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AUSTRIA

Ecofan Fuel Savings Report

In Zusammenarbeit mit der Fakultät für Ingenieurwissenschaften Waterloo, Kanada

Harald Pechmann I Sausbachweg 3 I 4643 Pettenbach
+43(0)650 4499700 I kontakt@ecofan.at I www.ecofan.at

Table of Contents

Ecofan Fuel Usage Testing Protocol

Ecofan Fuel Usage Report

Ecofan Fuel Usage Procedure

ECOFAN FUEL USAGE TEST PROTOCOL

Scope

This test protocol is to establish the measurement, evaluation and verification of the effectiveness of the Ecofan in reducing the quantity of fuel used, at a specified burn rate, to maintain a pre-determine human comfort level, as outlined in the Ashrae 55-2004 Standard[1] and ISO 7730-2005[2].

This test is not designed to determine or verify; human thermal comfort level or woodstove burn rates.

The amount of fuel that the Ecofan can potentially save the average homeowner will be expressed in kg/hr.

Data Quality Objectives

Adherence to the requirements of this procedure will enhance the quality of the data obtained, ensuring that the recorded results will withstand 3rd party auditing. All data collected will be accurate and repeatable.

Data will be in metric measurement, retaining at least one extra significant figure beyond that of the acquired data. Round off figures after the final calculation.

Summary of Testing Process

The testing will compare the wood fuel consumption between a wood stove operated under the same conditions, with and without an Ecofan. The testing process will include, but not be limited to:

a. Development of testing protocols and procedures; based on the guidelines set out in Ashrae 55-2004 Standard[1], and the EPA Method 28 Certification and Auditing of Wood Heaters[3];

b. Electronic Fluid Dynamic Modeling and analysis using FloEFD Pro 9 ™, a commercial CFD package by Mentor Graphics [4];

c. Verification of wood stove operations and control of wood burn rates, to ensure that specified burn rates can be achieved, during consecutive test runs;

d. Comparative testing of fuel usage/consumption, with and without an Ecofan;

e. Analysis of data and summarization of testing results;

f. Validation of test results to include witness testing.

The comparative testing will include the measurement of elapsed time, air/surface temperatures, and air velocity, at specified points within a test facility that is heated with a commercially available wood burning stove, operating at a specified wood stove settings. The tests will be initiated with the test facility being at pre-defined conditions.

All test results will be repeated for verification before becoming final results.

DEFINITIONS

Definitions for the purposes of this test will be; as per EPA Method 28 Certification and Auditing of Wood Heaters[1] and ANSI/Ashrae Standard 55-2004[2] and; including the following:

2 × 4: means 50 millimeters by 100 millimeters, as nominal dimensions for lumber.

Burn rate: means the rate at which test fuel is consumed in a wood heater. Burn rates will be measured and documented in kilograms of wood (dry basis) per hour (kg/hr).

Certification or audit test: means a series of at least three test runs conducted for certification or audit purposes that meet the burn rates established in the Ecofan Fuel Burn Rate Testing.

End of Test: The end of test is when the calculated T_O has been maintained for a minimum of 3 consecutive hours.

Occupied Zone: the region normally occupied by people within a space, generally considered to be between the floor and 1.8 m above the floor and more than 1.0 m from outside walls/windows or fixed heating, ventilating, or Air-conditioning equipment and 0.3 m from internal walls.

T_O: is defined as the calculated temperature, in the occupied zone at the point of occupancy as defined in the Ashrae 55 Standard 2004[1].

Temperature Operative: the uniform surface temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non uniform space; the difference between the plane radiant temperature of the two opposite sides of a small plane element.

Test facility: means the area that has been constructed to meet the Ontario Building Code Standards, in which the wood heater is installed, operated, and sampled for thermal comfort level.

Test run: is the period of time from when TO is achieved and maintained for minimum of 3 consecutive hours.

Wood Stove/Heater: means an enclosed, wood burning appliance capable of and intended for space heating or domestic water heating, as defined in the applicable regulation. For the purposes of this testing appliance is an E.P.A Drolet Pyropak wood stove.

GENERAL REQUIREMENTS

The results of this testing are specific to the test facility used for conducting the tests. These test results will be used to broadly determine fuel usage with and without the use of the Ecofan under normal operating conditions, but due to the extent of uncontrollable variables, variations in the results are expected.

Disclaimer

This test method may involve hazardous materials, operations, and equipment. This test method may not address all of the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to performing this test method.

Equipment and Supplies

Equipment utilize for this testing will be as specified in Appendix II – Data Recording Point Definition and Measurement Interval and Appendix III - Ecofan Equipment Listing.

Wood Heater

The Drolet E.P.A Pryropak wood stove and parts will be installed in conformance with the manufacturer's written installation instructions. The wood heater will be placed centrally on the platform scale and connected to the flue as per the manufacturer's recommendations.

Test Facility

The test facility will be 9.75 meters long by 6.4 meters wide by 2.4 meters high, constructed within an existing structure, to comply with the Ontario Building Code. The walls will be insulated to an R12 rating and the ceiling to an R20.   There will be a 30.5 centimeter air gap on three sides of the test facility, between the existing structure and the outside of the test facility walls. Refer to Appendix I Testing Facility Drawing. Simulation of outside conditions will be controlled via a heating and ventilation system (HVS), installed for this purpose. The cavity created between the test room and the outside walls will act as a "duct" for the HVS and will controlled air gap conditions. The cavity air will be a mix of outside air and re-circulated air. The inside and outside air temperature, humidity and barometric pressure will be closely monitored, to maintain similar conditions for each test. The specified outside conditions will be determined based on predicted daily high temperatures.

Test Fuel

The test fuel shall conform to the following requirements:

Fuel Species – The fuel species for this testing will be untreated, air-dried white ash lumber. The lumber shall be clear and free of knots.

Fuel Moisture - The test fuel shall have a moisture content range between 16 to 25 percent on a wet basis (19 to 25 percent dry basis). Fuel moisture content will be determined in accordance using a calibrated electronic moisture meter.

Fuel Temperature - The test fuel shall be maintain to the ambient temperature and humidity of the at the test facility.

Fuel Dimensions - The dimensions of each test fuel piece shall conform to the nominal measurements of 50 millimeters by 100 millimeters. Each piece of test fuel (not including spacers) shall be of equal length, and shall closely approximate 5/6 the dimensions of the length of the usable firebox. The fuel piece dimensions shall be determined in relation the usable firebox volume is less than or equal to 0.043 m3.

Test Fuel Spacers - The spacers shall be air-dried white ash lumber 130 × 40 × 20 mm. The spacers will be attached to the test fuel pieces with uncoated, un-galvanized nails. There will be no spacers attached to the top of the test fuel piece(s) on top of the test fuel charge.

Test Run Requirements.

At least one comparison test run will be completed for the specified burn rate, which will be sufficient to offset the calculated test facility heat loss.

The wood heater shall be operated with the primary air supply inlet control set at a pre-determined position; necessary to obtain the average burn rate required to maintain the desired thermal comfort level.

Wood Heater Temperature Monitors

The wood heater surface temperature sensors will be located at three locations on the wood heater exterior surface. The sensors will be positioned centrally on the top surface and the two sidewall surfaces. The sensors will be monitored and data recorded; as specified in Appendix II – Data Recording Point Definition and Measurement Interval.

Test Facility Conditions.

The test facility will be monitored and data recorded as specified in Appendix II – Data Recording Point Definition and Measurement Interval, Appendix V - Fuel Usage Testing Log Sheet Rev 5 and Appendix - VI 60 Channel Assignment Rev 2.

Test Run.

Each test run of the comparative testing will be completed as defined in the following paragraphs:

Pre-test Ignition: This portion of the test will consist of achieving at the desired thermal comfort level with a range of plus or minus 1°C. The testing technician will monitor air/surface temperatures, BP, RH and flue draft, during transition of the Test facility from “start condition” to achievement of the desired thermal comfort level. The test run will start once the temperature at the point of occupancy has been achieved for two consecutive temperature readings.

Test Run: This is the period between Start Test and End Test, during this time period the testing technician will maintain TO at the desired thermal comfort level, plus or minus 1.5°C for minimum of 3 hours to provide enough data for analysis. Air/surface temperatures, barometric pressure, test facility Relative Humidity, a flue static pressure will be monitored and recorded achievement of the desired thermal comfort level until end of test.

End Test Run: The end of test will at a minimum of 3 hours from achievement of the desired thermal comfort level.

Transition Periods (Integrate tests): For integrated testing there will be at least 1 hour between runs; with and without an Ecofan. The fire is to be maintained, but no fuel will be added until the temperature drops 1.5°C below the desired thermal comfort level. All data recording will be maintained through this portion of the test but will be considered the transition data and not included in fuel usage analysis.

Transition Period (Independent tests): There will be at least 12 hours between independent test runs; with and without an Ecofan. The test facility temperature will be maintained to 1.5°C below the desired thermal comfort level. No data will be record during this transition period and will not be included in fuel usage analysis.

Calibration and Standardizations

Quality Control, verification and calibration of test and collection equipment ensures accurate measurement of comfort level, fuel weight and burn rate. For the Ecofan Fuel Usage Test, all measurements and test data recordings will be verified and recorded with calibrated or verified test equipment. No unlisted equipment will be used in the execution of this test.

Quality control measures will include the validation of the precision and accuracy of records and measurements.

QC Measures:

Section	Description	QC Measure	Effect
2.2	Fuel weights	Check and Calibration of platform scale	Ensure accuracy of scales
3 & 4	Data collection	Validation and analysis of formulas, DAQ,	Ensure precision of measurements
3	Temperature Sensors	Random checks using calibrated sensors Calibration Procedure for Thermocouples Using Omega OMB-DAQ56 at 0°C using Ice Bath.	Ensure accuracy of measurements
2.1	Flue draft	Check and Calibration of Pitot Tube assembly	Ensure precision of measurements

A laboratory record of all calibrations shall be maintained using Appendix IV – Sensor Calibration Log.

Analytical Balance

The bench platform scale will be calibrated upon installation and annually thereafter. During the testing phase the scale accuracy will be verified at the end of each testing day by weighing one fuel load on two scales and comparing the difference. If there is less than 1% variance, the recorded values on the platform scale are valid.

Moisture Meter

Before its initial use and at least annually thereafter, calibrate the moisture meter as described in the manufacturer's instructions.

Anemometer

The anemometer to measure air velocity will be calibrated as specified in the manufacturer's instructions before the first test and annually thereafter.

Barometer

Calibrate against a mercury barometer before the first test and at least annually thereafter. Follow the manufacturer's instructions for operation.

Note: The barometric pressure reading may be obtained from the Wiarton Environment Canada Weather Station. Request the station value (which is the absolute barometric pressure) and adjust for elevation differences between the weather station and sampling point at a rate of minus 2.5 mm Hg per 30m elevation increase or plus 2.5 mm Hg per 30 m for elevation decrease.

iBTX-W-5

The OMEGA® iBTHX transmitter lets you monitor and record barometric pressure, temperature, relative humidity, and dew point over an Ethernet network or the Internet with no special software except a Web browser. The iBTHX serves active Web pages to display real time readings; display charts of barometric pressure, temperature, and humidity; or log data in standard data formats for use in a spreadsheet or data acquisition program such as Excel or Visual Basic. The iBTHX comes with a calibration kit that will be used for annual calibration.

Temperature Sensors

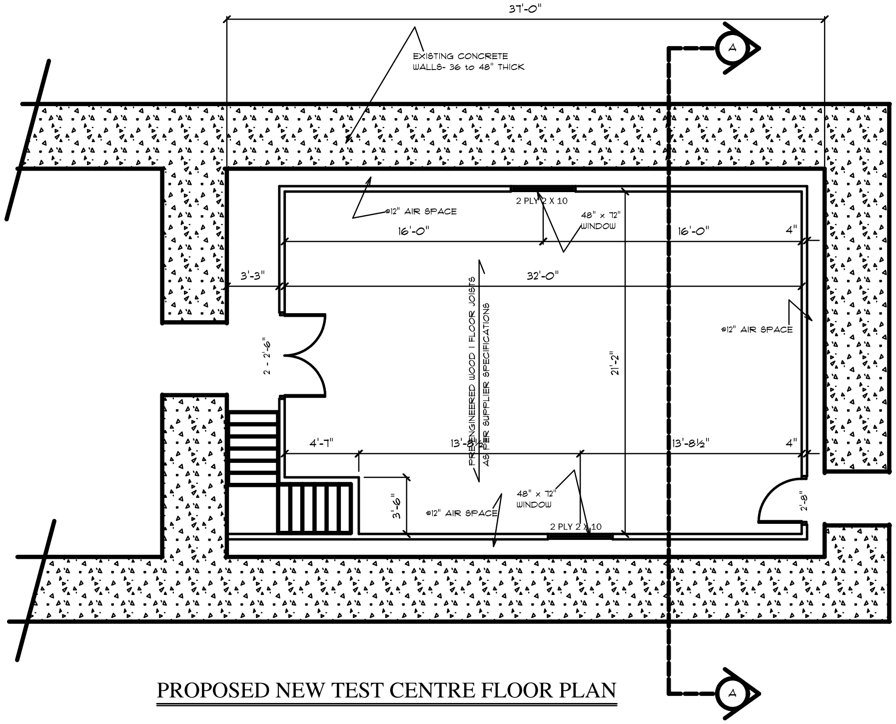
Calibrated temperature sensors (TS) must be calibrated against NIST standards before the first test; and at least annually thereafter. Following each days testing the temperature sensors will be verified by comparing the calibrated TS with non-calibrated TS’s. The TS must be within ±1ºC or they will not be used.

References and Standards.

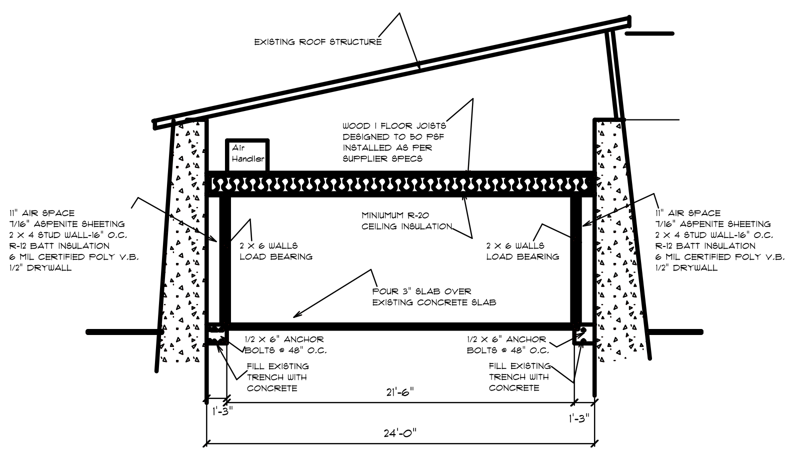
1. ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy, American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.
2. ISO 7730:2005(E), Ergonomics of the Thermal Environment, Third Edition 2005-11-15.
3. Method 28, Certification and Auditing Wood Heaters. Emission Measurement Center, CFR Promulgates Test Methods, U.S. EPA Technology Transfer Network, February 2000.
4. Mentor Graphics®, Head Quartered in Wilsonville, Oregon, http:www.mentor.com
5. Drolet Pyropak E.P.A. Wood Stove Manual, published by Stove Builder International Inc., 1700, Leon-Harmel, Quebec City (Quebec), Canada G1N 4R9
6. Ecofan Fuel usage Test Procedure, revision 6, Caframo Limited, June 2010.

Appendices

Appendix I Test Facility Drawing



PROPOSED NEW TEST CENTRE FLOOR PLAN



SECTION THRU A

NOTES AND SPECIFICATIONS

1. ALL WORK TO CONFORM TO THE ONTARIO BUILDING CODE AND LOCAL BYLAWS & THE CONTRACTOR OR OWNER SHALL CHECK & VERIFY WORK IS COMPLETED IN A GOOD WORKMANLIKE ORDER.
2. PRIOR TO PROCEEDING WITH CONSTRUCTION THE CONTRACTOR SHALL VERIFY ALL INFORMATION, DIMENSIONS & SPECIFICATIONS
3. TRUSSES(IF APPLICABLE)TO BE ENGINEERED AND INSTALLED AS PER SUPPLIER SPECS
4. ALL MATERIALS TO BE CONSTRUCTION GRADE OR EQUAL.
5. ALL NON REINFORCED CONCRETE AFTER 28 DAYS TO HAVE A COMPRESSIVE STRENGTH NOT LESS THAN- 4650 PSI FOR GARAGE & CARPORT FLOORS AND ALL EXTERIOR FLATWORK AND 2200 PSI FOR ALL OTHER APPLICATIONS
6. CONTRACTOR TO ENSURE ADEQUATE BEARING CAPACITY OF SOIL CONDITIONS AND ENSURE ALL FOOTINGS ARE PLACED ON SOLID BEARING UNDISTURBED SOIL.
7. ALL FOOTINGS TO BE POURED BELOW FROST LEVELS UNLESS SPECIFIED OTHERWISE.
8. ALL STRUCTURAL STEEL TO BE PRIMED BEFORE INSTALLATION.
9. WHERE FOOTING STEPS MAY VARY,STEP AT 1 VERTICAL TO 1 HORIZONTAL WITH A MAX STEP OF 24"
10. WHEN PRE-MANUFACTURED FLOOR JOISTS ARE USED THEY SHALL BE ENGINEERED BY THE SUPPLIER AND INSTALLED AS PER THE SPECIFICATIONS.
11. ALL LVL BEAMS REQUIRED MUST BE SIZED AND INSTALLED AS PER THE SUPPLIERS SPECIFICATIONS.
12. ROOF VENTS SHALL BE INSTALLED TO ALLOW 1 SQ FT OF VENTED SPACE AREA PER 300 SQ FT OF INSULATED CEILING AREA
13. ALL WINDOW AND DOOR HEADERS TO BE 2 PLY 2 X 10 UNLESS SPECIFIED OTHERWISE.
14. GUARDS ARE REQUIRED ON ALL OPEN SIDES OF LANDINGS AND PORCHES WHEN THE HEIGHT IS 24" GREATER THAN THE ADJACENT LEVEL OR GRADE

Caframo Ltd.
Wiarton, Ontario

Gary's Drafting & Design Service
RR#1 Shallow Lake, Ontario
519-372-0637

MINISTRY OF HOUSING QUALIFIED
Registration # 30528

PROJECT #	2009-28
PROJECT NAME	New Test Facility-PO#20555
DRAWING TITLE	Plan and Section
SCALE	1/4"= 1' - 0"
DATE	December 10, 2009
DRAWN BY	Gary McMillan (BCIN# 22804)
PAGE #	1 of 1

SoftPlan 10.2.1

Appendix II – Data Recording Point Definition and Measurement Interval

Item	Data Point	Location	Description	Collection Method	Timing
1	T_{S1}	East wall	Surface temperature of east wall midpoint between floor, ceiling, and adjacent walls.	Omega DAQ 56 with extension Module	1 minute intervals
2	T_{S2}	North wall	Surface temperature of North wall midpoint between floor, ceiling, and adjacent walls.	Omega DAQ 56 with extension Module	1 minute intervals
3	T_{S3}	West wall	Surface temperature of West wall midpoint between floor, ceiling, and adjacent walls.	Omega DAQ 56 with extension Module	1 minute intervals
4	T_{S4}	South Wall	Surface temperature of South wall midpoint between floor, ceiling, and adjacent walls.	Omega DAQ 56 with extension Module	1 minute intervals
5	T_{S5}	Floor	Floor surface temperature in the centre of the facility	Omega DAQ 56 with extension Module	1 minute intervals
6	T_{S6}	Ceiling	Ceiling surface temperature at the centre of the facility	Omega DAQ 56 with extension Module	1 minute intervals
7	T_{S7}	Couch	Surface temperature of the back of the couch, at its center point on the woodstove side.	Omega DAQ 56 with extension Module	1 minute intervals
8	ST_1	Stove Top	Surface temperature of the top surface of the wood stove at its center point	Omega DAQ 56 with extension Module	1 minute intervals
9	ST_2	Stove Stack	Surface temperature of the inside wall of the stove stack, adjacent to the manometer opening	Omega DAQ 56 with extension Module	1 minute intervals
10	ST_3	Stove South Side	Surface temperature of the south side surface of the wood stove at its center point	Omega DAQ 56 with extension Module	1 minute intervals
12	ST_4	Stove North Side	Surface temperature of the north surface of the wood stove at its center point	Omega DAQ 56 with extension Module	1 minute intervals
13	T_{A1}	East wall	Air Temperature of east wall 1.1 m from the floor and 1 m towards the center of the facility, midway between adjacent walls.	Omega DAQ 56 with extension Module	1 minute intervals
14	T_{A2}	North wall	Air Temperature of north wall 1.1 m from the floor and 1 m towards the center of the facility, midway between adjacent walls.	Omega DAQ 56 with extension Module	1 minute intervals
15	T_{A3}	South Wall	Air Temperature of west wall 1.1 m from the floor and 1 m towards the center of the facility, midway between adjacent walls.	Omega DAQ 56 with extension Module	1 minute intervals
16	T_{A4}	West Wall	Air Temperature of south wall 1.1 m from the floor and 1 m towards the center of the facility, midway between adjacent walls.	Omega DAQ 56 with extension Module	1 minute intervals
17	T_{A5}	South/East Corner	Air temperature measured at the point of 2 m from the south and east walls, measure 1.1 m above floor	Omega DAQ 56 with extension Module	1 minute intervals
18	T_{A6}	Position 1 on 3' arc from stove	Air temperature on arc is drawn 3' from center of wood stove, measured .6 m above floor. Position 1 on is on South end of arc.	Omega DAQ 56 with extension Module	1 minute intervals
19	T_{A7}	Position 2 on 3' arc from stove	Air temperature on arc is drawn 1 m from center of wood stove, measured .6 m above floor. Position 2 on is at the midpoint of arc.	Omega DAQ 56 with extension Module	1 minute intervals
20	T_{A8}	Position 3 on 3' arc from stove	Air temperature on arc is drawn 3' from center of wood stove, measured .6 m above floor. . Position 3 on is on North end of arc.	Omega DAQ 56 with extension Module	1 minute intervals

Appendix II – Data Recording Point Definition and Measurement Interval

Item	Data Point	Location	Description	Collection Method	Timing
21	T_{A9}	Position 1 on 6' arc from stove	Air temperature on arc is drawn 2 m from center of wood stove, measured .6 m above floor. . Position 1 on is on South end of arc.	Omega DAQ 56 with extension Module	1 minute intervals
22	T_{A10}	Position 2 on 6' arc from stove	Air temperature on arc is drawn 2 m from center of wood stove, measured .6 m above floor. . Position 2 on is at the midpoint of arc.	Omega DAQ 56 with extension Module	1 minute intervals
23	T_{A11}	Position 3 on 6' arc from stove	Air temperature on arc is drawn 6' from center of wood stove, measured .6 m above floor. Position 3 on is on north end of arc.	Omega DAQ 56 with extension Module	1 minute intervals
24	T_{A12}	Position 1 on 9' arc from stove	Air temperature on arc is drawn 9' from center of wood stove, measured .6 m above floor. Position 1 on is on south end of arc.	Omega DAQ 56 with extension Module	1 minute intervals
25	T_{A14}	West Air gap	Air temperature measure in the West air gap, located at the midpoint of the west wall.	Omega DAQ 56 with extension Module	1 minute intervals
26	T_{OP1}	Occupied Point .1 m	Air temperature measured at the point of occupancy measure .1 m above floor.	Omega DAQ 56 with extension Module	1 minute intervals
27	T_{OP2}	Occupied Point .6 m	Air temperature measured at the point of occupancy measure .6 m above floor.	Omega DAQ 56 with extension Module	1 minute intervals
28	T_{OP3}	Occupied Point 1.1 m	Air temperature measured at the point of occupancy measure 1.1 m above floor.	Omega DAQ 56 with extension Module	1 minute intervals
29	T_{OP4}	Occupied Point 1.7 m	Air temperature measured at the point of occupancy measure 1.7 m above floor.	Omega DAQ 56 with extension Module	1 minute intervals
30	BP_1	Center of facility	Barometric Pressure measured at the centre of the facility	Manually by Testing Technician	Beginning and end of test
31	BP_2	Outside	Barometric Pressure measured outside of the facility	Manually by Testing Technician	Beginning and end of test
32	RH_1	Center of facility	Relative Humidity measured at the center of the facility	Manually by Testing Technician	Beginning and end of test
33	RH_2	Outside	Relative Humidity measured outside of the facility	Manually by Testing Technician	Beginning and end of test
34	P_2	Inside stack at 8'	Static pressure inside the stack measured 8 feet above the combustion exit point.	Manually by Testing Technician	10 minute intervals
35	AS_3	Occupied Point 1.1 m	Air speed at the point of occupancy measured 1.1 m above the floor.	Omega DAQ 56 with extension Module	Beginning and end of test
36	T_{W1}	Centre of west cement wall	Surface temperature of the west cement wall, measured at the midpoint of the air gap side.	Omega DAQ 56 with extension Module	1 minute intervals
37	T_{W2}	Centre of south cement wall	Surface temperature of the south cement wall, measured at the midpoint of the air gap side.	Omega DAQ 56 with extension Module	1 minute intervals
38	T_{W3}	Centre of west outside of inside wall	Surface temperature of the west outside of the inside wall, measured at the midpoint of the air gap side.	Omega DAQ 56 with extension Module	1 minute intervals
.39	T_{W4}	Centre of south outside of inside wall	Surface temperature of the south outside of the inside wall, measured at the midpoint of the air gap side.	Omega DAQ 56 with extension Module	1 minute intervals
40	T_{W5}	Centre of North	Surface temperature of the north cement wall,	Omega DAQ 56	1 minute

Appendix II – Data Recording Point Definition and Measurement Interval

Item	Data Point	Location	Description	Collection Method	Timing
		cement wall	measured at the midpoint of the air gap side.	with extension Module	intervals
41	T_{W6}	Centre of east outside of inside wall	Surface temperature of the east outside of the inside wall, measured at the midpoint of the air gap side.	Omega DAQ 56 with extension Module	1 minute intervals
42	T_{W7}	Centre of north outside of inside wall	Surface temperature of the north outside of the inside wall, measured at the midpoint of the air gap side.	Omega DAQ 56 with extension Module	1 minute intervals
43	T_{W8}	Centre of east cement wall	Surface temperature of the east cement wall, measured at the midpoint of the air gap side.	Omega DAQ 56 with extension Module	1 minute intervals
44	T_{R1}	Top surface of radiant box	Surface temperature of the top surface of the radiant box, located at the point of occupancy at 1.1 m above the floor	Omega DAQ 56 with extension Module	1 minute intervals
45	T_{R2}	West surface of radiant box	Surface temperature of the top surface of the radiant box, located at the point of occupancy at 1.1 m above the floor.	Omega DAQ 56 with extension Module	1 minute intervals
46	T_{R3}	South surface of radiant box	Surface temperature of the top surface of the radiant box, located at the point of occupancy at 1.1 m above the floor	Omega DAQ 56 with extension Module	1 minute intervals
47	T_{R4}	North surface of radiant box	Surface temperature of the top surface of the radiant box, located at the point of occupancy at 1.1 m above the floor	Omega DAQ 56 with extension Module	1 minute intervals
48	T_{R5}	East surface of radiant box	Surface temperature of the top surface of the radiant box, located at the point of occupancy at 1.1 m above the floor	Omega DAQ 56 with extension Module	1 minute intervals
49+	T_{R6}	Bottom surface of radiant box	Surface temperature of the top surface of the radiant box, located at the point of occupancy at 1.1 m above the floor	Omega DAQ 56 with extension Module	1 minute intervals
50	T_{ATC}	Floating	Air temperature that can be co-located with other air temperature sensors to verify reading and accuracy	Manually by Testing Technician	15 minute intervals
51	T_{STC}	Floating	Surface temperature that can be co-located with other air temperature sensors to verify reading and accuracy	Manually by Testing Technician	15 minute intervals
52	T_O	Calculated	Calculated Comfort Temperature: $T_O = (T_{op(mean)} + T_{R(mean)})/2$	Omega DAQ 56 with extension Module	1 minute intervals
53	T_{C1}	North Ceiling	Surface temperature of the ceiling, located at 1 m from the north wall at the mid point.	Omega DAQ 56 with extension Module	1 minute intervals
54	T_{C2}	South Ceiling	Surface temperature of the ceiling, located at 1 m from the south wall at the mid point.	Omega DAQ 56 with extension Module	1 minute intervals
55	T_{C3}	West Ceiling	Surface temperature of the ceiling, located at 1 m from the west wall at the mid point.	Omega DAQ 56 with extension Module	1 minute intervals
56	T_{C4}	East Ceiling	Surface temperature of the ceiling, located at 1 m from the east wall at the mid point.	Omega DAQ 56 with extension Module	1 minute intervals
57	T_{L1}	North Loft Floor	Surface temperature of the loft floor, located at 1 m from the north wall at the midpoint.	Omega DAQ 56 with extension Module	1 minute intervals
58	T_{L2}	South Loft Floor	Surface temperature of the loft floor, located at 1 m from the north wall at the midpoint.	Omega DAQ 56 with extension Module	1 minute intervals
59	T_{L3}	West Loft Floor	Surface temperature of the loft floor, located at 1 m from the north wall at the midpoint.	Omega DAQ 56 with extension	1 minute intervals

Appendix II – Data Recording Point Definition and Measurement Interval

Item	Data Point	Location	Description	Collection Method	Timing
				Module	
60	T_{L4}	East Loft Floor	Surface temperature of the loft floor, located at 1 m from the north wall at the midpoint.	Omega DAQ 56 with extension Module	1 minute intervals
61	T_{NC}	North Air gap	Air temperature measure in the north air gap, located at the midpoint of the north wall.	Omega DAQ 56 with extension Module	1 minute intervals
62	T_{SC}	South Air gap	Air temperature measure in the south air gap, located at the midpoint of the south wall.	Omega DAQ 56 with extension Module	1 minute intervals
63	T_{LA}	Centre Loft	Air temperature of the loft, locate in the centre of the room, 1.1 m from the loft floor.	Omega DAQ 56 with extension Module	1 minute intervals

APPENDIX III EQUIPMENT LIST

Item #	Model #	Description	Cal/ certi	Mmt	Man.	Distributor	Calibration Period	Verification procedures
1	iBTX-W-5	IServer Server BAR & RH/T CMP-SC-NEW	Yes	Barometric Pressure Temperature Relative Humidity	Omega	Omega (1 week)	annual	iServer MicroServerTM for barometric pressure and temperature, LCD display, 2 MB flash memory card, 2-relay alarm and battery back-up, with AC power adaptor. Includes standard wand probe, cable 6" (152mm) with DB9 connector
2	CAL-3-HU-P-T (accessory for iBTX-M)	NIST-traceable calibration certificate, 3 humidity, barometric pressure and temp points (for new units)	Yes	Calibration	Omega	Omega (2 weeks)	annual	
3	CT485B-CAL-KIT (accessory for iBTX-M)	Calibration kit, 33% and 75% RH standards	Kit	Calibration		Omega (in stock)	annual	
4	Series 160S	Pitot Tube 24"(Rated to 1500°F (815°C)) Pitot Tube are designed specifically for flow measurement of dirty, particulate laden air or gas streams typical in environmental testing.	In-house	Air Flow	Topac	ITM - Toronto 16975 Leslie Street Newmarket, ON L3Y 9A1 Phone: 905-952-3750, Fax: 905-952-3751	annual	Before initial use check as per Sec 10.1 EPA Method 2 and verify
5	M200-DN0028	Manometer, 0-28"H2O, Differential	NIST	Airflow	Meriam	ITM - Toronto 16975 Leslie Street Newmarket, ON L3Y 9A1 Phone: 905-952-3750, Fax: 905-952-3751	annual	
6		Fittings estimate, tubing etc. for manometer		Airflow		ITM - Toronto 16975 Leslie Street Newmarket, ON L3Y 9A1 Phone: 905-952-3750, Fax: 905-952-3751	annual	
7	HCM-890	Humidifier (brand new cool mist in lab) 2 gallon (7.5 litres) output per day 650 - 1050 sq ft room	N/A	Humidity	Honeywell	Home Hardware	annual	
8	DDR2509EE	Dehumidifier -For areas up to 1500 sq. ft. depending on conditions 25 U.S. pint (11.8 litre) capacity per 24 hours	N/A	Humidity	Danby	Home Hardware	annual	
9	CMT-908	Electrophysics Dual Mode Moisture Meter, capable of electronic species compensation, pinless or pin-type	Calibration check tester included (16%)	Moisture	Electrophysics	Electrophysics, Box 40, West Lorne, Ontario N0L 2P0 Toll Free Phone or Fax: 1-800-244-9908	annual	
10	MP1-K-36-SMPW-M	Single Magnet Probe, Type K		Temperature	Omega	Omega	annual	

APPENDIX III EQUIPMENT LIST

Item #	Model #	Description	Cal/ certi	Mmt	Man.	Distributor	Calibration Period	Verification procedures
11	SA1-T	SELF ADHESIVE T/C TYPE T 5/PK	10@20°C 5@0°C 5@-10°C	Temperature	Omega	Omega	annual	
12	5TC-TT-T-30-36	Ready-Made Insulated Thermocouples - Package of 5	10@20°C 5@0°C	Temperature	Omega	Omega	annual	After each field use
13	EXTT-T-24-500	500 ft roll of Type T thermocouple extension wire		Temperature	Omega	Omega	annual	After each field use
14	EXTT-K-24-200	200 ft roll of Type K thermocouple extension wire		Temperature	Omega	Omega	annual	After each field use
15	SMPW-T-F	Glass-filled nylon, with window, T thermocouple type, female connector		Temperature	Omega	Omega	annual	After each field use
16	SMPW-T-M	Glass-filled nylon, with window, T thermocouple type, male connector		Temperature	Omega	Omega	annual	After each field use
17	SMPW-K-F	Glass-filled nylon, with window, K thermocouple type, female connector		Temperature	Omega	Omega	annual	After each field use
18	SMPW-K-M	Glass-filled nylon, with window, K thermocouple type, male connector		Temperature	Omega	Omega	annual	After each field use
19	MB2424MS-XX	MATRIX MILD STEEL BENCH PLATFORM SCALE Capacity: Calibrated Range 500lbs X 0.02lbs Platform Size: 24 " x 24 "	Yes	Weight	Matrix	Matrix Scale Service Inc. 301 Watline Avenue, Mississauga,Ontario L4Z 1P3 Tel: (905) 712-8987 Fax: (905) 712-4947	annual	
20	COMBICS 1	SARTORIUS COMBICS 1 PLUS STAINLESS STEEL INDICATOR		Weight	Sartorius	Matrix Scale Service Inc. 301 Watline Avenue, Mississauga,Ontario L4Z 1P3 Tel: (905) 712-8987 Fax: (905) 712-4947	annual	
21	8475	Air Velocity Transducers Omnidirectional (8475): - Omnidirectional probe tip - Accurate at low velocities from 10 to 100 ft/min (0.05 to 0.5 m/s) - Ideal for unknown or varying flow direction	Yes	Air velocity	TSI	Topac, 231 C J C HGWY, Suite 103, P.O. Box 660, Cohasset MA, USA, Tel:(781)740-8778 Fax:(781)740-8779	annual	
22		Pyropack Wood Stove	N/A					As per Drolet Pyropack Wood Stove Manual

Appendix IV -Sensor Calibration Log

ID #	Cal Date / Test #	Test Time Period	Variance/ Comments		Cal Date / Test #	Test Time Period	Variance/ Comments		Cal Date / Test #	Test Time Period	Variance/ Comments	
			Sensor	Temp Var			Sensor	Temp Var			Sensor	Temp Var
T_{S1}												
T_{S2}												
T_{S3}												
T_{S4}												
T_{S5}												
T_{S6}												
T_{S7}												
T_{S8}												
ST_{S1}												
ST_{S2}												
ST_{S3}												
ST_{S4}												
T_{A1}												
T_{A2}												
T_{A3}												
T_{A4}												
T_{A5}												
T_{A6}												
T_{A7}												
T_{A8}												
T_{A9}												
T_{A10}												
T_{A11}												
T_{A12}												

Appendix IV -Sensor Calibration Log

ID #	Cal Date / Test #	Test Time Period	Variance/ Comments		Cal Date / Test #	Test Time Period	Variance/ Comments		Cal Date / Test #	Test Time Period	Variance/ Comments	
T_{A13}												
T_{A14}												
T_{OP1}												
T_{OP2}												
T_{OP3}												
T_{OP4}												
T_{ST1}												
T_{ST2}												
AS_1												
AS_2												
AS_3												
AS_4												
T_{R1}												
T_{R2}												
T_{R3}												
T_{R4}												
T_{R5}												
T_{R6}												
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T_{W2}												
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T_{W6}												
T_{W7}												
T_{W8}												

FUEL USAGE TESTING DATA LOG SHEET

Wood Stove	Drolet Pyropak Wood Stove designed for 500 - 1000 square foot areas.														
Operator		**Date**			**Test**		**Ecofan**		Weather						
Fuel Used	The fuel used for this testing is dimensioned, 2 year air dried furniture grade white ash. Each test will consume: 3/4" x 3/4" x 15" white ash for kindling, 2" x 2" x 10" white ash for pre-ignition, and 2" x 4" x 15" white ash for fuel loads. Approximately .25 kg of cedar shingles and crumpled news print will be used for tinder.										**Comments:**				
Initial Room Temp Centre of Room		**Air Temp Outside**			**Barometric Pressure Outside**		**Relative Humidity Outside**		**Start Time**						
DAQ Recording Start time		**Relative Inside Humidity Start**			**Relative Humidity Inside Mid Test**		**Relative Humidity Inside End of Test**		**End of Test Time**						
Barometric Pressure Inside Start Test		**Barometric Pressure Inside Mid Test**			**Barometric Pressure Inside End of Test**		**Total Fuel Burnt (Kg)**		**Total Test Time (Hrs)**						
Air Velocity Start		**Air Velocity Mid test**			**Air velocity End of Test**		**Burn Rate Achieved**								
Kindling Temp		**Kindling % Moisture**			**Kindling Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**						
Pre-Ignition Fuel Temp		**Pre-Ignition Fuel % Moisture**			**Pre-Ignition Fuel Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 1 Temp		**Fuel Load 1 % Moisture**			**Fuel Load 1 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 2 Temp		**Fuel Load 2 % Moisture**			**Fuel Load 2 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 3 Temp		**Fuel Load 3 % Moisture**			**Fuel Load 3 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 4 Temp		**Fuel Load 4 % Moisture**			**Fuel Load 4 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 5 Temp		**Fuel Load 5 % Moisture**			**Fuel Load 5 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 6 Temp		**Fuel Load 6 % Moisture**			**Fuel Load 6 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 7 Temp		**Fuel Load 7 % Moisture**			**Fuel Load 7 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 8 Temp		**Fuel Load 8 % Moisture**			**Fuel Load 8 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 9 Temp		**Fuel Load 9 % Moisture**			**Fuel Load 9 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 10 Temp		**Fuel Load 10 % Moisture**			**Fuel Load 10 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 11 Temp		**Fuel Load 11 % Moisture**			**Fuel Load 11 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				
Fuel Load 12 Temp		**Fuel Load 12 % Moisture**			**Fuel Load 12 Weight (kg)**		**Wall Space Temp**		**Flue Static Pressure**		**Relative Humidity**				

Fuel Usage Testing Observations

Time HR:MIN	Air Control Setting	Room Temp T_{OP2}	Stove Temp ST_1	Scale Reading	Weight fuel to be added (kg)	Total weight (kg)	Comments	KG Consumed/ Interval	Honeywell	Static Press	Outside Air Temp	Relative Humid
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Appendix VI Data Logger 60 Channel Assignment

New DAQ 56 with Extension Module			Sensor Type	Existing DAQ 56 with Extension Module		
Channels 1 - 10 Assignment				**Channels 1 - 10 Assignment**		
Channel 1	Top1	Occupied Point @ .1 metres above floor	Type K	Channel 1	ST1	Temp Wood Stove Top Surface
Channel 2	Top2	Occupied Point @ 1.1 metres above floor	Type K	Channel 2	ST2	Temp Wood Stove Stack @ Manometer
Channel 3	Top3	Occupied Point @ .6 metres above floor	Type K	Channel 3	ST3	Temp Wood Stove South Surface
Channel 4	Top4	Occupied Point @ 1.7 metres above floor	Type K	Channel 4	ST4	Temp Wood Stove South Surface
Channel 5	TR1	Top Surface temperature of Occupied Box	Type T	Channel 5		Unassigned
Channel 6	TR2	West Surface temperature of Occupied Box	Type T	Channel 6	TS7	Surface Temp of Couch (Mid-point)
Channel 7	TR3	South Surface temperature of Occupied Box	Type T	Channel 7	TW1	Surface Temp West Cement wall of B#3
Channel 8	TR4	North Surface temperature of Occupied Box	Type T	Channel 8	TW2	Surface Temp South Cement wall of B#3
Channel 9	TR5	East Surface temperature of Occupied Box	Type T	Channel 9	TW5	Surface Temp North Cement wall of B#3
Channel 10	TR6	Bottom Surface temperature of Occupied Box	Type T	Channel 10	TW8	Surface Temp East Cement wall of B#3
Channels 11 - 20 Assignment				**Channels 11 - 20 Assignment**		
Channel 11	TS1	Surface Temp of East wall (Mid-point)	Type T	Channel 1	TA6	Air Temp 1 m arc @ .6 m on South end
Channel 12	TS2	Surface Temp of North wall (Mid-point)	Type T	Channel 2	TA7	Air Temp 1 m arc @ .6 m on Mid point
Channel 13	TS3	Surface Temp of South wall (Mid-point)	Type T	Channel 3	TA8	Air Temp 1 m arc @ .6 m on North end
Channel 14	TS4	Surface Temp of West wall (Mid-point)	Type T	Channel 4	TA12	Air Temp 3 m arc @ .6 m on South end
Channel 15	TS5	Surface Temp of Floor (Mid-point)	Type T	Channel 5	TA13	Air Temp 2 m North & East wall
Channel 16	TS6	Surface Temp of Ceiling wall (Mid-point)	Type T	Channel 6	TA14	Air Temp West Cavity
Channel 17	TW3	Surface Temp West Outside Internal wall	Type T	Channel 7	TC1	Surface Temp Inside Ceiling North
Channel 18	TW4	Surface Temp South Outside Internal wall	Type T	Channel 8	TC2	Surface Temp Inside Ceiling South
Channel 19	TW6	Surface Temp East Outside Internal wall	Type T	Channel 9	TC3	Surface Temp Inside Ceiling West
Channel 20	TW7	Surface Temp North Outside Internal wall	Type T	Channel 10	TC4	Surface Temp Inside Ceiling East
Channels 21 - 30 Assignment				**Channels 21 - 30 Assignment**		
Channel 21	TA1	Air Temp East wall midpoint @ 1.1m/1 m in	Type T	Channel 1	TL1	Surface Temp Loft Floor North
Channel 22	TA2	Air Temp North wall midpoint @ 1.1m/1 m in	Type T	Channel 2	TL2	Surface Temp Loft Floor South
Channel 23	TA3	Air Temp South wall midpoint @ 1.1m/1 m in	Type T	Channel 3	TL3	Surface Temp Loft Floor West
Channel 24	TA4	Air Temp West wall midpoint @ 1.1m/1 m in	Type T	Channel 4	TL4	Surface Temp Loft Floor East
Channel 25	TA5	Air Temp 2 m South & East walls @ 1.1 m	Type T	Channel 5	NC	Air Temp North Cavity
Channel 26	TA9	Air Temp 2 m arc @ 1.1 m on South end	Type T	Channel 6	SC	Air Temp South Cavity
Channel 27	TA10	Air Temp 2 m arc @ 1.1 m on Mid Point	Type T	Channel 7	TLA	Air Temp Loft Centre
Channel 28	TA11	Air Temp 2 m arc @ 1.1 m on North end	Type T	Channel 8	NA	
Channel 29	TAC	Calibrated Air Temperature Sensor	Type T	Channel 9	NA	
Channel 30	TSC	Calibrated Surface Temperature Sensor	Type T	Channel 10	Volts	Ecofan Voltage

Woodstove Comparative Testing to Determine Fuel Savings with the Use of a Thermoelectric Fan to Maintain Thermal Comfort

Viqar Haider, Mojtaba Pourvash, Dale Schnurr,
Caframo Ltd.
Wiarton, ON Canada N0H 2T0

Richard Culham, Peter Teertstra
Department of Mechanical & Mechatronics Engineering
University of Waterloo
Waterloo, ON Canada N2L 3G1

ABSTRACT

An experimental study is presented that provides credible evidence that the use of an Ecofan 800 fan on a wood stove reduces the amount of fuel required to maintain a prescribed level of thermal comfort. Test procedures and protocols based on existing standards and norms have been incorporated into a test facility that allows for a detailed examination of the dynamic heat transfer characteristics associated with woodstove operation in a controlled environment. Experimental results are validated using numerical simulations that further substantiate that the test findings show that the use of an Ecofan 800 fan during woodstove operation provides an average fuel saving of 14% for a range of test conditions studied while maintaining user comfort levels over extended periods.

INTRODUCTION

Rising fuel costs have increased the demand for efficient, solid fuel appliances as well as the associated consumer products that promise to enhance and improve the thermal performance of these appliances. These enhancements and improvements are ultimately designed to reduce fuel consumption and operating costs. Most wood stove manufacturers suggest that fuel usage can be improved, by installing a blower or a fan to redistribute the heat trapped at the back of the stove thereby improving the conditions for convective heat transfer. This will result in a more uniform heating of the room that feels more comfortable to occupants.

A review of existing standards and methodologies determined that there are no commonly accepted standard tests for conducting comparative testing of solid fuel appliances and associated consumer products, in "real life" conditions. The existing methodologies are primarily legislative driven and are directed at determining burn rates and/or stack emissions. The development of comparative testing procedures for wood stoves in "real life" situations is very complicated, as the operation of wood stoves is dynamic and steady state conditions are rarely achieved and measured values constantly change. Therefore, analyzing data to determine comparative results becomes very complicated due to the variability of the data.

In developing a standardized test methodology to properly address this situation; existing standards including "ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy"[1] "EPA Method 28 Certification and Auditing of Wood Stoves"[2], and "ISO 7730:2005, Ergonomics of the Thermal Environment"[3] were used as guidelines.

Woodstove Comparative Testing to Determine Fuel Savings with the Use of a Thermoelectric Fan to Maintain Thermal Comfort

TESTING PROCEDURE

The main focus of this testing is to determine the amount of fuel that could potentially be saved by maintaining a comfortable thermal environment for occupant through comparative testing with and without an Ecofan 800 fan. Most wood stove manufactures and consumers anticipate that a fan-assisted woodstove leads to improved thermal performance based on the fact that forced convection heat transfer induced by a fan, redistributes the warm air that is trapped around the wood stove, as well as the stagnant warm air at the top of the room. However, few studies have been performed in a controlled study to substantiate this belief. To investigate improved thermal comfort, ASHRAE Standard 55-2004 [1] guidelines was referenced in designing a controlled test facility in which air temperature, humidity and velocity sensors were installed to evaluate the thermal comfort level. The test facility, thermal environment, testing methodology and procedures are outlined as follows.

Test Facility

The test facility used in this study consists of a 9.75 meters long by 6.4 meters wide by 2.4 meters high room, constructed to local building code, within an existing structure. There is a 30.5 centimeter air gap on three sides of the test facility, between the existing structure and the outside of the test facility walls. The walls and ceiling are insulated to an R12 and R20 level, respectively. Outside air is conditioned by an air ventilation system, which is equipped with a heater and capable of circulating the conditioned outside air and maintaining a specified temperature between the test facility wall and the existing structure. The test facility is heavily instrumented with temperature sensing, fuel weight measurement and airflow velocity sensors at locations recommended by the ASHRAE Standard [1]. A computerized data acquisition system is used to log and save the data. Figure 1 depicts the test facility layout.

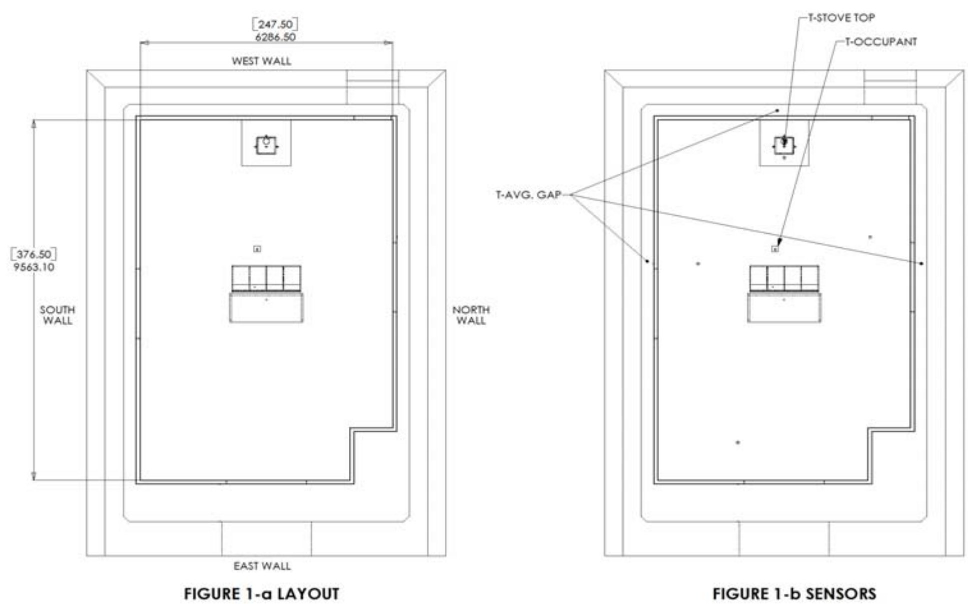


Figure 1 Test Facility Layout

As shown in Figure 1, a wood stove (Drolet Pyropak E.P.A. [4]) is placed by the west wall of the test facility. A couch was placed 3 meters in front of the stove; where the occupant Operative Temperature (T_o) is obtained.

Per ASHRAE Standard 55-2004 [1], T_o can be calculated with sufficient approximation as the mean value of air and mean radiant temperature, where relative air speed is small (<0.2 m/s) or where the difference between mean radiant and air temperature is small (<4 °C) [1]. Air temperature at the position of occupant is measured at four different heights; 0.1 m, 0.6 m, 1.1 m, and 1.7 m. These locations are at the ankle, knee and sitting/standing head positions of occupant. The mean air temperature is the average of temperature readings at these locations. Mean radiant temperature is defined as the temperature of a uniform, black enclosure that exchanges the same amount of thermal radiation with occupant as the actual enclosure [1]. To obtain radiant temperatures, a black box is placed at the head level of occupant above the couch with T-type thermocouples attached to all its faces. The mean radiant temperature is the average of these thermocouple readings. The operative temperature is then calculated from:

$$T_o = \frac{(T_a + T_r)}{2} \qquad (1)$$

where T_a and T_r are air and radiant temperatures, respectively. In addition, air temperature in other parts of the test facility was measured at 1.1 m and 2.0 m from all test facility walls and the four air gaps between the test facility and existing structure. Surface temperatures at mid point locations on the inside and outside of all walls as well as the ceiling and roof were recorded. The wood stove top, back and sides and chimney surface temperatures were also measured and recorded. Static pressure of the flue gasses in the chimney was also measured.

Test Facility Heat Loss calculation

As an index of thermal comfort, a room temperature of 22.5 °C was selected for occupant with a metabolic rate of sedentary or near sedentary and a medium clothing insulation.
The heat loss of the test facility was calculated based on the air temperature of the gap and final room temperatures of 0 °C and 22.5 °C, respectively. The power needed to raise the room temperature from initial 0 °C to 22.5 °C in a given time can be calculated from Equation 2.

$$Q = \frac{mC_p \Delta T}{t} \qquad (2)$$

where m and C_p are mass and specific heat at constant pressure of the air, t is the time interval and ΔT is the difference between the gap temperature and final temperature of the room. By substitution for the appropriate terms, the total required energy is estimated at 1152 W.

To calculate the heat loss for the test facility, thermal resistance of the walls, the two windows, and the ceiling must be evaluated. Table 1 shows the calculated values of these thermal resistances with their associated areas.

Table 1. Thermal Resistance of Test Facility Boundaries

Boundaries	Thermal Resistance (m^2 °C/W)	Area (m^2)
Walls	2.406	78.8
Windows	0.176	4.5
Ceiling	3.952	62.5

The transmission heat loss through the test facility boundaries can be calculated according to Equation (3).

$$Q_{Tr} = \frac{A\Delta T}{R} \qquad (3)$$

where A, R and ΔT, are the area, thermal resistance, and the difference between room and the gap temperatures, respectively. Substituting values for walls, windows, ceiling and ΔT in Equation 3 yields:

$$Q_{Tr} = \frac{78.8x22.5}{2.406} + \frac{4.5x22.5}{0.176} + \frac{62.5x22.5}{3.952} = 1662\,W \qquad (4)$$

Heat loss through the floor slab is through perimeter and is evaluated using Equation 5:

$$Q_{floor} = U'P\Delta T \qquad (5)$$

where U', P, and ΔT are edge coefficient, floor perimeter, and the difference between room and the ground temperatures, respectively. Heat loss through the floor is evaluated at 1799 W, assuming an edge coefficient of 2.47 W/m°C for the floor with minimum insulation and a ground temperature of 0 °C.
The total transmission heat loss will be the summation of heat loss through the boundaries of the facility is:

$$Q_{Tr} = 1662 + 1799 = 3461\,W \qquad (6)$$

The total heat loss is equal to the transmission heat loss plus the heat loss due to infiltration according to Equation 7.

$$Q_T = Q_{Tr} + Q_I \qquad (7)$$

where, Q_I is the infiltration heat loss that is caused by the air exchange between the test facility and outside. Assuming one air exchange per one hour, the infiltration heat loss would be equal to 1152 W. Substitution for appropriate terms in Equation 7 would yield the total heat loss in the test facility.

$$Q_T = Q_{Tr} + Q_I = 3461 + 1152 = 4613\,W \qquad (8)$$

Numerical Analysis of the Test Facility

To calculate and evaluate the impact of using an Ecofan 800 fan on a wood stove on the thermal environment of the test facility, a computational fluid dynamics analysis was performed. FloEFD Pro 9 ™, a commercial CFD package by Mentor Graphics [5]was used to simulate the test facility real case scenarios with and without a fan. The CFD images in Figure 2 clearly show that the warm air is more evenly distributed when a Ecofan 800 fan is used. In Figure 2a, when no fan is used, the warm air rises directly to the top, where it spreads out and stays at the top of the room. In Figure 2b however, when a fan is used warm air is pushed lower into the room by forced convection and mixes and distributes the warm air evenly.

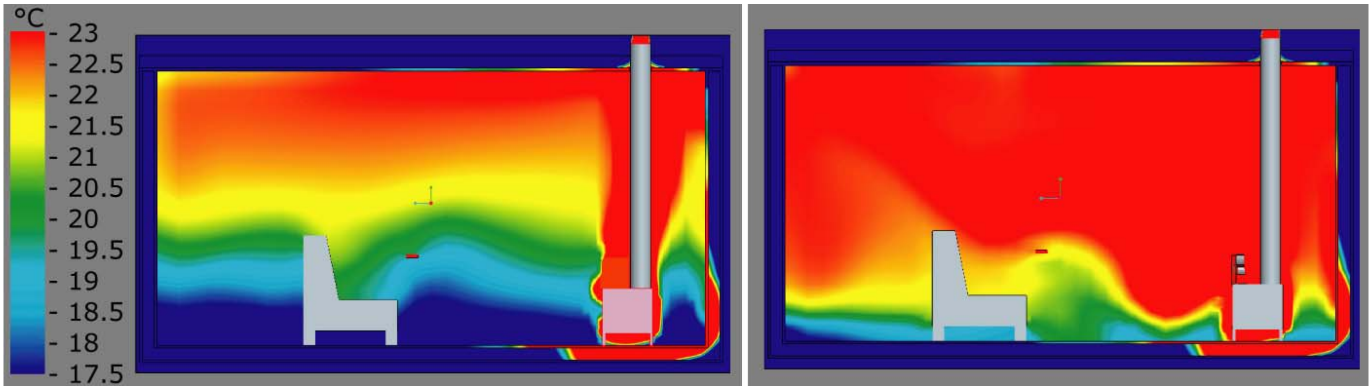


Figure 2 *CFD Image of Test Facility with a) no fan and b) with a fan*

Test Procedure

A new test protocol was developed as the objective for this investigation was unique. There have been a number of studies performed on wood stoves, but they are designed to evaluate wood stove burn rates and stove efficiency or stack emissions. However, there was no previous work designed to evaluate fuel savings where a specified thermal comfort for occupant was being maintained, using a thermo electric fan.

It is important to note that fuel savings subject of this study is not directly related to the efficiency of wood stoves. The net space heat lost to the outside ambient is the same whether or not a fan is used under the same environmental conditions. The use of a fan does not change the stove heat output, but it does circulate and distribute the warm air throughout the room. In other words, an Ecofan 800 fan draws the stagnant warm air from the top and back of a stove and forces it to the middle of the room. The enhanced forced convection heat transfer causes occupants to experience a more comfortable room temperature. This results in; less fuel reloads over the extended use of the wood stove.

It was important to design a test procedure that reflected real life scenarios, as close as possible. The intent of this investigation was to create a test method that could capture the true behavior of occupants trying to utilize the stove to achieve and maintain thermal comfort. With this consideration, long tests were designed in which the testing technician tried to maintain T_O at 22.5 °C. To accomplish this, the wood stove was started with a fixed amount of kindling and pretest ignition fire, with additional fuel loads during transition from initial test facility temperature to the prescribed room temperature, after which the test run would start. Wood fuel would only be added when the remaining fuel in the stove reached a minimum mass of 1 kg. The testing technician was allowed to control temperature by adjusting the air damper setting. In doing so, air to fuel ratio would change resulting in a change in burn rate thus affecting stove heat output. The stove was placed on an electronic scale and the mass of existing or consumed wood could be calculated at any instance of time. All data were electronically acquired by a computer data acquisition system. Upon test completion, raw data were processed to determine total consumed wood for the duration of the test and when divided by the time, burn rate in kg/hr were estimated. The burn rates were further normalized with respect to ΔT, to account for the difference in temperature gradients. A detailed description of the test procedure and data analysis can be obtained from Caframo Ecofan Fuel Usage Test Procedure document [6]

For the test protocol, EPA Method 28 for Certification and Auditing of Wood Heaters [2] was used as a general guideline. There were deviations; one of which was the type of fuel. The fuel used in this study was bark free untreated two-year air dried furniture grade white ash, as compared to Douglas fir used in EPA method 28 [2].

At the beginning of each test, 19 mm x 19 mm x 380 mm white ash (1.0 kg) is consumed for kindling, followed by 50 mm x 50 mm x 225 mm white ash (2.25 kg) for pre-ignition, and 50 mm x 100 mm x 380 mm white ash (3.25 kg) for fuel loads. All burn rates were in the category 2 of EPA method 28 (0.8 to 1.25 kg/hr).

The moisture content of wood fuel was measured by a moisture meter before placing it in the stove's firebox. The wood fuel used in this study had a moisture level ranging from 18 to 23%. The mass of moisture was deducted from the total mass to yield the wood dry mass.

An initial fuel usage test procedure was developed and several iterations of testing were competed before the procedure was finalized. The evolution of the test protocol is briefly explained in the following section.

Evolution of Wood Stove Fuel Usage Test Protocol and Procedure

Phase I: As specified by EPA Method 28, the objective of this phase was to standardize the pretest ignition procedures. Pretest ignition is required to ensure that a uniform charcoalization of the test fuel bed is achieved prior to loading test fuel charge. The pretest ignition consisted of loading crumpled newsprint, 1.0 kg of kindling and a pretest fuel load of 2.25 kg. The pretest ignition is allowed to burn until the fuel weight is consumed to approximately 20 – 25% of the weight of the test fuel charge. Stove operations and room temperature characterization was monitored and documented. At the end of this phase the pretest ignition procedure was updated and finalized.

Phase II: Test facility was brought to an initial condition of 10 °C and ambient outside relative humidity. Once pretest ignition was completed, the wood stove was charged with a single test load (3.25 kg) at a pre-set combustion air setting. Room temperature and stove operation were monitored and documented. Several tests were conducted at different combustion air settings and resulting burn rates. It was determined that the desired comfort level of 22.5 °C could not be achieved with a single fuel load from an initial room condition of 10 °C. Test procedure was revised to incorporate multiple fuel loads.

Phase III: This Phase was similar to Phase II, however, multiple fuel loads of 3.25 kg were added at set time intervals and a preset combustion air setting. Room temperature and stove operation were monitored and documented. Several tests were conducted at different combustion air settings and resulting burn rates. It was determined that the desired comfort level of 22.5 °C could be achieved with multiple fuel loads, however, as the test progressed the fuel loads were not being fully consumed during the prescribe time intervals and the wood stove became over filled with coals in various stages of combustion. After two consecutive fuel loads, additional fuel loads could not be added and combustion was becoming smothered at lower combustion air settings.

Phase IV: Testing multiple fuel loads of 3.25 kg were used, with a preset combustion air setting. However, additional fuel loads were only added when the total weight of fuel left in the Wood Stove was 1.2 kg. This ensured that there was sufficient room for the next fuel load to be added to the wood stove and that there was uniform combustion. Test runs were typically 7 to 10 hours in duration, and the desired thermal comfort temperature was achieved. However, it was determined that the resulting room temperature varied significantly due to the cyclic nature of the burn rate, the size of the fuel load (3.25 kg), and environmental influences. An analysis of the data collected determined that due to the significant variation in temperatures the data could not be used for fan/no fan comparisons. The analysis also determined that a majority of the test time and fuel consumed were used to bring the test facility from initial conditions of 10 °C to 22.5 °C. As a result actual test times at the desired comfort temperature were too short.

Phase V: Testing procedure was revised to reduce the fuel load (50 mm x 100 mm x 380 white ash weighing approximately 1.25 kg), with additional fuel loads only added when the total weight of fuel left in the wood stove was 1.2 kg and combustion air settings were pre-set. The test facility initial conditions were modified from 10 °C to 21 °C, to minimize time to transition from initial conditions to desired thermal comfort temperature. Environmental conditions for February and March indicated unusually warmer day time temperatures than normal. The dynamics of the environmental conditions significantly influenced the heat loss from the test facility and ultimately resulted in significant variation in test facility room temperature. An analysis of the data collected, determined that due to the significant variation in day time temperatures, the data could not be used for valid fan/no fan comparisons.

Phase VI: Testing was initiated in the evening and conducted through the night time. During the night environmental conditions tend to be more stable and outside temperatures are lower and more consistent. Testing procedures consisted of the reduced fuel loads, with additional fuel being added when the total weight of fuel left in the wood stove was 1.0 to 1.2 kg. In this phase, the testing technician was allowed to adjust the combustion air setting, as required to maintain a stabilized thermal comfort temperature. To compensate for unusually warm seasonal temperatures and to ensure consistent heat loss rates from the test facility; the thermal comfort temperature was defined as 22.5 °C above the stabilized air gap temperature.

RESULTS AND DISCUSSIONS

In January and February 2010, a large number of tests were conducted. However, not all the test runs could be considered in the data analysis. Some of the earlier tests were designed to characterize the wood stove and testing protocol. The test data that could be compiled and processed for thermal comfort and fuel usage interpretation is listed in Table 2. Some of these test runs are integrated continuous runs covering both fan-no fan conditions. Others are independent test pairs performed either on the same day or one day apart covering either fan or no fan condition. The results of the tests are shown in Table 2.

Table 2. Fuel Usage Test Runs

Test #	Fan	Time (hrs)	Stove Top Temp	Avg. T_O	Avg. T_{airGap}	ΔT	Fuel Burnt (Dry) kg/hr	Fuel Burnt per °C	Potential Savings Using a Fan, %
			°C						
1a	No	3.00	227.6	22.2	0.8	21.4	1.339	0.063	14
1b	Yes	3.00	204.0	22.3	1.4	20.9	1.123	0.054	
2a	No	3.00	213.7	22.4	1.1	21.4	1.196	0.056	10
2b	Yes	3.00	191.3	22.5	1.0	21.6	1.082	0.050	
3a	No	3.00	197.4	22.5	2.6	20.0	1.141	0.057	14
3b	Yes	3.00	197.0	22.3	2.7	19.8	0.963	0.049	
4a	No	4.00	179.5	22.5	3.8	18.9	1.092	0.058	28
4b	Yes	4.00	189.5	23.4	2.9	20.8	0.872	0.042	
5a	No	2.33	234.7	22.4	0.6	22.1	1.293	0.058	17
5b	Yes	2.33	206.4	22.2	0.8	21.8	1.050	0.048	
6	No	6.00	224.5	27.1	6.1	21.1	1.210	0.057	6
7	Yes	6.00	207.8	27.1	5.7	21.8	1.171	0.054	
8	No	8.00	215.4	26.5	6.6	20.8	1.245	0.060	15
9	Yes	8.00	209.6	27.3	5.5	22.1	1.135	0.051	
10a	No	3.00	241.4	27.7	5.8	22.4	1.411	0.063	12
10b	Yes	3.00	198.1	27.4	6.2	21.5	1.189	0.055	
11a	No	4.00	179.4	24.4	3.0	21.6	1.003	0.046	11
11b	Yes	4.00	178.4	23.9	3.0	21.2	0.979	0.042	

Table 2 shows a consistent trend of fuel savings from 6% to 28% with an average of 14.1% for the test runs with an Ecofan 800 fan. In analyzing the data, it is important to note the improvement that is seen in individual test pairs since they had comparable test conditions. The large degree of variability in percentages of improvement for different test pairs could be due to many uncontrolled variables inherent to unsteady nature of wood burning process. Environmental changes such as outside temperatures, humidity, barometric conditions might have contributed to the variability of the data since the individual test pairs were done over a wide range of meteorological conditions.

But a greater source of data variability is the way the wood stove was operated in the course of the experiments. Since the main criteria was to maintain the comfort temperature around 22.5 °C, the operator may have had to change the air damper setting a number of times in any given test run. Obviously, changing the air damper setting would change air to fuel ratio and that in turn change the fuel burning rate and efficiency accordingly. Change of the air damper setting is a means of controlling and maintaining temperature and reflects the real life scenario of wood stove operation. In the absence of an automatic control system, the occupant changes the air setting to reach a desirable thermal comfort. It is evident from the data that the occupant behavior to maintain a thermally comfortable environment seems different when a fan is used on the wood stove. Use of an Ecofan 800 provides a higher and more uniform comfort temperature, thus the occupant would tend to run the stove at a lower air damper setting. At lower settings, a more complete combustion takes place and efficiency of the burn increases. This result in less reloads of wood fuel over an extended use of the wood stove.

Wood fuel saving is not the only advantage of using a fan with wood stoves. A fan would create a thermal environment that is more pleasant and comfortable to occupant. ASHRAE Standard [1] has a number of scales for measuring local temperature discomfort, one of which is Vertical Air Temperature Difference. According to ASHRAE Standards [1], thermal stratification that results in the air temperature at the head level being warmer than the ankle may cause thermal discomfort [1]. In evaluating the Vertical Temperature Difference, the temperature at the ankle level could not be used since it had been observed that temperature sensing assembly at this level had touched the floor at some point and use of these values would have skewed the results. Alternatively, temperature at the knee level was used instead. Figure 3 compares the Vertical Temperature Difference for the Ecofan/no Ecofan condition in different test pairs. As it is evident, the Vertical Temperature Difference is less with a fan in all of the conducted tests. The difference is between 0.2 °C to 0.9 °C with an average of 0.5 °C. It must be noted that the difference would have been even more had the ankle level temperature been used in the evaluation of the Vertical Temperature Difference.

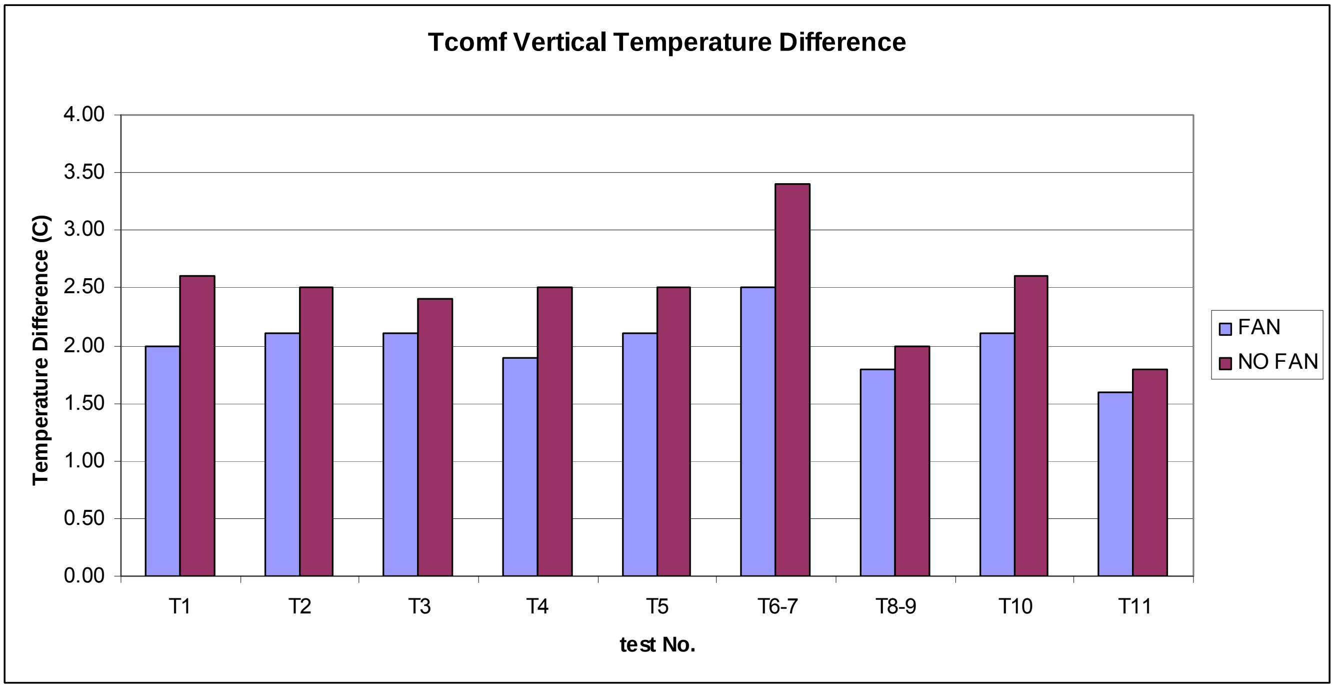


Figure 3 ***Vertical temperature differences at occupant operative temperature with and without fan***

This investigation establishes strong indications that use of a fan on a wood stove saves fuel and improves thermal comfort of occupant. However, to provide a more accurate quantitative measure of the fuel saving and thermal comfort, further studies are needed. The authors intend to design and conduct improved experiments in the fall of 2010 to adequately quantify advantages of using a fan when used with a wood stove. The new experiments will be conducted in a test facility with improved controlled environment that allows for below 0°C settings.

CONCLUSION

Test results shown in the preceding section of this report strongly suggest improvement in fuel saving and occupant thermal comfort when an Ecofan 800 fan is used with wood stoves.

In all the tests, a consistent and considerable percentage in fuel saving is reported when the thermo electric fan is used with the wood stove. The fuel saving is from 6% to 28% with an average of 14.1%. The large variability seen in the fuel saving between the experiments was expected. However, the test pairs are comparable since they were conducted in the same time frame and similar environmental conditions.

There is also a strong trend and indication that use of a Ecofan 800 fan improves the environmental thermal comfort. In every test, the Vertical Temperature Difference between occupant head and knee is less when a fan is used. The difference is from 0.2 °C to 0.9 °C with an average of 0.5 °C. The difference would have been even greater if the difference had been evaluated between occupant head and ankle.

NOMENCLATURE

A = area
C_p = Specific heat of air at constant pressure
m = Mass of test facility air
P = Perimeter
Q = Energy
R = Thermal Resistance
t = time
T_a = Air Temperature
T_o = Occupant Operative Temperature
T_r = Radiant Temperature
ΔT = Temperature gradient between test facility final and initial
U' = Edge Coefficient

Subscripts

a = air
air gap = air gap between the test facility and the original structure
floor = floor of the test facility
I = infiltration
o = operative
r = radiant
T = total

REFERENCES

1. ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy, American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

2. Method 28, Certification and Auditing Wood Heaters. Emission Measurement Center, CFR Promulgates Test Methods, U.S. EPA Technology Transfer Network, February 2000.

3. ISO 7730:2005(E), Ergonomics of the Thermal Environment, Third Edition 2005-11-15.

4. Drolet Pyropak E.P.A. Wood Stove Manual, published by Stove Builder International Inc., 1700, Leon-Harmel, Quebec City (Quebec), Canada G1N 4R9

5. Mentor Graphics®, Head Quartered in Wilsonville, Oregon, http:www.mentor.com

6. Ecofan Fuel usage Test Protocol, revision 6, Caframo Limited, June 2010.

ECOFAN FUEL USAGE TEST PROCEDURE

1. Scope

This test procedure is used to measure, evaluate and verify the effectiveness of an Ecofan 800, in reducing the quantity of fuel used under controlled conditions, at a specified burn rate, to maintain a thermal comfort level of 22.5° C, as calculated in the Ashrae 55 Standard Appendix C [1].

2. Summary of Method

Tests are to be conducted as either Integrated or Independent pairs, with comparable conditions, at specified burn rates; with and without an Ecofan. The testing procedure will consist of the following:

2.1 Pretest Ignition: The pretest ignition fire is required to establish a consistent coal bed and warm the wood stove and stack in preparation for testing. Fuel for the pretest ignition fire will be the same as the Test Fuel, as specified in the Ecofan Fuel Usage Test Protocol [2], and consists of 1.0 kg of kindling and 2.25 kg pretest fuel load. The combustion air control is to set at the full open position. Fuel weight and temperatures are to be monitored and recorded at 10 minute intervals.

2.2 Transition to Steady State: Once the pre-ignition fuel has been consumed to leave a total fuel weight of 1.0 kg, the first test fuel load is to be added. The transition period is required to warm the test facility to the specified thermal comfort level. The testing technician will monitor air/surface temperatures, BP, RH and flue draft, during transition of the Test facility from "start condition" to the desired thermal comfort level. The test run will start once the temperature at the point of occupancy (TO) has been achieved for two consecutive temperature readings.

2.3 Test Run: This is the period between Start Test and End Test, during this time period the testing technician will maintain TO at the desired thermal comfort level, plus or minus 1.5°C, for minimum of 3 hours to provide enough data for analysis. The test run will be conducted with or without an Ecofan on the wood stove. The air/surface temperatures, barometric pressure, Relative Humidity, and flue static pressure will be monitored and recorded at 10 minute intervals until the end of test.

2.4 Transition Time between Test Runs: For integrated testing there will be at least 1 hour between test runs; with and without an Ecofan. The fire is to be maintained, but no fuel will be added until the temperature drops 1.5°C below the desired thermal comfort level. All data recording will be maintained through this portion of the test but will be considered the transition data and not included in fuel usage analysis. There will be at least 12 hours between independent test runs; with and without an Ecofan. The test facility temperature will be maintained to 1.5°C below the desired thermal comfort level. No data will be recorded during this transition period and will not be included in fuel usage analysis.

2.5 End of Test Run: The test run will be ended when the To has been maintained to the pre-determined thermal comfort level, +/- 1.5°C for a minimum of 3 hours.

2.6 Data Monitoring and Recording All data will be monitored and recorded as specified by Ecofan Fuel Usage Protocol Appendices II, III, V, and VI [2].

3. Calibration

3.1 Test Equipment Calibration and Verification will be as per Quality Control and Calibration procedure [3].

4. Equipment and Supplies Summary

4.1 Test Facility – Test Facility will be as per Ecofan Fuel Usage Protocol Appendix I Test Facility Drawing

4.2 Test Equipment – Testing equipment and sensors will be as per Ecofan Fuel Usage Protocol Appendix II, III & VI.

5. Test Procedure

5.1 <u>Pretest Activities</u>:

5.1.1 Empty the stove of all ashes and take ash bucket outside.

5.1.2 Place the I-server probe outside of the test facility to record conditions outside. This will take approx 10-15 minutes for the probe to acclimatize.

5.1.1 Power on and zero the wood stove platform scale.

5.1.2 Power on and zero the fuel load counter scale.

5.1.3 Power on the PC 1 and initialize Fuel Usage Data Log Sheet; complete the yellow areas of the form.

5.1.4 Power on and zero the Merriam Digital. Set the program mode for manual data logging.

5.1.5 On Data collection PC, initialize pDaqView – shortcut on desktop may be used. Click on File and Open

5.1.6 Select Daq Configuration Fuel Usage Rev 2.CFG

5.1.7 Begin recording DAQ readings at a specific time, e.g. 2:15 rather than 2:13. To save records of official Test Run data, first stop the recording by clicking on the ARM trigger, click "yes to all", go to tools-Convert binary data-click the Format button and make sure that ASCII is checked, click OK, click Convert- convert to H:\Product\Test Records\Ecofan Fuel Usage\Testing Results and Recorded Data. It is then saved in the folder created for the month and day that the test was performed.

5.1.8 Open Channel Config file and click Play arrow.

5.1.9 Open file H:\Product\Test Records\Ecofan Fuel Usage\Testing Results and Recorded Data

5.2 Pretest Ignition Fire: The pretest ignition fire is the “start up” period, prior to Start of Test Run and is initiated approximately 30 minutes before the start of test. Pre-test ignition is to be conducted as follows:

5.2.1 Load the wood stove with 1.0 kg of kindling; consisting of; 6 x ½ sheets of crumpled newsprint, 10 pieces of 19 mm x 19 mm x 130 mm air dried white ash and cedar shake shavings. Place paper on bottom of fire box, placing kindling on top of paper and 2X2 on top of kindling.

5.2.2 Set the front damper to fully open position, open door and ignite the paper/kindling at a specific time e.g. 2:30.

5.2.3 Bring Iserver inside and hang on stand in centre of room. Allow to acclimatize.

5.2.4 Close the door and monitor the combustion. Prepare pretest ignition fuel load consisting of 5 pieces of 50 mm x 50 mm x 225 mm ash and two spacers. Measure and record the pretest ignition fuel load weight and moisture content.

5.2.5 At 10 minutes, observe and record platform scale reading, verify that that the kindling has been consumed to between 25 – 40% of its original weight. Open wood stove door, adjust coals as required and load the Pretest Ignition Fuel Load. Observe and record total weight.

Note: The wood stove door is not to be open for more than 1 minute. Verify that the Combustion air control is at the fully open position. Observe and record TOP2.

5.2.6 Prepare Test Fuel Load, consisting of 2 - 50 mm x 100 mm x 380 mm ash and two spacers, approximately 3.25 kg. Measure and record the fuel load weight and moisture content.

5.2.7 Monitor the total weight at 10 minute intervals, until the scale reading is approximately 1.0 kg. Record the platform scale reading, open wood stove, and adjust coals as required, load Fuel Load 1. Observe and record total weight. Move the combustion air control setting to the pre-determined setting, and record setting.

5.2.8 Monitor the wood stove operation at 10 minute intervals, manually log the flue static pressure on the Merriam Manometer and record all manual entries identified on the Data Log Sheet. Record observations and take photographs, as required.

5.2.9 When the scale reading is approximately 1.0 kg. Record the platform scale reading, open wood stove, and adjust coals as required, load Test Fuel Load 2. Observe and record total weight.

5.2.10 Monitor the wood stove operation at 10 minute intervals, manually log the flue static pressure on the Merriam Manometer and record all manual entries identified on the Data Log Sheet. Record observations and take photographs, as required.

5.2.11 Repeat steps 5.2.8 and 5.2.9 until the specified T_O has been achieved.

5.3 Start of Test Run (No Fan): Begins when T_O of 22.5 ºC is achieved. Once this temp has been reached, the Test Run consists of maintaining the Thermal comfort level between 21 ºC and 23 ºC while maintaining the desired burn rate for a minimum of 3 hours. The testing technician will monitor the T_O and may be required to add, before the total weight become 1.0 kg. This will only be allowed to maintain the desired thermal comfort level. The testing fuel load will consist of 1 - 50 mm x 100 mm x 380 mm ash, approximately 1.3 kg, to minimize the variation in actual burn rate. This phase of the testing is ideally be performed as integrated tests, with 2 test runs completed, one with and one without an Ecofan on the wood stove.

5.3.1 Prepare the next Test Fuel Load, consisting of 1 - 50 mm x 100 mm x 380 mm ash, approximately 1.3 kg. Measure and record the fuel load weight and moisture content.

5.3.2 Monitor the total weight at 10 minute intervals, until the scale reading is approximately 1.0 kg. Record the platform scale reading, open wood stove, and adjust coals as required, load the next Test Fuel Load. Observe and record total weight. Move the combustion air control setting to the pre-determined setting, and record setting.

5.3.3 Monitor the wood stove operation at 10 minute intervals, manually log the flue static pressure on the Merriam Manometer and record all manual entries identified on the Data Log Sheet. Record observations and take photographs, as required.

5.3.4 When the scale reading is approximately 1.0 kg. Record the platform scale reading, open wood stove, and adjust coals as required, load the next Test Fuel Load . Observe and record total weight.

5.3.5 Monitor the wood stove operation at 10 minute intervals, manually log the flue static pressure on the Merriam Manometer and record all manual entries identified on the Data Log Sheet. Record observations and take photographs, as required.

5.3.6 Repeat steps 5.3.3 and 5.3.5 until the end of test.

5.4 End of Test Run: The test run is completed when TO for a minimum of 3 consecutive hours. At the end of the test run, stop the measurement sampling, and record the final fuel weight, the run time, and all final measurement values.

5.5 Transition: There will be a minimum transition period of 1 hour between pairs of tests where the room will be allowed to drop below 21 ºC before commencing next Test Run.

5.6 Start of Test Run (Fan): Repeat from 5.8 Start of Test to 5.10 End of Test. The only difference should be the addition of the Ecofan. The objective is to provide a comparison of fuel used in test without a fan to a test with a fan under the same conditions. Testing can be reversed; with a fan compared to without a fan..

6. References and Standards.

6.1 ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy, American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

6.2 Method 28, Certification and Auditing Wood Heaters. Emission Measurement Center, CFR Promulgates Test Methods, U.S. EPA Technology Transfer Network, February 2000.

6.3 ISO 7730:2005(E), Ergonomics of the Thermal Environment, Third Edition 2005-11-15.

6.4 Drolet Pyropak E.P.A. Wood Stove Manual, published by Stove Builder International Inc., 1700, Leon-Harmel, Quebec City (Quebec), Canada G1N 4R9

6.5 Ecofan Fuel usage Test Protocol, revision 6, Caframo Limited, June 2010.

Appendix VII Fuel Usage Photo Gallery


Outside Structure


Framing of Test Facility


Insulation of Test Facility


Test Facility Dry Walled


Test Facility with Wood and Gas Stoves

Test Facility Configured for Tests

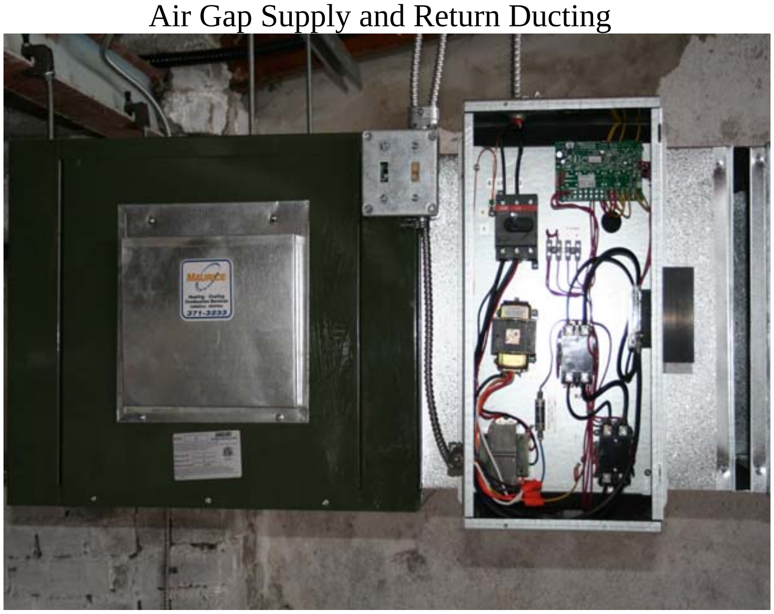
Appendix VII Fuel Usage Photo Gallery

Air Handler Installation

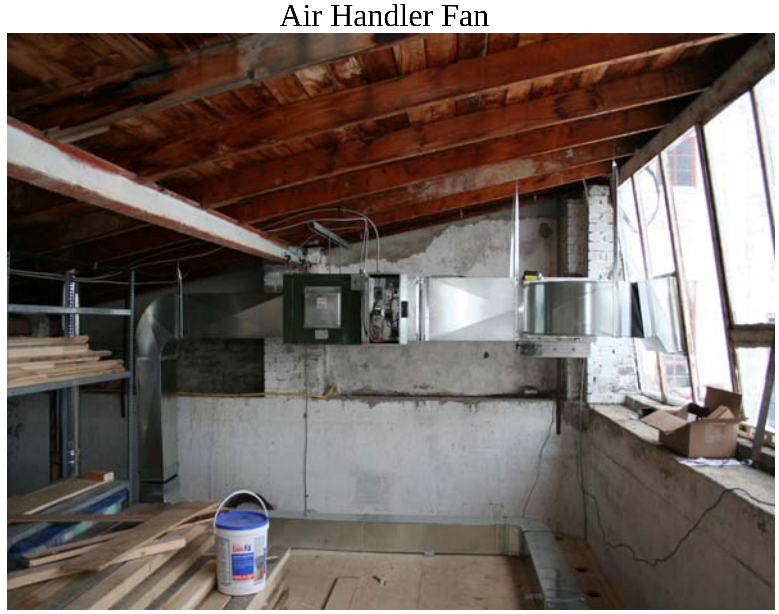
Outside Air Intake

Air Gap Supply and Return Ducting

Air Handler Fan



Air Handler Heater



Air Handler Installation Completed

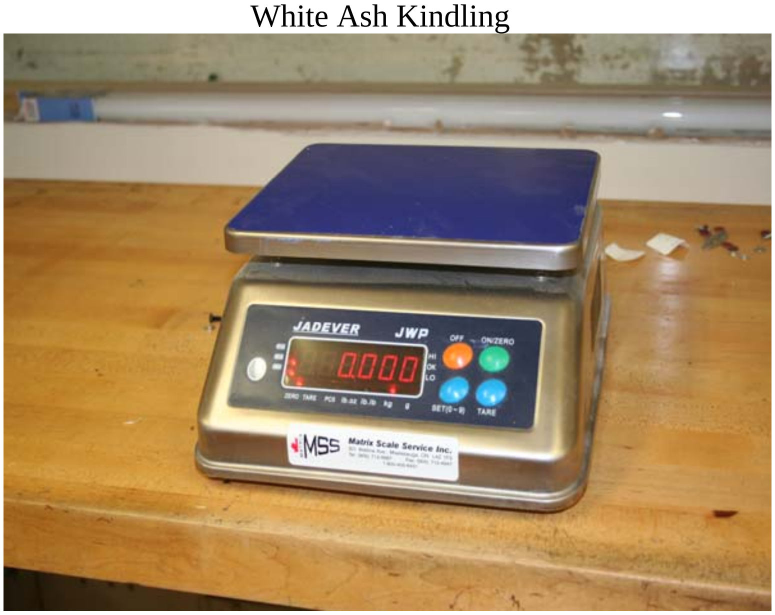
Appendix VII Fuel Usage Photo Gallery

Two Year Air Dried White Ash 2x 4 Lengths

Two Year Air Dried White Ash Cut for Testing

White Ash Kindling

White Ash 50 mm x 100 mm



Fuel Load Weigh Scale

Pre-ignition Fuel Load

Appendix VII Fuel Usage Photo Gallery

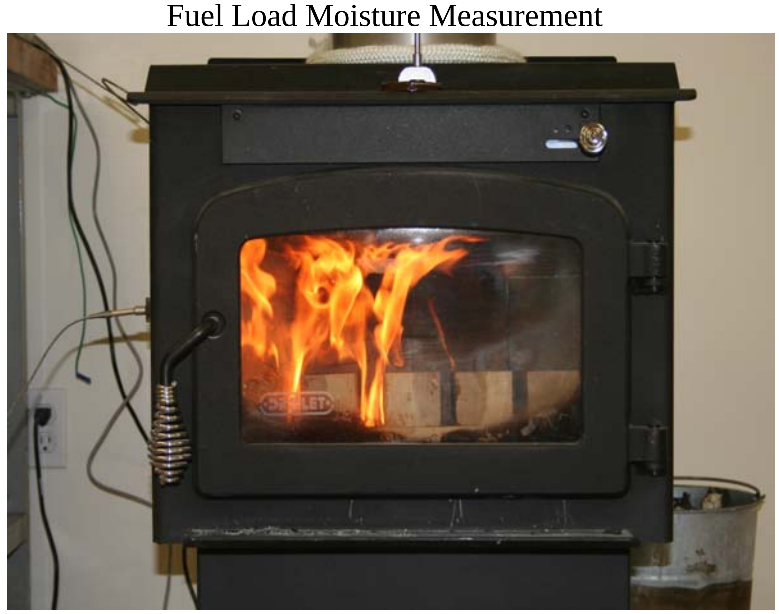
Fuel Load

Initial Fuel Load

Testing Fuel Load

Fuel Load Moisture Measurement

Pre-Test Ignition Fuel Load



Pre-Test Fuel Load Ignition

Appendix VII Fuel Usage Photo Gallery

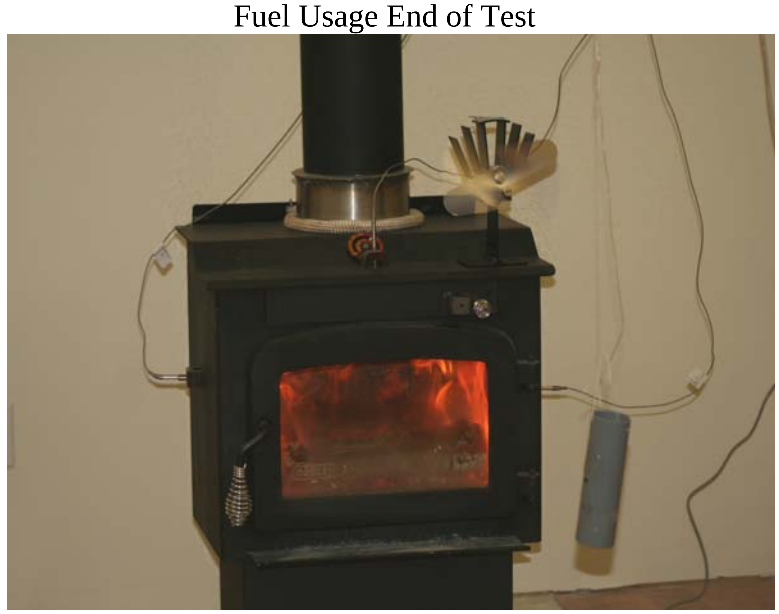
First Fuel Load Ignition

Fuel Usage Testing Underway

Fuel Usage Testing Underway

Fuel Usage End of Test

Ecofan 800 Used in Testing



Ecofan 800 in Operation