LNG Research Study

Legacy Floor Furnace

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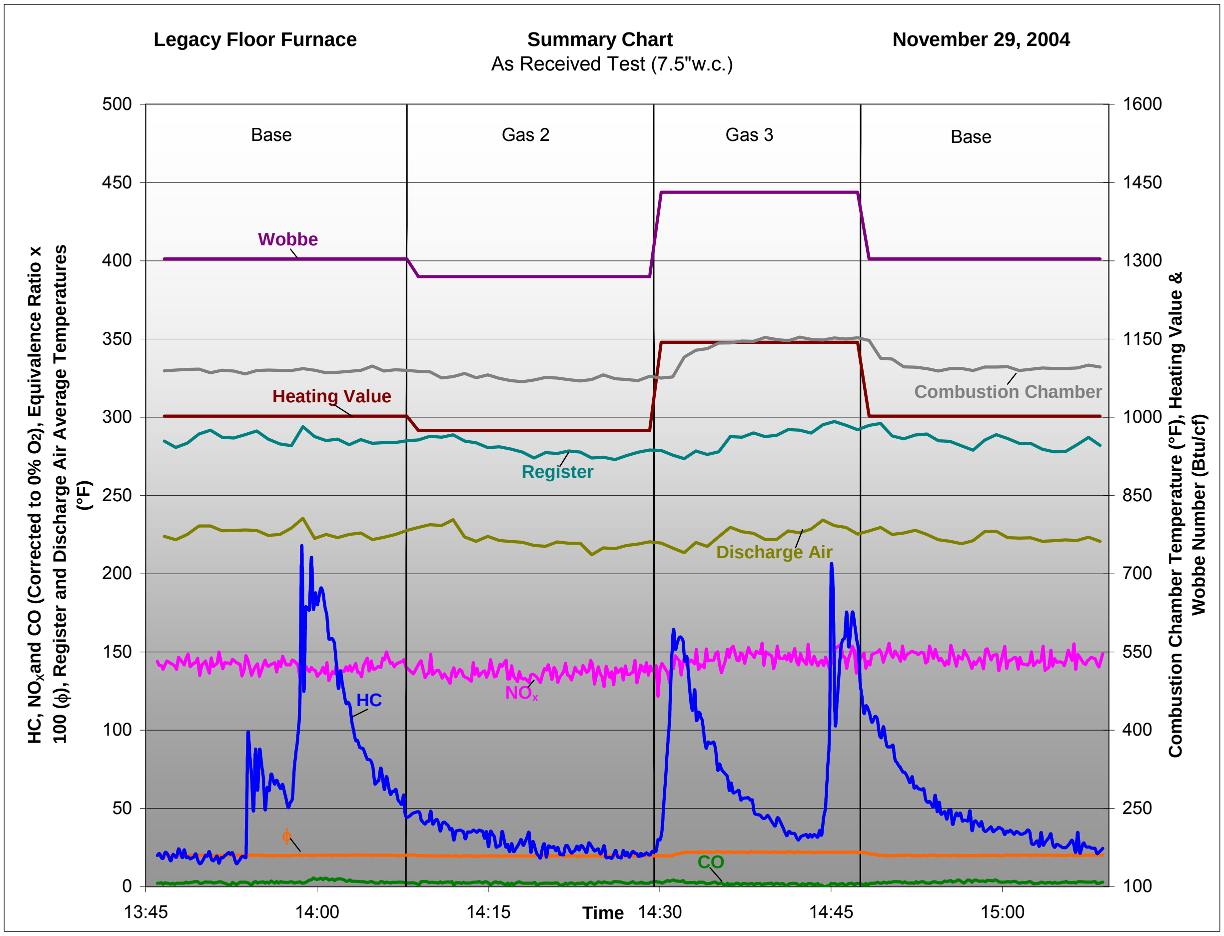
Results Summary

Results obtained during the testing of each gas and during the transitions between gases indicate that: (a) there are no operational, ignition, flame stability, or safety problems, (b) average CO emissions were below 8 ppm (corrected to 0% O_2), (c) NO_X emissions did not exceed 155 ppm (corrected to 0% O_2) and (d) HC peaks occurred randomly and were not related to transitions between gases. The cause of these peaks is unknown.

As Received Test

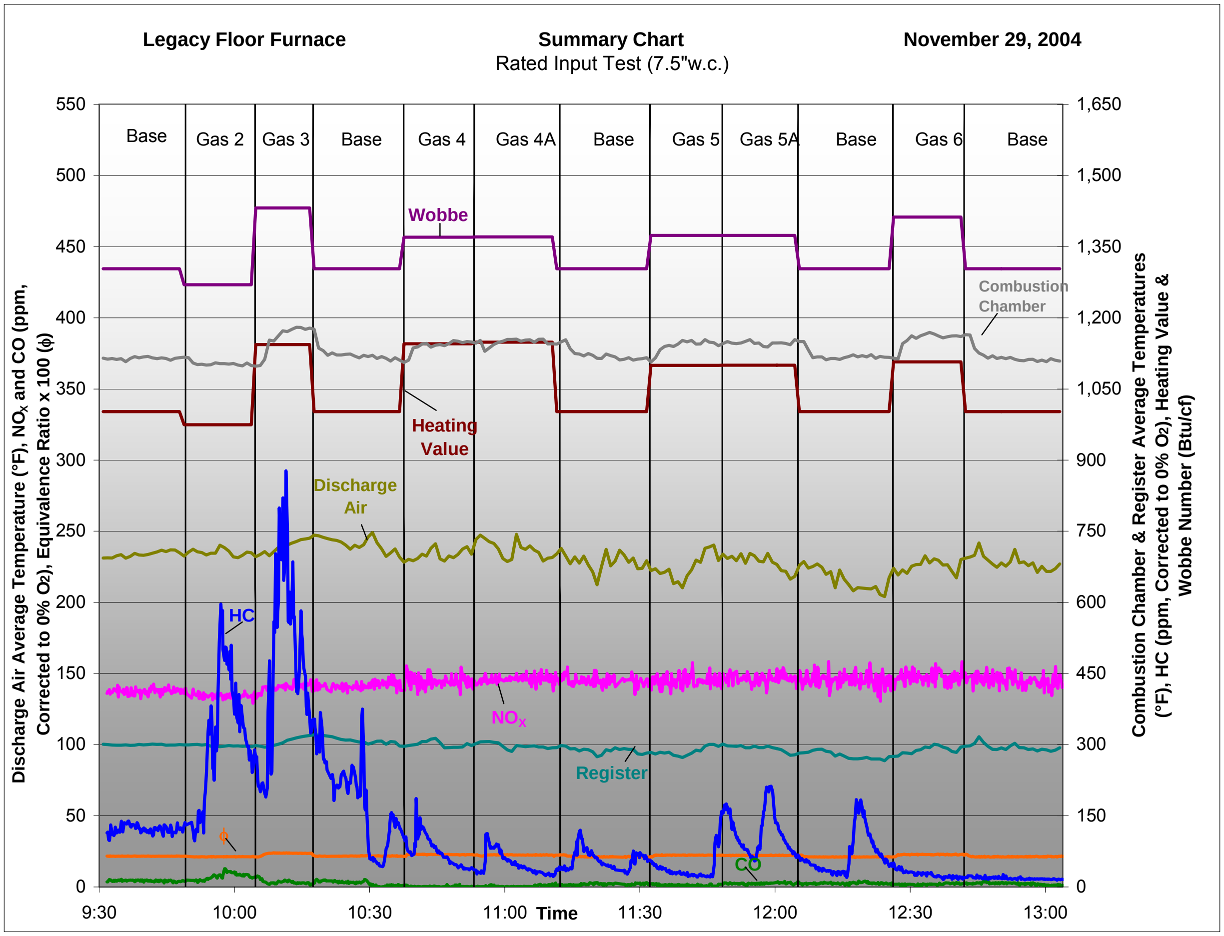
The purpose of this test was to evaluate the floor furnace performance prior to making any operational adjustments. Results indicate that NO_x emissions remained below 147 ppm for the entire test period. Baseline Gas NO_x emission values varied between 141 ppm and 146 ppm. Gas 2 (136 ppm) had the lowest NO_X emissions. The CO emissions were negligible for the entire test period. Generally, temperatures decreased with Gas 2 and increased with Gas 3.



NOTE: Emission test results are for information purposes, they were not the result of certified tests.

Rated Input Test

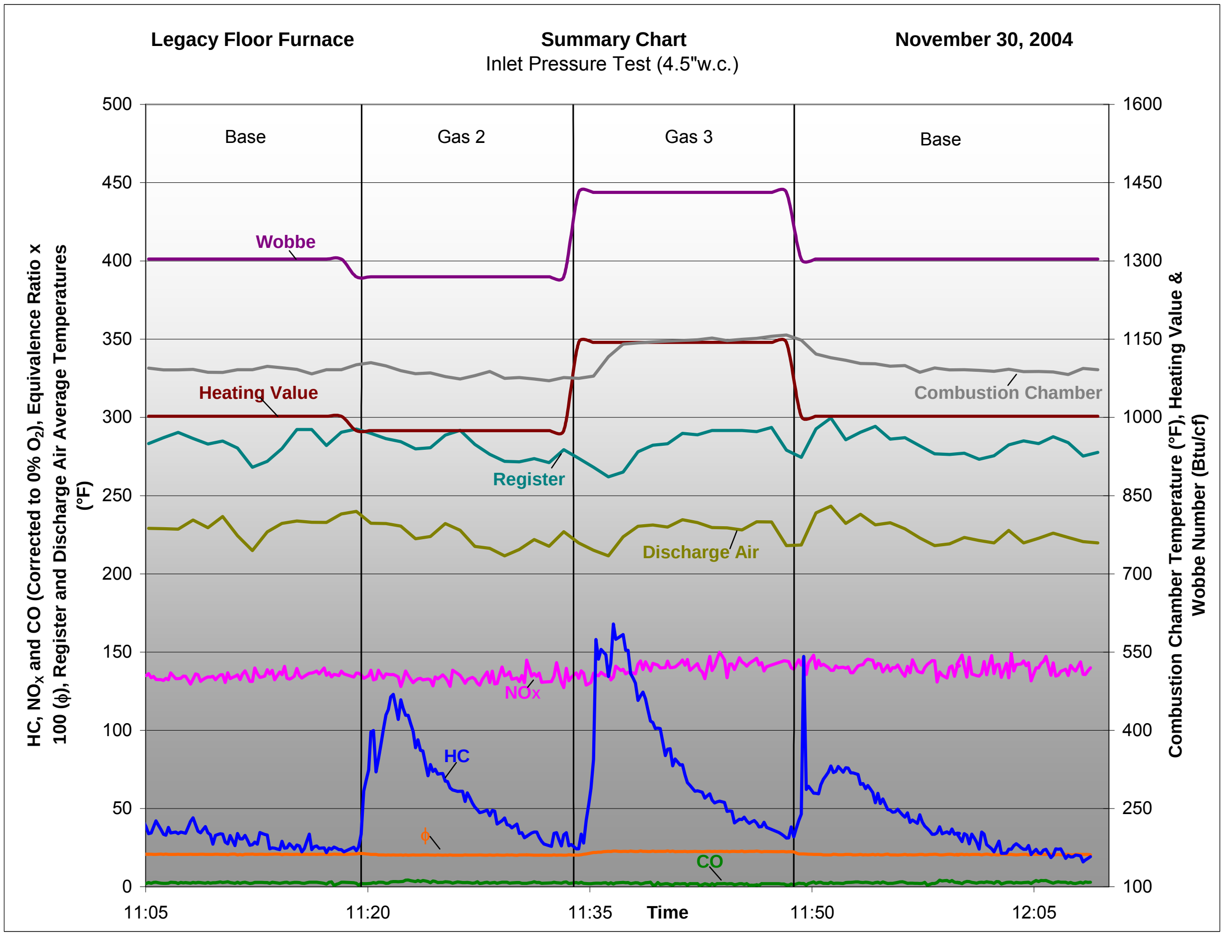
The purpose of this test was to examine furnace performance with various test gases after it was adjusted to operate at an input rate of 32,000 Btu/hr with Baseline Gas. Results indicate that NO_x emissions were fairly stable for the entire test period. NO_x emissions were highest with Gas 6 (147 ppm) followed by Gas 5A and Gas 4A (146 ppm). Baseline Gas NO_x emissions values varied between 137 ppm and 145 ppm. CO emissions were negligible during this test. Generally, temperatures decreased with Gas 2 and increased with richer gases.



NOTE: Emission test results are for information purposes, they were not the result of certified tests

Inlet Pressure Test

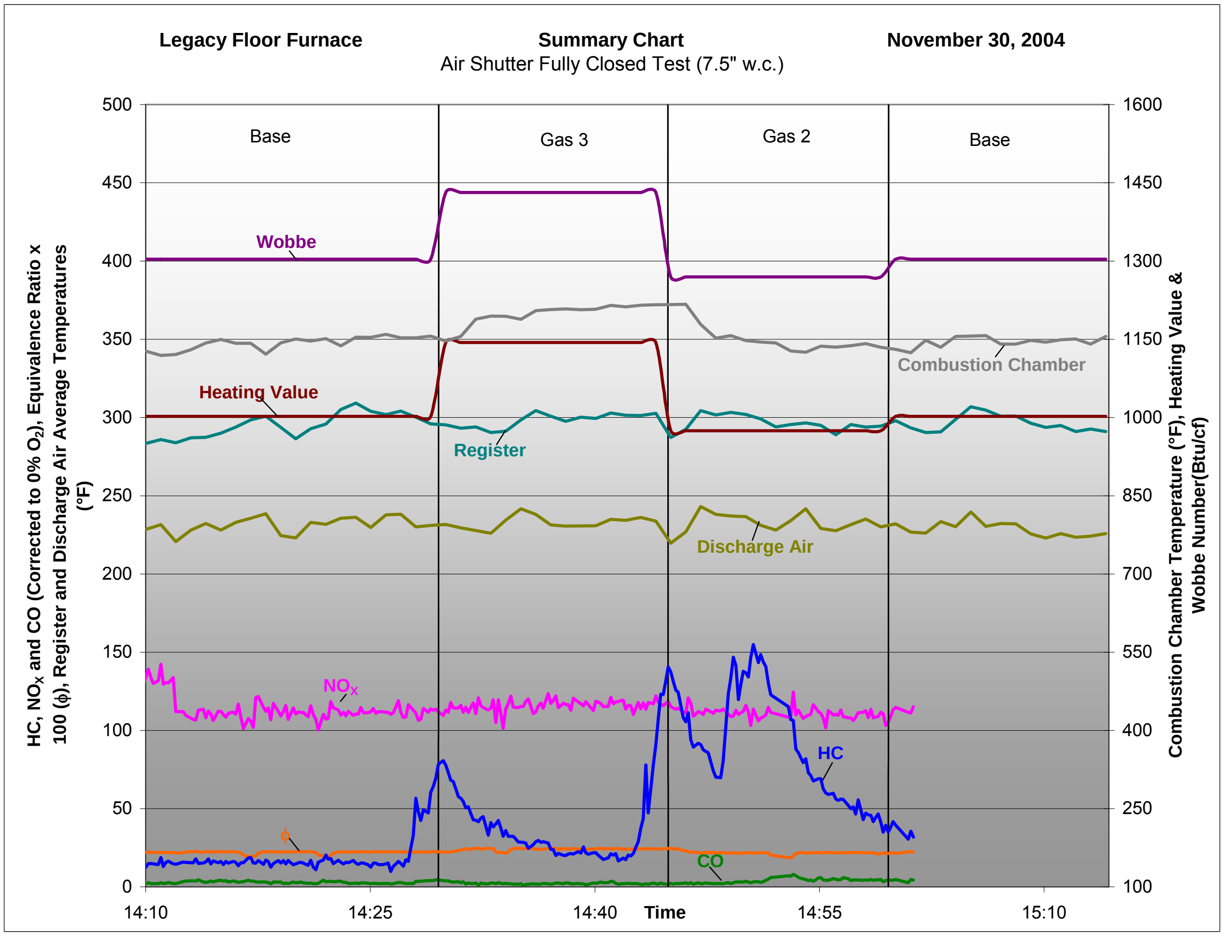
The purpose of this test was to evaluate any changes in the floor furnace performance when the unit was operated at different inlet pressures. Results indicate that NO_x emissions were fairly stable for the entire test period. NO_x emissions values were highest with Baseline Gas and Gas 3 (140 ppm). NO_X emissions were lowest with Gas 2 (134 ppm). CO emissions were negligible during this test. Generally, temperatures decreased with Gas 2 and increased with Gas 3.



NOTE: Emission test results are for information purposes, they were not the result of certified tests

Air Shutter Fully Closed Test

The purpose of this test was to simulate one of the possible problems for floor furnaces. According to a survey of Southern California Gas Company field service technicians, one of the problems encountered in the field with this type of appliance is a blocked or closed air shutter. Results indicate that NO_x emissions were fairly stable for the entire test period. NO_x emissions values were highest with Gas 3 (115 ppm) and lowest with Gas 2 (111 ppm). Baseline Gas NO_x emissions values ranged between 112 ppm and 113 ppm. CO emissions were negligible during this test. Generally, temperatures decreased with Gas 2 and increased with Gas 3.



NOTE: Emission test results are for information purposes, they were not the result of certified tests

Equipment Selection Criteria

This unit was selected because it is used extensively within the Southern California Gas Company service territory and was recommended for testing by a focus group composed of Southern California Gas Company instructors and field technicians. The focus group was concerned because some of the floor furnaces in the field have long venting systems that may have problems if gases of different calorific values are introduced into the gas distribution system. Floor furnaces are typically the oldest type of gas appliance found in our territory.

Equipment Specifications

- **Description:** Floor furnace with a 3-module heat exchanger (Manufactured approximately 1925)
- **Burner:** 2 atmospheric burners made of pressed steel and porcelain-coated
- **Maximum input rating:** ~32,000 Btu/hr
- **Minimum input rating:** ~22,400 Btu/hr
- **Type of fuel:** Natural gas
- **Required gas supply pressure:** 4.5 to 7.0 in. w.c.

Standards

A detailed description of the protocol and some of the rationale used to develop the test procedures are included in the appendix. The test protocol was developed based on the following test standards.

- ANSI Z21.86-2004

Installation

The floor furnace was tested inside the engineering test lab. It was mounted in a special cradle designed to hold the unit in the same manner it would be when installed in the floor of a home. The airflow paths for primary and secondary air were sized adequately so that there is no restriction to the flow. Various natural gases were supplied via appropriate piping pressure and pressure regulators.

This testing generally complied with the following description of the basic setup for the floor furnace test per ANSI Z21.86-2004, Section 10.7:

"Four nominal 2 X 12 inch pine boards shall be placed on edge in close contact with the side of the appliance, with the register resting on top. When necessary, one of these joists may be notched just sufficiently to clear the draft hood and any draft hood shielding furnished as a part of the draft hood or appliance. A nominal 1-inch thick wooden board just sufficient in size to cover the area of the draft hood shall be attached horizontally to the joist so its lower surface is level with the lower surface of the joist above the draft hood. A platform extending 28 inches from each edge of the register shall be constructed around the appliance. When tests are conducted on floor-register type appliances, 2 walls, 3 feet high, fitted together to form a corner, shall be placed on this platform so each wall is 3 inches from adjacent sides of the register."

Instrumentation was installed to perform testing on the floor furnace. Thermocouples were installed to measure the following temperatures: combustion air, joist surface facing floor furnace, fire box, burner and combustion chamber, register metal, hot air discharge, wall surface, exhaust duct, ambient air, and natural gas. Also, pressure transducers were installed to measure manifold and supply gas pressure. A dry gas meter was installed to measure the gas flow.

Four inch diameter, Type B gas vent was installed at the outlet of the floor furnace draft hood. First, a 24-inch long straight vent pipe was attached to the outlet of the draft hood and was routed horizontally. Connected to the outlet end of this pipe was a 90 degree elbow, which was aligned to discharge vertically. Connected to the outlet end of this elbow was a 60-inch long straight vent pipe, which was routed vertically (See Appendix H).

An integrated sampling probe, constructed per the AQMD protocol, 20 inches from the top of the gas vent pipe was installed. A three-point thermocouple grid (wired as a thermopile) was placed 6 inches from the bottom of the gas vent pipe.

Test Gases

The following gases have been specifically formulated to cover the range of compositions and calorific values of natural gases that could be delivered in the Southern California Gas Company territory by current natural gas suppliers and future LNG suppliers. Composition details are specified in Appendix C.

- **Baseline Gas** (Gas 1) - Low Wobbe (1,330 Btu/cf), low heat content gas (1,017 Btu/cf)
- **Gas 2** - Lowest-Wobbe (1,269 Btu/cf), lowest-heat content gas (974 Btu/cf)
- **Gas 3** - Highest-Wobbe (1,431 Btu/cf), highest-heat content gas (1,143 Btu/cf)
- **Gas 4** - Medium-Wobbe (1,370 Btu/cf), highest-heat content gas (1,145 Btu/cf)
- **Gas 4A** (4 component mix) - Medium-Wobbe (1,371 Btu/cf), highest-heat content gas (1,148 Btu/cf)
- **Gas 5** - Medium-Wobbe (1,374 Btu/cf), high-heat content gas (1,099 Btu/cf)
- **Gas 5A** (4 component mix) - Medium-Wobbe (1,374 Btu/cf), high-heat content gas (1,100 Btu/cf)
- **Gas 6** - High Wobbe (1.413 Btu/cf), high-heat content gas (1,107 Btu/cf)

Test Procedure

Test procedures were developed based on ANSI Z21.86-2004 requirements.

Before every test, the following steps were performed:

- All emissions analyzers were calibrated and checked for linearity.
- Data logger was enabled and temperatures, pressures, and gas flow readings were verified.

During every test, the following steps were performed:

- Baseline and Substitute Gases were run continuously with switching between gases taking less than 14 seconds.
- Emissions, pressure and temperature data was observed before, during and after changeover.

After every test, the following steps were performed:

- Data was downloaded to a laptop.
- Linearity and drift inspections were performed on all emissions analyzers.

As Received Test

Using Baseline Gas, the inlet pressure was adjusted to 7.5" w.c., then the floor furnace was allowed to "warm-up" for at least 60 minutes. During this time emissions, temperature and pressure data was monitored to ensure proper furnace operation. After "warm-up," collection of data began and the gases were run in the following order:

- Begin testing with Baseline Gas for 20 minutes.
- Switch to Gas 2 and run unit for 15 minutes.
- Switch to Gas 3 and run unit for 15 minutes.
- Conclude testing by reestablishing Baseline Gas and run unit for 20 minutes.

Since no operational and/or safety problems were encountered while testing with Gases 2 & 3, testing of all other Substitute Gases was not necessary. This test was conducted with an exhaust duct constructed to comply with ANSI Z21.86-2004. (NOTE: Air adjustment on the floor furnace may have accidentally changed during the process of removal and transfer from the residential site to the test chamber).

Rated Input Test

Using Baseline Gas, the inlet pressure was adjusted to 7.5" w.c. and the manifold pressure was adjusted to 4" w.c. The floor furnace was allowed to "warm-up" for at least 60 minutes. During this time emissions, temperature and pressure data was monitored to ensure proper furnace operation. After "warm-up," collection of data began and the gases were run in the following order:

- Begin testing with Baseline Gas for 20 minutes.
- Switch to Gas 2 and run unit for 15 minutes.
- Switch to Gas 3 and run unit for at least 15 minutes.
- Reestablish Baseline Gas and run unit for 20 minutes.
- Switch to Gas 4 and run unit for 15 minutes.
- Switch to Gas 4A and run unit for 15 minutes.

- Reestablish Baseline Gas and run unit for 20 minutes.
- Switch to Gas 5 and run unit for 15 minutes.
- Switch to Gas 5A and run unit for 15 minutes.
- Reestablish Baseline Gas and run unit for 20 minutes.
- Switch to Gas 6 and run unit for 15 minutes.
- Conclude testing with Baseline Gas and run unit for 20 minutes.

This test was conducted with an exhaust duct constructed to comply with ANSI Z21.86-2004.

Inlet Pressure Test

Using Baseline Gas, the floor furnace was allowed to "warm-up" for at least 60 minutes. During this time emissions, temperature and pressure data was monitored to ensure proper furnace operation. After "warm-up," the inlet pressure was adjusted to minimum inlet pressure (4.5" w.c.), collection of data began, and the gases were run in the following order:

- Begin testing with Baseline Gas for 20 minutes.
- Switch to Gas 2 and run unit for 15 minutes
- Switch to Gas 3 and run unit for 15 minutes.
- Conclude testing with Baseline Gas and run unit for 20 minutes.

After testing at minimum inlet pressure, the floor furnace was adjusted to increased inlet pressure (10.5" w.c.). Since the manifold pressure did not increase in value (compared to normal inlet pressure) when the adjustment was made, testing at increased inlet pressure was not conducted. This test was conducted with exhaust duct constructed to comply with ANSI Z21.86-2004.

Air Shutter Fully Closed Test

Using Baseline Gas, the inlet pressure was adjusted to 7.5" w.c. and air shutter was fully closed. The floor furnace was allowed to "warm-up" for at least 60 minutes. During this time emissions, temperature and pressure data was monitored to ensure proper furnace operation. After "warm-up," collection of data began and the gases were run in the following order:

- Begin testing with Baseline Gas for 20 minutes.
- Switch to Gas 2 and run unit for 15 minutes.
- Switch to Gas 3 and run unit for 15 minutes.
- Conclude testing with Baseline Gas and run unit for 20 minutes.

Since no operational and/or safety problems were encountered while testing with Gases 2 & 3, testing of all other Substitute Gases was not necessary. This test was conducted with an exhaust duct constructed to comply with ANSI Z21.86-2004

Cold Ignition Test

The floor furnace was adjusted to normal inlet pressure. Using Baseline Gas, the floor furnace was ignited from a cold start and operated for one minute. Visual observation of the flame, ignition delays and other phenomena was documented. This process was repeated 2 more times, allowing the floor furnace to reestablish cold start conditions in between each ignition.

The gas delivery system was then purged of Baseline Gas with Gas 3. Using Gas 3, the floor furnace was ignited from a cold start and operated for one minute. Visual observation of the flame, ignition delays and other phenomena was documented. This process was repeated 2 more times, allowing the floor furnace to reestablish cold start conditions in between each ignition.

The gas delivery system was then purged of Gas 3 with Baseline Gas. Using Baseline Gas, the floor furnace was ignited from a cold start and operated for one minute. Visual observation of the flame, ignition delays and other phenomena was documented. This process was repeated 2 more times, allowing the floor furnace to reestablish cold start conditions in between each ignition.

The gas delivery system was then purged of Baseline Gas with Gas 2. Using Gas 2, the floor furnace was ignited from a cold start and operated for one minute. Visual observation of the flame, ignition delays and other phenomena was documented. This process was repeated 2 more times, allowing the floor furnace to reestablish cold start conditions in between each ignition.

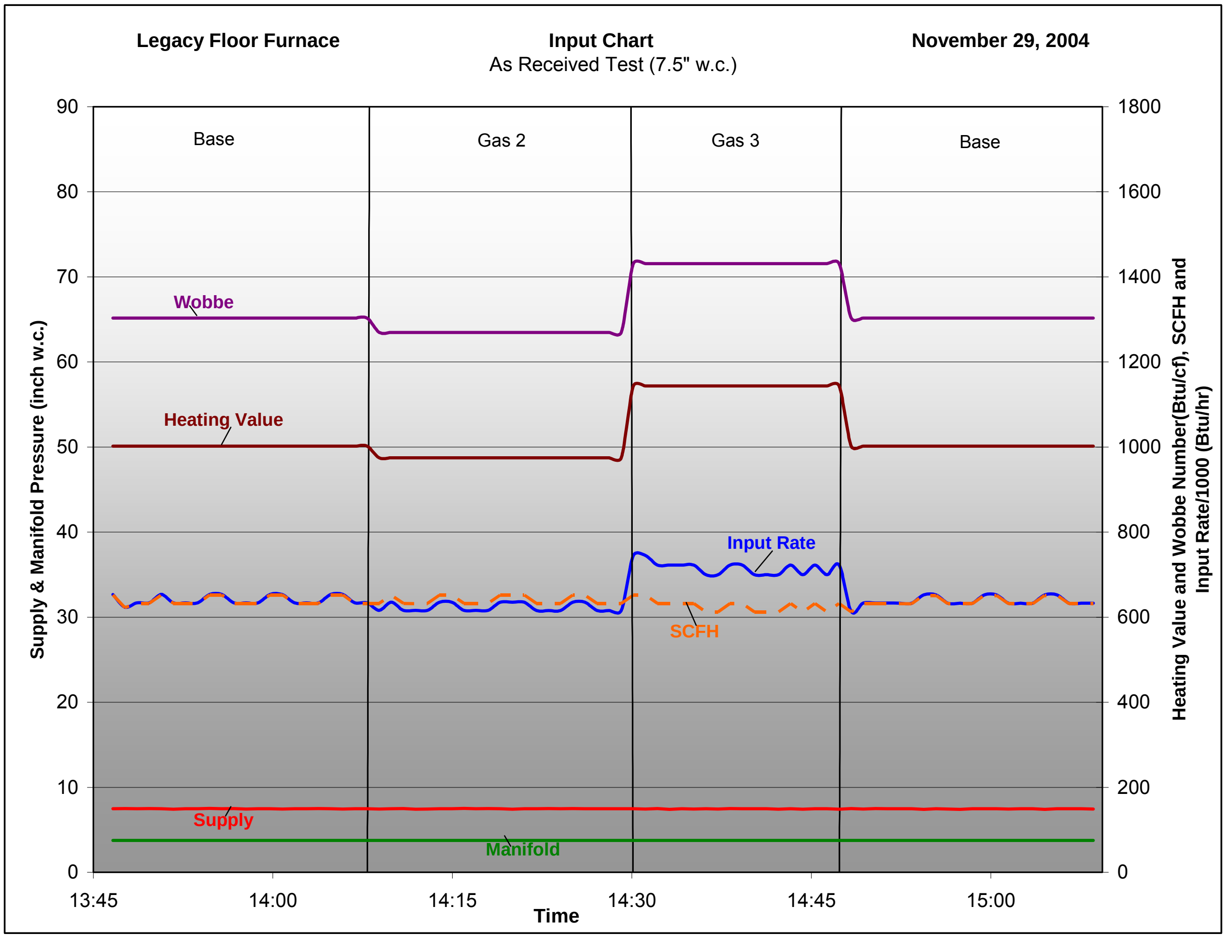
Results[1,2]

As Received Test

Input

The gas flow rate varied slightly for the entire test period. Gas 3 had the lowest flow rate (31 scfh) and the highest input rate (35,800 Btu/hr). Supply pressure and manifold pressure were both constant for the entire test period.

The fluctuation in gas flow (and input rate) originates from the number of pulses counted by the data logger during each minute. The number of pulses counted is dependant on the position of the dial relative to the location of the sensor and should vary no more than 0.05 cf per minute (since 1 pulse = 0.05 cf).

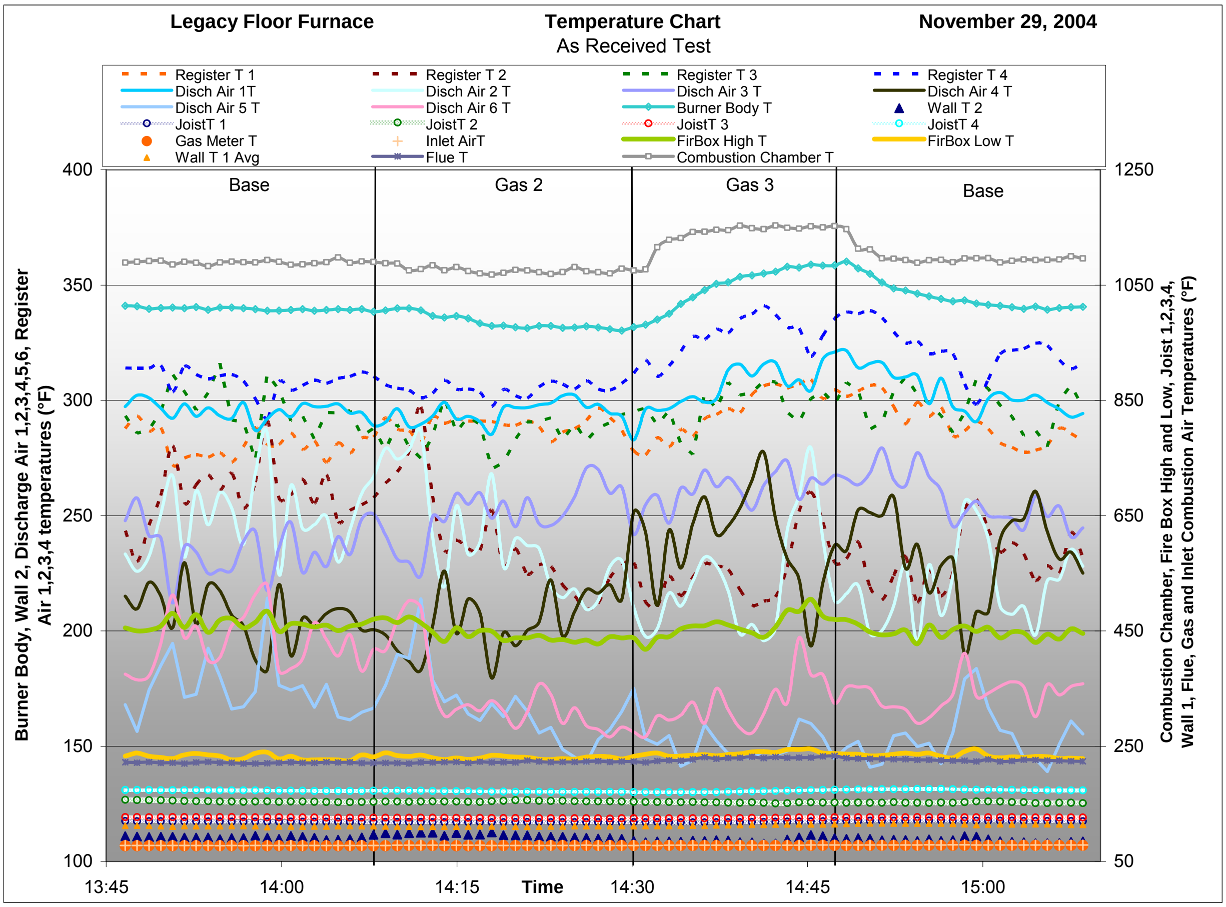


[1] All emissions, temperature and input values mentioned throughout the results section are average values.
[2] CO, HC & NO_X emissions data are corrected to 0% O_2

Temperatures

Generally, temperatures decreased with Gas 2 and increased with Gas 3. All discharge air temperatures showed noticeable fluctuation that, in many cases, did not appear to be related to the introduction of the test gases.

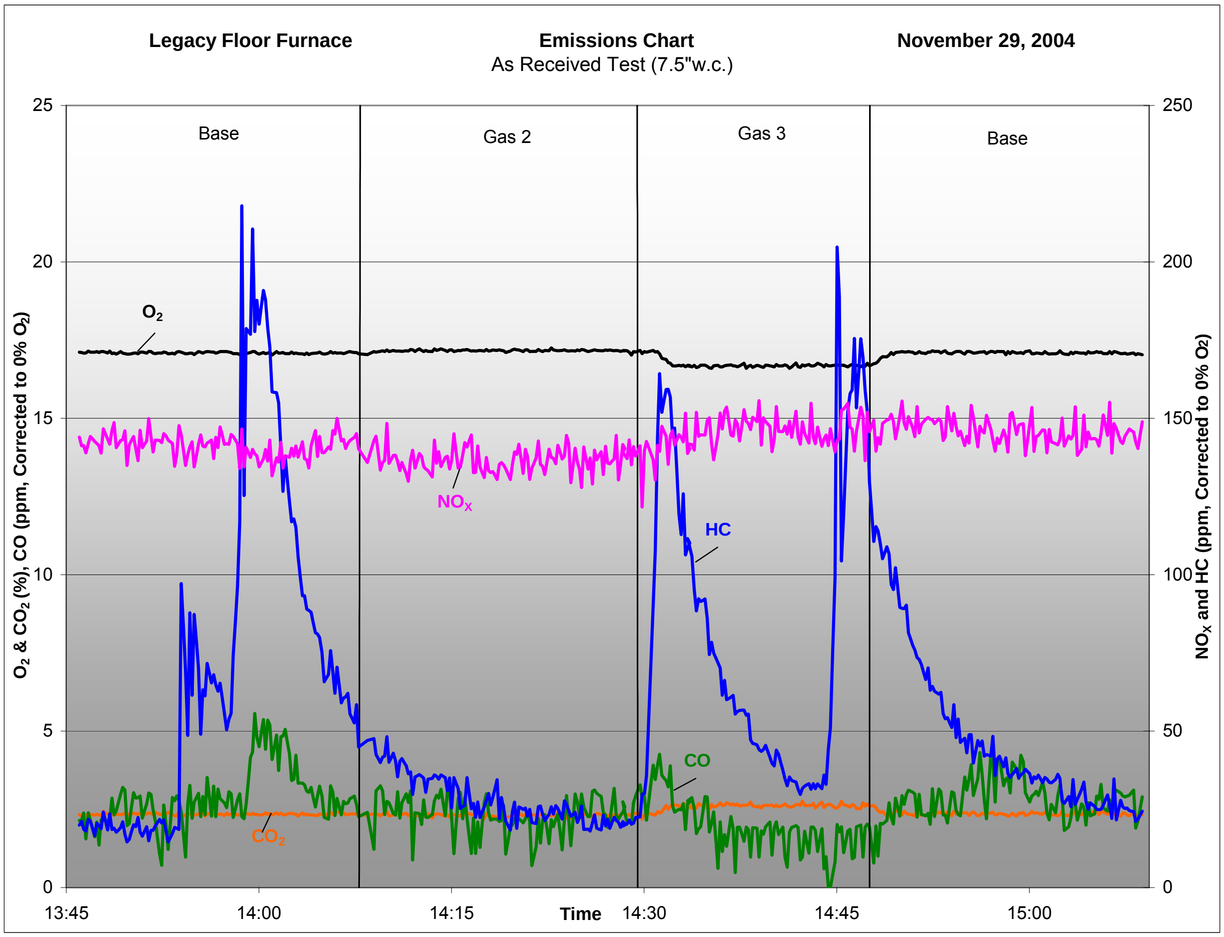
The firebox high, burner body, combustion chamber and most of the register temperatures all showed temperature increases with Gas 3 and decreases with Gas 2. The highest firebox high temperature was recorded during the last Baseline Gas run and both flue gas and firebox low temperatures remained fairly stable with all test gases.



Emissions

NO_x emissions were highest with the last Baseline Gas run (146 ppm) followed by Gas 3 (145 ppm). Gas 2 had the lowest NO_x emissions. CO emissions remained below 3.0 ppm for the entire testing period.

HC emissions displayed 4 noticeable peaks during the test period. The 1st and 2nd HC peaks occurred during the first Baseline Gas run with peak values over 95 ppm. The 3rd and 4th HC peak occurred with Gas 3 and displayed a peak value of over 160 ppm. The cause(s) of these peaks are unknown.



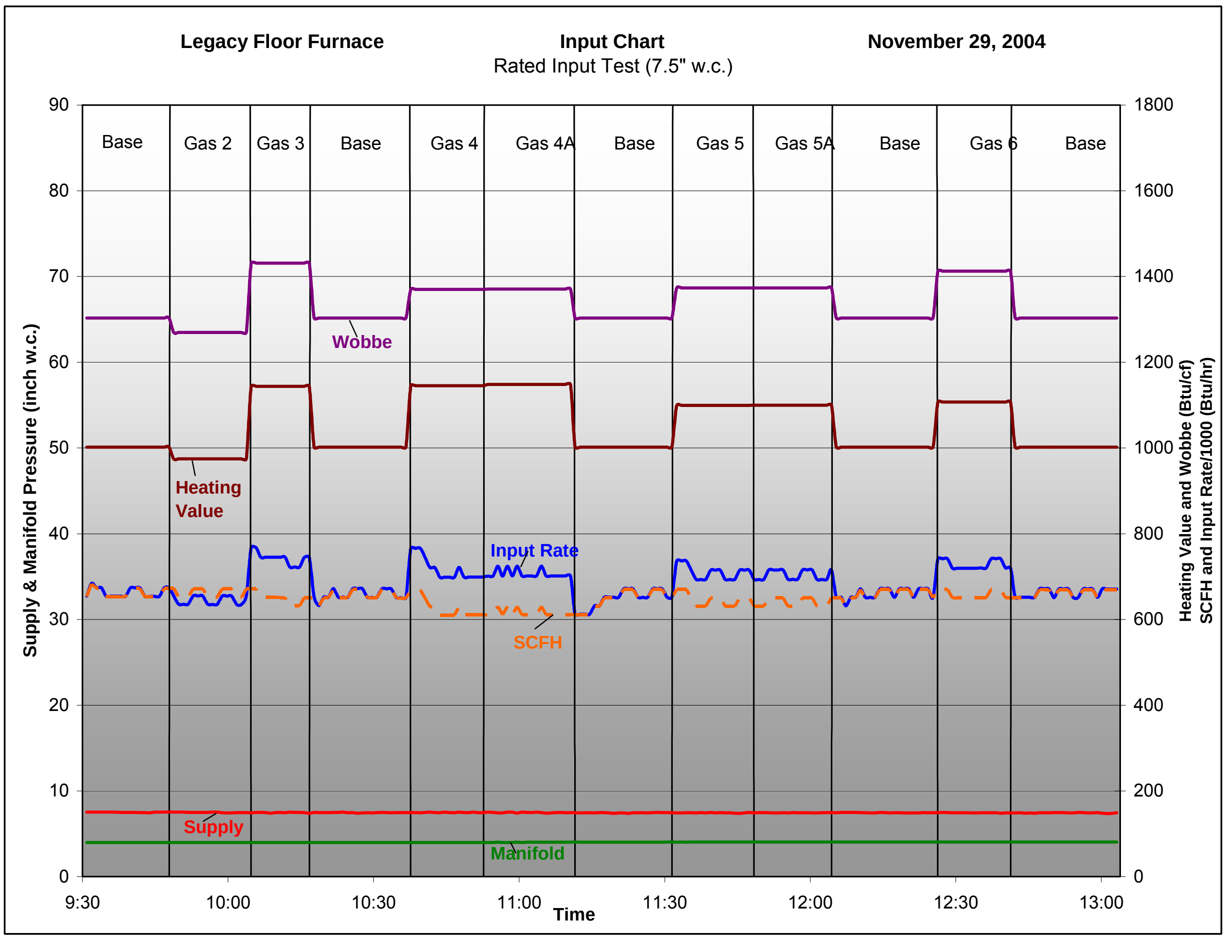
NOTE: Emission test results are for information purposes, they were not the result of certified tests.

Rated Input Test

Input

The gas flow rate decreased when Gases 4, 4A, 5 and 5A were introduced, with the lowest flow rate observed during Gas 4 and Gas 4A runs. The input rate increased when any of the medium-to-high Wobbe/high-heat content gases were introduced. The highest input rate was with Gas 3. Supply pressure and manifold pressure were both constant for the entire test period.

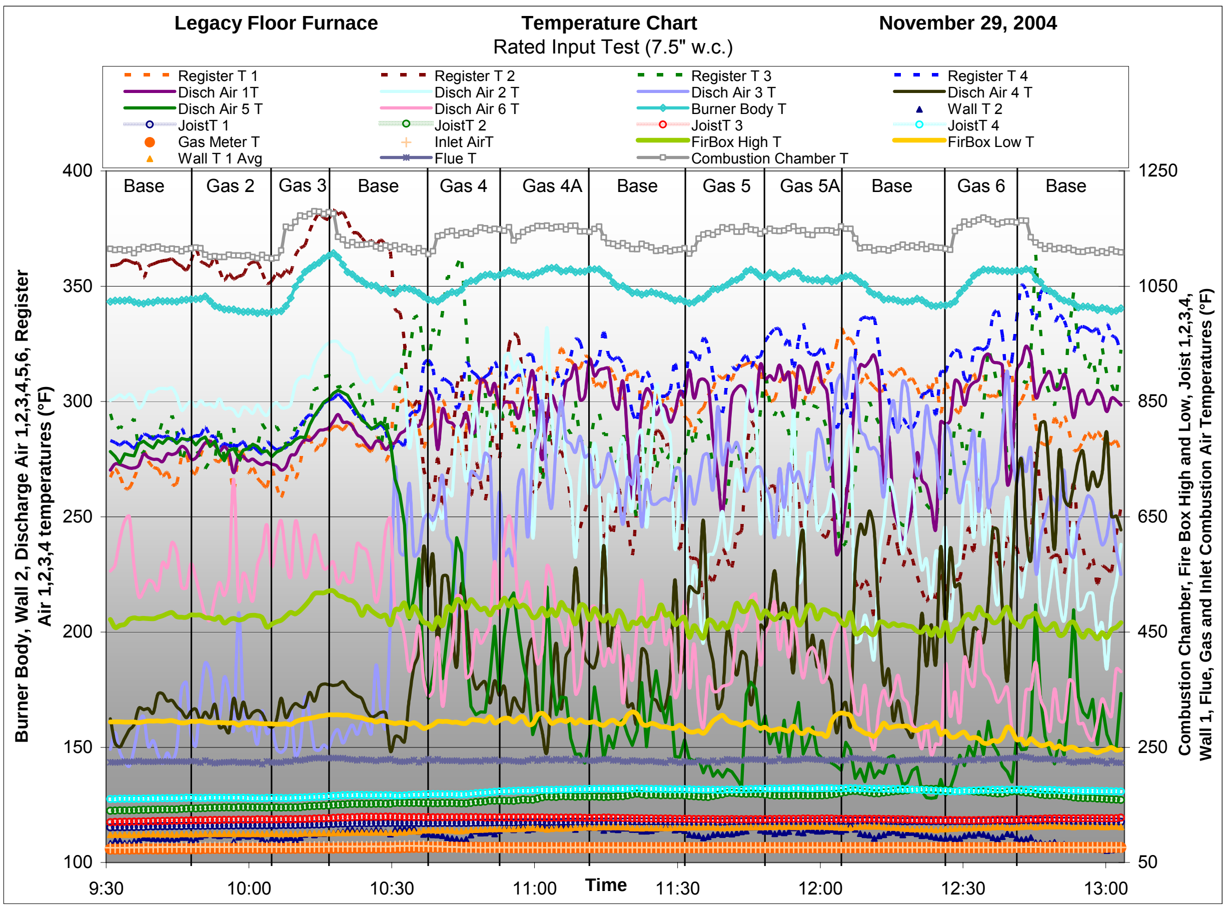
The fluctuation in gas flow (and input rate) originates from the number of pulses counted by the data logger during each minute. The number of pulses counted is dependant on the position of the dial relative to the location of the sensor and should vary no more than 0.05 cf per minute (since 1 pulse = 0.05 cf).



Temperatures

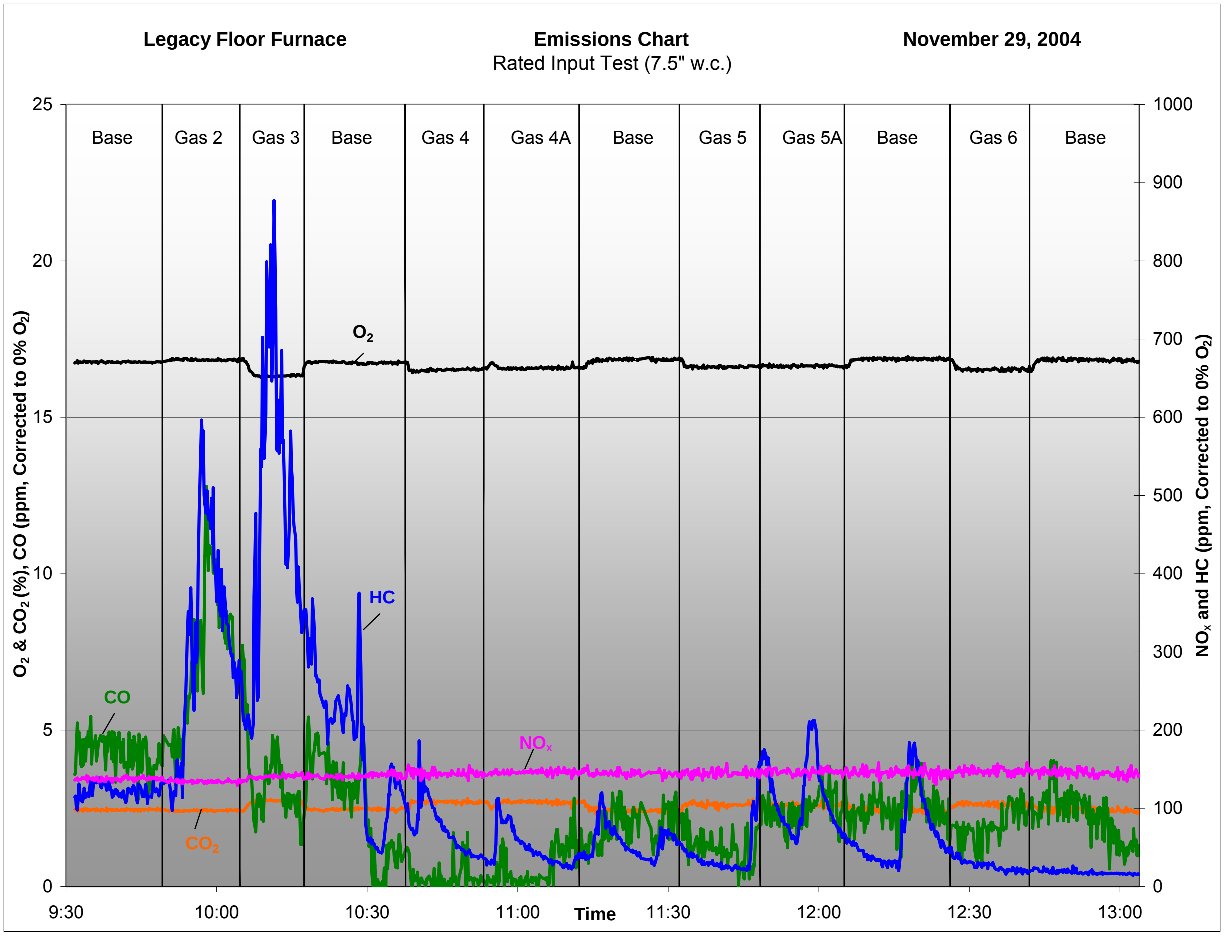
Compared to Baseline Gas, temperatures decreased with Gas 2 (lowest Wobbe/lowest-heat content gas) and increased with all medium-to-high Wobbe/high-heat content gases. All discharge air temperatures showed noticeable fluctuation that, in many cases, did not appear to be related to the introduction of the test gases. The most drastic changes were observed with Discharge Air temperatures 3T, 5T and 6T. However, it was unclear why these temperatures behaved in this manner right prior to the introduction of Gas 4.

The firebox, register, burner body and combustion chamber temperatures all showed temperature increases with medium-to-high Wobbe/high-heat content gases. The burner body and combustion chamber temperatures for Gas 2 showed a temperature decrease but the same could not be said for firebox and register temperatures. The flue gas temperature remained fairly constant for all test gases.



Emissions

NO_x emissions were fairly stable while CO and HC emissions values fluctuated throughout the entire test period. CO values for all medium-to-high Wobbe/high-heat content gases were below 5 ppm (negligible for Gases 4 and 4A) but above 7 ppm for Gas 2 (lowest Wobbe/lowest-heat content gas). HC emissions displayed 10 noticeable peaks during the test period; of which the cause(s) is unknown. Generally, CO and HC fluctuations followed similar trends.



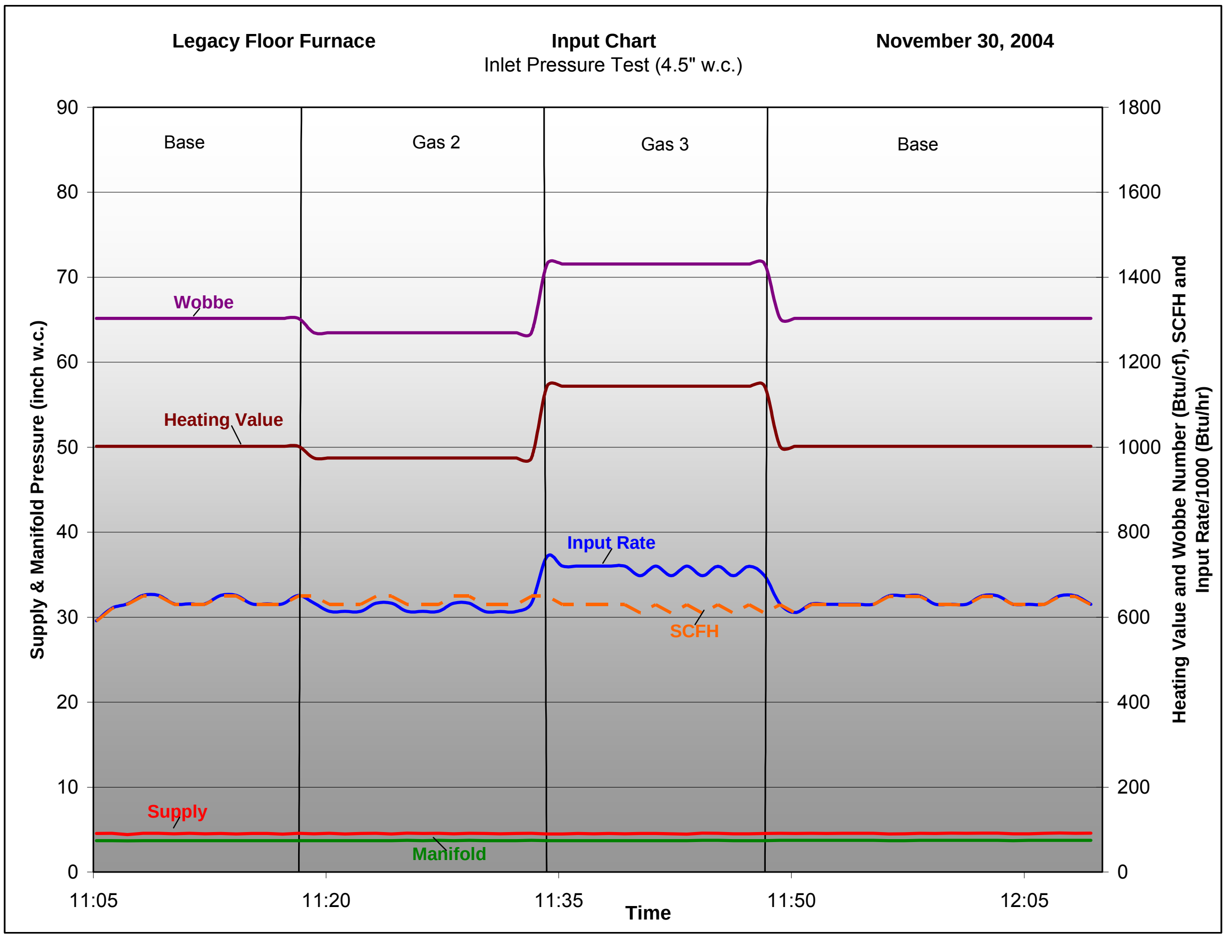
NOTE: Emission test results are for information purposes, they were not the result of certified tests.

Inlet Pressure Test

Input

The gas flow rate varied slightly for the entire test period. When Gas 3 was introduced the input rate was highest (35,700 Btu/hr) and the flow rate was lowest (31 scfh). Supply pressure and manifold pressure were both constant for the entire test period.

The fluctuation in gas flow (and input rate) originates from the number of pulses counted by the data logger during each minute. The number of pulses counted is dependant on the position of the dial relative to the location of the sensor and should vary no more than 0.05 cf per minute (since 1 pulse = 0.05 cf).

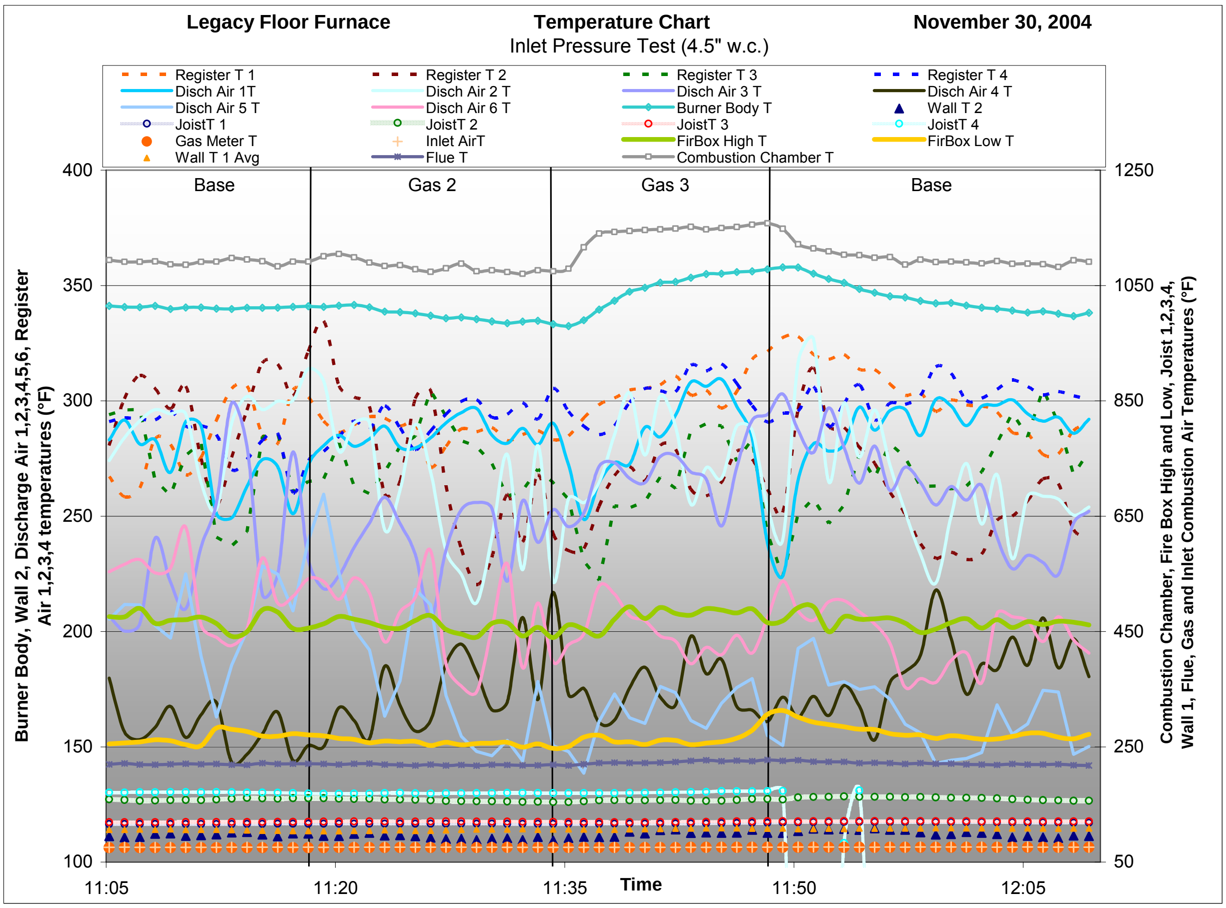


Temperatures

Compared with Baseline Gas, most temperatures decreased with Gas 2 and increased with Gas 3. All discharge air temperatures showed noticeable fluctuation that, in many cases, did not appear to be related to the introduction of the test gases.

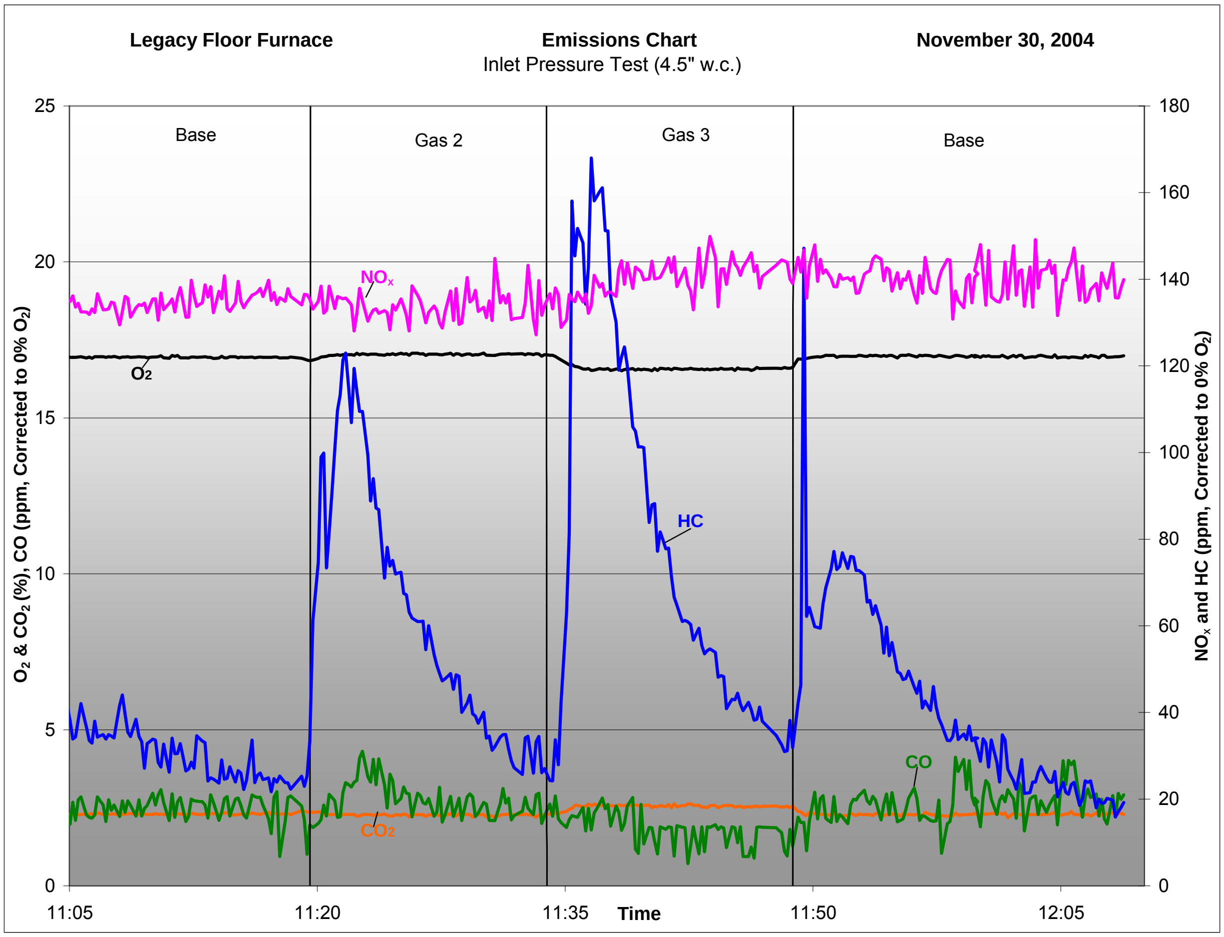
The firebox, register, burner body and combustion chamber temperatures all showed temperature increases with Gas 3 and decreases with Gas 2. The flue gas temperature remained fairly constant for all test gases.

The sudden drop in the Joist T4 temperature in the last Baseline Gas run was caused by an interruption in the thermocouple signal fed to the Data logger system.



Emissions

NO_x emissions were fairly stable for the entire test period and registered 140 ppm with Gas 3 and 134 ppm with Gas 2. NO_X emissions for Baseline Gas ranged between 135 ppm and 140 ppm. CO emissions were below 3 ppm for the entire test period. HC emissions displayed 3 noticeable peaks; of which the cause(s) is unknown.



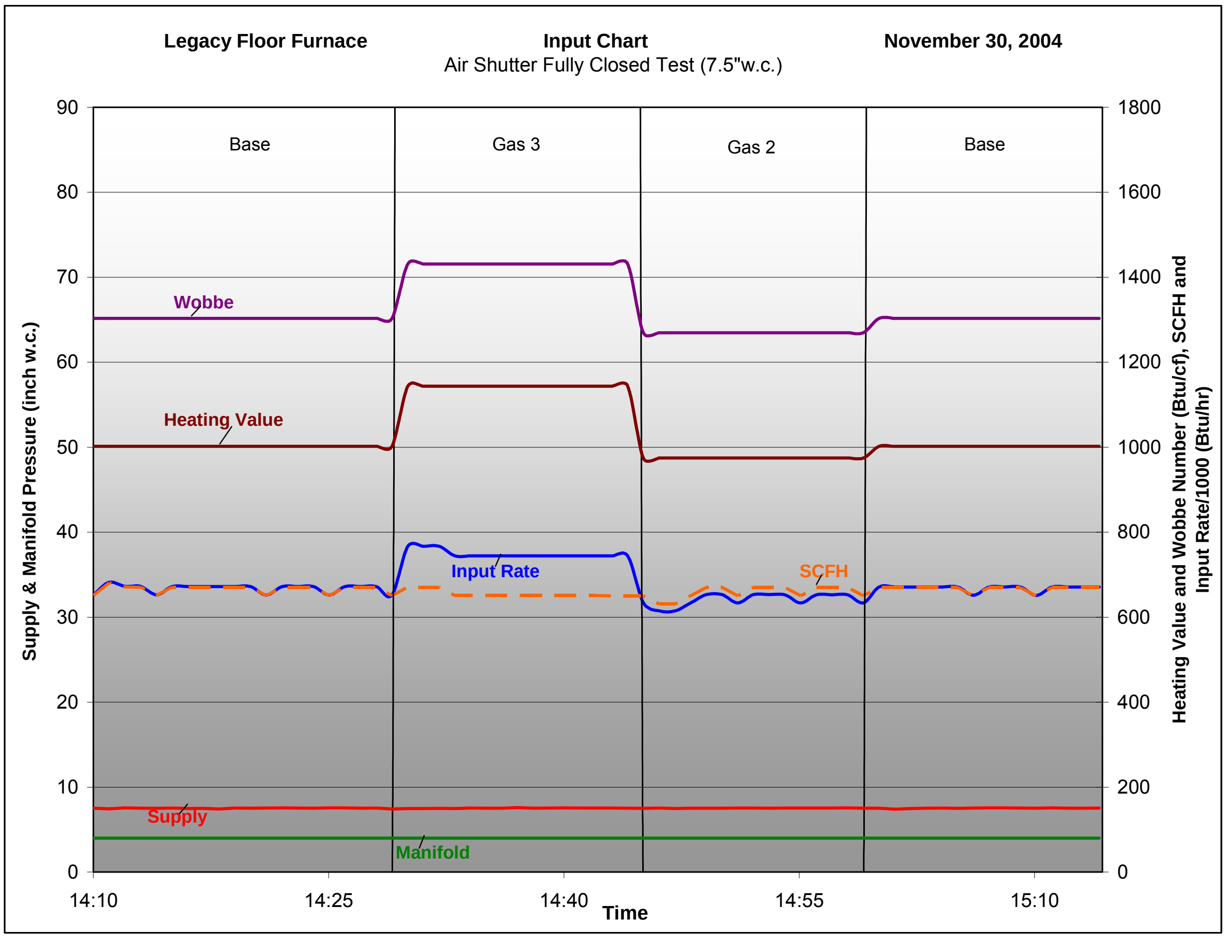
NOTE: Emission test results are for information purposes, they were not the result of certified tests.

Air Shutter Fully Closed Test

Input

The gas flow rate varied slightly for the entire test period. When Gas 3 was introduced the input rate was the highest (37,430 Btu/hr) and flow rate was the lowest (32.7 scfh). Supply pressure and manifold pressure were both constant for the entire test period.

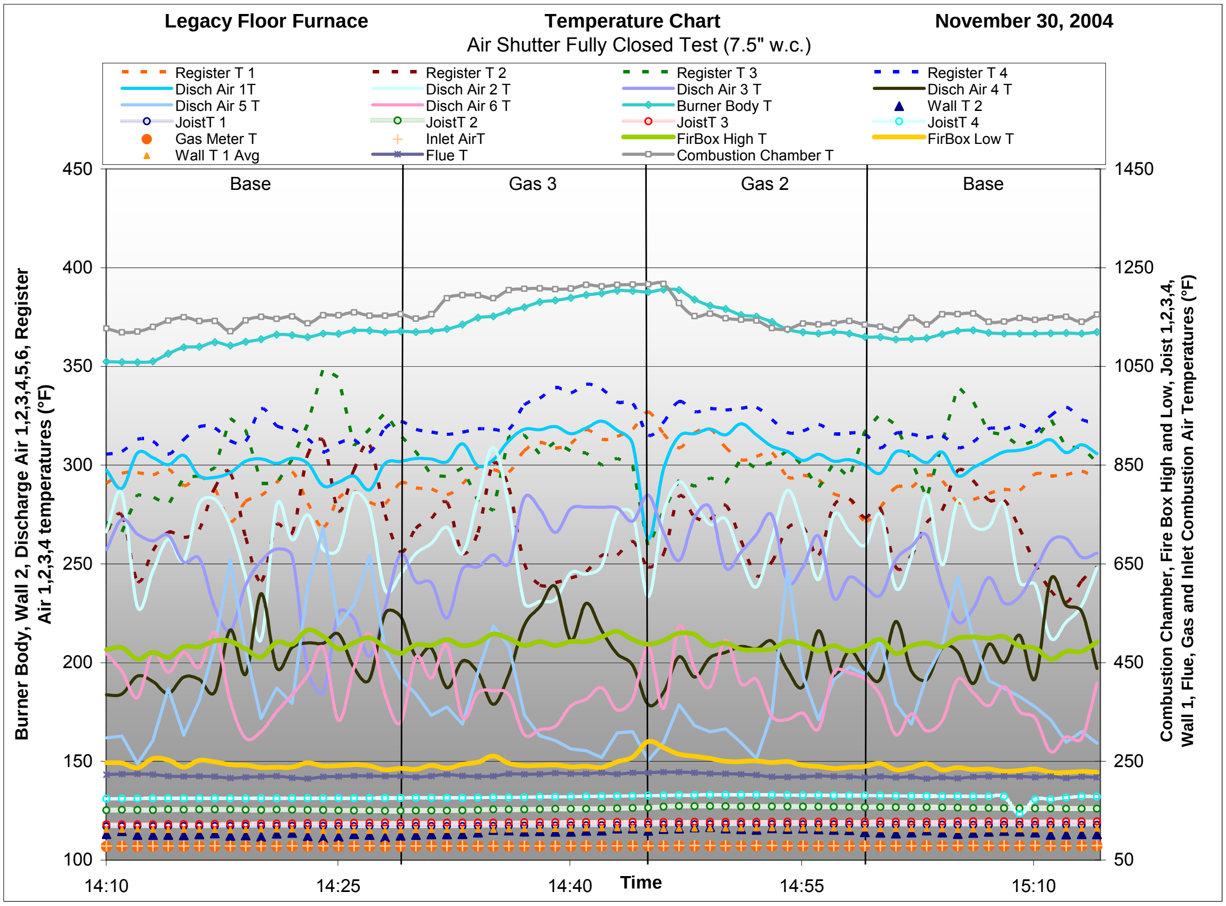
The fluctuation in gas flow (and input rate) originates from the number of pulses counted by the data logger during each minute. The number of pulses counted is dependant on the position of the dial relative to the location of the sensor and should vary no more than 0.05 cf per minute (since 1 pulse = 0.05 cf).



Temperatures

Generally, temperatures decreased with Gas 2 and increased with Gas 3. All discharge air temperatures showed noticeable fluctuation that in many cases did not appear to be related to the introduction of the test gases.

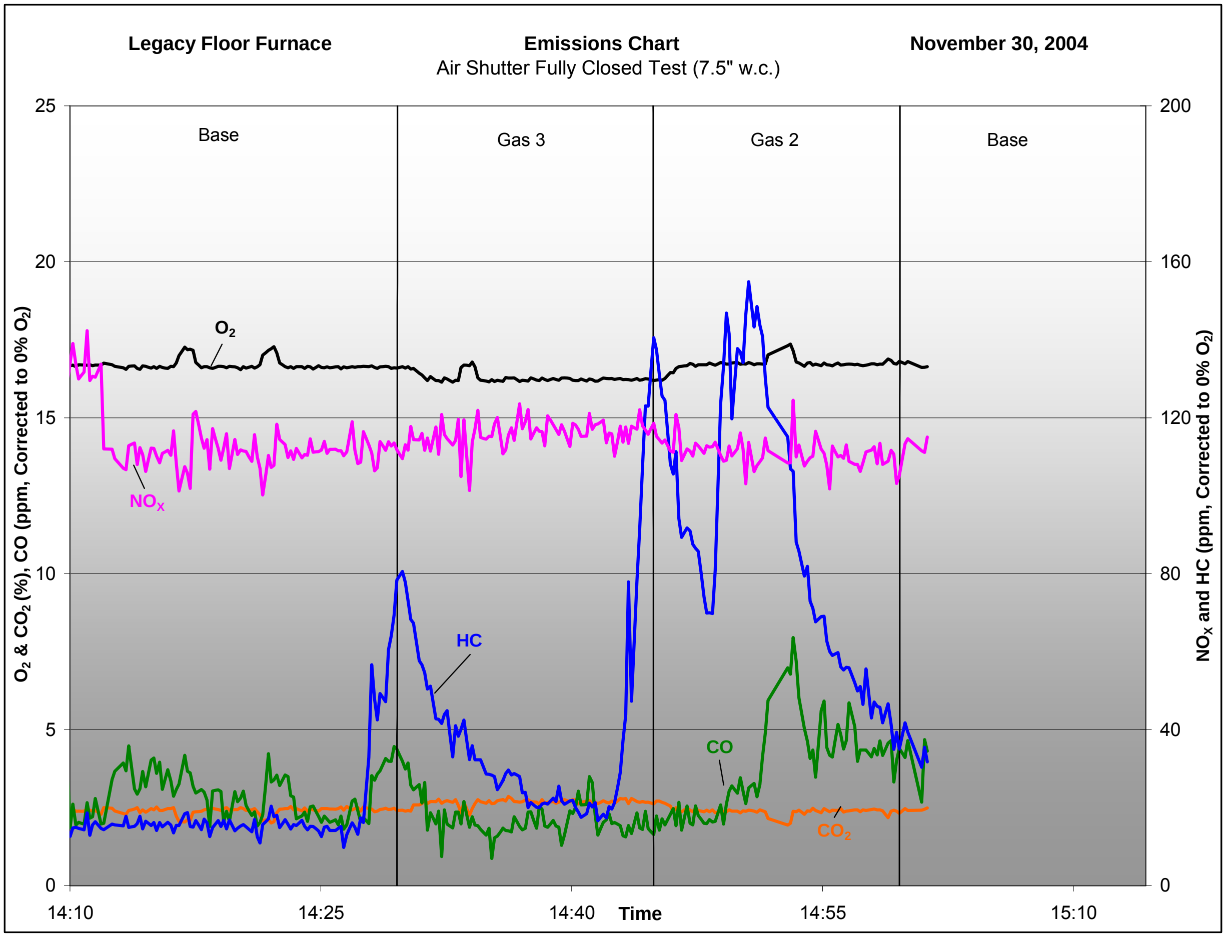
The firebox, register, burner body and combustion chamber temperatures all showed temperature increases with Gas 3 and decreases with Gas 2. The flue gas temperature remained fairly constant for all test gases.



Emissions

NO_x emissions were fairly stable for the entire test period but showed a minor decrease with Gas 2 (111 ppm) and a minor increase with Gas 3 (116 ppm). CO emissions were below 5 ppm for the entire test period. HC emissions displayed 3 noticeable peaks during the test period; of which the cause(s) is unknown.

Emissions analyzers were accidentally switched to calibration mode at the beginning of the last Baseline Gas run, which resulted in a short emissions test run.



NOTE: Emission test results are for information purposes, they were not the result of certified tests.

Cold Ignition Test

Orange tipping is normally luminance associated to high temperatures and not related with incomplete combustion.

Cold Ignition Test			
Gas	Ignition	Start-Up #	Comments & Observations
Baseline Gas	Normal and without delays	1	Soft flame with moderate orange tipping. Pilot had slight yellow tipping.
		2	Soft flame with moderate orange tipping. Pilot had slight yellow tipping.
		3	Soft flame with moderate orange tipping. Pilot had slight yellow tipping.
3	Normal and without delays	1	Long flame with continuous orange tipping. Pilot had continuous yellow tipping.
		2	Long flame with continuous orange tipping. Pilot had continuous yellow tipping.
		3	Long flame with continuous orange tipping. Pilot had continuous yellow tipping.
Baseline Gas	Normal and without delays	1	Soft flame with moderate orange tipping. Pilot had slight yellow tipping.
		2	Soft flame with moderate orange tipping. Pilot had slight yellow tipping.
		3	Soft flame with moderate orange tipping. Pilot had slight yellow tipping.
2	Normal and without delays	1	Long flame with low orange tipping. Pilot had slight yellow tipping.
		2	Long flame with low orange tipping. Pilot had slight yellow tipping.
		3	Long flame with low orange tipping. Pilot had slight yellow tipping.

Appendix A: Test Protocol

1. Standards

- ANSI Z21.86-2004
- South Coast Air Quality Management District-Instrumental Analyzer Procedure For Continuous Gaseous Emissions-District Method 100.1

2. Equipment Specifications

The floor furnace to be tested was recently removed from a single-family residence in Southern California. Little information is known about this furnace due to the absence of meaningful nameplate information. Experienced Southern California Gas Company service personnel estimate the age of the furnace to be approximately 80 years old.

- **Description:** Floor furnace with a 3-module heat exchanger (Manufactured approximately 1925)
- **Burner:** 2 porcelain-coated pressed steel atmospheric burners
- **Maximum input rating:** 32,000 Btu/hr
- **Minimum input rating:** 22,400 Btu/hr
- **Type of fuel:** Natural gas
- **Required gas supply pressure:** 4.5 to 7.0 in. w.c.

3. Test Arrangement

3.1. Basic Setup - The floor furnace will be tested inside the engineering test lab. It will be mounted in a special cradle designed to hold the unit in the same manner it would be when mounted in the floor of a home. The airflow paths for primary and secondary air will be sized adequately so that there is no restriction to flow. Various gaseous fuels will be supplied via appropriate piping pressure and pressure regulators.

The following is a description of the basic setup for the floor furnace test per ANSI Z21.86-2004, Section 10.7: "Four nominal 2 X 12 inch pine boards shall be placed on edge in close contact with the side of the appliance, with the register resting on top. When necessary, on of these joists may be notched just sufficiently to clear the draft hood and any draft hood shielding furnished as a part of the draft hood or appliance. A nominal 1-inch thick wooden board just sufficient in size to cover the area of the draft hood shall be attached horizontally to the joist so its lower surface is level with the lower surface of the joist above the draft hood. A platform extending 28 inches from each edge of the register shall be constructed around the appliance.When tests are conducted on floor-register type appliances, 2 walls, 3 feet high, fitted together to form a corner, shall be placed on this platform so each wall is 3 inches from adjacent sides of the register.

3.2. Electric Power - Electrical power will be supplied per the manufacturer's instructions.

3.3. Instrumentation - Instrumentation must be provided such that the operational, performance and safety characteristics of the furnace can be determined with considerable degree of engineering confidence and that no negative performance condition or factor goes undiscovered. The criteria called out in SCAQMD Protocol for rule 1146.2 should be followed if possible.

3.4. Vent pipe – The vent pipe must not restrict the flow of exhaust gases out of a floor furnace. If backpressure is being developed in the vent pipe, the pipe is too restrictive and should be enlarged. As a design parameter, floor furnace vent pipes should be designed to handle no more than about 3,800 Btu/hr/in^2. This means that for a furnace input rate of 50,000 Btu/hr the vent pipe should be, at least, 4 inches (12.57 in^2) in diameter. And if the floor furnace unit is rated up to 75,000 Btu/hr the vent pipe diameter should be increased to 5 inches (19.63 in^2).

4. Basic Operating Conditions

Unless otherwise specified by specific or unique test requirements, the following are to apply:

4.1. Ambient Temperature - Ambient temperature will be between 75°F and 85°F.

4.2. Appliance Operating Pressures - Manifold pressure: Measured in the gas piping system upstream of the burner and downstream of the gas control valve. The gas piping of this floor furnace required that the manifold pressure be measured upstream of the gas control valve and downstream of the gas regulator. Supply pressure: Measured immediately upstream of the gas regulator valve. Line pressure should be 8.0 ± 0.3" w.c.

4.3. Basic Firing Setup - Locate the floor furnace in a test frame that simulates correct floor installation and provides fresh air for combustion. Recirculation of combustion gases must not be permitted. Therefore, a draft hood should be attached and the vent pipe connected in compliance to applicable codes. Select an appropriate location for the thermostat. Plus, checking and adjusting the floor furnace for safe and efficient operation.

4.4. Venting of Combustion Gases - A draft hood must be installed on the unit. One square inch of flue vent area must be provided for each 3,800 Btu/hr of gas input into the unit. The vent pipe will be the same size as the outlet of the draft hood and should not run more than 15 ft horizontally. The horizontal section of the vent pipe should slope upward away from the furnace at a rate of at least ¼ inch per foot of length. The horizontal run of the vent pipe (including the draft hood) must not be more than 75% of the vertical vent pipe. For example, a 15 ft horizontal run would require a 20 ft vertical stack to create adequate draft. In actual installations, single walled vent pipe is never allowed, but will be permissible for testing.

4.5. Combustion and Furnace Makeup Air - There must be 1 in^2 of free ventilation area for each 1,000 Btu/hr that the unit is rated for (i.e. 50 in^2 of ventilation area for an input rating of 50,000 Btu/hr). Recirculation of combustion gases and products into the inlet air must be prohibited.

4.6. Support of Unit - The furnace should be supported evenly by the flange at the top of the outer casing. If not evenly supported on all four sides, stresses may be created that would lead to excessive noise during heating and cooling. Make sure that the grill is level during all operations and tests.

4.7. Combustion - A floor furnace shall not produce carbon monoxide in excess of 0.04 percent in an air-free sample of the flue gases when the appliance is tested in an atmosphere having approximately a normal oxygen supply (ANSI Z21.86-2004 Section 10.3).

4.8. Allowable Air Temperature - A floor furnace shall not discharge air at a temperature in excess of 280°F above room temperature (ANSI Z21.86-2004 Section 10.5).

4.9. Allowable Register Temperatures - The temperature on the surface of a horizontal floor furnace register shall not be greater than 160°F above room temperature (ANSI Z21.86-2004 Section 10.6).

4.10. Wall and Floor Temperatures - The temperature of combustible construction in contact with or adjacent to the side and register of a floor furnace shall not exceed 117°F above room temperature. The temperature of combustible construction in contact with or adjacent to the interior sides of the appliance shall not exceed 90°F above room temperature (ANSI Z21.86-2004 Section 10.7).

4.11. Flue Gas Temperature - The average temperature of the flue gases from a floor furnace shall not exceed 480°F above room temperature (ANSI Z21.86-2004 Section 10.8).

4.12. Allowable Heating Element and Load-Bearing Flue Gas Baffle Temperatures - From a cold start, all parts of the heating element in contact with flue gases shall attain a temperature of 150°F in less than 18 minutes. No external surface of the heating element or load-bearing flue gas baffle shall exceed the temperature rise of 1,030°F above room temperature (ANSI Z21.86-2004 Section 10.12).

5. Test Gases

The following gases will be utilized during testing and their composition details are specified in Appendix B of the Phase II Scope of Work:

- **Baseline Gas** (Gas 1) - Low Wobbe (1,330 Btu/cf), low heat content gas (1,017 Btu/hr)
- **Gas 2** - Lowest-Wobbe (1,269 Btu/cf), lowest-heat content gas (974 Btu/cf)
- **Gas 3** - Highest-Wobbe (1,436 Btu/cf), highest-heat content gas (1,152 Btu/cf)
- **Gas 4** - Medium-Wobbe (1,370 Btu/cf), highest-heat content gas (1,145 Btu/cf)
- **Gas 4A** (4 component mix) - Medium-Wobbe (1,371 Btu/cf), highest-heat content gas (1,148 Btu/cf)
- **Gas 5** - Medium-Wobbe (1,374 Btu/cf), high-heat content gas (1,099 Btu/cf)
- **Gas 5A** (4 component mix) - Medium-Wobbe (1,374 Btu/cf), high-heat content gas (1,100 Btu/cf)
- **Gas 6** - High Wobbe (1.413 Btu/cf), high-heat content gas (1,107 Btu/cf)

6. Testing

6.1. As Received Test

Using Baseline Gas, adjust the inlet pressure to 7.5" w.c. then allow the floor furnace to "warm-up" for at least 60 minutes. During this time, emissions, temperature and pressure data will be monitored. After "warm-up" and once steady-state conditions are achieved, begin testing and record temperature, pressure and emissions data. Unless otherwise specified, each run of Baseline Gas will be 20 minutes and Substitute Gases will be 15 minutes. Also, manual switching between test gases should take approximately 14 seconds.

Continue steady-state floor furnace operation with Baseline Gas and then conduct a high-speed switch to Gas 2. Continue data acquisition (per above) while operating with Gas 2, observing changes in data before, during, and after changeover.

Continue steady-state floor furnace operation with Gas 2 and then conduct a high-speed switch to Gas 3. Continue data acquisition (per above) while operating with Gas 3, observing changes in data before, during, and after changeover.

Continue steady-state floor furnace operation with Gas 3 and then conduct a high-speed switch to re-establish Baseline Gas. If operational and/or safety problems were encountered while testing with Gases 2 & 3, all other Substitute Gases will be tested immediately after the 2nd Baseline Gas run in the following order:

- Switch to Gas 4 and run unit for 15 minutes.
- Switch to Gas 4A and run unit for 15 minutes.
- Reestablish Baseline Gas and run unit for 20 minutes.
- Switch to Gas 5 and run unit for 15 minutes.
- Switch to Gas 5A and run unit for 15 minutes.
- Reestablish Baseline Gas and run unit for 20 minutes.
- Switch to Gas 6 and run unit for 15 minutes.
- Conclude testing by reestablishing Baseline Gas and run unit for 20 minutes.

This test is conducted with exhaust duct constructed to comply with ANSI Z21.86-2004. (**NOTE:** Air adjustment on the floor furnace may have accidentally changed during the process of removal and transfer from the residential site to the test chamber).

6.2. Rated Input Test

Using Baseline Gas, adjust the inlet pressure to 7.5" w.c. and the manifold pressure to 4" w.c.. Allow the floor furnace to "warm-up" for at least 60 minutes. During this time, emissions, temperature and pressure data will be monitored. After "warm-up" and once steady-state conditions are achieved, begin testing and record temperature, pressure, and emissions data. Unless otherwise specified, each run of Baseline Gas will be 20 minutes and Substitute Gases will be 15 minutes. Also, manual switching between test gases should take approximately 14 seconds.

Continue steady-state floor furnace operation with Baseline Gas and then conduct a high-speed switch to Gas 2. Continue data acquisition (per above) while operating with Gas 2, observing changes in data before, during, and after changeover.

Continue steady-state floor furnace operation with Gas 2 and then conduct a high-speed switch to Gas 3. Continue data acquisition (per above) while operating with Gas 3, observing changes in data before, during, and after changeover.

Continue steady-state floor furnace operation with Gas 3 and then conduct a high-speed switch to reestablish Baseline Gas. Continue data acquisition (per above) while operating with Baseline Gas, observing changes in data before, during, and after changeover.

The remaining Substitute Gases will be tested in the following order:

- Switch to Gas 4 and run unit for 15 minutes.
- Switch to Gas 4A and run unit for 15 minutes.
- Reestablish Baseline Gas and run unit for 20 minutes.
- Switch to Gas 5 and run unit for 15 minutes.
- Switch to Gas 5A and run unit for least 15 minutes.
- Reestablish Baseline Gas and run unit for least 20 minutes.
- Switch to Gas 6 and run unit for 15 minutes.
- Conclude testing with Baseline Gas and run unit for 20 minutes.

This test is conducted with exhaust duct constructed to comply with ANSI Z21.86-2004.

6.3. Inlet Pressure Test

Using Baseline Gas, allow the floor furnace to “warm-up” for at least 60 minutes at Normal Inlet Pressure. During this time, emissions, temperature and pressure data will be monitored. After “warm-up,” adjust the inlet pressure to Minimum Inlet Pressure (4.5” w.c.). Once steady-state conditions are achieved, begin testing and record temperature, pressure, and emissions data. Unless otherwise specified, each run of Baseline Gas will be 20 minutes and Substitute Gases will be 15 minutes. Also, manual switching between test gases should take approximately 14 seconds.

Continue steady-state floor furnace operation at Minimum Inlet Pressure with Baseline Gas and then conduct a high-speed switch to Gas 2. Continue data acquisition (per above) while operating with Gas 2, observing changes in data before, during, and after changeover.

Continue steady-state floor furnace operation at Minimum Inlet Pressure with Gas 2 and then conduct a high-speed switch to Gas 3. Continue data acquisition (per above) while operating with Gas 3, observing changes in data before, during, and after changeover.

Continue steady-state floor furnace operation at Minimum Inlet Pressure with Gas 3 and then conduct a high-speed switch to reestablish Baseline Gas. Continue data acquisition (per above) while operating with Baseline Gas, observing changes in data before, during, and after changeover.

Once testing at minimum inlet pressure has been concluded, increase the inlet pressure to (10.5" w.c.) and observe the manifold pressure. If the manifold pressure at Increased Inlet Pressure is not greater than the manifold pressure at Normal Inlet Pressure, tests at the increased inlet test pressure need not be conducted. On the other hand, if the manifold pressure increases, then continue the test per the following steps:

- Begin testing at Increased Inlet Pressure with Baseline Gas for 20 minutes.
- Switch to Gas 2 and run unit for 15 minutes.
- Switch to Gas 3 and run unit for 15 minutes.
- Conclude testing by reestablishing Baseline Gas and run unit for 20 minutes.

This test is conducted with exhaust duct constructed to comply with ANSI Z21.86-2004. Warm up unit with Baseline Gas for at least 60 minutes.

6.4. Air Shutter Fully Closed Test

Using Baseline Gas, adjust the inlet pressure to 7.5" w.c. and close the air shutter completely. Allow the floor furnace to "warm-up" for at least 60 minutes. During this time, emissions, temperature and pressure data will be monitored. After "warm-up" and once steady-state conditions are achieved, begin testing and record temperature, pressure, and emissions data. Unless otherwise specified, each run of Baseline Gas will be 20 minutes and Substitute Gases will be 15 minutes. Also, manual switching between test gases should take approximately 14 seconds.

Continue steady-state floor furnace operation with Baseline Gas and then conduct a high-speed switch to Gas 2. Continue data acquisition (per above) while operating with Gas 2, observing changes in data before, during, and after changeover.

Continue steady-state floor furnace operation with Gas 2 and then conduct a high-speed switch to Gas 3. Continue data acquisition (per above) while operating with Gas 3, observing changes in data before, during, and after changeover.

Continue steady-state floor furnace operation with Gas 3 and then conduct a high-speed switch to re-establish Baseline Gas. If operational and/or safety problems were encountered while testing with Gases 2 & 3, all other Substitute Gases will be tested immediately after the 2nd Baseline Gas run in the following order:

- Switch to Gas 4 and run unit for 15 minutes.
- Switch to Gas 4A and run unit for 15 minutes.
- Reestablish Baseline Gas and run unit for 20 minutes.

- Switch to Gas 5 and run unit for 15 minutes.
- Switch to Gas 5A and run unit for 15 minutes.
- Reestablish Baseline Gas and run unit for 20 minutes.
- Switch to Gas 6 and run unit for 15 minutes.
- Conclude testing by reestablishing Baseline Gas and run unit for 20 minutes.

This test is conducted with exhaust duct constructed to comply with ANSI Z21.86-2004.

6.5. Cold Ignition Test

Adjusted the floor furnace to normal inlet pressure. Using Baseline Gas, ignite the floor furnace from a cold start and operated for one minute. Document visual observations of the flame, ignition delays and other phenomena. Repeat this process 2 more times, allowing the floor furnace to reestablish cold start conditions in between each ignition.

Then purge the gas delivery system of Baseline Gas with Gas 3. Using Gas 3, ignite the floor furnace from a cold start and operated for one minute. Document visual observations of the flame, ignition delays and other phenomena. Repeat this process 2 more times, allowing the floor furnace to reestablish cold start conditions in between each ignition.

Then purge the gas delivery system of Gas 3 with Baseline Gas. Using Baseline Gas, ignite the floor furnace from a cold start and operated for one minute. Document visual observations of the flame, ignition delays and other phenomena. Repeat this process 2 more times, allowing the floor furnace to reestablish cold start conditions in between each ignition.

Then purge the gas delivery system of Baseline Gas with Gas 2. Using Gas 2, ignite the floor furnace from a cold start and operated for one minute. Document visual observations of the flame, ignition delays and other phenomena. Repeat this process 2 more times, allowing the floor furnace to reestablish cold start conditions in between each ignition.

7. Additional Testing

Conduct additional testing and/or testing with other gas blends, per the Phase II protocol, when test results or observations indicate it is necessary. If indicated additional testing is outside of the project scope, include appropriate comment in the test report.

8. Calculations

CO, HC & NO_X emissions values are to be calculated/corrected per the AQMD protocol for Rule 1121. Other calculations are to be per standard practice.

9. Measurement

The following test measurements will be taken:

- Gas Delivery System Parameters (Temperatures & Pressures)
- Supply & Manifold Pressure
- Fuel Gas Temperature
- Ambient Temperature
- Combustion Chamber Temperature
- Flue Temperature
- Joist Temperatures (4 Thermocouples)
- Discharge Temperatures (6 Thermocouples)
- Register Temperatures (4 Thermocouples)
- Inlet Air Temperature
- Fire Box Temperatures (High & Low)
- Wall Temperature (2 Thermocouples)
- Burner Body Temperature

Rationale

Test Method Difference from ANSI Z21.86-2004 Section 10.6

ANSI requires one thermocouple to be attached to the register for each 10 in^2 of register surface area. The dimensions of the floor furnace register are 18 inch by 30 inch. So the surface area of the register is 540 in^2. ANSI requires the installation of 54 thermocouples for this size of register. Fewer temperature measurements will be taken then recommended by ANSI due to equipment limitations. Consequently, four thermocouples will be attached to the furnace register to measure the surface temperature.

Test Method Difference from ANSI Z21.86-2004 Section 10.7

ANSI requires thermocouples to be located at 6-inch horizontal intervals. The linear dimensions of the combustible construction in contact with the floor furnace are equal to 96 linear inches (18+18+30+30). ANSI requires the installation of 16 (96/6) thermocouples for linear dimensions of this size. Fewer temperature measurements will be taken then recommended by ANSI due to equipment limitations. Consequently, four thermocouples will be attached to measure the temperature of combustible construction in contact with the floor furnace. Also, two thermocouples will be attached to measure temperature near the walls.

Appendix B: Table of Averages

As Received Test

Table of Averages Legacy Floor Furance As Received Test (7.5" w.c.) November 29, 2004				
Gases	**Base**	**2**	**3**	**Base**
HHV (Btu/cf)	1,002	974	1,144	1,002
Wobbe (Btu/cf)	1,303	1,269	1,431	1,303
Input Rate (Btu/hr)	32,011	31,158	35,812	31,875
Corrected SCFH	31.9	32.0	31.3	31.9
Emissions (not from certified tests)				
Raw O_2 (%)	17.1	17.2	16.7	17.1
Raw CO_2 (%)	2.3	2.3	2.6	2.4
CO (ppm @ 0% O_2)	2.9	2.3	2.0	2.8
HC (ppm @ 0% O_2)	70.5	28.0	81.7	49.0
NO_X (ppm @ 0% O_2)	141.2	136.7	145.3	146.0
Ultimate CO_2 (%)	12.9	12.9	13.0	12.9
Equivalence Ratio (Φ)	0.2	0.2	0.2	0.2
Temperatures (°F)				
Ambient	76.1	76.4	76.4	76.6
Gas	77.0	77.2	77.3	77.6
Stack	221.1	222.2	228.4	225.8
Inlet Air	77.6	77.8	78.0	78.3
Discharge Air 1	295.5	294.9	305.7	303.8
Discharge Air 2	249.1	240.3	220.5	219.6
Discharge Air 3	235.9	250.9	260.9	257.3
Discharge Air 4	207.1	203.8	239.9	234.5
Discharge Air 5	174.6	167.0	151.6	153.8
Discharge Air 6	194.8	172.4	167.6	172.3
Joist 1	118.9	118.0	118.3	120.2
Joist 2	154.1	154.2	152.2	152.0
Joist 3	126.3	125.1	125.2	126.4
Joist 4	172.9	171.3	171.3	174.3
Register 1	281.0	289.4	294.9	290.3
Register 2	259.1	238.9	226.2	230.8
Register 3	294.9	285.9	297.3	297.1
Register 4	309.0	304.7	327.1	322.3
Burner Body	339.7	334.1	349.1	345.1
FirBox High	461.4	444.7	458.1	447.7
FirBox Low	231.2	230.5	237.4	233.7
Wall 1	111.0	110.6	112.8	114.7
Wall 2	110.3	111.2	109.1	109.1
Combustion Chamber	1,090	1,076	1,137	1,098
Pressures				
Supply (in. w.c.)	7.5	7.5	7.5	7.5
Manifold (in. w.c.)	3.7	3.7	3.7	3.7

Rated Input

Table of Averages Legacy Floor Furance Rated Input Test (~32,000 Btu/hr and 7.5" w.c.) November 29, 2004												
Gases	**Base**	**2**	**3**	**Base**	**4**	**4A**	**Base**	**5**	**5A**	**Base**	**6**	**Base**
HHV (Btu/cf)	1,002	974	1,144	1,002	1,145	1,148	1,002	1,099	1,094	1,002	1,107	1,002
Wobbe (Btu/cf)	1,303	1,269	1,431	1,303	1,370	1,371	1,303	1,374	1,370	1,303	1,413	1,303
Input Rate (Btu/hr)	33,177	32,247	37,163	32,889	35,914	35,329	32,398	35,545	35,045	33,024	36,397	33,154
Corrected SCFH	33.1	33.2	32.3	32.8	31.2	30.9	32.4	32.3	32.0	33.0	32.9	33.2
Emissions (not from certified tests)												
Raw O_2 (%)	16.8	16.8	16.4	16.7	16.5	16.6	16.8	16.6	16.6	16.9	16.5	16.8
Raw CO_2 (%)	2.5	2.4	2.7	2.5	2.7	2.7	2.5	2.6	2.6	2.4	2.6	2.4
CO (ppm @ 0% O_2)	4.3	7.4	3.5	2.6	0.3	0.6	1.9	1.3	2.5	2.5	2.0	2.2
HC (ppm @ 0% O_2)	121.9	317.5	465.5	183.0	73.3	48.6	57.1	39.7	114.4	68.1	26.6	18.0
NO_X (ppm @ 0% O_2)	137.6	134.3	140.1	141.6	144.7	146.0	144.9	144.7	146.7	145.7	147.5	145.2
Ultimate CO_2 (%)	12.4	12.5	12.5	12.4	12.8	13.0	12.6	12.7	12.8	12.6	12.6	12.5
Equivalence Ratio (Φ)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Temperatures (°F)												
Ambient	75.2	75.9	76.3	77.0	75.4	74.2	74.4	74.3	74.2	74.2	74.1	74.2
Gas	73.6	74.3	74.7	75.5	76.3	75.5	75.5	75.6	75.5	75.6	75.7	75.8
Stack	224.9	223.9	227.6	227.8	226.9	227.7	226.1	226.7	227.9	228.4	228.7	227.3
Inlet Air	76.3	76.8	77.1	78.0	76.6	75.9	76.0	76.0	76.0	76.1	76.1	76.3
Discharge Air 1	274.8	276.7	279.8	286.7	295.9	300.0	299.0	296.8	297.0	277.4	303.8	305.6
Discharge Air 2	301.9	297.2	309.0	305.8	272.3	289.2	268.9	248.4	255.7	233.0	240.1	218.5
Discharge Air 3	153.1	168.6	154.2	192.6	250.4	269.2	263.0	272.6	273.2	286.9	274.5	250.1
Discharge Air 4	163.8	163.9	169.2	172.1	196.9	180.3	186.7	196.0	196.5	196.8	214.7	263.8
Discharge Air 5	280.5	279.7	286.9	271.9	189.2	176.4	159.7	147.7	151.5	137.7	144.9	163.0
Discharge Air 6	228.8	223.6	234.4	217.7	194.9	209.7	196.1	186.5	195.1	163.7	174.9	168.1
Joist 1	112.2	114.1	115.3	118.0	118.7	119.7	120.7	120.6	121.3	121.7	121.8	121.6
Joist 2	141.6	145.2	146.7	152.0	154.0	161.5	166.1	167.5	167.2	174.2	172.7	164.3
Joist 3	121.4	124.0	125.5	128.7	128.5	128.0	126.7	125.2	125.7	124.9	123.8	126.3
Joist 4	161.1	162.0	162.8	166.7	169.6	175.5	177.5	176.6	178.3	177.0	175.1	174.8
Register 1	269.5	272.6	274.3	287.9	297.0	310.0	304.7	307.0	310.7	309.5	305.7	287.3
Register 2	359.6	357.6	366.5	350.8	274.4	283.3	260.1	242.2	254.5	226.1	236.2	238.5
Register 3	286.1	279.6	293.9	305.9	321.0	286.7	277.2	277.9	284.2	265.9	289.8	317.8
Register 4	33.1	33.2	32.3	32.8	31.2	30.9	32.4	32.3	32.0	33.0	32.9	33.2
Burner Body	283.6	282.1	288.7	292.9	310.0	311.6	310.2	315.2	318.6	307.4	322.2	334.7
FirBox High	473.4	473.6	492.8	490.3	486.4	489.4	473.7	470.3	479.3	456.8	470.9	456.9
FirBox Low	294.2	292.4	296.7	296.7	294.1	297.5	291.9	288.4	284.0	283.2	268.1	250.1
Wall 1	98.8	99.7	100.1	102.4	106.5	109.3	110.5	110.9	112.0	110.1	110.3	112.4
Wall 2	109.8	111.1	111.3	113.7	111.8	115.2	114.5	112.7	113.6	112.3	111.3	107.4
Combustion Chamber	1,114	1,104	1,154	1,123	1,140	1,149	1,123	1,141	1,147	1,119	1,154	1,119
Pressures												
Supply (in. w.c.)	7.5	7.5	7.5	7.5	7.5	7.5	7.4	7.4	7.5	7.5	7.4	7.4
Manifold (in. w.c.)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

Inlet Pressure Test (4.5” w.c.)

Table of Averages Legacy Floor Furance Inlet Pressure Test (4.5" w.c.) November 30, 2004				
Gases	**Base**	**2**	**3**	**Base**
HHV (Btu/cf)	1,002	974	1,144	1,002
Wobbe (Btu/cf)	1,303	1,269	1,431	1,303
Input Rate (Btu/hr)	31,738	31,063	35,698	31,810
Corrected SCFH	31.8	31.9	31.1	31.7
Emissions (not from certified tests)				
Raw O_2 (%)	16.9	17.0	16.6	17.0
Raw CO_2 (%)	2.3	2.3	2.5	2.3
CO (ppm @ 0% O_2)	2.5	2.7	1.9	2.6
HC (ppm @ 0% O_2)	35.4	50.4	73.2	37.9
NO_X (ppm @ 0% O_2)	134.8	133.9	140.0	140.1
Ultimate CO_2 (%)	12.2	12.3	12.3	12.2
Equivalence Ratio (Φ)	0.2	0.2	0.2	0.2
Temperatures (°F)				
Ambient	74.1	74.1	74.1	74.1
Gas	75.0	75.2	75.4	75.6
Stack	219.9	218.7	223.0	221.1
Inlet Air	75.7	75.8	75.7	76.1
Discharge Air 1	272.9	285.3	282.1	287.2
Discharge Air 2	289.6	262.0	271.9	264.1
Discharge Air 3	236.0	239.0	267.7	260.9
Discharge Air 4	157.7	171.8	176.6	182.1
Discharge Air 5	206.6	183.0	162.8	163.8
Discharge Air 6	218.7	206.2	199.0	198.3
Joist 1	116.0	116.4	116.7	119.0
Joist 2	158.8	157.2	156.8	160.9
Joist 3	119.5	120.3	119.9	120.9
Joist 4	170.8	169.4	171.0	-401.8
Register 1	283.7	286.8	302.4	302.1
Register 2	297.0	272.5	262.1	259.2
Register 3	270.4	275.2	262.2	269.3
Register 4	283.9	291.1	301.2	301.9
Burner Body	340.5	337.4	347.7	344.7
FirBox High	468.3	460.1	473.2	466.9
FirBox Low	265.5	257.9	263.0	276.0
Wall 1	105.6	105.3	107.5	108.2
Wall 2	111.8	110.8	112.2	112.6
Combustion Chamber	1,091	1,084	1,137	1,098
Pressures				
Supply (in. w.c.)	4.5	4.5	4.5	4.5
Manifold (in. w.c.)	3.7	3.7	3.7	3.7

Air Shutter Fully Closed

Table of Averages Legacy Floor Furance Air Shutter Fully Closed Test (7.5" w.c.) November 30, 2004				
Gases	**Base**	**3**	**2**	**Base**
HHV (Btu/cf)	1,002	1,144	974	1,002
Wobbe (Btu/cf)	1,303	1,431	1,269	1,303
Input Rate (Btu/hr)	33,377	37,429	32,067	33,394
Corrected SCFH	33.3	32.7	32.9	33.3
Emissions (not from certified tests)				
Raw O_2 (%)	16.7	16.3	16.7	16.7
Raw CO_2 (%)	2.4	2.7	2.4	2.4
CO (ppm @ 0% O_2)	2.9	2.2	3.7	4.1
HC (ppm @ 0% O_2)	19.1	39.0	88.6	36.2
NO_X (ppm @ 0% O_2)	113.8	115.8	111.0	112.5
Ultimate CO_2 (%)	11.9	12.1	12.0	12.1
Equivalence Ratio (Φ)	0.2	0.2	0.2	0.2
Temperatures (°F)				
Ambient	76.6	76.8	77.0	77.4
Gas	77.8	78.0	78.3	78.6
Stack	220.0	223.3	222.6	218.9
Inlet Air	78.7	78.8	79.2	79.3
Discharge Air 1	298.1	311.6	306.0	305.3
Discharge Air 2	260.3	259.7	265.2	251.2
Discharge Air 3	239.3	261.1	257.7	248.1
Discharge Air 4	201.4	207.5	199.3	208.6
Discharge Air 5	198.9	174.4	177.9	179.9
Discharge Air 6	190.2	182.1	189.8	176.7
Joist 1	118.8	119.6	122.4	121.2
Joist 2	151.5	152.6	158.3	155.1
Joist 3	124.0	126.6	127.8	128.3
Joist 4	175.0	177.7	181.5	177.1
Register 1	287.3	303.2	302.0	291.2
Register 2	274.6	261.5	266.5	260.0
Register 3	304.1	301.1	294.1	310.2
Register 4	313.9	327.0	322.4	318.8
Burner Body	361.8	379.0	375.6	366.8
FirBox High	482.7	493.9	486.5	486.1
FirBox Low	243.1	244.2	252.9	230.6
Wall 1	111.5	113.2	114.5	113.5
Wall 2	112.7	114.4	115.6	113.7
Combustion Chamber	1,143	1,197	1,153	1,147
Pressures				
Supply (in. w.c.)	7.5	7.5	7.5	7.5
Manifold (in. w.c.)	4.0	4.0	4.0	4.0

Appendix C: Test Gases

Gas Analysis	Gas BASELINE	Gas 2	Gas 3	Gas 4	Gas 4A	Gas 5	Gas 5A	Gas 6
SAMPLE DATE	9/14/04	8/5/04	11/23/04	8/5/04	7/27/04	8/18/04	7/19/04	8/7/04
COMPONENTS	**MolPct**	**MolPct**	**MolPct**	**MolPct**	**MolPct**	**MolPct**	**MolPct**	**MolPct**
C6 + 57/28/14	0.0237	0.0307	0.0363	0.1858	0.0406	0.0737	0.0435	0.0000
NITROGEN	1.7762	1.0866	0.0841	1.0608	1.0782	0.8003	0.7777	0.0000
METHANE	94.4210	95.8713	87.5595	84.9713	84.3951	88.8139	90.8094	91.6800
CARBON DIOXIDE	1.3219	2.9973	0.0000	3.0005	3.0516	1.4074	1.4130	0.0000
ETHANE	1.6841	0.0000	8.7838	4.7846	0.0220	5.2987	0.0230	5.5300
PROPANE	0.3253	0.0141	2.5421	2.4015	11.3998	2.6048	6.9175	1.7500
i-BUTANE	0.0569	0.0000	0.9941	1.1936	0.0094	0.0022	0.0113	0.5200
n-BUTANE	0.0562	0.0000	0.0000	1.2074	0.0033	0.8424	0.0046	0.5200
NEOPENTANE	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-PENTANE	0.0176	0.0000	0.0000	0.5944	0.0000	0.1567	0.0000	0.0000
n-PENTANE	0.0122	0.0000	0.0000	0.6001	0.0000	0.0000	0.0000	0.0000
OXYGEN	0.3050	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TOTAL	**100.0001**	**100.0000**	**99.9999**	**100.0000**	**100.0000**	**100.000**	**100.0000**	**100.0000**
Compressibility Factor	0.997	0.998	0.997	0.996	0.997	0.997	0.997	0.997
HHV (Btu/real cubic foot)	**1002.1**	**974.45**	**1143.74**	**1145.1**	**1148.3**	**1099.4**	**1099.8**	**1107.1**
LHV (Btu/real cubic foot)	902.9	957.5	1123.83	1035.9	1039.5	993.1	993.6	999.8
Specific Gravity	0.5911	0.5893	0.6386	0.6989	0.7018	0.6407	0.641	0.6143
WOBBE Index	**1303.41**	**1269.38**	**1431.241**	**1369.73**	**1370.72**	**1373.50**	**1373.68**	**1412.53**

Appendix D: Zero, Span and Linearity Tables

November 29, 2004 (As Received Test)

	Zero, Span & Linearity Data As Received Test November 29, 2004	O_2 (%)	CO_2 (%)	CO (ppm)	HC (ppm)	NO_x (ppm)
	Analyzer Emission Ranges	**0 - 25**	**0 - 20**	**0 - 200**	**0 - 1000**	**0 - 100**
Zero	**Zero Calibration Gas (Low-Range Values)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Zero	**Allowable Zero Drift (Less Than ± 3% of Range)**	**0.75**	**0.60**	**6.00**	**30.00**	**3.00**
Zero	Zero Calibration - 1:29 PM	0.04	0.06	0.04	-0.62	0.05
Zero	Zero Drift Check - 3:16 PM	0.09	0.06	0.00	-0.25	0.09
Zero	**Total Drift Over Test Period**	**0.05**	**0.00**	**0.04**	**0.37**	**0.04**
Zero	**Was the Zero Drift Within Allowable Deviation?**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Span	**Span Calibration Gas (High-Range Values)**	**20.90**	**12.20**	**182.40**	**434.00**	**42.86**
Span	**Allowable Span Drift (Less Than ± 3% of Range)**	**0.75**	**0.60**	**6.00**	**30.00**	**3.00**
Span	Span Calibration - 1:34 PM	20.90	12.06	182.1	442.84	84.36
Span	Span Drift Check - 3:22 PM	20.92	12.05	182.16	442.87	84.36
Span	**Total Drift Over Test Period**	**0.02**	**0.01**	**0.06**	**0.03**	**0.00**
Span	**Was the Span Drift Within Allowable Deviation?**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Linearity	**Linearity Calibration Gas (Mid-Range Values)**	**9.03**	**8.00**	**79.50**	**217.00**	**17.80**
Linearity	**Allowable Linearity Drift (Less Than ±1% of Range)**	**0.25**	**0.20**	**2.00**	**10.00**	**1.00**
Linearity	Linearity Check - 1:38 PM	9.13	8.03	78.61	N/A	18.01
Linearity	**Difference From Mid-Range Values**	**0.10**	**0.03**	**0.89**	N/A	**0.21**
Linearity	**Was the Linearity Within Allowable Deviation?**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**
Linearity	Linearity Check - 3:25 PM	9.00	8.03	78.73	N/A	18.02
Linearity	**Difference From Mid-Range Values**	**0.03**	**0.03**	**0.77**	N/A	**0.22**
Linearity	**Was the Linearity Within Allowable Deviation?**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

November 29, 2004 (Rated Input Test)

	Zero, Span & Linearity Data Rated Input Test November 29, 2004	O_2 (%)	CO_2 (%)	CO (ppm)	HC (ppm)	NO_x (ppm)
	Analyzer Emission Ranges	**0 - 25**	**0 - 20**	**0 - 200**	**0 - 1000**	**0 - 100**
Zero	**Zero Calibration Gas (Low-Range Values)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Zero	**Allowable Zero Drift (Less Than ± 3% of Range)**	**0.75**	**0.60**	**6.00**	**30.00**	**3.00**
Zero	Zero Calibration - 1:29 PM	0.04	0.06	0.04	-0.62	0.05
Zero	Zero Drift Check - 3:16 PM	0.09	0.06	0.00	-0.25	0.09
Zero	**Total Drift Over Test Period**	**0.05**	**0.00**	**0.04**	**0.37**	**0.04**
Zero	**Was the Zero Drift Within Allowable Deviation?**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Span	**Span Calibration Gas (High-Range Values)**	**20.90**	**12.20**	**182.40**	**434.00**	**42.86**
Span	**Allowable Span Drift (Less Than ± 3% of Range)**	**0.75**	**0.60**	**6.00**	**30.00**	**3.00**
Span	Span Calibration - 1:34 PM	20.90	12.06	182.1	442.84	84.36
Span	Span Drift Check - 3:22 PM	20.92	12.05	182.16	442.87	84.36
Span	**Total Drift Over Test Period**	**0.02**	**0.01**	**0.06**	**0.03**	**0.00**
Span	**Was the Span Drift Within Allowable Deviation?**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Linearity	**Linearity Calibration Gas (Mid-Range Values)**	**9.03**	**8.00**	**79.50**	**217.00**	**17.80**
Linearity	**Allowable Linearity Drift (Less Than ±1% of Range)**	**0.25**	**0.20**	**2.00**	**10.00**	**1.00**
Linearity	Linearity Check - 1:38 PM	9.13	8.03	78.61	N/A	18.01
Linearity	**Difference From Mid-Range Values**	**0.10**	**0.03**	**0.89**	N/A	**0.21**
Linearity	**Was the Linearity Within Allowable Deviation?**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**
Linearity	Linearity Check - 3:25 PM	9.00	8.03	78.73	N/A	18.02
Linearity	**Difference From Mid-Range Values**	**0.03**	**0.03**	**0.77**	N/A	**0.22**
Linearity	**Was the Linearity Within Allowable Deviation?**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

November 30, 2004 (Inlet Pressure Test)

	Zero, Span & Linearity Data Inlet Pressure Test November 30, 2004	O_2 (%)	CO_2 (%)	CO (ppm)	HC (ppm)	NO_x (ppm)
	Analyzer Emission Ranges	**0 - 25**	**0 - 20**	**0 - 200**	**0 - 1000**	**0 - 100**
Zero	**Zero Calibration Gas (Low-Range Values)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Zero	**Allowable Zero Drift (Less Than ± 3% of Range)**	**0.75**	**0.60**	**6.00**	**30.00**	**3.00**
Zero	Zero Calibration - 10:50 AM	0.13	0.06	0.03	-0.36	-0.04
Zero	Zero Drift Check - 3:15 PM	0.06	0.06	-0.01	-0.67	0.01
Zero	**Total Drift Over Test Period**	**0.07**	**0.00**	**0.04**	**0.31**	**0.05**
Zero	**Was the Zero Drift Within Allowable Deviation?**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Span	**Span Calibration Gas (High-Range Values)**	**20.90**	**12.20**	**182.40**	**434.00**	**42.86**
Span	**Allowable Span Drift (Less Than ± 3% of Range)**	**0.75**	**0.60**	**6.00**	**30.00**	**3.00**
Span	Span Calibration - 10:55 AM	9.06	12.05	81.4	444.69	17.82
Span	Span Drift Check - 3:19 PM	20.92	12.04	182.56	443.36	84.71
Span	**Total Drift Over Test Period**	**11.86**	**0.01**	**101.16**	**1.33**	**66.89**
Span	**Was the Span Drift Within Allowable Deviation?**	**No**	**Yes**	**No**	**Yes**	**No**
Linearity	**Linearity Calibration Gas (Mid-Range Values)**	**9.03**	**8.00**	**79.50**	**217.00**	**17.80**
Linearity	**Allowable Linearity Drift (Less Than ±1% of Range)**	**0.25**	**0.20**	**2.00**	**10.00**	**1.00**
Linearity	Linearity Check - 3:22 PM	9.15	8.02	78.38	N/A	17.94
Linearity	**Difference From Mid-Range Values**	**0.12**	**0.02**	**1.12**	N/A	**0.14**
Linearity	**Was the Linearity Within Allowable Deviation?**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

November 30, 2004 (Air Shutter Fully Closed Test)

Zero, Span & Linearity Data
Air Shutter Fully Closed Test
November 30, 2004

		O_2 (%)	CO_2 (%)	CO (ppm)	HC (ppm)	NO_x (ppm)
	Analyzer Emission Ranges	**0 - 25**	**0 - 20**	**0 - 200**	**0 - 1000**	**0 - 100**
Zero	**Zero Calibration Gas (Low-Range Values)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Allowable Zero Drift (Less Than ± 3% of Range)	**0.75**	**0.60**	**6.00**	**30.00**	**3.00**
	Zero Calibration - 10:50 AM	0.13	0.06	0.03	-0.36	-0.04
	Zero Drift Check - 3:15 PM	0.06	0.06	-0.01	-0.67	0.01
	Total Drift Over Test Period	**0.07**	**0.00**	**0.04**	**0.31**	**0.05**
	Was the Zero Drift Within Allowable Deviation?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Span	**Span Calibration Gas (High-Range Values)**	**20.90**	**12.20**	**182.40**	**434.00**	**42.86**
	Allowable Span Drift (Less Than ± 3% of Range)	**0.75**	**0.60**	**6.00**	**30.00**	**3.00**
	Span Calibration - 10:55 AM	9.06	12.05	81.4	444.69	17.82
	Span Drift Check - 3:19 PM	20.92	12.04	182.56	443.36	84.71
	Total Drift Over Test Period	**11.86**	**0.01**	**101.16**	**1.33**	**66.89**
	Was the Span Drift Within Allowable Deviation?	**No**	**Yes**	**No**	**Yes**	**No**
Linearity	**Linearity Calibration Gas (Mid-Range Values)**	**9.03**	**8.00**	**79.50**	**217.00**	**17.80**
	Allowable Linearity Drift (Less Than ±1% of Range)	**0.25**	**0.20**	**2.00**	**10.00**	**1.00**
	Linearity Check - 3:22 PM	9.15	8.02	78.38	N/A	17.94
	Difference From Mid-Range Values	**0.12**	**0.02**	**1.12**	N/A	**0.14**
	Was the Linearity Within Allowable Deviation?	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Appendix E: Calculations

Emission Concentrations

Corrected to O_2 Standard (3% O_2)

$$\text{CO, HC \& NO}_x \text{ Concentrations (corrected to 3\% O}_2\text{)} = \text{Raw Concentrations (ppm)} \times \left[\frac{20.9 - 3}{20.9 - \%\,O_2}\right]$$

Where

Raw Concentration = Measured CO, HC & NO_x concentrations, by volume (ppm)

% O_2 = Measured O_2 Concentration

Ultimate CO_2

$$\text{Ult. CO}_2 = \text{Raw CO}_2 \times \left[\frac{20.9}{20.9 - \text{Raw O}_2}\right]$$

Where

Ult. CO_2 = Ultimate CO_2 (%)

Raw CO_2 = Measured CO_2 Concentration (%)

Raw O_2 = Measured O_2 Concentration (%)

% Excess Air

Constituent	Balanced Chemical Composition	Theo. Air	Theo. Flue Gas
Methane (CH_4)	$CH_4 + 2O_2 + 2(3.78)N_2$ ==> $1CO_2 + 2H_2O + 2(3.78)N_2$	9.56	8.56
Ethane (C_2H_6)	$C_2H_6 + 3.5O_2 + 3.5(3.78)N_2$ ==> $2CO_2 + 3H_2O + 3.5(3.78)N_2$	16.73	15.23
Propane (C_3H_8)	$C_3H_8 + 5O_2 + 5(3.78)N_2$ ==> $3CO_2 + 4H_2O + 5(3.78)N_2$	23.90	21.90
i-Butane (C_4H_{10})	$C_4H_{10} + 6.5O_2 + 6.5(3.78)N_2$ ==> $4CO_2 + 5H_2O + 6.5(3.78)N_2$	31.07	28.57
n-Butane (C_4H_{10})	$C_4H_{10} + 6.5O_2 + 6.5(3.78)N_2$ ==> $4CO_2 + 5H_2O + 6.5(3.78)N_2$	31.07	28.57
i-Pentane (C_5H_{12})	$C_5H_{12} + 8O_2 + 8(3.78)N_2$ ==> $5CO_2 + 6H_2O + 8(3.78)N_2$	38.24	35.24
n-Pentane (C_5H_{12})	$C_5H_{12} + 8O_2 + 8(3.78)N_2$ ==> $5CO_2 + 6H_2O + 8(3.78)N_2$	38.24	35.24
Hexanes (C_6H_{14})	$C_6H_{14} + 9.5O_2 + 9.5(3.78)N_2$ ==> $6CO_2 + 7H_2O + 9.5(3.78)N_2$	45.41	41.91

To determine the % Excess Air, the theoretical air and theoretical flue gas values for each gas tested must be calculated. The table above lists the constituents found in natural gas, the balanced chemical equations for each constituent and their respective theoretical air and theoretical flue gas values (expressed in moles).

The theoretical air value for each constituent is the sum of moles for both O_2 and N_2 on the reactants side of the balanced chemical equation (ex: For Methane, 2 moles of O_2 plus 7.56 moles of N_2 = 9.56 moles of Theoretical Air). The theoretical flue value for each constituent is the sum of moles for both CO_2 and N_2 on the product side of the balanced chemical equation (ex: For Methane, 1 mole of CO_2 plus 7.56 moles of N_2 = 8.56 moles of Theoretical Flue Gas).

Once the test gases have been analyzed (via gas chromatography), the % composition of each gas is used to determine the theoretical air and theoretical flue gas values for each gas tested. Thus,

$$\text{Theoretical Air} = \sum C_1P + C_2P + \ldots + C_nP$$

$$\text{Theoretical Flue} = \sum D_1P + D_2P + \ldots + D_nP$$

Where *C* is the theoretical air value for each constituent, *D* is the theoretical flue gas value for each constituent and *P* is the percent composition for each constituent (expressed as a decimal, not a percentage). Therefore, the % Excess Air is calculated as follows:

$$\%\,\text{Excess Air} = \left[\text{Theo. Flue Value} \times \frac{\text{Ult.}CO_2 - \text{Raw } CO_2}{\text{Theo. Air Value} \times \text{Raw } CO_2}\right] \times 100$$

Air/Fuel Ratio

$$\text{Air/Fuel Ratio} = \text{Theo. Air Value} + \frac{\text{Theo. Air Value} \times \%\,\text{Excess Air}}{100}$$

Equivalence Ratio (ϕ)

$$\text{Equivalence Ratio}\ (\phi) = \frac{100}{100 + \%\ \text{Excess Air}}$$

Gas Meter Correction

To determine the corrected SCFH for each appliance tested, the accuracy of the DTM-200A gas meter was checked to determine the correction factor for each meter (Table shown below).

Given the range of the input rate, the slope (m) of the line was determined setting y = average correction percentage and x = cubic feet per hour (cfh). Next, the y-intercept/correction factor (b) was determined using the y-intercept equation (y = mx + b). Once the correction factor (b) is known, the y-intercept equation was used again to calculate the corrected SCFH; this time x = uncorrected SCFH value.

Model Number: DTM-200A
Date: August 1, 2004
Meter Number: U258696
Prepared By: Joe Garcia
2 CU. FT. BELL NO. 4087
CPUC CERTIFICATE OF BELL PROVER ACCURACY # 1004

REPEATABILITY						
CFH	**% CORR.**	**% CORR.**	**% CORR.**	**% CORR.**	**% CORR.**	**Average**
50	0.78	0.67	0.48	0.58	0.53	**0.61**
100	0.57	0.58	0.66	0.72	0.66	**0.64**
150	0.85	0.84	0.95	1.18	1.11	**0.99**
200	0.78	1.03	0.90	0.87	0.88	**0.89**

Barometric Pressure Correction

Using the Standard Atmosphere Data for Altitudes to 60,000 ft Table (Table 3, *ASHRAE 1989 Fundamentals Handbook*, pg. 6.12), the barometric pressure at the test facility elevation was determined by linear interpolation. This value was subtracted from the barometric pressure value at sea level (29.921 in. Hg or 14.696 psia) to obtain the correction value. The correction value was subtracted from the barometric pressure reading specific to the hour and day of testing and then it was converted to absolute pressure (psia) using the following equation:

$$\text{Baro. Press (in.Hg)} \times \left[\frac{14.696\ \text{psia}}{29.921\ \text{in. Hg}}\right] = \text{Baro. Press(psia)}$$

SCFH (Uncorrected)

$$SCFH = ACFH \times \left[\frac{P_{Fuel}\,(psig) + P_{Barometric}\,(psia)}{P_{standard}}\right] \times \left[\frac{T_{standard}}{T_{Fuel}\,(^{o}F) + 459.67}\right]$$

Where

SCFH = Standard Cubic Feet per Hour (Uncorrected)

ACFH = Actual Cubic Feet per Hour

P_{Fuel} = Gas Supply Pressure (psig)

$P_{Barometric}$ = Barometric Pressure (psia)

$P_{standard}$ = Standard Pressure (14.696 psia)

$T_{standard}$ = Standard Temperature (519.67 R @ 1 atm)

T_{Fuel} = Fuel Temperature (°F)

SCFH (Corrected)

$$\text{Corrected SCFH} = \text{SCFH} + \text{Meter Correction Factor}$$

Input Rate (Btu/cf)

$$\text{Input Rate} = \text{Corrected SCFH} \times \text{HHV}$$

Where

HHV = Higher Heating Value (Btu/cf)

Wobbe Number (Btu/cf)

$$W_0 = \frac{HHV}{\sqrt{G}}$$

Where

W_0 = Wobbe Number (Btu/cf)

HHV = Higher Heating Value (Btu/cf)

G = Specific gravity of gas sample

Appendix F: Test Equipment

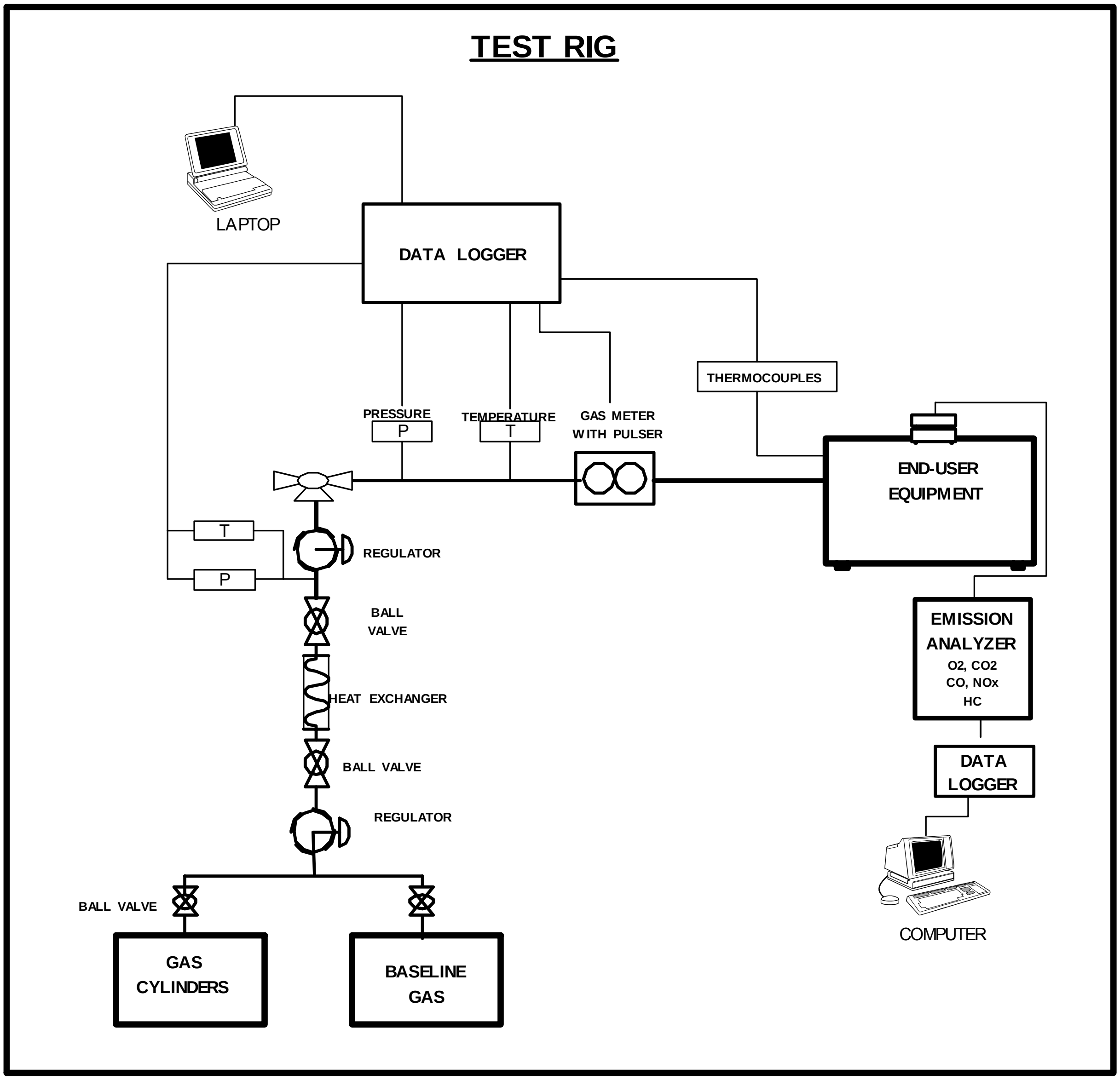
Emissions Analyzer				
Analyzer	**Manufacturer**	**Model**	**Type**	**Accuracy**
NO/NO_X	Thermo Environmental Instruments Inc.	10AR	Chemiluminescent	± 1% of full scale
CO	Thermo Environmental Instruments Inc.	48	Nondispersive infrared (NDIR) gas analyzer	± 1% of full scale
CO_2	Fuji	ZRH	Nondispersive infrared (NDIR) gas analyzer	± 1% of full scale
HC	California Analytical Instruments, Inc.	300 HFID	Flame ionization detector (FID)	± 1% of full scale
O_2	Teledyne	326RA	Electrochemical cell	± 1% of full scale

Calibration & Span Gases			
Gas	**Manufacturer**	**Type**	**Accuracy**
Calibration	Scott Specialty Gases	Certified Master Class - 0 %	± 2%
NO/NO_X	Scott Specialty Gases	Certified Master Class - 18.95 ppm	± 2%
CO	Scott Specialty Gases	Certified Master Class - 79.3 ppm	± 2%
CO_2	Scott Specialty Gases	Certified Master Class -12.1 %	± 2%
HC	Scott Specialty Gases	Certified Master Class - 0.5 ppm	± 2%
O_2	Scott Specialty Gases	Certified Master Class - 9.1 %	± 2%

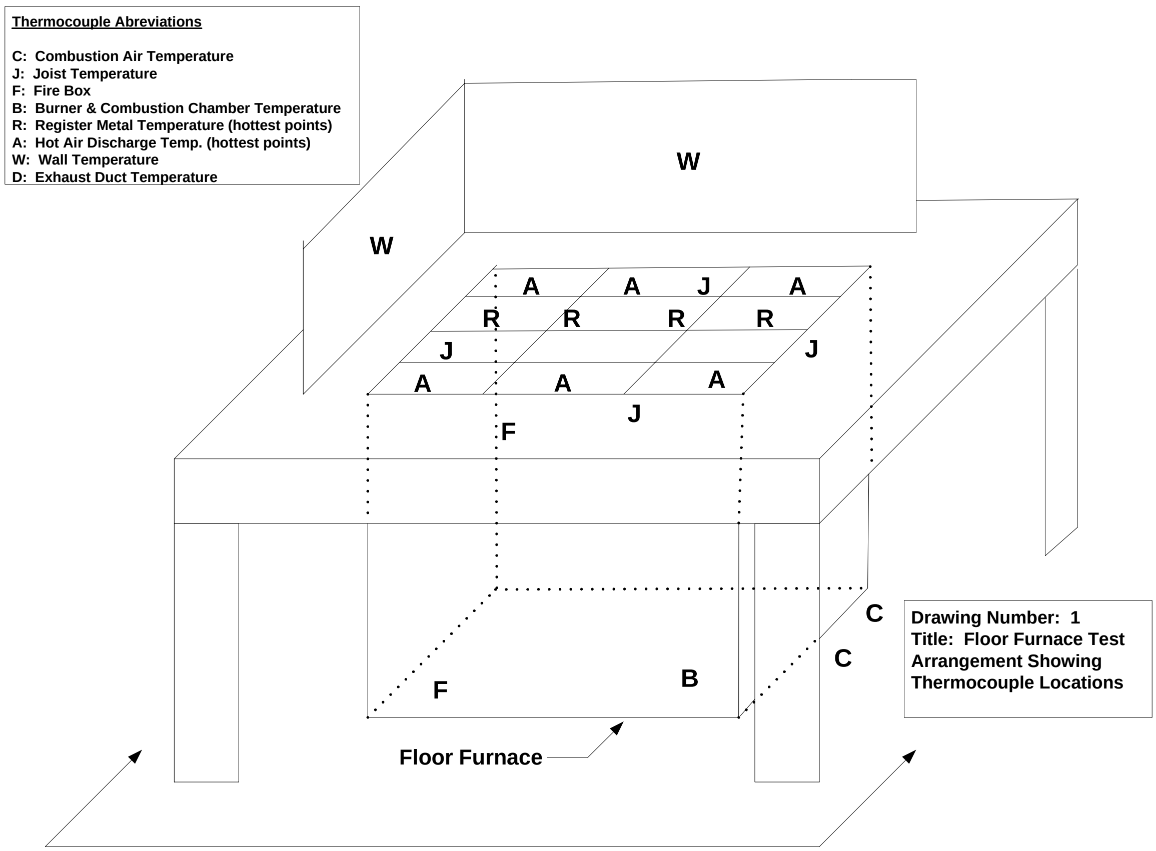
Test Equipment			
Equipment	**Manufacturer**	**Model**	**Accuracy**
Datalogger	Delphin	D51515	n/a
Gas Chromatigraph	Agilent	6890	± 0.5 BTU/scf
K	Omega Engineering Co.	KMQSS	2.2°C or 0.75%
J	Omega Engineering Co.	JMQSS	2.2°C or 0.75%
R	Omega Engineering Co.	RMQSS	2.2°C or 0.75%
T	Omega Engineering Co.	TMQSS	2.2°C or 0.75%
Dry Test Gas Meter 200 cf/h max	American Meter Company	DTM-200A	@ 200 cf/h – 100.1 % @60 cf/h – 99.9 %
Gas Meter Pulser 2 pulses per 1/10 cf	Rio Tronics	4008468	n/a
Gas Pressure Regulator	Fisher	299H	± 1.0 %
Differential Pressure Transmitter	Dwyer	607-4	±0.25 -0.50%
Pressure Transducer	Omega	PX205-100GI	±0.25% of full scale

Appendix G: Test Set-up/Schematic

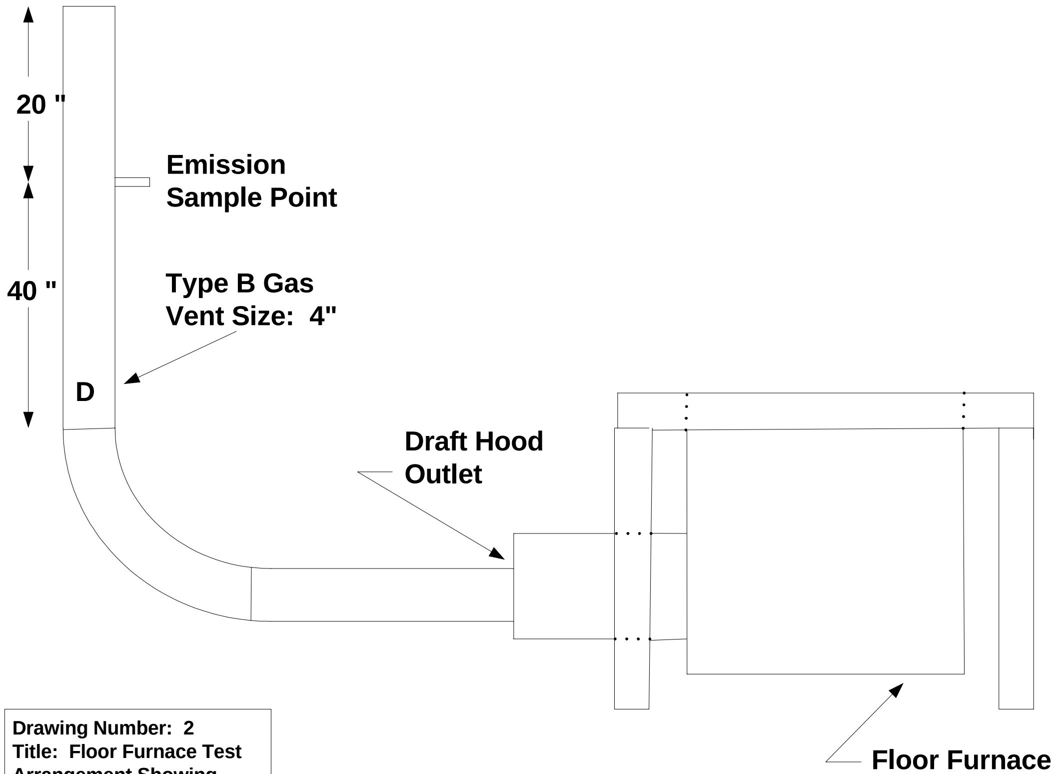
Equipment utilized for testing adheres to industry standards for testing laboratories that certify such equipment. The test rig is transportable and includes a data logger, emissions cart, gas meter, thermocouples and pressure transducers; plus, a gas regulation system that can take natural gas from 3,000 psig and deliver up to 2,000 cfh at low pressure (~8" w.c.). The test rig is illustrated below.



Appendix H: Equipment Set-up/Schematic



View 1



Drawing Number: 2
Title: Floor Furnace Test Arrangement Showing Exhaust Duct, View 1

View 1