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Solid-Fuel Heating Boilers Constructed to the Provisions of EN 303–5

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Prepared for:

BioHeatUSA

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This work was performed pursuant to KKAI Services Agreement #08111101 between Kevin Kennedy & Associates, Inc. and BioHeatUSA. This KKAI Report has been prepared for BioHeatUSA and only for BioHeatUSA and shall not be relied upon by any other person.

Respectfully submitted,

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C O N T E N T S

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1. Summary

We have carefully reviewed EN 303-5 and Section IV of the ASME Boiler and Pressure Vessel Code and the related Codes and Standards. Further, we have reviewed the typical documentation furnished to customers of the three European manufacturers of solid-fuel heating boilers. Based on that review, it is our conclusion that the subject boilers meet the intent of the Section IV Code and are at least as safe as other Section IV Code Stamped boilers.

2. Background

BioHeatUSA imports solid-fuel heating boilers from three European countries for use in the United States. These boilers are fabricated to the rules of EN 303-5, "Heating Boilers - Part 5: Heating Boilers for Solid-fuels, Hand and Automatically Stoked, Nominal Heat Output of Up to 300 kW - Terminology, Requirements, Testing and Marking." These boilers are not specifically addressed by the rules of ASME Section IV, "Rules for the Construction of Heating Boilers," because Section IV does not address rectangular boilers or solid-fuel heating boilers. However, some states in the U.S. have rules that require solid-fuel heating boilers to meet the provisions of ASME Section IV. This report is an evaluation of the rules used by the three European companies to show compliance with the intent of ASME Section IV, so that the European solid-fuel heating boilers can continue to be imported and installed as "State Specials," if necessary to otherwise comply with State rules that require these heating boilers to comply with the rules of ASME Section IV.

3. Scope

This report addresses use of solid-fuel heating boilers fabricated to the rules of the European Standard EN 303-5. The purpose of the evaluation is to demonstrate equivalence of safety for use of solid-fuel heating boilers fabricated to the rules of EN 303-5, for use in states of the United States, where the requirements for these types of boilers are to fabricate to the rules of Section IV of the ASME Boiler and Pressure Vessel Code.

The report addresses materials, design, fabrication, welding, inspection, quality control, nameplate marking, and overpressure protection. The report is intended to provide the technical information necessary for demonstrating the equivalence of safety for these boilers with the provisions of ASME Section IV.

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The current rules of Section IV of the ASME Boiler and Pressure Vessel Code apply to cylindrical boilers, whereas the boilers under consideration are rectangular in shape. ASME Section IV was not written to address either rectangular shaped boilers, or solid-fuel heating boilers, such as those being imported by BioHeatUSA. Further, ASME Section IV has no rules for design of any type rectangular boilers or pressure vessels.

4. European Suppliers

BioHeatUSA imports solid-fuel heating boilers from two companies located in Denmark; H. S. Tarm/Baxi and Scandtec. BioHeatUSA also imports solid-fuel heating boilers from Froeling, which is located in Austria. All of these boilers meet the rules of EN 303-5.

5. Materials

The pressure retaining plate materials used by the European manufacturers of the BioHeatUSA solid-fuel heating boilers are identified as 10025, Type S235JR. This steel is equivalent to ASME SA-285, Grade C, which is permitted for use in ASME Section IV boilers. We have reviewed the mill test reports for the S235JR steel, and the reports show compliance with the chemistry and mechanical property requirements of ASME SA-285, Grade C.

A material certification (EN 10204) for pressure retaining materials is required to be obtained by the boiler manufacturer. These certifications are equivalent to the mill test reports used in the United States.

6. Design

Section IV of the ASME Boiler and Pressure Vessel Code contains rules for design of cylindrical shells, and formed and flat heads, but not for rectangular pressure vessels. However, paragraph HG-501 provides that proof tests may be used to establish the permissible design pressure, if the rules of Section IV cannot be used to determine the required thickness. Clearly, there are no rules in Section IV that can be used to determine the required thickness of the pressure retaining portions of the rectangular boilers, because Section IV does not address these types of boilers. EN 303-5 also does not provide design rules to determine the thickness of rectangular solid-fuel heating boilers.

Despite the fact that ASME Section IV does not address rectangular-shaped boilers, it is possible to determine a hydrostatic test pressure that would be equivalent to the proof test pressure permitted to

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establish design acceptability of a Section IV boiler, where design rules are not provided. The hydrostatic test pressure equivalent to a proof test pressure can be determined by using formula (2a) provided in Section IV, paragraph HG-502.2(d)(2)(a).

(2a) $P = 0.5\ H\ S / (S + 5000)$

where: P = Design Pressure (psi)
H = Hydrostatic Proof Test Pressure (psi)
S = Specified Minimum Tensile Strength (psi)= 55,000 psi for S235JR

Therefore, $H = 2\ P\ (S + 5000) / S$

For these boilers: $P = 30$ psi, $S = 55{,}000$ psi

Therefore, $H = 2\ (30)\ (55{,}000 + 5000) / (55{,}000) = 60\ (60{,}000) / (55{,}000) = 65.5$ psi

65.5 psi /14.7 psi = 4.45 bar

Each and every solid-fuel heating boiler furnished by BioHeatUSA is hydrostatically tested to a pressure of at least 4.5 bar (66.5 psi.), which is 2.18 times the design pressure. This means that each boiler is proof tested by the manufacturer. During this proof test, no distortion or leakage is permitted. The Foeling boilers are tested at a pressure of 5.5 bar (81 psi), which is 2.7 times the design pressure.

On the basis of these proof tests, it can be concluded that not only does the design of the solid-fuel heating boilers meet the design requirements of EN 303-5, but, on the basis of the proof test of each boiler, each and every boiler meets the design provisions of Section IV of the ASME Boiler and Pressure Vessel Code.

7. Fabrication

The EN 303-5 Standard requires use of qualified welders and qualified welding procedures comparable to those required for Section IV and Section IX, "Welding and Brazing Qualifications," of the ASME Code. The applicable European Standard is EN 287-1, "Qualification Test of Welders – Fusion Welding – Part 1: Steels." The requirements of EN 303-5 and EN 287-1 are not identical to the requirements of ASME Sections IV and IX, because some of the essential variables are slightly different, but they do an equivalent job of demonstrating the effectiveness of the qualified welders and welding procedures. Further, TUV in Austria and DNV in Denmark monitor these qualifications. Also, the weld joint details provided in EN 303-5 are comparable to those in

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Section IV. Table 2 of EN 303-5 shows weld details that are equivalent, and almost identical, to the weld details permitted in Section IV of the ASME Code.

EN 303-5 requires that all welders be certified by an independent credentialed agency in accordance with EN 287-1. All the welders used by the three European fabricators are certified by such independent credentialed agencies. These are TUV in Austria and DNV in Denmark.

> TUV *(Technischer Überwachungsverein, English translation: Technical Inspection Association)* was founded over 140 years ago as a steam boiler inspection association similar to Hartford Steam Boiler (HSB). They now operate worldwide.
>
> DNV (*Stiftelsen Det Norske Veritas*) is an inspection organization founded over 140 years ago. It is similar to Lloyd's Register, American Bureau of Shipping, and HSB. Its current objective is safeguarding life, property, and the environment. It operates in more than 100 countries.

These organizations, among others in Europe, are known as "Notified Bodies." The "Notified Bodies" are evaluated and accepted by governments of European countries. The "Notified Bodies" provide services equivalent to those of North American Authorized Inspection Agencies, which are accredited by ASME.

Some subassemblies for boilers made by Scandtec are subcontracted to a manufacturer in Croatia. The welders and non-destructive examination (NDE) personnel in Croatia are trained and certified by PONDT (Pond, Ltd.). PONDT also performs surveillance of the welding and NDE performed on the subassemblies. PONDT was founded in 1993 in Zagreb, Croatia.

8. Examination

Neither EN 303-5 nor Section IV of the ASME Code requires volumetric (radiographic or ultrasonic) examination of the main weld seams of the boiler. Surface examination (magnetic particle or liquid penetrant) is also not required by either document. However, the three manufacturers all perform a liquid penetrant examination on all welds that cannot be examined after assembly and test of the solid-fuel heating boilers. This examination is performed prior to the welds becoming inaccessible.

9. Inspection

Section IV of the ASME Code requires use of an Authorized Inspector (AI) to monitor the

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manufacture of the boiler to assure that the requirements of the ASME Code have been met. In general, the duties of the AI are as follows:

a) assuring that the manufacturer has been properly authorized by ASME and is working to an approved quality control system

b) verifying that design calculations, drawings, specifications, procedures, records, and test results are available

c) verifying that welding procedures have been qualified

d) verifying that welders have been qualified

e) verifying that material imperfections were properly repaired

f) inspecting to confirm that material identification numbers have been properly transferred

g) witnessing proof tests

h) verifying that nameplates have been properly stamped and attached to the boiler

i) signing the certificate of inspection

Although the European code for solid-fuel heating boilers does not provide for use of an AI, there is a system that ensures that the activities performed by an AI for ASME Section IV heating boilers are performed on the European solid-fuel heating boilers. This system is implemented by the Notified Bodies described above.

1) Each fabricator works to the requirements of an accredited quality control program, complying with ISO-9001.

2) Drawings, specifications, procedures, records, and proof test results are available for each solid-fuel boiler. There are no ASME Code-type design calculations because the design is based on meeting the minimum thickness and details provided in EN 303-5. Each manufacturer is responsible for the design of their boilers in addition to meeting the minimum thickness and details in EN 303-5. Also, the proof test on each boiler confirms the integrity of the design.

3) Welding procedures are qualified.

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4) Welders are qualified and certified.

5) All material imperfections must be repaired, and welds not visible after fabrication are liquid penetrant examined before they are made inaccessible.

6) Material identification is maintained during fabrication.

7) The proof tests are reviewed by an independent inspector and recorded.

10. Testing

The requirements for performing hydrostatic tests in accordance with EN 303-5 are comparable to the requirements for hydrostatic testing in Section IV of the ASME Code. However, in addition to the requirements in EN 303-5 and Section IV, each and every boiler is individually proof tested to confirm its structural integrity.

11. Quality Control System

Section IV of the ASME Code requires use of a quality control system that addresses the following:

a) authority and responsibility

b) organization

c) drawings, design calculations, and specification control

d) material control

e) examination and inspection program

f) correction of nonconformities

g) calibration of measurement and test equipment

h) sample forms

i) independent inspector

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The three manufacturers all work under ISO-9001quality control programs reviewed and authorized by prominent European Notified Bodies. H. S. Tarm/Baxi and Froeling are reviewed and authorized by TUV, and Scandtec is reviewed and authorized by DNV. This, along with proof test of each boiler, and the extra non-destructive examination (NDE) performed, assure the pressure integrity of the boilers.

The ISO-9001 Quality Control System used by the three European fabricators is equivalent to the Section IV Quality Control System. It should be noted that ASME Interpretations I-92-91, VIII-1-92-203, and VIII-2-92-16 all identify that the ASME Quality Control Program can be restructured to be compatible with ISO-9000. Further, the ASME B16.5 Quality System Program is ISO-9000.

12. General Considerations

There are several noteworthy features required fo boilers constructed to the rules of EN 303-5.

1) Drawings or associated documents must specify the following:
   a) the materials used
   b) welding processes and types of weld seams
   c) maximum allowable operating temperature
   d) maximum allowable operating pressureS
   e) test pressure
   f) nominal heat output

2) The Quality Manual must identify inspections and tasks to be completed during the manufacturing process. The Quality Manual must
   a) describe the inspection system;
   b) specify duties and responsibilities in the Quality Control Program;
   c) specify all inspections and tests, along with the applicable acceptance criteria; and
   d) identify measuring and test equipment and their respective calibration requirements.

3) All welding must meet the criteria of EN 287-1, which requires the following.
   a) All welders must be qualified for the material to be welded.
   b) Welding Supervisors must be qualified welders.
   c) Welding must be free of defects.
   d) filler metals must be compatible with the base material.

4) Steels are limited to those listed in Table 1 of EN 303-5.
   a) All materials must have Certificates (EN 10204). These are equivalent to material test reports.

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5) EN 303-5 identifies minimum thickness for pressure retaining materials. No design formulas are required or provided.

6) Safety Issues
   a) Water compartments must be fully vented.
   b) Combustion chambers and flue gas passages must be designed so that dangerous accumulation of combustible gases is not possible.

7) Tests
   a) The manufacturer must assure that all pressure retaining materials conform to EN 303-5.
   b) The manufacturer must assure that welds comply with EN 303-5.
   c) During the hydrostatic or pneumatic tests, no leaks are permitted.
   d) The required hydrostatic test pressure is always 4.5 bar or greater.

8) The Name Plate must contain the following information:
   a) name and location of the manufacturer
   b) ID number and year of construction
   c) nominal heat output
   d) boiler class
   e) maximum allowable operating pressure
   f) maximum allowable operating temperature
   g) electrical connections and wattage

9) The manufacturer must provide the necessary technical information required for operation and the installation instructions.

10) Each type and size of boiler must be subjected to a boiler performance test.

13. CE Symbol

The three European manufacturers use the CE symbol as a "Declaration of Conformity" for the European Standards identified. In the case of these solid-fuel heating boilers, EN 303-5 is identified along with the other standards used.

14. Miscellaneous Provisions of Section IV of the ASME Code

1) BioHeatUSA furnishes the thermometers required by HG-612 of Section IV and locates

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them so that they indicate the temperature of the water in the boiler at or near the outlet. In addition, when digital gauges are provided as standard equipment by the manufacturer, BioHeatUSA furnishes analog gauges, in addition to the digital gauges. These extra gauges are provided to ensure that conditions can be monitored in case of power failure. This is an extra safety feature, not required by any Codes. EN 303-5 requires that temperature control and limiting devices be furnished with each boiler.

2) HG-613 requires each automatically-fired hot water supply boiler to be protected from over-heating by two temperature-operated controls. Even though the BioHeatUSA boilers may be hand fired, all boilers are fitted with a primary temperature controller with a maximum temperature limit from 90 C (194 F) to 94 C (201 F) and a redundant, manually-reset, high-temperature limit switch set at 100 C (212 F). Air is introduced by fans controlled by electric limit switches. When the fans are not operating, the boiler automatically stops burning. Over-heating is very rare with these boilers.

3) An important difference between ASME Section IV and EN 303-5 boilers is that ASME requires through-penetrating and welded pressure stays. The EN 303-5 boilers also use pressure stays, but they do not penetrate the firebox walls. Because of the corrosive effects of wood combustion, BioHeatUSA determined from experience that penetrating stays were a weak point in the boilers. Since 2001, the BioHeatUSA boilers have been furnished with non-penetrating stays, and there have been no failures due to corrosion of welds.

4) EN 303-5 recognizes that solid-fuels behave differently from other energy sources. The fuel supply with solid-fuels is difficult to turn on. Because EN 303-5 has been developed as a solid-fuel boiler code, it addresses other factors specifically important to operation of these types of boilers. There is much focus on the combustion process. With greater control of the combustion process, over-heating events are highly unlikely. This reduces the chance that an overpressure event would follow.

15. Related Requirements of EN 303-5

1) Flame or fired bed areas must allow for non-hazardous inspection.

2) All boilers must be designed so that all areas can be vented of the air and soluble oxygen.

3) Thermal insulation must be adequate and not outgas when heated.

4) All heating surfaces must be accessible for cleaning.

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5) The combustion system must be designed to withstand the pressure without leaking combustion gases into the building.

6) The ash chamber on all boilers must be adequate for a 12-hour combustion period, if automatic ash and clinker removal is not integral to the boiler.

7) EN 303-5 specifies efficiency levels.

8) EN 303-5 specifies emission limits.

9) EN 303-5 limits surface temperatures of the boiler.

16. BioHeatUSA Additions

In addition to meeting the provisions of EN 303-5 and specific provisions of ASME Section IV, BioHeatUSA ensures that each boiler design or model is tested and listed by Omni Test Laboratories. Omni is well known for the testing it performs on products such as gas-fired appliances (room heaters, fireplaces, wall and floor furnaces, and boilers); solid-fuel-fired appliances (room heaters, fireplaces, stoves, furnaces, and boilers); oil-fired appliances (room heaters, furnaces, stoves, and boilers); multi-fuel-fired appliances (furnaces and boilers); electric heaters (including other electrical components related to fuel burning equipment); and thermal protection (heat shields, wall and floor protectors, and hearth extensions).

As part of the testing and listing process, each boiler is deliberately overheated to test its safety systems and integrity.

Every boiler is provided with an ASME Stamped pressure relief valve set at 30 psi. The normal operating pressure of these boilers is only 12 psi, but the design pressure is 30 psi to account for any nonstandard operating conditions caused by the user of the boiler.

BioHeatUSA recommends or requires thermal storage systems for all of its boilers. Thermal storage allows for placing a constant load on the boiler, which helps to eliminate damaging condensation, makes over-heating almost unheard of, and virtually eliminates the possibility of creosote formation.

EN303-5-conforming pellet boilers sold by BioHeatUSA have relatively small fuel combustion zones. These zones, combined with the necessity for robust combustion air, create very controllable combustion characteristics. When heat is not needed, the boilers can shut off.

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Additionally, pellet boilers sold by BioHeatUSA have gauges to monitor both exhaust and water temperatures and shut down automatically if either is higher than allowable parameters. Over-heating is almost impossible.

BioHeatUSA has been furnishing these boilers for 35 years. In no case has there ever been a failure caused by the boilers.

17. Stamping with the CE Symbol

In Europe, stamping with the CE symbol identifies that the manufacturer has a certified quality program that was used to manufacture the item. The EN 303-5 Standard is identified on the nameplate on the boiler.

18. Conclusion

Based on our evaluation of documentation received from BioHeatUSA and the three European manufacturers, the authors of this report have determined that the BioHeatUSA boilers comply with the intent of the ASME Section IV Code for Heating Boilers.

19. Resumes

The resumes of the authors, Roger F. Reedy, P.E. and Rick W. Swayne, are included with this report as Attachment 1 and 2.