INTERCOMPANY MEMORANDUM

CAL CHEM CORPORATION

To: CHE Seniors

Date: Fall Quarter
File: CHE 435

From: CHE faculty
Laboratory Managers

Subject: **Water Heater Efficiency**

You are to explain the operation of a hot water heater. A working model and various control components are available in the laboratory. Develop a schematic representation of the control system and measure the appropriate variables. The heater is designed to use natural gas as fuel. In this area the Southern California Gas Company indicates that the heating value of their fuel is 1057 Btu/ft^3 at 60^{o}F and 1 atm. This heating value is based on the following composition of their natural gas:

Component	mole %
Air	1.55
Carbon dioxide, CO_2	0.92
Methane, CH_4	90.32
Ethane, C_2H_6	5.65
Propane, C_3H_8	1.19
Isobutane,i-C_4H_{10}	0.09
n-Butane,n-C_4H_{10}	0.14
Isopentane,i-C_5H_{12}	0.04
n-Pentane,n-C_5H_{12}	0.02
C_6+	0.08

Please check the heating value and the efficiency of the heater over a range of water flow rates. Use an enthalpy balance to approximate the heat loss to the surroundings exclusive of the heat exiting up the stack. This will give us an idea of the minimum space and air requirements needed in an enclosure for the heater. What gas pressure do we need normally? If equipment is available, do an analysis of the stack gas from the heater and determine the excess air being introduced with the burner arrangement supplied. Also perform any standard tests used to evaluate water heaters. Compare your ratings with those claimed for your water heater.

Heater Efficiency

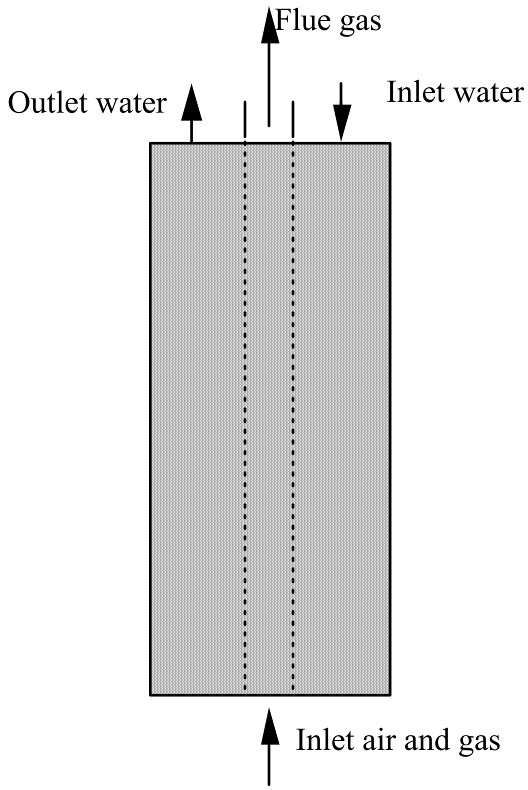

Fig. 1 Hot water heater

The schematic of the water heater used in the Unit Operation Laboratory is shown in Figure 1. The heat supplied to the water can be obtained from an energy balance over the gas streams

$$Q_{\text{supplied}} = \frac{n_{AR}\Delta\hat{H}_r^0}{\nu_A} + \sum_{outlet} n_i\hat{H}_i - \sum_{inlet} n_i\hat{H}_i \qquad (1)$$

where

A = any reactant or product
n_{AR} = moles of A produced or consumed in the process
ν_{A} = stoichiometeric coefficient of A

Reference conditions (Ref. 1): reactant and product species at T_o in the state of aggregation for which $\Delta\hat{H}_r^0$ is known, and nonreactive species at any convenient temperature. The first term on the right hand side of Eq.(1) can also be obtained from the heating value of the gas. The heat received by the water is given by

$$Q_{\text{received}} = n_{\text{w,out}}\hat{H}_{w,out} - n_{\text{w,in}}\hat{H}_{w,in} \qquad (2)$$

Experimental data can be collected by the following suggested procedure:

Starting up the Water Heater:

Light the pilot if necessary. The water heater in the Unit Operation Lab is similar to the set-up shown in Figure 2.

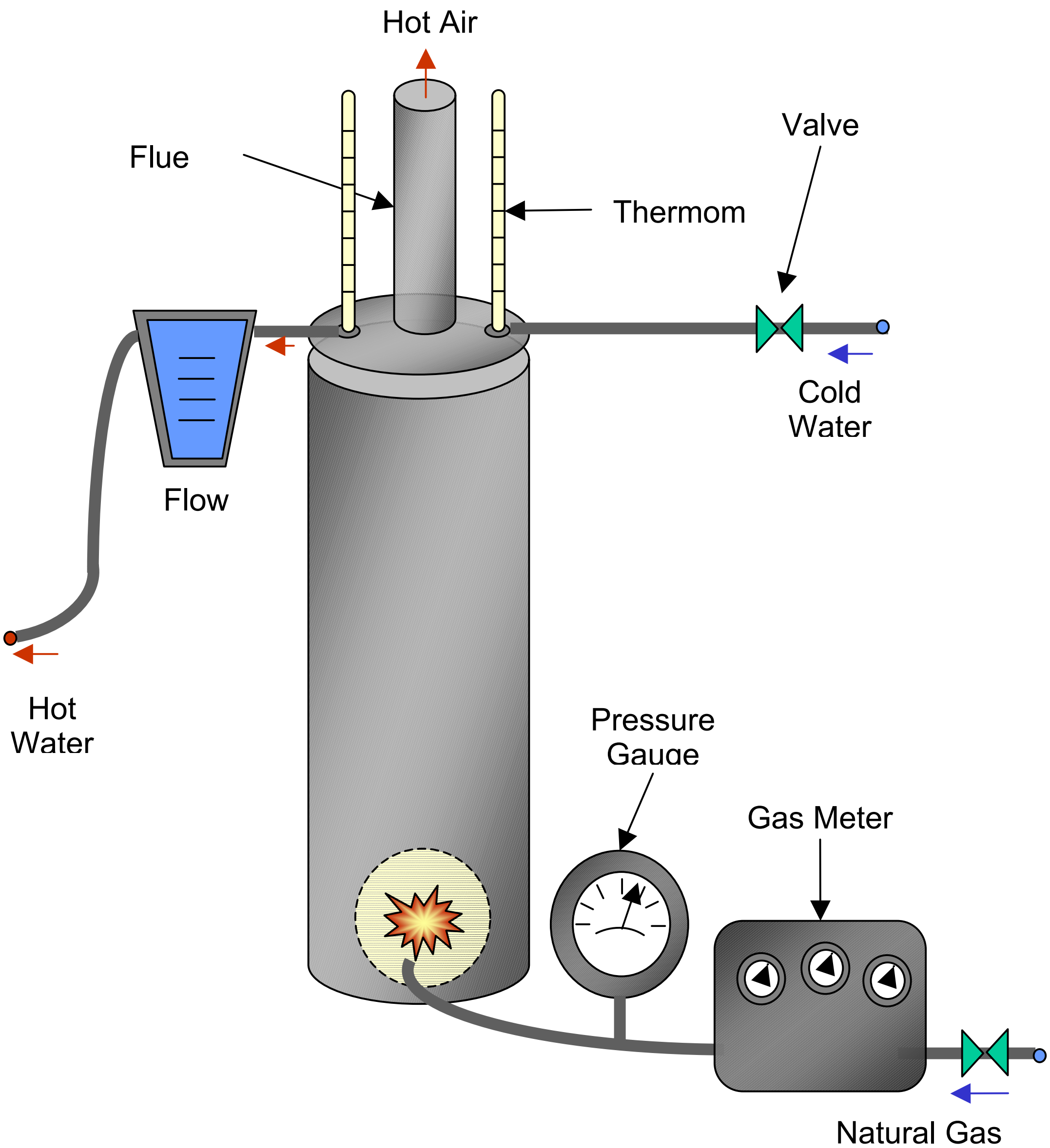

Figure 2 Water heater experiment.

Gas Analyzer Preparation:

1. Plug in the unit and turn it on.
2. Before operating, read the summary to become familiar with the operation of the gas analyzer.
3. Set the mode at "span" and take a reading at normal atmospheric condition. This calibrates the instrument. The unit should come to reset once it is finished. The unit is now ready to take readings.

Data Collection:

1. Read and record atmospheric temperature and pressure.
2. Adjust the water and gas rates to the desired values. Use the calibration graph to determine the water flow rate. Determine the volumetric gas rate. Record these flow rates.
3. Read and record the gas pressure.
4. Allow the system to reach steady temperature readings. Usually this will take 15-20 minutes.
5. Record the temperature readings of the inlet and outlet streams of water and gas streams. A digital thermocouple should be used to take the temperature of the gas exiting the stack. The water temperatures should be taken both by the water heater thermometers and by thermometers submerged in the flowing streams (at the inlet and outlet). Note any difference between these two temperatures.
6. Take readings from the gas analyzer by inserting the analyzer rod in the space between the heater and stack duct. To begin the reading process, press "start".
7. Keep the rod over the opening until a constant temperature reading is displayed. This should take about 2-3 minutes. Record the outlet gas temperature (duct temperature), percent oxygen, percent carbon dioxide, percent efficiency, and percent excess air.
8. Repeat steps 1-7 of data collection for other water and gas flow rates. To save time, take data at constant gas rate and varying water rate, then change the gas rate.

Minimum Data Analysis

1. Use the heat balance to valuate $|Q_{received}/Q_{supplied}|$ for various air flow rates and water flow rates.
2. Verify the gas heating value from the heat of combustion.

References

1. Felder R. M. and Rousseau R. W., Elementary Principles of Chemical Processes, Wiley, 2000, pg. 450