HARSCO INDUSTRIAL
Patterson-Kelley

MACH® GAS-FIRED BOILER

C1500 & C2000

C.S.A Design-Certified
Complies with ANSI Z21.13/CSA 4.9
Gas-Fired Low Pressure Steam and Hot Water Boilers

ASME Code, Section IV
Certified by Patterson-Kelley

C.S.A Design-Certified
Complies with ANSI Z21.13/CSA 4.9
Gas-Fired Low Pressure Steam and Hot Water Boilers

Installation Date: _____

Harsco Industrial, Patterson-Kelley
100 Burson Street,
East Stroudsburg, PA 18301
Telephone: (877) 728-5351,
Facsimile: (570) 476-7247
www.harscopk.com

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INSTALLATION & OWNER'S MANUAL
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⚠ WARNING

If the information in this manual is not followed exactly, a fire or explosion may result causing property damage, personal injury or loss of life.

Do not store or use gasoline or other flammable vapors or liquids in the vicinity of this or any other appliance.

Installation and service must be performed by a qualified installer, service agency, or the gas supplier.

⚠ WARNING It is essential to read, understand, and follow the recommendations of this manual before installing, operating, or servicing this equipment.

⚠ WARNING Installation and service must be performed by a qualified and knowledgeable individual who has been trained on the MACH® boiler. The same features which permit this boiler to achieve high-efficiency performance make it unlike most other boilers of this general size, so it is important to understand how this boiler operates.

What to do if you smell gas:

- Do not try to light any appliance.
- Do not touch any electrical switch; do not use any phone in your building.
- Immediately call your gas supplier from a neighbor's phone. Follow the gas supplier's instructions.
- If you cannot reach your gas supplier, call the fire department.

1.0 INTRODUCTION

The MACH® Gas-Fired Boiler is fully modulating using a variable speed combustion blower, sophisticated microprocessor controls, modulating gas safety shut off / control valves and a unique aluminum alloy heat exchanger capable of operating in a fully condensing mode to provide maximum efficiency in a minimum amount of space. The high-quality materials and thoroughly tested design of the boiler should provide years of trouble-free service if the instructions in this manual are followed carefully.

This manual covers installation of MACH® Boilers. The model numbers may be followed by a prefix or suffix letter in some cases to indicate special features or different options.

While details may differ slightly, basic operation is the same for all models. Boilers may be built to operate with natural gas or liquefied petroleum gas (propane). Check the rating plate for correct fuel usage and gas pressures.

The boiler is only a part of the complete heating system. This boiler may be fully operational and yet because of poor circulation, control, or other operating characteristics, not deliver heat to the desired location. Additional equipment such as temperature sensors, pumps, flow switches, balancing valves, and check valves will be required for satisfactory operation of any system. Harsco Industrial, Patterson-Kelley cannot be responsible for the design or operation of such systems and a qualified engineer or contractor must be consulted.

2.0 SAFETY

2.1 GENERAL

The MACH® gas-fired boiler **must** be:

- Installed, operated, and serviced in accordance with instructions contained in this manual and other supplemental MACH® boiler manuals.
- Installed by qualified personnel in accordance with designs prepared by qualified facility engineers including: structural, mechanical, electrical, and other applicable disciplines.
- Operated and serviced in accordance with a comprehensive safety program determined and established **by the customer**. Do not attempt to operate or service until such a program has been established.
- Operated and serviced by qualified and knowledgeable personnel in accordance with all applicable codes, laws, and regulations.

NOTICE!: Each safety device must be maintained and checked per the recommended schedule; refer to Section 5.1 of this manual.

2.2 TRAINING

Proper training is the best protection against accidents.

It is **essential** to read, understand, and follow the recommendations of this manual before installing, operating, or servicing this equipment. Failure to do so could result in fire or explosion and serious injury, death, and/or property damage.

Operating and service personnel must be thoroughly familiar with the basic construction of the MACH® boiler C1500 or C2000, the use and locations of the controls, the operation of the boiler, adjustment of its various mechanisms, and all applicable safety precautions. If any of the provisions of this manual are not fully and completely understood, contact Technical Service toll free at (877) 728-5351.

2.3 SAFETY FEATURES

It is the responsibility of the customer to maintain the safety features, such as but not limited to: guards, safety labels, safety controls, interlocks, lockout devices, in place and operable.

2.4 SAFETY LABELS

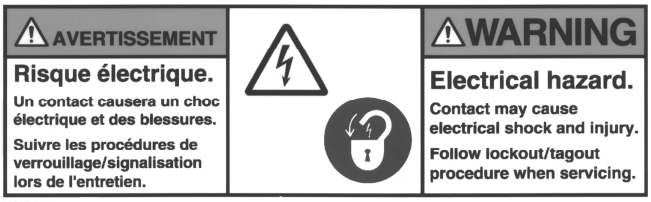
The following words are used in this manual to de-note the degree of seriousness of the individual hazards.

⚠ DANGER indicates an imminently hazardous situation which, if not avoided, **will** result in death or serious injury. This signal word is to be limited to the most extreme situations.

⚠ WARNING indicates a potentially hazardous situation which, if not avoided, **could** result in death or serious injury.

⚠ CAUTION indicates a potentially hazardous situation which, if not avoided, **may** result in minor or moderate injury. It may also be used to alert against unsafe practices.

NOTICE/NOTE - NOTICE is the preferred signal word to address practices not related to personal injury. The safety alert symbol is not used with this signal word.

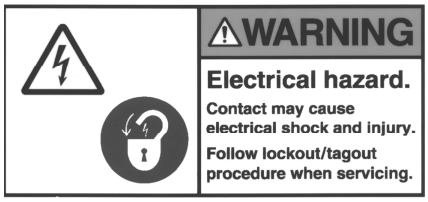


The safety labels shown above are affixed to your boiler. Although the labels are of high quality, they may become dislodged or unreadable over time. Contact Harsco Industrial, Patterson-Kelley toll-free at (877) 728-5351 for replacement labels.

2.5 SAFETY PRECAUTIONS

Provide a suitable location for the boiler, away from normal personnel traffic, with adequate working space, adequate clearances, proper ventilation and lighting, with a structure sufficiently strong and rigid to support the weight of the boiler, all piping, and accessories.

2.5.1 Electrical Hazards



- Shock hazard! Properly lockout/tagout the electrical service and all other energy sources before working on or near the boiler.
- Shock hazard! Do not spray water directly on this boiler or on any electrical components.
- Electrical hazard! Do not alter wiring connections.

2.5.2 Burn, Fire and Explosion Hazards

General Warning

- Burn, fire and explosion hazards! Installation must be in strict conformance to all applicable codes and standards including NFPA 54, ANSI Z223.1 and CAN/CSA B.149.1. Install all required vent lines for gas devices. Refer to Section 3.7.1.
- Hazard from incorrect fuels! Possible fire, explosion, overheating, and damage. Do not use any fuels except the design fuels for the unit.
- Overfire hazards! High pressure in gas or propane supply could result in overfiring of this appliance or other devices supplied from the same source.

- Fire and explosion hazards! Close the main gas shutoff before servicing boiler.
- Fire and explosion hazards! Do not store or use gasoline or other flammable vapors or liquids in the vicinity of this or any other gas fired appliance.

Hot Surface

- Burn hazard! Possible hot surfaces. Do not touch gas vent during firing operation. Use only factory recommended vent components.
- Burn hazard! Pipes, vents, and boiler components could be hot. Do not touch piping or stack surfaces during operation or immediately after shutdown of the boiler.
- Burn hazard! Hot fluids. Use caution when servicing or draining the boiler.

- Fire and explosion hazards! Use caution when servicing burner. Propane (LPG) is heavier than air and may linger in the combustion chamber, vent lines, or elsewhere.
- Gas leak hazard! Make sure the burner is installed correctly and burner hood is securely fastened following any maintenance performed on them. These connections cannot be tested after the burner is assembled.
- Gas leak hazard! All threaded gas connections must be made using a pipe compound that is resistant to liquefied petroleum. **Do not** use Teflon™ tape on threaded gas piping.
- Gas leak hazard! Check entire gas train for leaks after installation. If there is a smell of gas, shut down the boiler and obtain immediate assistance from trained service personnel and/or your local fire department.
- Excess pressure hazard! Possible fire and explosion from excess gas pressure. Make sure that gas inlet pressure does not exceed 14 inches W.C. to the regulator.
- Fire and explosion hazard! Failure to maintain all gas train components may result in malfunction of regulators and/or gas safety shut off / control valves. Annual inspection by factory-trained personnel for proper set-up and operation is recommended.
- Overfire and underfire hazards! Possible fire, explosion, overheating, and component failure. Do not attempt to adjust firing rate of the boiler. The firing rate must be adjusted **only** by factory trained personnel.

⚠ WARNING Gas may lose its odor. Proper gas sensing equipment and procedures should be used for leak checks.

2.5.3 Crush Hazards


General Warning

- Lifting hazards! Use properly rated lifting equipment to lift and position the boiler. The load is unbalanced. Test balance before lifting 3 ft. above the floor. Do not allow personnel beneath the lifted load. Refer to approximate weights in the table below:

Boiler Size	Weight in Pounds
C1500	1200
C2000	1400

- Bump hazard from overhead ductwork and piping. Install components with adequate vertical clearance.

2.5.4 Chemical Hazards


General Warning

- Chemical hazards from cleaning products. Use caution when cleaning the system. The use of professional assistance is recommended. Use safe procedures for the disposal of all cleaning solutions.
- Combustion Condensate – an acidic pH of approximately 3.0 to 5.0 can be expected. Use PVC, CPVC, or other corrosion resistant piping for drainage. Collection and disposal must be in accordance with all applicable regulations. A condensate neutralization kit is available. Please contact your local Harsco Industrial, Patterson-Kelley representative.

2.5.5 Pressure Hazards


General Warning

- Pressure hazard! Hot fluids. Install isolation valves on boiler water inlet and outlet. Make sure isolation valves are closed before servicing boiler.
- Pressure hazard! Hot fluids. Annually test safety relief valve for proper operation. Do not operate boiler with faulty relief valve.

2.5.6 Slip, Fall Hazards


General Warning

- Tripping hazard! Do not install piping on floor surfaces. Maintain clear path around boiler.
- Slip and fall hazard! Use drip pan to catch water while draining the boiler. Maintain dry floor surfaces.
- Slip and fall hazard! **Do not** locate intake or exhaust terminations directly above a walkway; dripping of condensation can cause icing of the walking surface. (see section 3.6.3)
- Fall hazard! Do not stand on any part of the boiler.
- Catch hazard! Do not wear rings, jewelry, long hair, loose clothing while working on the boiler.

3.0 INSTALLATION

⚠ WARNING Installation and service must be performed by a qualified installer, service agency, or gas supplier.

3.1 RECEIVING AND STORAGE

3.1.1 Initial Inspection

Upon receiving the boiler, inspect it for signs of shipping damage. Since some damage may be hidden, we recommend unpacking the boiler, removing the top, front, and side covers and inspect the boiler. Verify that the total number of pieces shown on the packing slip agrees with those actually received.

NOTICE! Note any damage, suspected potential damage, or shortage of materials on the freight bill and immediately notify the carrier. File all claims for shortage or damage with the carrier. Claims for hidden damages must be filed with your carrier within 7 days. The boiler carton is equipped with a "Tip (N) Tell". If "Tip (N) Tell" arrow point is blue, that indicates that the package has been on its side or tipped over in transit.

3.1.2 Storage Prior to Installation

If the boiler is not installed immediately, it must be stored in a location adequately protected from the weather and freezing conditions, preferably indoors. If this is not possible, then it should remain in the shipping container and be covered by a tarpaulin or other waterproof covering.

NOTICE! Controls and other equipment that are damaged or fail due to weather exposure are not covered by warranty.

3.2 COMPLIANCE WITH CODES

The MACH® Boiler with standard components and with many options complies with American National Standard/CSA Standard ANSI Z21.13/CSA 4.9, latest edition, Gas-Fired Low Pressure Steam and Hot Water Boilers.

The heat exchanger is constructed and stamped in accordance with ASME Boiler and Pressure Vessel Code, Section IV for 100 psig maximum operating pressure and/or 200º F maximum temperature.

Installation of the boiler must comply with the requirements of all national, state and local codes established by the authorities having jurisdiction. Authorities having jurisdiction should be consulted before installations are made.

Within the US, and in the absence of such local requirements, this boiler should be installed using the National Fuel Gas Code, ANSI Z223.1/NFPA 54, latest edition.

In Canada, the equipment shall be installed in accordance with the current Installation Code for Gas Burning Appliances and Equipment, CAN/CSA-B149, latest edition and applicable Provincial Regulations for the class, which should be carefully followed in all cases.

Where required by local codes, the installation must conform to American Society of Mechanical Engineers Safety Code for Controls and Safety Devices for Automatically Fired Boilers (ASME CSD-1).

In the Commonwealth of Massachusetts (a) this unit must be installed by a licensed pipe fitter / plumber, (b) field installed gas cocks must be "T" handle type, (c) piping of condensate shall conform to the State Plumbing Code, and (d) refer to the Massachusetts supplement for further details.

3.3 SETUP

3.3.1 Foundation

Provide a firm, level foundation, preferably of concrete.

NOTICE! The boiler may be installed on a combustible floor, however the boiler must **never** be installed on carpeting.

3.3.2 Placement

⚠ WARNING The wheels provided with this boiler are for positioning purposes only. When positioning this boiler, maintain positive control of it at all times. Do not attempt to move the boiler on surfaces that are not level. Failure to heed this warning could result in personal injury or death.

Lifting the front of the boiler slightly will allow the boiler to be rolled off the shipping skid onto the concrete foundation. Once in position, the wheel bolts may be removed allowing the wheels to recess up into the boiler. The base will sit flat on the provided foundation. If the boiler is to be pulled out for maintenance, the wheels may be left attached.

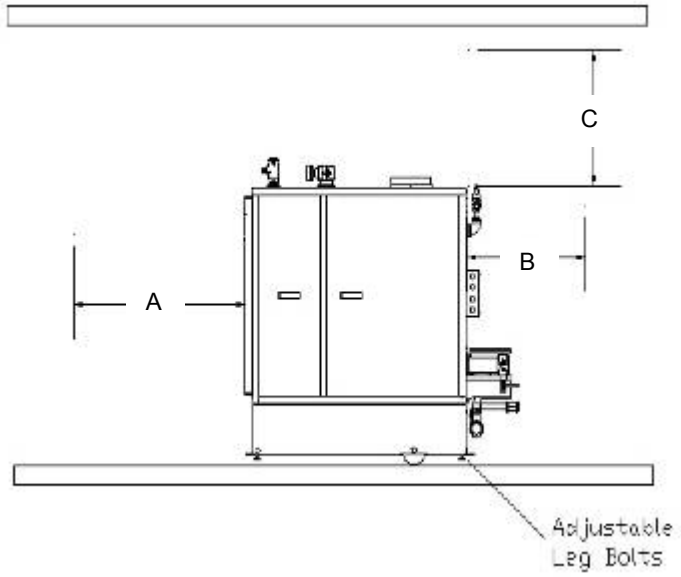
The boiler must be level to function properly. To assist in leveling the boiler, the four (4) adjustable leg bolts (1/2"- 13 NC) must be installed. The adjustable legs are also necessary to prevent distortion of the cabinet, (twisting, etc.) in addition to leveling.
Additionally there are three holes in the front and rear of the base that may be used for seismic anchoring.

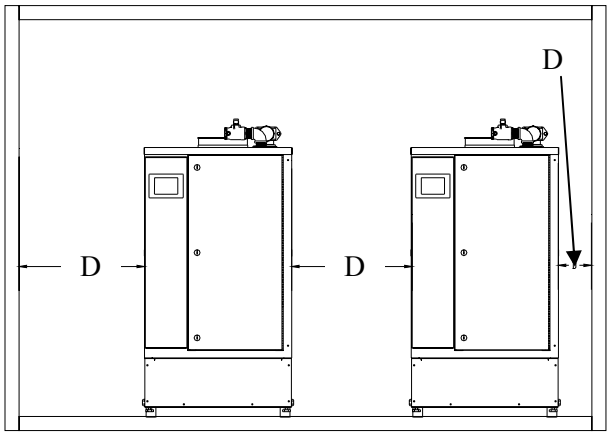
3.3.3 Clearances

If the boiler is to be installed near combustible surfaces, the minimum clearances shown in the pictures and table below must be maintained. Failure to provide for the service access clearances, even with non-combustible surfaces, may cause future problems servicing the boiler. The boiler must be installed in a space large in comparison to the boiler as described in the National Fuel Gas Code, ANSI Z223.1, latest edition.

Maintain a clearance from the vent to combustible surfaces of 18” or as specified in the vent manufacturer’s listed installation instructions.

Minimum Clearances from Adjacent Walls, Ceiling, and Obstructions (shown above &below)





† "C" Space required for pipes, ducts, etc. in this area above the boiler.

* Clearance depends upon exhaust vent configuration.

** Service access is required on left side of boiler to facilitate boiler maintenance. Minimum 2" clearance is required on right side. Do not put pipes, ducts, vents, etc in this space. Electrical conduit must be installed vertically so that the side doors can be opened.

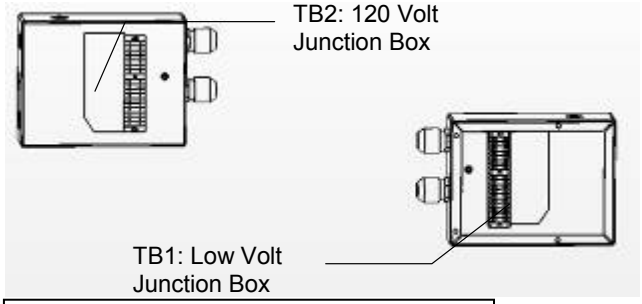
Type of Surface	Dimensions (inches)			
	A	B	C†	D
Combustible Surfaces Minimum Clearances	18	18	18	18
Recommended Service Clearances	30	12*	12	18**

⚠ CAUTION Bumping hazard from overhead ducts! Install all components with adequate vertical clearances.

3.4 ELECTRICAL CONNECTIONS

The boiler is wired for 120 volts, single phase, 60 hertz. The total operating amperage is indicated on the rating nameplate. Each MACH® C1500-C2000 boiler requires less than 15 amps. Before starting the boiler, check to ensure that the proper electrical service is connected to the boiler.

An external electrical disconnect (not supplied with the boiler) is required. The boiler electrical service must be installed and grounded in accordance with local codes or in the absence of such requirements, in the U.S. with National Electrical Codes, ANSI/NFPA No. 70 latest edition or, in Canada, to the Canadian Electrical Code, Part I, CSA C22.1, latest edition. Conduit must be installed vertically so that the side doors can be opened.



Customer Connections for the Boiler
Viewed from Front of Boiler.

NOTICE! A dedicated earth ground (green wire) and neutral is required to avoid nuisance shutdowns. Do not ground through the conduit. It is also important that proper polarity be maintained.

The electrical junction boxes are located at the front sides of the boiler. A detailed schematic of the connections is shown in section 6.1.

3.4.1 High Voltage (TB2) Terminal Block

The boiler power circuit requires 120 VAC, 60 hertz, with a dedicated neutral and ground as labeled. Electrical service must be rated for 8 amps minimum. Before starting the boiler, check to ensure that the proper voltage and amperage are connected to the boiler and that the boiler is connected to a suitable fused disconnect switch or circuit breaker. There must be less than 1.0V from Neutral (TB2-3) to Ground (TB2-8)

120VAC Switched Output- This contact closes when the boiler is switched on. This provides 120VAC 5Amp service to TB2-10. The neutral for this circuit is provided on TB2-3. When the boiler is switched off, this terminal is switched off as well.

3 Way Valve- This output is normally energized, keeping the three way valve providing heat to the building. The Domestic Hot Water (DHW) call for heat de-energizes this circuit, causing the 3 way valve to self close, thereby

providing heat to the DHW loop. This output provides 120VAC 0.5Amp service to TB2-11. The neutral for this circuit is provided on TB2-4.

DHW Pump Relay w/Delay Off - This output is enabled when there is a call for DHW. When the call for heat is removed, the output remains enabled for a period of time. This output provides 120VAC 0.5Amp service to TB2-12. The neutral for this circuit is provided on TB2-5.

Circ Pump Relay w/Delay Off - This output is enabled when there is a call for heat. When the call for heat is removed, the output remains enabled for a period of time. This output provides 120VAC 0.5Amp service to TB2-13. The neutral for this circuit is provided on TB2-6.

Damper Relay - This output is enabled when the call for heat is enabled. This output provides 120VAC service to TB2-14. The neutral for this circuit is provided on TB2-7. This circuit is for pilot duty only.

Master Alarm Relay – This contact closes in the event of an alarm output from the boiler control, connecting TB2-15 and TB2-16.

Flame Detected Relay – This contact closes whenever the boiler is firing, connecting TB2-17 and TB2-18.

3.4.2 Low Voltage (TB1) Terminal Block

Enable/Disable– TB1-1 and TB1-2 are used for enabling the boiler. Closing this circuit allows the boiler to run. Opening this circuit prevents the boiler from running. This circuit is energized by the boiler. It has a 24VAC potential. Devices connected to these terminals must be rated for 24VAC

External Interlock – TB1-3 and TB1-4 are used for attachment of an additional field safety device to the boiler control circuit. Closing this circuit allows the boiler to run. Opening this circuit prevents the boiler from running. This circuit is energized by the boiler with a 5V potential. Devices connected to these terminals must be rated for 5V.

Outdoor Temp Sensor – TB1-5 and TB1-6 are connected to the outdoor temperature sensor. The temperature control must be programmed to run an outdoor air schedule. The outdoor air sensor and programming help are available from the local Harsco Industrial, Patterson-Kelley Representative. This circuit is energized by the boiler with a 5V potential. The temperature sensor must be a NTC having 12k@25°C.

DHW Stat/Sensor – TB1-7 and TB1-8 are connected to the DHW temperature sensor or thermostat. This circuit is energized by the boiler with a 5V potential. The temperature sensor must be a NTC having 12k@25°C.

Header Temp Sensor – TB1-9 and TB1-10 are connected to the header temperature sensor. This circuit is energized by the boiler with a 5V potential. The temperature sensor must be a NTC having 12k@25°C.

DHW Flow Switch – TB1-11 is energized by the boiler with a 5V potential. This circuit connects through a flow switch on the domestic side of a domestic hot water system. The flow switch should close upon flow to provide a closed circuit back to TB1-12.

Analog Input– Remote signal for controlling the boiler. The boiler can be operated in a remote setpoint or a remote firing rate control mode. Input 0-10VDC signal on TB1-13 only. The 0V Analog Input is provided on TB1-14. The temperature control must be programmed to run with the analog input.

MODBUS® – TB1-17 and TB1-18 are used for connecting a MODBUS® building management system. (See the ENVI™ Control Advanced Users Guide for more information)

Cascade – TB1-19 and TB1-20 are used to connect between boilers that are part of a Master/Member Network. Up to 24 boilers may be connected together. (See the ENVI™ Control Advanced Users Guide for more information)

3.5 INLET AIR AND EXHAUST VENTING

3.5.1 Applicable Codes & Standards

CODES
United States:

NFPA 54/ANSI Z223.1	National Fuel Gas Code
NFPA/ANSI 211	Chimneys, Fireplaces, Vents and Solid Fuel Burning Appliances

Canada

CAN/CSA B149.1	Installation Codes for Gas Burning Equipment

STANDARDS

UL 1738	Venting Systems for Gas-Burning Appliances, Categories II, III, and IV
ULC S636-95	Standard for Type BH Venting Systems
Sheet Metal and	Thermoplastic Duct Construction Manual

Air Conditioning Contractors National Association (SMACNA)

These codes and standards contain information for the venting of gas fired appliances, including, but not limited to vent sizing, location, clearance to combustibles, and safe installation practices. The installation must comply with both the above Federal Codes and with state, provincial and local codes.

⚠ WARNING Design and installation of venting systems should be done only by qualified and knowledgeable venting systems personnel and in accordance with vent system manufacturer's installation instructions. Installing a boiler or vent system using improper installation methods or materials can result in serious injury or death due to fire or asphyxiation.

⚠ WARNING Before connecting a boiler to a venting system, it must be determined whether the boiler is to be installed in a conventional or Direct Vent configuration. In the US, provisions for combustion and ventilation air must be in accordance with NFPA 54/ANSI Z223.1, *National Fuel Gas Code*, latest edition, or applicable provisions of the local building codes. In Canada, combustion and ventilation air openings shall comply with CAN/CSA B-149.1 *Natural Gas and Propane Installation Code*.

⚠ WARNING For correct installation of vent system, read all of these instructions and refer to vent manufacturer's instructions.

Failure to use a proper vent system (types and materials), as described in this manual will void the boiler warranty and may result in rapid deterioration of the venting system, creating a health or life safety hazard.

Faulty vent installation can allow toxic fumes to be released into living areas. This may cause property damage, serious bodily injury or death.

3.5.1.1 Gas Vent Categories

Several codes and standards have categorized appliances in accordance with the flue gas temperature and pressure produced by the appliance. Categories are defined as follows:

- ***Category I*** An appliance that operates with a non-positive vent static pressure and with a vent temperature that avoids excessive condensate production in the vent.
- ***Category II*** An appliance that operates with a non-positive vent static pressure and with a vent temperature that may cause excessive condensate production in the vent.
- ***Category III*** An appliance that operates with a positive vent static pressure and with a vent temperature that avoids excessive condensate production in the vent.

- ***Category IV*** An appliance that operates with a positive vent static pressure and with a vent temperature that may cause excessive condensate production in the vent.
- ***Direct Vent*** An appliance that is constructed and installed so that all air for combustion is derived directly from outdoors and all flue gases are discharged to the outdoors.

3.5.1.2 Venting Materials for Flue/Exhaust Systems

MACH® boilers are Category IV appliances, which vent with a positive exhaust pressure and with a temperature that is likely to cause condensation in the vent. Therefore, any venting system used with the MACH® boiler must comply with the requirements for Category IV venting systems as specified in the latest edition of NFPA 54/ANSI Z223.1 in the US or the latest edition of CAN/CSA B-149.1 in Canada.

⚠ WARNING

The venting materials listed below are intended for the venting of gas burning appliances only. Do not use these venting materials for venting liquid or solid fuel (such as oil, kerosene, wood or coal) appliances

Maintain clearances to combustibles as listed in the vent manufacturer's installation instructions or as set forth in the codes and standards listed in this section.

Do not use these vent pipes for incinerators of any sort.

This boiler is not certified for use with PVC nor CPVC venting. Use of PVC or CPVC vent may result in vent failure and possible serious injury or death.

Table of Acceptable Materials for Venting Systems

Manufactured Venting
US and Canada Factory Fabricated Metallic Vent Systems listed and labeled to UL1738 (Titled: *Venting Systems for Gas-Burning Appliances, Categories II, III, and IV)*

Table of Applicable Vent Materials by MACH® Boiler Model

MACH® Boiler Model		AL29-4C	316L SS	PVC or CPVC
US	C1500 – C2000	X	X	No
CAN	C1500 – C2000	X	X	No

3.5.2 Combustion Air

Combustion air must be free from dust, lint, etc. The presence of such materials in the air supplied to the burner could cause nuisance "Low Air" shutdowns or premature burner failure. The boiler should not be operated during construction while the possibility of drywall dust, demolition dust, etc. exists.

The combustion air supply must be completely free of chemical fumes which may be corrosive when burned in the boiler. Common chemicals which must be avoided are fluorocarbons and other halogenated compounds, most commonly present as refrigerants or solvents, such as freon, trichlorethylene, perchlorethylene, chlorine, etc. These chemicals, when burned, form acids which quickly attack the boiler and the boiler stack. The result is improper combustion and premature boiler failure.

⚠ WARNING Under no circumstances shall the boiler room ever be under a negative pressure. Particular care should be taken when exhaust fans, compressors, air-handling units or other equipment may rob air from the boiler. Note that this equipment might be in rooms other than the boiler room.

3.5.2.1 Air Inlet Requirements – United States (NFPA 54/ANSI Z223.1 & NFPA/ANSI 211)

When air is supplied from inside the building, the total required volume shall be the sum of the required volume for all the appliances located in the mechanical room. Adjacent rooms furnished with fixed openings communicating directly with the mechanical room are considered part of the required volume. The minimum volume is 50 ft^3 per 1000 Btu/hr (4.8 m^3/kW) of installed appliance input capacity.

Openings used to connect indoor spaces to obtain the required minimum volume shall be sized as follows:

- When rooms are on the same floor, each opening shall have an area equal to 1 square inch for each 1000 Btu/hr (2200 mm^2 / kW) of installed appliance input capacity, but not less than 100 square inches. One opening should commence less than 12 inches above the floor and the other less than 12 inches below the ceiling. The minimum dimension of air openings shall be 3 inches.
- When rooms are on different floors, each opening shall have an area equal to 2 square inches for each 1000 Btu/hr (4400 mm^2 / kW) of installed appliance input capacity.

When combustion air is supplied from outside the building, the boiler room shall be provided with one or two openings to ensure adequate combustion air and proper ventilation.

When using one permanent opening, the opening shall commence within 12 inches of the ceiling and shall communicate directly with the outdoors or through a vertical or horizontal duct that communicates to the outdoors.

- Minimum free area of the opening is 1 square inch for each 3000 Btu/hr (700 mm^2 / kW) of installed appliance input capacity, and
- Not less than the sum of the areas of all vent connectors in the room.

When using two permanent openings, one opening shall commence within 12 inches above the floor and the other within 12 inches below the ceiling, preferably on opposite walls. The openings shall communicate directly, or by way of ducts, with free outdoor air. The minimum net free area of the openings shall be calculated in accordance with the following:

- When air is taken directly from outside the building, each opening (minimum of two, as outlined above), 1 square inch for each 4,000 Btu per hour (550 mm^2/kW) of total boiler input is required.
- When air is taken from the outdoors through a vertical duct into the mechanical room, 1 square inch per 4,000 Btu per hour (550 mm^2/kW) of total boiler input is required.
- When air is taken from the outdoors through a horizontal duct into the mechanical room, 1 square inch per 2,000 Btu per hour (1100 mm^2/kW) of total boiler input is required.

NOTE:
1. The required size of openings for combustion and ventilation air shall be based on the net free area of the opening.
2. Screens shall be not smaller than ¼”
3. Motorized louvers shall be interlocked with the appliance so that they are proven open prior to main burner ignition and operation.

Table of US Minimum area of ventilation openings per boiler (sq inches)

MACH® Boiler MODEL	AIR SOURCE					
	INDOOR AIR SUPPLY		OUTDOOR AIR SUPPLY			
	SAME FLOOR	DIFF FLOORS	ONE OPENING	TWO OPENINGS		
				DIRECT	VERT DUCT	HORIZ DUCT
C1500	1500	3000	500	375	375	750
C2000	2000	4000	667	500	500	1000

3.5.2.2 Air Inlet Requirements – Canada (CAN/CSA B149.1)

A. Ventilation of the space occupied by fuel burning appliance(s) or equipment shall be supplied by a ventilation opening at the highest practicable point communicating with the outdoors. The total cross sectional area of the ventilation opening must be either 10% of the net free area required for combustion air or 10 sq. in. (6500 mm^2), whichever is greater.

B. Use the following opening calculation for MACH ®or MODU-FIRE® FD boilers:

When combustion air is supplied for a forced draft burner by natural airflow from the outdoors and there is no draft regulator or draft hood in the same space, there shall be a permanent opening with a cross sectional area not less than 1 sq. in/ 30,000 Btu/Hr (70 mm^2/kW) of the total rated input to the burner(s). This opening must not interfere with the ventilation air opening defined in paragraph A.

C. Use the following opening calculation for P-K THERMIFIC® boilers or other natural draft or fan-assist appliances:

When combustion air is supplied for natural or fan-assisted burners by natural airflow from the outdoors, there shall be a permanent opening with a cross sectional area not less than 1 sq. in/ 7000 Btu/Hr (321 mm^2/kW) up to and including 1,000,000 Btu/Hr plus 1 sq. in. / 14,000 Btu/Hr (155 mm^2/kW) in excess 1,000,000 Btu/Hr. This opening must be either located at or ducted to a point not more than 18 in. (450 mm) nor less than 6 in. (150 mm) above floor level. This opening is in addition to the ventilation air opening defined in paragraph A.

D. When combustion air is supplied by natural airflow into a space containing both types of appliance described in paragraphs B and C, the cross sectional area of the opening shall be not less than the sum of the cross sectional areas for all appliances in the space as calculated by the applicable method . This opening is in addition to the ventilation air opening defined in paragraph A.

E. When a duct is used to meet the requirement for combustion air supply, as described in paragraphs A through D, above, the opening of the duct shall be located so there is no possibility of cold air affecting steam or water piping, electrical equipment or mechanical equipment.

F. When combustion air is supplied by mechanical means, an airflow-sensing device must be installed. It must be wired into the pre-ignition limit string to prevent the burner from starting or to stop an operating burner in case of air supply failure.

G. When all combustion air is supplied through a make-up air heater, and the appliance is interlocked to the heater, the requirements of paragraphs A through F do not apply.

NOTE:

1. The free area of a combustion air supply opening is calculated by deducting the blockage area of any fixed louvers, grilles or screens from the total area of the opening.
2. Screens shall be not smaller than ¼”
3. Motorized louvers shall be interlocked with the appliance so that they are proven open prior to main burner ignition and operation

Table of Canadian Minimum Area of Combustion and Ventilation Air Openings

MACH® Boiler		Required Combustion Air Opening		Ventilation Air Opening	
Model #	Input (Btu/Hr)	in^2	mm^2	in^2	mm^2
C1500	1,500,000	50	32,258	10	6,452
C2000	2,000,000	67	43,226	10	6,452

3.5.3 Flue Venting

This boiler is not certified for use with Type "B" vent nor with PVC/CPVC venting.

This boiler is a Category IV appliance (condensing – positive pressure) as it is defined in ANSI Z21.13/CSA 4.9, latest edition. The vent material must be as listed in Table in section 3.5.3. The exhaust vent can be run horizontally or vertically.

Vent installations shall be in accordance with NFPA54/ANSI Z223.1, the *National Fuel Gas Code*, or CAN/CSA-B149.1, the *Natural Gas and Propane Installation Code*, or applicable provisions of the local building codes.

3.5.3.1 VENT SIZING

The vent must be sized in accordance with the ASHRAE Systems and Equipment handbook, Chapter 30 or according to the vent manufacturer's recommendations. When using manufactured venting systems, consult your vent supplier for correct sizing and structural support requirements.

Table of Vent Design Parameters

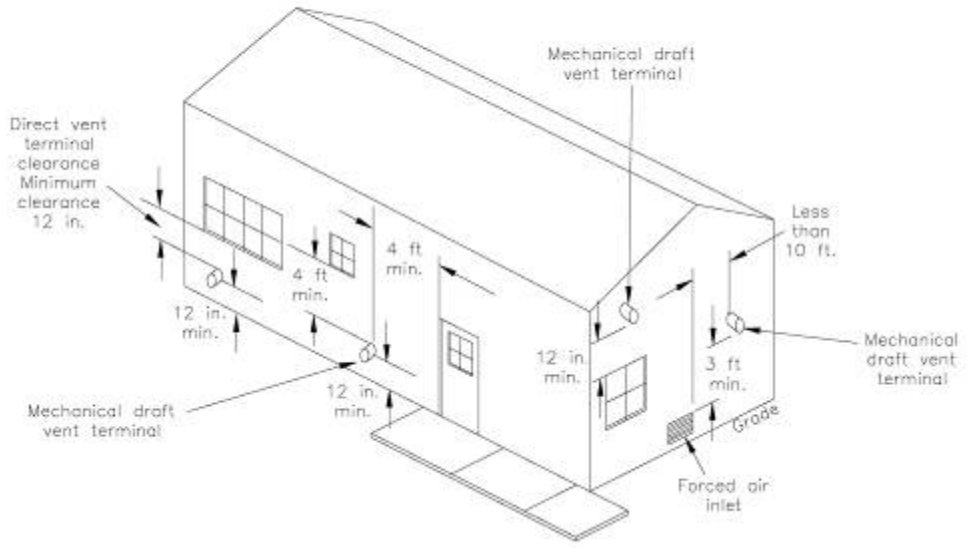
MACH® Boiler Model	Frictional Resistance	Stack Temperature	CO_2 Natural Gas	CO_2 LP Gas
C1500-C2000	0.22"	185°F	9.2%	10.5%

⚠ CAUTION All boiler venting systems should be designed by a qualified venting professional experienced in venting system design. The information contained herein should be used as a guide only and is not intended to be used in lieu of qualified technical expertise.

⚠ WARNING **Do not use a barometric damper with this boiler**. This is a positive pressure system. Flue gases may leak into the room.

3.5.3.2 Required Clearances

Provide clearances between combustion air intake, exhaust vent, roof and wall surfaces, doors and window, and snow line. Refer to Figure below: Termination Clearances – Forced Draft and Direct Vent Installations.



Reference: NFPA 54/ANSI Z223.1 National Fuel Gas Code

⚠ WARNING Do not locate intake or exhaust terminations directly above a walkway; dripping of condensation can cause icing of the walking surface. Maintain a minimum clearance of 4 ft (1.22 m) horizontally from any electric of gas meter, regulator or relief equipment.

Conventional Vent Systems Clearances

The following termination clearance requirements are for conventional, non-direct vent installations.

- The vent system shall terminate at least 3 ft above a forced air inlet within 10 feet horizontally.
- The vent system shall terminate at least 4 ft below, 4 ft horizontally from or 1 ft above any door, operable window or gravity inlet into any building. The bottom of the vent terminal shall be at least 12 in. above grade or highest expected snow line (if applicable).
- Through the wall terminations shall not terminate over public walkways or over an area where condensate or vapor could create a nuisance or hazard or could be detrimental to the operation of regulators, relief valves or other equipment.

Direct Vent (Sealed Combustion) Systems Clearances

- The vent terminal shall be located at least 12 in. from any air opening into a building. The bottom of the vent terminal shall be at least 12 in. above grade. Both the vent and air intake terminals must be at least 12 in. above the highest expected snow line.
- Through the wall terminations shall not terminate over public walkways or over an area where condensate or vapor could create a nuisance or hazard or could be detrimental to the operation of regulators, relief valves or other equipment.
- When multiple direct vent appliances are adjacent, the exhaust must terminate at least 10 feet horizontally or three feet vertically from the air intake of another appliance.

Interior Component Clearances

All vent system components shall be installed so as to maintain the following required minimum clearances:

	Combustible	Non-Combustibles
Unlisted single wall metal pipe	Do NOT Use	Do NOT Use
Single wall CPVC pipe	Do NOT Use	Do NOT Use
UL 1738 listed Category IV vent	Per manufacturer's listing	Per manufacturer's listing

NOTICE! Make sure that the weight of the vent is **not supported** by the boiler vent collar. **The collar is not designed to support the weight of the vent.** The CPVC or manufactured vent system shall be supported in accordance with the manufacturer's instructions. Horizontal vent sections shall be supported in a manner to prevent sags or low spots where condensate can collect. Structural supports must be connected to building elements of sufficient strength to withstand the weight of the vent system and any bending forces imposed by the venting system.

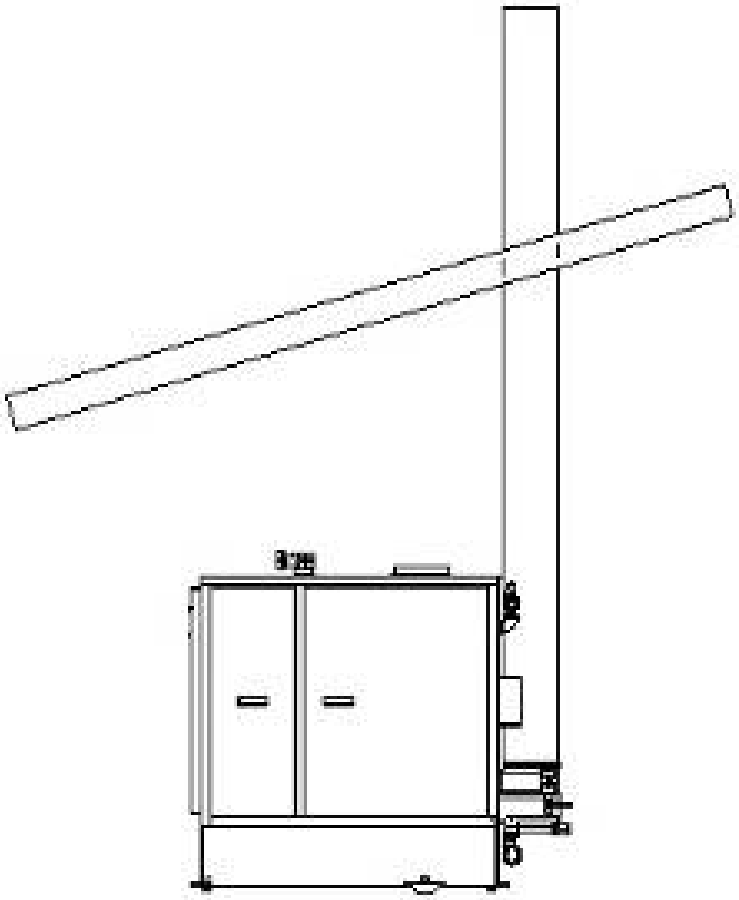
3.5.3.3 Flue Connection

⚠ WARNING The boiler vent should not be connected into any portion of another mechanical draft system without consulting the vent manufacturer. The boiler shall not be connected to any part of a vent system serving a Category I or II appliance, nor shall a Category I or II appliance be connected to any part of the vent system serving this appliance. Improper interconnection of venting systems may result in leakage of flue gases into occupied spaces.

The connection from the boiler to the vent should be as direct as possible and the upward slope of any horizontal breaching should be at least 1/4 inch per linear foot.

The complete exhaust with drain system is shown in the figure below. The appliance connector should incorporate provisions to drain condensate formed in the vent system. The connector shall include a drained boot tee, a drained lateral tee or a horizontal or vertical drain section.

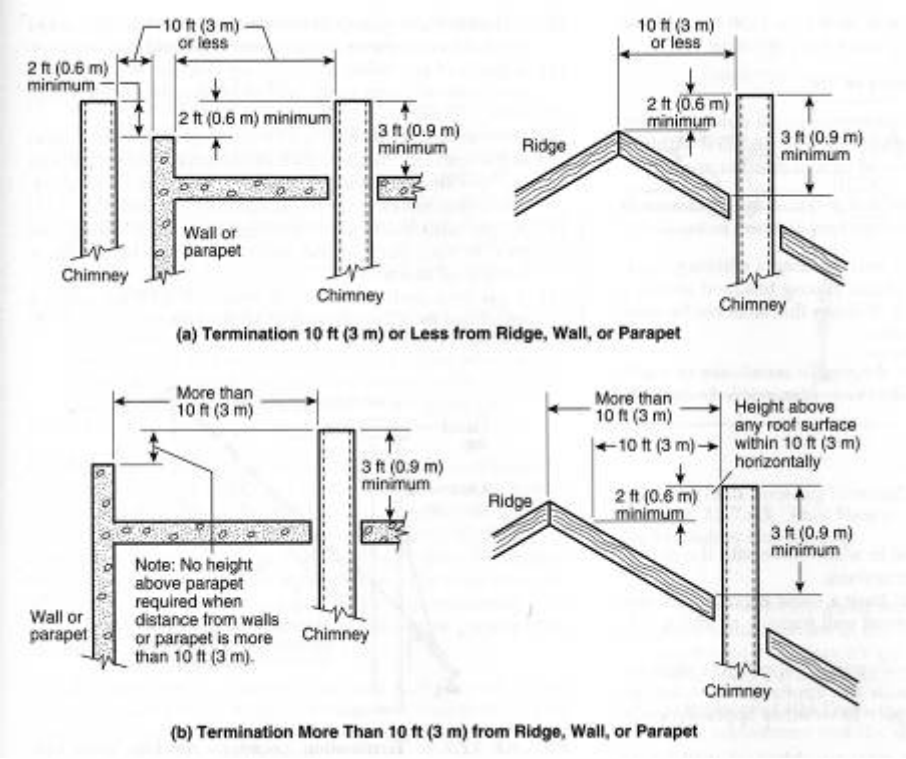
NOTE! The condensate formed from natural gas flue gases is acidic. The condensate shall be drained iin accordance with local code requirements. A condensate neutralizer may be required by local code.



3.5.3.4 Vent Terminations

The vent shall extend at least three (3) feet above the roof, or at least two (2) feet above the highest part of any structure within ten (10) feet of the vent. This is illustrated in the following diagram. Additionally the boiler vent shall terminate at least 3 ft above a forced air inlet located within 10 ft.

Reference: NFPA 54/ANSI Z223.1 National Fuel Gas Code



To prevent the possible re-circulation of flue gases, the vent designer must take into consideration such things as prevailing winds, eddy zones, building configurations, etc. Harsco Industrial, Patterson-Kelley can not be responsible for the effects such adverse conditions may have on the operation of the boilers. Dimensions listed above are minimums and may not be sufficient for conditions at a specific job site.

Vertical vents are allowed to be terminated with a variety of ends, including plain straight pipe, elbow or vent tee. Horizontal vents must be terminated as illustrated in section 3.5.5. A birdscreen with 1" x 1" openings is recommended for the termination. Harsco Industrial, Patterson-Kelley does not recommend using a vent rain cap of any type.

3.5.4 Venting for Multiple Boilers

The venting instructions in this manual apply to a **single** boiler.

Venting systems for multiple boilers must be designed by experienced and knowledgeable professionals. The venting system must prevent backflow of exhaust gas through idle boilers.

3.5.5 Sealed Combustion/Direct Vent Systems

The MACH® Boilers are also certified for operation with a sealed combustion air and pressurized venting system. Such a system employs a sealed combustion air intake duct leading from outdoors and a sealed exhaust vent terminating outdoors. Air flow through the system is maintained by the combustion air fan. Allowable configurations of vent and air intake terminations are illustrated below.

The combined pressure drop of the air supply duct and exhaust vent must not exceed 0.44" w.c. This pressure drop includes both the inlet and vent ducts friction loss. For example, if the inlet air duct loss is -0.2" w.c., the vent duct loss cannot exceed 0.24" w.c.

3.5.5.1 Intake Duct Materials and Sizes

Air Requirements – SCFM

Boiler Size	Required SCFM
1500	350
2000	467

The air intake duct can be fabricated from PVC, CPVC, single wall galvanized steel, or other suitable materials. The duct must be rigid enough to maintain the full required cross sectional area under all operating conditions. Proper sealing of the intake ductwork is necessary to prevent infiltration of air from conditioned space. Joints in PVC or CPVC must be cemented. For galvanized duct, wrap each joint and seam with adhesive aluminum tape or other sealant. The installation of a birdscreen on the intake termination is recommended. Ensure that the screen does not become blocked with snow, ice, insects etc.

3.5.5.2 Intake Duct Connection to Boiler

Connect the air supply duct to the 10" OD collar on the top of the boiler. Fasten the duct to the collar with sheet metal screws at 90º angles. Seal the joint.

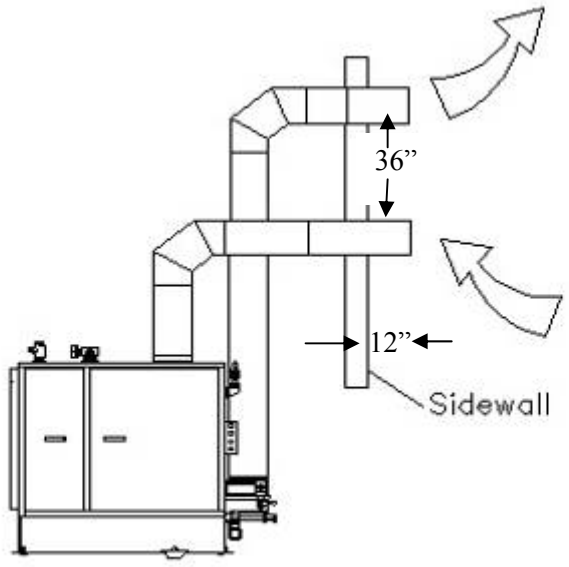
3.5.5.3 Intake/Exhaust Layout

The MACH® Boilers C1500-C2000 are certified for direct sidewall venting with a sidewall air inlet only.

Both the air inlet and the exhaust vent must terminate on the same wall of the building and must utilize the same type of termination fitting with the same orientation. Allowable termination fittings are: 90° elbows, tees, or straight vents.

NOTICE! Do not install this boiler with sidewall vent and room air inlet!

The figure shows the sidewall penetration requirements. The exhaust vent must be at least 3 feet above the air intake. The air intake and exhaust vent must extend at least 12 inches from the exterior wall.



Typical Sidewall Venting.

3.5.6 Removing an Existing Boiler

(from a common venting system)

When an existing boiler is removed from a common venting system, the common venting system is likely to be too large for proper venting of the appliances remaining connected to it.

At the time of removal of an existing boiler, while the other appliances remaining connected to the common venting system are not in operation, the following steps should be followed with each appliance remaining connected to the common venting system placed in operation:

1. Seal any unused openings in the common venting system.
2. Visually inspect the venting system for proper size and horizontal pitch and determine that there is no blockage or restriction, leakage, corrosion or other deficiency which could cause an unsafe condition.
3. Insofar as is practical, close all building doors and windows and all doors between the space in which the appliances remaining connected to the common venting system are located and other spaces of the building. Turn on clothes dryers and any appliances not connected to the common venting system. Turn on any exhaust fans, such as range hoods and bathroom exhausts, so they will operate at maximum speed. Do not operate a summer exhaust fan. Close fireplace dampers.
4. Place the appliance being inspected in operation. Follow the lighting instructions. Adjust the thermostat so that the appliance will operate continuously.
5. Test for spillage at the draft hood relief opening after 5 minutes of main burner operation. Use the flame of a match or candle or smoke from a cigarette, cigar or pipe.
6. After it has been determined that each appliance remaining connected to the common venting system properly vents when tested as outlined above, return doors, windows, exhaust fans, fireplace dampers and any other gas-burning appliance to their previous conditions of use.

Any improper operation of the common venting system should be corrected so the installation conforms with the National Fuel Gas Code, ANSI Z223.1 and CSA B149 Installation Code. When resizing any portion of the common venting system, the common vent system should be resized to approach the minimum size as determined using the appropriate tables.

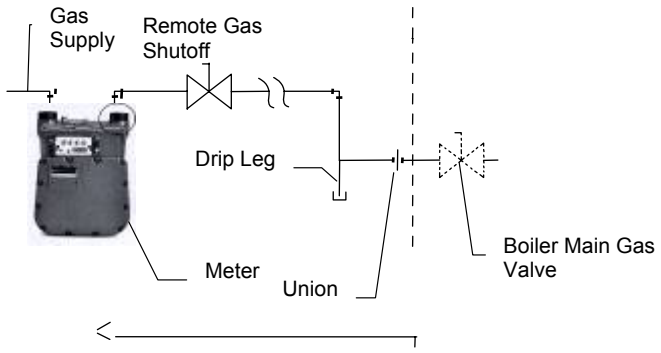
3.6 GAS PIPING

Before making the gas hook-up, make sure the boiler is being supplied with the type of fuel shown on the boiler nameplate.

The boiler shall be installed such that the gas ignition system components are protected from water (dripping, spraying, rain, etc.) during appliance operation and service (circulator replacement, control replacement, etc.)

The boiler is factory fire-tested and adjusted for proper combustion with natural gas supply pressure of 7” W.C. Typical gas pressure supply for natural gas is 7" W.C. The gas train components are certified to handle a maximum inlet pressure of 14" W.C. (1/2 psig.). If the available gas pressure exceeds 14" W.C., a suitable additional intermediate gas pressure regulator of the "lock up" type must be provided to reduce the pressure to less than 14" W.C.

⚠ WARNING All threaded connections must be made using a pipe compound that is resistant to the action of liquefied petroleum gases. **Do not use Teflon tape on gas line threads.**



Field Gas Piping

Install a sediment trap (drip leg) and a union connection upstream of the primary manual shutoff valve on the boiler. Gas piping should be installed in accordance with National Fuel Gas Code, ANSI Z223.1, latest edition, and any other local codes which may apply. In Canada, please refer to CSA-B.149. In the Commonwealth of Massachusetts, the gas cock must be a "T-handle type."

See Pipe Capacity for Natural Gas chart (below) for required pipe size, based on overall length of pipe from meter plus equivalent length of all fittings. Approximate sizing may be based on 1 cubic foot of natural gas per 1,000 Btu per hour input, i.e., 1,500,000 Btu per hour requires about 1,500 cubic feet per hour. (See "Typical Boiler Operating Conditions," Section 4.3, for more information.)
Pipe Capacity for Natural Gas

Nominal Iron Pipe Size (Inches)	**Internal Diameter (Inches)**	**Equivalent Pipe Length**		**Maximum Capacity in Cubic Feet of Natural Gas per Hour Pressure Drop of 0.5 inch Water Column/Equivalent Length of Pipe (in feet)**						
		90º Ell (Feet)	Tee (Feet)	20	40	60	80	100	150	200
1/2	0.622	1.55	3.1	120	82	66	57	50	40	35
3/4	0.824	2.06	4.12	250	170	138	118	103	84	72
1	1.049	2.62	5.24	465	320	260	220	195	160	135
1- 1/4	1.380	3.45	6.9	950	660	530	460	400	325	280
1- 1/2	1.610	4.02	8.04	1460	990	810	690	620	500	430
2	2.067	5.17	10.3	2750	1900	1520	1300	1150	950	800
2- 1/2	2.469	6.16	12.3	4350	3000	2400	2050	1850	1500	1280
3	3.068	7.67	15.3	7700	5300	4300	3700	3250	2650	2280
4	4.026	10.1	20.2	15800	10900	8800	7500	6700	5500	4600

3.6.1 Gas Supply Piping by Installer

The boiler and all gas piping connections should be pressure-tested and must be checked for leaks before being placed into service. Test with compressed air or inert gas if possible.

The boiler must be **disconnected** at the boiler manual shut-off valve (located at the end of the supplied gas train) from the gas supply piping system during any pressure testing of the system at pressures in excess of 1/2 psig (14" W.C.).

During any pressure testing of the gas supply piping system at pressures equal to or less than 1/2 psig (14" W.C.), the boiler should be isolated from the gas supply piping system by closing the manual shut-off.

Some leak test solutions, including soap and water, may cause corrosion. These solutions should be rinsed-off with water after testing.

3.7 BOILER WATER PIPING

3.7.1 Piping Design

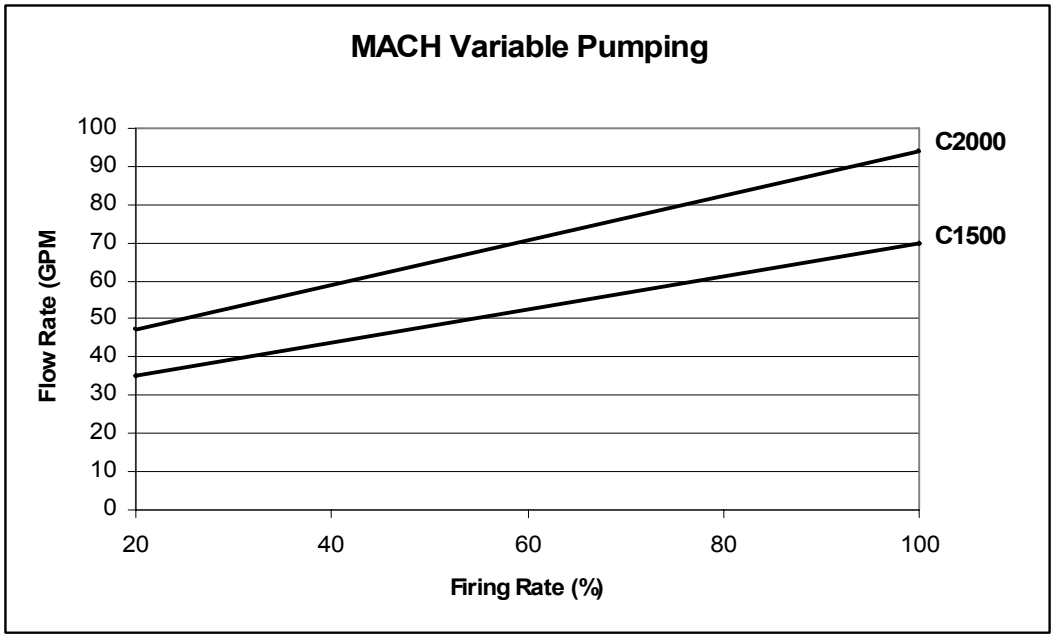
Water Flow in System

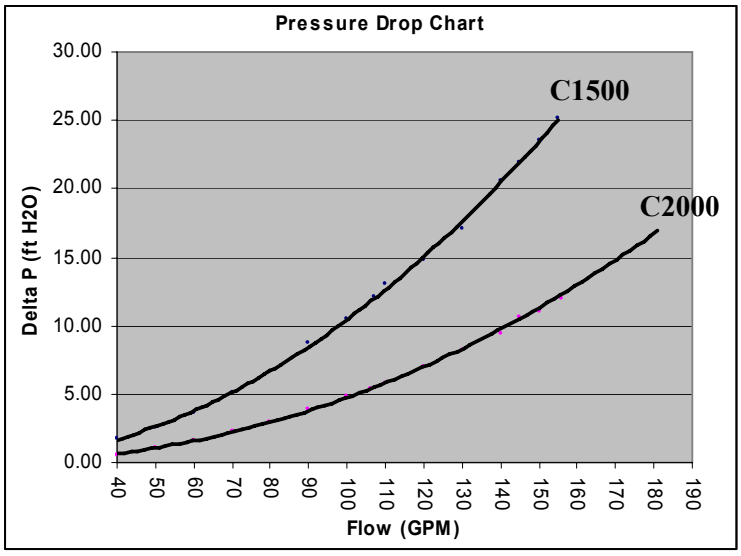
For proper water flow requirements see below. Incorrect flow may result in eventual damage or premature failure of the equipment.

Proper flow rates may be achieved through a combination of primary and secondary flow loops. Multiple zones and pumps may result in different flow rates at different times. Consideration must be given to all possible conditions and their consequences.

Model	Max Flow GPM for 20ºF □T	Min Flow GPM for 40ºF □T	DP ft. at max flow
2000	188	94	17.5
1500	141	70	20

For minimum flow rates at other than maximum firing rate, see MACH® Boiler Variable Pumping Graph (below)





3.7.1.1 Piping With Refrigeration Machines

When installed in a two-pipe system that provides both chilled and hot water, the control system should be configured so as to limit the time rate of change of temperature at the boiler. Consult your authorized Harsco Industrial, Patterson-Kelley boiler representative for application guidance.

3.7.1.2 Piping With Air Handling Units

The boiler piping system of a hot water heating boiler connected to heating coils located in air handling units, where they may be exposed to refrigerated air circulation, must be equipped with flow control valves or other automatic means to prevent gravity circulation of the boiler water during the cooling cycle.

3.7.2 Boiler Inlet and Outlet Connections

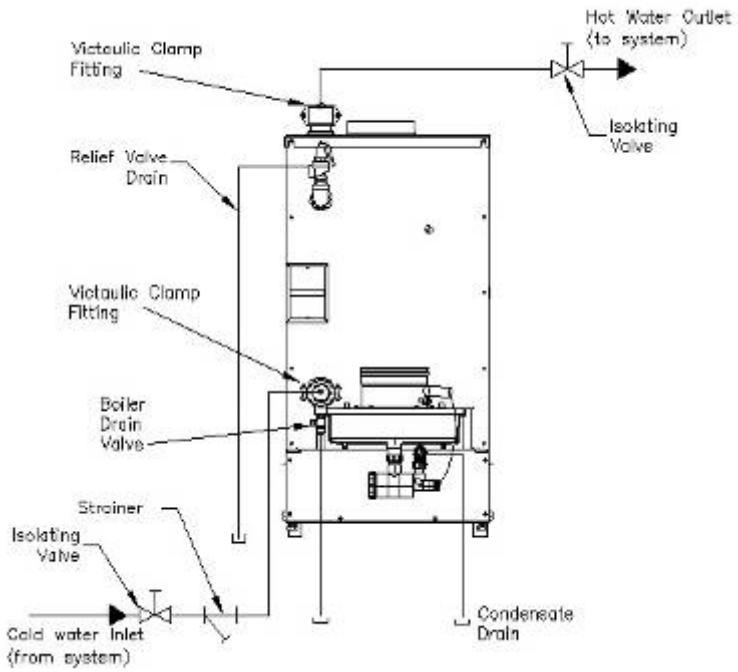
All water connections should be in compliance with national, state and local code requirements.

Notice! The boiler is furnished with 2.5" grooved connections for Victaulic Style Couplings. These coupling must be used with the EPDM Victaulic seals. Adapters from Victaulic to NPT are available from the factory. Isolating valves must be installed in both water connections for ease of service.

The bottom rear connection to the boiler is the INLET and must be used for the return from the system.

The top vertical connection to the boiler is the OUTLET and must be connected as the supply to the system.

NOTICE! Condensate Trap must be piped to drain in accordance with all national, state and local codes. If installed outdoors, it must be field heat traced.



3.7.3 Boiler Water Piping by Installer

Strainer

To avoid possible contamination of the boiler with dirt, rust or sediment from the system, a strainer near the boiler inlet is strongly recommended. Even new systems may contain sufficient foreign material to eventually reduce the performance of the heat exchanger. Adequate circulation of good clean water is essential to maximum efficiency and long life of the boiler.

Relief Valve Piping

Each boiler is supplied with a pressure-relief valve sized in accordance with ASME requirements. Lower pressure relief valves are available, contact your Harsco Industrial, Patterson-Kelley representative. The relief valve should be piped to a suitable floor drain. Reducing couplings or other restrictions are not permitted in the discharge line.

Low Water Cut-off

The boiler is furnished with a probe-type low water cut-off; no field piping is required. If the water level in the boiler drops below the probe, the boiler will shut down and a LOCKOUT LOW WATER LEVEL will be displayed on the control panel. The low water cutoff circuit will automatically reset when the low water condition clears; however the boiler controls will retain the lockout condition until the reset button on the display is depressed.

NOTICE! The low water cutout probe only prevents boiler operation when the water level in the boiler is insufficient. It does not detect low water conditions in other parts of the system. Installation of high point vents or additional low water safety devices to protect the system should be considered.

Installation of external limit controls may be required by certain codes or in certain installations. Review applicable local codes for details.

Drain Valve and Piping

A drain valve is installed in the inlet (system return) header connection to the boiler. Prior to draining the boiler for maintenance or testing, electrical power and gas supply must be turned off to the boiler. The boiler must then be isolated from the system at the supply and return connections prior to draining water from the boiler.

NOTICE! This drain valve is factory installed for draining of the boiler water only, not the entire system. Draining of the system through the boiler will result in depositing sediment from the system in the boiler which will result in poor heat transfer characteristics of the boiler and early boiler failure.

Condensate Drain

The condensate is acidic (pH between 3.0 and 5.0) and may be corrosive to some building drain systems. A condensate neutralization system may be required and is available from Harsco Industrial, Patterson-Kelley.

Disposal of condensate must comply with all state and local codes.

The boiler could generate up to one gallon of condensate per 100,000 BTU input.

MACH® Boiler	Gal of Condensate (per hour maximum)
C1500	15
C2000	20

3.7.4 Flushing and Filling

Water Quality
The MACH® boiler heat exchanger is made of an aluminum alloy. The heat exchanger requires proper water conditions to remain efficient and function properly.

NOTICE! Glycol or other treatment chemicals added to the system must be certified by the chemical manufacturer for use in multi-metal systems that include cast aluminum boilers. A list of manufacturers known to certify multi-metal treatments is included in Appendix 3.

NOTICE! Under no circumstances should petroleum based cleaning or sealing compounds be used in the boiler system.

NOTICE! Under no circumstances should the hydronic system be flushed while the boiler is attached to the system since the debris or corrosion products could accumulate in the boiler and plug the boiler heat exchanger.

NOTICE! If the piping system attached to this unit will be chemically cleaned, the boiler must be disconnected from the system and a bypass installed so that the chemical cleaning solution does not circulate through the boiler. Following chemical cleaning, the system should be thoroughly rinsed to remove cleaning agents prior to reconnecting the boiler to the system.

3.8 PRE-START CHECK LIST

Before attempting to start the boiler, make sure the following items have been completed.

1. Inspect the gas train, blower, ignition electrode and boiler in general to be sure there was no damage during shipment or installation.
2. Flue gas from the boiler is properly vented; (refer to Section 3.5)
3. Gas connection has been made, pressure tested for leakage and the line purged of air. Make sure all required vents have been installed. (refer to Section 3.6)
4. Water connections are complete and the boiler and system have been filled and purged of air. (refer to Section 3.7)
5. The boiler is connected to a 120 volt power source with a disconnect having adequate overload protection. (refer to Section 3.4)
6. Combustion air openings are not obstructed in any way and have adequate capacity. (refer to Section 3.5)
7. The boiler is placed the proper distance from any combustible walls (refer to Section 3.3.3).
8. Relief valves have been piped to an acceptable drain. (refer to Section 3.7)
9. Condensate piping is properly connected. (refer to Section 3.7)
10. Verify system water quality is within specifications. (refer to Appendix 3)

3.9 SAFETY CHECKS

The following checks of safety systems must be made before putting the boiler into normal operation.

Before firing the boiler refer to Sections 4.1 and 4.2 for information on the use of the controls, lighting, and shut-down procedures.

⚠ WARNING Never attempt to operate a boiler that has failed to pass all the safety checks described below.

⚠ WARNING After checking controls by manual adjustment, make sure they are always reset to their proper settings.

NOTICE! If the expected error code(s) do not appear, call for qualified service.

3.9.1 Test of Ignition Safety System

Test the ignition system safety shutdown as follows:

1) Cycle the boiler on by generating a heat request. (See Section 3.10)
2) Place the boiler in operation at the high fire setting.
3) Smoothly close the downstream manual isolation valve to reduce the gas flow and cause flame failure.
4) The display will show LOCKING FLAME FAILURE indicating a flame failure. The lockout will remain until the control is reset.

After completing this test, turn off the boiler and open the downstream manual isolation valve and turn the boiler back on.

3.9.2 Test of Low Water Cut-off

The boiler is furnished with a probe-type low water cut-off in the outlet nozzle. Test as follows:

Push and hold the red “Push to test” button for at least 5 seconds. A manual lockout reset error displaying LOCKOUT LOW WATER LEVEL on the display panel should occur. The LED indicator on the Low Water cut-off will no longer be illuminated.

(Optional Test Method)

First turn the boiler off, and then turn the pump off. Isolate the boiler from the system. Drain the water level below the low water cut-off probe. Turn the boiler back on. It should not operate, and a manual lockout reset error displaying LOCKOUT LOW WATER LEVEL on the display panel should occur. The LED indicator on the Low Water cut-off will no longer be illuminated.

Return the system to normal operation by refilling and restarting the boiler and pump.

3.9.3 Test of High-Limit Control

Fire the boiler and test the high limit control as follows:

With the main burner operating, turn down the temperature setting on the "high-limit" thermostat until the main burner shuts off. A manual reset lockout displaying LOCKING HIGH LIMIT on the display panel will occur. The high-limit switch must be manually reset prior to resetting the boiler at the display panel. Readjust the high-limit thermostat to the desired setpoint.

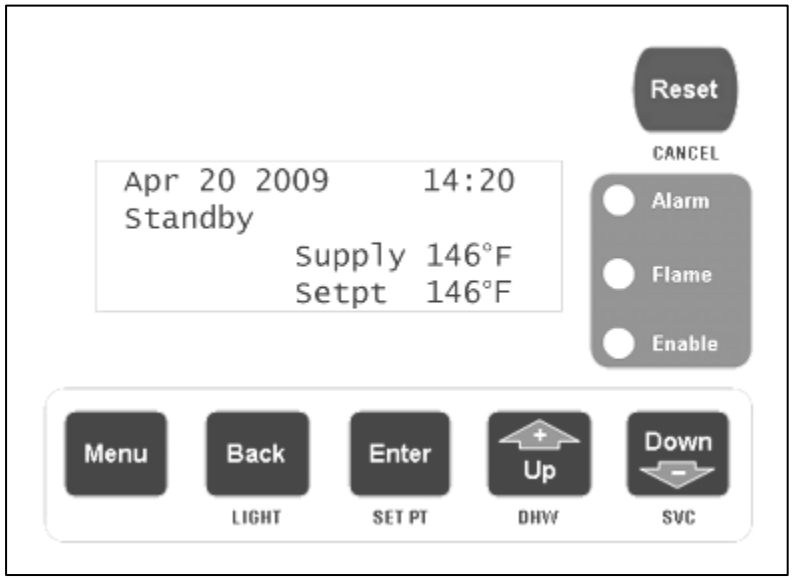
3.9.4 Test of Gas Pressure Switches

Low Gas Pressure Switch
The boiler is furnished with a low gas pressure switch. The operation of this switch must be checked by slowly closing the main gas cock while the burner is operating. The switch should shut down the main burner. When the gas pressure switch opens, a manual reset lockout displaying LOCKING LOW GAS PRESSURE on the display panel will occur. Upon re-opening the main gas cock, the LOCKING LOW GAS PRESSURE will remain on until the display panel is manually reset.

High Gas Pressure Switch
The boiler is furnished with a high pressure switch that must be checked by closing the downstream gas cock with the boiler off. When the boiler is started, it should enter its normal starting cycle and fail on high gas pressure when the automatic gas valves open. The high gas pressure switch actuation is evident when a manual reset lockout displaying LOCKING HIGH GAS PRESSURE on the display panel occurs. Upon re-opening the gas cock, the LOCKING HIGH GAS PRESSURE indicator will remain on until the display panel is manually reset.

3.10 INITIAL ADJUSTMENTS

3.10.1 Operating Temperature Controller

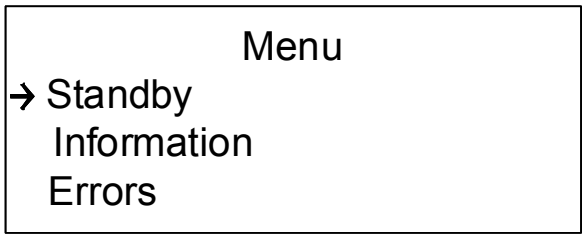


The MACH® boilers C1500-2000 are equipped with ENVI™ Control; an intelligent control system with advanced features such as text-based display, communication capabilities, and boiler sequencing. Errors are date and time stamped providing built-in history of boiler status and performance. This control constantly tracks the load by recording burner high, low and mid run hours. One control to do it all – temperature control, flame safeguard, firing rate control, blocked flue protection, outdoor air reset, freeze protection, built-in cascade sequencing, MODBUS communication and more.

⚠ CAUTION The user should become thoroughly familiar with the operation of the boiler and controls before attempting to make any adjustments.

The boiler control has a text display panel. The display panel is used to setup and monitor boiler operation by means of six push buttons MENU, BACK, ENTER, UP, DOWN, and RESET as shown above. The buttons across the bottom are used to navigate through the various screens. The four line screen shows boiler operating information on various screens. The display screen is backlit for ease of viewing. Pressing any key will illuminate the backlight.

The standby screen is shown upon startup. This screen shows the date, time, boiler status, supply temp and setpoint temp. Pushing the menu button displays a menu of options.



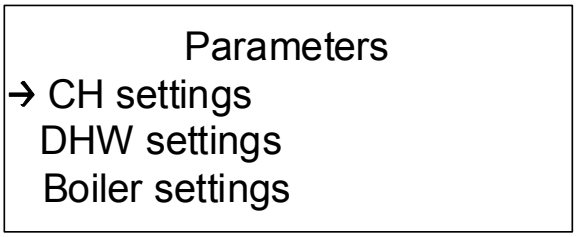
The menu includes access to the Standby, Information, Errors, Program Parameters, Configuration, Cascade, and Service Menu. The Up and Down buttons are used to position the arrow next to the desired option and the enter button is pushed to enter that option. The list is displayed and may have more than four lines. Use the down arrow to view the complete list.

⚠ CAUTION

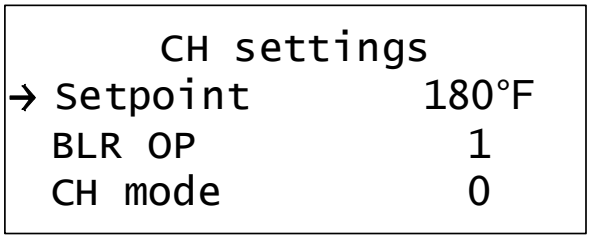
Changing parameters requires an understanding of the parameters and the functionality of the boiler. The boiler may not function properly if parameters are changed from the factory values.

3.10.2 Boiler Setpoint

The factory default setpoint is 180 °F. If a different setpoint is desired, push the menu button and then select PROGRAM PARAMETERS from the menu. A screen opens that allows the user to view and change operating parameters (see screenshot below.)



Select the CH settings to adjust parameters related to the boilers Comfort Heat function.



For example, selecting the Setpoint parameter opens up a screen that allows the setpoint to be changed.

```
     CH settings
Setpoint
Value:  180˚F
Range:  45˚F – 185˚F
```

The up or down buttons are used to adjust the CH setpoint up or down as desired. The enter button is pushed once the desired temperature is reached.

3.10.3 Other CH Parameters

Other settings include the following items:

Description	Value	Units
CH Setpoint	###	°F
BLR OP (Off = 0, On = 1, Off/Pump On = 2, and On/Pump On = 3)	#	0-3
CH Mode	#	0-8
Hysteres On (On Differential)	##	°F
Hysteres Off (Off Differential)	##	°F
Post Pump time	###	Sec

Additional CH Parameters are available and used for the various CH Modes other than mode 0, the standard Setpoint & (Thermo)Stat control mode. These modes are further described in the ENVI™ Control Advanced User's Guide.

3.10.4 Other Parameters

Other parameters include the settings for DHW (Domestic Hot Water), Boiler Settings and OEM Settings. Boiler and OEM Settings are used during the initial programming of the control and are not adjustable.

3.10.5 Additional Menu Items

In the main menu, Standby, Information, Errors, Program Parameters, Configuration, Cascade, and Service Menus are available. They are used for various functions of the boiler. These functions are described further in the ENVI™ Control Advanced User's Guide.

These menu items will be described briefly here:

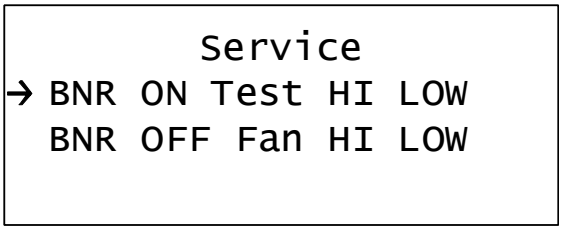
- STANDBY is the default screen and is shown during normal boiler operation.
- The INFORMATION menu lists items that the boiler monitors such as temperatures, operating conditions, and status of switches and components.
- The ERRORS menu has information about the boiler status at the time of an error.
- The PARAMETERS menu allows the user to set up selected boiler functions and operating modes.
- The CONFIGURATION menu covers basic display information such as language, units, date/time, etc.
- The CASCADE menu is used to sequence multiple boilers (up to 24 max) in a Master/Member network system. Use of this function is described in detail in the Advanced User's Guide.
- The SERVICE menu is described below.

3.10.6 Service Menu:

Two test modes are available in the service menu.

BNR ON TEST HI LOW

BNR OFF FAN HI LOW



The first test mode allows the service technician to hold the boiler in high or low fire during firing operation so that the combustion adjustment can be performed as indicated below.

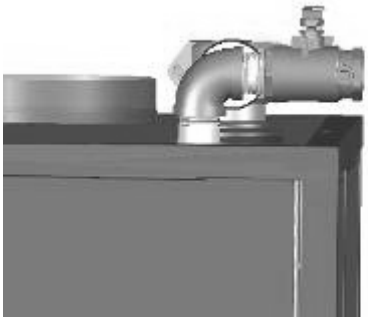
The second test mode checks the fan rate with the burner off at high speed or at low speed.

These test modes will automatically terminate after 15 minutes of inactivity or can be terminated from the control/display panel by pressing the cancel/reset button

3.11 BURNER ADJUSTMENT

NOTICE! Adjustments shall only be performed by service representative specifically trained and certified to perform maintenance on the Harsco Industrial, Patterson-Kelley MACH® boiler. Verify proper operation after servicing.

See rating plate for the minimum and maximum inlet gas pressure of the boiler. The supply pressure during main burner operation must be greater than the minimum indicated on the rating plate. Nominal gas supply pressure is 7" W.C. for natural gas. The gas pressure must not exceed 14" W.C. which is the maximum allowable pressure on the gas train components. Each boiler is furnished with a manual shut-off valve which has an integrated test port. This port is located on the upstream side of the valve body for measuring supply pressure. (See figure below.)



The air flow is pre-set at the factory prior to shipment. Gas flow is dependent primarily on fan speed not upstream gas pressure. The air/gas ratio may have to be adjusted to obtain proper combustion readings for specific local conditions. A combustion analyzer must be used. Combustion should be adjusted in accordance with Table of Combustion Exhaust Settings

NOTICE! For high altitude adjustments (greater than 2,000 feet above sea level), derate the boiler by 4% for each 1000 ft above sea level.

Table of Combustion Exhaust Settings

Fuel	Nominal Inlet Gas Pressure*	High Fire Setting		Low Fire Setting	
		% O_2	% CO_2	% O_2	% CO_2
Natural Gas	7" W.C	5.0 ± 0.2	9.0 ± 0.2	5.2 ± 0.2	8.8 ± 0.2
Propane	11" W.C	5.0 ± 0.2	10.4 ± 0.3	5.2 ± 0.2	10.3 ± 0.3

3.11.1 Combustion Setup and Adjustment

Boiler Test Mode for High and Low fire:

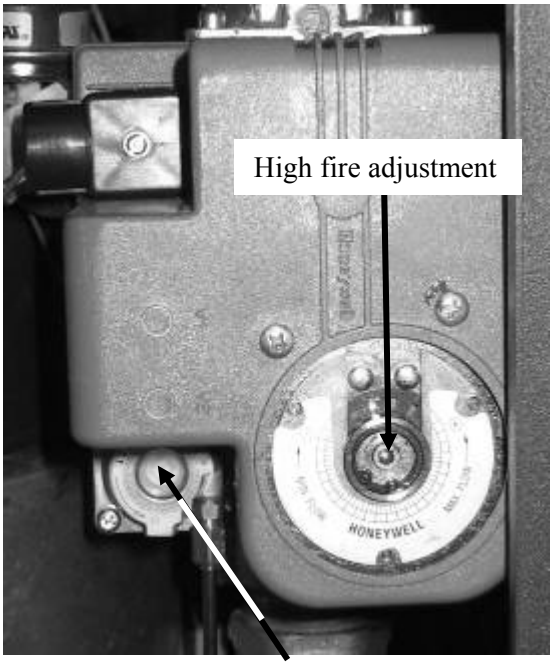
Set the combustion using the Service Menu BNR ON TEST HI & BNR ON TEST LOW modes. These test modes should be used when checking and setting the gas safety shut off / control valves on the MACH® boiler. In this mode a heat request is required. Once the boiler cycles on, use the arrow keys to access the Service Menu and select the BNR ON TEST HI/LOW mode and push enter. Then select BNR ON TEST HI or the BNR ON TEST LOW mode and push enter. The boiler will ramp to high or low fire.

NOTICE! There must be sufficient load to operate the boiler at high fire to perform the following adjustments. Start the boiler and observe proper operating parameters for the system.

The supply pressure during main burner operation must be greater than the minimum indicated on the rating plate which is 3" W.C. for natural gas. Nominal gas supply pressure is 7" W.C. for natural gas. The gas pressure must not exceed 14" W.C. which is the maximum allowable pressure on the gas train components.

Required Tools: TORX® T40 or 5 mm hex wrench, 3 mm or 7/64 in hex wrench, Combustion analyzer

C1500/C2000 Adjusting Low and High



Analyzer in Exhaust Vent

Start the boiler and observe proper operating parameters for the system. The combustion analyzer probe should be placed in the stack outlet to measure the combustion parameters. The MACH® boilers are equipped with a combined gas/air control and gas safety shut off control valves. The valve functions with the variable speed combustion blower to supply the correct gas air ratio for optimum performance and efficiency.

High Fire Setting
Set boiler to the "BNR ON TEST HI", as described above, to achieve maximum firing rate of the boiler. Check combustion readings using a combustion analyzer. If combustion readings are not in accordance with Table of Combustion Exhaust Settings, adjust as follows:, adjust as follows:

Remove the flat, round, plastic cap from the gas valve. Using a 3mm (7/64") hex wrench, adjust the high fire screw (see the figure below) on each of the gas control valves by turning clockwise or counterclockwise to achieve the desired CO_2 or O_2 level; see Table 3-1 for correct settings. (There will be a time delay between the adjustment and the response of the CO_2/O_2 combustion analyzer). Adjust the settings in small increments. When desired adjustments are complete, reinstall the blue plastic cap on the gas valve. Clockwise rotation decreases gas flow. Counterclockwise rotation increases gas flow.

Low Fire Setting
Set boiler to the "BNR ON TEST LOW", as described above, to achieve minimum firing rate of the boiler. Check combustion readings using a combustion analyzer. If combustion readings are not in accordance with Table of Combustion Exhaust Settings, adjust as follows:

Remove the gray cap on the gas regulator using a slotted screwdriver. This will expose the low fire adjustment screw. Using a TORX® T40 or a 5 mm hex wrench, adjust the low fire screw on the pressure regulator (see the figure above) to achieve the correct CO_2 /O_2 level. Adjustments to low fire should not exceed ¼ turn at a time before allowing the readings to respond and stabilize. Clockwise rotation increases gas flow. Counterclockwise rotation decreases gas flow. After the low fire adjustment is made, reinstall the slotted cap on the regulator.

NOTICE! The rotation of the Low Fire adjustment screw is opposite to the High Fire adjustment screw.

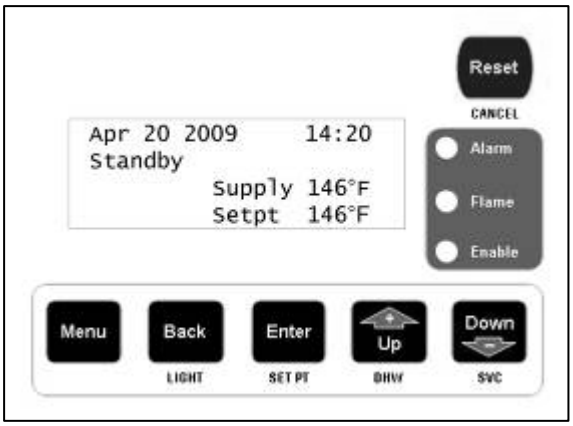
Following all gas valve adjustments, check for proper light-off and verify correct fuel/air mix and combustion quality throughout the entire firing range (from low fire to high fire).

3.11.2 Checking Flame Signal

Using the control panel, enter the information mode and scroll down to FLAME SIGNAL. When the boiler is firing, the FLAME SIGNAL will be "yes" and when the boiler is not firing, the FLAME SIGNAL will be "no".

4.0 OPERATION

4.1 GENERAL



4.1.1 Control Panel

Become familiar with the basic operation of the boiler. The operating instructions are located inside the gray door at the front of the boiler on MACH® boiler C1500-2000.

4.1.2 Tests

All Harsco Industrial, Patterson-Kelley boilers are fire tested at the factory prior to shipment. This procedure includes testing of the limits and adjustment of combustion parameters. This testing and setup information is recorded on the "Factory Firetest" label located on the back of the boiler.

4.2 NORMAL LIGHTING AND SHUT-DOWN PROCEDURES

⚠ WARNING Do not use this boiler if any part has been under water. Immediately call a qualified service technician to inspect the boiler and to replace any part of the control system and any gas control which has been under water.

4.2.1 Initial Lighting Procedures

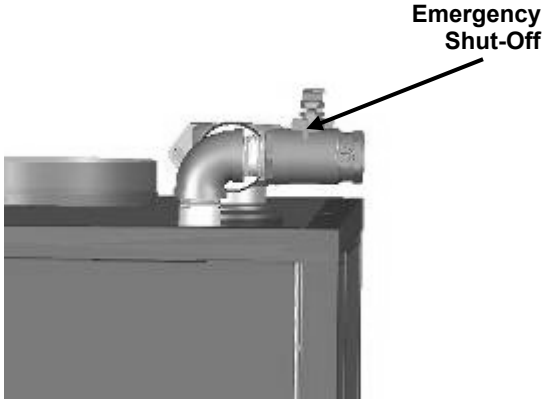
1. Make sure the system is filled with water and water is circulating in the system. Turn on electrical supply and open the gas supply valves to the boiler.
2. Turn the on/off switch to the on position.. If an error is indicated, see Section 5.5 of this manual to troubleshoot the problem and take the necessary corrective action before proceeding.
3. Set the desired high temperature limit and operating temperature. The controller will now complete the automatic firing sequence.

4.2.2 Normal Shut Down Procedures

1. Turn the on/off switch to the off position.
2. Close all manual gas valves. (for extended period.)

4.2.3 Emergency Shut-Off

⚠ WARNING If overheating occurs or the gas supply fails to shut off, do not turn off or disconnect the electrical supply to the pump. Instead, shut off the gas supply at a location external to the boiler.



4.3 TYPICAL BOILER UTILITY REQUIREMENTS

MACH® Boiler Model	Input Rating (BTU/Hr)	Total Amperage	Natural Gas (1030 Btu/cu. ft.*)	
			Gas Rate (CFH)	Output Capacity (Btu/hr)
C1500	1,500,000	Less than 15	1456*	1,440,000
C2000	2,000,000	Less than 15	1942*	1,920,000

Note: The heat exchanger is constructed and stamped for 100 psig maximum operating pressure and 200º F maximum temperature.

5.0 MAINTENANCE

5.1 MAINTENANCE AND INSPECTION SCHEDULE

This schedule applies when the boiler is in use. Verify proper operation after servicing.

⚠ WARNING Label all wires prior to disconnection when servicing controls. Wiring errors can cause improper and dangerous operation.

⚠ WARNING Use care when reassembling main gas line to assure all connections are tight.

⚠ WARNING Use care when servicing boiler in order to prevent the accumulation of gas in or around the combustion chamber.

⚠ WARNING General lockout/ tagout procedure must be employed when servicing this unit.

⚠ WARNING Determine the cause of any lockout before resetting the boiler. If able to determine cause of lockout, then appropriate corrective action should be taken. If not able to determine cause of the problem, call a qualified service technician.

5.1.1 Daily

Observe operating temperature and general conditions. Make sure that the flow of combustion and ventilating air to the boiler is not obstructed. Determine the cause of any service codes or lockouts on the display panel. Observe any unusual noises or operating conditions and make the necessary corrections. Notify responsible individuals for required corrective action or repair.

⚠ WARNING Check daily to be sure that the boiler area is free and clear of any combustible materials, including flammable vapors and liquids.

5.1.2 Weekly

Observe the conditions of the main flame. A normal high fire flame is blue and orange. If the high fire flame is yellow then corrective action must be taken. In normal low fire operation the burner will glow yellowish-orange.

Correct air adjustment is essential to the efficient operation of this boiler. If an adjustment in the combustion is necessary, call a qualified and knowledgeable installer or service agency who has been trained on the Harsco Industrial, Patterson-Kelley MACH® boilers.

5.1.3 Monthly (During Operation)

1. Using the control panel, enter the information mode and scroll down view the flame signal. When the boiler is firing, the signal will be “yes” and when the boiler is not firing, the signal will be “no”.
2. Test high-limit Control. Refer to Section 3.9.
3. Test operating temperature controls by reducing or increasing temperature setting as necessary to check burner operation.
4. Test the low water level cut-out. Refer to Section 3.9.
5. Test low gas pressure switch. Refer to Section 3.9.
6. Check the condensate drain system. Clean and flush as necessary.

Installation and service must be performed by a qualified and knowledgeable installer or service agency who has been trained on the Harsco Industrial, Patterson-Kelley MACH® boilers.

5.1.4 Semi-Annually (required for boilers operated year round)

In addition to the recommended monthly service:

1. Clean burner of any accumulated dust or lint. See Section 5.2 on "Cleaning the Burner."
2. Inspect burner for any signs of deterioration or corrosion. Replace immediately if deterioration or corrosion is evident.
3. Check the pH level of the system fluid (refer to section 3.7.4)
4. Inspect and clean the condensate system and check for leaks. If a condensate neutralization kit is present, open the lid and inspect the limestone rocks. If they are absent or have been significantly worn away, replace them with new limestone rocks. Use hi-calcium (or pure) limestone.

Installation and service must be performed by a qualified installer or service agency who has been trained on the Harsco Industrial, Patterson-Kelley MACH® boiler.

The blower motor is permanently lubricated and does not require periodic lubrication.

5.1.5 Annually

In addition to the recommended monthly service:

1. Inspect and clean the inlet screen of any accumulated dust or lint.
2. Check burner and clean off any soot or foreign material that may have accumulated. See Section 5.2 on "Cleaning the Burner." Check for corrosion of the burner and its parts. If there is evidence of deterioration or corrosion, replace immediately. Inspect combustion chamber when the burner is removed for inspection. Note any signs of deterioration. Clean as necessary.
3. Inspect and clean heat exchanger. Remove the various covers to inspect the flue gas passageways. Clean the combustion side casting pins by flushing with clean water and blowing dry with compressed air. Do not use any cleaning agents or solvents. Do not use soap. A soft nylon brush may be used in accessible areas. Be sure to inspect the condensate collection pan that is the lowest part of the heat exchanger.
4. Replace the ignitor and gasket.

5. Drain and flush the water side of the heat exchanger as required (separate from system flush) using clean water only.
6. Inspect and clean the condensate system and check for leaks. If a condensate neutralization kit is present, open the lid and inspect the limestone rocks. If they are absent or have been significantly worn away, replace them with new limestone rocks. Use hi-calcium (or pure) limestone.
7. Examine the venting system at least once a year. Refer to the vent manufacturer's instructions for requirements in addition to those listed below.
   a. Check all joints and pipe connections for tightness.
   b. Check pipe for corrosion or deterioration. If any piping needs replacing, do so immediately.
   c. Inspect and clean any screens in the vent terminal
8. Qualified service personnel should thoroughly inspect the heating system and correct any problems prior to re-starting the boiler.
9. Perform combustion analysis and readjust as necessary according to section 3.11. It is recommended that a copy of this report is filed for future reference.
10. Perform a leak test of the gas valves in accordance with the manufacturer's instructions.

Installation and service must be performed by a qualified installer or service agency that has been trained on the MACH® boiler.

5.2 CLEANING THE BURNER

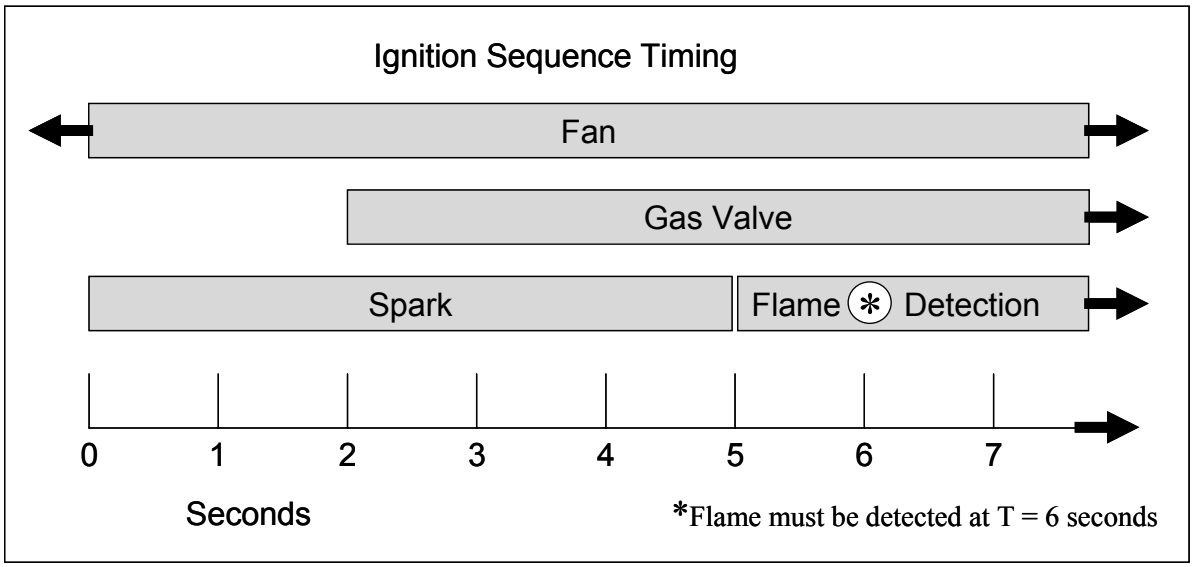
1. Lockout/tagout gas supply to the boiler.
2. Lockout/tagout electrical power to the boiler.
3. Open the front door of the boiler.
4. Disconnect the two electrical connections to the blower
5. Remove the ignition electrode.
6. Remove the six screws on the bottom of the blower.
7. Remove the three nuts holding the blower outlet on the boiler casting.
8. Pull the blower w/outlet and set aside. Inspect burner gasket, replace if damaged.
9. Reaching inside the burner, carefully remove the burner. Clean using low pressure air to remove any dust or lint from the burner.
10. Reassemble being sure to install all gaskets and seals properly.

5.3 AFTER ALL REPAIRS OR MAINTENANCE

1. Follow "Pre-Start Check List" (Section 3.8) and all "Safety Checks" (Section 3.9).
2. Check gas pressure. (Section 3.11)
3. Perform combustion check. Adjust gas flow if necessary. (Section 3.11).

5.4 SEQUENCE OF OPERATION

1. When the Boiler On/Off switch is turned on, power is provided through a circuit breaker to the boiler control and the combustion blower.
2. If the high gas, low gas or low water level control is open, the boiler control locks out and displays an error.
3. When the water temperature is below the boiler control setpoint minus the hysteresis (On Differential), a heat request is generated.
4. Provided all limits are made, the boiler will attempt to start.
5. The controller checks that the air pressure switch is open indicating no airflow. The blower is driven towards the prestart fan speed. When the air pressure switch closes, the 25 second pre-purge time is started. After the pre-purge, the blower is driven to the ignition speed.
6. A trial for ignition begins. The sequence of events is illustrated graphically below.
7. After ignition, the fan may be driven to low fire before the boiler is released to modulation.
8. The control modulates the firing rate between low and high fire to maintain the desired outlet water temperature.
9. The burner will continue firing until the outlet water temperature reaches set point plus hysteresis (Off Differential). At this temperature the fuel supply is shut off and the combustion air fan continues to run for a 30 second post-purge.
10. When the water temperature is reduced by the load on the system, a heat request is generated. The operating sequence will recycle to step 4.



NOTICE! Once the boiler begins the ignition sequence, the firing sequence will continue until main flame is reached regardless of heat request. The sequence can be interrupted by turning the power switch off.

5.5 TROUBLESHOOTING

⚠ WARNING If any "Manual Reset" limit device trips, **DO NOT** reset without determining and correcting the cause. (Manual Reset Limits include: Flame safeguard, high or low gas pressure, high temperature limit, stack temperature, low water level.)

The ENVI™ boiler control will display text based error descriptions to indicate any problems with the boiler. There are two types of lockouts the control may experience: manual reset lockouts requiring an operator to press the reset button, and automatic reset lockouts that will self reset when the error condition clears. A listing of errors and their service codes is included at the end of this section.

Should the unit fail to operate, call a qualified service technician to troubleshoot the problem and implement corrective actions.

5.5.1 The Loss of Power

In the event of a power failure, the display panel is not illuminated and the entire system is de-energized, closing all automatic valves and halting all boiler operations. When power is restored the sequence of operation will resume at Step 4. If any error/lockout is present when the power is lost, the control will retain that error/lockout and display the error/lockout when the power is restored.

5.5.2 Loss of Water Level

The low water switch opens when there is insufficient water level in the boiler. Lockout LOW WATER LEVEL is shown on the display, the burner operation is interrupted, and the boiler locks out. When the correct water level is re-established, and the control reset button is pressed, the boiler will reset and will start the sequence at Step 4.

5.5.3 Low Gas Pressure

The low gas pressure switch opens when there is (or has been) insufficient gas pressure available for proper operation of the boiler. If an external gas-supply shut-off valve is closed for any reason, a low gas condition will result. Locking LOW GAS PRESSURE is shown on the display, the burner operation is interrupted, and the boiler locks out. When proper gas pressure is restored, and the control reset button is pressed, the boiler will reset and will start the sequence at Step 4.

5.5.4 High Gas Pressure

The high gas pressure switch opens when there is (or has been) excessive gas pressure for the proper operation of the boiler Locking HIGH GAS PRESSURE is shown on the display, the burner operation is interrupted, and the boiler locks out. When proper gas pressure is restored, and the control reset button is pressed, the boiler will reset and will start the sequence at Step 4.

5.5.5 High Water Temperature

When the boiler water has exceeded both the operating and high-limit temperature the high limit switch opens, and Locking HIGH LIMIT is shown on the display. When the water temperature falls below the high-limit temperature, the boiler will remain locked out until the water high limit switch is manually reset and the front panel reset button is pressed. Once reset, the control will restart the sequence of operation at Step 4.

5.5.6 Low Air

If the display panel indicates Locking AIR SWITCH NOT OPEN or Locking AIR SWITCH NOT CLOSED this indicates improper airflow through the boiler. Check the hoses leading to the air switches. Verify proper blower operation. An air switch error does not necessarily mean that the air switch is defective.

When AIR SWITCH NOT OPEN is shown on the display, check that the air switch is open when the fan is off. Check that there is no air flow through the boiler when the fan is off.

When AIR SWITCH NOT CLOSED is shown on the display, check that the air switch is closed when the fan is running. If the air switch does not close within 5 minutes during purge, the boiler locks out. Check that the burner is clean ("Cleaning the Burner," Section 5.2) and that there are no obstructions to airflow in the intake or exhaust ducts.

5.5.7 Flame Failure

In the event of a flame failure, the main fuel valves are de-energized and a manual reset lockout occurs. Locking IGNITION FAILURE or Lockout FLAME FAILURE is shown on the display. The cause of flame failure must be diagnosed and repaired before the control is reset.

When IGNITION FAILURE is shown on the display, the boiler did not light during a trial for ignition. Check that the spark, electrode, ignition wire, and gas valve are functioning properly.

When FLAME FAILURE is shown on the display, the boiler lost the flame during run. Check that the combustion is setup properly, the gas pressure is correct, as well as other combustion parameters.

5.5.8 Flame Error

Locking LATE FLAME

Blocking FALSE FLAME

These errors signify flame error. This may be caused by a failed or leaky gas valve or a flame detector malfunction. If gas valve leakage is suspected, the unit must be isolated by turning off the main gas supply line. Qualified and knowledgeable service personnel must be called to evaluate and repair/replace the failed parts.

5.5.9 Stack Problem

BLOCKED_FLUE_indicates that the high exhaust back pressure switch has tripped. This may be caused by a blocked stack, a blocked air inlet, or a blocked condensate system. When the blockage is removed, the boiler will automatically restart.

A comprehensive listing of the locking and blocking error codes is provided below.

5.5.10 Manual Reset Error Codes – A##

Code	ENVI™ Control Display	Lockout	Description
A00	NED	Unassigned	No Error Description, Call For Service
A01	IGNITION FAILURE	Ignition Failure	During an attempt to light, no flame was detected
A02	FLAME FAILURE	Flame Failure	During run, the flame was lost
A03	HIGH LIMIT	High Limit	The temperature in the boiler exceeded the setting on the High Limit Control
A05	INT ERR GAS VLV RLY	Internal Error Gas Valve Relay	Call for service.
A06	INT ERR SAFETY RLY	Internal Error Safety Relay	Call for service.
A07	LOW FLOW / ILK	Low Water Flow or Open Interlock Jumper	Water Flow is Inadequate or Interlock Jumper is Open
A09	INTERAL ERROR 9 or 27 or 28 or 29 or 30	Internal Error 9 or 27 or 28 or 29 or 30	Call for service.
A10	INT ERR E2PROM ERR	Internal Error E2PROM Err	Call for service.
A12	INT ERR E2PROM SIG	Internal Error E2PROM Sig	Call for service.
A13	INTERAL ERROR 13	Internal Error 13	Call for service.
A14	INTERAL ERROR 14	Internal Error 14	Call for service.
A15	INTERAL ERROR 16	Internal Error 16	Call for service.
A16	INTERAL ERROR 22	Internal Error 22	Call for service.
A18	INTERAL ERROR 19	Internal Error 19	Call for service.
A19	LATE FLAME	Late Flame	Flame still present after boiler gas valve closed during post purge
A20	EARLY FLAME	Early Flame	Flame detected before boiler gas valve opened during pre purge
A30	HIGH GAS PRESSURE	High Gas Pressure Error	The gas pressure is too high and has tripped the HGPS
A31	LOW GAS PRESSURE	Low Gas Pressure Error	The gas pressure is too low and has tripped the LGPS
A32	INTERAL ERROR 23	Internal Error 23	Call for service.
A33	FAN WRONG SPEED	Wrong Fan Speed Error	Fan deviation more than 300 rpm for > 1 sec (ignored when fan > 4200 rpm)
A34	AIR SWITCH NOT OPEN	Air Switch Not Open	Air switch does not open when fan is off
A35	AIR SWITCH NOT CLOSE	Air Switch Not Closed	Air switch does not close when fan is running
A37	UV SENSOR DEFECT	UV Sensor Defective	Self Check function of UV detector has indicated a failure
A38	MAX DT EXCEEDED	Max Delta Temp Exceeded	Maximum temperature differential across the boiler has been exceeded
A39	RAPID RISE INLET TMP	Rapid Rise Inlet Error	Inlet temperature is rising too rapidly
A40	RAPID RISE OUT TEMP	Rapid Rise Outlet Error	Outlet temperature is rising too rapidly
A41	RAPID RISE HX TEMP	Rapid Rise HX Temp	Temperature across heat exchanger is rising faster than allowed
A43	LOW WATER LEVEL	Low Water Cutoff	Water is too low for boiler to operate
A45	INTERNAL ERROR 31	Internal Error 31	Call for service.

Note: When an Internal Error occurs, as identified above, the failure is internal to the ENVI™ boiler control and replacement of the ENVI™ control is required. A qualified service technician must replace the ENVI™ control.

5.5.11 Auto-reset Error Codes – E##

Code	ENVI™ Control Display	Lockout	Description
E01	OUT TEMP SENS OPEN	Outlet Temperature Sensor Open	Boiler outlet water temperature sensor open circuit
E02	IN TEMP SENS OPEN	Inlet Temperature Sensor Open	Boiler inlet water sensor temperature open circuit
E03	FLUE TMP SENS OPEN	Flue Temperature Sensor Open	Boiler flue gas temperature sensor open circuit
E04	DHW TEMP SENS OPEN	DHW Temperature Sensor Open	Domestic Hot Water temperature sensor open circuit
E05	HX TEMP SENS OPEN	Heat Exchanger Temperature Sensor Open	Heat Exchange temperature sensor open circuit
E11	OUT TEMP SENS SHORT	Outlet Temperature Sensor Short	Boiler outlet water temperature sensor short circuit
E12	IN TEMP SENS SHORT	Inlet Temperature Sensor Short	Boiler inlet water temperature sensor short circuit
E13	FLUE TMP SENS SHORT	Flue Temperature Sensor Short	Boiler flue gas temperature sensor short circuit
E14	DHW TEMP SENS SHORT	DHW Temperature Sensor Short	Domestic Hot Water temperature sensor short circuit
E15	HX TEMP SENS SHORT	Heat Exchanger Temperature Sensor Short	Heat Exchange temperature sensor short circuit
E16	HEADER SENS SHORT	Header Temperature Sensor is defective	Header temperature sensor on IF board has a short circuit or an open circuit
E18	LINE NEUTRAL REV	Electrical Error	Hot and Neutral are reversed
E20	FALSE FLAME	False Flame	Flame detected when no flame should be present
E21	LOW FLOW / ILK	Low Water Flow or Open Interlock Circuit	E21 converts to A07 after 5 minutes
E22	NO GROUND 60 HZ ERR	No Ground error	No ground connected or voltage on ground
E23	LINE FREQUENCY ERR	Line Frequency Error	Line frequency deviates from 60Hz by more than 2%
E24	FAULTY GROUND	Faulty Ground	Ground/Earth connection is not functioning correctly
E30	HIGH FLUE TEMP	Flue Gas Temperature Too High	Temperature of the flue gas is greater than setpoint + differential
E32	HIGH INLET TEMP	Inlet Temp Too High	Inlet water is greater than 194°F
E34	BLOCKED FLUE	Blocked Flue	Hi exhaust back pressure switch is tripped due to excess pressure in the flue/stack or excessive negative cabinet pressure
E41	REVERSE FLOW IN OUT	Reversed Water Flow	The water flow through the boiler is reversed (Inlet water is hotter than outlet water)
E42	INTERAL ERROR 48	Internal Error 48	Call for service.
E46	INTERAL ERROR 35	Internal Error 35	Call for service.
E47	INTERAL ERROR 36	Internal Error 36	Call for service.
E48	INTERAL ERROR 37	Internal Error 37	Call for service.
E49	RAPID RISE HX ERROR	Rapid Rise Heat Exchanger Temperature	Temperature across heat exchanger is rising faster than allowed
E50	RAPID RISE ERROR	Rapid Rise Outlet Temp	Temperature of the Outlet water is rising faster than allowed
E51	INTERNAL ERROR 67	Internal Error 67	Call for Service
E52	WRONG BOILER TYPE	Wrong Boiler Type	Control and Boiler do not match (control is programmed for another type of Harsco boiler)
E 54	IF COMM FAILURE	Interface Board Failure	No communication with Interface Board

6.0 PARTS/TECHNICAL SUPPORT

Spare parts and replacement parts can be ordered from Harsco Industrial, Patterson-Kelley by calling toll free (877) 728-5351. The fax number is (570) 476-7247. Technical information is also available at the above number and at the Harsco Industrial, Patterson-Kelly website www.harscopk.com.

⚠ WARNING Use of Non-Factory-Authorized replacement parts are not recommended for this equipment. All control components are engineered for safety and are designed to work in unison with each of the other components. Use of non-factory-authorized replacement parts jeopardizes the functionality of the safety features as well as the performance of the boiler.

When ordering replacement parts please have the **model number** and **serial number** of your boiler available. Typical schematic drawings are shown on the following pages. Drawings specific to your particular boiler can also be supplied by your local Harsco Industrial, Patterson-Kelley representative.

6.1 WIRING DIAGRAMS

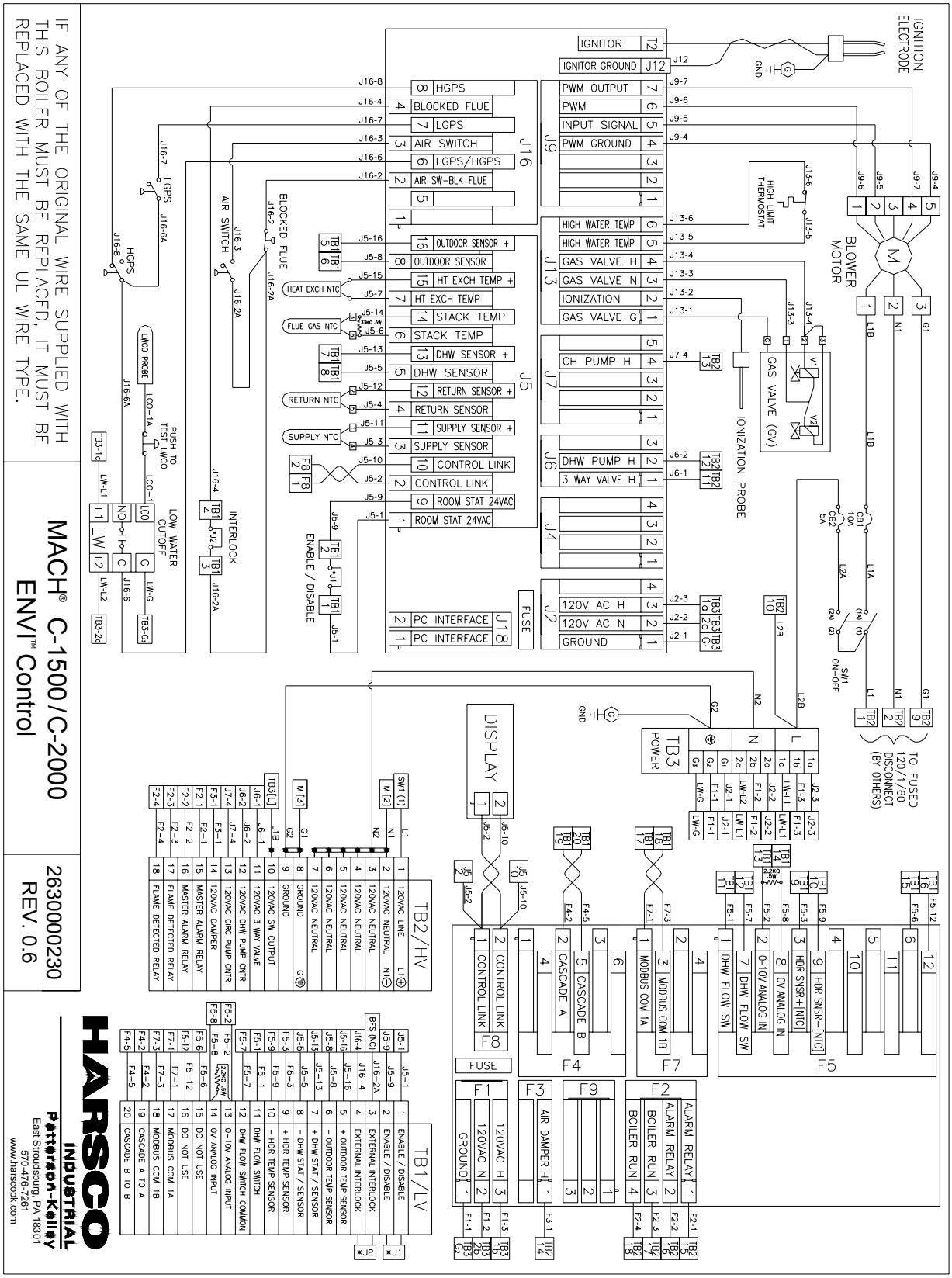
6.1.1 Terminal Block Assignments – High Voltage Circuit (TB2)

Terminal Number	Label	Description
1	120 VAC LINE	Boiler Supply Power, 120 VAC, 1 ph , 60 Hz
2	120 VAC NEUTRAL	Boiler Supply Neutral, 0 VAC
3	120 VAC NEUTRAL	Neutral for use with TB2-10, Switched Output
4	120 VAC NEUTRAL	Neutral for use with TB2-11, 3 Way Valve
5	120 VAC NEUTRAL	Neutral for use with TB2-12, DHW Pump Contactor
6	120 VAC NEUTRAL	Neutral for use with TB2-13, CIRC Pump Contactor
7	120 VAC NEUTRAL	Neutral for use with TB2-14, Damper Output
8	GROUND	Boiler Supply Ground, 0 VAC
9	GROUND	Boiler Supply Ground, 0 VAC
10	120VAC SW OUTPUT	120V AC output when boiler is switched on (4 amp max)
11	120VAC 3 WAY VALVE	120V AC output during CH Mode. 3 way valve is normally closed (not powered) for DHW, and powered open for CH Mode.
12	120VAC DHW PUMP CNTR	120V AC output when boiler is in DHW Mode (pilot duty only)
13	120VAC CIRC PUMP CNTR	120V AC output when boiler is in CH Mode (pilot duty only)
14	120VAC DAMPER	120V AC output when boiler is enabled (pilot duty only)
15	MASTER ALARM RELAY	This circuit closes when the boiler is in an alarm state
16	MASTER ALARM RELAY	
17	FLAME DETECTED RELAY	This circuit closes when the boiler is firing
18	FLAME DETECTED RELAY	

6.1.2 Terminal Block Assignments – Low Voltage Circuit (TB1)

Terminal Number	Label	Description
1	ENABLE / DISABLE	Boiler Enable, Contact Closure.
2	ENABLE / DISABLE	**DO NOT ENERGIZE.**
3	EXTERNAL INTERLOCK	External Limit, Contact Closure.
4	EXTERNAL INTERLOCK	**DO NOT ENERGIZE.**
5	OUTDOOR TEMP SENSOR	Outdoor temperature sensor
6	OUTDOOR TEMP SENSOR	
7	DHW STAT OR SENSOR	Domestic Hot Water sensor or thermostat
8	DHW STAT OR SENSOR	
9	HEADER TEMP SENSOR	Header temperature sensor
10	HEADER TEMP SENSOR	
11	DHW FLOW SWITCH	Domestic Hot Water flow switch
12	DHW FLOW SWITCH COMMON	DHW flow switch indicates potable water flow/usage
13	0-10V ANALOG INPUT	Variable Input (VDC) for remote control of boiler (+)
14	0V ANALOG INPUT	0V for use with TB1-13 (-)
15	For Future Use	Not Used
16	For Future Use	
17	MODBUS COM 1A	Modbus connection to boiler
18	MODBUS COM 1B	
19	CASCADE A TO A	Cascade connection between boilers
20	CASCADE B TO B	

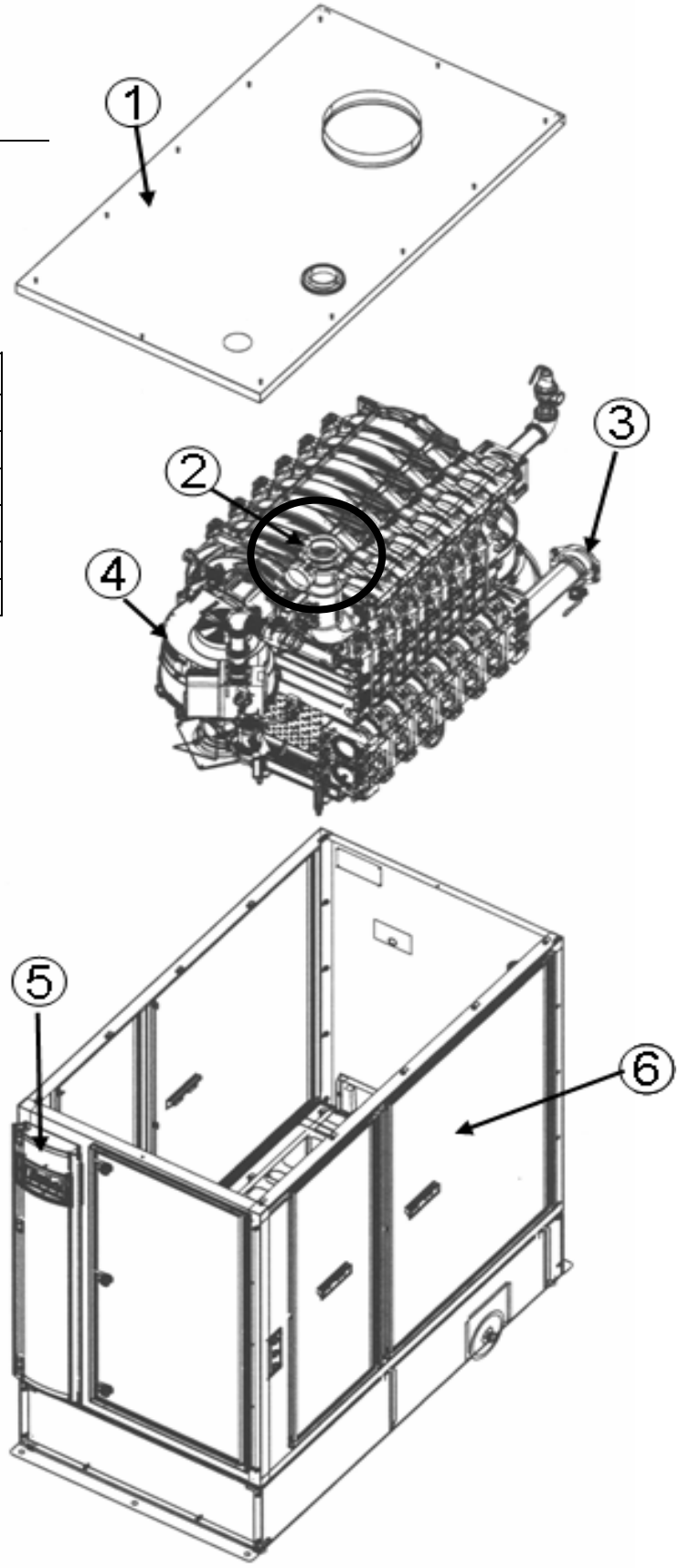
6.1.3 MACH® Boiler C1500/C2000 Wiring Diagram



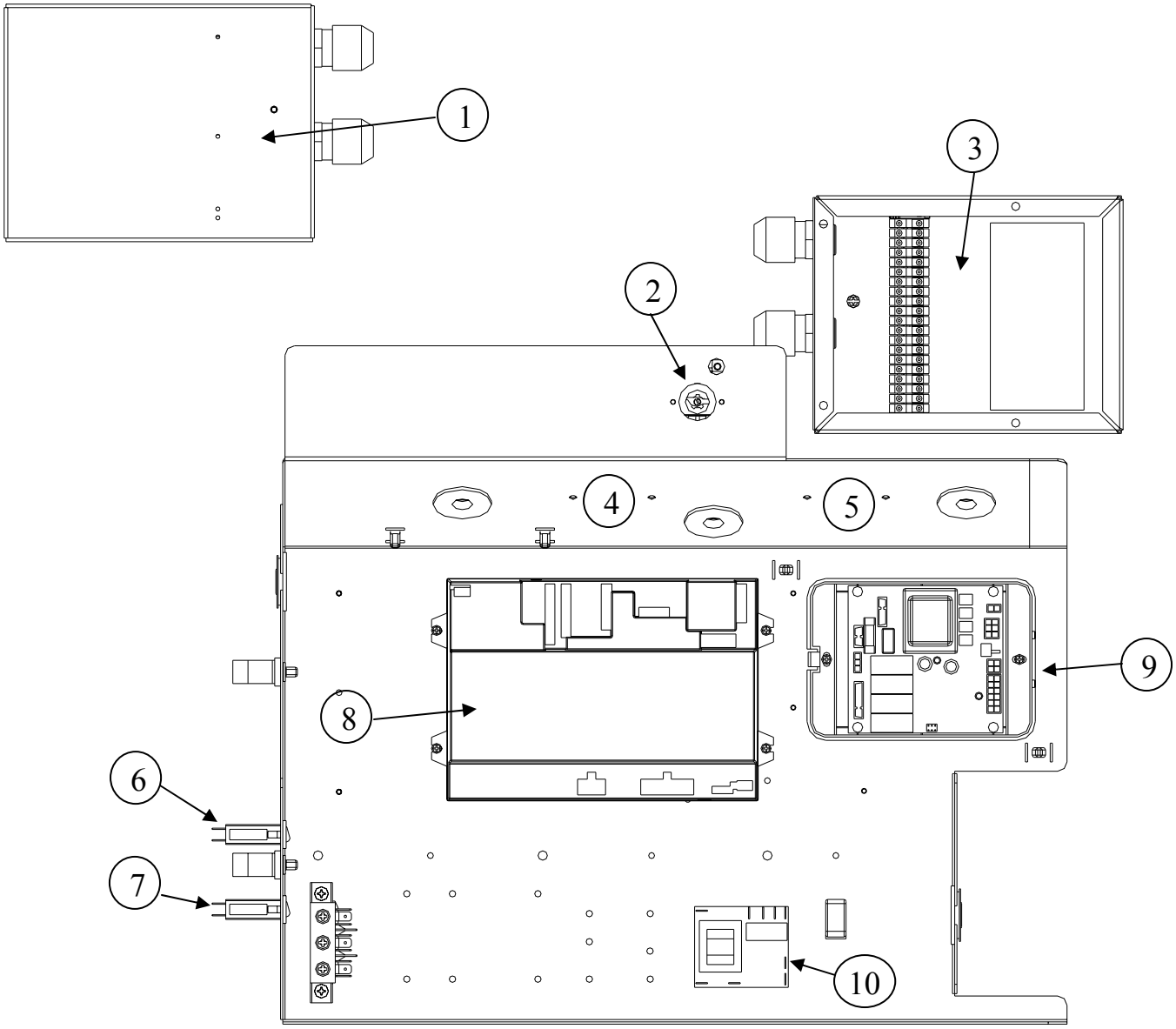
6.2 BOILER PARTS LIST

6.2.1 Main Assembly

Mark	Description
1	Cabinet Top
2	Boiler Outlet
3	Boiler Inlet
4	Blower/Burner Assembly
5	Front Control Panel
6	Cabinet

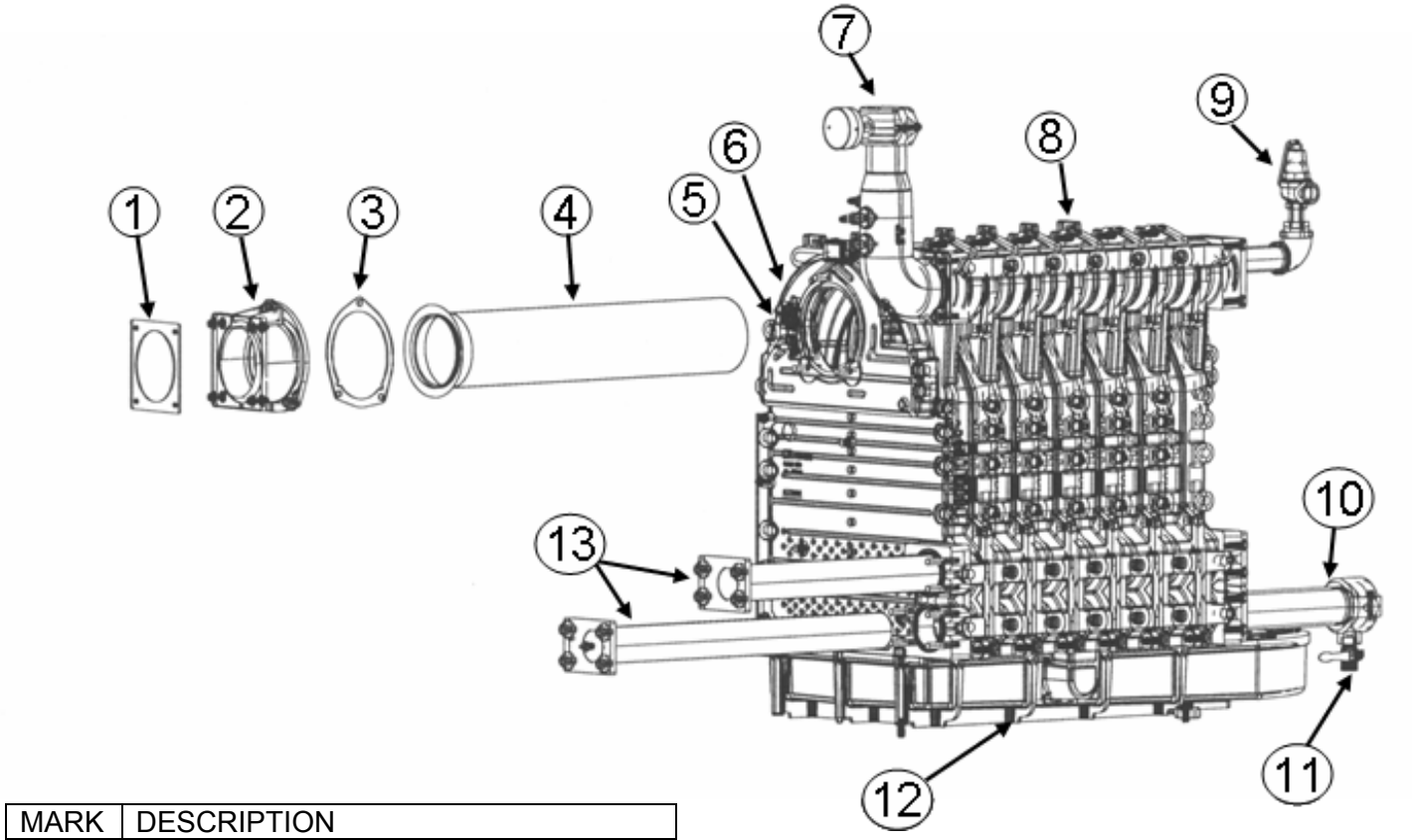


6.2.2 Control Panel



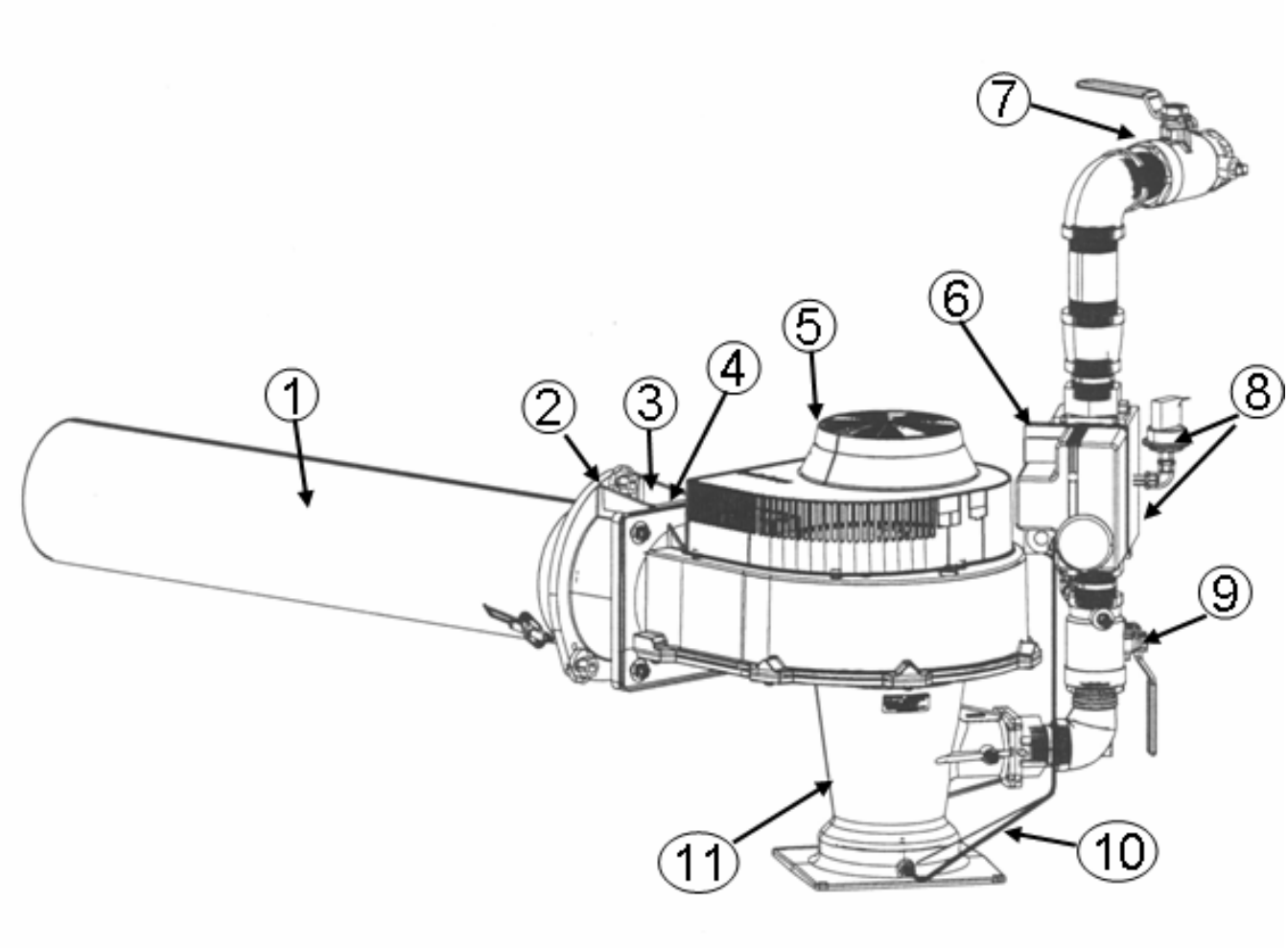
Mark	Description		
1	Terminal Block 2 (TB2) 120V	6	5 Amp Circuit Breaker
2	High Temperature Limit	7	10 Amp Circuit Breaker
3	Terminal Block 1 (TB1) Low V	8	ENVI™ Control Main Board
4	Air Switch (on back)	9	ENVI™ Control Interface Board
5	High Exhaust Back Pressure Switch (HEBPS) on back	10	Low Water Cut-Off Board

6.2.3 MACH® Boiler C1500/C2000 Heat Engine



MARK	DESCRIPTION
1	Blower Outlet Gasket
2	Blower Outlet Transition
3	Burner Gasket
4	Burner
5	Ignition
6	Sight Glass Window
7	Outlet Water Manifold
8	Heat Exchanger Sectional Castings
9	Relief Vavle
10	Inlet Water Connection
11	Boiler Drain Valve
12	Condensate Collector w/Rear Drain
13	Inlet Flow Pipes

6.2.4 MACH® Boiler C1500/C2000 Gas Train



Mark	Description
1	Burner
2	Burner Gasket
3	Blower Outlet Transition Piece
4	Blower Outlet Gasket
5	Blower
6	Automatic Gas Valve
7	Main Gas Shutoff Valve
8	High & Low Gas Pressure Switches
9	Secondary Manual Shutoff Vavle
10	Gas Valve Sensing Line
11	Venturi

7.0 LIMITED WARRANTY

Subject to the terms and conditions herein, Harsco Industrial, Patterson-Kelley, Seller warrants to the original owner at the original installation site that products manufactured by Seller will be free from defects in materials and workmanship for a period of one (1) years from date of start up (the "Warranty Period"), provided that startup is completed within six months from the date of shipment. The heat exchanger and burner will be warranted for a period of five (5) years from the date of shipment (the “Warranty Period”).

REMEDY
The sole remedy of this warranty is expressly limited to the repair or replacement of any part found to be defective under conditions of normal use within the Warranty Period. Installation is not included.

WARRANTY
The owner must notify the original installer of the Product and Seller (Attention: Harsco Industrial, Patterson-Kelley, 100 Burson Street, East Stroudsburg, PA 18301), in writing, within the Warranty Period, providing a detailed description of all claimed defects. Transportation to the factory or other designated facility for repairs of any products or items alleged defective shall, in all events, be the responsibility and at the cost of the owner.

EXCLUSIONS
Seller shall have no liability for and this warranty does not cover:

A. Incidental, special or consequential damages, such as loss of the use of products, facilities or production, inconvenience, loss of time or labor expense involved in repairing or replacing the alleged defective Product.
B. The performance of any Product under conditions varying materially from those under which such Product is usually tested under industry standards at of the time of shipment.
C. Any damage to the Product due to abrasion, erosion, corrosion, deterioration, abnormal temperatures or the influence of foreign matter or energy.
D. The design or operation of owner's plant or equipment or of any facility or system of which any Product may be made a part.
E. The suitability of any Product for any particular application.
F. Any failure resulting from misuse, modification not authorized by Seller in writing, improper installation or lack of or improper maintenance.
G. Equipment furnished by the owner, either mounted or unmounted, or when contracted for by the owner to be installed or handled.
H. Leakage or other malfunction caused by:
    1. Defective installations in general and specifically, any installation which is made:
        a. in violation of applicable state or local plumbing housing or building codes,
        b. contrary to the written instructions furnished with the unit
    2. Adverse local conditions in general and, specifically, sediment or lime precipitation in the tubes and/or headers or corrosive elements in the atmosphere.
    3. Misuse in general and, specifically, operation and maintenance contrary to the written instructions furnished with the unit, disconnection, alteration or addition of components or apparatus, not approved by Seller, operation with fuels or settings other than those set forth on the rating plate or accidental or exterior damage.
I. Production of noise, odors, discoloration or rusty water.
J. Damage to surrounding area or property caused by leakage or malfunction.
K. Costs associated with the replacement and/or repair of the unit including: any freight, shipping or delivery charges, any removal, installation or reinstallation charges, any material and/or permits required for installation, reinstallation or repair, charges to return the boiler and or components. Seller's liability under this warranty shall not in any case exceed the amount paid for the Product found to be defective.

THIRD PARTY WARRANTIES
For goods or components not manufactured by Seller, the warranty obligations of Seller shall, in all respects, conform and be limited to one (1) year from the date of shipment.

SEVERABILITY
To the extent that any provision of this warranty would be void or prohibited under applicable law, such provisions shall be limited in effect to the minimum extent necessary to render the remaining provisions hereof enforceable.

NO OTHER WARRANTIES
Seller makes no implied warranty of merchantability or fitness for a particular purpose or other warranties with respect to any products or services except as expressly set forth in this limited warranty.

8.0 MACH® BOILER FIRE TEST REPORT

MACH® BOILER
FIRE-TEST REPORT

Date: _____

Boiler Serial # _____ Model # _____

Installation: Name: _____ City: _____

State: _____ Zip: _____ Contact _____ Phone: _____

Installer Name: _____ Type of Installation: _____ (Hotel, School, etc.)

Fuel: Natural Gas _____ Propane _____

Outdoor Temperature Sensor Connected Yes: _____ No: _____

1. Factory Fire-Test : (copy from boiler label)

	High	Low
Inlet Gas	"w.c.	"w.c.
Oxygen (O2)	%	%
Carbon Dioxide (CO2)	%	%
Carbon Monoxide (CO)	ppm	ppm
Gross Stack Temp.	° F	° F

Field Fire-Test: DATE: _____

	High	Low
Inlet Gas	"w.c.	"w.c.
Oxygen (O2)	%	%
Carbon Dioxide (CO2)	%	%
Carbon Monoxide (CO)	ppm	ppm
Nox	ppm	ppm
Gross Stack Temp.	° F	° F
Combustion Air Temp.	° F	° F
Stack Press.(exhaust)	"w.c.	"w.c.
Main Flame Signal	Yes/No	Yes/No
Efficiency	%	%
Comb. Air Pres. (intake)	"w.c.	"w.c.

2. Water Inlet temperature: ° F Water Outlet temperature: ° F
3. Flow through boiler: GPM
4. Operating Temperature Setpoint: ° F (from internal OR external control)
5. Stack Pressure (measured where stack exits boiler): "w.c. (High) "w.c. (Low)
6. Approximate stack lengths: Ft. Horizontal Ft. Vertical Flue Pipe Diameter
7. Incoming Electrical Power Volts a.c. Less than 1 volt between neutral and ground
8. **Sytem Water pH level**
9. Comments:

Performed by: _____
(Print Name)

Please return a copy to Harsco Industrial, Patterson-Kelley, ATTN: Boiler Technical Service
Harsco Industrial, Patterson-Kelley • 100 Burson Street • E. Stroudsburg, PA 18301
Phone: (570) 476-7261 • Fax: (570) 476-7247 • www.harscopk.com

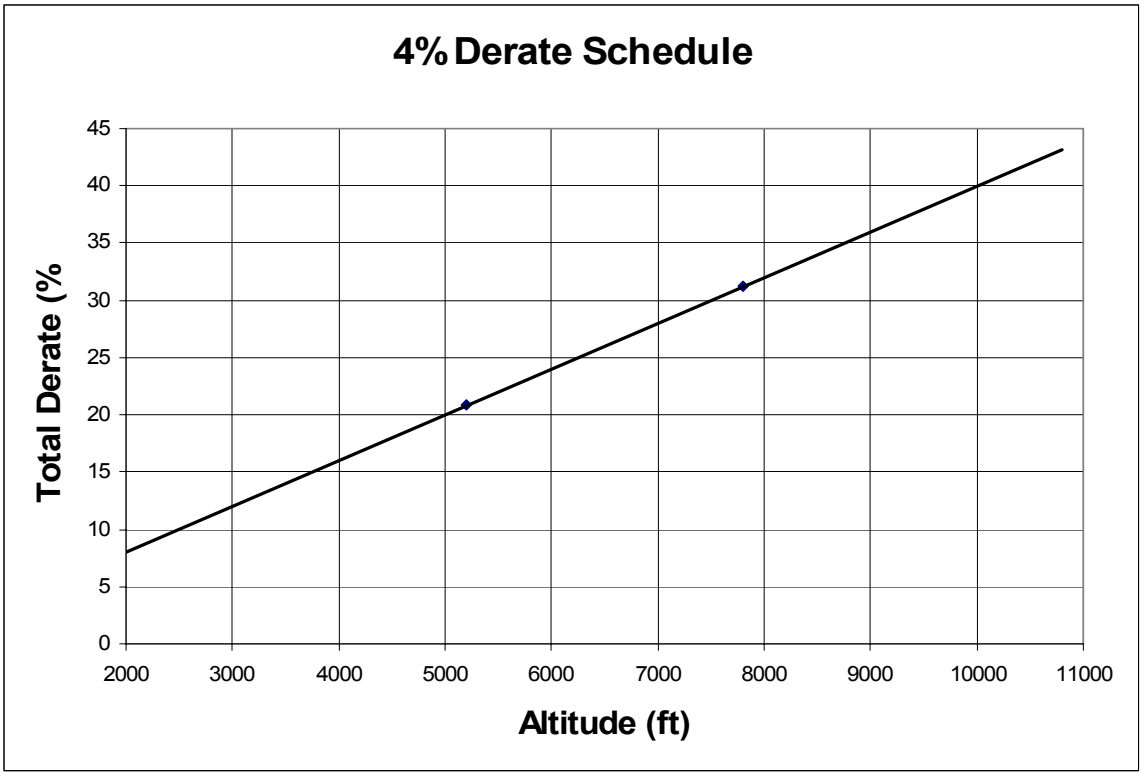
APPENDIX 1 – MAINTENANCE LOG

Date	Hi/Low Fire	O_2	CO	CO_2	Stack Temp	pH	Action	By

APPENDIX 2 – MACH® BOILER ALTITUDE DERATE SCHEDULE

For installations over 2000 ft elevations, a derate schedule is applied. The boiler input rating must be reduced by 4% per 1000 ft.

This is illustrated using the following graph.



Derate procedure is as follows:
With the boiler at high fire, adjust the gas valves (as described in section 3.10.4) to get 5% O_2 in the flue gas. If this cannot be achieved, perform the following steps:

- If the O_2% is too high, then the inlet gas pressure should be adjusted to the minimum pressure allowed, typically 5" w.c. The gas valve should be adjusted to obtain approximately 5% O_2. If the O_2% is still too high, the fan speed may be lowered. This procedure should only be performed by factory trained personnel.
- If the O_2% is too low, then the gas valve settings should be reduced.

This procedure is also described in Bulletin 06-08.

APPENDIX 3 - MACH® WATER CHEMISTRY

The MACH® boiler uses an aluminum alloy that will withstand the acidic condensate (pH ~ 3.0 to 5.0) formed when firing natural or LP gas under conditions which cause the flue gas to condense on the fire side of the heat exchanger. However, the alloy is not resistant to highly alkaline (pH >9.0) environments , so care must be exercised to assure that the water inside the heat exchanger remains in the neutral range (pH ~ 6.0 – 8.5). Other metals, such as steel, cast iron or copper that are commonly found in hydronic heating systems are reactive in neutral to acidic environments so water chemistry must include buffers and protectants that prevent corrosion of these metals. In response to these needs, many chemical treatment manufacturers have devised *multi-metal* treatments that protect aluminum, steel, iron and copper based metals.

The manufacturer of the chemical treatment system must certify that the treatment is intended for use in hydronic systems that include cast aluminum boilers. Additionally, the manufacturer should guarantee that the treatment system, when used in accordance with the manufacturer's instructions, will not damage the boiler, piping, pumps, terminal units and associated components of the hydronic system.

The water quality requirements for the MACH® Boiler are as follows:

- The pH must be between 6.0 and 8.5.
- The hydronic heating system must be a closed loop system. Free oxygen, in particular, can cause formation the form of iron oxides (rust) and electrolytic action in the presence of oxygen causes the formation of magnetite in un-inhibited water. When mixed with sludge - formed when calcium compounds, primarily CaCO3, are heated – magnetite and rust form very hard scale that significantly reduces system efficiencies and shortens the life expectancy of the heating system. Thus it is important to maintain a tight system to avoid the introduction of fresh water make up, which contains dissolved oxygen, minerals and other potential contaminants - makeup water should not be more than 5% of the total volume per year.
- The hardness must be less than 200 ppm
- The chloride must be less than 150 ppm
- Total solids must be less than 1000 ppm
- Other contaminants should be less than 1 ppm

Flushing, Cleaning and Treating the System

NOTICE!

For new installations, begin with step 1

For retrofit installations, the boiler must be isolated from the piping system to prevent introduction of sludge and other contaminants into the boiler. Under no circumstances should the hydronic system be flushed while the boiler is attached to the system. Debris or corrosion products may accumulate in the boiler and plug the heat exchanger. The boiler must be disconnected from the system and a bypass installed so that the chemical cleaning solution does not circulate through the boiler.

1. Thoroughly flush the system to remove as many contaminants as possible.
2. Fill the system with water, add the cleaning chemicals and circulate as per the chemical supplier instructions.
3. Drain and flush the system thoroughly until the water becomes tap water clear.
4. Add the Multi-Metal protector/scale inhibitor to the system following the chemical supplier instructions for the recommended concentration.
5. For systems requiring freeze protection, use an uninhibited, virgin propylene glycol and add treatment as recommended by the chemical treatment manufacturer. **Do not** use automotive type glycol in any heating system.

6. To be sure that the boiler is not air-bound, open the pressure-relief valve located at the rear of the boiler. Leave the relief valve open until a steady flow of water is observed. Close the valve and finish filling the system.

NOTICE! Phosphate based water treatment are not generally recommended.

The following companies have certified their water treatment systems as safe for use with multi-metal hydronic system that include aluminum boilers:

Fernox
Hydronic Agencies Ltd.
Sean Leonard
Edmonton, AB, CANADA
Phone: (780) 452-8661
Toll Free: (877) FERNOX4U
(877-337-6694)
Fax: (780) 488-2304
Email: sales@hydronicagencies.com
www.hydronicagencies.com

Fernox USA
Cookson Electronics
Brian Conrad
Altoona PA
Phone: (814) 946-1611
Toll Free (800) 289-3797
Fax: (814) 944-8094
Email: fernox_americas@cooksonelectronics.com
www.fernox.com

Rhomar Water Management, Inc.
Dwight Hedgepeth
Springfield, MO
Phone: (417) 862-2600,
Toll Free: (800) 543-5975
Fax: (417) 862-6410
Email: peggy@rhomarwater.com
www.rhomarwater.com

H-O-H Water Technology, Inc.
Steve Sadowski
Greendale, WI
Phone: (414) 421-2070,
Toll Free: (800) 944-9746
Fax: (414) 421-2077
Email: ssadowski@hohwatertechnology.com
www.hohwatertechnology.com

Sentinel Performance Solutions Ltd.
Marathon Distributors
Rich Ronchka
Mississauga ON Canada
Toll Free: (888) 602-5360
www.sentinel-solutions.net/en/

Sentinel Performance Solutions Ltd.
Douglas Products and Packaging
Liberty, MO
Toll Free: (877) 567-2560
Email: customerservice@douglasproducts.com
www.douglasproducts.com