IMPROVING BOILER EFFICIENCY MODELING BASED ON AMBIENT AIR TEMPERATURE

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ABSTRACT

Optimum economic operation in a large power plant can cut operating costs substantially. Individual plant equipment should be operated under conditions that are most favorable for maximizing its efficiency. It is widely accepted that boiler load significantly effects boiler efficiency.

In the study reported here, the measured performance of a 300,000 lb/h steam boiler was found to show more dependence on ambient air temperature than on boiler load. It also showed an unexplained dependence on the month of the year that is comparable to the load dependence.

INTRODUCTION

The Texas A&M University central power plant is a combined heat and power (CHP) plant with a total net steam rating of 750,000 lb/h at 600 psig, 750°F superheated steam and a total electricity generation capacity of 36.5 MW. There are four gas-fueled steam boilers, three steam turbine generators, and more than a dozen chillers.

In 1985, Texas A&M University retained an engineering consultant to perform an energy study of the plant system. The study included performance testing of major plant equipment such as the boilers, steam turbine generators, and the absorption and centrifugal chillers. Using the study test results, mathematical models were created to represent energy production and consumption for each piece of power plant equipment. These models were later connected to build a computer program that simulated the entire power plant operation.

The boiler investigated in this paper is a D-type water-tube boiler installed in 1973, with a rated steam capacity of 300,000 lb/h at a design pressure and temperature of 600 psig and 750 °F, respectively. As noted in Figure 1, the boiler feed water is first preheated to around 250°F (process A - 0) and then pressurized by the feed water pump to 700 psig (process 0 - 1). The pressurized feed water is then heated (process 1 - 2), evaporated (process 2 - 3) inside the boiler drum and finally superheated (process 3 -4).

The original boiler efficiency model created from the consultant's energy study is shown in Figure 2. This is a typical 2^{nd} order performance curve such as can be seen in most existing literature [1][2]. According to this particular model, the boiler efficiency is maximized when the boiler steam load is around 230,000 lb/h.

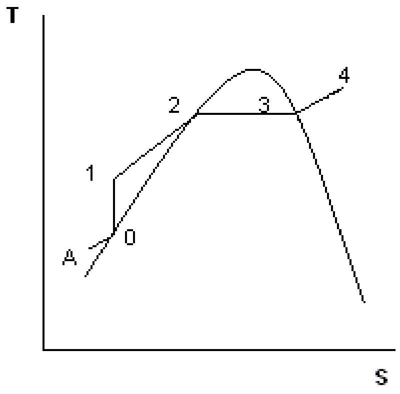

Figure 1. Steam boiler thermodynamic process

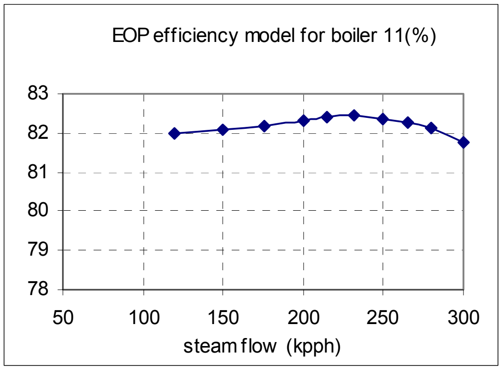

Figure 2. Original efficiency model for the boiler in study [3]

BOILER EFFICIENCY DETERMINATION

The following data are available from the plant's control system on a continuous basis: steam flow (in lb/h), feed water flow (in lb/h), natural gas flow (in std. ft^3/h), combustion air flow (in std. ft^3/h), stack oxygen concentration level (in %), stack incombustible (carbon monoxide) concentration level (in %) and stack flue gas temperature (°F).

The input-output method and the heat loss method are the two best-known methods for boiler efficiency calculation; the latter is applied in this study, as recommended by ASME [4]. According to the heat loss method, the overall boiler efficiency can be determined as [4]

$$\eta_g = 1 - L_{df} - L_{fh} - L_{am} - L_{rad} - L_{bd} - L_{oth}, \qquad (1)$$

where each of the boiler losses is described and calculated as below:

1) Dry flue gas loss - heat loss caused by elevated flue gas temperature

   $$L_{df} = C_p \times (AF' \times \rho_{air} + \rho_{fuel}) \times (T_g - T_a) / HHV, \qquad (2)$$

   where

   C_p - specific heat of flue gas, 0.24 Btu/lb-°F

   AF' - actual air to fuel ratio, mole-air/mole-fuel. The air to fuel ratio can be determined from a flue gas analysis [5][6].

   ρ_{air} - air density under standard conditions.

   ρ_{fuel} - fuel density, 0.04575 lb/ft^3

   T_g - flue gas temperature, °F

   T_a - ambient air temperature, °F

   HHV - fuel higher heat value, Btu/ft^3

2) Fuel hydrogen and moisture loss - latent heat loss of H_2O produced in combustion

   $$L_{fh} = \frac{9\alpha B}{W_f} \times \rho_{fuel} \times (h_{gv} - h_{aw}) / HHV,$$ where

   B - moles of hydrogen in 1 mole of fuel

   W_f - fuel molecular weight

   h_{gv} - enthalpy of steam at partial pressure of vapor in flue gas (1 psia for simplicity) and temperature of flue gas, 1239.9 Btu/lb when flue gas temperature is 399 °F

   h_{aw} - enthalpy of water at ambient temperature, 65 Btu/lb at 97 °F

3) Air moisture loss - heat loss caused by moisture in combustion air

   $$L_{am} = AF' \times \rho_{air} \times w_a \times (h_{gv} - h_{av}) / HHV,$$

   where

   W_a - combustion air humidity ratio, lb water per lb dry air

   h_{av} - enthalpy of saturated vapor at ambient air temperature, 1103.4 Btu/lb at 97 °F

4) Radiation loss (L_{rad}), blowdown loss (L_{bd}), and other losses (L_{oth}) are assumed to be independent of boiler load, and are estimated as 0.015, 0.03 and 0.005 respectively [4].

Twelve months of hourly data (from January to December, 1999) were retrieved from the control system. Using the formulas described above, boiler efficiency and air-fuel ratio can be calculated for each of the data records retrieved. The calculated boiler efficiency data are shown in Figure 3. It is interesting to note that the efficiency data are almost evenly distributed in a range from 79% to 82%, with the corresponding boiler steam load similarly distributed between 100,000 and 200,000 lb/h. The efficiency characteristic shown in this figure is significantly different from the one shown in Figure 2 that is currently imbedded in the simulation program. In fact, Figure 3 indicates that either the boiler steam load has an insignificant effect on boiler efficiency or its influence is overshadowed by a much stronger factor.

BOILER EFFICIENCY DATA ANALYSIS

A closer look at the data in Figure 3 revealed noticeable shifts in boiler efficiency from month to month. This is more clearly demonstrated in Figure 4, where data for each month is individually marked. Only four months were chosen to show the clear stratification from month to month. As shown in this figure, boiler efficiency is generally higher in a summer month than in a winter (or spring) month, which indicates the possible involvement of outdoor temperature in the models.

To estimate the influence of air temperature on the boiler efficiency, the efficiency data were reproduced as a function of outdoor air temperature, as shown in Figure 5.

It is obvious that the boiler efficiency has a very strong positive correlation with outside air temperature, indicating air temperature is possibly a dominant factor in determining boiler efficiency, which is not reflected in the original model at all. The spread in boiler efficiency at a specific outdoor temperature may be caused by the variation in the boiler load.

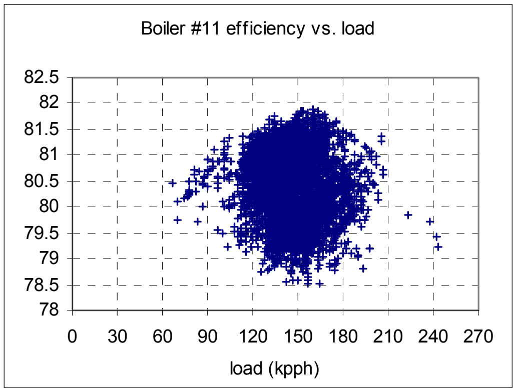

Figure 3. Calculated boiler efficiency

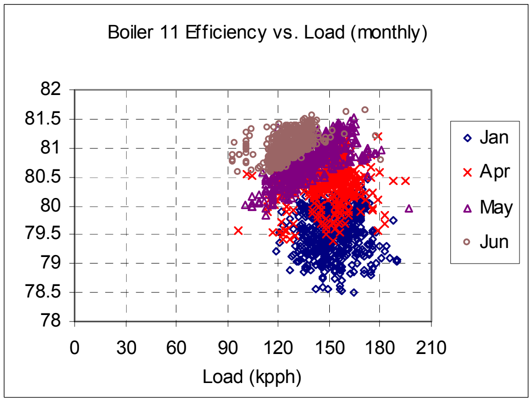

Figure 4. Boiler efficiency separated by month

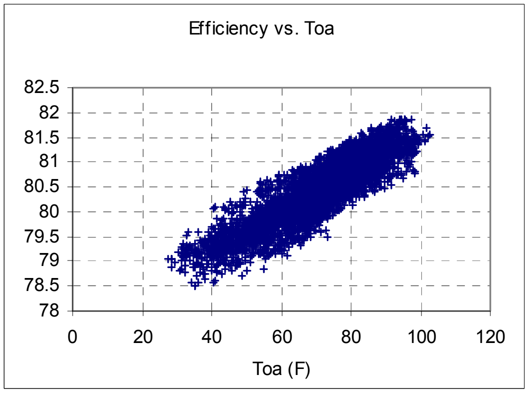

Figure 5. Boiler efficiency as a function of outdoor air temperature

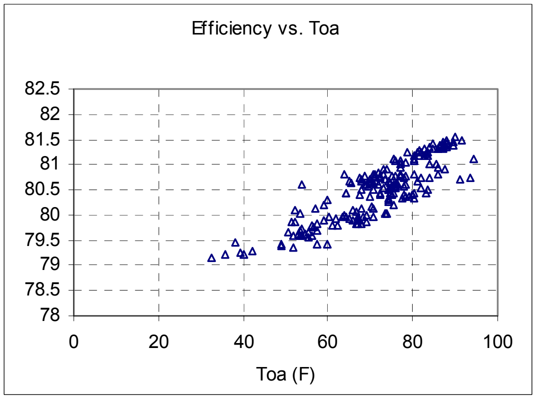

Figure 6. Boiler efficiency when steam load is around 140,000 lb/h

To clarify the unique effect of outdoor air temperature on boiler efficiency, one can remove the possible influence of boiler load by displaying those data that have identical load conditions. Figure 6 shows the group of data with the boiler load within the range from 139,500 to 140,500 lb/h. A strong relationship between boiler efficiency and outside air temperature is demonstrated, though the scatter is only partially reduced.

Figure 5 together with Figure 6 conclusively demonstrates that the boiler efficiency is primarily a function of the outdoor air temperature, but is also affected by other secondary factors.

The influence of outside air temperature on boiler efficiency can be naturally explained. Under comparable conditions, more fuel heat is spent on heating combustion air when the outside air temperature is low; therefore, the boiler efficiency is decreased. Meanwhile, since the air density increases as the temperature decreases, meaning that for the same steam load, more (excess) air is introduced as combustion air in cooler weather than in warmer weather (provided that the volumetric air-fuel ratio is being maintained by the control system), which further decreases the boiler efficiency in colder weather.

Similarly, in order to evaluate the influence of steam load on boiler efficiency, the effect of the outdoor air temperature has to be eliminated first. That means the relationship between steam load and boiler efficiency should be evaluated under the same (or very close) outdoor air temperature conditions. One such observation was made by filtering all the data and leaving only those data records whose corresponding outdoor air temperatures fall into the range from 74.5°F to 75.5°F, as shown in Figure 7. This figure suggests that the overall boiler efficiency may be a weakly curved pattern as a function of the boiler load when outdoor air temperature is more or less constant, though it is not a very clear pattern. This pattern is consistent with the earlier hypothesis that the steam load influences boiler efficiency.

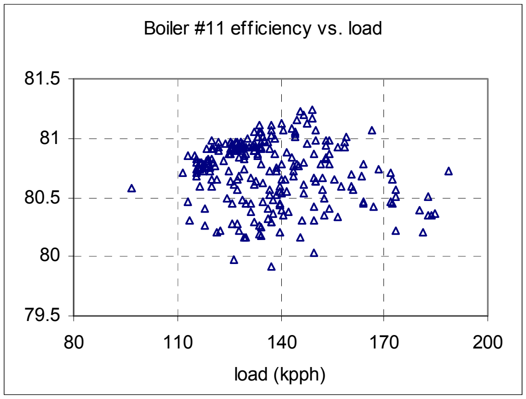

Figure 7. Boiler efficiency when outside air temperature is around 75 °F

BOILER EFFICIENCY MODEL

Figure 5 suggests the boiler efficiency data might be modeled as a simple linear function of the outside air temperature in the form of

$$\eta = A + D \times T_{oa}$$

The best values for those coefficients can be determined from any readily available optimization routine, such as the "Solver" imbedded in Microsoft Excel. The mathematical equation for this model is determined as

$$\eta = 77.49 + 0.042 \times T_{oa}$$

The boiler efficiencies modeled by this equation, together with the original efficiency data are shown Figure 8. Even though the predicted data match the general pattern of the measured data, the scatter in the latter is not reflected. Some of the statistics associated with this model are:

Average Error = 0.236%
RMSE = 0.289 %
$R^2 = 0.790$

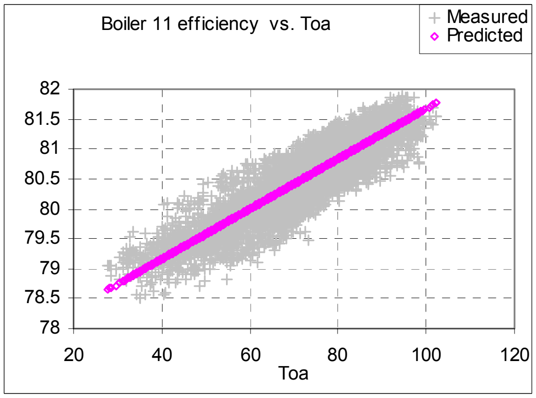

Figure 8. Boiler efficiency model as a function of outside air temperature

At this point, it is natural to try to model the boiler efficiency based on the two influential factors - the outside air temperature and the boiler steam load. The general signatures shown in Figure 6 and Figure 7 suggest the model should involve a linear dependence on outdoor temperature and a second order dependence on the boiler load. The mathematic equation for this model is determined as

$$\eta = 77.19 + 0.0056 \times Load - 0.00002 \times Load^{2} + 0.042 \times T_{oa}$$

The comparison between the predicted boiler efficiencies by this equation and the original efficiency data are shown in Figure 9. Compared with the model shown in Figure 8, this model has only marginal improvement. There is still considerably more scatter in the measured data than in the predicted data. Some of the statistics associated with this model are:

Average Error = 0.232 (%)
RMSE = 0.287 (%)
R^2 = 0.792

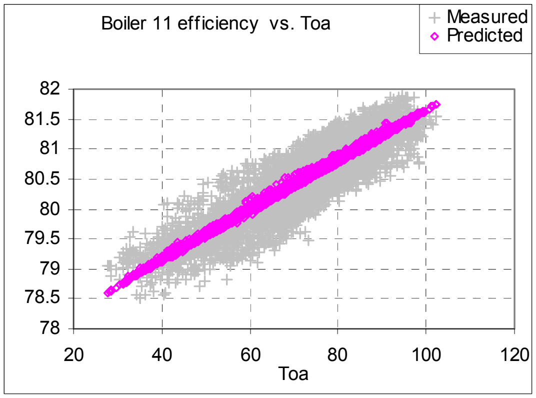

Figure 9. Predicted and measured boiler efficiency vs. outside air temperature

Figure 10 shows the same comparison with regard to the boiler load. It shows that the model predictions cover the range of the observed data.

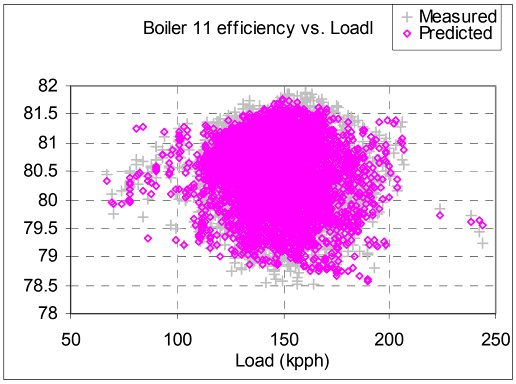

Figure 10. Predicted and measured boiler efficiency vs. boiler load

The regression model generally fits the measured data well, but explains only 79% of the efficiency variation observed. The discrepancy between the model and the measurements suggests that there is at least one other factor influencing boiler efficiency in addition to the outside air temperature and the boiler load. This suggests another examination of the data as a function of time-of-year. The data of Figure 7 is re-constructed so that the data is further separated into groups according to the month the data points lie in, as shown in Figure 11 (only those data points occurring in January, April, May and June are displayed to avoid data overlap).

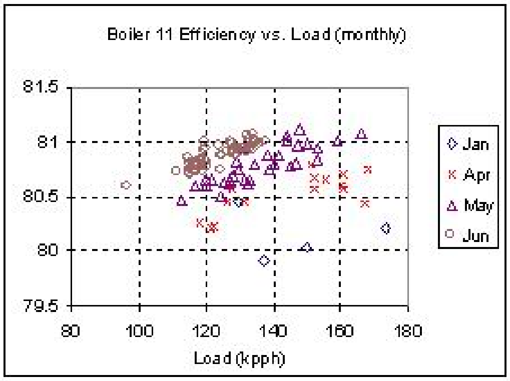

Figure 11. Boiler efficiency when outdoor temperature is around 75 °F (monthly separated)

It is interesting to note that the efficiency data are still stratified on a monthly basis even though the effect of the outdoor air temperature has been eliminated. In fact, the efficiency data for each individual month shows a much clearer pattern than when they are mingled together. This stratification can only be explained with factors other than the outside air temperature and the boiler steam load that have been discovered so far. It looks like the specific month within which the boiler is operated has caused the unexplained stratification. It is desirable to see how well the measured efficiency data can be modeled with similar polynomial equations, only this time one model will be created for each month. Figure 13, for example, shows the model developed specifically for the May data where the model coefficients are

A = 73.8173, B = 0.05775,
C = -0.00017, D = 0.03092

The corresponding statistics for the regression are

Average Error = 0.08 (%)
RMSE = 0.10 (%)
$R^2 = 0.91$

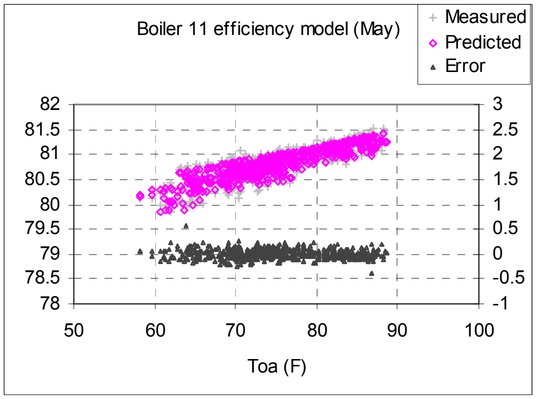

Figure 12. Predicted and measured boiler efficiency vs. outside air temperature (May)

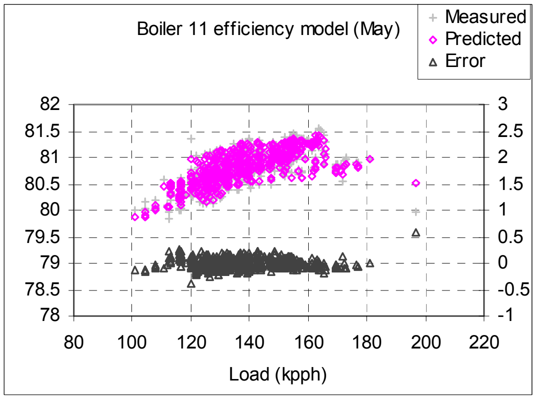

Figure 13. Predicted and measured boiler efficiency vs. boiler load (May)

It is obvious that this specific "May model" fits the measured data much better than the one developed for the whole year. Actually it is such a good fit that the predicted data almost totally overlaps the measured data. Unfortunately, not all the monthly models are as good as the "May model", even though they are generally acceptable. Table 1 shows the characteristic parameters of all the models for each of the twelve months. There are two RMSE values for each model in the table. The first RMSEs are calculated when the equations for a specific month is used to simulate the data for that month, while the second RMSEs are calculated when the same equation is used to simulate the data for the entire year. It is clear that the second RMSEs are general much bigger than the first RMSEs, indicating none of the twelve models developed for each month is good enough to represent the boiler efficiency for the whole year.

Table 1. Characteristic parameters of boiler efficiency models for each month

Month	A	B	C	D	Avg. Error	$RMSE^1$	$RMSE^2$	R^2
Jan	77.028	0.01282	-0.00003	0.02433	0.160	0.214	0.668	0.6705
Feb	71.851	0.11207	-0.00051	0.03960	0.332	0.387	0.802	0.6863
Mar	79.873	-0.02882	0.00012	0.03145	0.202	0.246	0.379	0.5550
Apr	74.820	0.03860	-0.00012	0.03446	0.117	0.149	0.338	0.8179
May	73.817	0.05775	-0.00017	0.03092	0.076	0.096	0.463	0.9141
Jun	76.570	0.02399	-0.00007	0.03198	0.055	0.072	0.502	0.8930
Jul	73.258	0.07770	-0.00025	0.02574	0.078	0.102	0.609	0.8282
Aug	70.253	0.10676	-0.00035	0.02944	0.239	0.315	0.405	0.3497
Sep	77.201	0.00143	0.00002	0.03668	0.146	0.182	0.341	0.8043
Oct	75.067	0.03699	-0.00011	0.02957	0.109	0.138	0.434	0.8461
Nov	75.067	0.03393	-0.00009	0.03075	0.117	0.146	0.449	0.7523
Dec	72.702	0.06155	-0.00018	0.03577	0.135	0.180	0.414	0.7952

CONCLUSIONS

Boiler efficiency modeling based on the measured operational data for a 300,000 lb/h boiler shows that the boiler efficiency is not only a function of boiler load, as the original model indicates, but is a stronger function of the outside air temperature. The newly created boiler efficiency model also shows interesting monthly behavior that cannot be fully explained at this time. The original boiler efficiency model implemented in the plant optimization program, as do those documented in many papers in the literature does not reflect boilers' practical operation correctly and therefore should be replaced by the newly developed models.

The direct impact of this finding is that for different weather conditions, the boiler might need to be loaded differently in order to maximize its efficiency. In a multiple boiler system, the optimized load distribution should be determined in the context of ambient weather conditions. The boiler performance data provided by boiler manufacturers needs to include a set of boiler performance curves corresponding to different weather conditions.

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Homes produced with airtight duct systems (around 15% savings in Htg and Cooling Energy)

Palm Harbor Homes	22,000
Southern Energy Homes	8,000
Cavalier Homes	1,000
	= = =
Subtotal	31,000

Technical measures incorporated in BAIHP homes include some or many of the following features - better insulated envelopes (including Structural Insulated Panels and Insulated Concrete Forms), unvented attics, "cool" roofs, advanced air distribution systems, interior duct systems, fan integrated positive pressure dehumidified air ventilation in hot humid climates, quiet exhaust fan ventilation in cool climates, solar water heaters, heat pump water heaters, high efficiency right sized heating/cooling equipment, and gas fired combo space/water heating systems.

HOMES BY THE FLORIDA HOME ENERGY AND RESOURCES ORGANIZATION (FL.H.E.R.O.)

Over 400 single and multifamily homes have been constructed in the Gainesville, FL area with technical assistance from FL H.E.R.O. These homes were constructed by over a dozen different builders. In this paper data from 310 of these homes is presented. These homes have featured better envelopes and windows, interior and/or duct systems with adequate returns, fan integrated positive pressure dehumidified air ventilation, high efficiency right sized heating/cooling equipment, and gas fired combo space/water heating systems. The innovative outside air (OA) system is described below.

The OA duct is located in the back porch (Figure 1) or in the soffit (Figure 2). The OA is filtered through a 12"x12" filter (which is readily available) located in a grill (Figure 3) which is attached to the OA duct box. The flex OA duct size varies depending on the system size - 4" for up to 2.5 tons, 5" for 3 to 4 ton and 6" for a 5 ton system. The OA duct terminates in the return air plenum after a manually adjustable butterfly damper (Figure 4).

Figure 1 OA Intake Duct in Back Porch

Figure 2 OA Intake Duct in Soffit

Figure 3 Filter Backed Grill Covering the OA Intake

Figure 4 Butterfly Damper for OA control

The damper can be set during commissioning and closed by the homeowner in case the OA quality is poor (e.g. forest fire). This system introduces filtered and conditioned ventilation air only when the cooling or heating system is operational. The ventilation air also positively pressurizes the house. Data on the amount of ventilation air or positive pressurization is not available from a large sample of homes. A few measurements indicate that about 25 to 45 cfm of ventilation air is provided which pressurizes the house in the range of +0.2 to +0.4 pascals.

Measured Home Energy Ratings (HERS) and airtightness on these FL. H.E.R.O. homes is presented next in figures 5 through 8. Data is presented for both single family detached (SF) and multifamily homes (MF). See Table 2 below.

Table 2. Summary statistics on FL.H.E.R.O. Homes
n = sample size

	SF	MF
Median cond area	1,909	970
% constructed with 2x4 frame or frame and block	94%	100%
Avg. Conditioned Area, ft^2	1,993 (n=164)	1,184 (n=146)
Avg. HERS score	87.0 (n=164)	88.0 (n=146)
Avg. ACH50	4.5 (n=164)	5.2 (n=146)
Avg. Qtot (CFM25 as %of floor area)	6.9% (n=25)	5.0% (n=72)
Avg. Qout (CFM25 as %of floor area)	3.0% (n=15)	1.4% (n=4)

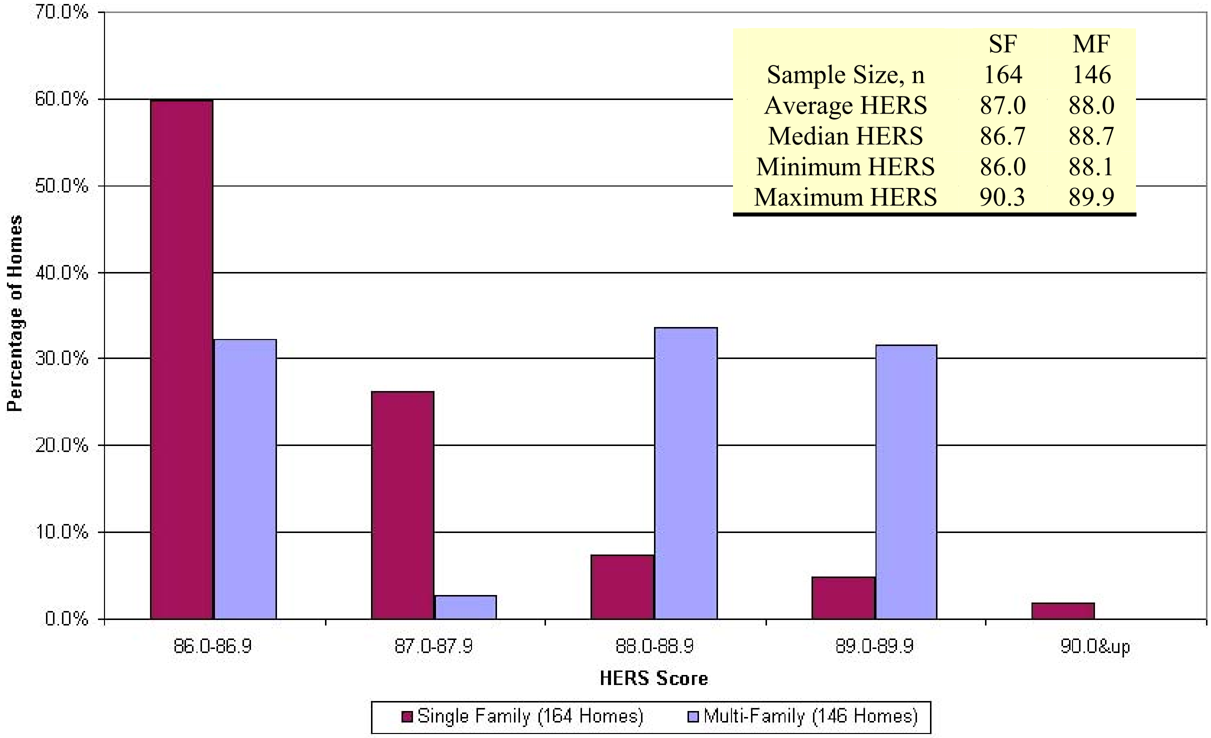
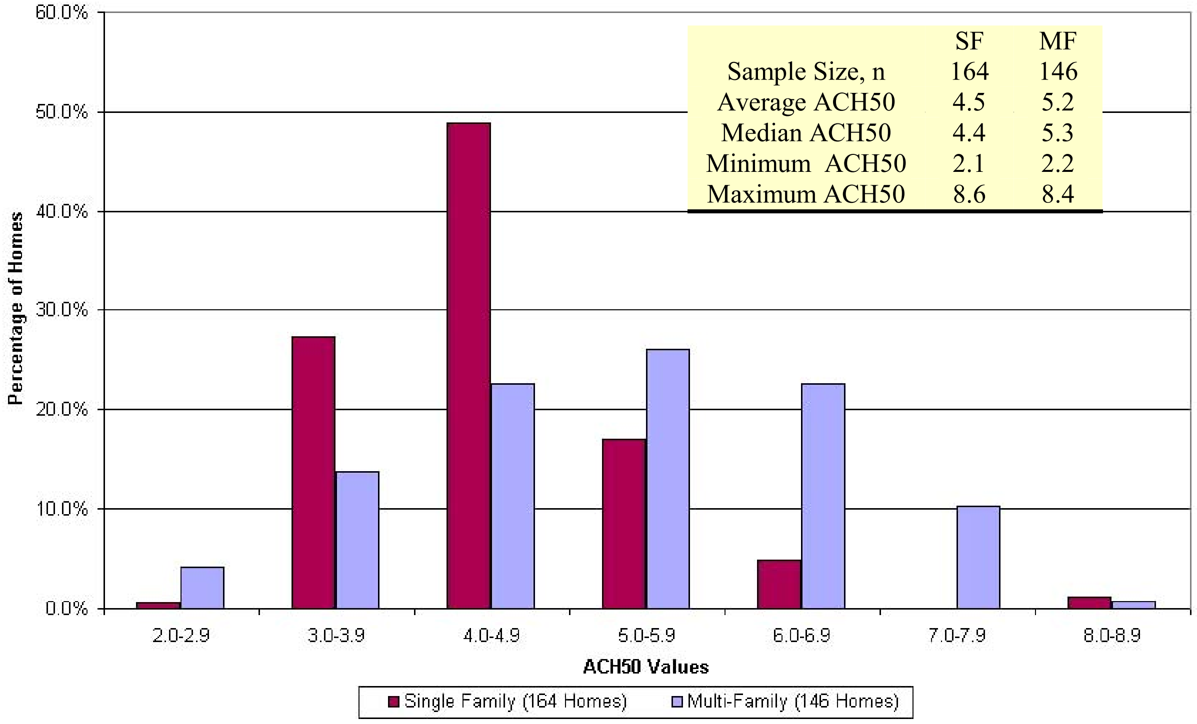
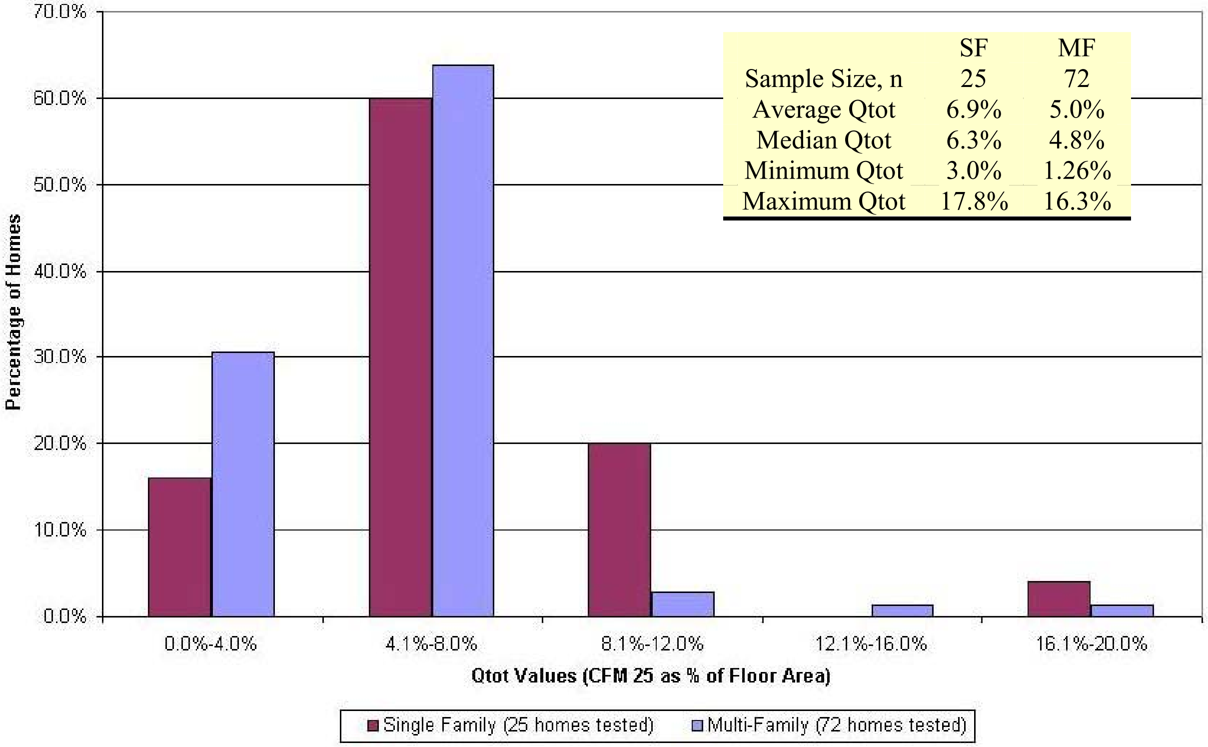


Figure 5 HERS Scores for FL H.E.R.O. Homes



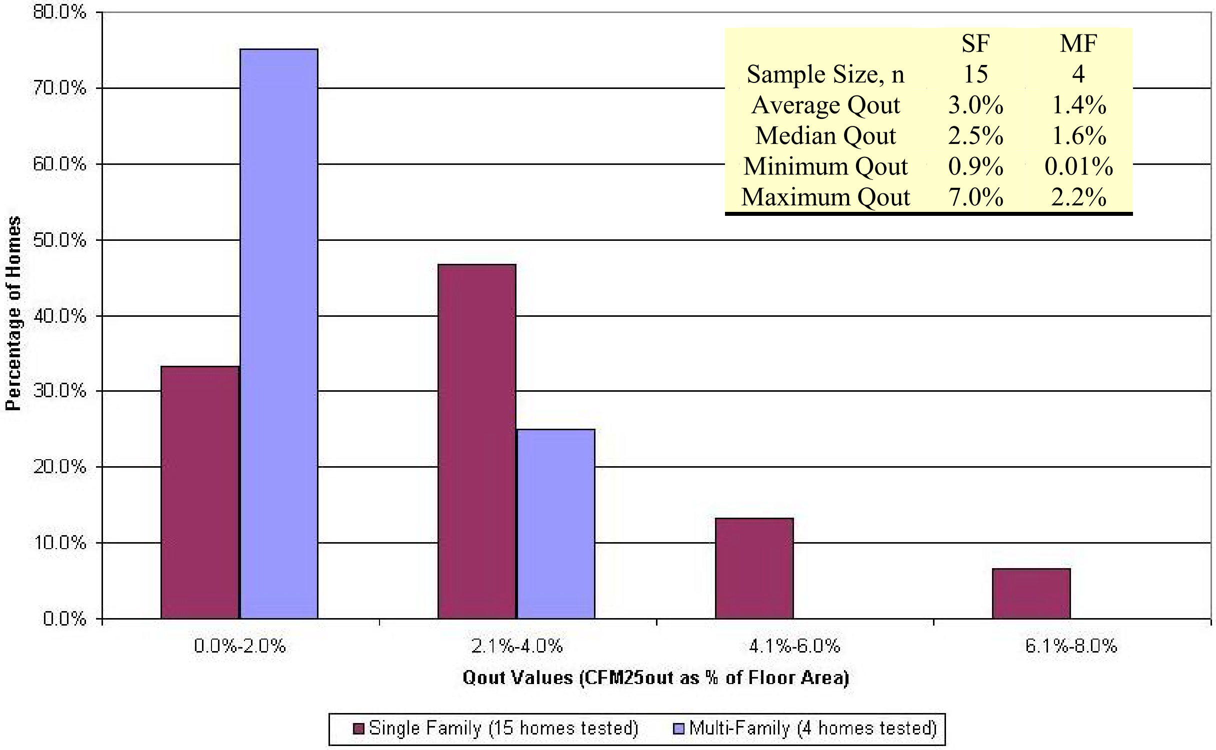
	SF	MF
Sample Size, n	164	146
Average ACH50	4.5	5.2
Median ACH50	4.4	5.3
Minimum ACH50	2.1	2.2
Maximum ACH50	8.6	8.4

Figure 6 ACH50 Values for FL H.E.R.O. Homes



	SF	MF
Sample Size, n	25	72
Average Qtot	6.9%	5.0%
Median Qtot	6.3%	4.8%
Minimum Qtot	3.0%	1.26%
Maximum Qtot	17.8%	16.3%

Figure 7 Qtot Values for FL H.E.R.O. Homes



	SF	MF
Sample Size, n	15	4
Average Qout	3.0%	1.4%
Median Qout	2.5%	1.6%
Minimum Qout	0.9%	0.01%
Maximum Qout	7.0%	2.2%

Figure 8 Qout Values for FL H.E.R.O. Homes

Data is available for other typical non BAIHP, new Florida homes (FPL , 1995 and Cummings et al, 2001). The FPL study had a sample size of over 300 single family homes and the median Qout was 7.5% , three times that of the FL. H.E.R.O. homes. In the Cummings study of 11 homes the measured average values were : ACH50= 5.7, Qtot=9.4% and Qout=4.7%. Although the sample sizes are small the FL. H.E.R.O. homes appear to have significantly more airtight duct systems than typical homes.

The remainder of the paper presents status of other tasks of the BAIHP project.

OTHER BAIHP TASKS

Moisture Problems in HUD code homes

The BAIHP team expends considerable effort working to solve moisture problems in existing manufactured homes in the hot, humid Southeast.

Some manufactured homes in Florida and the Gulfcoast have experienced soft walls, buckled floors, mold, water in light fixtures and related problems. According to the Manufactured Housing Research Alliance (MHRA), who we collaborate with, moisture problems are the highest priority research project for the industry.

The BAIHP team has conducted diagnostic tests (blower door, duct blaster, pressure mapping, moisture meter readings) on about 40 such problem homes from five manufacturers in the past two years and shared the results with MHRA. These homes were newly built (generally less than 3 years old) and in some cases just a few months old when the problems appeared. The most frequent causes were:

- Leaky supply ducts and/or inadequate return air pathways resulting in long term negative pressures.
- Inadequate moisture removal from oversized a/c systems and/or clogged condensate drain, and/or continuous running of the air handler fan.
- Presence of vinyl covered wallboard or flooring on which moist air condenses creating mold, buckling, soft walls etc.
- Low cooling thermostat set point (68-75F), below the ambient dew point.
- Tears in the belly board and/or poor site drainage and/or poor crawlspace ventilation creating high rates of moisture diffusion to the floor.

Note that these homes typically experience very high cooling bills as the homeowners try to compensate for the moisture problems by lowering the thermostat setpoints. These findings have been reported in a peer reviewed paper presented at the ASHRAE IAQ 2001. conference (Moyer et al)

The Good News:

As a result of our recommendations and hands-on training, BAIHP partner Palm Harbor Homes (PHH) has transformed duct design and construction practices in all of its 15 factories nationwide producing about 11,000 homes/yr. All Palm Harbor Home duct systems are now constructed with mastic to nearly eliminate air leakage and produced with return air pathways for a total cost of <$10/home!! The PHH factory in AL which had a high number of homes with moisture problems has not had a single problem home the past year!

Field Monitoring

Several houses and portable classrooms are being monitored and the data displayed on the web. (Visit http://www.infomonitors.com/). Of special interest is the side-by-side monitoring of two manufactured homes on the campus of the North Carolina A & T U. where the advanced home is saving about 70% in heating energy and nearly 40% in cooling energy, proving that the Building America goal can be met in manufactured housing. Other monitored sites include the Washington State U. Energy House in Olympia, WA; the Hoak residence in Orlando, FL; two portable classrooms in Marysville, WA; a classroom each in Boise, ID and Portland, OR. See other papers being presented at this symposium for details on two recently completed projects giving results from duct repairs in manufactured homes (Withers et al) and side by side monitoring of insulated concrete form and base case homes (Chasar et al).

"Cool" Roofs and Unvented Attics

Seven side-by-side Habitat homes in Ft. Myers, FL. were tested under unoccupied conditions to examine the effects of alternative roofing strategies. After normalizing the data to account for occupancy and minor differences in thermostat set points and equipment efficiencies, the sealed attic saved 9% and the white roofs saved about 20% cooling energy compared to the base case house with a dark shingle roof for the summer season in South Florida. Visit http://www.fsec.ucf.edu/%7Ebdac/pubs/coolroof/exsum.htm for more information.

Habitat for Humanity

Habitat for Humanity affiliates work in the local community to raise capital and recruit volunteers. The volunteers build affordable housing for and with buyers who can't qualify for conventional loans but do meet certain income guidelines. For some affiliates, reducing utility costs has become part of the affordability definition.

To help affiliates make decisions about what will be cost effective for their climate, BAIHP researchers have developed examples of Energy Star homes for more than a dozen different locations. These are available on the web at http://www.fsec.ucf.edu/bldg/baihp/casestud/hfh_estar/index.htm . The characteristics of the homes were developed in conjunction with Habitat for Humanity International (HFHI), as well as Executive Directors and Construction Managers from many affiliates. Work is continuing with HFHI to respond to affiliates requesting a home energy rating through an Energy and Environmental Practices Survey. 36 affiliates have been contacted and home energy ratings are being arranged using combinations of local raters, Building America staff, and HFHI staff.

HFHI has posted the examples of Energy Star Habitat homes on the internal web site PartnerNet which is available to affiliates nationwide.

"Green" Housing

A point based standard for constructing green homes in Florida has been developed and may be viewed at http://www.floridagreenbuildings.org/. The first community of 270 homes incorporating these principles is now under construction in Gainesville, FL. The first home constructed and certified according to these standards has won an NAHB energy award.

BAIHP researchers are participating as building science - sustainable products advisor to the HUD Hope VI project in Miami, redeveloping an inner city area with over 500 units of new affordable and energy efficient housing.

Healthy Housing

BAIHP researchers are participating in the development of national technical and program standards for healthy housing being developed by the American Lung Association.

A 50-year-old house in Orlando is being remodeled to include energy efficient and healthy features as a demonstration project.

EnergyGauge USA®

This FSEC developed software uses the hourly DOE 2.1E engine with FSEC enhancements and a user-friendly front end to accurately calculate home energy ratings and energy performance. This software is now available. Please visit http://energygauge.com/ for more information.

Industrial Engineering Applications

The UCF Industrial Engineering (UCFIE) team supported the development and ongoing research of the Quality Modular Building Task Force organized by the Hickory consortium, which includes thirteen of the nation's largest modular homebuilders. UCFIE led in research efforts involving factory design, quality systems and set & finish processes. UCFIE used research findings to assist in the analysis and design of two new modular housing factories – Excel homes, Liverpool, PA and Cardinal Homes - Wyliesburg, VA.

CONCLUSIONS

The entire BAIHP team of over 20 researchers and students are involved in a wide variety of activities to enhance the energy efficiency, indoor air quality and durability of new housing and portable classrooms.

In addition to energy efficiency, durability, health, comfort and safety BAIHP builders typically consider resource and water efficiency. For example, in Gainesville, FL BAIHP builders have incorporated the following features in developments:

- Better planned communities
- More attention given to preserving the natural environment
- Use of reclaimed sewage water for landscaping
- Use of native plants that require less water
- Storm water percolating basins to recharge the ground water
- Designated recreational areas
- Better designed and built infrastructure
- Energy efficient direct vented gas fireplaces (not smoke producing wood)

ACKNOWLEDGEMENTS

This research was sponsored, in large part, by the U.S. Department of Energy, Office of Building Technology, State and Community Programs under cooperative agreement no. DE-FC36-99GO10478 administered by the U.S. DOE Golden field office. This support does not constitute an endorsement by DOE of the views expressed in this report.

The authors appreciate the encouragement and support from George James, program manager in Washington DC and Keith Bennett, project officer in Golden CO.

Special thanks to Bert Kessler of Palm Harbor Homes, Mike Dalton of Stylecrest Sales, Mike Wade of Southern Energy Homes and David Hoak of Alten Design for the hundreds of hours they have each contributed to the success of BAIHP.

We are grateful to our sponsors, industry partners, collaborators and colleagues for this opportunity to make a difference.

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