Replace the Natural Gas Boiler with one of the Available Electric Boilers (Arc 2.1224)

(The analysis below was extracted from one of the assessment reports by the Clemson University Industrial Assessment Center (IAC). This is only an example recommendation and hence, not all the background information and sources for numbers are included here.)

Est. Gas Consumption Savings	= ***197 MMBtu/yr***
Est. Eenrgy Consumption Cost Savings	= ***$1,478/yr***
Est. Implementation Cost	= ***$750***
Simple Payback Period	= ***6.1months***

Recommended Action:
It is recommended that the natural gas boiler is replaced with one of the electric boiler units (available at plant) to achieve efficiency improvement and energy consumption savings.

Background:
The plant uses a type CT Columbia Natural Gas boiler with 20HP capacity (~15kW). The boiler runs during all three shifts to satisfy the steam requirement of the plant. The plant manager let the assessment team know that there are eight electric boilers bought few years back and currently not in use. These boilers are 58kW Chromalox Electric Boilers. It is known that electric boilers do not suffer from flu gas loss through chimney like the natural gas types and therefore have the higher utilization efficiency rate between 95% to 100% [1]. The assessment team recommends that natural gas boiler be replaced with one of the available electric boiler units to achieve efficiency improvement and energy consumption savings.

The average unit cost that the plant is being charged for natural gas is $7.5/MMBtu. The plant is charged an average of $0.059/kWh for electric consumption. Total annual hour of operations for current natural gas boiler is around 8,760 hours.

Anticipated Savings:
The result of the boiler combustion test conducted on the assessment day is presented in Figure below (Figure 1). We use the Bacharach Insight Plus analyzer to evaluate the combustion efficiency and flue gas quality. The gas-fired combustion efficiency of the boiler is measured at 73.1%.

BACHARACH

The Measurable Difference

Insight Plus 04/26/18,12:04:29 PM Natural Gas	
O2	9.2 %
CO	3 ppm
Eff	73.1 %
CO2	6.6 %
T-Stk	563 F
T-Air	73.3 F
EA	70.4 %
CO(0)	5 ppm
Pre	-60 Pa

Figure 1. Combustion test results for the boiler

According to operations management the steam requirement of the plant is typically in the range of 50% to 70% of the boiler capacity. The boiler burns throughout the year for a total of 8,760 hours approximately. Therefore, by assuming an average of 60% steam load, the average annual energy consumption of the boiler, *AEC*, can be estimated as follows:

$$\text{AEC} = \text{Heat input (MMBtu/h)} \times \text{Steam load (\%)} \times \text{Operational hours}$$

$$\mathbf{AEC = 0.051\ MMBtu/h \times 60\% \times 8{,}760h = 268.1\ MMBtu}$$

According to the DOE sourcebook for Steam System Performance [2], we can estimate the amount of energy saving due to efficiency improvement from boiler replacement. Assuming an efficiency level of 95% for new replaced boiler, the annual energy saving, *AES*, can be obtained as follows:

$$\text{AES} = \text{AEC} \times (1 - \text{Eff}_{NG} / \text{Eff}_{E})$$

$$\mathbf{AES = 268.1\ MMBtu \times (1 - 0.730.95) = 62.1\ MMBtu}$$

To estimate the annual energy cost saving we have to note that, by replacing the natural gas boiler with an electric boiler, energy cost should be paid based on electrical consumption ($0.059/kWh) instead of natural gas consumption ($7.5/MMBtu). First, we estimate the annual energy cost using the natural gas boiler, AEC_{NG}, as follows:

$$AE_{CNG} = AES \times (1/Eff_{NG}) \times (\$7.5/MMBtu)$$

$$\boldsymbol{AE_{CNG} = AES \times (1/0.73) \times (\$7.5/MMBtu) = \$2{,}744}$$

The electric boilers at the plant have higher capacity (~58kW) and are more efficient (95-100%). Therefore, to satisfy the same energy requirement of original boiler (268.1 MMBtu) using an electric boiler would require only 2,265 annual hours of operation. Then, estimated annual energy cost using the electric boiler, AEC_E, can be obtained as follows:

$$AEC_E = AES \times 293.071 \frac{kWh}{MMBtu} \times \frac{Capacity_{NG}}{Capacity_E} \times Operational\ hours \times \frac{1}{Eff_E} \times \frac{\$0.059}{kWh}$$

$$\boldsymbol{AEC_E = \$1{,}266}$$

The amount of annual energy cost saving, AECS, can be estimated by calculating the difference between annual energy cost of natural gas boiler and the electric boiler:

$$AECS = AE_{CNG} - AEC_E$$

$$\boldsymbol{AECS = \$2{,}744 - \$1{,}266 = \$1{,}478}$$

Implementation Cost:
Since the electric boiler units are previously bought, there is no need for any capital investment to buy a new unit. The only implementation cost would be related to labor cost to put the new boiler into operation. We assume a one-time cost of $750 to put the electric boiler into operation:

Implementation Cost (IC) = $750

Simple Payback Period:
The *simple payback period, SPP*, is the time required to pass before the estimated total cost savings equal the estimated implementation cost, and is calculated by:

$$SPP = \frac{IC}{AECS} \times 12\ months/yr.$$

$$SPP = \frac{\$750}{\$1478/yr.} \times 12\ months/yr.$$

SPP = 6.1 months

References:

1. Efficiency, D.O.o.E. Furnaces and Boilers. Available from: https://www.energy.gov/energysaver/home-heating-systems/furnaces-and-boilers
2. U.S. Department of Energy, A.M.O., Improving Steam System Performance: A Sourcebook for Industry. 2017.