (see Section 5.a). Detailed results for each run can be found in Table 3.

2.d Emission Regulation Comparison

NOx emission rates are above the permitted limits. The results as well as the emission limits are summarized by Table 2.

3. Source Description

Sections 3.a through 3.e provide a detailed description of the process.

3.a Process Description

Steel is annealed to soften and improve formability prior to coating it with zinc. Annealing is performed in a non-oxidizing atmosphere to enhance the reactivity of the steel's surface with the molten zinc. The annealing furnace consists of a heating zone and a soaking zone equipped with natural gas fired burners. There are 6 to 8 temperature control areas in the heating zone of the furnace. Each control area is equipped with multiple-reaction pyrometers to control burner-firing rates to ensure that the steel is annealed at the proper temperature. The soaking zone has one temperature control area and also utilizes a multiple-reaction pyrometer. The steel strip passes through the heating zone 12 to 18 times, depending on the design of the steel, and then passes through the soaking zone twice.

In order to minimize carbon monoxide (CO) emissions from the combustion of natural gas, high NOx / low CO burners are used for heating the furnace. Reductions of CO emissions are achieved by limiting the excess oxygen used for combustion, resulting in higher NOx emissions. These NOx emissions in the form of nitrogen oxide (NO) and nitrogen dioxide (NO2) are then reduced by utilizing a Selective Catalytic Reduction (SCR) Unit. The SCR reduces NOx by injecting urea into the exhaust gas stream. The urea reacts with water vapor to produce ammonia and carbon dioxide. The NOx reacts with the ammonia to form water vapor and nitrogen. A catalyst is used to accelerate the reaction, improving the SCR efficiency. The ammonia/NOx reactions in the SCR unit require a minimum inlet flue gas temperature of 475°F. Maintaining temperatures above the 475°F threshold is not an issue during normal operations due to furnace temperatures in excess of 1000°F for most of the steel grades processed.

3.b Process Instrumentation

The process operating parameters relevant to the emissions test program is the tons of steel processed, the amount of urea used, and the amount of natural gas used. Process data is included in Appendix E.

4. Sampling and Analytical Procedures

Sections 4.a through 4.d provide a summary of the sampling and analytical procedures used.

4.a Sampling Train and Field Procedures

Measurement of exhaust gas velocity and molecular weight were conducted using the following reference test methods codified at Title 40, Part 60, Appendix A of the Code of Federal Regulations (40 CFR 60, Appendix A):

- Method 1 - *"Location of the Sampling Site and Sampling Points"*
- Method 2 - *"Determination of Stack Gas Velocity and Volumetric Flowrate"*
- Method 3 - *"Determination of Molecular Weight of Dry Stack Gas"*
- Method 4 - *"Determination of Moisture Content in Stack Gases"*
- Method 7E - *"Determination of Nitrogen Oxides Emissions From Stationary Sources (Instrumental Analyzer Procedure)*

Stack gas velocity traverses were conducted in accordance with the procedures outlined in Methods 1 and 2. Figure 1 presents the test ports and traverse/sampling point locations used. A cyclonic flow evaluation was conducted. The sampling location was determined to be cyclonic. The duct work was inspected and no alternative locations were available. An S-type pitot tube and thermocouple assembly calibrated in accordance with Method 2, Section 4.1.1 was used to measure exhaust gas velocity pressures and temperatures during testing. Because the pitot tube dimensions outlined in Sections 2.6 through 2.8 were within the specified limits, the baseline pitot tube coefficient of 0.84 (dimensionless) was assigned for this testing. In addition to the normal velocity traverses BTEC conducted a flow study where the pitot tube was rotated 90 degrees from the null angle. NOx emission test results based on these flowrate measurements are presented in Table 4.

Molecular weight determinations were conducted according to Method 3. The equipment used for this evaluation consisted of a one-way squeeze bulb with connecting tubing and a set of Fyrite® combustion gas analyzers.

The NOx content of the gas stream was measured using a Thermo Model 42i NOx gas analyzer. The gas stream was drawn through a stainless-steel probe with a heated in-line filter to remove any particulate, a heated Teflon® sample line, through a refrigerated Teflon® sample conditioner to remove the moisture from the sample before it entered the NOx analyzer. Data was recorded on a PC equipped with data acquisition software. Recorded NOx concentrations were averaged and reported for the duration of each 60-minute test (as drift corrected per Method 7E). A drawing of the sampling train used for the testing program is presented as Figure 2.

In accordance with Method 7E, a 3-point (zero, mid, and high) bias check and calibration check was performed on the NOx analyzer prior to initiating the test program. Following each test run, a 2-point (zero and mid) calibration drift check was performed. The NOx analyzer was operated at the 0-200 ppm range.

4.b Recovery and Analytical Procedures

Recovery and analytical procedures were described in Section 4.a.

4.c Sampling Ports

Sampling ports are located on the stack and meet Method 1 criteria.

4.d Traverse Points

Sampling port and traverse point locations are illustrated by Figure 1.

5. Test Results and Discussion

Sections 5.a through 5.k provide a summary of the test results.

5.a Results Tabulation

The results of the emissions test program are summarized by Table 2. Detailed data for each test run can be found in Table 3.

5.b Discussion of Results

The NOx emissions are greater than the permitted limits as demonstrated by Table 2. Detailed results for each run are summarized by Table 3.

5.c Sampling Procedure Variations

There were no sampling variations used during the emission compliance test program other than cyclonic flow at the sampling location. The annealing furnace exhaust stack does not meet the criteria for non cyclonic flow. The average null angle determined was 38.7° which is greater than the allowable angle of 20°. In addition to the normal velocity traverses, BTEC conducted a flow study where the pitot tube was rotated 90 degrees from the null angle. NOx emission test results based on these flowrate measurements are presented in Table 4.

5.d Process or Control Device Upsets

No upset conditions occurred during testing.

5.e Control Device Maintenance

No maintenance was performed during the test program.

5.f Re-Test

The emissions test program was originally conducted in May 2013. During this test event, the steel being processed did not generate enough heat to trigger the urea injection so the test program was conducted without urea injection.

5.g Audit Sample Analyses

No audit samples were collected as part of the test program.

5.h Calibration Sheets

Relevant equipment calibration documents are provided as Appendix C.

5.i Sample Calculations

Sample calculations are provided in Appendix D.

5.j Field Data Sheets

Field data sheets are presented in Appendix B.

5.k Laboratory Data

The test program required no laboratory data.

TABLES

Table 1
Test Personnel

Name and Title	Affiliation	Telephone
Todd Wessel Senior Project Manager	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(616) 885-4013
Mr. Paul Molenda Environmental Technician	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8070
Mr. Paul Draper Environmental Technician	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8070
Mr. John Bozick Environmental Department	U. S. Steel No. 1 Quality Drive Ecorse, Michigan 48229	(313) 749-2747
Ms. Katherine Koster Michigan Department of Environmental Quality	Cadillac Place, Suite 2-300 3058 West Grand Blvd. Detroit, Michigan 48202-6058	(313) 456-4678
Mr. Mark Dziadosz Michigan Department of Environmental Quality	Cadillac Place, Suite 2-300 3058 West Grand Blvd. Detroit, Michigan 48202-6058	(586) 753-3745

Table 2
Test Program Results Summary
Annealing Furnace Exhaust
Test Date: October 24, 2013

Pollutant	Concentration ppm	Emission Rate lb/hr	Permit Limit lb/hr
NOx	94.92	8.49	6.6

Table 3
Annealing Furnace NOx Emission Rates
US Steel
Ecorse, Michigan
BTEC Project No. 13-4459.00
Sampling Dates: October 24, 2013

Parameter	**Run 1**	**Run 2**	**Run 3**	**Average**
Test Run Date	10/24/2013	10/24/2013	10/24/2013	
Test Run Time	10:09-11:09	11:22-12:22	12:37-13:37	
Outlet Flowrate				
ACFM	19,405	21,046	19,710	20,054
SCFM	13,366	14,509	13,569	13,815
SDCFM	12,323	13,145	12,117	12,528
NOx Concentration (ppmv dry)	90.9	95.3	98.5	94.9
NOx Emission Rate (lb/hr)	8.00	8.94	8.52	8.49
NOx Permit Limit (lb/hr)	6.60	6.60	6.60	6.60

scfm = standard cubic feet per minute
ppmv wet = parts per million on a volume-to-volume basis, wet
lb/hr = pounds per hour
MW = molecular weight (NOx = 46.01, Ammonia = 17.03)
24.14 = molar volume of air at standard conditions (70°F, 29.92" Hg)
35.31 = ft^3 per m^3
453600 = mg per lb

Equations
lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453,600 * ***scfm*** * 60

Table 4
Annealing Furnace NOx Emission Rates Alternate Flow
US Steel
Ecorse, Michigan
BTEC Project No. 13-4459.00
Sampling Dates: October 24, 2013

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	10/24/2013	10/24/2013	10/24/2013	
Test Run Time	10:09-11:09	11:22-12:22	12:37-13:37	
Outlet Flowrate 1				
ACFM 1	19,217	19,729	21,764	20,237
SCFM 1	13,229	13,598	14,987	13,938
SDCFM 1	12,197	12,320	13,383	12,633
NOx Concentration (ppmv dry)	90.9	95.3	98.5	94.9
NOx Emission Rate (lb/hr)	7.92	8.38	9.41	8.57
NOx Permit Limit (lb/hr)	6.60	6.60	6.60	6.60

1 - This flow was derived by locating a null flow angle and then rotating the pitot tube 90 degrees from the zero plain

scfm = standard cubic feet per minute

ppmv wet = parts per million on a volume-to-volume basis, wet

lb/hr = pounds per hour

MW = molecular weight (NOx = 46.01, Ammonia = 17.03)

24.14 = molar volume of air at standard conditions (70°F, 29.92" Hg)

35.31 = ft^3 per m^3

453600 = mg per lb

Equations

lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453,600 * ***scfm*** * 60

FIGURES

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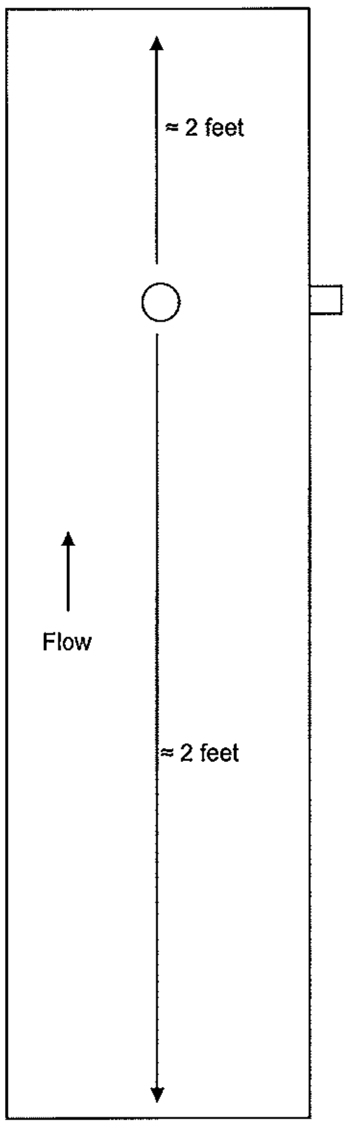
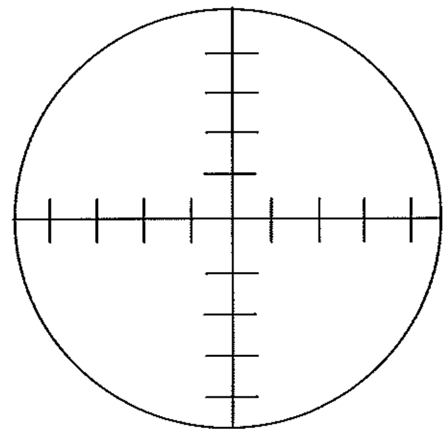
diameter = 59 inches





Not to Scale

Points	Distance "
1	1.9
2	6.2
3	11.4
4	19.1
5	39.9
6	47.6
7	52.8
8	57.1

Figure 1

Site:	Sampling Date:	
Annealing Furnace **US Steel** **Ecorse, Michigan**	**October 24, 2013**	**BT Environmental Consulting, Inc.** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**

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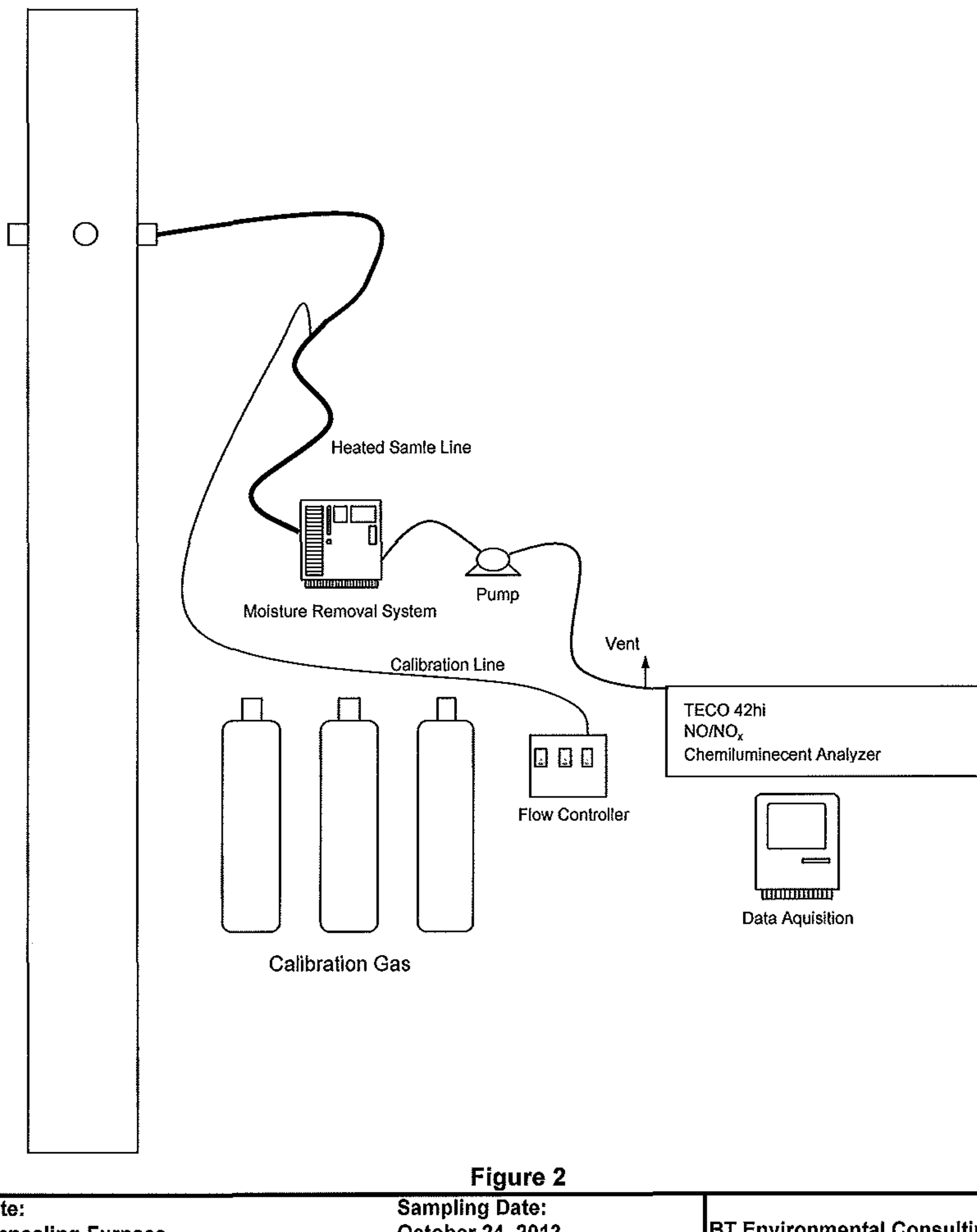

Figure 2

Site: **Annealing Furnace** **U.S. Steel** **Ecorse, Michigan**	**Sampling Date:** **October 24, 2013**	**<u>BT Environmental Consulting Inc.</u>** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**