Add Economizers to Boilers to Recapture Heat from the Flue Exhaust (Arc 2.2421)

(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	= ***11,157.4 MMBtu/yr***
Est. Gas Consumption Cost Savings	= ***$47,531 /yr***
Est. Implementation Cost	= ***$15,500***
Simple Payback Period	= ***3.9 months***

Recommended Action:
It is recommended that an economizer be added to the boiler systems to recapture the heat from the flume exhaust and use it for pre-heating the boiler feed water.

Background:
The plant uses two Clayton Industries Model E504 Standard boilers with 500HP capacity fueled with natural gas. One of the boilers is running throughout the year and the other one is used only for redundancy cases. Economizers are air-to-liquid heat exchangers designed to preheat boiler feed water. They may also be used to heat process of domestic water, or to provide hot liquids for space heating or make-up air heating equipment.

Most economizers have finned tube heat exchangers constructed of stainless steel while the inlet and outlet ducts are carbon steel lined with suitable insulation. Maximum recommended waste gas temperatures for standard units are around 1,800°F.

According to economizer manufacturers, fuel consumption is reduced approximately 1% for each 40°F reduction in flue gas temperature. The higher the flue gas temperature, the greater the potential for energy savings. The following graph shows the effect of pre-heating combustion air on available heat:

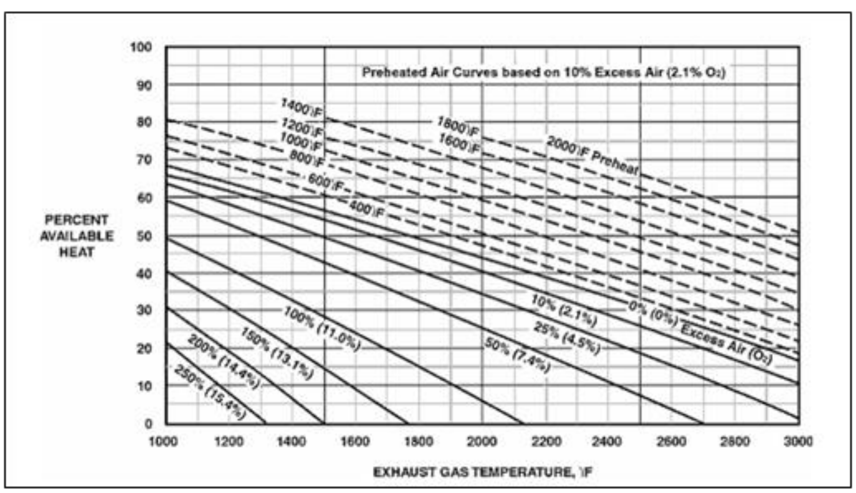

Figure 1. The effect of pre-heating combustion air on available heat.

The average annual natural gas consumption for the plant from years 2015 and 2016 has been 114,226 MMBtu. The average unit cost that the plant is being charged for natural gas is $4.26/MMBtu.

<u>Anticipated Savings</u>:
The gas-fired combustion efficiency of the boiler was measured at 79.2% using the Bacharach Insight Plus analyzer. According to operations management the steam requirement of the plant is typically around 50% of the boiler capacity. The boiler specifications presented in figure below indicate that the nominal heat input for the installed boiler is about 20.412 MMBtu/h (Figure 2) using natural gas fuel.

MODEL E504	MODEL E504 Standard	MODEL SE504 with Super Economizer	MODEL EG504-FMB with Low NOx Burner	MODEL SEG504-FMB with Low NOx Burner and Super Economizer
BOILER HORSEPOWER	500	500	500	500
HEAT INPUT, BTU/hr — Oil	20,165,663	19,462,209	NA	NA
HEAT INPUT, BTU/hr — Gas	20,411,585	19,691,176	20,663,580	19,691,176
NET HEAT OUTPUT, BTU/hr	16,737,500	16,737,500	16,737,500	16,737,500
EQUIVALENT OUTPUT (from and at 212°F feedwater and 0 PSIG steam)	17,250 lbs/hr	17,250 lbs/hr	17,250 lbs/hr	17,250 lbs/hr
DESIGN PRESSURE (see note 1)	65 - 500 PSIG	65 - 500 PSIG	65 - 500 PSIG	65 - 500 PSIG
STEAM OPERATING PRESSURE (determined by design pressure)	60 - 450 PSIG	60 - 450 PSIG	60 - 450 PSIG	60 - 450 PSIG
OIL CONSUMPTION at maximum steam output (see note 2)	143.4 gph	138.4 gph	N/A	N/A
GAS CONSUMPTION at maximum steam output (see note 3)	20,412 cfh	19,691 cfh	20,664 cfh	19,691 cfh
BURNER CONTROLS modulating	5 to 1 Turndown	5 to 1 Turndown	4 to 1 Turndown	4 to 1 Turndown
EFFICIENCY				
oil-fired efficiency %	83%	86%	NA	NA
gas-fired efficiency %	82%	85%	81%	85%
ELECTRIC MOTORS, HP (see note 4)	Blower / Pump	Blower / Pump	Blower / Pump / Cooling	Blower / Pump / Cooling
design pressure 15-300 psig	25 / 20	25 / 20	30 / 20 / 7.5	30 / 20 / 7.5
design pressure 301-500 psig	25 / 30	25 / 30	30 / 30 / 7.5	30 / 30 / 7.5
ELECTRIC FLA, based on 460 V (see note 5)				
design pressure 15-300 psig	74	74	92	92
design pressure 301-500 psig	85	85	107	107
GAS SUPPLY PRESSURE REQUIRED	5 to 10 psig	5 to 10 psig	5 to 10 psig	5 to 10 psig
ATOMIZING AIR REQUIRED (see note 6)				
Capacity	30 scfm	30 scfm	NA	NA
Minimum pressure	70 psig	70 psig	NA	NA
AIR SUPPLY REQUIRED (FMB -see note 7)	N/A	N/A	5 scfm @ 3 to 150 psig	5 scfm @ 3 to 150 psig
WATER SUPPLY REQUIRED	2,650 gph	2,650 gph	2,650 gph	2,650 gph
HEATING SURFACE	912 sq.ft.	1,207 sq.ft.	912 sq.ft.	1,207 sq.ft.
EXHAUST STACK CONNECTION, o.d.	32 in.	32 in.	32 in.	32 in.
APPROXIMATE OVERALL DIMENSIONS				
length	133 in.	133 in.	156 in.	156 in.
width	131 in.	131 in.	142 in.	142 in.
height	131 in.	157 in.	135 in.	161 in.
WEIGHT				
installed - wet	17,408 lbs	20,400 lbs	17,708 lbs	20,700 lbs
shipping	14,790 lbs	17,190 lbs	15,090 lbs	17,490 lbs
FW pump skid	2,000 lbs	2,000 lbs	2,000 lbs	2,000 lbs

1) Design pressures are available up to 3000 psig. Consult factory for details.
2) Based on No. 2 fuel oil with a High Heat Value (HHV) of 140,600 BTU/Gal.
3) Based on Natural Gas with a High Heat Value (HHV) of 1,000 BTU/Ft.³
4) Oil fired units also use a separate motor driven fuel oil pump - 3/4 HP
4) Continuous running. For 575 V multiply by 0.8; for 380 V multiply by 1.1; for 230 V multiply by 2.0; for 208 V multiply by 2.2.
5) Atomizing air required for oil burner.
6) Compressed air required for FMB.
The description and specifications shown were in effect at the time this publication was approved for printing. Clayton Industries, whose policy is one of continuous improvement, reserves the right to discontinue models, or change specifications or design, without notice.

Figure 2. Boiler specifications for Model E504 Standard

Therefore, the annual estimated energy consumption of the boiler, *EEC*, can be determined as follows:

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

$$\mathbf{EEC = 20.412\ MMBtu/h \times 50\% \times 8760h = 89{,}402.7\ MMBtu}$$

A high quality recuperator could recover up to 60% of this waste heat. Accordingly, the potential energy savings from the installation of a recuperator on the process boiler, AES, can be determined as:

$$AES = EEC \times (1 - Eff1) \times RC$$

where *RC* is the percent of energy recoverable by recuperator, so

$$\mathbf{AES = 89{,}4012.7 \times (1 - 0.792) \times 0.6 = 11{,}157.4\ MMBtu}$$

Finally, the estimated annual energy cost saving, *AECS*, can be determined based on the unit energy consumption charge for natural gas:

$$AECS = AES \times (\$4.26/MMBtu)$$

$$\boldsymbol{AECS = 11{,}157.4 \times (\$4.26/MMBtu) = \$47{,}531}$$

Implementation Cost:

Many boiler companies sell off-the shelf boiler recuperators of various sizes and efficiencies. The cost of a recuperator capable of handling the exhaust flow rate of the boiler as well as having efficiency greater than 70% would be about $10,000 and the anticipated installations costs would run to about $5,500. Therefore, the implementation cost, *IC*¸ would be approximately around $15,500.

Implementation Cost (IC) = $15,500

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:

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

$$SPP = \frac{15{,}500}{47{,}531} \times 12\ months/year$$

SPP = 3.9 months