

# VAMC BOILER PLANT SAFETY TESTING EVALUATION

VISN: 23

VAMC: Sioux Falls

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## 1. Introduction

This report details the results of the steam generation system safety device testing conducted over a span of three days at Sioux Falls VAMC in VISN 23. Under contract with the Department of Veterans Affairs, the Boiler Efficiency Institute evaluated the major boiler plant safety devices serving the entire plant and those safety devices serving one of the boilers at the facility. The references for the testing include:

- VHA Boiler Plant Safety Device Testing Manual, Third Edition
- VHA Directive 2008-062 Boiler Plant Operations

The report first lists safety devices serving the whole plant and then safety devices serving the boilers. Reported are: results of each safety device tested, comments and recommendations. See Table 1 for a summary of safety device testing results. Table 1 only includes devices with compliance problems/failures.

## 2. Safety Device Awareness

The Veterans Health Administration regards boiler safety as so important that they require as a matter of policy that Medical Center Directors be notified if a boiler safety device is found to be non-functional. Each safety device installed on the boilers or serving the whole boiler plant mitigates risk or is part of a system to mitigate risk. Safety devices and systems must be properly installed, properly calibrated, properly tested and maintained to be effective in mitigating risk. Boiler plants inherently have the potential for catastrophic failure. When a device is found to be inadequate, prompt repair is essential to ensure a safe working environment.

## 3. Report Summary

This summary is a listing of all the safety devices that either:

- are not present and need to be installed,
- have failed,
- or are not effective because of improper setpoints or installation.

This report contains two kinds of information: safety deficiencies and recommendations for remedying these safety issues. Recommendations are intended only as a guide and are not fully engineered solutions.

The summary table includes device failure categories and action time limits for correcting the deficiencies. These categories and associated action time limits are established and assigned by VA Central Office. These time limits do not in any way permit the unsafe operation of boiler plant equipment. Safe operation of boiler plant equipment is still the responsibility of site specific utility operation management and staff.

Any and all adjustments made during testing were made by or with the supervision of VAMC boiler operators. Recommendations for corrections are made briefly in the summary and in more detail in the following sections.

**ALL SAFETY DEVICES ARE ESSENTIAL. THE NON-EXISTANCE, FAILURE, OR IMPROPER SETPOINT OR APPLICATION OF ANY SAFETY DEVICE HAS THE POTENTIAL FOR THE OCCURANCE OF EVENTS THAT MAY INTERRUPT STEAM PRODUCTION, CAUSE HARM TO PERSONNEL AND DAMAGE OR DESTROY EQUIPMENT.**

Table 1: Safety Device Failure Summary

<b>Failed BEI Inspection in 2009</b>	<b>Boiler Support Equipment</b>	<b>Deficiencies - Recommendations</b>	<b>Category / Action Time Limit</b>
<i>Plant Devices</i>			
Yes	<b>5.1 Condensate Storage Tank High Water Alarm</b>	The probe activated the alarm correctly at approximately 70% of the tank diameter.  There were unlocked valves that can isolate the current alarm. These valves were made to "lock open only" during testing, so the failure was corrected.	
Yes	<b>5.2 Condensate Storage Tank Low Water Alarm</b>	The alarm functioned properly at approximately 25% of the tank diameter. There were unlocked valves that can isolate the current alarm. These valves were made to "lock open only" during testing, so the failure was corrected.	
Yes	<b>5.3 Feedwater Deaerator High Water Alarm</b>	The alarm functioned properly at approximately 60% of the tank diameter. There were unlocked valves that can isolate the current alarm. These valves were made to "lock open only" during testing, so the failure was corrected.	
Yes	<b>5.4 Feedwater Deaerator Low Water Alarm</b>	The alarm functioned properly at approximately 25% of the tank diameter. There were unlocked valves that can isolate the current alarm. These valves were made to "lock open only" during testing, so the failure was corrected.	
Yes	<b>5.5 Feedwater Deaerator Overflow System</b>	The overflow activated at an acceptable water level. However, the deaerator tank overflow discharges into the condensate tank. This creates the potential for pressurizing this non-pressure rated tank. An engineering analysis must be done if this system is to remain unchanged. Recommend discharging deaerator overflow to an appropriate and safe drain. To leave the overflow routed to the condensate tank, the VA requires the condensate tank to be maintained as a pressure vessel with the same requirements that are placed on the DA tank (non-destructive testing etc.).	

		Also, there is a manual valve on the overflow line. This valve must be made to be "lock open only" so that the lock proves the valve is in the open position.
Yes	<b>5.6 Feedwater Deaerator Steam Safety Valve</b>	<p>The VA requires non-destructive testing of the DA tank to include ultra-sonic thickness testing and magnetic particle testing every 6 years. The tank was manufactured in 1993, and there is no record of the required testing.</p> <p>The tank pressure was increased to 20 psig, and the steam pressure safety valve failed to open.</p> <p>Perform the required testing and replace the safety valve.</p>
NA*	<b>5.7 Safety Valve following a Steam Pressure Reducing Valve Station (PRV)</b>	<p>The valve opened properly at 20 psig. However, the valve is undersized. According to plant operators, the PRV size was increased a year or two ago, but the safety valve was not changed to meet the increased capacity. Replace the steam pressure safety valve with a valve rated for at least 8,100 lbs/hr.</p> <p>To accommodate an accumulation test, plumb the PRV sensing line with a valve that will allow the sensing line to be vented to the boiler plant. The vent valve should be located between the manual valve on the sensing line and the PRV .</p>
Yes	<b>5.9 Safety Relief Valve Economizer</b>	A hydro pump was not available for testing. Provide a hydrostatic pump and test the relief valve.
No	<b>5.11 Boiler Plant Building Combustible and Carbon Monoxide Monitor</b>	<p>The current system is a high quality system that can be calibrated. All 5 sensors failed for various reasons. Combustible sensor 1 is locked with an error message. Combustible sensor 2 is calibrated correctly but does not activate an alarm at 10% of the lower explosive limit. CO sensors 1 and 2 are not calibrated properly. CO sensor 3 has a blank display. No alarms activated for any sensor with 20% LEL and 50 ppm CO test gas.</p>
Yes	<b>5.12 Provisions for Admission of Combustion Air into the Boiler Plant Building</b>	<p>There are inadequate fixed openings for providing combustion air to the boilers.</p> <p>An engineering / economic analysis must be done to determine whether fixed openings or an outside air damper interlock should be installed to insure that there is adequate combustion air to the boilers.</p>

<b><i>Boiler Devices</i></b>		
Yes	<b>6.1.1 Low Water Cutoff (LWCO)</b>	Both switches activated with water level 1.5 inches from the bottom of the gage glass. The primary low water cutoff and auxiliary low water cutoff should be set with approximately 1 inch of separation to accommodate the VA low water level testing procedure. A good set of setpoints for the low water switches are: Low Water Alarm at 3.5 inches, LWCO at 2.5 inches, and ALWCO at 1.5 inches.
No	<b>6.1.3 Low Water Alarm (LWA)</b>	The switch activated with water level 3 inches from the bottom of the gage glass. However, the audible alarm was not activated. The switch must activate an audible alarm.
No	<b>6.1.4 High Water Alarm (HWA)</b>	The switch activated with water level 3 inches from the top of the gage glass. However, the audible alarm was not activated. The switch must activate an audible alarm.
Yes	<b>6.2.1 Steam Safety Valves (SV)</b>	<p>SV#1 lifted at 140 psig and reseated at 132 psig.</p> <p>The second safety never lifted. According to the boiler capacity and the capacity of the steam valve that lifted, the boiler is not tuned to produce its rated capacity. It may be possible to tune the boiler and achieve rated capacity and subsequently lift both safeties.</p> <p>An alternative to tuning the boiler for higher steam capacity is to replace the safety valves. In this case, the safeties should be resized so that the first safety relieves approximately 1,000 lb/hr less than the full measured capacity of the boiler. The second should relieve approximately 1,000 lb/hr more than the full rated of the boiler.</p>
No	<b>6.2.2 Operating Steam Pressure Limit Switch (Recycling)</b>	The boiler pressure was increased to 140 psig, and the steam pressure safety valves opened. The excess steam pressure did not trigger a shutdown. Adjust the recycle switch to trip at 125 psig.
No	<b>6.2.3 High Steam Pressure Limit Switch (Non-recycling)</b>	The boiler pressure was increased to 140 psig, and the steam pressure safety valves opened. The excess steam pressure did not trigger a shutdown. Adjust the Non-recycle switch to trip at 130 psig.
NA*	<b>6.3.2 High Pressure Gas Fuel</b>	The switch is not located properly. The VA requires a high gas pressure switch downstream of the automatic shutoff valves and upstream of the fuel flow control valve (firing rate

	<b>Cutoff Switch (HPFCS)</b>	<p>control). The existing switch is downstream of the firing rate control valve. Move the existing switch or add another switch to the correct location.</p> <p>The correct location and required testing valves and test ports are shown on p.61 of the VHA Boiler Plant Safety Device Testing Manual Third Edition. Adjust the switch to trip at 120% of the regulated gas pressure.</p>
NA*	<b>6.3.4 Gas Train Solenoid Vent Valve – Operation and Leak Test</b>	A pressure tap and manual valve (with a lock that is lockable only in the operating position) must be added downstream of the automatic vent valve to accommodate leak test. See p.62 of VHA Boiler Plant Safety Device Testing Manual Third Edition. Any manual valve on the vent line must be locked and lockable only in the operating position.
NA*	<b>6.3.6 Automatic Pilot Gas Shutoff Valves – Leak Test</b>	The system is not plumbed for testing. Install a pressure tap after the downstream pilot gas shutoff valve. A manual valve must be installed after the downstream pressure tap. See p.63 of VHA Boiler Plant Safety Device Testing Manual Third Edition.
NA*	<b>6.3.7 Pilot Gas Train Solenoid Vent Valve – Operation and Leak Test</b>	A pressure tap and manual valve that is lockable only in the operating position must be added downstream of the automatic vent valve to accommodate leak test. See p.63 of VHA Boiler Plant Safety Device Testing Manual Third Edition. Any manual valve on the vent line must be locked and lockable only in the operating position.
NA*	<b>6.4.1 Low Pressure Oil Fuel Cutoff Switch (LPFCS)</b>	Adjust the switch to trip the burner offline if the oil pressure drops to 87 psig.
NA*	<b>6.4.2 High Pressure Oil Fuel Cutoff Switch (HPFCS)</b>	There is no switch installed. Install a switch downstream of the pressure reducing station and upstream of the fuel flow control valve. See p.80 of the VHA Boiler Plant Safety Device Testing Manual Third Edition and set to trip boiler offline at 110% of the regulated pressure.
NA*	<b>6.4.3 Low Oil Atomizing Media Pressure Switch (LAMPS)</b>	The switch failed to activate at 18 psig. Adjust the switch to trip the burner if the atomizing pressure drops to 21 psig.



NA*	<b>6.4.4 Automatic Oil Fuel Shutoff Valves – Leak Test</b>	The upstream valve held tight, but the downstream valve is not plumbed for testing. Install a test port and manual shutoff valve downstream of the second automatic shut off valve.
NA*	<b>6.5 Burner and Air Train Safety Devices: Flame Scanner</b>	The VA requires a self-checking UV flame scanner.
NA*	<b>6.5 Burner and Air Train Safety Devices: Programmer</b>	<p>The original controls were replaced with Siemens controllers in 2012-2013. The VA requires the burner management system be separate from the firing rate controller. For this installation, a single unit seems to serve both functions. This suggestion is based on previous experience with similar controllers and not detailed knowledge of this exact controller. Further investigation and coordination with Doug Ryan at VACO is needed to fully evaluate this controller.</p> <p>It should be noted that the VA requires low fire proving switches &amp; high purge switches (separate from the potentiometer for control). According to the installation contractor, this controller does not accommodate those switches.</p>
NA*	<b>6.5.6 Low-Fire Proving Switch</b>	The VA requires a low fire proving switch that is separate from the potentiometer used for firing rate control purposes. There isn't a separate switch on this system. Three switches must be provided: one for the gas flow control valve, one for the oil flow control valve, and one for the forced draft damper. According to the installation contractor, the Siemens system does not support the required switches. Other sites with similar control issues have engineered a circuit that interrupts the pilot gas valves based on the low fire proving switches. Custom engineering and coordination with Doug Ryan at VACO will be needed to solve this deficiency.
NA*	<b>6.5.7 Forced Draft Damper Wide-Open Pre-Purge Proving Switch</b>	The VA requires a high purge position proving switch that is separate from the potentiometer used for firing rate control purposes. There isn't a separate switch on this system. According to the installation contractor, the Siemens system does not support the required switch. Custom engineering and coordination with Doug Ryan at VACO will be needed to solve this deficiency.
NA*	<b>6.5.8 Combustion</b>	This switch is not plumbed for testing. Add a valve lockable only in the operating position as shown on p.71 of the VHA Boiler Plant Safety Device Testing Manual Third Edition.

	<b>Air Pressure Switch</b>	The switch is set too low and must be adjusted to trip at approximately 10.5 inches of water column.
NA*	<b>6.5.9 Pre-Purge Airflow Proving Switch</b>	The VA requires a high purge flow proving switch that is plumbed to sense the pressure drop from the fan discharge to the boiler outlet. There isn't a switch on this system. According to the installation contractor, the Siemens system does not support the required switch. Custom engineering and coordination with Doug Ryan at VACO will be needed to solve this deficiency.
NA*	<b>6.5.10 Forced Draft Motor Interlock</b>	Current relay switches must be added to all three phases. The relay switches must be compatible with the variable speed drive used to control fan speed.
NA*	<b>6.5.12 Minimum Pilot Flame Test and Low Pilot Gas Pressure Switch</b>	The Siemens controller doesn't provide a switch to put the programmer in test mode. Simplify testing by plumbing an isolation valve (lock open only) between the switch and the pilot gas line. Install a testport between the switch and the lock open only valve. With this setup, the switch can be isolated for easy setpoint adjustment and testing.
NA*	<b>6.5.13 Low Flue Gas Oxygen Alarm and Cutout</b>	The oxygen was lowered to less than 1%. The alarm indication appeared on the controller. No audible activated, and the boiler stayed online. Modify the system to alarm and shut the burner down.

\*NA is used to indicate that the fuel trains and burners have been replaced since the 2009 testing.

#### 4. General Comments and Recommendations

This site engineers and boiler plant operators were all helpful and friendly during the visit. Additionally, the operators seemed bright and willing to learn. The plant is very clean and is a comfortable place to work. With respect to appearance, there are not many boiler plants in the VHA system that exceeds Sioux Falls.

As illustrated by the failure summary in this report, there are shortcomings in meeting the safety device testing and maintenance requirements set forth by VACO. It should also be noted that safety device testing records are incomplete. The missing records appear to coincide with the installation of the new burners and controls. The testing record provided is from January 2013. Testing for most of the devices is required every 6 months.

There are potential tuning/fuel issues that are not listed in the summary table. Please see the section on combustion efficiency for those details.

## 5. Safety Device Testing Results for Plant Support Equipment

### 5.1. Condensate Storage Tank High Water Alarm

**Purpose:** High water level may be an indication of condensate transfer pump failure that could lead to low water condition in the feedwater deaerator and in the boilers. There may be a failure of make-up water controls.

**Recommended set point:** 4 inches below overflow level and 2/3 of tank height.

**Potential hazards due to failure of high water alarm:** Feedwater deaerator running dry and, consequently, boiler feed pumps running dry will cause overheating and damage to pumps and potential for plant shut down. Failure of make-up water controls (in open position) could lead to significant cost from waste of water and condensate from the tank overflow if this occurs over a long time period.

**Recommended type of device:** Conductivity probe type switch. Float type switches have high failure rate in this application where they are exposed to flash steam that causes seals to harden and prevent float movement.

**VA Master Specification section:** 23 50 11 (old 15625).

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD232111-05.pdf <http://www.cfm.va.gov/>

**Failure rate of float types:** 48% (BEI study of VA boiler plants).

**Make and Model:** Warrick

**Did it function properly:** See Comments

**Category & Action Time Limit:**

**Comments:** The probe activated alarm functioned correctly at approximately 70% of the tank diameter.

There were unlocked valves that can isolate the current alarm. These valves were made to "lock open only" during test, so the failure was corrected.

### 5.2. Condensate Storage Tank Low Water Alarm

**Purpose:** Low water level is an indication of make-up water failure or condensate return failure. Immediate action must be taken to avoid plant shutdown.

**Recommended set point:** Approx. 1/3 of tank height.

**Potential hazards due to failure of low water alarm:** Low water in condensate storage tank can cause overheating and damage to condensate transfer pumps. Likely to "starve" feedwater deaerator and boiler feed pumps resulting in boiler feed pumps running dry and damaging pumps and potential for plant shut down

**Recommended type of device:** Float type or conductivity probe type is acceptable.

**VA Master Specification section:** 23 50 11 (old 15625).

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD232111-05.pdf <http://www.cfm.va.gov/>

**Failure rate of float types:** 19% (BEI study of VA boiler plants).

**Make and Model:** Mercoid Float

**Did it function properly:** See Comments

**Category & Action Time Limit:**

**Comments:** The alarm functioned properly at approximately 25% of the tank diameter. There were unlocked valves that can isolate the current alarm. These valves were made to "lock open only" during test, so the failure was corrected.

**5.3. Feedwater Deaerator High Water Alarm**

**Purpose:** Warns of high water level before overflow occurs. High water may be due to failure of inlet water control valve system.

**Recommended set point:** 4 inches below overflow level and 2/3 of tank height.

**Potential hazards due to failure of high water alarm:** Excess water level can cause dangerous water hammer in the DA as the water level encroaches into the steam space.

**Recommended type of device:** Conductivity probe type switch. Float type switches have high failure rate in this application where they are exposed to steam that causes seals to harden and prevent float movement.

**VA Master Specification section:** 23 50 11 (old 15625).

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD232111-06.pdf <http://www.cfm.va.gov/>

**Failure rate of float types:** 59% (BEI study of VA boiler plants).

**Make and Model:** Warrick Probe

**Did it function properly:** See Comments

**Category & Action Time Limit:**

**Comments:** The alarm functioned properly at approximately 60% of the tank diameter. There were unlocked valves that can isolate the current alarm. These valves were made to "lock open only" during test, so the failure was corrected.

**5.4. Feedwater Deaerator Low Water Alarm**

**Purpose:** Warns of low water level before water level drops too low to adequately supply the boiler feed pumps.

**Recommended set point:** Approx. 1/3 of tank height.

**Potential hazards due to failure of low water alarm:** Damage to boiler feed pumps if they run dry and possible plant shut down.

**Recommended type of device:** Float type or conductivity probe type is acceptable.

**VA Master Specification section:** 23 50 11 (old 15625)

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD232111-06.pdf <http://www.cfm.va.gov/>

**Failure rate of float types:** 25% (BEI study of VA boiler plants.)

**Make and Model:** Mercoid

**Did it function properly:** See Comments

**Category & Action Time Limit:**

**Comments:** The alarm functioned properly at approximately 25% of the tank diameter. There were unlocked valves that can isolate the current alarm. These valves were made to "lock open only" during test, so the failure was corrected.

**5.5. Feedwater Deaerator Overflow System**

**Purpose:** Drain excessive water level.

**Recommended set point:** Determined by deaerator manufacturer to maximize water storage and avoid water hammer from excessive water level impinging on the deaerator steam space. This level should be at least 4" below the top of the tank.

**Potential hazards from failure of overflow device:** Water hammer and rupture of deaerator, opening of safety valve. Potential for scalding hot water flowing down into the boiler room from ruptured deaerator or from safety valve.

**Recommended type of device:** Independent control system with conductivity probe water level sensor and butterfly type overflow valve. Float type overflow valves have very high failure rate and are no longer specified.

**VA Master Specification section:** 23 50 11 (old 15625).

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD232111-06.pdf <http://www.cfm.va.gov/>

**Failure rate of float type overflow valves:** 61% (BEI study of VA boiler plants.)

**Make and Model:** Powered Valve

**Did it function properly:** No

**Category & Action Time Limit:** Infrastructure Class 2 - 6 Months

**Comments:** The overflow activated at an acceptable water level. However, the deaerator tank overflow discharges into the condensate tank. This creates the potential for pressurizing this non-pressure rated tank. An engineering analysis must be done if this system is to remain unchanged. Recommend discharging deaerator overflow to an appropriate and safe drain. To leave the overflow routed to the condensate tank, the VA requires the condensate tank to be maintained as a pressure vessel with the same requirements placed on the DA tank (non-destructive testing ect).

Also, there is a manual valve on the overflow line. This valve must be made to be "lock open only" so that the lock proves the valve is in the open position.

## 5.6. Feedwater Deaerator Steam Safety Valve

**Purpose:** Serves as "sentinel" valve mounted on deaerator warning of excessive steam pressure. In combination with the safety valves on the steam pressure reducing station serving the deaerator, it protects the deaerator pressure vessel from overpressure.

**Recommended set point and capacity:** 10 psig. Capacity should be 500-1000 lb/hr. Normal operating pressure of deaerators is 5 psig. Pressure vessel design pressure is usually 30 psig. The safety valve on the steam pressure reducing station serving the deaerator should be set at 15 psig.

**Potential hazards from failure of safety valve:** Rupture of deaerator pressure vessel because of overpressure. Scalding hot water and steam may fill a large portion of the boiler plant.

**Recommended type of device:** ASME and National Board-rated steam safety valve.

**VA Master Specification sections:** 23 21 11 (old 15339), 23 50 11 (old 15625).

<http://www.cfm.va.gov/>

**VA Standard Details:** SD232111-02.pdf, SD232111-03.pdf.

<http://www.cfm.va.gov/>

**Failure rate of deaerator safety valves:** 82% (BEI study of VA boiler plants.)

**Make and Model:** Kunkle

**Setpoint:** 15 psig

**DA maximum allowable working pressure (MAWP):** 30 psig

**DA operating pressure:** 7 psig

**Date of non-destructive test of DA tank welds:** Never

**Did it function properly:** No

**Lift Pressure:** psig

**Category & Action Time Limit:** Device Failure - 6 Weeks

**Comments:** The VA requires non-destructive testing of the DA tank to include ultra-sonic thickness testing and magnetic particle testing every 6 years. The tank was manufactured in 1993, and there is no record of the required testing.

The tank pressure was increased to 20 psig, and the steam pressure safety valve failed to open.

Perform the required testing and replace.

#### 5.7. Safety Valve following a Steam Pressure Reducing Valve Station (PRV)

**Purpose:** Protect downstream steam systems from overpressure due to failure of PRV.

**Recommended set point and capacity:** 10 - 15 psi above set point of pressure reducing valve. The flow capacity must exceed the maximum capacity of the wide open PRV, or the manual bypass around the PRV, whichever is greater. If there are two PRVs in parallel, the safety valve capacity should be based on the largest PRV, wide open.

**Potential hazards from failure of safety valve:** Rupture of pressure vessel or accessory connected to the steam system. Potential of filling space at location of ruptured pressure vessel with steam and scalding hot water.

**Recommended type of device:** ASME and National Board-rated steam safety valve.

**VA Master Specification section:** 23 21 11 (old 15339)<http://www.cfm.va.gov/>

**VA Standard Detail:** SD232111-02.pdf, SD232111-03.pdf.

<http://www.cfm.va.gov/>

**Failure rate of safety valves following PRVs:** 56% (BEI study of VA boiler plants.)

**Make and Model:** Kunkle **Serving the DA tank and plant heat.**

**Setpoint:** 20

**Upstream Pressure:** 115 psig

**Downstream Pressure:** 7 psig

**Safety Capacity:** 3474 lbs/hr

**Bypass Capacity:** 2900 lbs/hr

**PRV Capacity:** 8100 lbs/hr

**Did it function properly:** No

**Lift Pressure:** 20 psig

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** The valve opened properly at 20 psig. However, the valve is undersized. According to plant operators, the PRV size was increased a year or two ago, but the safety valve was not changed to meet the increased capacity. Replace the steam pressure safety valve with a valve rated for at least 8,100 lbs/hr.

To accommodate an accumulation test, plumb the PRV line with a valve that will allow the sensing line to be vented to the boiler plant. The vent valve should be located between the manual valve on the sensing line and the PRV .

### 5.8. Propane Pilot Backup System

**Purpose:** Alternate pilot burner fuel for igniting main oil burner when natural gas is not available for the pilot burner (igniter).

**Recommended setpoint:** Propane header set at 5 psig. (Lowest practical pressure.)

**Potential hazards from failure of propane system:** Inability to ignite oil burners when natural gas is not available for the pilot burners. Natural gas supply could be interrupted because of distribution system failure.

**Recommended type of system:** Portable tanks located outside the building connected to pilot burners with permanent piping.

**VA Master Specification sections:** 23 21 11 (old 15339), 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624). <http://www.cfm.va.gov/>

**VA Standard Details:** SD235239-03.pdf. <http://www.cfm.va.gov/>

**Failure rate of propane system:** 30% (BEI study of VA boiler plants.)

**Did it function properly:** Yes

**Category & Action Time Limit:**

**Comments:**

### 5.9. Safety Relief Valve – Economizer

**Purpose:** Protect economizer from overpressure. Overpressure may result from operation of boiler with economizer valved off and water in economizer not drained.

**Recommended setpoint:** Approx. 275 psig. Based on temperature/pressure limitations of boiler feed piping system.

**Potential hazards from failure of safety relief valve:** Over-pressurizing of economizer resulting in tube failure. Scalding hot water and steam could be released into the boiler room.

**Recommended type of device:** ASME and National Board certified safety relief valve designed for steam and hot water service.

**VA Master Specification section:** 23 52 39 (old 15622), 23 52 33 (old 15624). <http://www.cfm.va.gov/>

**VA Standard Detail:** SD232111-08.pdf. <http://www.cfm.va.gov/>

**Failure rate of economizer safety relief valves:** 40% (BEI study of VA boiler plants.)

**Make and Model:** Kunkle

**Setpoint:** 270 psig



**Feedwater pump maximum discharge pressure:****Did it function properly:** No**Category & Action Time Limit:** Device Failure - 6 Weeks**Comments:** A hydro pump was not available for testing. Provide a hydrostatic and test the relief valve.**5.10. Oil Liquid Relief Valve – Pump Set****Purpose:** Protect oil pumping system from overpressure. Overpressure may be due to failure of back pressure regulator (pressure control valve) or starting the pump with the discharge valves closed.**Recommended setpoint:** Approx. 10 psi above setpoint of back pressure regulator.**Potential hazards from failure of oil relief valve:** Rupture of oil system apparatus, such as pressure switches or damage to pumps. Excess oil burner pressure resulting in dangerous fuel-rich flame that could cause damaging furnace “puffs” or explosion.**Recommended type of device:** Liquid relief valve sized for maximum pump capacity and designed to shut tight.**VA Master Specification section:** 23 50 11 (old 15625). <http://www.cfm.va.gov/>**VA Standard Detail:** SD235239-04.pdf. <http://www.cfm.va.gov/>**Failure rate of oil relief valves:** 40% (BEI study of VA boiler plants.)**Make and Model:** Not recorded**Setpoint:** unknown**Pump discharge pressure:** 110 psig**Did it function properly:** Yes**Category & Action Time Limit:****Comments:** Both valves functioned correctly at 130 psig with a maximum accumulation pressure of 140 psig.**5.11. Boiler Plant Building Combustible and Carbon Monoxide Monitor****Purpose:** Warns of presence of combustibles or carbon monoxide in the building. This can be the result of flue gas leaks in the boiler setting or breeching and improper burner adjustments.**Recommended setpoint:** 50 ppm carbon monoxide. 10% of the lower explosive limit.**Hazard from failure of the monitor:** Carbon monoxide may cause death of personnel. Combustible gas may explode.**Recommended type of monitoring system:** Multiple sensors located near potential sources and in locations where personnel are normally working. Industrial-type automatic system. Recommend 2 combustible sensors high in the plant, CO monitors close to the boilers near potential flue gas leak points and in personnel rooms (particularly those with exhaust systems).**VA Master Specification section:** 23 09 11 (old 15901).<http://www.cfm.va.gov/>**VA Standard Detail:** None.**Failure rate of monitoring system:** 93%. (BEI study of VA boiler plants. In most cases, the monitoring system was not present.)



**Make and Model:** Not Recorded

**Setpoint:**

**Did it function properly:** No

**Category & Action Time Limit:** Device Failure - 6 Weeks

**Comments:** The current system is a high quality system that can be calibrated. All 5 sensors failed for various reasons. Combustible sensor 1 is locked with an error message. Combustible sensor 2 is calibrated correctly but does not activate an alarm at 10% of the lower explosive limit. CO sensors 1 and 2 are not calibrated properly. CO sensor 3 has a blank display. No alarms activated for any sensor with 20% LEL and 50 ppm CO test gas.

## **5.12. Provisions for Admission of Combustion Air into the Boiler Plant Building**

**Purpose:** Air from outside the building is necessary for proper combustion in the boilers. There must be provisions for supplying this air.

**Recommended setpoint:** There must be sufficient outside air admitted to the building so that the negative pressure in the building is negligible. "Negligible" can be defined as -0.05 inches water column.

**Hazards from failure to provide the outside air:** Combustion in the furnace can become fuel-rich due to lack of sufficient combustion air. Boiler steam output capacity can be reduced due to reduced burner capacity from lack of adequate combustion air. Fuel-rich firing can be dangerous if combustion air is increased suddenly. An explosion can occur that damages equipment and injures personnel. Cold outside air can be drawn down the stack of non-operating boilers and freeze the water in the boilers. This can cause serious damage to boilers.

**Recommended type of outside air admission system:** The preferred system in cold climates is a heating and ventilating unit that brings in 100% outside air and heats it to at least 60 degrees F. This should be interlocked with the burners so that they can't fire unless the H&V unit is running. In milder climates, louvers in the building wall are acceptable. They should be interlocked with the burner controls so that they are proved open for the burners to fire.

**VA Master Specification section:** 23 73 00 (old 15763).

<http://www.cfm.va.gov/>

**VA Standard Detail:** HVAC details <http://www.cfm.va.gov/>

**Type of combustion air make-up system:** Movable Louvers

**Make and model:**

**Did it function properly:** No

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:**

There are inadequate fixed openings for providing combustion air to the boilers.

An engineering / economic analysis must be done to determine whether fixed openings or an outside air damper interlock should be installed to insure that there is adequate combustion air to the boilers.

## 6. Safety Device Testing Results for Boiler No. 3

Table 3: Description of Boiler and Burner

Boiler # 3	
<b>Manufacturer:</b>	Johnston
<b>Model:</b>	
<b>Serial #: National Board No.:</b>	Not Recorded
<b>Typical Operating Pressure:</b>	115 psig
<b>Date of Manufacture:</b>	1980
<b>Design Pressure/Capacity:</b>	200 psig 13,800 lbs/hr
Burner	
<b>Manufacturer:</b>	Power Flame (installed 2012-2013)
<b>Fuels:</b>	Natural gas and #2 fuel oil

## 6.1. Boiler Water Level Control

## 6.1.1. Low Water Cutoff (LWCO)

**Purpose:** Primary control to shutdown burner if boiler water level is too low. This could result from failure of feedwater pump or boiler water level control system.

**Recommended setpoint:** As required by boiler manufacturer and at least 1" below the low water alarm. Water level in the gage glass must be clearly visible from the operating floor at the set point.

**Potential hazard from failure of LWCO:** Water level in boiler may go sufficiently low to cause boiler explosion if the auxiliary low water cutoff (ALWCO) also fails. This double failure has been witnessed in a VA plant. Low boiler water is a major cause of boiler accidents.

**Recommended type of cutoff device:** The LWCO and ALWCO should be of different types so that both are not subject to the same mode of failure.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624), 23 09 11 (old 15901). <http://www.cfm.va.gov/>

**VA Standard Details:** SD235239-01.pdf, SD235233-01.pdf.

<http://www.cfm.va.gov/>

**Failure rate of LWCO:** 14% (BEI study of VA boiler plants.)

**Make and Model:** MM Float

**Did it function properly:** No

**Category & Action Time Limit:** Adjustments - 3 Weeks

**Comments:** The switch activated with water level 1.5 inches from the bottom of the gage glass. The primary low water cutoff and auxiliary low water cutoff should be set with approximately 1 inch of separation to accommodate the VA low water level testing procedure. A good set of setpoints for the low water switches are: Low Water Alarm at 3.5 inches, LWCO at 2.5 inches, and ALWCO at 1.5 inches.

## 6.1.2. Auxiliary Low Water Cutoff (ALWCO)

**Purpose:** Secondary control to shutdown burner if boiler water level is too low and the primary low water cutoff (LWCO) fails to operate.

**Recommended setpoint:** As required by boiler manufacturer. Located at least 1" below the low water cutoff (LWCO) setpoint. Water must be visible in gage glass at the setpoint.

**Potential hazard from failure of ALWCO:** Water level in boiler goes sufficiently low to cause boiler explosion.

**Recommended type of cutoff device:** The LWCO and ALWCO should be of different types so that both are not subject to the same mode of failure.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624), 23 09 11 (old 15901). <http://www.cfm.va.gov/>

**VA Standard Details:** SD235239-01.pdf, SD235233-01.pdf.

<http://www.cfm.va.gov/>

**Failure rate of ALWCO:** 32% (BEI study of VA boiler plants.)

**Make and Model:** Warrich Probe

**Did it function properly:** Yes

**Category & Action Time Limit:**

**Comments:** The switch activated with water level 1.5 inches from the bottom of the gage glass.

#### 6.1.3. Low Water Alarm (LWA)

**Purpose:** Provides advance warning of low water condition in boiler allowing personnel to correct situation before low water cutoff occurs.

**Recommended setpoint:** At least 1" above the set point of the primary low water cutoff (LWCO).

**Potential hazard from failure of LWA:** Unplanned burner shut down due to operation of low water cutoffs. Boiler explosion from low water if the low water cutoffs do not operate properly.

**Recommended type of LWA device:** The LWA provides a visual and audible signal but does not shut down the burner.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624), 23 09 11 (old 15901). <http://www.cfm.va.gov/>

**VA Standard Details:** SD235239-01.pdf, SD235233-01.pdf.

<http://www.cfm.va.gov/>

**Failure rate of LWA device:** 11% (BEI study of VA boiler plants.)

**Make and Model:** Warrick Probe

**Did it function properly:** No

**Category & Action Time Limit:** Device Failure - 6 Weeks

**Comments:** The switch activated with water level 3 inches from the bottom of the gage glass. However, the audible alarm was not activated. The switch must activate an audible alarm.

#### 6.1.4. High Water Alarm (HWA)

**Purpose:** Provides warning of high water level in boiler.

**Recommended setpoint:** As recommended by boiler manufacturer. Water level in the gage glass must be clearly visible from the operating floor at the set point.

**Potential hazard from failure of HWA:** Water level could increase sufficiently to cause tremendous carryover of liquid water with the boiler steam

into the steam piping resulting in dangerous water hammer. Potential for piping rupture releasing steam into the boiler room.

**Recommended type of HWA:** The HWA provides a visual and audible signal but does not shut down the burner.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624), 23 09 11 (old 15901). <http://www.cfm.va.gov/>

**VA Standard Details:** SD235239-01.pdf, SD235233-01.pdf.

<http://www.cfm.va.gov/>

**Failure rate of HWA device:** 7% (BEI study of VA boiler plants.)

**Make and Model:** Warrick Probe

**Did it function properly:** No

**Category & Action Time Limit:** Device Failure - 6 Weeks

**Comments:** The switch activated with water level 3 inches from the top of the gage glass. However, the audible alarm was not activated. The switch must activate an audible alarm.

## 6.2. Pressure Containment

### 6.2.1. Steam Safety Valves (SV)

**Purpose:** Protects boiler pressure vessel from overpressure. Multiple valves are required on all except very small boilers as allowed by ASME Code.

**Recommended setpoint:** SV with lowest set point should be 10 psig above set point of non-recycle high pressure cutout. This should be approximately 30 psig above normal operating pressure of steam header. 5 psig between set points of multiple safety valves. All setpoints must be below the design pressure of the boiler.

**Potential hazard from failure of SV:** Boiler pressure vessel explosion due to overpressure releasing large quantities of steam and hot water into the boiler plant. Severe damage to the boiler and to the plant.

**Recommended type of SV:** ASME/NB certified steam safety valves rated for power boiler (ASME Section I) service.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624). <http://www.cfm.va.gov/>

**VA Standard Details:** SD232111-02.pdf, SD232111-03.pdf.

<http://www.cfm.va.gov/>

**Failure rate of boiler SV:** 33% (BEI study of VA boiler plants.)

**Make and Model:** Kunkle

**Setpoint:** SV#1--140 psig (10160 lbs/hr) SV# 2--145 psig (10489 lbs/hr).

**Did it function properly:** No

**Category & Action Time Limit:** Device Failure - 6 Weeks

**Comments:** SV#1 lifted at 140 psig and reseated at 132 psig.

The second safety never lifted. According to the boiler capacity and the capacity of the steam valve that lifted, the boiler is not tuned to produce its rated capacity. It may be possible to tune the boiler and achieve rated capacity and subsequently lift both safeties.

An alternative to tuning the boiler for higher steam capacity is to replace the safety valves. In this case, the safeties should be resized so that the first safety relieves approximately 1,000 lb/hr less than the full measured capacity of the boiler. The second should relieve approximately 1,000 lb/hr more than the full rated of the boiler.

#### 6.2.2. Operating Steam Pressure Limit Switch (Recycling)

**Purpose:** Shuts down burner if boiler steam pressure exceeds setpoint. Allows burner to automatically restart when pressure decreases sufficiently. Operates mainly during periods when steam demands are less than the steam produced at the lowest firing rate of the burner.

**Recommended setpoint:** Approximately 15 psig above normal steam header pressure. 5 psig above boiler steam pressure at high fire.

**Potential hazard from failure of operating limit switch:** Boiler explosion from overpressure if there are also failures of the non-recycling pressure switch and the boiler safety valves. Excess pressure on steam distribution system that could cause pressure reducing valves in the system to fail. This has the potential for overpressuring steam systems downstream from the pressure reducing stations if the pressure reducing station safety valves fail.

**Recommended type of pressure switch:** Switch must be UL and FM approved for this service.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624), 23 09 11 (old 15901). <http://www.cfm.va.gov/>

**VA Standard Details:** SD235239-01.pdf, SD235233-01.pdf.  
<http://www.cfm.va.gov/>

**Failure rate of operating limit switch:** 29% (BEI study of VA boiler plants.)

**Make and Model:** Honeywell

**Setpoint:**

**Did it function properly:** No

**Category & Action Time Limit:** Adjustments - 3 Weeks

**Comments:** The boiler pressure was increased to 140 psig, and the steam pressure safety valves opened. The excess steam pressure did not trigger a shutdown. Adjust the recycle switch to trip at 125 psig.

#### 6.2.3. High Steam Pressure Limit Switch (Non-recycling)

**Purpose:** Causes shut down of burner if boiler steam pressure exceeds setpoint. Does not allow burner to automatically restart when pressure decreases.

**Recommended setpoint:** Approximately 5 psig above set point of recycling pressure switch. 5 psig below lowest set point of boiler safety valves.

**Potential hazard from failure of operating limit switch:** Boiler explosion from overpressure if there are also failures of the boiler safety valves. Excess pressure on steam distribution system that could cause pressure reducing valves in the system to fail. This has the potential for overpressuring steam systems downstream from the pressure reducing stations if the pressure reducing station safety valves fail.

**Recommended type of pressure switch:** Switch must be UL and FM approved for this service.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624), 23 09 11 (old 15901). <http://www.cfm.va.gov/>

**VA Standard Details:** SD235239-01.pdf, SD235233-01.pdf.

<http://www.cfm.va.gov/>

**Failure rate of non-recycling limit switch:** 36% (BEI study of VA boiler plants.)

**Make and Model:** Honeywell

**Setpoint:**

**Did it function properly:** No

**Category & Action Time Limit:** Adjustments - 3 Weeks

**Comments:** The boiler pressure was increased to 140 psig, and the steam pressure safety valves opened. The excess steam pressure did not trigger a shutdown. Adjust the recycle switch to trip at 130 psig.

### 6.3. Fuel Train Safety Devices – Natural Gas Section

#### 6.3.1. Low Pressure Gas Fuel Cutoff Switch (LPFCS)

**Purpose:** Shuts down the burner if the fuel pressure drops to the setpoint. This can be the result of a pressure regulator failure or clogged fuel filter.

**Recommended setpoint:** Per burner manufacturer's instructions, which should be within 15-20% of the normal operating pressure.

**Potential hazard from failure of the cutoff switch:** As an example, a pressure regulator malfunction that allows the fuel pressure to drop and then allows the fuel pressure to increase could result in a furnace explosion from the excess air present in the furnace and the sudden increase of fuel into the furnace.

**Recommended type of pressure switch:** UL and FM approved for gas fuel service.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD235239-03.pdf. <http://www.cfm.va.gov/>

**Failure rate of LPFCS:** 46% (BEI study of VA boiler plants.)

**Make and Model:** Mercoid

**Fuel train operating pressure:** 0.45 psig

**Setpoint:** Unknown

**Did it function properly:** Yes

**Category & Action Time Limit:**

**Comments:** The switch tripped the boiler offline at 0.36 psig.

#### 6.3.2. High Pressure Gas Fuel Cutoff Switch (HPFCS)

**Purpose:** Shuts down the burner if the fuel pressure rises to the setpoint. This can be the result of a pressure regulator failure.

**Recommended setpoint:** Per burner manufacturer's recommendations which should be within 15-20% of the normal operating pressure.

**Potential hazard from failure of the cutoff switch:** Flame may become very fuel-rich and generate large amounts of carbon monoxide (CO). Change of burner firing rates or shut down may suddenly introduce more combustion air



resulting in a damaging furnace “puff” when the excess fuel explodes. A fuel-rich flame is always dangerous.

**Recommended type of pressure switch:** UL and FM approved for gas fuel service.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD235239-03.pdf. <http://www.cfm.va.gov/>

**Failure rate of HPFCS:** 43% (BEI study of VA boiler plants.)

**Make and Model:** Mercoid

**Fuel train operating pressure:** 0.45 psig

**Setpoint:**

**Did it function properly:** No

**Category & Action Time Limit:**

**Comments:** The switch is not located properly. The VA requires a high gas pressure switch downstream of the automatic shutoff valves and upstream of the fuel flow control valve (firing rate control). The existing switch is downstream of the firing rate control valve. Move the existing switch or add another switch downstream to the correct location.

The correct location and required testing valves and test ports are shown on p.61 of the VHA Boiler Plant Safety Device Testing Manual Third Edition. Adjust the switch to trip at 120% of the regulated gas pressure.

#### 6.3.3. Automatic Gas Fuel Shutoff Valves – Leak Test

**Purpose:** Open-shut, normally closed valves that operate to start and stop the fuel flow to the main burner. It is essential to have two valves in series with an automatic vent in between and with leak test connections.

**Recommended setpoint:** Zero seat leakage; also called “bubble-tight”.

**Potential hazard from valve seat leakage:** Unburned fuel will collect in the furnace when the burner is not operating and may explode when burner is started. Serious damage to boiler and hazard to personnel may result.

**Recommended type of fuel valves:** UL and FM approved for the fuel service.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624). <http://www.cfm.va.gov/>

**VA Standard Detail:** SD235239-03.pdf. <http://www.cfm.va.gov/>

**Leak failure rate of automatic fuel shut off valves:** Data not available.

**Make and Model:** Maxon

**Did it function properly:** Yes

**Category & Action Time Limit:**

**Comments:** Did not leak.

#### 6.3.4. Gas Train Solenoid Vent Valve – Operation and Leak Test

**Purpose:** Open-shut, normally open valve that automatically vents the space between the two automatic fuel shut off valves when the burner is not firing. If the first fuel shut off valve leaks, the leakage will be vented and the second fuel shut off valve will not be pressurized.

**Recommended setpoint:** Zero leakage.

**Potential hazard from valve failure:** If vent valve fails closed, it will pressurize the second automatic shut off valve if the first shut off valve is leaking. If the second shut off valve also leaks, the boiler can be filled with fuel which will explode when the burner is started. Leakage of the vent valve seat results in gas loss to the atmosphere with the accompanying cost of the gas.

**Recommended type of vent valve:** UL approved for the fuel service.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624). <http://www.cfm.va.gov/>

**VA Standard Details:** SD235239-03.pdf. <http://www.cfm.va.gov/>

**Leak Failure rate of vent valves:** 23% (BEI study of VA boiler plants.)

**Make and Model:** ASCO

**Did it function properly:** No

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** A pressure tap and manual valve (with a lock that is lockable only in the operating position) must be added downstream of the automatic vent valve to accommodate leak test. See p.62 of VHA Boiler Plant Safety Device Testing Manual Third Edition. Any manual valve on the vent line must be locked and lockable only in the operating position.

#### 6.3.5. Automatic Gas Fuel Shutoff Valves – Proof of Closure (POC)

**Purpose:** Proof that the valves are closed is provided by electrical switches in the valves that sense the position of the valves, open or closed. The switches are in an electrical circuit to the burner management control system. The valves must be “proven” closed before the burner management control allows the ignition sequence to start.

**Potential hazard from failure (or absence) of POC switch:** A boiler explosion would occur if the pilot burner is ignited with the main fuel valves open and the furnace full of fuel.

**Recommended type of POC switch:** The switch is furnished with UL and FM approved automatic fuel safety shut off valves.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624). <http://www.cfm.va.gov/>

**VA Standard Details:** None.

**Failure rate of POC switches:** 42% (BEI study of VA boiler plants.)

Typically valves without POC or with POC but not monitored by burner management systems.

**Make and Model:** Maxon

**Did it function properly:** Yes

**Category & Action Time Limit:**

**Comments:**

#### 6.3.6. Automatic Pilot Gas Shutoff Valves – Leak Test

**Purpose:** Open-shut, normally closed solenoid valves that operate to start and stop the fuel flow to the pilot burner. It is essential to have two valves in series with an automatic vent in between and with leak test connections.

**Recommended setpoint:** Zero seat leakage; also called “bubble-tight”.



**Potential hazard from valve seat leakage:** Unburned fuel will collect in the furnace when the burner is not operating and may explode when burner is started. Serious damage to boiler and hazard to personnel may result.

**Recommended type of fuel valves:** UL and FM approved for the fuel service.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624). <http://www.cfm.va.gov/>

**VA Standard Detail:** SD235239-03.pdf. <http://www.cfm.va.gov/>

**Leak failure rate of automatic fuel shut off valves:** Data not available.

**Make and Model:** ASCO

**Did it function properly:** No

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** The system is not plumbed for testing. Install a pressure tap after the downstream pilot gas shutoff valve. A manual valve must be installed after the downstream pressure tap. See p.63 of VHA Boiler Plant Safety Device Testing Manual Third Edition.

#### 6.3.7. Pilot Gas Train Solenoid Vent Valve – Operation and Leak Test

**Purpose:** Open-shut, normally open solenoid valve that automatically vents the space between the two automatic pilot fuel shut off valves when the pilot burner is not firing. If the first fuel shut off valve leaks, the leakage will be vented and the second fuel shut off valve will not be pressurized.

**Recommended setpoint:** Zero leakage.

**Potential hazard from valve failure:** If vent valve fails closed, it will pressurize the second automatic shut off valve if the first shut off valve is leaking. If the second shut off valve also leaks, the boiler can be filled with fuel which will explode when the burner is started. Leakage of the vent valve seat results in gas loss to the atmosphere with the accompanying cost of the gas.

**Recommended type of vent valve:** UL approved for the fuel service.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624). <http://www.cfm.va.gov/>

**VA Standard Details:** SD235239-03.pdf. <http://www.cfm.va.gov/>

**Leak Failure rate of vent valves:** Not available.

**Make and Model:** ASCO

**Did it function properly:** No

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** A pressure tap and manual valve that is lockable only is the operating position should be added downstream of the automatic vent valve to accommodate leak test. See p.63 of VHA Boiler Plant Safety Device Testing Manual Third Edition. Any manual valve on the vent line must be locked and lockable only in the operating position.

### 6.4. Fuel Train Safety Devices – #2 Oil Section

#### 6.4.1. Low Pressure Oil Fuel Cutoff Switch (LPFCS)

**Purpose:** Shuts down the burner if the fuel pressure decreases to the setpoint of the switch. The pressure decrease can be the result of a pressure regulator failure or clogged filter.

**Recommended setpoint:** Per burner manufacturer's instructions which should be within 10% of the normal operating pressure.

**Potential hazard from failure of the cutoff switch:** As an example, a pressure regulator malfunction that allows the fuel pressure to drop and then allows the fuel pressure to increase could result in a furnace explosion from the excess air present in the furnace and the sudden increase of fuel into the furnace.

**Recommended type of pressure switch:** UL and FM approved for Propane fuel service.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD235239-04.pdf. <http://www.cfm.va.gov/>

**Failure rate of LPFCS:** 46% (BEI study of VA boiler plants.)

**Make and Model:** Ashcroft

**Fuel train operating pressure:** 97 psig

**Setpoint:**

**Did it function properly:** No

**Category & Action Time Limit:** Adjustments - 3 Weeks

**Comments:** Adjust the switch to trip the burner offline if the oil pressure drops to 87 psig.

#### 6.4.2. High Pressure Oil Fuel Cutoff Switch (HPFCS)

**Purpose:** Shuts down the burner if the fuel pressure rises to the setpoint. The pressure increase can be the result of a pressure regulator failure.

**Recommended setpoint:** Per burner manufacturer's recommendations, which should be within 10% of the normal operating pressure.

**Potential hazard from failure of the cutoff switch:** A fuel pressure rise will cause the flame to become fuel-rich and potentially generate large amounts of carbon monoxide (CO) and smoke. Change of burner firing rates or shut down may suddenly introduce more combustion air resulting in a damaging furnace "puff" when the excess fuel explodes. A fuel-rich flame is always dangerous.

**Recommended type of pressure switch:** UL and FM approved for propane fuel service.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD235239-04.pdf. <http://www.cfm.va.gov/>

**Failure rate of HPFCS:** 43% (BEI study of VA boiler plants.)

**Make and Model:** None

**Fuel train operating pressure:** 97 psig

**Setpoint:**

**Did it function properly:** No

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** There is no switch installed. Install a switch downstream of the pressure reducing station and upstream of the fuel flow control valve. See p.80 of the VHA Boiler Plant Safety Device Testing Manual Third Edition and set to trip boiler offline at 110% of the regulated pressure.

#### 6.4.3. Low Oil Atomizing Media Pressure Switch (LAMPS)

**Purpose:** Shuts down the burner if the atomizing media (steam or compressed air) pressure at the entrance to the atomizing valve train is insufficient for proper atomization of the fuel oil.

**Recommended setpoint:** Per burner manufacturer's recommendations and above the pressure at which the flame becomes unstable or smoky. The set point must not be lower than 80% of the minimum typical atomizing pressure.

**Potential hazard from failure of the switch:** Flame may become unstable, smoky, have high carbon monoxide. Flame may be momentarily extinguished and relight with a furnace "puff" that could be damaging.

**Recommended type of pressure switch:** UL listed for burner service.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD235239-04.pdf. <http://www.cfm.va.gov/>

**Failure rate of LAMPS:** 32% (BEI study of VA boiler plants.)

**Make and Model:** Aschcroft

**Atomizing train operating pressure:** 25 psig during purge

**Setpoint:**

**Did it function properly:** No

**Category & Action Time Limit:** Adjustments - 3 Weeks

**Comments:** The switch failed to activate at 18 psig. Adjust the switch to trip the burner if the atomizing pressure drops to 21 psig.

#### 6.4.4. Automatic Oil Fuel Shutoff Valves – Leak Test

**Purpose:** Open-shut, normally closed valves that operate to start and stop the fuel flow to the main burner. Valves must shut tightly to prevent unburned fuel from collecting in the boiler when the burner is not firing. It is essential to have two valves in series and with leak test connections.

**Recommended setpoint:** Zero leakage; also called "bubble-tight".

**Potential hazard from valve leakage:** Unburned fuel will collect in the furnace and may explode when burner is started. Serious damage to boiler and hazard to personnel will result.

**Recommended type of fuel valves:** UL and FM approved for fuel service.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624). <http://www.cfm.va.gov/>

**VA Standard Detail:** SD235239-04.pdf. <http://www.cfm.va.gov/>

**Leak Failure rate of automatic fuel shut off valves:** Data not available.

**Make and Model:** Siemens

**Did it function properly:** No

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** The upstream valve held tight, but the downstream valve is not plumbed for testing. Install a test port and manual shutoff valve downstream of the second automatic shut off valve.

#### 6.4.5. Automatic Oil Fuel Shutoff Valves – Proof of Closure (POC)

**Purpose:** Proof that the valves are closed is provided by electrical switches in the valves that sense the position of the valves, open or closed. The switches are in an electrical circuit to the burner management control system. The valves must be “proven” closed before the burner management control allows the ignition sequence to start.

**Potential hazard from failure (or absence) of POC switch:** A boiler explosion would occur if the pilot burner is ignited with the main fuel valves open and the furnace full of fuel.

**Recommended type of POC switch:** The switch is furnished with UL and FM approved automatic fuel safety shut off valves.

**VA Master Specification sections:** 23 52 39 (old 15622), 23 52 33 (old 15623), 23 52 33 (old 15624). <http://www.cfm.va.gov/>

**VA Standard Details:** None.

**Failure rate of POC switches:** 42% (BEI study of VA boiler plants. Valves without POC or with POC but not monitored by burner management systems.)

**Make and Model:** Siemens

**Did it function properly:** Yes

**Category & Action Time Limit:**

**Comments:** Both worked.

#### 6.5. Burner and Air Train Safety Devices

##### **Burner Management Programmer:**

**Microprocessor type programmers are required:** This type includes Fireye E100, E110, BurnerLogix, Honeywell 7800 series and others.

**Non-microprocessor programmers are not acceptable:** Often the non-microprocessor programmers have easily adjustable timing systems as part of the programmer or electrically connected to the programmer. These adjustable timing systems can be hazardous if they are incorrectly adjusted. An example is the adjusting of a timer to reduce the pre-purge time in order to have faster light-off of the burner. Non-microprocessor programmers should be replaced.

**Rebuilt programmers must be replaced immediately:** These are not accepted by a major code and by some regulatory authorities and are no longer available from the major manufacturers. They should be immediately replaced by new programmers. A malfunctioning programmer could cause a major boiler explosion.

**Programmer make and model:** Siemens

**Is it acceptable:** No

**Category & Action Time Limit:**

**Comments:** The original controls were replaced with Siemens controllers in 2012-2013. The VA requires the burner management system be separate from the firing rate controller. For this installation, a single units seems to serve both functions. This suggestion is based on previous experience with similar controllers and not detailed knowledge of this exact controller. Further investigation and coordination with Doug Ryan at VACO is needed to fully evaluate this controller.

It should be noted that the VA requires low fire proving switches and high purge switches (separate from the potentiometer for control). According to the installation contractor, this controller does not accommodate those switches.

**Flame Scanner:**

**UV self-checking scanners are required.** This type provides the best assurance of safe flame detection.

**Infrared (IR) scanners are acceptable only in limited circumstances:** This type can sense the radiation from hot refractory or the “flicker” from oil/steam fog as flame and therefore not respond to an actual flame failure. The latest technology for these systems claims to overcome this problem by “learning” the actual flame “flicker” frequency and amplitude and thus reject background radiation. IR systems using this learning technology are permitted on specific burners when it has been determined by trained burner technicians or the burner manufacturer that UV scanners are not capable of reliably sensing the flame.

**UV non-self-checking scanners (are not permitted):** This type is usually applied only on boilers that cycle on and off frequently. Boilers in VAMC central plants are not in this category. UV non-self-checking scanners can fail in an unsafe mode. This is usually not critical in boilers that frequently cycle on and off because a scanner failure is detected by the burner management programmer during the start-up process and the boiler is not allowed to fire.

**Scanner make and model:** IR

**Is it acceptable:** No: IR

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** The VA requires a self-checking UV flame scanner.

**6.5.1. Flame Scanner – Test for Flame Failure Response Time (FFRT)**

**Purpose:** FFRT is the elapsed time from disappearance of the flame until power to automatic fuel valves is interrupted by the burner management programmer. Response time must be minimized to limit the amount of unburned fuel remaining in the furnace after a “flame-out”.

**Required FFRT (code requirement):** 4 seconds or less. NFPA-85 Code requirement.

**Potential hazard from excessive response time, or no response:** Unburned fuel will collect in the furnace and may explode if there is an ignition source.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Details:** None.

**Failure rate of flame scanners:** 7% (BEI study of VA boiler plants.)

**Timing:** 2 sec.

**Did it function properly:** Yes

**Category & Action Time Limit:**

**Comments:**

#### 6.5.2. UV Scanner Not Sensing Ignition Spark

**Purpose:** UV scanners are sensitive to the ignition spark and will treat it as a proven flame. To avoid this problem, the scanner must be aimed so that the spark is not in view.

**Potential hazard from UV scanner sensing the ignition spark:** The programmer will allow the main fuel valves to open with no pilot flame present. The main flame will not be ignited quickly, large quantities of fuel may collect in the furnace, and an explosion may occur.

**Recommended type of burner management programmer:** Programmers with “early spark termination” are recommended. These programmers shut down the ignition spark before the main fuel valves open. If the scanner does not see the pilot flame, the start-up is automatically terminated before the main fuel valves open.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Details:** None.

**Failure rate of scanner seeing ignition spark:** 7%. (BEI study of VA boiler plants.)

**Make and model:**

**Did it function properly:** Yes

**Category & Action Time Limit:**

**Comments:**

#### 6.5.3. Igniter Timing – Pilot Trial for Ignition (PTFI)

**Purpose:** Limit the ignition sequence timing for safety and efficiency.

**Required PTFI (code requirement):** 10 seconds or less. Add 4 seconds for the flame failure response time.

**Potential hazard from excessive PTFI time:** If pilot flame does not quickly ignite, excessive unburned fuel may collect in the furnace causing an explosion if there is an ignition source.

**Recommended type of control:** Microprocessor-based programmer, UL and FM approved.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Details:** None.

**Failure rate of PTFI:** 4% (BEI study of VA boiler plants.)

**Timing:** 10 sec.

**Did it function properly:** Yes

**Category & Action Time Limit:**

**Comments:**

#### 6.5.4. Main Flame Trial for Ignition Timing (MTFI)

**Purpose:** Limit the main flame ignition sequence timing for safety and efficiency.



**Required MTFI (code requirement):** 10 seconds or less on natural gas and No. 2 oil. 15 seconds or less for heavy oil. Add 4 seconds for the flame failure response time (FFRT).

**Potential hazard from excessive MTFI time:** If main flame does not ignite quickly, excessive unburned fuel may collect in the furnace causing an explosion if there is an ignition source.

**Recommended type of control:** Microprocessor-based programmer, UL and FM approved.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Details:** None.

**Failure rate of MTFI:** 18% (BEI study of VA boiler plants.)

**Timing:** 5.7 sec.

**Did it function properly:** Yes

**Category & Action Time Limit:**

**Comments:**

#### 6.5.5. Pre-purge and Post-purge Timer

**Purpose:** Provide sufficient air flow through the boiler prior to ignition and after shut down to remove any potentially explosive gases resulting from the presence of unburned fuel. The unburned fuel can collect in the furnace due to a burner malfunction or a malfunction of the fuel control valves.

**Required minimum pre-purge timing (code requirement):** 4 air changes for fire tube boilers; 8 air changes for water tube boilers. This translates into an approximate minimum purge time of 1 minute for fire tube boilers and 2 minutes for water tube boilers. Precise purge requirements can be obtained from the boiler manufacturer or calculated using the volume (overall length x width x height) of the boiler and the airflow of the forced draft fan at high fire.

**Required post-purge timing (code requirement):** 15 seconds at airflow rate not exceeding that at which it was shut down.

**Potential hazard from insufficient pre-purge timing:** A major boiler explosion can occur from ignition of explosive gases in the furnace when the ignition sequence is started. There is no hazard from extra pre-purge timing; the downside is the longer time required to place the boiler in service.

**Recommended type of control:** Microprocessor-based programmer, UL and FM approved. Timing not adjustable after "burn-in" of controller.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Details:** None.

**Failure rate of pre- or post-purge timing:** 21% (BEI study of VA boiler plants.)

**Time from low to high fire:** 30 sec.

**Time in high fire:** 30 sec.

**Total equivalent time in high purge:** 45

**Post-purge:** 15

**Did it function properly:** Yes

#### 6.5.6. Low-Fire Proving Switch

**Purpose:** Signals the burner management programmer that the fuel and air flow are at a low fire position prior to ignition of pilot burner.

**Recommended setpoint:** Within 5% of the low fire position.

**Potential hazard from ignition at position other than low fire:** Ignition could be explosive because of the large amount of fuel and air igniting. Damage to boiler could occur along with hazard to personnel.

**Recommended type of control:** Sealed snap-acting switch actuated by lever contacting fuel valve control arm. See VA Master Specifications for alternatives.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** None.

**Failure rate of proving switch:** 18% (BEI study of VA boiler plants.)

**Make and model:** None

**Did it function properly:** No

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** The VA requires a low fire proving switch that is separate from the potentiometer used for firing rate control purposes. There isn't a separate switch on this system. Three switches must be provided: one for the gas flow control valve, one for the oil flow control valve, and one for the forced draft damper. According to the installation contractor, the Siemens system does not support the required switches. Other sites with similar control issues have engineered a circuit that interrupts the pilot gas valves based on the low fire proving switches. Custom engineering and coordination with Doug Ryan at VACO will be needed to solve this deficiency.

#### 6.5.7. Forced Draft Damper Wide-Open Pre-Purge Proving Switch

**Purpose:** Signals the burner management programmer that the forced draft damper is properly positioned to achieve full flow of pre-purge air.

**Recommended setpoint:** Within 5% of the wide-open damper position.

**Potential hazard from not achieving wide-open damper position:**

Insufficient purge air flow may not purge the boiler of all explosive gases. An explosion could result during the ignition sequence.

**Recommended type of control:** Position switch actuated by lever arm attached to damper.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** None.

**Failure rate of proving switch:** 39% (BEI study of VA boiler plants.) (Also called "vane interlock switch.")

**Make and model:** None

**Did it function properly:** No

**Category & Action Time Limit:**



**Comments:** The VA requires a high purge position proving switch that is separate from the potentiometer used for firing rate control purposes. There isn't a separate switch on this system. According to the installation contractor, the Siemens system does not support the required switch. Custom engineering and coordination with Doug Ryan at VACO will be needed to solve this deficiency.

#### 6.5.8. Combustion Air Pressure Switch

**Purpose:** Signals the burner management programmer that there is combustion air pressure that will cause airflow.

**Recommended setpoint:** 80% of the minimum pressure differential.

**Potential hazard from switch failure:** Forced draft fan or damper drive may fail and cause the flame to be fuel-rich. There may be an explosion if the fan or damper is suddenly activated to increase the air supply.

**Recommended type of switch:** UL and FM approved differential pressure switch.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** None.

**Failure rate of combustion airflow switch:** 36% (BEI study of VA boiler plants.)

**Make and model:** Dwyer

**Location of sensing lines:** fan inlet (downstream of the damper) to fan discharge

**Switch setpoint:** 4 inches wc

**Minimum delta P:** 12.5 inches wc

**Maximum delta P:** 14.5 inches wc

**Did it function properly:** No

**Category & Action Time Limit:**

**Comments:** This switch is not plumbed for testing. Add a valve lockable only in the operating position as shown on p.71 of the VHA Boiler Plant Safety Device Testing Manual Third Edition.

The switch is set too low and must be adjusted to trip at approximately 10.5 inches of water column.

#### 6.5.9. Pre-Purge Airflow Proving Switch

**Purpose:** Signals the burner management programmer that there is sufficient pre-purge air flow.

**Required setpoint (Code requirement):** Must achieve at least 70% of required airflow at maximum capacity of burner. Recommend that switch be set at 80% of maximum delta P.

**Hazard from switch failure:** Required pre-purge may not be achieved and some combustible gases may remain in the furnace when the burner is ignited. An explosion can occur.

**Recommended type of switch:** UL and FM approved differential pressure switch. The switch must be piped so that the differential pressure is sensed

from the boiler furnace to the boiler outlet. There must be no movable pressure restriction, such as a damper or burner register, between the sensing points.

**VA Master Specification Section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** None.

**Failure rate of pre-purge airflow switch:** 43% (BEI study of VA boiler plants.)

**Make and model:** None

**Location of sensing lines:**

**Switch setpoint:**

**Maximum delta P:**

**Did it function properly:** No

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** The VA requires a high purge flow proving switch that is plumbed to sense the pressure drop from the fan discharge to the boiler outlet. There isn't a separate switch on this system. According to the installation contractor, the Siemens system does not support the required switch. Custom engineering and coordination with Doug Ryan at VACO will be needed to solve this deficiency.

#### 6.5.10. Forced Draft Motor Interlock

**Purpose:** Signals to burner management programmer that proper power supply is flowing to the forced draft fan motor.

**Hazard from interlock failure:** Fan motor may be running at lower speed due to "single-phasing" or other problem or may not be running. Lack of combustion air will cause fuel-rich fire. Explosion may occur if the air flow suddenly increases.

**Recommended type of interlock:** Current relay on all power phases.

Auxiliary contact on motor starter is not acceptable because it does not prove that power is flowing to the motor.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** None.

**Failure rate of interlock:** 15% (BEI study of VA boiler plants.)

**Type of interlock:**

**Did it function properly:** No

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** Current relay switches should be added to all three phases. The relay switches must be compatible with the variable speed drive used to control fan speed.

#### 6.5.11. Forced Draft Fan Variable Speed Drive (VSD) Interlock

**Purpose:** Prove that fan is providing the correct amount of combustion air for a particular firing rate.

**Hazard from interlock failure:** Combustion upset may occur that results in fuel-rich or lean flame that will be unstable. This is dangerous if the flame

blows-out and then reignites or if air is suddenly introduced into a fuel-rich situation. Explosions and hazards to personnel may result.

**Recommended type of interlock:** VFD fault and run contacts and speed sensor on fan shaft.

**VA Master Specification sections:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** None.

**Failure rate of interlock:** Data not available.

**Type of control:**

**Make and model:**

**Did it function properly:** Not tested

**Category & Action Time Limit:**

**Comments:** The VSD is setup to operate at 95% at low fire and 100% at high fire. With such small variation in fan speed, the system is effectively set up as a fixed speed system. See combustion air pressure test.

#### 6.5.12. Minimum Pilot Flame Test and Low Pilot Gas Pressure Switch

**Purpose:** The pilot gas pressure must be sufficient to provide a pilot flame sufficiently large to quickly ignite the main flame.

**Recommended setpoint:** Pressure at which the pilot flame will quickly ignite the main flame, which should be within 80% of the normal operating pressure. .

**Hazard from switch failure:** The pilot gas pressure regulator may fail and allow the pilot pressure to decrease to a point where the pilot flame is too small to quickly ignite the main flame. The result may be a build up of unburned fuel in the furnace and an explosion if it suddenly ignites. This could cause damage to the boiler and harm to personnel.

**Recommended type of interlock:** UL and FM approved pressure switch.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** SD235239-03.pdf. <http://www.cfm.va.gov/>

**Failure rate of interlock:** 57% (BEI study of VA boiler plants. In many cases, the switches are not present.)

**Make and model:** Not Recorded

**LP pilot cutout setpoint:**

**Did it function properly:** Not tested

**Category & Action Time Limit:** Infrastructure Class 1 - 3 Months

**Comments:** The Siemens controller doesn't provide a switch to put the programmer in test mode. Simplify testing by plumbing an isolation valve (lock open only) between the switch and the pilot gas line. Install a testport between the switch and the lock open only valve. With this setup, the switch can be isolated for easy setpoint adjustment and testing.

#### 6.5.13. Low Flue Gas Oxygen Alarm and Cutout

**Purpose:** Warns and provides burner shut down if flue gas oxygen (excess air) approaches an unsafe level.

**Recommended setpoint:** Approximately one percentage point below the lowest normal flue gas oxygen for normal burner operation and no more than 200 ppm CO or combustibles in the flue gas..

**Hazard from interlock and alarm failure:** Flame may become fuel rich due to failure of combustion controls or other fault. A fuel rich flame can result in an explosion if there is a sudden introduction of combustion air, such as at the post-purge.

**Recommended type of interlock and alarm:** Zirconium-oxide oxygen sensing system with automatic calibration.

**VA Master Specification section:** 23 09 11 (old 15901).

<http://www.cfm.va.gov/>

**VA Standard Detail:** None.

**Failure rate of interlock/alarm:** 80%. (BEI study of VA boiler plants.)

**Make and model:** Rosemount

**Setpoint:**

**Did it function properly:** No

**Category & Action Time Limit:** Device Failure - 6 Weeks

**Comments:** The oxygen was lowered to less than 1%. The alarm indication appeared on the controller. No audible activated, and the boiler stayed online. Modify the system to alarm and shut the burner down.

## 7. Combustion Efficiency Results (Natural Gas)

*Table 4: Combustion Efficiency for Boiler # 3*

Load	Steam (PSIG)	O <sub>2</sub> (%)	CO (ppm)	T-Stack (F)	Efficiency (%)
Low	110	7.7	26	353	81.4
Mid	110	6.3	25	397	80.9
High	120	5.8	26	347	80

The boiler tuning on natural gas is okay, but consider tuning to operate with less excess air. During the low oxygen test, the air was reduced significantly without producing unburned combustibles. For example, at mid-fire the stack oxygen was reduced from 6.3% to 1.5%. At 1.5% oxygen, the CO level was still very low 26 ppm. Tuning the burners to operate with less excess air will improve the efficiency of the boilers.

Also, the boiler plant operators noted chunks of debris and black build up in the Morrison tube. “Dirty” flames were noted during testing on fuel oil. The flame was improved by increasing the atomization pressure slightly. A systematic study is needed to determine the cause of the buildup. When tuned properly and using good fuel oil no buildup should be observed in the Morrison tube.