



COLD CLIMATE HOUSING RESEARCH CENTER

CCHRC

Research Report RR 2003-01

Combustion Air Study

Final Report - February 18, 2008

Dr. John Davies, Research Director, CCHRC
Robert Maxwell, Principal, Alaska Energy Associates
Doug Maydole, Owner, Doug's Burner Services

Funded by

The Alaska Housing Finance Corporation
PO Box 101020, Anchorage, AK 99510-1020

Grant # CCH-03-CCH-1

Disclaimer:

This project to conduct a combustion air evaluation in the Fairbanks area was begun by Robert Maxwell in 2002. The purpose of the study was to assess the sufficiency of current practices in combustion air supply for atmospherically vented heating appliances, and assess the performance of power-vented heating appliances. In addition to the original scope of work, it was proposed to investigate the exhaust requirements of a variety of garages. Studies have indicated that the air communication potential between the house and attached garages may be very significant. Therefore during the combustion air study, for buildings of different air tightness, it was proposed to measure the volumes and relative air tightness between the two building components (house and garage).

For a variety of reasons, this project was begun but never completed. Following Robert's death in 2006 we have decided to terminate the project. Since some work was accomplished and was reported to CCHRC both in writing in the form of progress and interim reports and verbally to myself, rather than lose this effort entirely, I have endeavored to summarize what was done and to draw whatever limited conclusions might be had. While I did participate in some of the work that was done at my house, I did not work on any of the other houses and don't have access to any of Robert's working notes from this project, so my knowledge of the actual methodology is limited.

I have listed both Robert Maxwell and Doug Maydole as authors of this report; this was done to give them credit for the work that they did on the project. However, the report was assembled/written entirely by me some years later so as to recoup whatever information was still available. For this reason, whatever errors remain in the report are mine and not theirs.

Dr. John Davies
February 18, 2008

Table of Contents

	Page
Cover	1
Disclaimer	2
Table of Contents	3
Introduction and Background	4
Methodology	5
Results	7
Conclusions	7
Appendix I – Report to City of Fairbanks	8
Appendix II – Code action taken by the City of Fairbanks	9

Introduction and Background

[From the revised proposal, 07-18-02] “The Cold Climate Housing Research Center is proposing to conduct a combustion air evaluation in the Fairbanks area. The purpose of the study is to assess sufficiency of current practices in combustion air supply for atmospherically vented heating appliances, and assess the performance of power-vented heating appliances. To date, there has been no formal measurement or analysis of heating systems located within the pressure envelope of homes. The vast majority of heating systems in the Interior are oil-fired boilers.

Sealed combustion boilers in this environment have not been successful due to the extreme cold temperatures of supply air, resulting in poor efficiency and very short life cycle. There are mixed opinions whether naturally aspirated appliances can be isolated in small mechanical rooms for similar reasons, but no tangible evidence whether combustion air is sufficiently tempered. Consequently, heating systems are located within the pressure envelope of the home, which can be affected by zonal pressure, stack effect, fan induction, tight construction, etc. In performing structural investigations of over 2000 homes in Interior Alaska, the visible evidence of backdrafting, flame rollout, and excessive condensation is common. Two of the three are hazards for the occupants and/or the structure.

This problem was also a primary concern of the Alaska Health House Standards Committee (Developing Partners). The consensus of the Standards Committee was to have CCHRC conduct research and provide recommendations (teleconference 2/23/01).

[material omitted]

Garage Combustion Air study

In addition to the original scope of work, we propose to investigate the exhaust requirements of a variety of garages. Studies have indicated that the air communication potential between the house and attached garages may be very significant. Therefore during the combustion air study, we will look at buildings of various air tightness, measure the volumes and relative air tightness between the two building components. The APT will be used to determine the amount of CFM required to maintain -2pa house WRT garage (house with reference to garage) in a variety of garages and building types. CO monitors in the home and garage will measure the CO accumulation in the house under a variety of conditions.

The study will also encompass other aspects including:

- Using an exhaust fan on a timer that is activated by the garage door to eliminate auto exhaust CO from the house.
- For adequate elimination of CO and other byproducts of exhaust , how long must it run ?

- The limit of pressure and CFM created by a fan before it negatively impacts combustion or other aspects of the building
- How will adequate combustion air impact the CFM required to accomplish the negative pressure
- Compile a best practices technique for determining garage exhaust requirements in new and retrofit applications.
- Determine if other issues besides car exhaust need to be considered in garage exhaust strategies”

Methodology

[from revised proposal, 07-18-02]

Procedure:

“Each house will be measured and evaluated to determine:

- House and combustion appliance zone (CAZ) surface area & volume;
- Common wall surface area and leakage;
- Quantify air leakage of house and CAZ;
- Measure combustion air (vented and ambient).

The study will involve measuring combustion appliance zone (CAZ) and flue pressures at rest, startup, normal operation and worse case depressurization on approximately twelve to fifteen homes in the Fairbanks area. Attempts will be made to also measure and/or induce stack and wind effect. Additionally, we will measure zonal pressures, carbon monoxide (CO) communication, and data log CO and pressure levels under normal living conditions for a minimum of 3 days. This will include installing data loggers when winds or varying barometric pressures are expected. During operation/testing, a heating technician/mechanical engineer will monitor combustion gases to evaluate efficiency, backdrafting, etc., and to study the measurable combustion gas indicators that may be backdrafting. This information will be used to perform a quantitative analysis of manufacturer specifications vs. actual installation/performance and CAZ ventilation.

[At my house, 1998 Kittiwake Drive, we tested the boiler (Weil McClain, 155,000 BTU/hr) to see how much combustion air it required. The boiler is located in a separate CAZ in a two-car garage. There is a four-inch combustion air duct into the CAZ from outdoors. The doorway to this CAZ was sealed and the boiler operated normally (there was no reduction in the overdraft.) Next, the air duct was necked down to a three inch diameter; there was a very slight but almost un-measurable reduction in the overdraft. Finally, the air duct was reduced to a two-inch diameter; this time the overdraft was reduced from 0.05 to 0.04 inches water gauge. We concluded that the 4 inch duct was adequate.]

Since CO is primary by product and indicator of poor appliance venting, this study will measure CO generation and communication with the living area. As a control protocol, testing will not commence until all measured CO levels are zero. This will ensure there are no measurements inaccuracies due to residual car engine exhaust. However, sustained data logging will include CO measurements and transmission during car startups. Representative homes with and without an air barrier between the CAZ and living area will be measured. The leakage of the separation wall/floor between these areas will be measured using the blower door with APT; and calculated using the Blasnik Open Door Method. This will also be verified by performing simultaneous blower door testing (two blower doors) on both the CAZ and living space on a representative sample of homes.

Homes with power vented oil-fired boilers will also be evaluated in a similar manner to determine performance and limitations of this equipment in a severe cold environment. The hypothesis being power vented, naturally aspirated appliances are not affected by normal/worst case depressurization of the home. Which may be the solution to this problem for new construction (to include Health House) and retrofit.

Equipment:

- APT (CCHRC)
- Blower Door, 2 (Staff*)
- Data Loggers (CCHRC/AHFC)
- Magnehelic Gauges (Staff)
- Digital Manometer (Staff)
- Digital Psychrometer (Staff)
- Carbon Monoxide Monitor (Staff)
- Pressure Pan (Staff)
- Appliance test equipment (Contracted**)
- Laptop (CCHRC)
- Flow Hood or Anemometer
- Carbon Monoxide Data Loggers

*Robert Maxwell

** Doug Maydole

Timeline:

Study is expected to commence the second week of January 2002, and be completed by July 2002.”

Results

[from CAS Summary 3-3-03, Robert Maxwell]

Four residential dwellings have been completed to-date; three are used in this comparison.

One dwelling had adequate separation from the garage (Combustion Appliance Zone) so that the negative pressure from exhaust appliances in the dwelling did not impact the positive draft of the boiler. That home had a flow through the six-inch round duct combustion air inlet of 19 cfm in a two-car garage. The estimated leakage area between the house and garage was 4 square inches, and 41 square inches between the garage and outside (including the combustion air inlet.)

Other homes had, by comparison, an average of 13.0 square inches of leakage area between the house and the garage, and 16.5 square inches between the garage and outside. These other dwellings had less than 5 inch-diameter round duct net clear openings for combustion air; and both openings were in two-car garages.

A six inch diameter round duct for the combustion air inlet seems adequate to protect against the negative pressures created by exhaust appliances when the leakage area between the combustion air zone (garage) and the house is less than the leakage area between the combustion appliance zone and outdoors.

Conclusions

Based on observations at four houses [progress report 3-3-03 and personal communications], it appears that an approximately 150,000 BTU/hour boiler located in a two-car garage needs a minimum of a four-inch diameter duct for combustion air and about a 6-inch diameter duct to provide protection against back-drafting. To avoid down-drafting boilers in this range, it appears necessary to maintain the pressure in the combustion appliance zone (CAZ) above minus 16 Pascals relative to outdoors. Specifically, the leakage area between the CAZ and the house should be less than the leakage area between the CAZ and outdoors. There was no back-drafting pressure when the ratio of these leakage areas was about 1:10. CCHRC staff met with individuals on the City of Fairbanks Code Review Board and presented data collected from this study on combustion air requirements for oil-fired boilers. This information was incorporated in new code requirements and adopted in April 2003 as an amendment to the 2000 International Mechanical Code.

Appendix I

Report to the City of Fairbanks Code Review Commission

March 5, 2003

City of Fairbanks Code Review Commission
Richard Tilly, Chair
800 Cushman Street
Fairbanks, AK 99701

Dear Commission Members,

We have completed data collection for four houses with oil-fired boilers ranging from 145 to 175 thousand gross BTUs. To avoid down-drafting boilers in this range, it appears necessary to maintain the pressure in the combustion appliance zone (CAZ) above minus 16 Pascals relative to outdoors. In these houses, pressure separation of the CAZ from the living space ranged from almost complete to none. For the three houses in which there was some separation, the CAZ was a two-car garage. A six-inch round combustion air inlet into the CAZ seems adequate when the leakage area between the CAZ and the living space is less than the leakage area between the CAZ and outdoors. In the case where the CAZ was tightest, a six-inch round inlet provided almost all of the combustion air required (19 cfm).

Accordingly, we recommend that you require one square inch of ventilation into the CAZ for each five thousand gross BTU capacity of an oil-fired boiler. This would result in the following specifications, for example:

Boiler size (gross BTU)	Req'd ventilation (sq. in.)	Round duct diam. (in.)
60,000	12	4
100,000	20	5
140,000	28	6
180,000	36	7

Of course, the more pressure separation there is between the CAZ and the living space, the better.

Dr. John Davies, Director of Research

CC: Steve Shuttleworth, Fax 459-6719

Appendix II

Oil Fired Appliance Combustion Air Duct Sizing (From the City of Fairbanks Code Review Commission 3-12-03)

Minimum combustion air duct size shall be 1 square inch per 6000 Btu/hr input. Or use Table 1. Only one opening is required.

Table1.

Appliance Size	C/A duct min. free area	Min. round duct size	
Up to 120,000 Btu/hr input	12 sq.in.	4" round	
Up to 155,000 Btu/hr input	19 sq.in.	5" round	
Up to 175,000 Btu/hr input	28 sq.in.	6" round	

Exception 1: If the boiler (or other oil-fired appliance) is located in a two (or more) car garage, the combustion air duct is allowed to be one size smaller than shown in Table 1.

Free Area → Boiler Size ↓	1 sq. inch per 6000 Btu/hr		Round Duct Size Inches	Free Area Sq. In.
100,000 Btu/hr example	16.7 sq. in. 5 " round		3	7.1
105,000 Btu/hr (0.75 gph nozzle)	17.5 5		4	12.6
119,000 Btu/hr (0.85 gph nozzle)	19.8 5 or 6		5	19.6
140,000 Btu/hr (1.0 gph nozzle)	23.3 6		6	28.3
154,000 Btu/hr (1.1 gph nozzle)	25.7 6		7	38.5
168,000 Btu/hr (1.2 gph nozzle)	28.0 6		8	50.3
175,000 Btu/hr (1.25 gph nozzle)	29.2 7			