AR No. # - Boiler Fan VFD with O2 Controls

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Recommendation

Install an oxygen (O2) sensor in the boiler stack and a variable frequency drive (VFD) on the forced draft fan to control fan speed based on oxygen content. This will increase combustion efficiency by optimizing the air-fuel ratio and reduce natural gas consumption by 2.0%. Additionally, it will reduce fan power causing a 50% decrease in fan electrical consumption.

Annual Savings Summary

Source	*Quantity*	*Units*	*Cost Savings*
Electrical Consumption	50,000	kWh (site)	$2,500
Natural Gas	500	MMBtu	$2,500
Total	**671**	**MMBtu**	**$5,000**

Implementation Cost Summary

Description	*Cost*	*Payback (yrs)*
Implementation Cost	$5,617	1.1

Facility Background

The 10.0 MMBtu/hr boiler uses a 10 hp forced draft fan with an outlet damper to control air flow. A damper controls air flow by increasing flow resistance. Partially closed dampers are inefficient because significant power is required to overcome the added resistance.

During the site assessment, facility personnel informed us that (describe process and when airflow into boiler needs to be maximum, and when it is turned down using the damper or inlet vane.) Fan and Motor data were collected using a power quality analyzer and HOBO dataloggers. The data was analyzed using the Motor Analysis Tool (MAT) and the Fan Control Analysis Tool (FCAT). This data was used to create a boiler operation profile. It was found that the boiler operates at an average capacity of (enter percent capacity from CEAT)

Combustion data was collected using a combustion gas analyzer, and efficiency was analyzed in the Combustion Efficiency Analysis Tool (CEAT). The excess oxygen was (enter %O2 here) and the combustion efficiency was (enter here from CEAT).

AR No. # - Boiler Fan VFD with O2 Controls

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Technology Background

Variable Frequency Drives (VFDs) vary the fan impeller speed instead of restricting airflow like a damper or inlet vane. When the boiler requires a smaller amount of air, the VFD reduces motor speed to produce the required airflow while using the least amount of energy. Likewise, it will increase motor speed as more air is demanded by the boiler. Savings are achieved by installing a VFD to reduce the electrical power required to operate the fan at specified settings. The power savings available by switching to a VFD controlled system are represented by general curves of percent loaded power versus percent loaded capacity which are found in the FCAT.

Ideally, a boiler would use just enough combustion air to burn all of the fuel, with no excess air. Excess air carries heat up the stack and reduces boiler efficiency. However, all burners require some excess air to ensure complete combustion. Practically, natural gas boilers should be able to achieve 4.0% excess oxygen.

An oxygen sensor placed in the boiler stack can be used to control the VFD. The sensor detects the excess oxygen in the stack, and if it exceeds a set percentage, the VFD will switch the boiler fan to a lower setting to decrease the airflow. This will optimize boiler combustion efficiency.

Proposal

Install an oxygen sensor in the boiler stack to measure excess oxygen from combustion. Set the damper in the boiler forced draft fan to wide open and install a VFD to control fan impeller speed based on excess oxygen. This will reduce excess oxygen in the combustion process and improve efficiency. Also install a VFD bypassso the process can continue uninterrupted if the VFD fails, needs maintenance, or needs reprogramming. If implemented, natural gas costs will be reduced by $2,500 annually and fan electrical costs will be reduced by $2,500 annually, totaling to $5,000 annual cost savings. The estimated implementation cost is $5,617 resulting in a 1.1 year payback.

Notes

Fan electrical savings were calculated based on the change in control strategy assuming the airflow will remain the same. However, the current airflow is more than what is required for combustion so additional savings will occur with airflow reductions. Associated savings are expected to be small and are not calculated in this recommendation.

The proposed excess oxygen set point was determined based on industry standards for combustion systems. However, achieving this set point may be difficult depending on the specific system. Savings will be less if the excess oxygen cannot be fully lowered to the desired set point.

Based on	Data Collection	Author	Orange Team Review	Black Team Review
Unmodified Template	*Insert Name* *Insert Name*	*Insert Name*	*Insert Name*	*Insert Name*

AR No. # - Analysis

Oregon State University | Energy Efficiency Center

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Data Collected

Boiler Data

Boiler Fan Type		*Forced Draft*		
Current Fan Control Type		*Outlet Damper*		
Operating Hours		*8,760*	hrs/yr	**(N. 1)**
Maximum Firing Rate		*10.00*	MMBtu/hr	**(N. 2)**
Fan Motor Horsepower		*10*	hp	**(N. 2)**

Utility Data

Incremental Electricity Cost	(IC_E)	*$0.0500*	/kWh	**(Rf. 1)**
Incremental Natural Gas Cost	(IC_G)	*$5.00*	/MMBtu	**(Rf. 1)**

Savings Analysis

Electrical Savings

Current Fan Electrical Consumption	(E_{CE})	*100,000*	kWh	**(Rf. 2)**
Fan Electrical Energy Savings	(E_{SE})	*50,000*	kWh	**(Rf. 2)**
Electrical Cost Savings	(S_E)	*$2,500*	/yr	**(Eq. 1)**

Natural Gas Savings

Current Boiler Natural Gas Consumption	(E_{CG})	*25,000*	MMBtu/yr	**(Rf. 3)**
Boiler Natural Gas Energy Savings	(E_{SG})	*500*	MMBtu/yr	**(Rf. 3)**
Natural Gas Cost Savings	(S_G)	*$2,500*	/yr	**(Eq. 2)**

Implementation Cost Analysis

Material Costs

Boiler Fan VFD	(C_{VFD})	*$1,289*		**(N. 3)**
Electrical Circuitry/Bypass	(C_{EC})	*$1,630*		**(N. 3)**
O_2 Sensor	(C_S)	*$785*		**(Rf. 4)**
Controller	(C_C)	*$800*		**(Rf. 4)**
Total Material Cost	(C_M)	*$4,504*		**(Eq. 3)**

Labor Costs

VFD Installation	(C_{LVFD})	*$1,000*		**(N. 3)**
Controller Installation	(C_{LC})	*$113*		**(Rf. 4)**
Total Labor Cost	(C_L)	*$1,113*		**(Eq. 4)**

Economic Results

Annual Cost Savings	(S)	*$5,000*	/yr	**(Eq. 5)**
Implementation Cost	(C_I)	*$5,617*		**(Eq. 6)**
Simple Payback	(t_{PB})	*1.1*	years	**(Eq. 7)**

Notes

N. 1) Data provided by facility personnel.

N. 2) Data found on boiler name plates.

N. 3) VFD Equipment Cost estimated based on AC Drive VFD prices found at http://www.grainger.com/ Prices will vary with brand and input/output phase, amperage, and voltage.

Equations

Eq. 1) Electrical Cost Savings (CS_E)

$$E_{SE} \times IC_E$$

Eq. 2) Natural Gas Cost Savings (CS_G)

$$E_{SG} \times IC_G$$

Eq. 3) Total Material Cost (C_M)

$$C_{VFD} + C_{EC} + C_S + C_C$$

Eq. 4) Total Labor Cost (C_L)

$$C_{LVFD} + C_{LC}$$

Eq. 5) Annual Cost Savings (S)

$$S_E + S_G$$

Eq. 6) Implementation Cost (C_I)

$$C_M + C_L$$

Eq. 7) Simple Payback (t_{PB})

$$\frac{C_I}{S}$$

References

Rf. 1) Developed in the Utility Analysis located in the Site Data section.

Rf. 2) Developed in the following Fan Control Analysis Tool (FCAT).

Rf. 3) Developed in the following Combustion Efficiency Analysis Tool (CEAT).

Rf. 4) RSMeans Mechanical Cost Data 2012. Pg. 269. O_2 Sensor cost estimated using carbon monoxide detector cost.