Choosing The Right Steam Boiler

Planning With Priorities

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Introduction:
What are my priorities for a boiler?

With all the different Boiler designs on the market, it is difficult for someone who is unfamiliar with the various technologies, to select the best Boiler for a given application.

Like most equipment selections, asking the right questions is often the key. In this case : What are my priorities for this steam boiler?

- **Safety (always first).**
- **Reliability.**
- **Life cycle economics.**
- **Low first cost.**
- **High performance.**

Steam boilers can be dangerous, even low pressure steam boilers, so **safety is always first**. *Operator error* is the leading cause of boiler failure, so training and proper maintenance are essential.

As for the other for priorities, the owner/operator/engineer are the ones who must put those priorities in their proper order. In this eBook, we will cover what are the tradeoffs and considerations for each priority.

Reliability

A proven boiler design should (1) incorporates heat transfer surfaces that are conservatively sized (not over fired), (2) It should have features that are selected with the operator's skill sets in mind, (3) It should be a safe and reliable selection. In typical applications this might be a two, three, or four pass fire tube design with an economizer to improve efficiency. When selecting various options, economics often drive final decisions. Run hours and fuel cost are the most impactful variables in the savings calculations.

Water quality is a second leading cause of failure and often can be a challenge for boiler plant owners & operators. Water quality has a huge impact on boiler life and performance. Of the various designs, fire tubes are the least affected by poor water quality. They are also the least costly to repair if scale or oxygen pitting is encountered. Water softeners, demineralizers or reverse osmosis systems (sometimes used in combination) are often used to improve feed water quality. Water tube type boilers or low water volume designs may, be also be considered, but since they require higher quality water to avoid scale formation, the first and ongoing cost of water conditioning should be included in their evaluation.

Water tube type boilers generally are more compact and more responsive to steam load swings. Sometimes these designs may also be more efficient. However, if water quality drops and goes uncorrected, these boilers will more quickly scale up resulting in inefficient, even potentially unsafe conditions.

One particular manufacturer of low volume boilers has developed an onboard water quality monitoring system which will alarm when feed water condition drops to unacceptable levels. This type of system, coupled with extra safety features, like high stack temperature monitoring, and automated blowdown systems can result in higher reliability and improved safety.

Boiler scale on water side

Onboard water monitoring system

Lowest Life Cycle Economics

Institutions and industrial clients often choose boilers based on the lowest lifecycle cost. This will typically take into consideration: first cost, operating schedules, estimated boiler life, overall boiler efficiency, warranty, annual operating costs for parts and parasitic loads, such as fan horsepower and blowdown requirements. When evaluating ongoing maintenance costs, it is wise to determine if parts and service are proprietary. Can they be sourced competitively in the local market?

In applications where lifecycle cost is the secondary priority, (remember “safety first”) engineers look for these following attributes in a boiler design:

1. Large Furnaces:

Boilers with large furnaces and very low quote “volumetric heat release rate". This means that furnace volume and heating surface is large enough to allow for complete combustion to occur without the flames impinging on the furnace walls, and that there is enough heating surface so the furnace steel is not overheated causing high internal stress is due to thermal expansion. Furnace volume is perhaps the most overlooked aspect of boiler design in the marketplace. The furnace steel typically transfers 80% of the overall heat exchange because this steel is exposed to both radiant heat transfer and convective heat transfer, so large furnaces are needed to keep heat flux rates at reasonable levels. Safety, reliability, operability, emissions, efficiency and lifecycle cost are all favorably impacted by enlarging the furnaces and boilers.

2. Internal water circulation patterns

Well-designed boilers also consider internal water circulation patterns. As the water inside of a boiler is heated, it becomes more buoyant and rises up through the boiler. This internal up flow of water cools the heating surfaces and will improve both the life and efficiency of the boiler. If the boiler designer take this into account they would include some flow area for the water to flow back to the bottom, (cooler areas) of the boiler. In water tube boilers, this is accommodated by the addition of external “downcomers”. In firetube designs, there should be adequate room between the outer rows of tubes and the boiler shell so that the water has a return path to the bottom of the boiler, setting up an internal circulation loop which keeps the steel cool and efficiently transferring heat.

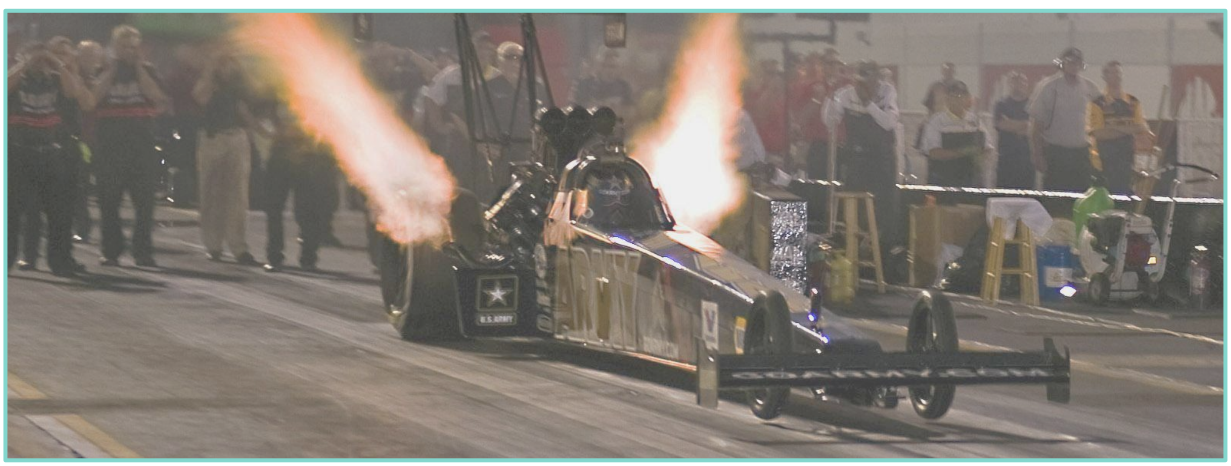
3. Gas flow paths

Adequate gas flow paths to maintain even flow and appropriate velocity across boiler heating services is another feature of a well-designed Boiler. If the flue gases are unevenly channeled across heating surfaces, with high velocity in some areas and lower velocities in others, then uneven heat transfer will result and hot and cool spots may develop within the unit. Gas side heat transfer is mostly convective and is optimized by keeping the gasses properly channeled through the boiler. A good gas side design recognizes that, as the flue gasses cool, they decrease in volume, with heating surfaces arranged to take advantage of this volumetric change.

Type O

The primary "parasitic" cost associated with boiler operation is the electrical power needed to run the combustion air fan. The combustion air or blower fan must overcome the pressure drop of the burner + boiler as well as the economizer and any duct work needed to force the flue gasses through the stack to the atmosphere outside the boiler room. Stack effects are usually negative for tall stacks, and tend to reduce backpressure.

Different boiler designs will have significantly different back pressures and therefore drastically different parasitic power losses. As the cost of electrical power increases, the parasitic loads become more costly to boiler owners. For example, an older 200 hp “Ohio Special” steam boiler, with a Low Nox Burner that has 350 total square feet of heating surface (smaller vessel & heating surface has higher pressure drop), may have 11” (water column) of furnace pressure and require a 25 hp blower for combustion air. While a full sized 200 hp boiler will have about 1,000 square ft of heating surface and a backpressure of 4” pressure, may only require a 7 ½ hp fan motor. The difference of 17.5 hp would cost an owner $7,892.00 / year. [using : 0.7457kw/hp, 6,000 hours run time / year, 0.10 $/kWh). Consider parasitic losses in your decision making process if the life cycle cost of a boiler is high on your list of priorities.



Boiler vendors and manufactures can, and do, take a shortcuts to make their first cost lower by providing boilers with rearranged heating services (small furnaces and big economizers). Further, small gas passes use fan hp to increase convection heat transfer, but increase the electrical load (parasitic power requirement) of the boiler, so owners are cheated twice, once by getting a hot running, stressed out boiler and secondly by paying extra (kWh) to run it day in and day out. Furnace steel is generally far more expensive than finned economizer heating surface so to drive first cost down some suppliers might provide small / hot furnaces and make up for it with a big economizer to try and maintain overall unit efficiency (hot/cheap boiler + large/ inexpensive economizer). Since hot running boilers are more likely to fail early, these owners will get penalized a third time if they are forced to buy proprietary replacement parts or service directly from the boiler manufacture or exclusive service provider.

Parts and service quickly add up when life cycle cost of owning a boiler is considered, so be sure to find out if replacement parts and service may be competitively sourced (for the life of the boiler) or if you are required to purchase proprietary parts and service only from an exclusive authorized dealer. As a test, compare the cost of a standard ignitor or water column assembly sourced from a local supply house to the same parts which may only be single sourced from the Dealer's designated supplier. If manufacturers require that the labor for repairs be directed back to their local dealer or your warranty will be voided, you may be looking at a significantly higher life cycle cost item when it comes to year in / year out maintenance for the boiler.

High Performance Boilers

Since we are focusing on steam boilers, we will not address hot water condensing type boilers, although under the right conditions steam boilers may be fitted with condensing heat recovery systems.

Usually it is the industrial and power sectors that require an extra level of performance from their boilers. Whether that is the ability to track a rapidly changing steam load, or quickly ramp from a cold start to full steam, or even perform reliably under extreme conditions, these units are not normally specified for heating or campus type applications.

High performance boilers fall into a special category since their operation is connected to process where there is a high cost associated with the loss of steam or poor steam quality. Industrial processes that need heat or pressure may be lost at significant expense to the plant owner if the entire batch must be scrapped due to boiler or steam system failure. Some features that improve a boiler's performance may be the following:

1. Two or three element level control.

If loads change quickly, the feed water system will need to respond accordingly. In a three element level control system, steam flow from the boiler, feed water flow to the boiler and boiler water level are all transmitted to a level controller which applies PID (Proportional – Integral – Derivative) control functions and an appropriate output signal to the feed water valve so that water level will stay steady even for when the steam load is dynamic.

2. Digital fuel and air controls.

Separate drives for fuel valves and air delivery systems allow accurate matching of fuel and air over the full range of the boilers capacity. These systems respond quickly to rapid load swings, but also minimize the excess air allowed into the combustion process, which keeps stack losses to a minimum level from low to high fire.

3. Draft controls

When stacks exceed 60' above the operating level, there is sufficient difference in barometric pressure from the operating level to the outlet of the stack , this can affect furnace pressure. By controlling the draft with a modulating damper at the boiler outlet, a constant furnace pressure is achieved, which makes combustion much easier to control.

4. Larger steam drums

In general, rapid changes to boiler operation are to be avoided. Larger steam drums act as a storage vessel for steam before it flows into the plant steam distribution system. Steam velocities inside the boiler must be managed to avoid "carryover" of boiler water with steam into the piping system. To do this boiler designers increase drum size which increases the "steam disengaging area" to reduce the steam velocity. Slower moving steam can't take water particles and less carryover is the result. This makes it easier on the water level control system as well. Like furnace size, larger steam drums are better for operability, safety, reliability rapid response to load swings.

5. Automated Surface Blowdown Systems.

A good water management program will include top and bottom blowdown systems, which purge a small amount of boiler water this is usually 1-4% of the total boiler capacity, in order to maintain appropriate levels of impurities in the boiler water. ASME (American Society of Mechanical Engineers) and ABMA (American Boiler Manufacturers Association) publish industry standards for various steam pressures.

Automated blowdown systems come in various types, but they function to control the amount of water which is purged in order to maintain appropriate water quality inside the boiler.

- The most basic, is not actually automated at all, it is a constant flow surface blow off system which utilizes a simple needle valve to continuously meter out a small amount of water. These systems are used in situations where steam loads and boiler water make up rates are daily constant. These systems are inexpensive and may be fitted with a solenoid valve to close when the boiler goes off to save on blowdown. They impose a constant drain on the steam system (parasitic load) when the plant is up and operating.

- Truly automated systems are more often used on larger systems. These systems utilize a conductivity sensor which read the level of impurities in a water stream and sends a signal to a microprocessor. These systems are needed when things change regularly in the steam system. As the condensate return rates change, or water hardness changes, or boiler steaming rates change, then automated systems can adjust accordingly to maintain boiler water chemistry. Where a basic fixed or metering type system will dump perhaps 2-4% of the boiler output (maximum continuous rated output !) an automated system may purge only 0.5-1% . The savings can be substantial.

Poor water quality in combination with improper type or operation of blow down systems is a leading cause of premature boiler failure. Therefore spending some time choosing the right type of system, then monitoring it and maintaining it pays dividends and improves boiler room safety.

6. Warm up cycles or controls.

Standby heating coils or minimum temp controls are sometimes used to keep boilers in standby mode.

7.Instrumentation and controls

Instrumentation and controls are becoming more sophisticated and at the same time more reliable. It is not unusual to see PLC and touch screens on 300 hp boilers these days. When instrumenting boilers, the first consideration is safety, so our recommendation is to use the manufacturer's options for controls and interface to plant wide systems unless there is a compelling reason to involve a third party in the process. There are many good integrators out there to help when controls need to be customized for the project.

8.Specialized burners and controls

Specialized burners and controls is a whole other topic, but, triple redundancy, ultra-low emissions, high turndown, low excess air, and more are all options to be considered. Again, simple is preferred, but sometimes more complex solutions are the only way to achieve the required level of performance needed in today’s industrial applications.

Conclusion

A well-designed boiler that has been properly applied to a particular task borders on a "thing of beauty", at least to us boiler industry veterans. Plant owners, even plant engineers might not recognize how wonderful a quality boiler that is well maintained, and well matched to its duty is. However, they do know what a curse a poorly designed or or poorly selected boiler can be. A troublesome boiler may cause them to lose production, keep them awake at night wondering what is next, or worst of all it may injure a fellow worker.

There is a lot going on inside industrial steam boilers, thermodynamics from mass and energy balances, compressible fluid flow, heat transfer to combustion chemistry. All the stuff in those big thick books that engineering students hated in college, it's all happening at once right there inside your boiler. Fortunately, boiler technology and manufacturing has evolved to a very high level and safety systems have certainly kept pace.

The keys to selecting the proper boiler design are:

1. Keep safety first, training, log books, maintenance are all part of that, regardless of boiler type.
2. Know your process, how fast do things change, what are the operating limits, will things change in the future?
3. Avoid oversizing for peak-peak loads, consider a second unit or a "pony" boiler for extended low load operation.
4. Understand all the cost factors that go into operating a boiler: power for fan, fuel costs, efficiency, water and chemical requirements, proprietary parts and service vs competitive sourcing, parts availability, what does your downtime cost you, can your current operators run the proposed system safely and efficiently, physical space requirements, sound attenuation, insurance requirements.
5. If a boiler goes down, do you want to have N+1 or two units at 75% of peak load, or perhaps have an emergency plan and hook ups to bring in a rental boiler.
6. Research boiler types that meet your capacity and pressure requirements.
7. Visit with vendors, tell them about your project, check with references and go see some equipment, talk to the operators.
8. Take your time, because a well selected, well designed and built boiler will last 40-50 years and will perform flawlessly. A poorly selected unit will be an ongoing nightmare, the good news: it might fail in a year or two.

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