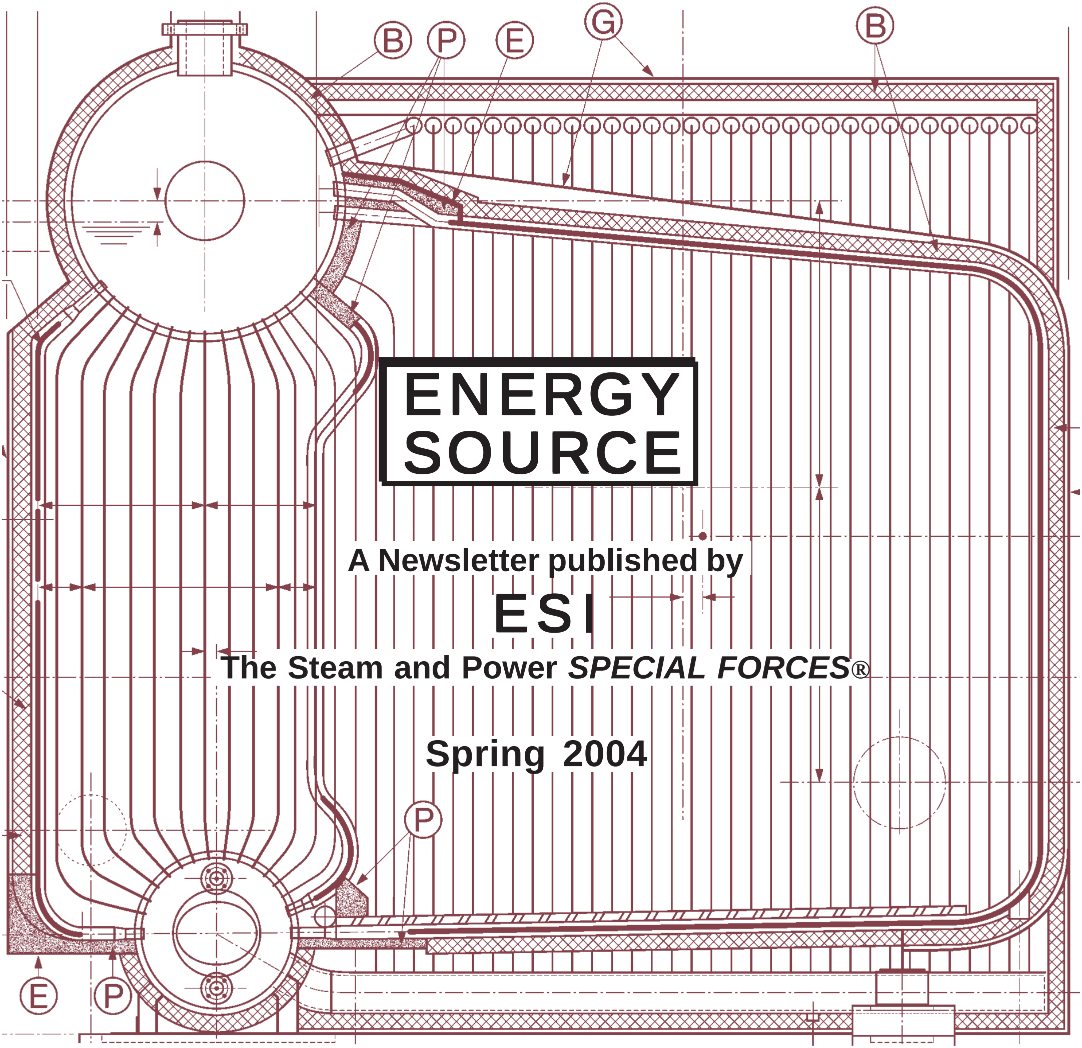

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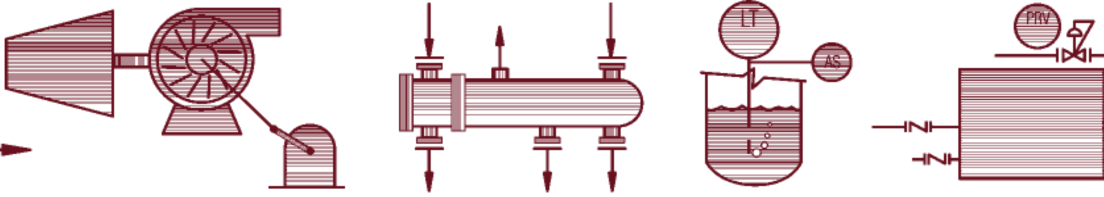

THE BUYER'S GUIDE TO PACKAGE BOILER DESIGN

By: *William L. Reeves, P.E., President, ESI*

Editor's Note: "The Buyer's Guide To Package Boiler Design" concludes with a discussion regarding the critical design parameters of package boiler auxiliary equipment. For the previous articles in this series, please visit the News & Events Section of our website at www.esitenn.com.

The operational reliability and availability of auxiliary equipment is more often than not, the critical determining factor in the overall success of the package boiler installation. The *Winter 2004 Issue* of the *ENERGY SOURCE* discussed the current state of burner technology; therefore, this auxiliary equipment discussion will be limited to the following:

- Economizer
- Boiler Trim
- Forced Draft Fan
- Instrumentation & Controls

The air heater has purposely been left off the list above. With lower NO_x requirements, heated air causes increased NO_x generation; therefore, the use of an air heater as the final heat trap on package boilers is not widely used anymore. Instead, due to both lower NO_x emissions requirements and lower relative cost per unit of heat recovered, economizers are now almost exclusively used when firing natural gas and fuel oil.

Economizer

There are two types of economizers, extended surface (finned tube) and bare tube. Finned tube economizers are popular because the heat transfer surface is dramatically increased for a lower cost than bare tube economizers.

Natural Gas and #2 Fuel Oil - Finned tube economizers are the proper selection for natural gas and #2 fuel oil firing. Although some manufacturers will provide as many as 5 fins per inch, ESI prefers to limit our designs to 4 fins per inch on natural gas firing only and 3 fins per inch when firing #2 fuel oil. Generally, an economizer is designed and purchased with the ability to add a future sootblower, but the finned tube economizer should not undergo any significant fouling provided the burner is tuned and operated properly.

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If you have any suggestions or comments about the newsletter feel free to call us at 770-427-6200 or e-mail us at energysource@esitenn.com.

Deanna White
Managing Editor

The economizer design exit flue gas temperature will vary depending on the fuel being fired. A design temperature of 300ºF is reasonable for predominantly natural gas operations. A design temperature of 325ºF makes more sense when #2 fuel oil is the predominant fuel and especially if a significant amount of the operation will be at low steam loads.

#6 Fuel Oil - Firing #6 fuel oil is a different story. Typically a bare tube economizer is the design of choice. However, depending upon the ash, sulfur, and vanadium content of the oil, ESI will ocassionally use a finned tube

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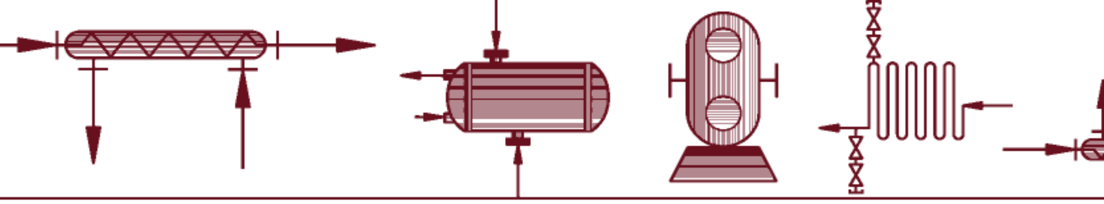

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economizer designed with at most 2 fins per inch. An economizer firing #6 fuel oil should always be equipped with sootblowers. Also, a standard design feature for ESI is the use of forged tube return bends. Although slightly more expensive, this design feature eliminates thinning when bending return bends and significantly reduces the propensity for stress corrosion in the tube bends.

When firing #6 oil, in order to avoid potential cold-end corrosion, an economizer design exit gas temperature of 350ºF should be the target along with a feedwater temperature to the economizer at 250ºF or above. The feedwater temperature can be achieved by operating the deaerator at 15 psig or installing a steam-heated boiler feedwater heat exchanger to increase the boiler feedwater temperature from a deaerator operating at a lower pressure than 15 psig. The bottom line is to ensure that in the traditional countercurrent design, the economizer gas exit/feedwater inlet temperature operates well above the sulfuric acid dew point down to the maximum practical turndown limit. When feedwater temperatures reach 250ºF or higher, feed pump bearing and mechanical seals will need to be water cooled for good longevity. An economizer used on a #6 oil-fired boiler should also be well designed between the inner casing, the insulation layer, and the outer casing so that cold bridging does not result in significant inner casing condensation and corrosion.

Because some economizer designs and applications were so poor in the past, economizers got a very bad reputation. In poor applications they were likely to corrode and fail, thus requiring a feedwater bypass arrangement around the economizer. ESI prefers not to install a 3-valve bypass around an economizer because this design requires that the economizer be equipped with a safety relief valve, thus introducing another piece of equipment in the system that requires maintenance, testing, etc. A properly designed and installed economizer should be as reliable as the package boiler pressure parts.

Boiler Trim

ESI's standard package boiler trim includes a prismatic type gauge glass assembly. Some boiler manufacturers utilize tubular gauge glasses; however, ESI does not recommend their use for safety reasons. The gauge glass and water column design should be arranged so that the low water trip occurs when the water level is visible in the lower part of the gauge glass. Also, the gauge glass must be positioned so that the visible bottom of the glass is at least two inches above the water level at which damage could occur due to downcomer starvation. Another standard trim feature should be two low water fuel cutouts, preferably an electric conductance probe type and a mechanical float type. As part of the low water cutout circuits, a dual pushbutton bypass system should be installed to allow daily blowdown and testing of the low water trip devices to ensure safe operation. A high water trip, which also forces the boiler feedwater control valve to the closed position, is another recommended feature that protects against dangerous flooding of the main steam line in the event of boiler feedwater control system failure.

In order to ensure long reliable service and low maintenance, despite lower boiler design pressures, ESI's standard valve trim package utilizes OS&Y, rising stem, 800# forged steel valves on all steam, feedwater, and blowdown service. In order to mitigate operational problems at high turndown operation, the boiler non-return valve generally should include disc skirts to eliminate chatter at low loads.

Another design tip is even when #6 fuel oil firing is not anticipated for a package boiler, always design and supply the unit with a wall box in the casing and other attachments for the future installation of sootblowers. This inconsequential expense provides future fuel flexibility in today's volatile fuel markets without pressure part modifications.

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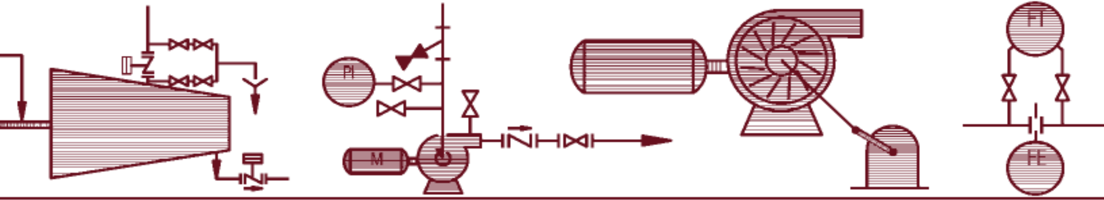
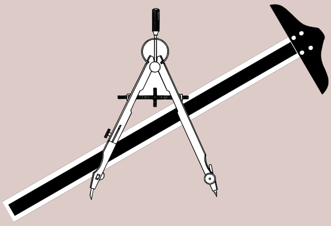


DESIGN TIPS



The success of any steam and power installation is the integration of hundreds of subtle design features that ensure everything operates satisfactorily.

Following are a few design tips:

- **Deaerator Height-** When setting NPSH requirements for pumps operating at elevated fluid temperatures, make sure to include the effect vapor pressure will have on the calculations. The vapor pressure of the fluid is subtracted from the head pressure. Therefore, pumps that pump water at saturated conditions, such as boiler feedwater pumps downstream of a deaerator, have only the tank height to provide the required head.

- **Pump Discharge Pressure-** When specifying a vessel, heat exchangers and piping components downstream of a pump, make sure to consider the dead head of the pump. The discharge pressure of a centrifugal pump increases as the flow decreases so the maximum pressure the system will see is at the lowest flow. All system components should be designed for this condition.

- **Piping Systems at Elevated Temperature-** When selecting piping components for systems which operate at elevated temperatures, be sure to incorporate the effect that temperature has on materials. Often at very high temperatures, fittings lose a significant amount of their design pressure strength.

- **Gas Safety Shut-off Valves-** When selecting natural gas safety shut-off valves, be sure to consider not only the operating pressure, but also the maximum pressure the system can incur in the event of a regulator failure. Many safety valves are only rated for 40 psig while the system pressures upstream of the pressure regulators operate at much higher pressures.

- **Solid Fuel Handling-** When specifying solid material conveying systems, consider using two different densities for the material. Use a higher density for horsepower and material strength calculations and use a lower density for capacity and volume calculations. By using a density range, you will account for the natural variation in the material and design a conservative, forgiving system.

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Forced Draft Fan

The forced draft fan requirements and features that should be included in an application are highly dependent on the size of the FD fan. The inlet damper should always be designed to maximize efficiency by imparting a pre-spin on the inlet air and should include sealed or external bearings capable of being lubricated. ESI recommends that the inlet air to the forced draft fan be ducted to an outside wall louver assembly complete with rain hood and bird screen and properly sized for a low face velocity. This system will reduce noise in the boiler house and significantly reduce boiler house heating requirements in the winter. If flue gas recirculation (FGR) to the FD fan inlet is utilized, it is critical that the system design ensure that moisture in the FGR cannot condense and freeze the inlet damper assembly during cold weather operation. This can be accomplished by preheating the combustion air prior to the FGR mixing tee.

When a boiler that utilizes FGR for NO_x control is being commissioned, the optimum ratio of FGR to combustion air for the entire boiler load range is determined. ESI always recommends that a boiler exhaust gas O_2 monitor be installed as a minimum; however, to further optimize and as a combustion safeguard, a second O_2 monitor should be mounted on the burner windbox.

If a boiler is operated at less than 60% rated steam capacity for a significant portion of the year, the use of an FD fan variable frequency drive (VFD) is generally economically justifiable. The following table provides other general guidelines ESI follows regarding the selection of FD fans on package boiler installations.

Size (HP)	Arrangement	Bearing Type	Vibration Monitoring
<125	4	Grease Ball	No
125-150	1, 7, or 9	Grease Ball	No
200-300	3 or 7	Grease Ball or Sleeve Oil	No
350-500	3	Sleeve Oil	No
>500	3	Sleeve Oil	Yes

Instrumentation & Controls

Package boiler burner management systems are typically standard designs that comply with NFPA 85 requirements. Depending upon the end user's insurance carrier (Factory Mutual or another), other design standards might be required. In larger boilers and with boilers where operational reliability is very critical, ESI recommends the installation of redundant self-checking flame scanners. ESI designs always include a first-out annunciator indicator system with the burner management system to enable operators to quickly determine the cause of burner failure and correct it to mitigate the loss of steam production.

On larger boilers with long steam drums, ESI has occasionally experienced significant steam drum water level differential from one end to the other at high firing rates. Generally, in boilers over 200,000 pph and over 400 psig operation, we would recommend the installation of drum level transmitters on both ends of the steam drum. The drum level control loop would utilize an average signal from both of the transmitters.

Burner combustion modulation systems range from very inexpensive mechanical jackshaft type that provide basic proportional control to the very sophisticated cross-limited metered type with oxygen trim using a distributed control system (DCS) that has significant trending and reporting capability. The mechanical

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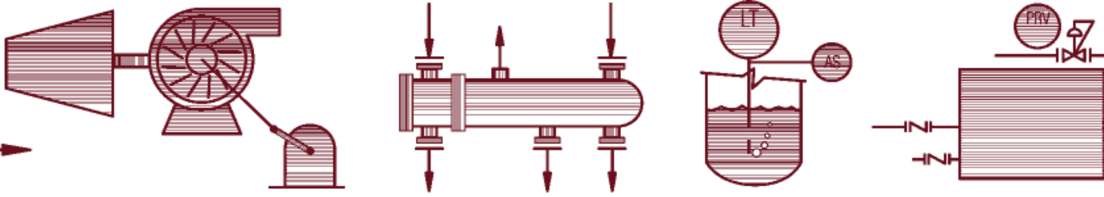

Just A Reminder

ESI has expertise in all aspects of steam and power-related systems including: Complete Steam and Power Generating Systems, Material Handling Systems, Water Treatment Systems, Instrumentation and Controls, Environmental Compliance, Biomass Dryers, Carbon Burnout Systems, and several first-of-a-kind technologies.

ESI has experience combusting a wide range of fuels including: Natural Gas/Fuel Oil, Coal, Paper Mill Sludge, Biomass, and several other "Plant Opportunity Fuels".

Please visit the Project Case Studies Section of our website @ www.esitenn.com to see some of the projects ESI has performed or contact ESI at 770-427-6200 for more information. Call ESI for all your Steam & Power Needs!

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jackshaft control system will have an inherent inefficiency due to limited fuel/air ratio characterization capability. This inefficiency will become worse over time due to mechanical wear. However, they can be the proper application for many smaller boilers. A boiler with a steam capacity over 60,000 pph will almost always utilize the more sophisticated fully metered type system due to the need to minimize a significant annual fuel cost. The combustion control system that is the proper technical and economic selection for each facility is dependent upon the following parameters:

- Average fuel input
- Fuel cost
- Required fuel flexibility
- Required availability
- Required on-line fuel switching
- Required emissions monitoring
- Level of emissions control
- Monitoring frequency by operating staff

Conclusion

This concludes our series on package boiler design. Over ESI's 25 year history, we have purchased and installed numerous package boilers of various steam capacities, design types, and steam pressures and temperatures. If ESI can be of assistance in determining the capital cost required or the feasibility of a new package boiler installation, or if you have current problems with the operation and maintenance of an existing package boiler, please contact Jay Garrett at 770-427-6200 or jgarrett@esitenn.com. ESI offers this assistance as a complimentary service to our clients.

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