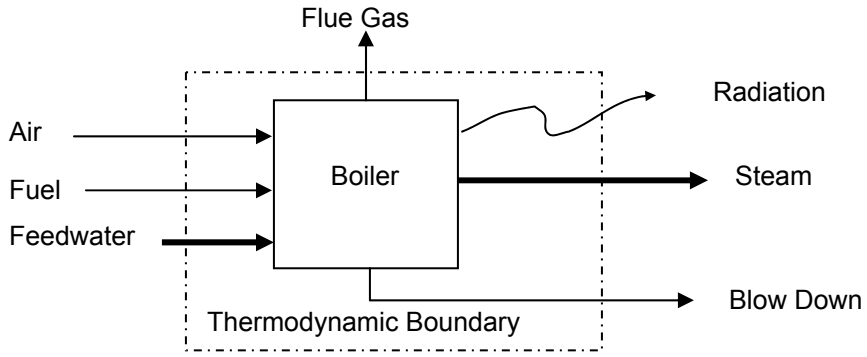
# Simplified Combustion Calculations
## Combustion Control Systems (CCS)

**Introduction**

The sizing of various boiler control field devices requires fluid flow rate information that may not be available from vendors or owners. Basic thermodynamic energy balance calculations can be used for determining these flows and is the subject of this paper.

**Boiler Energy Balance**




**Input / Output Efficiency**

The efficiency is defined as the amount of energy gained converting the feedwater to steam (neglecting Blow Down), the output, divided by the amount of fuel energy used for this conversion, the input. This allows the calculation of heat input for known heat output by (In = Out / Eff). See Table 1 below:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Boiler Rating: | | 50,000 | LB/HR | 100 | PSIG | Sat. | | |
| Steam: | 1,190.20 | BTU/LB | from Steam Tables | | 100 | PSIG | Sat. | |
| FW: | 198.7 | BTU/LB | from Steam Tables | | 150 | PSIG | 230 | DEG F |
| Gain: | 991.50 | BTU/LB | Note: 1000 BTU/LB is commonly assumed for Saturated Steam | | | | | |
| Output: | 50,000 | X | 991.50 | = | 49.575 | MMBTU/HR | | |
| Efficiency: | 80% | Assumed (Typical) | | | | | | |
| Input: | 49.575 | / | 80% | = | 61.969 | MMBTU/HR of fuel used | | |

*Table 1 Determine Fuel Flow in Terms of Heat*

**Fuel Properties**

Once the fuel heat flow is determined, it may be converted to mass or volumetric flows given the fuel type. Normal design values for common fuels are given in Table 2 below. These values are used in Vendor sizing programs for flow elements. Note that actual values for fuel properties should be used if known.

| Property | Natural Gas | | No. 2 Oil | | No. 6 Oil | |
|---|---|---|---|---|---|---|
| High Heat Value, Mass | 23,200 | BTU/LB | 19,500 | BTU/LB | 18,600 | BTU/LB |
| High Heat Value, Vol | 1,000 | BTU/SCF | 139,000 | BTU/GAL | 150,000 | BTU/GAL |
| Specific Gravity | 0.6 | at14.7a,60l | 0.85 | | 0.97 | |
| Density ( 14.7 Psia, 60 F) | 0.0458 | LB/FT3 | 53.4 | LB/FT3 | 60.7 | LB/FT3 |
| Viscosity | 0.013 | cP at 60F | 6.7 | cP at100F | 32 | cP at200F |
| Stoichiometric Air / MMBTU | 718 | Lb | 727 | Lb | 740 | Lb |
| Typical Excess Air | 10% | | 15% | | 15% | |
| O2 at Typical Excess Air | 1.7% | | 2.7% | | 2.7% | |

*Table 2 Fuel Properties*

**Flow Calculations**

Using the example given in Table 1, the flows are calculated as follows in Table 3.

| | | | | | | |
|---|---|---|---|---|---|---|
| Boiler Rating: | | 50,000 | LB/HR | 100 | PSIG | Sat. |
| Fuel Heat Input: | | 61.969 | MMBTU/HR of fuel used | | | |
| Gas Flow: | 61.969 | / | 23,200 | = | 2,671 | LB/HR |
| | 61.969 | / | 1,000 | = | 61,969 | SCFH |
| Stoic Air | 61.969 | X | 718 | = | 44,494 | LB/HR |
| at 10%Air | 44,494 | X | 1.1 | = | 48,943 | LB/HR |
| Oil Flow: | 61.969 | / | 19,500 | = | 3,178 | LB/HR |
| | 61.969 | / | 139,000 | = | 446 | GPH |
| Stoic Air | 61.969 | X | 727 | = | 45,051 | LB/HR |
| at 15%Air | 45,051 | X | 1.15 | = | 51,809 | LB/HR |

*Table 3 Flow Calculations*

**Summary**

The above fuel properties and procedures allow flow calculations of sufficient accuracy to size flow elements, in the absence of more detailed information, for normal boiler fuels.