VA Boiler
Safety Device Testing
AT
Fayetteville, AR
March and April, 2016

VISN: 16
VAMC: Fayetteville, AR
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1. Introduction

This report details the results of the steam generation system safety device testing conducted at the Fayetteville VAMC in VISN 16. Tests were conducted for the Plant Devices and for One of the Steam Boilers (Boiler No. 2) on March 15-17, 2016 as part of BEI's contract with the VA (Contract Number VA255-15-Q-0762). Boilers 1 and 3 were tested on April 11-12, 2016 under a direct purchase order from the Fayetteville VA. This combined report is being submitted both to VACO, and to the Fayetteville VA.

The references for the testing include:
VHA Boiler Plant Safety Device Testing Manual, Third Edition
VHA Directive 2008-062 Boiler Plant Operations

The report considers the safety devices serving the plant as a whole, and those serving Boilers Number 1 through 4. Reported are: results of each safety device tested, comments and recommendations. Table 1 presents a summary of the Failed safety device testing results.

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. As this is a new installation, and has not yet been turned over to the VA for operation, it is recommended that all safety devices on this boiler be installed, adjusted and approved before completion of the installation contract.

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
* 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.

All tests reported herein were conducted in the presence of one or more employees of the facility, and in some cases the actual tests were conducted by VA personnel with BEI supervision. All noted safety device failures are listed briefly in the summary table, and more fully detailed 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.

3.1.1 Plant Device Failures	
Device	**Nature of Failure**
High Water Alarm on Condensate Tank	Wrong Device
High Water Alarm on Deaerator Tank	LOOP valves
Low Water Alarm on Deaerator Tank	Setpoint, LOOP valves
Deaerator Overflow Drain System	Isolation Valve must be LOOP (Lockable only in the Open Position)
Deaerator Steam Safety Valve	No NDT of tank
Dangerous Gas Monitoring in the Boiler Plant	Remote test plumbing for inaccessible sensors No Off-site alarm repeat. No Test Gases.

3.1.2 Boiler No. 1 Device Failures	
Device	**Nature of Failure**
Recycle Boiler Steam Pressure Limit Switch	Install actual switch
Non-Recycle Boiler Steam Pressure Limit Switch	Setpoint
Low Fuel Gas Pressure Cutoff Switch	Setpoint- points out inadequacy of Regulator
High Fuel Gas Pressure Cutoff Switch	Not plumbed correctly
Automatic Fuel Gas Solenoid Vent Valve Leak Test	Manual valve in Vent Line must be LOOP
Automatic Pilot Gas Solenoid Vent Valve Leak Test	Manual valve in Vent Line must be LOOP
Low Pressure Oil Fuel Cutoff Switch	Setpoint too low
High Pressure Oil Fuel Cutoff Switch	Setpoint too high Isolation Valve must be LOOP
Low Oil Atomizing Media Pressure Switch	Setpoint too low
Burner Management Programmer	No Stand-Alone BMS installed
Flame Scanner	Wrong Device Type
Low Fire Proving Switch	Not monitored by BMS
Forced Draft Damper Wide Open Proving Switch	Not monitored by BMS
Combustion Air Pressure Switch	Not Plumbed Correctly
Purge Airflow Proving Switch	Not plumbed correctly. Not monitored by BMS.
Forced Draft Motor Interlock Switch	Install split-core type.
Low Flue Gas Oxygen Cutout	Monitor only.
Liquid Relief Valve on Economizer	Not accessible

3.1.3 Boiler No. 2 Device Failures	
Device	**Nature of Failure**
Steam Safety Valves	Did not successfully lift second valve.
Recycle Boiler Steam Pressure Limit Switch	Install actual switch
High Fuel Gas Pressure Cutoff Switch	Not plumbed correctly
Automatic Fuel Gas Solenoid Vent Valve Leak Test	Manual valve in Vent Line must be LOOP
Automatic Pilot Gas Solenoid Vent Valve Leak Test	Valve leaks through. Manual valve in Vent Line must be LOOP
High Pressure Oil Fuel Cutoff Switch	Isolation Valve must be LOOP
Low Oil Atomizing Media Pressure Switch	Setpoint too low
Burner Management Programmer	No Stand-Alone BMS installed
Flame Scanner	Wrong Device Type
Low Fire Proving Switch	Not monitored by BMS
Forced Draft Damper Wide Open Proving Switch	Not monitored by BMS
Combustion Air Pressure Switch	Not Plumbed Correctly
Purge Airflow Proving Switch	Not plumbed correctly. Not monitored by BMS.
Forced Draft Motor Interlock Switch	Install split-core type.
Low Flue Gas Oxygen Cutout	Monitor only.

3.1.4 Boiler No. 3 Device Failures	
Device	**Nature of Failure**
Recycle Boiler Steam Pressure Limit Switch	Install actual switch
Non-Recycle Boiler Steam Pressure Limit Switch	Setpoint
Low Fuel Gas Pressure Cutoff Switch	Setpoint
High Fuel Gas Pressure Cutoff Switch	Not plumbed correctly
Automatic Fuel Gas Solenoid Vent Valve Leak Test	Manual valve in Vent Line must be LOOP
Proof-Of-Closure Switches-gas	Setpoint is at the absolute limit.
Automatic Pilot Gas Solenoid Vent Valve Leak Test	Manual valve in Vent Line must be LOOP
High Pressure Oil Fuel Cutoff Switch	Setpoint too high Isolation Valve must be LOOP
Low Oil Atomizing Media Pressure Switch	Setpoint too low
Burner Management Programmer	No Stand-Alone BMS installed
Flame Scanner	Wrong Device Type
Flame Failure Response Time	Cannot test due to High Gas Pressure Switch incorrect installation.
Low Fire Proving Switch	Not monitored by BMS
Forced Draft Damper Wide Open Proving Switch	Not monitored by BMS
Combustion Air Pressure Switch	Not Plumbed Correctly
Purge Airflow Proving Switch	Not plumbed correctly. Not monitored by BMS.
Forced Draft Motor Interlock Switch	Install split-core type.
Low Flue Gas Oxygen Cutout	Monitor only.
Liquid Relief Valve on Economizer	Not accessible

4. Safety Device Testing Results for Plant Support Equipment

4.1. 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: http://www.cfm.va.gov/cfm/TIL/spec / 235011.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/ SD232111-05.pdf
Failure rate of float types: 48% (BEI study of VA boiler plants).
Make and Model: McDonnell & Miller Float
Did it function properly: No
Comments: Wrong Device Type- must be conductivity Probe. Device did not activate an alarm.

4.2. 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: http://www.cfm.va.gov/cfm/TIL/spec / 235011.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/ SD232111-05.pdf
Failure rate of float types: 19% (BEI study of VA boiler plants).
Make and Model: McDonnell & Miller Float
Did it function properly: Yes
Comments: Activated at 1/3 of tank height. There is no isolation valve in the water column.

4.3. 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: http://www.cfm.va.gov/cfm/TIL/spec / 235011.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/ SD232111-06.pdf
Failure rate of float types: 59% (BEI study of VA boiler plants).
Make and Model: Warrick Probe
Did it function properly: No
Comments: The alarm setpoint is at approximately 1/3 of the tank height. This setpoint must be raised in order to have an allowable setpoint for the Low Water Alarm (4.4). Additionally, there are valves which can isolate the probe column from the tank. These valves must be made Lockable Only in the Open Position (LOOP) and kept locked open except for short periods of time when testing or maintenance are ongoing. During any such time, extreme caution must be taken to ensure that the correct water level in the Deaerator is maintained.

4.4. 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:
http://www.cfm.va.gov/cfm/TIL/spec / 235011.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/ SD232111-06.pdf
Failure rate of float types: 25% (BEI study of VA boiler plants.)
Make and Model: Warrick Probe
Did it function properly: No
Comments: Alarm activated at 1/5 of tank height. This setpoint must not be lower than 1/3 of the tank height. See note at 4.3 regarding LOOP isolation valves.

4.5. 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: http://www.cfm.va.gov/cfm/TIL/spec / 235011.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/ SD232111-06.pdf
Failure rate of float type overflow valves: 61% (BEI study of VA boiler plants.)
Make and Model: Warrick Probe with Triad electric Valve
Did it function properly: No
Comments: There is a manual valve in the overflow drain line, and this valve was found closed at the time of the testing. This valve must either be removed, or modified so as to be Lockable Only in the open Position- and then kept locked open.

4.6. 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 deaerator 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: http://www.cfm.va.gov/cfm/TIL/spec/232111.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD232111-02.pdf
Failure rate of deaerator safety valves: 82% (BEI study of VA boiler plants.)
Make and Model: Kunkle
Setpoint: 10 psig
DA maximum allowable working pressure (MAWP): 50 psig
DA operating pressure: 5 psig
Date of non-destructive test of DA tank welds: 2004- New Tank
Did it function properly: No.
Lift Pressure: N/A
Comments: Plant personnel have no record of a NDT for this tank. Valve was not tested.

4.7. 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: http://www.cfm.va.gov/cfm/TIL/spec/232111.doc, http://www.cfm.va.gov/cfm/TIL/spec/235011.doc
VA Standard Detail:http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD232111-02.pdf http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD232111-03.pdf
Failure rate of safety valves following PRVs: 56% (BEI study of VA boiler plants.)
Make and Model: Kunkle
Serving the Deaerator.
Setpoint: 15 psig
Upstream Pressure: 120 psig
Downstream Pressure: 5 psig
Safety Capacity: 10377
Bypass Capacity:
PRV Capacity:
Did it function properly: Yes
Lift Pressure: 18 psig
Reseat Pressure: 17 psig
Comments: Adequate. Pressure gage should be replaced.

4.8.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: 80% of regulated 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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Failure rate of propane system: 30% (BEI study of VA boiler plants.)
Did it function properly: Yes
Comments: Propane system functioned adequately. However, the system in use is a portable ("grill" tank and a flexible connection hose. The tank, and spares, are stored inside the Boiler House. Strong consideration should be given to installing a permanent, hard-piped system with a single (larger) tank outside the building.

4.9. 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: http://www.cfm.va.gov/cfm/TIL/spec/235011.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Failure rate of oil relief valves: 40% (BEI study of VA boiler plants.)
Make and Model: Kunkle
Setpoint: 100
Pump discharge pressure: 90 psig
Did it function properly: Yes.
Comments: Liquid Relief Valves performed properly.

4.10. 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 setpoints: 50 ppm carbon monoxide and 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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
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: Sensidyne Sensalert
Setpoint: CO 30ppm, CH4 10% LEL
Did it function properly: No
Comments: One CO and one Combustible Gas sensor are mounted overhead- and are inaccessible for testing or maintenance. One of these sensors has malfunctioned. It is recommended that this system be brought up to proper operating condition, and that the inaccessible sensors be equipped with Remote Testing collars, to allow providing test gas to the sensor from a safe location. Additionally, there is no Combustibles test gas available in the plant. Obtain a cylinder of 10% LEL Methane for testing these sensors.

4.11. 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 injure 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: http://www.cfm.va.gov/cfm/TIL/spec/237300.doc
VA Standard Detail: None.
Type of combustion air make-up system:
Make and model:
Did it function properly: N/A
Comments: There is adequate fixed opening in this facility for combustion air supply.

5. Safety Device Testing Results for Boiler No. 1

Table 5.1 Description of Boiler and Burner

Boiler # 1	
Manufacturer:	Cleaver Brooks
Model:	CB 200-250-150
Serial #: National Board No.:	OL 103245
Typical Operating Pressure:	120 psig / 85 psig
Date of Manufacture:	2004
Design Pressure/Capacity:	150 psig
Burner	
Manufacturer:	Cleaver Brooks
Fuels:	Natural Gas and #2 FO

5.1. Boiler Water Level Control

5.1.1. 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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-01.pdf
Failure rate of LWCO: 14% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks Levelmaster
Did it function properly: Yes
Comments: The switch activated with water level 2.5 inches from the bottom of the gage glass.

5.1.2. 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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-01.pdf
Failure rate of ALWCO: 32% (BEI study of VA boiler plants.)
Make and Model: Warrick Probe
Did it function properly: Yes
Comments: The switch activated with water level 1.25 inch from the bottom of the gage glass.

5.1.3. **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 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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-01.pdf
Failure rate of LWA device: 11% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks Levelmaster
Did it function properly: Yes
Comments: The switch activated with water level 3.0 inches from the bottom of the gage glass.

5.1.4. **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). www.va.gov/facmgt/standard/
VA Standard Details: SD235239-1.pdf, SD235233-01.pdf. www.va.gov/facmgt/standard/
Failure rate of HWA device: 7% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks Levelmaster
Did it function properly: Yes
Comments: The switch activated with water level 2.5 inches from the top of the gage glass.

5.2. Pressure Containment

5.2.1. **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. A minimum of 5 psig should be allowed 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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD232111-02.pdf
Failure rate of boiler SV: 33% (BEI study of VA boiler plants.)
Make and Model: Kunkle
Setpoint: SV#1—Kunkle 135 psig (3848 lbs/hr) SV# 2--Kunkle 140 psig (6195 lbs/hr).
Did it function properly: No
Comments: The first valve lift pressure was 142 psig, more than 5% above the setpoint. The second valve lift pressure was 145 psig, approximately 4% above the setpoint. The drains for the safety valves should be run separately.

5.2.2. **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 over-pressuring 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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-01.pdf
Failure rate of operating limit switch: 29% (BEI study of VA boiler plants.)
Make and Model: Transducer connected to Fireye Nexus system
Setpoint: 128 psig
Did it function properly: No.
Comments: Recommend adding a second, dedicated steam pressure cutoff switch.

5.2.3. **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 over-pressuring 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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details: http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-01.pdf
Failure rate of non-recycling limit switch: 36% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Setpoint: 135 psig
Did it function properly: No.
Comments: Set pressure of this switch is the same as the setpoint of the first Steam Safety Valve.

5.3. Fuel Train Safety Devices – Natural Gas Section

5.3.1. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Failure rate of LPFCS: 46% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Fuel train operating pressure: 0.8 psig
Setpoint: 0.61 psig
Did it function properly: No.
Comments: This switch is close-mounted to the body of the upstream Automatic Gas Fuel Shutoff Valve. The "Dip" in gas pressure at lightoff is to pressures as low as 0.65 psig, where the required minimum setpoint for the regulated gas pressure is 0.64 psig (80%). Raising the setpoint to the required level would make lighting the boiler a difficult proposition. The performance of the Gas Regulator to comply with the appropriate VA Specifications must be addressed to correct this failure.

5.3.2. **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:
http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Failure rate of HPFCS: 43% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Fuel train operating pressure: 0.8 psig
Setpoint: unknown
Did it function properly: No
Comments: This switch is close-mounted to the body of the downstream Automatic Gas Fuel Shutoff Valve, and is not plumbed to be testable.

5.3.3. **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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak failure rate of automatic fuel shut off valves: Data not available.
Make and Model: Honeywell
Did it function properly: Yes.
Comments: No leaks were detected.

5.3.4. **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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak Failure rate of vent valves: 23% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks
Did it function properly: No.
Comments: The Solenoid valve did not leak. The manual valve in the vent line must be made Lockable Only in the Open Position, and kept locked except during leak testing.

5.3.5. **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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
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: Honeywell
Did it function properly: Yes.
Comments: Functions as intended.

5.3.6. **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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak failure rate of automatic fuel shut off valves: Data not available.
Make and Model: ASCO
Did it function properly: Yes
Comments: No leaks were detected.

5.3.7. **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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak Failure rate of vent valves: Not available.
Make and Model: ASCO
Did it function properly: No.
Comments: The Solenoid valve did not leak. The manual valve in the vent line must be made Lockable Only in the Open Position, and kept locked except during leak testing.

5.4. Fuel Train Safety Devices – #2 Oil Section

5.4.1. **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 fuel service.
VA Master Specification section: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Failure rate of LPFCS: 46% (BEI study of VA boiler plants.)
Make and Model: Honeywell

Fuel train operating pressure: 30 psig
Setpoint: 23 psig
Did it function properly: No.
Comments: The switch setpoint is too low (less than 90% of the regulated oil pressure). This device has too much deadband (offset between make and break pressures) to function correctly at this oil pressure. Replace with an appropriate switch.

5.4.2. **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 fuel service.
VA Master Specification section:
http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Failure rate of HPFCS: 43% (BEI study of VA boiler plants.)
Make and Model: Mercoid Snap Switch
Fuel train operating pressure: 53 psig
Setpoint: 63 psig
Did it function properly: No.
Comments: The switch setpoint is too high (greater than 110% of the regulated oil pressure). This device has too much deadband (offset between make and break pressures) to function correctly at this oil pressure. Replace with an appropriate switch. There is an isolation valve between this switch and the fuel oil line to the burner. This valve must be made lockable only in the open position (LOOP), and kept locked except during testing.

5.4.3. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Failure rate of LAMPS: 32% (BEI study of VA boiler plants.)

Make and Model: Cleaver Brooks
Atomizing train operating pressure: 11.6 psig (at purge, 14.5 at low fire)
Setpoint: 4.45 psig
Did it function properly: No.
Comments: Setpoint is too low (below 80%.)

5.4.4. **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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Leak Failure rate of automatic fuel shut off valves: Data not available.
Make and Model: Asco
Did it function properly: Yes.
Comments: No leaks were detected.

5.4.5. **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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
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: Asco
Did it function properly: Yes
Comments: Functioned correctly.

5.4.6. **Burner Position Switch**
Purpose: Electrical switch that proves that oil gun is in proper position for firing. Generally furnished only on Cleaver-Brooks burners.
Potential hazard from failure of switch: Attempting to fire with the oil gun improperly positioned may result in oil and atomizing media being sprayed into the boiler room. This is explosive if there is an ignition source.
Recommended type of position switch: Mechanical contact arm that is actuated by presence of oil gun in proper position.
VA Master Specification section: None.
VA Standard Detail: None.
Failure rate of position switches: 0%. (BEI study of VA boiler plants.)
Make and Model: Square-D
Did it function properly: Yes
Comments: Functioned correctly.

5.5. 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: Fireye Nexus
Is it acceptable: No.
Comments: This system combines combustion control and Burner Safety features into a single device. Additionally, the safety circuits for pre-purge and low-fire proving do not operate correctly. A separate (true) Boiler Safety system must be installed, independent from the combustion control system.

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.
VA Master Specification section: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
Scanner make and model: Fireye 9007 (IR)
Is it acceptable: No
Comments: It is recommended that this device be replaced with a Self-Checking, UV Flame Scanner, meeting the current VA requirements. Some modification of the burner front may be necessary to achieve proper operation.

5.5.1. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of flame scanners: 7% (BEI study of VA boiler plants.)
Timing: 4 sec
Did it function properly: Yes.
Comments: Worked as required.

5.5.2. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of scanner seeing ignition spark: 7%. (BEI study of VA boiler plants.)
Make and model: Fireye 9007 IR
Did it function properly: Yes
Comments: Worked as required.

5.5.3. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of PTFI: 4% (BEI study of VA boiler plants.)
Timing: 10 sec.
Did it function properly: Yes
Comments: Worked as required.

5.5.4. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of MTFI: 18% (BEI study of VA boiler plants.)
Timing: 13 sec.
Did it function properly: Yes
Comments: Worked as required.

5.5.5. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
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: 18 sec.
Time in high fire: 45 sec.
Time from high to low fire: 18 sec.
Total equivalent time in high purge: 63
Did it function properly: YES
Comments: Adequate Purge time is provided.

5.5.6. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of proving switch: 18% (BEI study of VA boiler plants.)
Make and model: Omron (all three) Button switches
Did it function properly: (Air: No, Gas: No, Oil: No)
Comments: All three switches are wired in series, and were found to be wired into the Nexus controller. It appears that the controller is not reading these switches even though they are wired in. This situation would best be rectified by the installation of a proper Burner Safety system as discussed above in 5.5.

5.5.7. **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 10% 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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc

VA Standard Detail: None.
Failure rate of proving switch: 39% (BEI study of VA boiler plants.) (Also called "vane interlock switch.)
Make and model: Omron
Did it function properly: No.
Comments: This switch was found to be wired into the Nexus controller, but the controller response is not affected by the action of this switch. This situation would best be rectified by the installation of a proper Burner Safety system as discussed above in 5.5.

5.5.8. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of combustion airflow switch: 36% (BEI study of VA boiler plants.)
Make and model: Honeywell
Location of sensing lines: Fan Inlet to Windbox
Switch setpoint: N/A inwc
Minimum delta P: N/A inwc
Maximum delta P: N/A inwc
Did it function properly: No
Comments: This device is not installed in agreement with the VA Requirements, and therefore cannot be tested in an acceptable manner. The installation must be modified to conform with the VA Boiler Plant Safety Device Testing Manual (3rd Edition).

5.5.9. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of pre-purge airflow switch: 43% (BEI study of VA boiler plants.)
Make and model: Cleveland
Location of sensing lines: Burner Throat to boiler outlet (before Catalyst, economizer and outlet damper)

Switch setpoint: N/A inwc
Maximum delta P: N/A inwc
Did it function properly: No.
Comments: This device is not plumbed to see the correct signal (High Pressure side is plumbed to the Windbox, upstream of the FD Damper). Additionally, the action of this switch has no effect on the controller. This situation would best be rectified by the installation of a proper Burner Safety system as discussed above in 5.5.

5.5.10. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of interlock: 15% (BEI study of VA boiler plants.)
Type of interlock: Solid Core Current Transformer Switches
Did it function properly: No
Comments: These devices can only be tested by raising the current setpoint. Recommend replacing with split-core type devices which will allow proper testing.

5.5.11. **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:
http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Failure rate of interlock: 57% (BEI study of VA boiler plants. In many cases, the switches are not present.)
Make and model: Honeywell
Regulated Pilot Gas Pressure: 2 inwc
Low pilot cutout setpoint: 1.6 inwc
Did it function properly: Yes.
Comments: Functioned correctly.

5.5.12 **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of interlock/alarm: 80%. (BEI study of VA boiler plants.)
Make and model: Fireye Nexus (Monitor Only)
Setpoint: N/A
Did it function properly: No.
Comments: The current system incorporates neither an audible alarm nor an interlock. This deficiency could probably best be corrected with a revision of the controls and safety systems on this boiler, as discussed in section 5.5.

5.5.13 **Liquid Relief Valve on Economizer**
Purpose: Protects economizer from damage due to over-pressure.
Recommended setpoint: Less than Manufacturer's rated pressure for the economizer tubes.
Hazard from failure of the interlock: Rupture of economizer pressure system during boiler operation with high exhaust stack temperatures and low feedwater flows.
Recommended type of device: Liquid relief valve sized for appropriate pressure and capacity (Per economizer's manufacturer's recommendations) and designed to shut tight.
VA Master Specification section: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD232111-08.pdf
Failure rate of monitoring system: Data not available.
Make and model: Unknown
Setpoint: Unknown
Did it function properly: No
Comments: The Economizer is inaccessible under normal circumstances. The tag data should be made available in an accessible location, and the relief valve and appropriate isolation valves and test ports installed near floor level- or else an extensive elevated walkway should be installed.

6. Safety Device Testing Results for Boiler No. 2

Table 6.1 Description of Boiler and Burner

Boiler # 2	
Manufacturer:	Cleaver Brooks
Model:	CB200-250-150
Serial #: National Board No.:	OL103246
Typical Operating Pressure:	120 psig
Date of Manufacture:	2004
Design Pressure/Capacity:	150 psig
Burner	
Manufacturer:	Cleaver Brooks
Fuels:	Natural Gas and #2 FO

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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235233-01.pdf
Failure rate of LWCO: 14% (BEI study of VA boiler plants.)
Make and Model: CB Levelmaster
Did it function properly: Yes
Comments: Switch activated with 1.5 inches of water visible in the gage glass.

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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235233-01.pdf
Failure rate of ALWCO: 32% (BEI study of VA boiler plants.)
Make and Model: Warrick Probe
Did it function properly: Yes
Comments: Switch activated with 1.5 inches of water visible in the gage glass. Recommend adding separation to the setpoints of these two devices. Additionally, the probe (Auxiliary) appears to activate slightly before the Levelmaster (Primary)

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 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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235233-01.pdf
Failure rate of LWA device: 11% (BEI study of VA boiler plants.)
Make and Model: CB Levelmaster
Did it function properly: Yes
Comments: Switch activated with 2.5 inches of water visible in the gage glass.

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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235233-01.pdf
Failure rate of HWA device: 7% (BEI study of VA boiler plants.)
Make and Model: CB Levelmaster
Did it function properly: Yes
Comments: Switch activated with 1.5 inches visible above the water level in the gage glass.

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. A minimum of 5 psig should be allowed 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:http://www.cfm.va.gov/cfm/TIL/spec/235233.doc

VA Standard Details:

http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD232111-03.pdf

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

Make and Model: Kunkle

Setpoint: SV#1—135 psig (3848 lbs/hr) SV# 2-- 140 psig (6195 lbs/hr).

Did it function properly: No.

Comments: The boiler cycled off before reaching the lift pressure of the second safety valve. A better documented procedure (Site Specific Testing Procedure) is needed for properly adjusting the steam pressure setpoints in the Fireye Nexus system.

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 over-pressuring 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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc

VA Standard Details:

http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235233-01.pdf

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

Make and Model: Fireye/Nexus

Setpoint: 128 psig

Did it function properly: No.

Comments: Recommend adding a second, dedicated steam pressure cutoff switch.

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 over-pressuring 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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235233-01.pdf
Failure rate of operating limit switch: 29% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Setpoint: 130 psig
Did it function properly: Yes.
Comments: Functioned as intended at 129psig.

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Failure rate of LPFCS: 46% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Fuel train operating pressure: 0.9 psig
Setpoint: less than 0.4 psig as found. Adjusted to 0.72 psig.
Did it function properly: Yes.
Comments: Functions correctly after adjustment.

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Failure rate of HPFCS: 43% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Fuel train operating pressure: 0.9 psig
Setpoint: N/T
Did it function properly: No.
Comments: This device is not installed in accordance with VA requirements, and cannot therefore be tested by the proper procedure.

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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak failure rate of automatic fuel shut off valves: Data not available.
Make and Model: Honeywell
Did it function properly: Yes
Comments: Valve performance is acceptable.

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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
VA Standard Detail:http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak Failure rate of vent valves: 23% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks
Did it function properly: No.
Comments: No leaks were detected. The manual Valve in the vent line must be modified to comply with the Lockable Only in the Open Position requirements, and a lock must be installed.

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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
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: Honeywell
Did it function properly: Yes.
Comments: Functioned correctly within requirements.

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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
VA Standard Detail:http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak failure rate of automatic fuel shut off valves: Data not available.
Make and Model: ASCO
Did it function properly: Yes
Comments: No leaks detected.

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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak Failure rate of vent valves: Not available.
Make and Model: ASCO
Did it function properly: No.
Comments: The automatic Vent Valve leaks through. The manual Valve in the vent line must be modified to comply with the Lockable Only in the Open Position requirements, and a lock must be installed.

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 fuel service.
VA Master Specification section: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Failure rate of LPFCS: 46% (BEI study of VA boiler plants.)

Make and Model: Honeywell
Fuel train operating pressure: 28.5 psig
Setpoint: 25 psig
Did it function properly: Yes.
Comments: The installed switch is designed for operating pressures of up to 150psig. A lower maximum pressure range switch would provide more reliable operation at the current operating oil pressures.

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 fuel service.
VA Master Specification section: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Failure rate of HPFCS: 43% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Fuel train operating pressure: 29 psig
Setpoint: 125 psig as found. Adjusted to 32psig
Did it function properly: No.
Comments: The switch was adjusted to an acceptable setpoint, but is of a design suited to much higher pressure operation. It is recommended that this switch be replaced with one having a range better suited to the current operating oil pressures. The isolation valve must be made Lockable Only in the Open Position, and kept locked open,

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Failure rate of LAMPS: 32% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks
Atomizing train operating pressure: 14 psig (Purge)

Setpoint: 9.5 psig
Did it function properly: No
Comments: This switch has too much deadband (separation between the minimum pressure required for it to "make", and the "break" setpoint. With the 14 psig level, the minimum allowable setpoint is 11.2 psig. When the switch is adjusted to the point that the pressure at Purge (14psig) is just adequate to cause the switch to "Make" the circuit, the trip point is approximately 9.5 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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
VA Standard Detail: http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Leak Failure rate of automatic fuel shut off valves: Data not available.
Make and Model: Asco
Did it function properly: Yes
Comments: No leaks were detected.

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: http://www.cfm.va.gov/cfm/TIL/spec/235233.doc
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: Asco
Did it function properly: Yes
Comments: Functioned correctly within requirements.

6.4.6. **Burner Position Switch**
Purpose: Electrical switch that proves that oil gun is in proper position for firing. Generally furnished only on Cleaver-Brooks burners.
Potential hazard from failure of switch: Attempting to fire with the oil gun improperly positioned may result in oil and atomizing media being sprayed into the boiler room. This is explosive if there is an ignition source.
Recommended type of position switch: Mechanical contact arm that is actuated by presence of oil gun in proper position.
VA Master Specification section: None.
VA Standard Detail: None.
Failure rate of position switches: 0%. (BEI study of VA boiler plants.)
Make and Model: Square-D
Did it function properly: Yes
Comments: Functioned correctly.

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: Fireye Nexus
Is it acceptable: No
Comments: This system combines combustion control and Burner Safety features into a single device. Additionally, the safety circuits for pre-purge and low-fire proving do not operate correctly. A separate (true) Boiler Safety system must be installed, independent from the combustion control system.

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.
VA Master Specification section: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
Scanner make and model: Fireye 9007 (IR)
Is it acceptable: No
Comments: It is recommended that this device be replaced with a Self-Checking, UV Flame Scanner, meeting the current VA requirements. Some modification of the burner front may be necessary to achieve proper operation.

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of flame scanners: 7% (BEI study of VA boiler plants.)
Timing: 2.5 sec
Did it function properly: Yes.
Comments: Response time is adequate.

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of scanner seeing ignition spark: 7%. (BEI study of VA boiler plants.)
Make and model: Fireye 9007
Did it function properly: Yes
Comments: IR Scanners do not detect spark.

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of PTFI: 4% (BEI study of VA boiler plants.)
Timing: 10 sec.
Did it function properly: Yes
Comments: Worked as required.

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of MTFI: 18% (BEI study of VA boiler plants.)
Timing: 14 seconds
Did it function properly: Yes
Comments: Functioned correctly within the allowable time.

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
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: 17 sec.
Time in high fire: 30 sec.
Time from high to low fire: 25 sec.
Total equivalent time in high purge: 51
Did it function properly: YES
Comments: Adequate Purge time appears to be provided.

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of proving switch: 18% (BEI study of VA boiler plants.)
Make and model: Omron (all three) Button switches
Did it function properly: (Air: No, Gas: No, Oil: No)
Comments: All three switches are wired in series, but were found to be not wired into the Nexus controller. It appears that the controller is not reading these switches even when they are wired in (from observations on the other two boilers.) This situation would best be rectified by the installation of a proper Burner Safety system as discussed above in 6.5.

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 10% 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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of proving switch: 39% (BEI study of VA boiler plants.) (Also called "vane interlock switch.)
Make and model: Omron

Did it function properly: No.
Comments: This switch was found to be not wired into the Nexus controller. It appears that the controller is not reading this switch even when it is wired in (from observations on the other two boilers.) This situation would best be rectified by the installation of a proper Burner Safety system as discussed above in 6.5.

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of combustion airflow switch: 36% (BEI study of VA boiler plants.)
Make and model: Cleveland
Location of sensing lines: Fan Inlet to Windbox
Switch setpoint: N/A inwc
Minimum delta P: N/A inwc
Maximum delta P: N/A inwc
Did it function properly: No
Comments: This device is not installed in agreement with the VA Requirements, and therefore cannot be tested in an acceptable manner. The installation must be modified to conform with the VA Boiler Plant Safety Device Testing Manual (3rd Edition).

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of pre-purge airflow switch: 43% (BEI study of VA boiler plants.)
Make and model: Cleveland
Location of sensing lines: Burner Throat to boiler outlet (before Catalyst, economizer and outlet damper)
Switch setpoint: N/A inwc
Maximum delta P: N/A inwc
Did it function properly: No.

Comments: This device is not plumbed to see the correct signal (High Pressure side is plumbed to the Windbox, upstream of the FD Damper). Additionally, this switch was found to be not wired into the Nexus controller. It appears that the controller is not reading this switch even when it is wired in (from observations on the other two boilers.) This situation would best be rectified by the installation of a proper Burner Safety system as discussed above in 6.5.

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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of interlock: 15% (BEI study of VA boiler plants.)
Type of interlock: Solid Core Current Transformer Switches
Did it function properly: No
Comments: These devices can only be tested by disconnecting, rerouting and reconnecting the three power conductors to the FD Fan Motor, one at a time, and attempting to start the boiler with the core bypassed. The preferred system utilizes split-core transformers that can be tested by unlatching an individual unit with the fan running- to verify shutdown occurs

6.5.11. 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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Failure rate of interlock: 57% (BEI study of VA boiler plants. In many cases, the switches are not present.)
Make and model: Honeywell
Regulated Pilot Gas Pressure: 2 inwc
Low pilot cutout setpoint: 1.6 inwc
Did it function properly: yes
Comments: Functioned Correctly

6.5.12 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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc

VA Standard Detail: None.

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

Make and model: Fireye Nexus (Monitor Only)

Setpoint: N/A

Did it function properly: No.

Comments: The current system incorporates neither an audible alarm nor an interlock. This deficiency could probably best be corrected with a revision of the controls and safety systems on this boiler, as discussed in section 6.5.

7. Safety Device Testing Results for Boiler No. 3

Table 7.1 Description of Boiler and Burner

Boiler # 3	
Manufacturer:	Cleaver Brooks
Model:	CB200-250-150
Serial #: National Board No.:	OL103247
Typical Operating Pressure:	120 psig
Date of Manufacture:	2004
Design Pressure/Capacity:	150 psig
Burner	
Manufacturer:	Cleaver Brooks
Fuels:	Natural Gas and #2 FO

7.1. Boiler Water Level Control

7.1.1. 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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-01.pdf
Failure rate of LWCO: 14% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks Levelmaster
Did it function properly: Yes
Comments: The switch activated with water level 2 inches from the bottom of the gage glass.

7.1.2. 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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-01.pdf
Failure rate of ALWCO: 32% (BEI study of VA boiler plants.)
Make and Model: Warrick Probe
Did it function properly: Yes
Comments: The switch activated with water level 1 inch from the bottom of the gage glass.

7.1.3. **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 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:http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-01.pdf
Failure rate of LWA device: 11% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks Levelmaster
Did it function properly: Yes
Comments: The switch activated with water level 2.5 inches from the bottom of the gage glass.

7.1.4. **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). www.va.gov/facmgt/standard/
VA Standard Details: SD235239-1.pdf, SD235233-01.pdf. www.va.gov/facmgt/standard/
Failure rate of HWA device: 7% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks Levelmaster
Did it function properly: Yes
Comments: The switch activated with water level 2.5 inch from the top of the gage glass.

7.2. Pressure Containment

7.2.1. **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. A minimum of 5 psig should be allowed 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:http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD232111-02.pdf
Failure rate of boiler SV: 33% (BEI study of VA boiler plants.)
Make and Model: Kunkle
Setpoint: SV#1—Kunkle 130 psig (3848 lbs/hr) SV# 2-- Kunkle 135 psig (6195 lbs/hr).
Did it function properly: Yes.
Comments: Functioned correctly.

7.2.2. **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 over-pressuring 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:http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-01.pdf
Failure rate of operating limit switch: 29% (BEI study of VA boiler plants.)
Make and Model: Fireye/Nexus
Setpoint: 128 psig
Did it function properly: No.
Comments: Recommend adding a second, dedicated steam pressure cutoff switch.

7.2.3. **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 over-pressuring 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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Details:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-01.pdf
Failure rate of non-recycling limit switch: 36% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Setpoint: 130
Did it function properly: Yes.
Comments: The switch functioned as intended.

7.3. Fuel Train Safety Devices – Natural Gas Section

7.3.1. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Failure rate of LPFCS: 46% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Fuel train operating pressure: 0.83 psig
Setpoint: 0.5 psig
Did it function properly: No.
Comments: Setpoint must be raised to 80% or more of the low fire regulated pressure.

7.3.2. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Failure rate of HPFCS: 43% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Fuel train operating pressure: 0.83 psig
Setpoint: N/T
Did it function properly: No.
Comments: This device is not installed in accordance with VA requirements, and cannot therefore be tested by the proper procedure.

7.3.3. **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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail: http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak failure rate of automatic fuel shut off valves: Data not available.
Make and Model: Honeywell
Did it function properly: Yes.
Comments: No leaks were detected.

7.3.4. **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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak Failure rate of vent valves: 23% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks
Did it function properly: No.
Comments: No leaks were detected. The manual Valve in the vent line must be modified to comply with the Lockable Only in the Open Position requirements, and a lock must be installed.

7.3.5. **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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
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: Honeywell
Did it function properly: Caution.
Comments: The occurrence of switch-break and gas-flow are (as nearly as can be determined) simultaneous. Per the specifications from Honeywell, the Proof of Closure switches on these valves are not adjustable. These must be closely monitored (by testing to the correct method) to ensure that there is no further degradation of the system. If the point is reached where gas flow can occur while the Proof of Closure switch remains "made", the valves must be replaced.

7.3.6. **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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak failure rate of automatic fuel shut off valves: Data not available.
Make and Model: ASCO
Did it function properly: Yes
Comments: No leaks detected.

7.3.7. **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: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Leak Failure rate of vent valves: Not available.
Make and Model: ASCO
Did it function properly: No.
Comments: The automatic Vent Valve does not leak. The manual Valve in the vent line must be modified to comply with the Lockable Only in the Open Position requirements, and a lock must be installed.

7.4. Fuel Train Safety Devices – #2 Oil Section

7.4.1. **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 fuel service.
VA Master Specification section: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Failure rate of LPFCS: 46% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Fuel train operating pressure: 34.5 psig
Setpoint: 31 psig
Did it function properly: Yes.
Comments: Functioned as intended.

7.4.2. **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 fuel service.
VA Master Specification section: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Failure rate of HPFCS: 43% (BEI study of VA boiler plants.)
Make and Model: Honeywell
Fuel train operating pressure: 36 psig
Setpoint: 42psig
Did it function properly: No.
Comments: An attempt was made to adjust this switch to an acceptable setpoint, but is of a design suited to much higher pressure operation, and has too much deadband for the regulated oil pressure. The indicated setpoint differs significantly from the actual trip pressure (approximately 25 psig difference.) It is recommended that this switch be replaced with one having a range better suited to the current operating oil pressures. The isolation valve must be made Lockable Only in the Open Position, and kept locked open.

7.4.3. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Failure rate of LAMPS: 32% (BEI study of VA boiler plants.)
Make and Model: Cleaver Brooks
Atomizing train operating pressure: 11.5 psig (at purge, 12.6 at low fire)
Setpoint: 7 psig
Did it function properly: No.
Comments: Setpoint is too low.

7.4.4. **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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-04.pdf
Leak Failure rate of automatic fuel shut off valves: Data not available.
Make and Model: Asco
Did it function properly: Yes.
Comments: No leaks detected.

7.4.5. **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:
http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
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: Asco
Did it function properly: Yes
Comments: Functioned correctly.

7.4.6. **Burner Position Switch**
Purpose: Electrical switch that proves that oil gun is in proper position for firing. Generally furnished only on Cleaver-Brooks burners.
Potential hazard from failure of switch: Attempting to fire with the oil gun improperly positioned may result in oil and atomizing media being sprayed into the boiler room. This is explosive if there is an ignition source.
Recommended type of position switch: Mechanical contact arm that is actuated by presence of oil gun in proper position.
VA Master Specification section: None.
VA Standard Detail: None.
Failure rate of position switches: 0%. (BEI study of VA boiler plants.)

Make and Model: Square-D
Did it function properly: Yes
Comments: Functioned correctly.

7.5. 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: Fireye Nexus
Is it acceptable: No
Comments: This system combines combustion control and Burner Safety features into a single device. Additionally, the safety circuits for pre-purge and low-fire proving do not operate correctly. A separate (true) Boiler Safety system must be installed, independent from the combustion control system.

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.
VA Master Specification section: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
Scanner make and model: Fireye 9007 (IR)
Is it acceptable: No
Comments: It is recommended that this device be replaced with a Self-Checking, UV Flame Scanner, meeting the current VA requirements. Some modification of the burner front may be necessary to achieve proper operation.

7.5.1. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of flame scanners: 7% (BEI study of VA boiler plants.)
Timing: Unknown
Did it function properly: No.
Comments: Could not be tested by the approved method. The High Gas Pressure Switch trips the boiler offline before the Flame Scanner responds.

7.5.2. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of scanner seeing ignition spark: 7%. (BEI study of VA boiler plants.)
Make and model: Fireye IR
Did it function properly: Yes
Comments: Worked as required.

7.5.3. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of PTFI: 4% (BEI study of VA boiler plants.)
Timing: 10 sec.
Did it function properly: Yes
Comments: Worked as required.

7.5.4. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Details: None.
Failure rate of MTFI: 18% (BEI study of VA boiler plants.)
Timing: 13.5 sec.
Did it function properly: Yes
Comments: Worked as required.

7.5.5. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
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: 20 sec.
Time in high fire: 45 sec.
Time from high to low fire: 20 sec.
Total equivalent time in high purge: 65
Did it function properly: YES
Comments: Adequate Purge time is provided.

7.5.6. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of proving switch: 18% (BEI study of VA boiler plants.)
Make and model: Omron (all three) Button switches
Did it function properly: (Air: No, Gas: No, Oil: No)
Comments: All three switches are wired in series, but were found to be not wired into the Nexus controller. It appears that the controller is not reading these switches even when they are wired in (from observations on Boiler 1.) This situation would best be rectified by the installation of a proper Burner Safety system as discussed above in 7.5.

7.5.7. **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 10% 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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of proving switch: 39% (BEI study of VA boiler plants.) (Also called "vane interlock switch.)
Make and model: Omron
Did it function properly: No.
Comments: This switch was found to be not wired into the Nexus controller. It appears that the controller is not reading this switch even when it is wired in (from observations Boiler 1.) This situation would best be rectified by the installation of a proper Burner Safety system as discussed above in 7.5.

7.5.8. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of combustion airflow switch: 36% (BEI study of VA boiler plants.)
Make and model: Cleveland

Location of sensing lines: Fan Inlet to Windbox
Switch setpoint: N/A inwc
Minimum delta P: N/A inwc
Maximum delta P: N/A inwc
Did it function properly: No
Comments: This device is not installed in agreement with the VA Requirements, and therefore cannot be tested in an acceptable manner. The installation must be modified to conform with the VA Boiler Plant Safety Device Testing Manual (3rd Edition).

7.5.9. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of pre-purge airflow switch: 43% (BEI study of VA boiler plants.)
Make and model: Cleveland
Location of sensing lines: Burner Throat to boiler outlet (before Catalyst, economizer and outlet damper)
Switch setpoint: N/A inwc
Maximum delta P: N/A inwc
Did it function properly: No.
Comments: This device is not plumbed to see the correct signal (High Pressure side is plumbed to the Windbox, upstream of the FD Damper). Additionally, this switch was found to be not wired into the Nexus controller. It appears that the controller is not reading this switch even when it is wired in (from observations on Boiler 1.) This situation would best be rectified by the installation of a proper Burner Safety system as discussed above in 7.5.

7.5.10. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of interlock: 15% (BEI study of VA boiler plants.)
Type of interlock: Current Transformer Switches

Did it function properly: No
Comments: These devices can only be tested by disconnecting, rerouting and reconnecting the three power conductors to the FD Fan Motor, one at a time, and attempting to start the boiler with the core bypassed, or by changing the setpoint while the boiler is running. The preferred system utilizes split-core transformers that can be tested by unlatching an individual unit with the fan running- to verify shutdown occurs

7.5.11. **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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD235239-03.pdf
Failure rate of interlock: 57% (BEI study of VA boiler plants. In many cases, the switches are not present.)
Make and model: Honeywell
Regulated Pilot Gas Pressure: 4.5 inwc
Low pilot cutout setpoint: 3.8 inwc
Did it function properly: Yes.
Comments: This switch functioned correctly.

7.5.12 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: http://www.cfm.va.gov/cfm/TIL/spec/230911.doc
VA Standard Detail: None.
Failure rate of interlock/alarm: 80%. (BEI study of VA boiler plants.)
Make and model: Fireye Nexus (Monitor Only)
Setpoint: N/A
Did it function properly: No.
Comments: The current system incorporates neither an audible alarm nor an interlock. This deficiency could probably best be corrected with a revision of the controls and safety systems on this boiler, as discussed in section 7.5.

7.5.13 **Liquid Relief Valve on Economizer**
Purpose: Protects economizer from damage due to over-pressure.
Recommended setpoint: Less than Manufacturer's rated pressure for the economizer tubes.
Hazard from failure of the interlock: Rupture of economizer pressure system during boiler operation with high exhaust stack temperatures and low feedwater flows.
Recommended type of device: Liquid relief valve sized for appropriate pressure and capacity (Per economizer's manufacturer's recommendations) and designed to shut tight.
VA Master Specification section: http://www.cfm.va.gov/cfm/TIL/spec/235239.doc
VA Standard Detail:
http://www.cfm.va.gov/cfm/til/sDetail/Div23HVACSteam/SD232111-08.pdf
Failure rate of monitoring system: Data not available.
Make and model: Unknown
Setpoint: Unknown
Did it function properly: No
Comments: The Economizer is inaccessible under normal circumstances. The tag data should be made available in an accessible location, and the relief valve and appropriate isolation valves and test ports installed near floor level- or else an extensive elevated walkway should be installed.