Engineering Consulting & Training Services

CARMAGEN Engineering, Inc. eNewsReport

March 2011

Increasing Fired Heater Thermal Efficiency

By Lester W. Davis, Jr.

Increasing the thermal efficiency of a Fired Heater reduces the heater's carbon footprint and operating costs. For example, assuming a Fired Heater with a heat release of 100 MBTU/hr, an increase in efficiency of 1% will result in a savings of $38K/yr at a fuel cost of $4 per MBTU.

The thermal efficiency of a Fired Heater is an indication of how much of the total heat fired is absorbed by the process, and can be defined by the following equation:

$$Eff = Q_a/Q_f$$

Where:

Eff = Efficiency

Q_a = Heat absorbed by the process

Q_f = Heat fired

The amount of heat fired may by readily obtained by measuring the flow rate of the fuel fired (lb/hr) and the fuel's heating value (BTU/lb). The amount of heat absorbed by the process is not readily known. Therefore we turn our attention to the Fired Heater heat losses. By subtracting the heat losses from the heat fired, we can determine the heat absorbed by the process. The equation for efficiency then becomes:

$$Eff = Q_f - Q_l/Q_f$$

Where:

Q_l = Fired Heater heat losses

There are two areas that determine the heat losses from a Fired Heater:

1. Stack losses are related to the temperature of the flue gas and the amount of flue gas leaving the stack.
2. The heat losses are also due to radiation from the Fired Heater casing.

Upcoming Training Courses held in our NJ offices

- Course 1510, *Mechanical Design of Process Plant Equipment,* April 12-15, 2011
- Course 1210, *Process Design for Process Plant Equipment* May 24-26, 2011
- Course 1302, *Relief System Design,* June 21-23, 2011

For more information, see our website at www.carmagen.com.

For a copy of our 2Q 2011 course catalog, please email pterry@carmagen.com.

Work Highlights

Mechanical Engineering

Provided mechanical engineering Cold Eyes Review of a refinery's upcoming operating plan for their delayed coker unit. This review was prompted due to reliability issues that the drums have had in the past. Drum repair, operating, and design recommendations were provided with the goal of improving the future reliability of the existing drums, and to consider for possible replacement drums later.

Process, Operations & Safety

Provided essential multi-unit technical support and onsite start-up assistance for a domestic client's refinery-wide turnaround, including FCC, fluid coker, hydrogen plant, sulfur plant, and amine scrubbing areas. Assisted with emergency shutdown incident investigations and FCC troubleshooting.

STACK LOSSES

As discussed, stack temperature of the flue gas at some temperature indicates the amount of heat lost to the atmosphere. By performing an analysis of the fuel fired we can determine the amount of constituents in the flue gas in terms of mole % or wt %. Knowing the flue gas constituent fractions, which are typically H_2O, N_2,and CO_2, we can find their enthalpy in terms of BTU/lb. For example, CO_2 at 600°F is about 120 BTU/lb while N_2 is about 135 BTU/lb and O_2 is about 123 BTU/lb. By summing up the constituent enthalpies we determine the BTU/lb of flue gas and heat leaving the stack. Most Thermodynamic and Combustion references have this information in table or graphic form. See Figures 1 and 2 (next page) taken from API Recommended Practice 532.

RADIATION LOSSES

The heat loss from the Fired Heater casing can be determined using a rigorous analysis which involves:

1. Measuring the temperature of the casing with a contact thermocouple or an infrared camera.
2. Measuring or noting the air velocity.
3. Referring to a Transmission Curve which plots the difference between the casing temperature and ambient temperature against the heat transmission rate as a function of the air velocity.
4. Multiplying the transmission rate (BTU/ft^2/Hr) by the surface area (ft^2) produces the radiation loss (BTU/Hr).

In general, we find that the radiation losses are comparatively small. Therefore for design purposes, after calculating the fuel required to support process conditions, the following guidelines are normally used to cover radiation losses:

1. For Fired Heaters designed to absorb more than 100 MBTU/hr, the calculated net fuel required is increased by 1% (i.e., multiplied by 1.01).
2. For Fired Heaters designed to absorb between 15 and 100 MBTU/hr, the calculated net fuel required is increased by 2% (i.e., multiplied by 1.02).
3. For Fired Heaters designed to absorb less than 15 MBTU/hr, the calculated net fuel required is increased by 3% (i.e., multiplied by 1.03).

EXCESS AIR LOSSES

Excess air influences stack loss by decreasing or increasing the stack gas flow rate. To minimize the flue gas flow rate, the excess air to the burners should be minimized. This can be accomplished by first testing the Fired Heater to determine the minimum excess air level at which it can safely operate.

AIR LEAKAGE LOSSES

Fired Heaters typically operate at an internal pressure which is less than atmospheric or negative. Therefore, any openings in the Fired Heater will allow ambient air to be infiltrated or leaked into the box. The result of this leakage has the same effect on flue gas rates as operating at high excess air levels through the burners. To reduce the air infiltration, the openings should be sealed.

To determine the amount of air being leaked, a portable O_2 analyzer should be used to measure the O_2 entering and leaving the convection section. The openings typically occur at tube penetrations and header boxes which are mostly located in the convection section. A visual inspection should be made of these areas, and also of the radiant section around peep doors and outlet piping.

There will always be some air infiltration. The object is to minimize it to below 1% excess O_2.

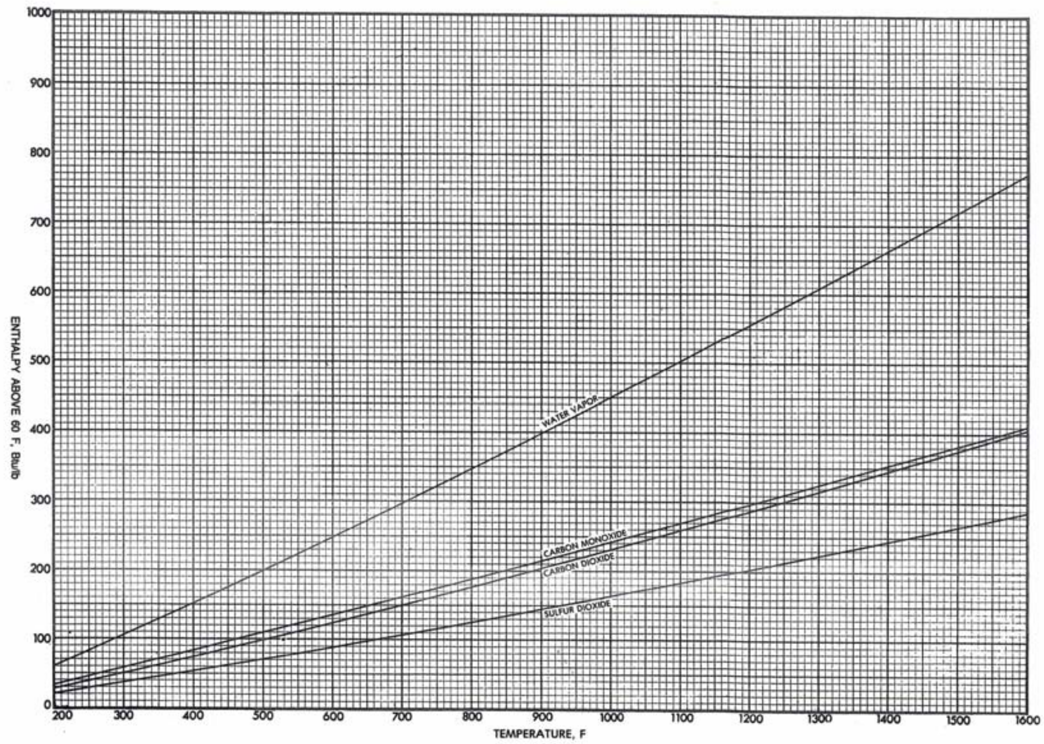
SUMMARY

Increasing the thermal efficiency of a Fired Heater reduces the heater's carbon footprint and operating costs. This article provided a simple definition of thermal efficiency, and identified the main factors that affect it. A focused audit done by an experienced fired equipment engineer can often quickly identify things that may easily be done to improve thermal efficiency without making any capital investments.

About the Author

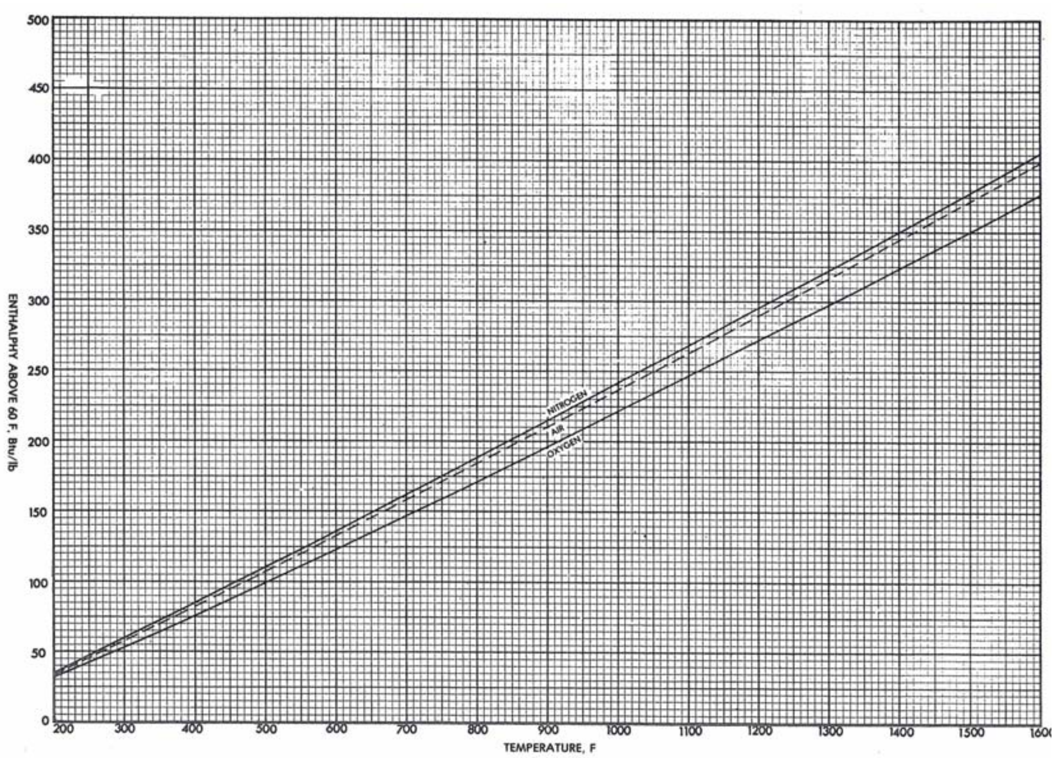
Les Davis has over 44 years of experience as a Stationary Equipment Engineer specializing in Combustion/Fired Equipment, 34 of those years with ExxonMobil Research and Engineering. He has provided a significant amount of onsite, technical support to a major refinery covering energy efficiency improvements, carbon emission reductions, capital projects, operations support, and general fired equipment problem solving.

Please contact Vince Carucci (vcarucci@carmagen.com) if you'd like more information on Carmagen's expertise in this area.



NOTE: This figure is taken from the *Technical Data Book—Petroleum Refining* (English edition), Chapter 14, "Combustion," p. 14-23, American Petroleum Institute, Washington, D.C., 1966.

Figure 1 – Enthalpy of H_2O, CO, CO_2, and SO_2



NOTE: This figure is taken from the *Technical Data Book—Petroleum Refining* (English edition), Chapter 14, "Combustion," p. 14-25, American Petroleum Institute, Washington, D. C., 1966.

Figure 2 – Enthalpy of Air, O_2, and N_2