# Over-Sizing of Residential Forced-Air Heating Systems in Southcentral Alaska Homes

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The author would like to express his appreciation to Alan Mitchell, Analysis North, for his valuable support, including the hardware and software developed to collect and analyze the data provided in this report.  The author would also like to express his appreciation to the builders and heating contractors who participated in the study.

# Executive Summary

The purpose of this study was to develop a method for monitoring forced-air furnaces during winter conditions and to determine how well they are sized for the home's design heat load. Results of the furnace monitoring compared the AkWarm Energy Rating Software design heat load calculation to the furnace runtime design heat load calculation. Potential errors in the runtime and the AkWarm estimate are briefly discussed in Appendix A. Analysis of these errors was beyond the scope of this project.

Local builders and heating contractors were encouraged to participate. Of the 19 homes represented in this study, 7 were model homes of local builders, and 3 were from heating contractors. The 9 remaining homes were solicited from co-workers and participants in a prior, unrelated indoor air study the author was involved in. Most homes were modestly sized, with living areas ranging from 1050 square feet to 2482 square feet, averaging 1670 square feet. The average age of the homes studied was approximately 3 years; no homes were older than 7 years.

Unnecessary over-sizing of forced-air heating systems increases the installation cost to the builder and, subsequently, to the homebuyer. Over-sizing also reduces comfort and increases noise due to higher airflows and larger furnace fans. Constructions savings from downsizing heating and distribution systems may be several hundred dollars in a simple forced-air heating application, or several thousand dollars for radiant floor heating systems.

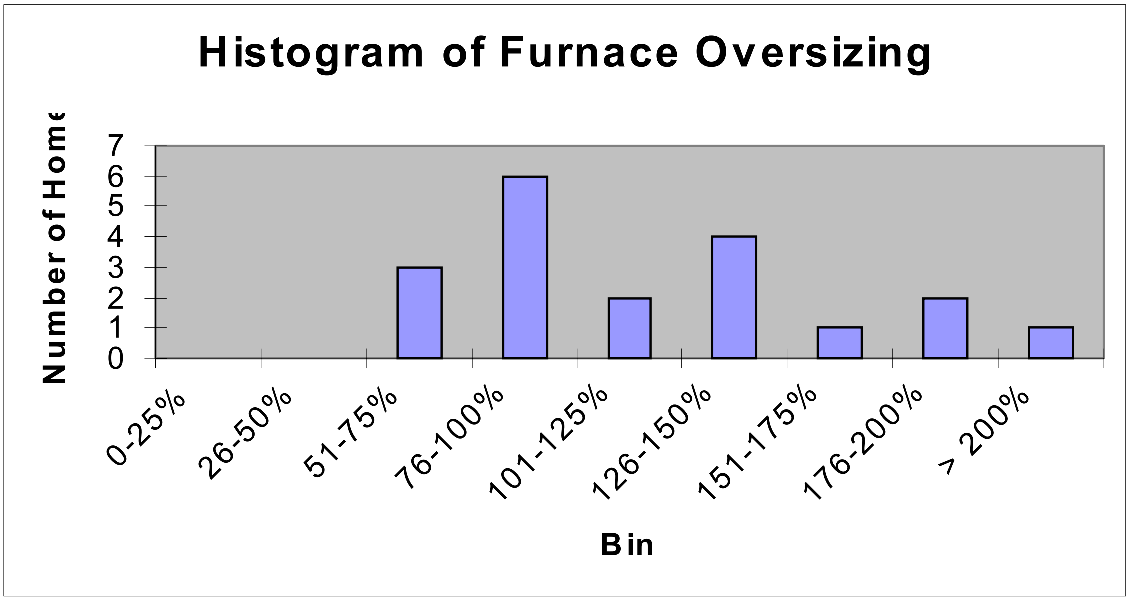
In discussion with several local heating contractors many oversized furnaces can be attributed to the methods heating contractors typically use to size heating systems. A "rule of thumb," common for Anchorage area homes, is 40 btu's heat loss per square foot of floor area. Little regard for actual insulation levels, air tightness, or other heat loss factors are taken into account when sizing a furnace. ***This study found that forced-air furnaces in Southcentral Alaska are oversized on average 121%.***

AkWarm energy rating software was developed, and is used, by Alaska Housing Finance Corporation to verify energy efficiency requirements, and as an incentive for financing energy efficient homes. In addition to an energy rating, AkWarm provides a separate calculation of a design heat load estimate for the house being rated.

The AkWarm design heat load calculation utilizes energy rater inputs for all building surface areas: volume, insulation values, and detailed air leakage from blower door air tightness results. For heating climates, the level of detail provided in AkWarm exceeds most other residential design heat loss calculation methods. Nearly all new homes built in Alaska are energy rated. Validating the accuracy of the AkWarm design heat loss calculation would provide the industry with a very useful and inexpensive tool for accurately sizing heating systems in Alaska homes. ***This study found AkWarm, on average, to overestimate the design heat load by 8%, and in no case under-estimated the design heat load by more than 11%.***

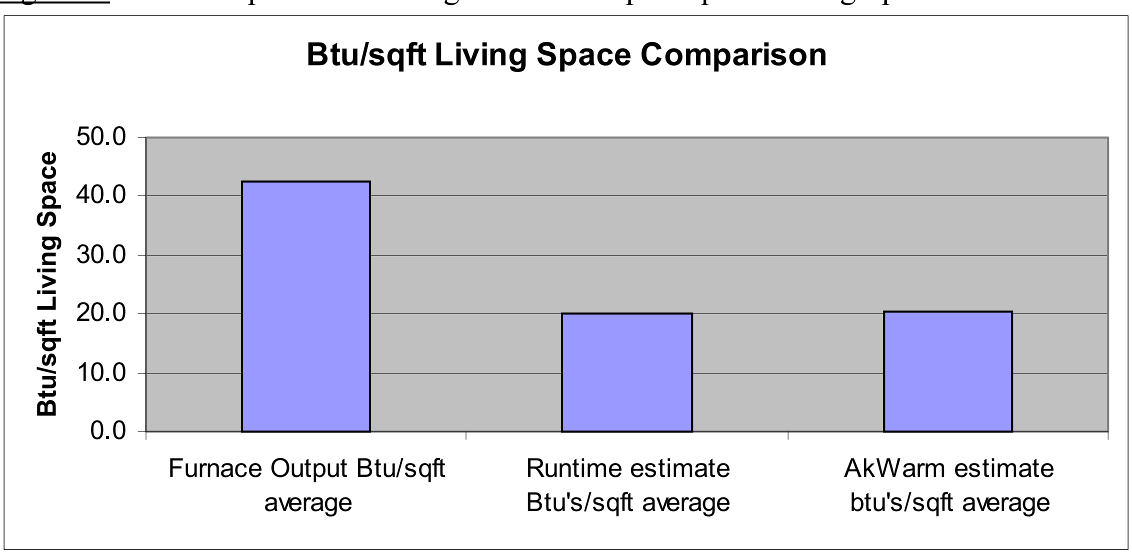
During the winter of 2001 and 2002, 23 homes were monitored. Unfortunately, 4 homes had to be dropped from analysis due to data collection problems. The furnace monitoring study included installing a runtime data logger on the furnace, and temperature data loggers at the home to record indoor and outdoor temperatures. Furnace runtime was plotted against the outdoor temperature during the several week monitoring period, and a projected energy use at the design outdoor temperature was calculated. For Anchorage and the Mat-Su Valley, –18 degrees and –28 degrees Fahrenheit were used, respectively, as design outdoor temperatures.

Figure 1. Histogram of Furnace Over-Sizing Compared To the Runtime Design Heat Load Estimate



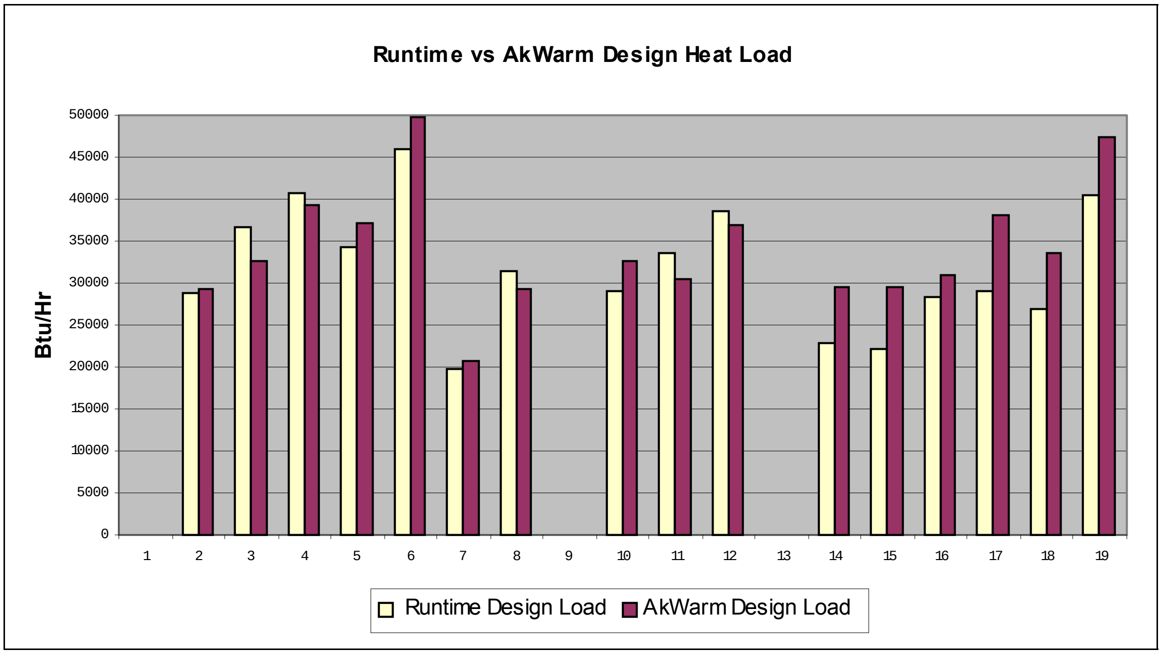

The range of over-sizing is shown in the histogram above.
For example, 6 homes had furnaces that were over-sized 76-100%.

Figure 2. Comparison of Design Heat Load per Sqft of Living Space.



Looking at the Btu/sqft of heating load, the average installed furnace capacity is 42.8 Btu/sqft of living space. The furnace runtime estimate for the average heat load per sqft of living space was 19.7 Btu/sqft. The AkWarm estimate was 20.9 Btu/sqft. Again this graph shows significant over-sizing in the furnaces studied. This graph also shows that the AkWarm design heat load estimate is very close, on average, to the measured heat load estimate.

Figure 3. Runtime vs. AkWarm Design Heat Load Estimate




The AkWarm estimate for the design heat load was, on average, 8% higher than the runtime-monitoring estimate. The range varied from AkWarm over-estimating the design heat load by 33% to AkWarm underestimating by 11%. It should be noted that neither the runtime nor the AkWarm estimate is necessarily correct. Both methods may contain some variables or unknowns due to input or measurement errors, and/or occupant lifestyles. Some of these potential errors are discussed later in the study.

## Discussion of Results:

Heating systems are over-sized because of antiquated sizing standards and the general lack of information regarding the heat loss characteristics of a home. The less you know about the construction of a home, the greater the safety factor needs to be. The results of this study clearly indicate the potential for downsizing furnaces in new homes.

In light of all the uncertainty in estimating design heat loads from plan ratings, AkWarm appears to provide a reasonable estimate. If the AkWarm design heat load report were modified to allow the user to add a reasonable safety margin and improve the report, the AkWarm energy rating software can provide a reliable estimate for sizing heating systems in Alaskan homes.

Features of the individual home should be considered, too. Many new homes have direct vent gas fireplaces installed with heat output of 15,000 – 30,000 Btu/hr. This system could supplement the heat load of a home, further minimizing the need for any excess safety capacity. Another option is a two-stage gas furnace to significantly reduce airflow and improve comfort. For approximately 85% of the year, a two-stage furnace would operate on low speed, reducing airflow rates and improving comfort while still providing the additional heating capacity for the coldest days of the year. High efficiency ECM blower motors would significantly reduce electrical consumption, and could be tied into a continuous ventilation strategy.

When dealing with actual heating loads of 20 Btu/sqft of living area, (less, if you treat the crawlspace heat load as a separate zone) alternative heating strategies are quite viable. Combination systems that use a standard or high efficiency domestic water heater to supply both domestic hot water and space heating are readily available. Incorporating under-floor radiant heating, at a fraction of the cost of conventional gypcrete installation, makes radiant heating more competitive with forced-air heat. Utilizing a combo heating system, with the air handler and ductwork located inside the house envelope is a viable solution to indoor air quality problems associated with furnaces and ductwork in garages. Integrating whole house ventilation and a fan/coil supplied by a domestic water heater offers additional opportunities for improving the quality of housing at a reasonable cost as compared to separate systems.

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# Purpose

The purpose of this study was to develop a method for monitoring forced-air furnaces during winter conditions and to determine how well they are sized for the home's design heat load. The results of the furnace monitoring also compared the AkWarm Energy Rating Software design heat load calculation to the furnace runtime design heat load calculation. Potential errors in the runtime and the AkWarm estimate are briefly discussed in Appendix A. Analysis of these errors was beyond the scope of this project.

# Background

The majority of new homes in Anchorage heat with a forced-air gas furnace. Heating contractors generally rely on a simple Btu/sqft method for sizing furnaces. With the adoption of the Alaska Building Energy Efficiency Standards (BEES) in 1992, the efficiency of homes, large and small, improved. Also, adoption of more stringent building codes and inspections has improved quality of construction. The improved efficiency and quality of homes built today significantly reduces potential heating load differences between similar homes, and should allow heating contractors to be more precise on their sizing calculations. Nearly every new home built has an AkWarm energy rating with available design heat loss information. All new homes constructed within the municipality of Anchorage must submit a design heat loss calculation for plans review, these are either the AkWarm report or a separate worksheet provided by the municipality. Unfortunately few, if any, of the local residential heating system contractors utilize the available design heat load reports, or utilize their own design tools to properly size heating systems.

<u>Over-sizing issues:</u>

- Over-sized forced-air heating systems increase the installation cost to the builder and subsequently to the homebuyer. Potential construction saving may be as modest as several hundred dollars, or several thousand dollars, depending on heating system size and type.
- Over-sized furnaces reduce comfort due to increased air flow (wind chill effect), and increase noise levels due to the higher airflows. Double the size of a furnace in a small home and an increase in duct and fan noise is inevitable.
- A common complaint of new homebuyers in small two story homes is that the upstairs is too hot and the downstairs too cold. This may be due, in part, to the amount of warm air being delivered to the home. A blast of warm air into the lower level of a home is likely to rise along the open stairway to the upper floor . A smaller more continuous flow of warm air can be better-controlled and will likely result in a more constant temperature throughout the house.
- Previous research (Tooley, Natural Florida Retrofit, Inc.) has shown increased air leakage, due to pressure imbalances in a home caused by forced-air furnaces. The greater the flow of air into and out of rooms the greater the potential is for large air pressure imbalances to occur and more uncontrolled air leakage to and from the home, and higher heating bills result. For example, many upstairs bedrooms without proper air balancing are subject to increased air pressure as warm air is delivered to the room. This increase in air pressure drives warm moist air into the

attic, causing ice dams and moisture problems within an attic. Reducing airflow rates by 30% -50% would significantly reduce the pressure imbalances found in a home, and subsequently reduce the amount of potentially damaging air leakage in to and out of the home.

- Increased maintenance cost due to increased cycling of the furnace has not been clearly demonstrated. However, most heating experts agree that excessive cycling of equipment shortens the life of many components.

Furnace Sizing Methods:

The heating and cooling industry have numerous load calculation tools available. These range from simple worksheets such as Manual J for residential buildings, to sophisticated computer software programs developed by the Department of Energy for extremely large buildings.

Anchorage heating contractors typically use a standard heat loss per square foot of floor area (Btu/sqft) for their region to determine the overall furnace size. Little regard for actual insulation levels, air tightness, or other heat loss factors is taken into account. For example, a 4 Star Home would receive the same size furnace as a similar sized, yet very energy efficient, 5 Star Plus Home.

The AkWarm Energy Rating Software was developed and is used by Alaska Housing Finance Corporation to verify energy efficiency requirements and as incentive for financing energy efficient homes. In addition to an energy rating, AkWarm provides a separate calculation of a design heat loss estimate for the house being rated.

The AkWarm design heat loss calculation utilizes rater-input detailed areas, insulation values, air leakage and ventilation rates, and blower door air tightness results. The level of detail provided in AkWarm exceeds most other residential design heat loss calculation methods. Validating and/or improving the accuracy of the AkWarm design heat loss calculation would provide builders with a very useful and inexpensive tool for accurately sizing heating systems. Nearly all new homes in Alaska are energy rated utilizing AkWarm software. Using the AkWarm design heat load estimate, a builder has a tool to verify he has purchased a properly sized heating system for the home and can avoid the pitfalls of grossly oversized heating systems.

## Methodology

Selection of Homes:

In order to evaluate the AkWarm design heat load calculation, homes were selected that were less than 6 years old. Because the focus of this study was to allow builders to see how well their heating contractors are sizing their heating systems, local builders were encouraged to participate. Letters to the local Homebuilder Associations, along with follow-up phones calls to area builders resulted in the monitoring of 7 model homes. Solicitation of co-workers and homeowners who were participating in an unrelated indoor air quality study made up the remaining homes. The model homes were typically unoccupied except during daytime hours. One model home was sold and occupied during the monitoring period. The occupied homes were typically 2-4 household members, with several townhouse style homes occupied by a single occupant. No extreme circumstances were observed that would have significantly impacted the results.

Furnace Monitoring Equipment and Software:

Monitoring furnace runtime was accomplished by using the DataWatcher, a data logger locally developed by Analysis North. For each hour, the DataWatcher records the percentage of the hour that the furnace was on. For the gas furnaces monitored in this study, a motor/appliance sensor was used to sense the magnetic field of the 24 volt gas valve. The sensor was simply attached to the side of the gas valve with a small piece of Velcro. A small clamp-on current sensor was also utilized to monitor the gas valve on one home. Each home in the study had a separate heater for the garage. The garage heater was not monitored, and the AkWarm garage heat load was ignored.

The HOBO Pro temperature logger, ONSET Corp., was used for monitoring indoor and outdoor temperatures

Watchlink, the DataWatcher software, was used for downloading and analyzing the runtime furnace data. Boxcar Pro was used to download the HOBO data loggers. In addition to the download software, Analysis North developed companion software, for analyzing runtime and outdoor temperatures. The software directly imports the DataWatcher runtime file and an outdoor temperature text file for analysis. The software plots daily average temperature and furnace runtime for the monitoring period.

**Test Procedure:**

The furnace cover was removed and the motor/appliance sensor was installed on the gas valve utilizing a strip of Velcro. The sensor wire was fed thru the louvered furnace cover to the runtime data logger. With the furnace cover re-installed, the data logger was observed thru one on/off furnace cycle to assure proper functioning.

An indoor temperature logger was installed in the vicinity of the house thermostat in the main living space of the home. Depending upon location and accessibility, the outdoor temperature logger was usually installed on the north side of the home to minimize solar effects, and secured to the gas meter mount or the electric meter base. In several instances, the logger was installed under a raised deck on the north side of the home. Because the outdoor loggers were susceptible to theft or mischief, they needed to be located as inconspicuously as possible. In most cases, there was little foot traffic due to deep snow around the house.

The furnaces were data logged for 2-4 weeks. Whenever possible, furnaces were monitored long enough to have experienced a wide range of outdoor temperature conditions. The length of time furnaces were monitored was a trade-off between availability of loggers and the scheduling and coordinating of the visits. At the end of the monitoring period, the motor/appliance sensor was removed from the gas valve and the runtime data logger and temperature loggers were downloaded to a computer for analysis.

## Data Analysis:

Outdoor temperatures were adjusted based upon a normalized design indoor temperature of 70 degree Fahrenheit using the following formula[2] :

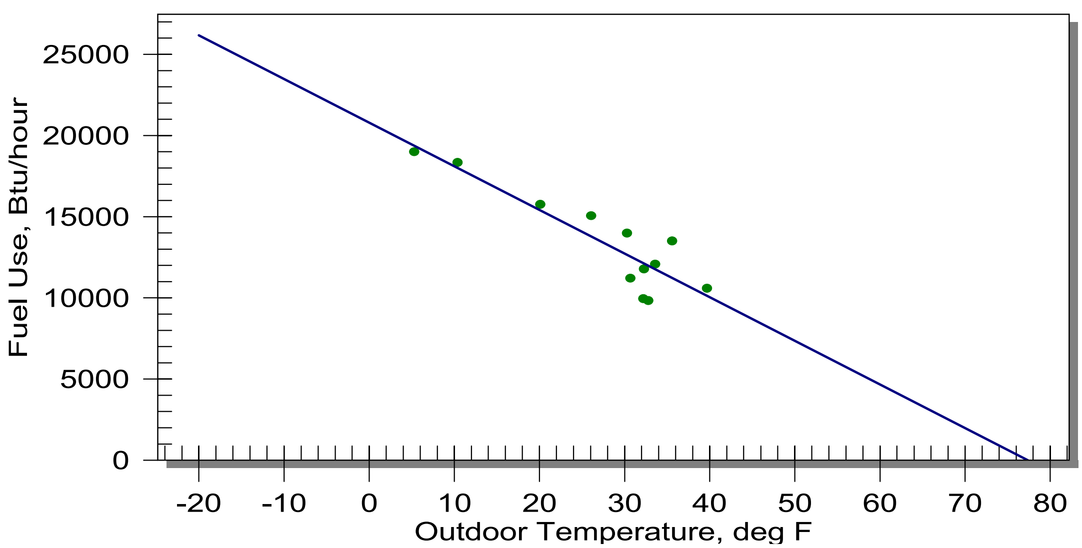
Adjusted Outdoor Temperature = 70 deg.F – Indoor Temp + Outdoor Temp

This temperature adjustment resulted in a small 1% reduction in the design heat load estimate as compared to the raw data analysis. This indicates indoor temperatures in the homes were averaging slightly less than 70 degrees.

In an effort to minimize the effects of solar and internal heat gains, a nighttime only analysis was performed. The hours from 10 pm to 6 am were used in the nighttime only analysis. The nighttime only analysis did not work well with homes utilizing a setback temperature control, especially those homes which had multiple temperature setbacks. Those homes where the indoor temperature data revealed a regular setback temperature, the nighttime only analysis was not used.

Average daily outdoor temperatures were plotted against the average daily furnace runtimes. A sample graph is shown in Figure 4.

Figure 4. Example Runtime and Outdoor Temperature Plot (note: the Fuel Use axis is actually output btu/hour of the furnace)




The runtime datalogger software performed a linear regression analysis to correlate outdoor temperature with furnace output. This regression model was then used to predict furnace output at the design temperature. Standard statistical regression techniques were used to determine the 90% confidence interval surrounding this best estimate of the design heat load. The 90% confidence interval has the property that there is a 5% chance that the actual design heat load exceeds the upper endpoint of the interval and a 5% chance that the heat load is less than the lower endpoint of the interval.

# Problems Encountered:

The HOBO data loggers used were very susceptible to stopping. The manufacturer provided several software and hardware upgrades, but the problem continued to persist. Several indoor and outdoor temperature loggers failed during the study. In several instances where the outdoor temperature logger failed, we were able to utilize outdoor temperature data from a nearby home being monitored, or from Anchorage airport weather. Where indoor temperature data was lost, the indoor air temperature was assumed to be 70 degrees. In one home both indoor and outdoor temperature loggers failed and there was no appropriate outdoor temperatures to use. The home was omitted from the study. In another instance, the outdoor temperature logger was stolen and later recovered, but the data was found to be useless.

The Runtime data logger motor/appliance sensor was susceptible to noise from other motors, such as the combustion blower on several furnace models. Usually one could adjust the sensitivity of the motor/appliance sensor to avoid any false readings from other sources, but the sensor became susceptible to properly catching the gas valve operation. This problem with sensor "noise" from the several troublesome furnace models was later resolved by using a clamp-on current sensor that sensed when power to the gas valve was occurring.

Analysis of furnace cycle lengths from the runtime data identified 3 homes which had sensor problems. 2 homes had several thousand cycles less than 15 seconds indicating a poor sensor read and were omitted from the study. A third home had an annual furnace check during the monitoring period. The service man failed to re-attach the sensor on the gas valve properly and much of the data was questionable and the home rejected.

## Results & Discussion:

Table 1. General Information for House Monitoring

| HOUSE MONITORING DATA | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| House ID | Days Monitored | Mid-Monitoring Date | High Outdoor Temp Recorded | Low Outdoor Temp Recorded | Outdoor delta Temp. | Temp. Setback Used | Living Floor Area (sqft) | Furnace Btu/Hr Output | Furnace Btu/sqft of Living Floor area |
| 1 | 21 | 3/4/2001 | 38 | 12 | 26 | No | | 90,000 | |
| 2 | 19 | 3/4/2001 | 40 | 12 | 28 | No | 1595 | 54,000 | 33.86 |
| 3 | 17 | 3/5/2001 | 41 | 15 | 26 | No | 1738 | 72,000 | 41.43 |
| 4 | 21 | 3/2/2001 | 43 | 15 | 28 | N/A | 2055 | 80,000 | 38.93 |
| 5 | 18 | 3/6/2001 | 40 | 18 | 22 | No | 1767 | 80,000 | 45.27 |
| 6 | 25 | 3/2/2001 | 42 | 12 | 30 | No | 2209 | 80,000 | 36.22 |
| 7 | 21 | 3/3/2002 | 37 | 16 | 21 | Yes | 1335 | 64,000 | 47.94 |
| 8 | 12 | 3/26/2002 | 37 | 16 | 21 | No | 1382 | 73,000 | 52.82 |
| 9 | 22 | 3/3/2001 | 39 | 12 | 27 | Yes | 1050 | 55,000 | 52.38 |
| 10 | 21 | 12/15/2001 | 33 | -24 | 57 | No | 1588 | 54,000 | 34.01 |
| 11 | 23 | 12/15/2001 | 33 | -18 | 51 | No | 1468 | 56,000 | 38.15 |
| 12 | 19 | 12/24/2001 | 41 | -19 | 60 | N/A | 1522 | 95,000 | 62.42 |
| 13 | 27 | 12/20/2001 | 35 | -8 | 43 | Yes | 1714 | 80,000 | 46.67 |
| 14 | 26 | 1/18/2002 | 37 | -1 | 38 | No | 1297 | 48,000 | 37.01 |
| 15 | 29 | 1/18/2002 | 38 | -1 | 39 | No | 1297 | 48,000 | 37.01 |
| 16 | 23 | 3/17/2002 | 33 | 14 | 19 | No | 1342 | 48,000 | 35.77 |
| 17 | 22 | 2/19/2002 | 35 | 4 | 31 | Yes | 1730 | 80,000 | 46.24 |
| 20 | 24 | 3/19/2002 | 35 | 15 | 20 | Yes | 1486 | 64,000 | 43.07 |
| 21 | 18 | 3/22/2002 | 33 | 16 | 17 | Yes | 2482 | 104,000 | 41.90 |
| **Averages** | **21** | | **37** | **6** | **32** | | **1614** | **69737** | **42.8** |

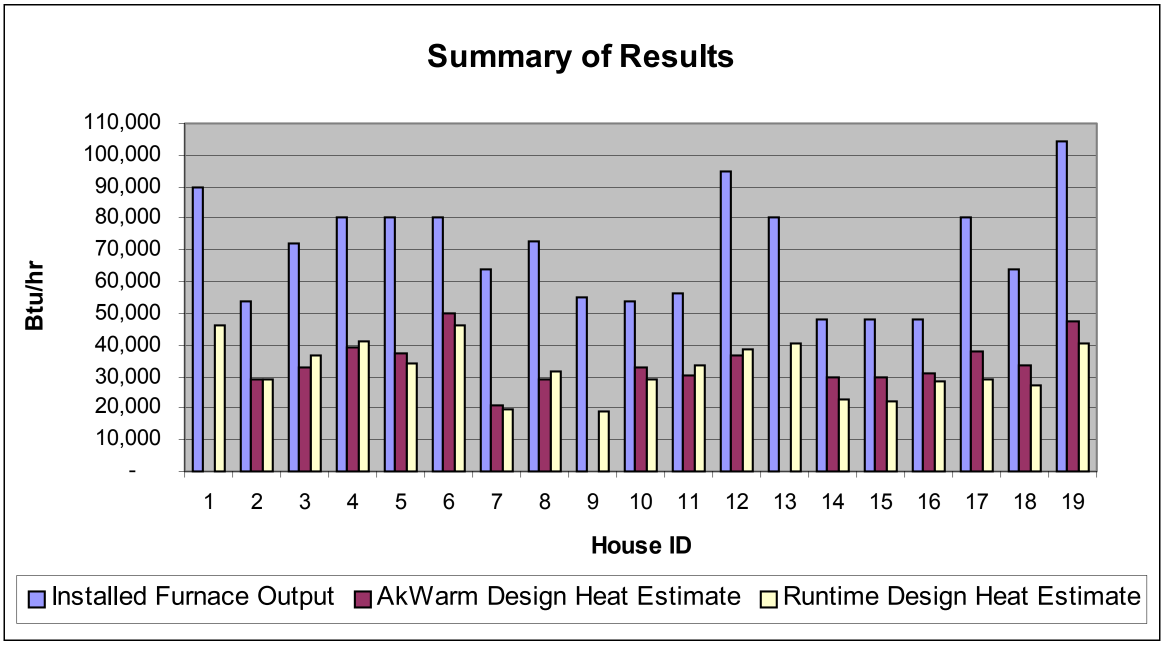
Table 2. Runtime Monitoring Results

| House ID | Runtime Btu/ Deg.F | Runtime Balance Point | Runtime Design Load | Runtime Design Load 90% Confidence Interval<br>Low Design Load | High Design Load | HighLoad / Best Est. - 1 |
|---|---|---|---|---|---|---|
| 1 | 613.1 | 57.5 | 46,257 | 35,264 | 57,250 | 24% |
| 2 | 259.9 | 82.7 | 28,782 | 23,817 | 33,747 | 17% |
| 3 | 449.1 | 63.8 | 36,742 | 27,771 | 45,713 | 24% |
| 4 | 475.7 | 67.8 | 40,812 | 34,134 | 47,491 | 16% |
| 5 | 369.7 | 74.5 | 34,177 | 28,420 | 39,933 | 17% |
| 6 | 546.0 | 66.1 | 45,913 | 40,538 | 51,288 | 12% |
| 7 | 234.2 | 66.6 | 19,823 | 16,559 | 23,087 | 16% |
| 8 | 422.4 | 56.2 | 31,346 | 28,084 | 34,608 | 10% |
| 9 | 186.6 | 73.9 | 19,002 | 16,402 | 21,602 | 14% |
| 10 | 290.2 | 72.4 | 29,133 | 26,683 | 31,582 | 8% |
| 11 | 323.0 | 76.2 | 33,665 | 27,353 | 39,977 | 19% |
| 12 | 424.9 | 62.7 | 38,533 | 30,461 | 46,606 | 21% |
| 13 | 485.5 | 65.2 | 40,416 | 20,185 | 25,601 | 12% |
| 14 | 273.2 | 65.8 | 22,893 | 17,605 | 26,703 | 21% |
| 15 | 389.5 | 38.9 | 22,154 | 23,817 | 28,721 | 9% |
| 16 | 389.9 | 54.5 | 28,257 | 22,200 | 34,315 | 21% |
| 17 | 335.1 | 68.8 | 29,089 | 25,354 | 32,823 | 13% |
| 18 | 341.9 | 60.8 | 26,947 | 20,094 | 33,801 | 25% |
| 19 | 505.0 | 62.1 | 40,444 | 30,513 | 50,375 | 25% |

Table 3. Summary of Design Heat Load and Furnace Sizing Results.

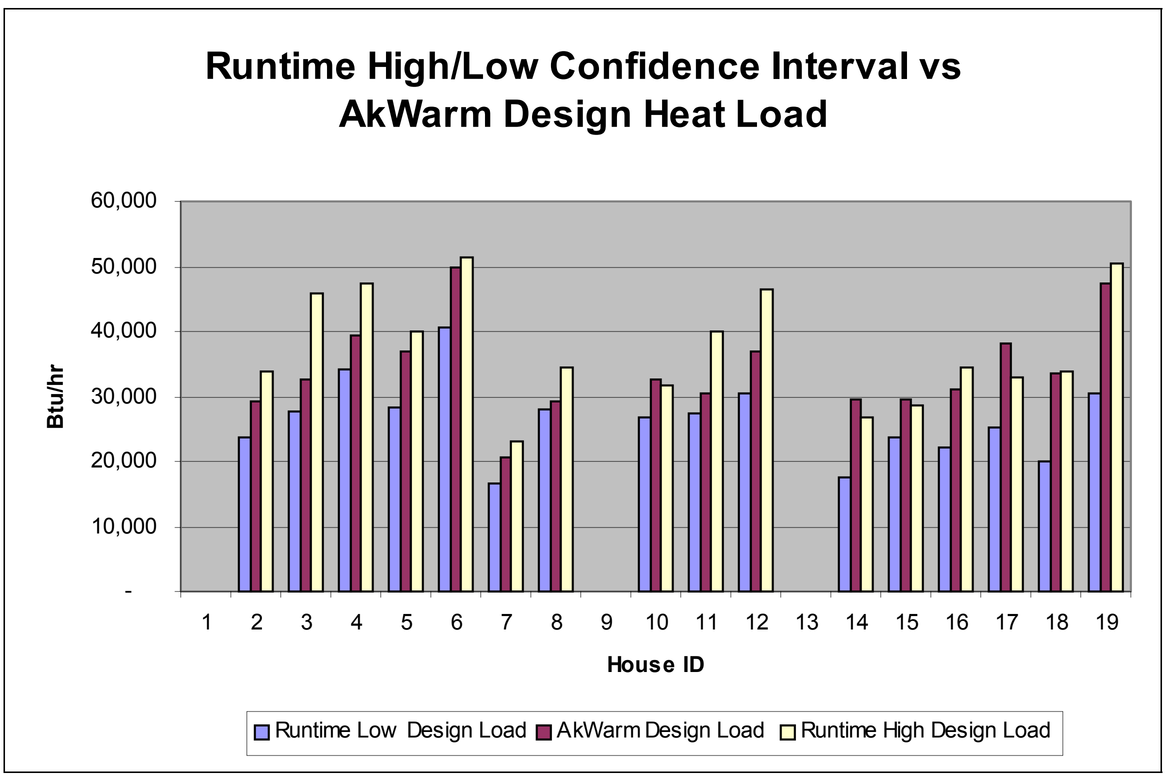
| **House ID** | **Furnace Output** | **Runtime Design Load** | **AkWarm Design Load** |
|---|---|---|---|
| 1 | 90,000 | 46,257 | |
| 2 | 54,000 | 28,782 | 29,380 |
| 3 | 72,000 | 36,742 | 32,710 |
| 4 | 80,000 | 40,812 | 39,345 |
| 5 | 80,000 | 34,177 | 37,057 |
| 6 | 80,000 | 45,913 | 49,746 |
| 7 | 64,000 | 19,823 | 20,689 |
| 8 | 73,000 | 31,346 | 29,234 |
| 9 | 55,000 | 19,002 | |
| 10 | 54,000 | 29,133 | 32,575 |
| 11 | 56,000 | 33,665 | 30,380 |
| 12 | 95,000 | 38,533 | 36,946 |
| 13 | 80,000 | 40,416 | |
| 14 | 48,000 | 22,893 | 29,418 |
| 15 | 48,000 | 22,154 | 29,418 |
| 16 | 48,000 | 28,257 | 30,985 |
| 17 | 80,000 | 29,089 | 38,139 |
| 18 | 64,000 | 26,947 | 33,537 |
| 19 | 104,000 | 40,444 | 47,441 |

Figure 5. Comparison of Design Heat Load Estimates and Actual Furnace Size




The graph above displays the large difference between the installed furnace size and the measured design heat load for each home. Based upon this study, the furnaces were found, on average, to be 121% oversized. **Least oversized was 66%, the worst 223%.**

**Figure 6.** Runtime Design Heat Load High/Low Confidence Interval vs. AkWarm



AkWarm was found to be within the 90% Confidence Interval in 12 out of the 16 homes with available AkWarm Data. In the four homes where AkWarm was outside the 90% Confidence Interval, the AkWarm estimate was higher than the runtime estimate. The reason for AkWarm over-estimating design heat load for those four homes was unclear. See Appendix A for a discussion on possible errors. In none of the homes studied, did AkWarm excessively under-estimate the design heat load.

# Conclusions

Heating systems are oversized because of antiquated sizing standards, and a general lack of information regarding heat loss characteristics of a home. The results of this study clearly indicate the potential for downsizing furnaces in new homes. In light of all the uncertainty in estimating design heat loads from plans, AkWarm appears to provide a reasonable design heat load estimate and could be used to improve the heating system size. Formatting the AkWarm design heat load report to conform to Manual J or other industry standard design heat load programs should improve the acceptance by the Alaska heating industry.

Many new homes have direct vent gas fireplaces installed which are rated as "heating systems" that could supplement the heat load of a home by 30% - 50%, further minimizing the need for safety capacity. Another low cost option is to install a two-stage gas furnace to reduce airflow and improve comfort. For approximately 85% of the year, a two-stage furnace would operate on the low speed, reducing airflow rates and improving comfort while still providing the additional heating capacity for the coldest days of the year.

With actual heating loads of 20 Btu/sqft of living area for most homes being built today in Southcentral Alaska, ( less if you deduct the crawlspace and heat it separately) many alternative heating strategies are quite viable.

Combo systems, using a standard or high-efficiency domestic water heater to supply both domestic hot water and space heating are readily available and code approved.

- Under-floor radiant heating utilizing a domestic water heater can be installed at a fraction of the cost of conventional gypcrete radiant floor installations, making radiant floor heating more competitive with forced-air. Nothing drives change like competition.
- Utilizing a combo heating system is a solution to many indoor air quality problems by eliminating furnaces and ductwork in garages.
- Integrating whole house ventilation with a combo heating system offers additional opportunities for improving indoor air quality at a reasonable cost.

Furnace Runtime Protocol Observations:

Short-term runtime monitoring of furnaces can provide a reasonable method for estimating the design heat load of a home.

- Monitoring periods of 3-4 weeks during the low solar months with periods of cold outdoor temperatures will provide the best results.

- Monitoring indoor temperatures identified homes using a setback thermostat, which caused problems for nighttime only analysis. Adjusting for changes in indoor air temperature improved accuracy slightly.
- Nighttime only analysis was useful during high solar months.
- Available nearby weather data could eliminate the need for individual outdoor temperature monitoring.

AkWarm Design Heat Load Calculation Observations:

The AkWarm design heat load estimate, with an additional 20% - 30% safety margin can provide a reasonable method for sizing furnaces. The existing design heat load report is lacking in details. Some improvements include:

- Additional input to adjust for local design outdoor temperatures
- Additional input for safety margins
- Design heat load broken down for house and garage
- Some adjustment for heat flow from house to garage
- Air leakage adjustment input for multifamily units
- Ventilation heat load adjustment for design outdoor temp. conditions.
- Detailed design heat load report consistent with heating industry standards

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# Appendix A

**Discussion of Potential Errors in Estimating Design Heat Loads:**

There are numerous factors which may significantly effect the design heat load estimate of a home by monitoring runtime or calculating from plans. A few of those factors are listed below:

- True furnace efficiency - AkWarm utilizes the Gas Appliance Manufacturers Association (GAMA) efficiency ratings for furnaces. These ratings do not consider duct leakage, increased air leakage from pressure imbalances, over-sizing inefficiencies, or poor installation practices.
- Rater input errors –Small errors in measuring surface areas, volumes, or installed R-values will likely have a small effect on the AkWarm design heat loss estimate, but gross errors could significantly impact the results.
- Blower door air leakage estimate – Air leakage is a significant heat loss component in a home. Estimating natural air leakage from a blower door test can be a major source of error. Condos, for example, are typically blower door tested as individual units; air leakage between units is calculated as outdoor air leakage and may significantly over-estimate natural air leakage. Attached garages and vented crawlspaces also add uncertainty to the natural air leakage estimate.
- Many attached garages are not insulated from the house and are kept cooler than the adjoining home. Separate garage heaters are common. Heat flow from the house to the garage through an uninsulated common wall or ceiling, or any supply air duct leakage increases the design heat load for the home, while reducing the load on the garage heater.
- Ground heat loss - Several of the homes monitored were recently completed. Thus, ground temperatures are likely to be colder, resulting in an increased heat flow for a short period of time.
- AkWarm does not provide for any internal gains when estimating design heat loads. Internal heat gains may represent 5% – 10% of the design heat load of a home, depending upon occupant loading and lifestyles, lighting and appliance efficiencies, or cooking activity
- Solar gains vary depending upon the time of year and house orientation. Nighttime data should eliminate most of the solar effects.
- AkWarm assumes a minimum continuous ventilation rate depending upon the ventilation strategy and the estimated natural air leakage rates. Actual ventilation rates may vary, especially during cold, dry periods.
- Gas fireplaces were not monitored for use in this study. Fireplace usage during the monitoring period would affect the design heat load estimate.
- Model homes were subject to high usage during the day, with essentially no internal gains at night. Garages were used for tools and material storage. Adjacent units may not have been heated to same indoor temperatures.