ABMA®

LEADERSHIP FOR THE BOILER INDUSTRY

BOILER INSTALLATION GUIDE

Addressing Common Issues Impacting Safety & Performance of Boilers

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This publication shares some of the common boiler installation problems encountered by ABMA members over the years. While this document is not meant to address every potential issue involved in a boiler installation, it may help reduce some common problems.

We hope this publication assists installers and end-users of boilers and ensures boilers are properly installed enabling the end-user to operate as safe and efficiently as possible.

We welcome your feedback on this publication along with ideas for future contributions from ABMA. Feel free to send any comments to **info@abma.com**.

DISCLAIMER

While this document is technically sound, it is advisory only and to be used as a guide for qualified personnel. This publication is not intended to be definitive, nor are the methods and procedures described in this publication the only methods and procedures. Any use made of the information in this publication is entirely within the control and discretion of the manufacturer and is wholly voluntary. ABMA expressly disclaims any responsibility for damages arising from the use, application, or reliance on the recommendations and information contained herein.

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BOILER INSTALLATION GUIDE

There are numerous codes and regulations that offer a great amount of information on how to properly design and install boiler systems (see listing at end). Some may say that there are too many codes and regulations.

For example, there are numerous regulations on how to size combustion air supplies, and they often do not agree. The wide variety of combustion systems and boiler applications makes it impossible to have simple clear requirements that would work for application. As a result, there are some problems that can arise, and some of those are addressed here.

Note: this is not a complete listing of all boiler room installation issues. A thorough review and implementation of all codes and regulations is required by experienced and knowledgeable technicians to provide a safe and efficient installation.

I. Combustion Air Supply

Boilers require an air source for combustion. If the air supply is restricted, it can result in high levels of unburned fuel (emissions and lost energy), the generation of Carbon Monoxide and potentially an explosive situation. There are helpful guidelines in the "National Fuel Gas Code" regulations (NFPA54/ANSI Z223.1). State and local requirements must also be followed in addition to special requirements defined by the manufacturer.

COMMON COMBUSTION AIR ISSUES

A. The State Boiler Inspector is the ultimate authority in all issues related to the boiler. If there are concerns about the combustion air supply or other items, contact your state's inspector.

B. The boiler needs an unrestricted source of fresh air for combustion, usually provided by louvered opening in the boiler room wall. Blocking these openings can be dangerous, but sometimes are done because of the cold air entering the room, making it uncomfortable, especially in cold weather. Covering these vents can result in unburned fuel, high emissions, the generation of Carbon Monoxide, and potentially explosive conditions.

C. Controls that open and close these louvers when the boiler cycles on and off must be designed for fail-safe operation. If the boiler is firing and the combustion air supply is restricted, it will result in unburned fuel, high emissions, Carbon Monoxide generation, and potentially explosive conditions.

D. Adding ventilation fans and/or barometric dampers can rob the boiler of the combustion air source. Any air users added to the boiler room can result in a need for more outside air, or larger openings to supply sufficient air.

E. The inlet air should be tempered before contacting the boiler to prevent contact with water piping (potential freezing) and large swings in combustion air temperature which can result in combustion noise due to large changes in fuel-air-ratio.

F. Outside ducted air inlets must be designed according to the boiler/burner manufacturers requirements in addition to any local and state codes. Inlet air ducts that can be plugged because of poor design or require more pressure than the burner can provide has the potential to create a hazard.

II. Stacks and Ductwork

Stacks and duct work used to direct the flue gas out of the boiler room can have a major impact on the successful operation of the boiler, and indirectly, the safety of the boiler operation. The "National Fuel Code" (NFPA54/ANSI Z223.1) covers this area in detail but does not cover the need for smooth transitional flow often required in some larger commercial and industrial boilers.

Higher combustion intensity of certain units can be more susceptible to upsets in the flue gas flow downstream of the furnace. These upsets or turbulence can feed back into the combustion zone and result in combustion noise or rumbling, which can damage equipment.

The specific boiler/burner manual provides the details on what type of transitions are required, and these must be followed to prevent combustion noise and vibrations. The ABMA publication "*Packaged Boiler Engineering Manual*" offers a helpful general overview for typical Firetube boilers and other large commercial and industrial products.

Stack design can a significant impact. A good stack design will provide a smooth flow and transition of the flue gas as it exits the building while a poor design that has turbulence due to sharp transitions and changing velocities can cause combustion rumbling and severe pulsations.

ADDITIONAL VENT REQUIREMENTS FOR LARGE COMMERCIAL AND INDUSTRIAL BOILERS

Large commercial and industrial boilers operate at higher levels of heat intensity and velocity due to the much larger heat input and a need to keep sizes manageable. This requires additional efforts to prevent turbulent zones that may cause feedback into the combustion process, resulting in combustion noise like rumbling or harmonic oscillations. This generally takes the form of smaller angular transitions (no more than a 45-degree change) in all connections and transitions.

A. Merging flows should be done at an angle (usually 45 degrees), but never at a 90-degree connection.

B. Additional boilers in a common duct must include increasing diameters to prevent sudden velocity changes.

C. The structure should be sufficiently strong to resist the normal pulsations from combustion without vibration. Square ducts are not good in these applications for that reason. Access doors need to be sufficiently robust to resist the normal pulsations from the combustion process.

D. Large flat surfaces can act as resonators for the combustion process, and result in mechanical problems. Combustion noise or rumbling can result in mechanical damage, and equipment failures.

E. Duct connections to a vertical stack should be made with a 45-degree connection, and never located opposite another boiler entry (opposing flows).

F. The details of the stack and duct design should follow the boiler/burner manufacturer's instructions.

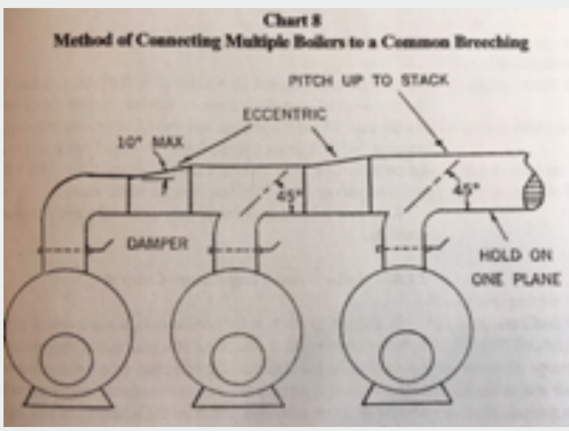
G. The stack must also be designed to meet the draft requirements of the boiler/burner package. This may require additional equipment and controls.

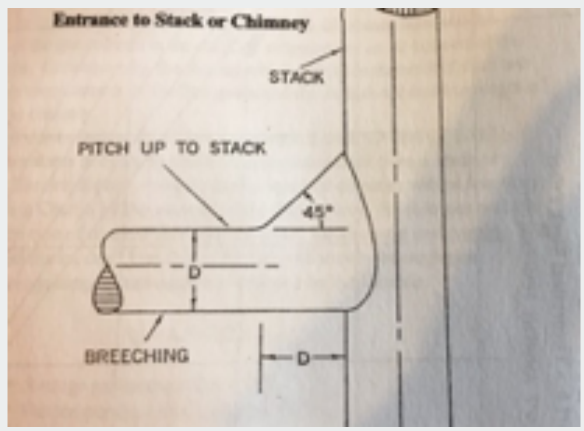
H. Drains may be required to allow condensate to be removed.

The installation (on the left) includes a 45-degree boiler connection to the breeching, but with a single mitered cut. It does not have an increase in stack diameter as an additional boiler was added and it does not have a 45-degree connection to the stack.

The ABMA publishes "PACKAGED BOILER ENGINEERING MANUAL" which provides guidelines for stack and breeching designs, with a summary below.

As shown below, the flow must be angled between each connection, with a change in diameter as the flow rate changes with additional boilers. Refer to this book for more complete details.





III. Draft Controls

The vent or stack design for a boiler is supposed to provide the draft required by the boiler/burner manufacturer. This is usually around 0.05" to 0.5" (inches of water column) of negative or positive draft. Most applications with short stacks have no problems meeting this requirement, but applications with tall stacks or multiple boilers connected to a single common stack often can't be designed to meet these draft requirements. The solution is to use draft controls to the manufacturers requirements. Barometric dampers are the most common type and generally work well, but they can only be used in negative draft applications.

Damper controls are also common to measure draft and control dampers but can generate other problems. These controls can cause large swings in draft as they attempt to modulate the damper to control the draft. This is an especially problematic with high turndown burners and low emission burners. These large swings in draft can result in combustion noise, carbon monoxide generation and in extreme cases, an explosive condition.

Experience tends to show that boiler/burners with relatively small turndowns that are not low emission types can tolerate larger swings in draft, and because of the lower turndown, they tend to be easier to control. Because of this, there is a tendency to consider the required draft to be a target of the final control position, and that larger swings outside the manufacturers listed draft to be acceptable. Unfortunately, units with Flue Gas Recirculation (FGR) and other low emission requirements cannot tolerate these swings in draft without serious potential problems.

The control can also be complicated with high draft conditions. A very tall stack can have a draft of over 2”, and damper-based control will have more difficulty dealing with this large pressure. Barometric dampers are well suited to handle high draft conditions, but they also can cause high air flow rates, taking energy from the boiler room.

Most manufacturers now offer a “Feed Forward” control which uses the firing rate to help locate the proper damper position and greatly improve the control accuracy and can eliminate the large swings in draft.

PROBLEMS WITH DAMPER CONTROLLED DRAFT

There are several issues that can occur with draft control systems that use dampers to restrict flow to manage the draft. Many of these are the result of changes in the burners, making older systems obsolete. Here are some of the key problems.

A. Damper controls that do not use a rapid speed drive will have problems keeping up with the modulation of the burner. It was common to use standard modulation motors in the past, with the same speed of modulation as the burner, but the damper would often fall behind the burner changing rate, resulting in high and low drafts.

B. Flue Gas Recirculation (FGR) systems have an additional issue, because high stack pressures can result in rich burner operation. A higher stack pressure will force more flue gas into the burner, reducing the combustion air flow causing a fuel rich condition with the potential for an explosive condition.

C. Draft control for high turndown burners can be more difficult because of the very low flow rates at low fire. At these low rates, the damper is close to the closed position, and any adjustments result in large swings in flow and pressure. A system that does not have a feed forward positioning element will struggle and will have large swings in draft. Additionally, dampers that do not have tight control will not be able to limit the draft at these low flow rates because the leakage would be too large.

D. Proper sensor piping is critical to prevent condensate collection that would yield a false draft reading.

E. Multi-blade dampers should be used in the more difficult applications because they provide better control, especially at lower flow rates.

F. The controls must provide full pre-purge and post-purge operation for safety.

Barometric dampers do not have the issues above, partly because they work in the opposite mode, where the damper is open at low flow rates, adjusting is easier and more accurate. They are fast acting by design, eliminating the speed of movement issue. They can also be applied in multiple locations, like each boiler connected to a common stack, making it easier to handle complicated systems. There are some limitations, like the dampers can only be used with negative drafts and they require larger combustion air openings to provide this additional air.

If the application has any combination of high turndown, low emissions, multiple boilers connections and/or tall stack, and a damper type control is used, it is highly recommended that a feed forward control be considered.

IV. Gas Train Design

There are many codes and regulations covering the design of natural gas fuel trains, including The National Fuel Gas Code, CSD-1, NFPA-85 and numerous other codes from Underwriters Laboratories (UL) and insurance providers. There are some potential issues with gas trains in new installations that can result in major problems.

The most common issues are proper sizing, pressure protection and construction debris in the gas line. While there are ample regulations covering the gas train piping, the fact that these activities cover several different functional areas (utility supply, facility distribution and local boiler application) make it a prime target for problems.

COMMON GAS TRAIN INSTALLATION PROBLEMS

A. The gas train must be capable of supplying both the quantity and pressure of gas required to support all the users in that line. Sometimes not all users are accounted for in the requirements. It is common for some users to be missed in this process, resulting in an undersized gas train.

B. Sometimes there is an issue of how much pressure drop can be used in the line (which means it is not available to the boiler), and at the pressure stated by the job site. It is common to state that the pressure available to the boiler is 5 PSI because that is the supply into the building, but the person doing the line sizing assumes they can use 1 or 2 PSI pressure in the line loss and other users, which means the boiler will only see 3 PSI.

C. New installations often have new piping which has some debris in it from construction. This debris must be cleaned out before starting the unit, but the cleanout is often not done or not done well. The result is the debris gets into the valves and blocks proper operation, including unsafe operation (valves held open by the debris). Some gas valves come with filters, and the filter becomes plugged with debris causing a pressure drop that prevent proper operation of the equipment. Proper cleaning of the lines and placing a drip leg in the line before the equipment fuel train will prevent these problems.

D. In applications where the gas supply pressure is relatively high (above the boiler gas train rating), and only a single pressure regulator is used to reduce the pressure to the boiler, the pressure leakage past this valve can cause a serious problem. The problem here is that there are usually two different parties involved, one providing a pressure into the building and another providing the boiler, based on that pressure. Neither party may be aware of the danger this may cause, even though it is well addressed in the codes and regulations. Clear communications are necessary for all parties along with oversight to ensure proper installations.

E. If too many elbows or tees are used in the piping between the pressure regulator and burner, there may flow restrictions and prevent the unit from firing at full capacity.

F. If a pilot line is connected downstream of a shutoff regulator, the pilot may not operate.

G. Proper gas train sizing is critical for good performance, especially with high turndown burners. Oversized pressure regulators can result in gas pulsations and combustion issues.

The photo (on the left) shows how two regulators are connected in series to provide safety protection when the supply pressure is higher than the pressure rating of the boiler gas train. A relief valve could have been used instead of the second pressure regulator.

V. Combustion Tuning

Burner controls have become much more complicated with requirements for emission controls, higher turndowns and improved efficiency. The burner setups have also been complicated by controls used to meet added performance features and a desire to integrate system controls. These new requirements need to be addressed by knowledgeable people trained in the technology and equipment. If a service technician doesn't know how to properly tune the equipment, they can waste time and money, and make the problem worse or, more importantly, unsafe.

If the burner has a simple control system (On-Off, Low-Hi-Low, linkage or similar mechanical system), then general knowledge of those systems should be adequate for simple burner controls. If the control is a parallel positioning control, full metered control or other computer type control, then specific training and experience may be required to safely tune the burner.

The technician must also have a calibrated combustion analyzer to set combustion. If the burner is a low emissions burner, the combustion analyzer must also be capable of measuring those emission elements (like NOx and CO). Modern burners can't be tuned by simply viewing the flame and setting the excess air, and often have unique requirements to obtain the low emission performance. For example, a low NOx burner may require the specific NOx setting to provide safe reliable operation, and lower or higher NOx operation can result in failure or unsafe operation.

ISSUES RELATED TO EQUIPMENT TUNING

A. When the boiler was installed, the installing contractor should have provided a list of all safety controls and a "written precaution that the operating, testing and servicing only be performed by a qualified individual".

B. If you have an "Operating Permit" that is based on certain emission limits, then your service technician must be able to confirm that you are in compliance with those limits. NOX and CO emissions are easy to measure with the correct analyzer. Particulate Matter (PM, PM10, PM2.5…), Volatile Organic Compounds (often stated as VOC or HC) and specific target elements may require other special testing to verify, if required.

C. Many burners have unique setup requirements, especially low emission and high turndown burners. In those cases, the service technician must be trained to properly setup that equipment. Contact the manufacturer for details.

D. Sometimes there will be a need for multiple service technicians to properly tune and/or repair equipment. This is especially true when a specialized control is combined with a specialized burner, and there are no service technicians trained in both areas. When other equipment and controls are added, like VFD's, integrated controls communications and equipment like water treatment and stack cleanup are involved, more expertise may be required. When the control set up is installation specific, it is recommended that the programming be password protected.

E. It is far too common to find steam boilers set up with operating steam pressure limits too close together, causing the boiler to rapid cycle on, up to high fire and off. This results in very poor efficiency and can harm the boiler with additional thermal shock. Adjusting the controls to allow normal operation with few on and off cycles is part of performing a good setup.

F. The boiler should be tuned at its actual operating pressure and listed firing rates to obtain accurate performance settings. If it is tuned at a low steam pressure or water temperature, it may have different internal pressures that will cause different combustion settings when operated at normal pressures or temperatures.

VI. Safety Controls

Boilers handle a large quantity of energy, and because of this, they can be dangerous if not properly maintained. Boiler safety is a major concern for all parties and needs to be treated accordingly. One of the actions that can help promote safety is the formal documentation that owners and users should have to address and maintain the safety controls of the boiler.

All boilers and burners are equipped with numerous safety controls that can prevent hazardous conditions. These controls need to be checked at installation, after any control change or upgrade and annually, at a minimum. Also, over time, these controls may need to be replaced. Failure to maintain and test the operation of these safety controls can lead to serious safety problems.

SAFETY CONTROL REQUIREMENTS

Instrumentation and controls include water level controls, safety relief valves, pressure or temperature controls, flame safeguards, burner management (the safe sequence of startup and shutdown), fuel train controls, fuel-air-ratio controls and other items. Their installation, testing and maintenance are critical to the safety of the operation of the boiler and facility. There are many different regulations in addition to the manufacturers requirements that need to be followed to provide a safe environment.

A. The American Society of Mechanical Engineers (ASME) has a committee that covers Controls and Safety Devices (CSD-1) and they publish regulations that are required by most states. CSD-1 requires the installing contractor to "obtain from the boiler manufacturer pertinent operating, testing, servicing and cleaning instructions for the controls and safety devices". It is the responsibility of the installing contractor to deliver these instructions, together with complete wiring and piping diagrams, and a written precaution that the operating, testing and servicing only be performed by a qualified individual to the owner/user and to obtain a receipt for the instructions. CSD-1 requirements frequently are applied to units up to 12,500,000 Btu/hr input with NFPA-85 requirements used on larger sizes.

B. UL also has requirements for the actual safety controls and their applications. Boiler and burners listed by UL (or other approved listing agency like CSA and ETL) have been investigated to meet these requirements. Listed products are often preferred because they have been independently tested and are monitors by inspection to insure the product meets the intended requirements. Larger equipment (typically over 500 BHP or 20,000,000 Btu/hr input) typically is more specialized and not listed.

C. Insurance companies often have special requirements for safety controls that are more stringent than the above codes, and manufacturers can build to these and other requirements upon request.

D. Requirements in Canada are similar but vary some. Canada has its own requirements for safety controls and installations.

E. Level controls on high pressure boilers should use high temperature wire.

F. High and low gas pressure switches should be set within the CSD-1 range of 50% under or over the actual expected manifold pressure.

G. If fresh air dampers are tied to the boiler operation (open when boiler on), the interlock should not allow the boiler to operate if the dampers fail to open.

VII. Piping and Valves

The single largest issue with piping and valves is proper sizing, that enables the system to work properly. This is complicated by the fact that each area can have different design requirements and operating issues. In most areas, obtaining the proper flow without too much pressure drop is the key issue. For level controls, the issues are more related to inspection and cleanout without areas that could trap water or allow sediment buildup. Blowdown piping is concerned about removing solids.

Care must be taken to be sure that the requirements of each piping area are met. The ASME pressure vessel code and the National Boiler Inspectors Installation code are the great starting points, and they provide a lot of details to handle the piping design. Valves and controls may be covered by a variety of other codes like CSD-1, NFPA-85 and UL.

SOME GENERAL COMMENTS ON PIPING AND VALVES

A. The design of the steam and hot water piping, including the type and thickness of the materials, is covered in the ASME code, similar to the pressure vessel design.

B. The valves, fittings, and all components must be rated for the design pressure or the system in review.

C. The pipe routing must be designed to absorb the expansion and contraction that can occur with the temperature changes (cold when shut down, hot when running). Pipe stress analysis per ASME B31.1 is typically used to ensure piping stresses are within allowable values.

D. The piping and supports should be designed to ensure loads on boiler connections and/or are within allowable values.

E. All external steam and hot water piping must be considered for insulation, both for personnel protection and for prevention of heat loss.

F. Safety relief valves must be piped to a safe location, without a direct connection to the safety valve itself.

G. The size of steam piping and valves can change based on the steam pressure, including the steam nozzle, safety valves and non-return valves.

For liquid level controls:

A. Care must be taken to avoid traps and sags which could affect the controls or prevent the proper blowdown of the device and piping.

B. Blowdown and drain piping must be routed to a safe point of discharge to enable the operator to safely operate the valves without interference from the discharge. Also, consider the location of the discharge to ensure it will not affect other nearby plant personnel.

C. All piping must be designed for inspection and cleaning.

D. The level control valves must be located for safe operator access with no interference.

For blowdown piping:

A. The discharge must be handled in a safe manner and may require cooling and/or treatment depending on local codes. This is also a source of heat recovery.

B. Two valves are required, a quick opening and slow opening valve.

C. The blowdown piping should be designed to allow the water and sediment to be evacuated with each blowdown.

D. Do not allow water to collect in the piping, as it can cause water hammer.

For steam piping:

A. Valves and piping must be selected to work within the expected operating pressure and flow rates and the maximum velocity for the boiler to prevent carryover.

B. Pipe sizing and valve selection require careful study of the pressure drops to provide the required pressure at the operating equipment with the expected flow rates.

C. Maximum instantaneous flows must be considered, and efforts made to limit these flow rates to prevent carryover and pressure drops.

D. The piping must provide good condensate removal and prevent accumulation of condensate.

INCORRECT

*Water column installed at incorrect elevation resulting in a dangerous water trap situation that will **not** allow the water gage glass, alarms and low water cutout to operate correctly*

CORRECT

VIII. Outdoor Installations

Boilers located outdoors have additional issues based on their locations. The obvious concern is freezing conditions but rain and high humidity can also damage the boiler and components and large swings in temperature can cause combustion problems.

If the temperature falls below freezing, there is significant possibility of damage to the equipment and combustion system. Some components have a limited temperature operating range which may be exceeded by outdoor environment.

Most of these issues can be handled, but only if the manufacturer is aware of the application details.

SOME COMMON ENVIRONMENTAL ISSUES

A. If the temperature can drop below freezing, then freeze protection may be required. Items like instruments, instrument lines, blowdown lines, water column piping and other similar lines that do not have flow are potential freeze areas. They can be heat traced or protected in some other manner.

B. Extreme high or low temperatures can exceed the allowable temperature range of different operating controls, valves and safety devices. The solution may involve changing the component to one that has the required temperature range or providing protection for the component.

C. The components exposed to the environment will require the correct NEMA listing to prevent water damage. For example, motors that are outdoors will generally need to be rated as TEFC.

D. High humidity can cause problems with condensation, corrosion and premature failure. A common method of dealing with this is to place critical components in a cabinet and control the environment inside the cabinet.

E. Large swings in air temperature will result in large swings in excess air of the burner. Burner fans provide a constant volume of air, and the density of the air changes with temperature. For example, changing from 40 oF to 120 oF will result in a 15% change in excess air (the burner could go from 20% to 5% excess air). There are controls that can help this (oxygen trim and combustion air density trim) and seasonal tune ups can greatly reduce the variations.

APPENDIX A

CODE & REGULATION GROUPS

American National Standards Institute (ANSI) – This is a private non-profit organization that oversees the development of voluntary consensus standards for products, services, processes, systems, and personnel in the United States. The organization also coordinates U.S. standards with international standards so that American products can be used worldwide.

American Society of Mechanical Engineers (ASME) – This is a not-for-profit membership organization across all engineering discipline and provides codes for the design of boiler, pressure vessels and related piping.

Canadian Standards Association (CSA) – This organization writes Canadian codes and provides testing, inspection and product listings. They can provide product listings for the US market, testing to the US codes.

CSD-1 – A subgroup of ASME that provides codes for control safety devises for boilers and pressure vessels. These codes are intended for equipment up to 12,500 MBH with NFPA-85 for higher ratings. Most states require compliance to CSD-1.

The National Board of Boiler and Pressure Vessel Inspectors (NBBI) – This organization promotes greater safety to life and property through uniformity in the construction, installation, repair, maintenance, and inspection of pressure equipment and oversees adherence to laws, rules, and regulations relating to boilers and pressure vessels.

National Fire Protection Association (NFPA) – This is a global nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. NFPA delivers information and knowledge through more than 300 consensus codes and standards including the following codes focused on boilers.

National Fuel Gas Code, NFPA-54
National Electric Code, NFPA-70
Exhaust systems, NFPA-91
Glossary of Terms, NFPA-97

State Boiler Inspector – Each state has a state inspector or similar position which has the ultimate authority for all issues related to boilers in their respective state.

Underwriters Laboratories (UL)–This group assists with code writing and provides testing, inspection and product listings. UL provides product listings for the Canadian market as well.

APPENDIX B

TERMS USED IN THE TEXT

American Boiler Manufacturers Association (ABMA) – ABMA is an association of boiler manufacturers and manufacturers of related equipment that advocates for the safe production and operation of boilers, facilitates advancement in energy efficiency, and provides solutions for member companies.

Barometric Dampers – A damper connected to the breeching, stack or chimney, that will introduce air sufficient to maintain a desired (draft) pressure. These are the most common products used to control draft.

Breeching, Ductwork and venting – A combination of ducts, stacks, and/or chimneys used to direct the products of combustion out of the building.

Chimney, Stack – A vertical duct used to direct flue gas.

Combustion Air – Air used to support the burning of fuel. There must be a relatively large source of air to support combustion and completely and safely burn all the fuel.

Carbon Monoxide – The result of incomplete combustion. It is a poisonous gas.

Condensation – Water vapor generated in the combustion process which condenses at lower temperatures.

Draft – The natural lift or negative pressure caused by hot air or flue gas flowing up a stack or chimney. The amount of draft is a function of the temperature difference and height of the stack

Draft control – Draft controls are devices that use dampers in the stack and breeching to control the pressure (draft).

ETL–The ETL Mark is proof of product compliance to appropriate test standards, similar to UL.

Explosive Condition – This is a condition where there is a specific mixture of combustible fuel and air, which could ignite simultaneously.

Feed Forward Control – A control that provides an immediate output based on certain inputs. Other control functions make small adjustments, monitor change and make additional adjustments, which slows response.

Flue Gas – The products of combustion, containing nitrogen, carbon dioxide, oxygen, water vapor and small amounts of other gases.

Flue Gas Recirculation (FGR) – This is a method of reducing NOx emissions. Some flue gas is routed back to the combustion zone to cool the flame.

Packaged Boiler Engineering Manual – This is an ABMA publication that covers applications of packaged boilers.

Product Listing or Listed Product – This is a condition where a product is tested to meet certain standards and then the manufacturing of the product is inspected to ensure that the product continues to be built to the original test standards.

Rumbling, Combustion Noise, Pulsations – The combustion process is often not a smooth continuous process and can be influenced by external conditions like turbulence to create fluctuating combustion conditions. These can be violent.

Stack – A vertical flue or chimney for the discharge of flue gas.

TEFC – A type of motor design that is Totally Enclosed and Fan Cooled for dirty environments.

Turbulent zone – A flow regime in fluid dynamics characterized by chaotic changes in pressure and flow velocity.

Turndown – The ratio of energy input capable in a burner. It is the ratio of the maximum energy input to the minimum energy input.

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