Investigating the Impact of Boiler Aging In Replacement Decisions

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ABSTRACT

Traditionally boilers were believed to operate efficiently for fifteen to twenty years at the end of which they are typically replaced. When it is time for replacement, one primary aspect most often considered is simply the age of the boiler and its impact on the boiler efficiency. This paper will discuss the result of the investigation that proves more variables are to be considered than just the age of the boiler when deciding to replace boilers. The investigation includes effect of maintenance, operation hours, feed water treatment and sizing of boilers on its performance. Maintenance of boilers includes cleaning and replacing metal parts in the boiler such as water tubes, regular inspection of metals for deterioration and routine tune up of the boilers. The impact of good maintenance on boiler will not only improve performance but also extend the life of the boiler. The proper sizing of a boiler is also a key issue when considering a replacement. If a boiler is undersized or oversized, then replacing it with a proper sized boiler is a sensible alternative. Factors such as feed water systems and their impact on boiler performance will be considered in this investigation. It will be established that the relationship between the age of the boiler and the efficiency of the system is highly dependent on the various above-mentioned variables.

Introduction

Most industrial boiler systems are considered to be an essential and critical part of operations. Boilers are used to satisfy process needs and space conditioning needs in a facility. Industrial boilers have to satisfy critical process requirements for which proper operation of the boiler is necessary. For this reason, facility personnel monitor boiler performance and conditions routinely. If the existing boiler happens to be over 15 years, facility personnel most often consider boiler replacement as an obvious alternative simply because of age. This is the consensus seen during New Jersey Program for Manufacturing Excellence audits performed by Center for Advanced Energy Systems staff. It should be noted that there are many other parameters that should be considered beside the boiler age when replacement is being considered. This paper will discuss the different parameters that should be considered and evaluated before allowing for a boiler replacement.

Evaluation Process:

In large oil and gas processing plants like Saudi Aramco protocols have been employed to determine condition of the boiler as the boilers age. This company operates several large boilers ranging from 150-625 psi operating pressure and use assessment protocol to maintain serviceability and uninterrupted production. This assessment protocol also helps them with long term maintenance planning and identifies boilers that need replacing. The Boiler Condition Assessment (BAC) used by Saudi Aramco is a three-phase process that is intended to provide trouble free operation of their boilers. Phase-I of the BAC involves review of maintenance and operational history of the boiler. Phase-II involves actual boiler assessment which includes on-site inspection and examination of the boiler. Phase-III involves detailed engineering analysis that provides information on remaining life and essential upgrades needed for the boiler [6].

An assessment protocol similar to that used by Saudi Aramco is suggested, when deciding to replace or upgrade a current boiler. This assessment protocol will incorporate a methodical review of several parameters such as boiler service history, current operating conditions, boiler performance and financial analysis in a three-phase approach.

Phase-I:

- Review of Service History of the Boiler
    - Maintenance History
    - Operating Hours on the boiler
- Review of Current Operating Conditions of the boiler
    - Boiler Performance
    - Boiler Load factor
    - Feed Water System
    - Burner Performance and Emission

Phase-II:

- Boiler Condition Assessment that examines critical parts of the boiler

Phase-III:

- Financial Analysis of Boiler Upgrade Versus Boiler Replacement

Phase-I

Service History

Review of boiler service history should examine maintenance records of routine work performed on the boiler. For example, routine stack tests and boiler flue gas ratio adjustment of a boiler indicates that boiler efficiency is maintained. This data, if collected will show historical performance of the boiler and will indicate if boiler performance is deteriorating over the years. Service history will also include review of any overhaul done to the boiler such as re-tubing, burner or economizer upgrades. This will reveal the true history of the boiler.

Another parameter that is a true representative of a boiler age is it operating hours. Most often boilers encountered during plant assessments are part of a large boiler system with multiple boilers. In these cases, a typical boiler might be much older than its operating hours. During an NJME assessment visit, the audit team encountered a high pressure water tube boiler that was purchased in 1971. Because the boiler plant had 4 other boilers of similar size or above, the actual run hours on the boilers were shared among the 5 boilers, contributing to only 60,000 hours on this particular boiler. The plant personnel were evaluating the performance of the boiler system and had an idea of replacing the old boiler with a brand new boiler. The audit team performed a series of tests including stack test to verify efficiency of the boiler and determined that performance of the boiler was comparable to the other younger boilers. This indicates that simple age of the boiler is not sufficient to determine whether a boiler replacement is appropriate. A combination of current boiler operating condition and a detailed condition assessment is necessary to determine if replacement is an appropriate option.

Current Operating Conditions

Another essential step in the evaluation is to methodically review the current operating conditions of the boiler. The evaluation should begin with the analysis of the boiler capacity and its ability to satisfy the current plant load. Sometimes, boilers are oversized and are usually operated under partly loaded conditions where the performance efficiencies are compromised. This makes a good case for boiler replacement, where a correct sized boiler will operate at its peak efficiency at full load. Typically new boilers can achieve up to 85% in efficiency if they are fully loaded and economizers are employed. If the boiler is undersized or if the plant anticipates production expansion, then review of the boiler performance will help decide if a larger new boiler is appropriate or an additional new boiler that adds capacity over the current boiler could satisfy the needs. According to boiler manufacturer Babcock and Wilcox, at least 70% of a boiler's capacity is available for 30 years before any capital expenditure is needed for a boiler upgrade. The boiler life could be extended for twenty more years where at least 85% of capacity will be available with large capital expenditure project and 75% of capacity will be available with small capital expenditure [3]. So it is very essential to determine the load of the facility and properly satisfy it with the boiler capacity available in the plant efficiently.

Another integral part of the boiler system that should be evaluated is its feed water treatment system. Feed water treatment is an essential part of boiler operation, since scale tends to form in the heat transfer surfaces. Scale lowers the thermal conductivity of the surface and promotes poor heat transfer. "The presence of scale is equivalent to having a thin film of insulation across the path of heat transfer from the furnace gases to the boiler water. This heat-insulating material retards heat transfer and causes a loss in boiler efficiency. Stack gas temperatures may increase as the boiler absorbs less heat from the furnace gases." (Energy Matters, May 1999) In addition to decreased heat transfer, scale causes overheating of boiler water tubes and cause tube failure. Re-tubing of the boilers is a very expensive upgrade and thus it makes feed water treatment an essential step in boiler operation. Phosphates, chelates, and polymers are commonly used for water treatment in boiler plant. By properly treating the water the life of the boiler tubes will be extended.

Boilers that are old have efficiency and emission concerns that need to be addressed. One common energy efficient upgrade that is typically done with old boilers is the burner upgrades. "A poorly designed boiler with an efficient burner may perform better than a well designed boiler with a poor burner." [4] One sure upgrade recommended for old boiler would be to upgrade burners. Upgrading burners will help better fuel and air mixing for combustion and will impact the emissions of the boiler. There are low NO_x burners available that help control emission of the boiler making it competitive with newer boilers. However, low NO_x burners tend to provide harsh conditions in the boiler that causes sulfidation corrosion and erosion. This high rate deterioration is noted to cause failure of major boiler components such as waterwalls and burners [5]. Currently, there is ongoing research that is developing and evaluating coatings to use in boiler that would prevent such failure. But at the present moment, it should still be noted that low NO_x burners while improving combustion efficiency, might also be compromising the structural integrity of the boiler.

At the end of this phase, a clear picture of the boilers maintenance history including upgrades done to the boiler should be known.

Phase-II

Once the initial evaluation of the boiler's service history and operational conditions are completed then the proper step is to perform an actual condition assessment of the boiler. The protocol for such assessment would involve evaluation of the various components of the boiler. An example of such a protocol is the "Boiler Fitness Survey" program available through Babcock & Wilcox that was developed based on approach used by Electric Power Research Institute (EPRI) to survey utility boilers [1]. Even before an actual assessment, guidelines similar to that developed by B&W given below in Table 1 could be used to compare maintenance records to see what component is in need of replacement.

Table 1. Component Replacement Schedule for a Typical High Temperature, High Pressure Boiler

Typical Life (Years)	Component Replaced	Cause for Replacement
20	Miscellaneous Tubing	Corrosion, erosion, overheating
20	Attemperator	Fatigue
25	Superheater (SH)	Creep
25	SH Outlet Header	Creep Fatigue
25	Burners and Throats	Overheating, Corrosion
30	Repeater	Creep
35	Primary Economizer	Corrosion
40	Lower Furnace	Overheating, Corrosion
Note: The actual component life is highly variable depending on the specific design, operation, maintenance and fuel		

Source: Babcock & Wilcox, 1992

The assessment services available through large commercial boiler makers range from simple visual inspection to more detailed technical survey using technology such as radiography. Typically these tests are done for pressure critical part not only for reliability reasons but also for safety reasons. The following boiler components are identified by B&W as critical parts that are in need of condition assessment prior to a replacement decision[1]:

- All Boiler Drums – steam, lower, uptake, downtake, etc
- Steam and Water Headers
- All Tubing
- All Steam and Feed Water Piping
- Deaerator
- Attemperator

The assessment types recommended for all of these components are nondestructive in nature and involve data collection about these components either through visual inspection or technical testing. For example, the assessment of steam and water headers for lower temperature boilers involves Magnetic Particle testing or Wet Fluorescent Magnetic Particle testing. These tests will be able to reveal corrosion, erosion as well as creep due to cyclic thermal expansion experience by the boiler. The same assessment methods could be used to detect corrosion of steam drum, and upon detection of corrosion Ultrasonic Thickness Testing could be used to evaluate the degree of metal loss due to corrosion[1]. Boiler makers also provide an assessment that gives information on remaining useful life of these components. This assessment could help determine if replacement of a specific component is needed at this point of time.

Phase-III

Financial Analysis

Based on the results obtained from condition assessment a financial evaluation could be made on whether boiler replacement is a suitable alternative for a particular situation. In order to demonstrate a financial analysis, a case history of a boiler encountered during a plant assessment is used.

Table 2. Cost for Implementing Boiler Upgrade Verses Buying New Boiler

Old Boiler		
Boiler Rating:	120,000 pph	650 psig
Current Efficiency:	70%	
Proposed Efficiency:	78-80%	
Boiler Year	1976	
Condition Assessment Performed		
Boiler Tube Analysis		$ 40,000*
Flue Gas Testing and Engineering Analysis		$ 5,000
Upgrades Suggested		
Full Re-tubing of the Boiler		$ 300,000*
Low No_x Burner Upgrade		$ 230,000
Engineering Services		$ 100,000
Total Cost		**$ 675,000**
New Boiler		
New Boiler Rating:	120,000 pph	650 psig
Current Efficiency:	83.5%	
Boiler Year	2006	
New Boiler Projected Cost		
Boiler and Installation		$ 1,200,000*
Engineering Services		$ 100,000
Total Cost		**$ 1,300,000**

[1]Vendor Quotation

Based on the financial Analysis provided above, it is evident that with half the capital investment, the efficiency of a boiler can be improved 8-10%. It should be noted that the cost estimates provided above are based on preliminary estimates provided by vendors. So in this case, the boiler upgrade is a more desirable alternative than a boiler replacement.

Conclusion

When boiler replacement is considered, an assessment protocol involving evaluation of boiler's current operation, actual condition assessment and a financial analysis should be performed before deciding to purchase a new boiler. It should be noted that there is no single critical criteria that determines if a boiler is too old for operation such as its age. A combination of the performance characteristics, structural integrity and environmental performance of the boiler should be evaluated before replacement decision is made. When dealing with small to medium sized manufacturing facilities, capital investment most often drives the decision making. Therefore, the financial analysis portion of the process might be more essential in the decision making process.

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