PACKAGED FIRETUBE BOILERS

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FOREWORD

This document was originally prepared by the Packaged Firetube Boiler Manufacturers Subcommittee of the Commercial Systems Group of the American Boiler Manufacturers Association. This update has been reviewed and editorially revised by the Commercial Systems Group for re-release. The contents are offered for information and as guidance only. The ABMA does not assume responsibility or liability for consequences arising from implementation or failure to implement the information or guidance contained herein. Also, the contents of this guide should not be construed as an endorsement by ABMA of any product or manufacturer.

WHY PACKAGED FIRETUBE BOILERS?

HISTORY

The 1930's saw the boiler industry in a period of transition. Earlier units had relied mainly on solid fuels such as coal. The 1930's were the beginning of a period of conversion to oil and gas fuels. In addition, increasing labor costs started a swing away from the venerable brick set horizontal return tubular boiler (HRT), which had been an industry mainstay. These conditions made the situation ripe for a switch to the modified Scotch marine boiler, a design which originated from the Scottish Clyde shipyards, where the boiler could be mounted on its own supporting members and shipped completely assembled. The burner and controls were added on installation in the field and were most frequently from several different manufacturers.

Because there was divided responsibility in this earlier arrangement, the industry was ready for the introduction of the Packaged Firetube Boiler (PFT) in the mid 1930's. The popularity of the Packaged Firetube Boiler increased rapidly, so much so in fact, that in 1946, immediately after World War II, the American Boiler Manufacturers Association (ABMA) established a special product section to represent the PFT manufacturers

DEVELOPMENT

Most packaged firetube boilers are the lineal descendants of the basic Scotch design modified for stationary service. The reasons for selecting this design as the boiler for the PFT unit include:

- Minimum radiation loss
- Requires no masonry or refractory setting
- The design prevents the leakage of cool air into the furnace
- Large steaming capacity for the space occupied
- Low head room required for installation
- Large water content is excellent for heating applications
- Does not require special foundation
- This design provides for precipitates, scale and silt collection in space below the furnace, which is relatively cool and from which they can easily be removed in the event poor water quality exists.

One of the early problems with the Scotch design boiler was poor internal circulation. This problem coupled with the large boiler water content tended to make these boilers slow steamers. Improvement in boiler designs with better furnace location within the boiler shell and more scientific firetube layout has largely eliminated the problem.

Large water content also makes the packaged firetube boiler an excellent selection for process load applications that require quick response to load demands. Large diameter shells allow greater steam storage space and steam releasing area.

Another issue that has been discussed endlessly over the years is the design criterion of square feet of heating surface per boiler horsepower. To understand this issue it is necessary to review the genesis of the term "boiler horsepower" (Bhp). The term originally related to the quantity of steam necessary to operate a one horsepower steam engine. Due to variations in engine efficiencies, this quantity of steam was itself a variable. Tests conducted in 1876 on a modern (for the time) steam engine determined that it took approximately 30 pounds of steam per hour to produce 1 horsepower (mechanical) of work. In 1889 the American Society of Mechanical Engineers (ASME) standardized the term "Boiler Horsepower" as being based on a conventional steam engine steam rate of 30 pounds of steam per hour (PPH) at 70-psig pressure and feedwater of 100 degrees F. This definition was later modified to: "Boiler Horsepower – the unit of capacity expressed as equivalent evaporation of 34.5 pounds of water per hour from and at 212 degrees F (33,475 Btu per hour.)"

During this period it was determined that steel boilers had 10 square feet of heating surface for each horsepower (mechanical) produced by the attached steam engine. It must be kept in mind that boilers utilized at that time were brick set and had large areas of refractory. This meant that the boiler had a heat absorption rate of 3,347 Btu per hour per square foot of heating surface. The equipment used for these tests was the "state of the art" for the time (late 1800's). Thereafter, it became the industry practice to rate boilers in boiler horsepower and to base this rating on heating surface, e.g. 1 Bhp per 10 square feet of heating surface.

As time passed, boiler designs and materials technology improvements including enhanced heating surfaces served to provide for improved heat transfer characteristics. Fuel burning systems improved, allowing the use of smaller diameter tubes further increasing boiler efficiency. Thus, the old criterion of 10 square feet of heating surface per boiler horsepower was no longer valid. The historical evaporation rate of 3.45 pounds of steam per hour per square foot of boiler heating surface became obsolete. Due to engineering progress, improvements in heat utilization such as enhanced heat transfer surfaces, and better circulation of water and combustion products, the present evaporation rate may be as high as 19.2 pounds of steam per hour per square foot or higher. This results in a design criterion of 1.44 to 5 square feet of heating surface per boiler horsepower.

The early PFT units were composed of assemblies of boilers, fuel burning systems and controls. Manufacturer's used available burners and control components. The intensive competition of the PFT field forced companies to improve their products with an eye to more efficient combustion through improved firing methods, advanced control systems and better fuel burning equipment compatibility.

The compatibility of forced draft burners and boiler furnaces has improved over the years resulting in cleaner, more efficient combustion emitting a significantly lower level of air pollutants. Recent advances in control systems have improved the optimization of fuel-air ratios, and provided the ability to hold tighter steam pressures or water temperatures. They can also include oxygen trim and flue gas analysis.

MODERN PACKAGED FIRETUBE BOILERS

Modern Packaged Firetube Boilers are engineered, built, and guaranteed in material, workmanship and performance by one firm, with one manufacturer furnishing and assuming responsibility for all components in the assembled unit, such as burner, boiler, controls and all auxiliaries. Modern Packaged Firetube boilers are usually fire tested prior to shipment.

Today's Packaged Firetube Boilers are available in a wide variety of designs. The basic combustion gas flow pattern for all designs has the actual combustion occurring in the furnace with hot gases passing through the full-length banks of firetubes. These boilers are available in single pass, 2 pass, 3 pass and 4 pass patterns. All patterns are available in both Wet-Back and Dry-Back designs.

In the past few years, improvements in construction have resulted in more compact and less costly packages. Larger access doors supported by hinges or davits have made interior surfaces more accessible for cleaning and inspection. Radiation heat losses have been reduced to a minimum by improved shell design and insulation.

Fuel burning and combustion control equipment have been continuously improved. A majority of the packaged firetube boilers use forced draft fans. An increasing number of the units are equipped with modulating or other control systems to match the firing rate to load demand as nearly as possible.

Flame safeguard control systems are generally of the programming type and are frequently microprocessor based. Such systems may include LED displays for self-diagnosis of system problems. Flame detectors have been improved and are matched to the unit and fuels.

As the various unit components complement one another, the PFT assemblies are quite compact and can be shipped complete with several auxiliary components. The only size restrictions are common carrier shipping clearance and weight restrictions.

APPLICATION

Packaged firetube boilers are available in sizes from 10 to 3,000 boiler horsepower (335 to 100,425 MBH).. They can be ordered and are suitable for either low pressure steam (15 psig) or hot water (not exceeding 160 psig or 250°F) applications (ASME Section IV) or for high pressures steam to 450 psig (ASME Section I) for process applications.

They are particularly useful for steam heating applications with sluggish condensate return systems because their relatively large water content will partially compensate for the time delay during which condensate is returned to the boiler.

PFT units are fuel flexible. Standard units are available with fuel burning equipment to fire natural or LP gas, and all grades of fuel oil, #2 through #6. Units to fire both fuel gas and fuel oil with either manual or automatic fuel changeover can also be ordered. Specially designed units can also be ordered to fire coal or other solid fuels.

Control systems and fuel valve trains are supplied to meet jurisdictional requirements and those of customers or various insurance or control codes. . These requirements include but are not necessarily limited to:

- American Gas Association (Z21.13)
- American Society of Mechanical Engineers (CSD-1)
- American Society of Mechanical Engineers (B&PV Code Section I & IV)
- National Fire Protection Association (NFPA 85 –2001)
- Underwriters Laboratories (UL 726 and/or 795)
- Factory Mutual (FM)
- Industrial Risk Insurers (IRI)

The PFT units are frequently tested and listed or labeled by nationally recognized testing laboratories as complying with an appropriate national standard thus minimizing the work of the application engineer in determining compliance with specifications.

In the United States and Canada the boiler pressure vessel is required to be constructed and stamped in accordance with the ASME Boiler and Pressure Vessel code and in most jurisdictions stamped and registered with the National Board of Boiler and Pressure Vessel Inspectors (NBBI). The ASME Code Symbol is stamped on the boiler shell after testing and inspecting by an authorized third party inspector insuring compliance with the ASME Code requirements. Certain manufacturers have the ability to adapt their boiler designs to other overseas Codes and Standards, such as those of the European Community or China.

ECONOMICS

When analyzing the costs of various types of boiler systems, the following should be carefully considered:

- Space requirements for PFT units are frequently less than that for other types due to their compact design and low headroom needed. Although space must be provided for possible boiler tube replacement, this can be minimized by locating the unit opposite a door or window which can be opened for the purpose of removing tubes if it is ever necessary; No special foundations are required;
- The equipment, if fire tested prior to shipment, may be pre-adjusted for specified combustion efficiency, allowing minimizing of fuel consumption during startup. This procedure assures the operational testing of all components;
- Normal unit life with proper maintenance and boiler water treatment may exceed that of other heating systems, reducing life cycle cost;

- The unit is fuel flexible – it can be manufactured to burn a variety of fuels – thus the most economical fuel for the time can be selected. If the unit is manufactured to burn a particular fuel it can be modified should an alternate fuel become economically attractive;
- Due to standardization, complete wiring and piping diagrams are available before equipment purchase thus allowing the application engineer to properly design the entire system;
- The unit can be located anywhere from basement to penthouse to a remote location;
- Modern control systems can be arranged for remote monitoring of the unit;
- While some direct attention to the automatically controlled unit is required, it is normally minimal, and training programs are available for personnel affected;
- Factory trained service technicians are available through the local unit distributor.
- High turndown ratios (output) are available for certain sizes of boiler;
- Water treatment, while necessary, may be less costly than certain other boiler types;

CONCLUSION

Summary of characteristics –

1. The heavy steel structural base distributes weight evenly on the boiler room floor requiring no special foundation.
2. The units include a burner designed to match the boiler available for any grade of fuel oil, gas or combination gas-oil.
3. A totally enclosed and pre-wired control cabinet is generally mounted on the unit containing the latest electronic programming and flame failure safety controls. This control system may be microprocessor based and can contain self-diagnostics. Operating controls, limits, interlocks; motor starters and similar equipment wired and ready for electric service to be connected are included.
4. Forced draft firing requires minimal stack to vent combustion gases. Lower stack temperatures contribute to high operating efficiency.
5. The unit design provides gas-tight operation.
6. Large furnace volume with low heat release provides excellent primary heating surface, complete combustion with smooth starts, clean firing, unrestricted gas flow and quiet operation.
7. Heavy lifting attachments are provided to facilitate positioning the unit.
8. Engineered tube sheet layouts provide for good water circulation and easier cleaning.
9. The steel outer jacket over insulation protects the unit and provides a neat appearance.

Adherence to these principles should provide a purchaser with a boiler meeting all local, state, and federal safety and environmental Codes as well as being economical, long lasting and which can be easily maintained and operated over its life span.