IMPACT COMPLIANCE & TESTING

AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM
FNC HEAT TREATING FURNACES

WOODWORTH, INC.
HOMER FACILITY

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AIR QUALITY DIVISION

1.0 INTRODUCTION

Woodworth, Inc. (Woodworth) (Facility SRN: P0547) owns and operates ferritic nitrocarburizing (FNC) heat treating furnaces at its facility in Homer, Calhoun County, Michigan. The FNC heat treating furnaces are identified as EUHEATTREAT1 through EUHEATTREAT16 (collectively, as flexible group FGHEATTREAT) in Permit to Install (PTI) No. 64-15B.

Air emission compliance testing was performed to satisfy the following requirements contained in PTI No. 64-15B:

- *The permittee shall verify the NOX and ammonia emission rate from FGHEATTREAT by testing at owner's expense, in accordance with Department requirements within 180 days of permit issuance.*

- SC I.1. specifies a nitrogen oxides (NO_x) emission limit of 36.17 pounds per FNC cycle for FGHEATTREAT.

The compliance testing was performed by Impact Compliance and Testing, Inc., (ICT), formerly Derenzo Environmental Services, a Michigan-based environmental consulting and testing company. ICT representatives Jory VanEss and Andrew Rusnak performed the field sampling and measurements February 5 – 8, 2019.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan that was reviewed and approved by the Michigan Department of Environmental Quality (MDEQ). MDEQ representatives Mr. David Patterson and Ms. Amanda Chapel observed portions of the testing project.

Questions regarding this emission test report should be directed to:

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Report Certification

This test report was prepared by ICT based on field sampling data collected by ICT. Facility process data were collected by Woodworth. This test report has been reviewed by Woodworth. representatives and approved for submittal to the MDEQ.

I certify that the testing was conducted in accordance with the specified test methods and submitted test plan unless otherwise specified in this report. I believe the information provided in this report and its attachments are true, accurate, and complete.

Report Prepared By:

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Technical Manager
Impact Compliance & Testing, Inc.

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

WWI has been permitted to install and operate sixteen (16) heat treat furnaces that are identified as emission units EUHEATTREAT1 through EUHEATTREAT16 (collectively FGHEATTREAT). As of the date of this test report, ten (10) furnaces have been installed and are operational. The remaining units are either under construction or are planned for construction in the near future. The furnaces are used to heat treat brake rotors.

The brake rotors treated at the WWI Homer facility are subjected to two separate treatment steps:

1. Stress relief heat treatment that is performed on the brake rotor after casting, and
2. Ferritic nitrocarburizing (FNC) treatment performed on the brake rotor after machining.

The metal heat treating process is a batch-type process and has a specific cycle; in general racks of parts are loaded into the furnace, the furnace is heated, the burner ramps down to idle mode to maintain the desired furnace temperature for several hours, the furnace is cooled, and the parts are unloaded.

FNC treatment results in greater rotor performance, enhanced durability, corrosion performance, and wear resistance. In gaseous FNC treatment, the atmosphere within the furnace is purged of ambient air (oxygen) and replaced with a controlled mixture of nitrogen, ammonia, and methane (natural gas). In the high temperature furnace, the ammonia is cracked into nitrogen and hydrogen. Nitrogen and carbon diffuse into the surface of the ferrous material at controlled temperatures to result in the desired properties.

2.2 Rated Capacities and Air Emission Controls

The heat treat furnace has a capacity of approximately six (6) MMBtu/hr.

The entire FNC cycle has a duration of approximately 24 hours. Approximately 6.5 hours of the cycle time uses the FNC process gas (FNC gas phase), which includes ammonia. During the FNC gas phase portion of the cycle, residual methane and hydrogen are ignited and burned off via the oven exhaust burn-off tower. At the end of the cycle, the FNC atmosphere is purged with nitrogen.

During the FNC gas phase portion of the cycle (approximately 6.5 hours), residual methane and hydrogen are ignited and burned off via the oven exhaust burn-off tower. The burn-off tower consists of vertical sections of insulated pipe. The furnace exhaust is introduced at the base of the tower through piping that disperses the gas within the tower. Natural gas fueled burners at the base of the tower ignite the gas mixture, which burns as it travels through the tower. Ambient air is allowed into the flame section by gaps between the insulated sections.

The purpose of the burn-off tower is to combust hydrogen and methane exiting the furnace before it is discharged to the ambient air. However, it also has the potential to convert residual ammonia in the furnace exhaust to NO_x.

2.3 Sampling Locations

The furnace exhaust gas is directed through dedicated burn-off towers and is released to the atmosphere through dedicated vertical exhaust stacks with vertical release points. The exhaust stacks for the furnaces are identical.

The exhaust stack sampling ports for the furnaces are located in a vertical exhaust stack with an inner diameter of 32.0 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 12.0 inches (0.38 duct diameters) upstream and 48.0 inches (1.5 duct diameters) downstream from any flow disturbance. The location does not satisfy the USEPA Method 1 criteria for a representative sample location. This was specified in the approved test plan as a variation from normal sampling procedures.

Individual traverse points were determined in accordance with USEPA Method 1.

Appendix 1 provides diagrams of the emission test sampling locations.

3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

3.1 Purpose and Objective of the Tests

The FGHEATTREAT Testing / Sampling conditions in PTI 64-15B specify:

> *The permittee shall verify the NOx and ammonia emission rate from FGHEATTREAT by testing at owner's expense, in accordance with Department requirements within 180 days of permit issuance.*

Therefore, one (1) batch (during FNC gas phase) from three (3) separate furnaces contained in FGHEATTREAT were each sampled for NO_x and ammonia (NH_3) emissions and exhaust gas oxygen (O_2) and carbon dioxide (CO_2) content.

3.2 Operating Conditions During the Compliance Tests

The testing was performed while the heat treat furnace was operated in the FNC gas phase. ICT representatives recorded the test times and phases for each test period.

The load weight for each batch was recorded by Woodworth representatives.

Appendix 2 provides operating records recorded by Woodworth representatives for each test period.

Table 3.1 presents a summary of the load weights during the test periods.

3.3 Summary of Air Pollutant Sampling Results

The gases exhausted from three (3) heat treat furnaces (EUHEATTREAT6, 7 and 8) were each sampled for one (1) test period encompassing the entire FNC gas phase period (approximately 6.58 hours) during the compliance testing performed February 5 – 8, 2019.

Table 3.2 presents the average measured NO_x and NH_3 emission rates for the furnaces (average of the three test periods).

Test results for each sampling period and comparison to the permitted emission rates are presented in Section 6.0 of this report.

Table 3.1 Load weights during the test periods

Parameter	EUHEATTREAT6	EUHEATTREAT7	EUHEATTREAT8
Parts (lb)	60,006	45,535	51,429
Fixtures (lb)	16,870	15,134	16,746
Total (lb)	76,876	60,669	68,175

Table 3.2 Average measured emission rates for heat treat furnaces (three-test average)

	NO_x Emission Rates	NH_3 Emission Rates
Emission Unit	(lb/FNC cycle)[1]	(lb/hr)
FGHEATTREAT	29.4	0.37
Permit Limit	*36.17*	-

<u>Notes for Table 3.2:</u>

1. Includes 25.9 lb/cycle during the FNC gas phase (tested emissions) and 3.5 lb/cycle from natural gas combustion during all other phases (calculated, as presented in the approved test protocol).

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the air emission testing was reviewed and approved by the MDEQ. This section provides a summary of the sampling and analytical procedures that were used during the Woodworth testing periods.

4.1 Summary of Sampling Methods

USEPA Method 1	Exhaust gas velocity measurement locations were determined based on the physical stack arrangement and requirements in USEPA Method 1
USEPA Method 2	Exhaust gas velocity pressure was determined using a Type-S Pitot tube connected to a red oil incline manometer; temperature was measured using a K-type thermocouple connected to the Pitot tube.
USEPA Method 3A	Exhaust gas O_2 and CO_2 content was determined using a zirconium oxide and FTIR analyzer, respectively.
ASTM D6348	Exhaust gas NO_x, NH_3 and moisture concentration was measured using a Fourier transform infrared spectroscopy (FTIR) analyzer.

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The furnace exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 during each test. Four (4) traverses were conducted during each batch. Each traverse was performed during a separate phase of the FNC gas phase period (i.e., distinct time period that has different inlet gas flowrates). A traverse was performed during the burn-start, FNC1, FNC2 and FNC3 phases of the FNC gas phase. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure at each traverse point across the stack cross section. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube. The Pitot tube and connective tubing were leak-checked prior to use to verify the integrity of the measurement system.

The absence of significant cyclonic flow for the exhaust configuration was verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each velocity traverse point with the planes of the face openings of the Pitot tube perpendicular to the stack cross-sectional plane. The Pitot tube was then rotated to determine the null angle (rotational angle as measured from the perpendicular, or reference, position at which the differential pressure is equal to zero).

Appendix 3 provides exhaust gas flowrate calculations and field data sheets.

4.3 Exhaust Gas Molecular Weight Determination (USEPA Method 3A)

CO_2 and O_2 content in the furnace exhaust gas stream was measured during each traverse performed during each test period in accordance with USEPA Method 3A. The CO_2 content of the exhaust was monitored using a MKS Multi-Gas 2030 Fourier transform infrared (FTIR) spectrometer. The O_2 content of the exhaust was monitored using a Amatek RM CEM O_2/IQ wet gas analyzer that uses a zirconium oxide sensor.

During each sampling period, a sample of the furnace exhaust gas stream was extracted from the stack using the FTIR sampling system. The FTIR was used to measure the CO_2 content of the exhaust gas. The exhaust of the FTIR sampling system was connected directly to the inlet of the O_2 instrument via a heated jumper. The O_2 measurement cell is heated to prevent moisture condensation. O_2 instrument response data were recorded using a Yokogawa data acquisition system that monitored the analog output of the instrumental analyzer continuously and logged data as 30-second averages. The CO_2 and O_2 concentration of the exhaust gas was recorded on field data sheets at the time each velocity traverse was performed.

Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and bias (described in Section 5.0 of this document). Sampling times were recorded on field data sheets.

Appendix 4 provides O_2 and CO_2 calculation sheets. Raw instrument response data are provided in Appendix 5.

4.4 Determination of NO_x and NH_3 Emissions (ASTM D6348)

NO_x, NH_3 and moisture concentrations in the furnace exhaust gas streams were determined using a MKS Multi-Gas 2030 FTIR spectrometer.

Samples of the exhaust gas were delivered directly to the instrumental analyzer using a Teflon® heated sample line, heated head pump and heated filter to prevent condensation. The sample to the FTIR analyzer was not conditioned to remove moisture. Therefore, raw NO, NO_2 and NH_3 measurements correspond to standard conditions with no moisture correction (wet basis). The instrument calculated a NO_x concentration on a dry basis using the sum of the measured NO and NO_2 concentrations and the measured moisture concentration.

A calibration transfer standard (CTS), ethylene standard, and nitrogen zero gas were analyzed before and after each test run. Analyte spiking, of each furnace, with nitrogen oxide, ammonia and sulfur hexafluoride was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR. Data was collected at 0.5 cm^{-1} resolution. Instrument response was recorded using MKS data acquisition software. Spiking with nitrogen oxide was performed before and after each batch run and also during the batch run on the setup day. Spiking with ammonia was performed before, during and after each batch run.

Appendix 4 provides NO_x and NH_3 calculation sheets. Instrument response data for the FTIR is provided in Appendix 5.

5.0 QA/QC ACTIVITIES

5.1 Instrument Calibration and System Bias Checks

At the beginning of each day of the testing program, initial three-point instrument calibrations were performed for the CO_2 and O_2 analyzers by injecting calibration gas directly into the inlet sample port for each instrument. Bias checks were performed prior to and at the conclusion of each sampling period by introducing the upscale calibration gas and zero gas into the sampling system (at the instrumental analyzer inlet) and determining the instrument response against the initial instrument calibration readings.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of CO_2, and O_2 in nitrogen and zeroed using hydrocarbon free nitrogen.

5.2 FTIR QA/QC Activities

At the beginning of each day a calibration transfer standard (CTS, ethylene gas), analyte of interest (nitrogen oxide and ammonia) and nitrogen calibration gas were directly injected into the FTIR to evaluate the unit response.

Prior to and after each test run the CTS was analyzed. The ethylene was passed through the entire system (system purge) to verify the sampling system response and to ensure that the sampling system remained leak-free at the stack location. Nitrogen was also passed through the sampling system to ensure the system is free of contaminants.

Analyte spiking, of each emission unit, prior to and after sampling (and during the batch on setup day), with nitrogen oxide was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR and assured the ability of the FTIR to quantify that compound in the presence of effluent gas. Analyte spiking, of each emission unit, prior to, during and after sampling, with ammonia was also performed. The spike target dilution ratio was 1:10 (1 part cal gas; 9 parts stack gas).

As part of the data validation procedure, reference spectra were manually fit to that of the sample spectra (two spectra from each test period) and a concentration was determined. Concentration data was manually validated using the MKS MG2000 method analyzer software. The software used multi-point calibration curves to quantify each spectrum. The software-calculated results were then compared with the measured concentrations to ensure the quality of the data.

Appendix 6 presents test equipment quality assurance data (instrument calibration and bias check records, calibration gas, Pitot tube calibration records and FTIR QA/QC data).

6.0 RESULTS

6.1 Test Results and Allowable Emission Limits

Furnace operating data and air pollutant emission measurement results for each batch test period are presented in Table 6.1.

The three-test average NH3 emission rate for the furnaces was 0.37 lb/hr

The three-test average NOx emission rate for the furnaces was 25.9 lb/FNC gas phase. As presented in the approved test plan the NOx emission rate for the entire cycle is calculated as follows:

> The furnaces use a maximum of 35,000 cubic feet of natural gas per load (35 MCF/load). Air pollutant emissions from the combustion of natural gas in the furnaces were calculated using default air pollutant emission factors from USEPA's Compilation of Air Pollutant Emission Factors for Stationary Point and Area Sources (AP-42) Section 1.4 for natural gas external combustion.
>
> [1] (35,000 CF natural gas) x (100 lb NOx/MMcf) = 3.5 lbs NOx/cycle
>
> NOx emissions during the FNC gas phase (presented above) were determined based on the average emission rate for the three (3) one-hour test periods and the duration of the gas phase:
>
> [2] NOx FNC gas phase (lbs) = (NOx emission rate, lb/hr) x (gas phase duration, hrs)
>
> [3] Total NOx / FNC cycle = (3.5 lbs NOx) + (lbs NOx FNC gas phase)

Therefore, the overall calculated NOx FNC cycle emission rate is 29.4 lb/FNC cycle. The permitted emission limit is 36.17 lb/FNC cycle. The results of the performance testing demonstrates compliance with the emission limit specified in PTI No. 64-15B.

6.2 Variations from Normal Sampling Procedures or Operating Conditions

The testing for all pollutants was performed in accordance with USEPA and ASTM methods and the approved test protocol. The furnaces were operated at their normal operating conditions and no variations from normal operating conditions occurred during the furnace test periods.

Measured flowrates during the testing on EUHEATTREAT6 (performed on February 8, 2019) were greater than the flowrates measured on EUHEATTREAT7 and 8 (performed on February 6 and 7, 2019) and greater than what would be normally expected. This is attributed to high wind speeds (wind speeds during testing ranged from 17 to 26 mph). The high wind speed induced a vacuum as it flowed across the exhaust stack exit and pulled a greater amount of building air out of the facility through the exhaust stack (Bernoulli Effect). In order to accommodate the sampling trailer electrical needs the door to the facility had to be propped open near the furnace (allowing ambient air to enter the facility near the furnace). The building (operating under a negative pressure) constantly drew a large amount of cold (ambient temperature was 15 °F during testing) air into the facility and subsequently through the burn off tower and out the roof exhaust. The flame in the tested burn off tower near the open door was noticeably smaller (compared to other operating furnaces operating at greater distance from the open door) due to the cold air draft. The smaller flame is believed to have resulted in higher measured exhaust NH_3 and lower measured NO_x concentrations (due to the lower combustion temperature in the burn off tower resulting in lower conversion of NH_3 to NO_x), compared to what was measured the prior two (2) days. The propped open door and introduction of a stream of cold air is not normal operating conditions. While all three tests demonstrated compliance with the permitted NO_x emission limit, we believe that Test Nos. 1 and 2 are more indicative of normal operating conditions at the facility.

Table 6.1 Measured exhaust gas conditions and NO_x and NH_3 air pollutant emission rates for FGHEATTREAT

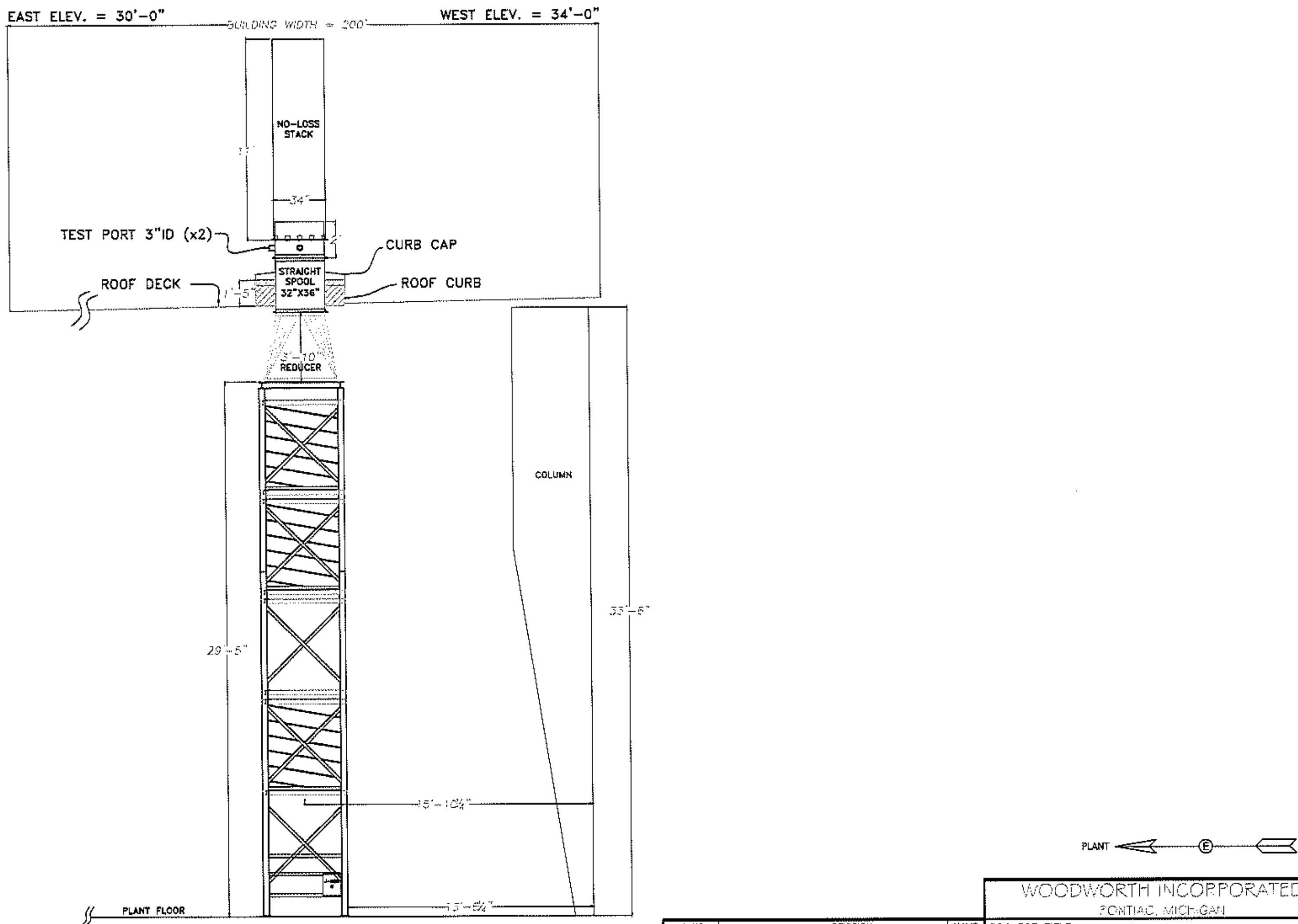
Test No.	1	2	3	
Furnace No.	8	7	6	
Test date	2/6/2019	2/7/2019	2/8/2019	Three Test
Test period (24-hr clock)	927-1602	825-1500	853-1528	Average
Furnace Load Weights				
Parts (lb)	60,006	45,535	51,429	52,323
Fixtures (lb)	16,870	15,134	16,746	16,250
Total Weight (lb)	76,876	60,669	68,175	68,573
Exhaust Gas Composition				
CO_2 content (% vol)	0.09	0.31	0.22	0.21
O_2 content (% vol)	19.2	19.4	19.6	19.4
Moisture (% vol)	2.29	2.08	1.37	1.91
Exhaust gas flowrate (dscfm)	6,601	6,766	10,284	7,884
Exhaust gas flowrate (scfm)	6,741	6,861	10,429	8,010
Ammonia				
NH_3 conc. (ppmv)	11.1	11.9	24.4	15.8
NH_3 emissions (lb/hr)	0.20	0.22	0.70	0.37
Nitrogen Oxides				
NO_x conc. (ppmvd)	85.4	67.1	55.1	69.2
NO_x emissions FNC gas phase (lb/cycle)	27.7	22.1	28.0	25.9
NO_x emissions total FNC cycle (lb/cycle)[1]	31.2	25.6	31.5	29.4
Permitted emissions (lb/cycle)[2]	-	-	-	36.17

Notes for Table No. 6.1:

1. Calculated emission rate includes 3.5 lb/cycle from natural gas combustion as presented in approved test plan and Section 6.1.
2. Presented emission limit is for each FNC cycle for FGHEATTREAT.

APPENDIX 1

- Figure 1 – Sample Port Diagram



DATE	REVISION	NAME
9/25/15	REMOVED DUCT #2	QUEZ

WOODWORTH INCORPORATED
PONTIAC, MICHIGAN

PROJECT TITLE: BURN-OFF TOWER (FOR H01-H16)			
SCALE THIS:	DRAWN BY:	CHECKED BY:	APP'D BY:
DATE: 10/10/15	SHEET OF SHEETS		DRAWING NO. WWH-BO-01