



Laboratory Evaluation of Advanced Integrated Mechanical Systems (AIMS)

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**26 Pages
2 Appendices**

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Scope and Introduction

This testing protocol applies to factory-engineered packaged natural gas-fuelled systems that perform all of the following three functions

1. Space Heating,
2. Domestic Water Heating, and
3. Ventilation with heat recovery.

An AIMS provides air filtration for a circulating airstream, and may also have provision for other space conditioning functions such as cooling, humidification etc.

Purpose

The purpose of this testing protocol is to identify basic performance and function/safety test requirements for AIMS and to establish methods for testing AIMS prototypes in a controlled laboratory environment. These procedures are intended as an indicator of AIMS performance under standardized test conditions and loads, and are not intended to provide comprehensive performance indicators for all applications and loads. When the AIMS are sufficiently developed to consider certification to appropriate appliance standards, additional testing requirements may apply.

The specific test procedures and test loads in this document are applicable to AIMS that have been designed to comply with the requirements of the industry consortium AIMS project. A number of performance requirements for AIMS were outlined in the AIMS RFP that was issued by HRAI on August 16, 1999.

This document provides specific details describing the test methods and test setups that will be used to determine whether AIMS satisfy the performance requirements from the RFP. For certain requirements from the RFP (filter performance, sound), no laboratory tests are specified, because the performance will be verified by different mechanisms. Despite the fact that laboratory tests are not required for these parameters, they are included in section 4 of this document for clarity.

Comment: Laboratory testing procedures cannot anticipate all operating conditions, system influences and control system interactions that may result from different installations or location-specific differences in system space-heating loads or DHW use profiles that an AIMS may encounter in the field. The procedures in this document should be considered in the context of providing a common basis for evaluation of the performance of AIMS prototypes, with a common set of system loads that have been developed by the AIMS consortium.

Definitions and Abbreviations

AFUE: Annual Fuel Utilization Efficiency

AIMS: Advanced Integrated Mechanical System

DHW: Domestic Hot Water

DOE: United States Department of Energy

EF: Energy Factor

GAMA: Gas Appliance Manufacturers Association

HRAI: Heating Refrigeration & Air Conditioning Institute of Canada

NRCan: Natural Resources Canada

SRE: Sensible Recovery Efficiency

Reference Publications

AIMS RFP, HRAI, August 16, 1999

ANSI Z21.10.3-1998 / CSA 4.3-M98 Standard for Gas Water Heaters, Volume III
“Storage Water Heaters, with Input Ratings Above 75,000 Btu Per Hour, Circulating and Instantaneous”.

ANSI/ASHRAE 103-1993 “Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers”

ANSI/ASHRAE 124-1991 “Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances”

ANSI Z21.10.1-1998/CSA 4.1-M98 “Gas Water Heaters, Volume I – Storage Water Heaters, with input ratings of 75,000 Btu Per Hour or less”, CSA International

ANSI Z21.10.3-1998/CSA 4.3-M98 “Gas Water Heaters, Volume III – Storage Water Heaters, with input ratings above 75,000 Btu Per Hour, Circulating and Instantaneous”

B149.1-00 “Natural Gas and Propane Installation Code”, CSA International

B 149.3-00 “Code for the field Approval of Fuel-Related Components on Appliances and Equipment”, CSA International

CAN/CSA-C439-88 “Standard Methods of Test for Rating the Performance of Heat Recovery Ventilators”, CSA International

CAN/CSA-F280-M90 “Determining the Required Capacity of Residential Space Heating and Cooling Appliances”, CSA International

“Consumers’ Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment”, Gas Appliance Manufacturers Association (published twice per year)

“Unified Canadian Guideline for Integrated Combo Systems- Design, Selection and Installation”, HRAI: July 1997

“Uniform Test Method for Measuring the Energy Consumption of Water Heaters”-
Federal Register 10CFRpart430 Appendix E, January 1,1999.

“Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers”-
Federal Register 10CFRpart430 Appendix N, January 1,1999.

Tolerances

Where direct reference is made to another standard or test method, the tolerances specified by that method shall apply. Unless stated otherwise, the required measurement tolerances shall be as follows:

Parameter	Tolerance
Temperature, absolute value	± 1 °C (±2 °F)
Temperature difference ΔT	± 0.5 °C (±1 °F)
Relative Humidity	± 5 %
Pressure	± 1 % (see note)
Power (W)	± 1 % of reading
All Other	± 1 % of reading

Note: The required accuracy of pressure measuring instruments shall be $\pm 1\%$ of reading. When this would require accuracy better than ± 2.5 Pa, the required accuracy shall be ± 2.5 Pa.

Airflow Measurement Tolerance

Airflow may be determined by any laboratory-approved method if the cumulative accuracy of the instrumentation and laboratory measurement procedure permits measurement within the following tolerance

- a) $\pm 5\%$ of the actual airflow, for airflow up to 100 l/s, or
- b) ± 5 l/s, for airflow above 100 l/s

Rationale for Testing Approach

The majority of current North American performance testing methods for furnaces, boilers, and water heaters are now harmonized with the current US DOE procedures. It is clear that the procedures do not address a variety of installation-specific issues, and the DOE procedures utilize load, system sizing, and inlet water temperature values that may not be typical of Canadian AIMS applications. Nevertheless, in both Canada and the United States, furnaces, water heaters and boilers are already subject to minimum efficiency standards, based on performance tests using the published methods. Because of this, product tests for AIMS use the recognized procedures and produce equivalent performance ratings wherever possible. As well, additional tests are identified to provide performance information for the ventilation mode and the integrated functions of AIMS products. These functions are not presently addressed by test procedures or minimum efficiency standards.

1.0 System Setup

The AIMS shall be setup in accordance with the manufacturer's instructions. In the event that instructions are not provided, the system shall be setup in accordance with HRAI installation guidelines and existing test standard requirements for the specific tests being performed.

Tests shall be performed with supply voltage maintained at 120 VAC $\pm 1\%$, and at nominally 60 Hz, or at a different voltage if specified by the AIMS manufacturer.

Air filter(s) shall be supplied by the AIMS manufacturer and installed for all tests described in this document with the exception of section 1.1.

1.1 Space Heating Test

The AFUE and parasitic energy consumption for the space heating function of the system shall be determined using the existing DOE procedures for isolated combustion systems as outlined in the US Federal Register, 10CFRpart430 Appendix N. The January 1, 1999 edition of Appendix N is available on-line from www.access.gpo.gov/nara/index.html, and it references ASHRAE 103-93.

Space heating tests shall be performed with no DHW draws. For these tests the ventilation port inlets and outlets shall be disconnected and sealed, and any supplemental ventilation fans shall be shut off to ensure that there is no ventilation flow or associated parasitic energy consumption.

The design heating requirement (DHR) for the tests shall be 14 kW (47,780 Btu/h). These tests will produce ratings data that are directly comparable to the data published by GAMA for conventional gas furnaces and space heating boilers. NO_x shall be monitored during the tests. The test data shall be reported in a detailed laboratory test report and a performance specification sheet similar to Figure 1 (Appendix B).

1.2 Water Heating Tests

Water heating tests described in this section shall be performed with no space heating load or ventilation flow, and with the water loop to the fancoil shut off and isolated to ensure that no water flow through the coil can occur. The tests will produce ratings data that are directly comparable to the data published by GAMA for conventional single function and combination water heaters. The tests will also provide information on water heater performance with reduced water inlet temperature. The test data shall be reported in a detailed laboratory test report and a performance specification sheet similar to Figure 1 (Appendix B).

Comment: The intent of the tests in this section is to check the performance of the DHW module of the AIMS as if it were a “stand-alone” water heater. Because of this, the space heating coil and ventilation ports have to be sealed to eliminate system losses attributable to thermosyphon or other energy leakage within the system. The DHW delivery of the AIMS with the space heating fan-coil not isolated is covered in Section 3.1, and a test specifically to investigate thermosyphon losses is covered in section 4.1.

Standard DHW Tests

Tests for the water heating functions of the system shall be performed using the existing DOE procedures as described in 10CFRpart430 Appendix E. The January 1, 1999 edition of Appendix E is available on-line from www.access.gpo.gov/nara/index.html. The procedure is recognized by GAMA and is used for their directory of certified water heaters.

The first hour rating test and the simulated use test shall be performed. NO_x shall be monitored during the tests.

Application Rating Tests

An additional set of application rating tests (first hour rating test and simulated use test) are required with water ΔT of 90°F (50°C).

For application rating tests, the procedures are identical to the standard DHW tests described in 10CFRpart430 Appendix E, except that the inlet water temperature shall be maintained at 45°F (7.2°C), instead of 58°F (14.4°C). The nominal water outlet temperature is 135°F (57.2°C) for application rating tests as well as standard DHW tests.

Comment: Application rating tests with increased water temperature difference are informative, and provide a useful demonstration of system reserve and performance with reduced inlet water temperature. The AIMS RFP includes a minimum energy factor for standard DHW tests. No AIMS energy efficiency or mandatory delivery requirements are incorporated for application rating tests with 90°F water ΔT .

Additional tests of the DHW delivery are required to ensure that the system can satisfy the DHW delivery requirements that were identified in the AIMS RFP. These tests and requirements are covered in section 3.1 of this document.

1.3 Combined Annual Efficiency

Combined annual efficiency (CAE) shall be calculated using the formulae from the ASHRAE 124-1991 standard, using the performance data obtained from the space heater tests and standard water heater tests described above. CAE is simply an arithmetic calculation using the results from 1.1 and 1.2 and does not require any additional testing. Computation of CAE is for information only and does not imply endorsement of the calculation procedure nor attribute any significance to the calculated value in the context of AIMS performance.

Comment: The AIMS project has no CAE-based performance requirements. However, CAE shall be calculated and included in the laboratory test report so that the data is available.

1.4 Ventilation and Heat Recovery Tests

1.4.1 Ventilation Performance: Ventilation Flowrate Tests

The system shall be installed according to the manufacturer's instructions and operated at the "continuous operating setting" with no calls for space heating or DHW heating. The supply air duct from the AIMS for the space heating function/ventilation air distribution and the exhaust air duct shall be discharged a sufficient distance from the test setup to avoid contaminating the return air or ambient air with tracer gas.

Airflow shall be measured in the supply and exhaust ducts which are provided to connect the ventilation system to the outdoors (for tests of conventional HRVs using CSA C439, these air ducts are designated as station #1 for the supply air inlet and station #4 for the exhaust air outlet). Appendix A provides a simplified test schematic of a conventional HRV that illustrates the numbering conventions for the measurement stations.

A test shall be carried out to determine cross-leakage from outdoor air to exhaust (supply air leakage). An inert tracer gas shall be injected before Station #1. The tracer gas injection rate and measurement technique used shall be sufficient that a carry-over of 0.1 percentage from station #1 into station #4 is within the measuring capability of the device being used. The amount of tracer gas added to station #1 shall not increase the overall mass flow in station #1 by more than 1 %.

Air samples shall be drawn from Stations #1 and #4 to determine the carry-over to the exhaust air stream from the supply air delivered by the AIMS. These measurements are required to verify tracer gas balance and as a crosscheck of the circulating air flowrate through the AIMS. Measurements are also required from ambient air surrounding the AIMS and return air to the AIMS to confirm the absence of the tracer gas. Contamination by the tracer gas may occur. If the results indicate more than 0.1 percentage

contamination of the ambient air or the return air, the test shall be considered invalid and repeated. The sampling equipment required is:

- Multi-point sampling grids extending into all stations;
- A means of collecting and transporting air samples to the analyser; and
- A gas chromatograph analyser or alternative instrument which satisfies the measurement accuracy criteria

A continuous air sample shall be drawn from each sampling grid. Samples shall be drawn by a laboratory-approved procedure that ensures that leakage or dilution does not occur in the sampling system.

Tracer gas tests shall be conducted with the supply air inlet and laboratory ambient temperature conditions maintained between 15°C and 35°C with no addition of heat or moisture. Relative humidity shall be maintained within \pm five percent between 20 percent and 60 percent for the duration of the tests.

Comment: Performing the tracer gas tests as described directly measures leakage from station #1 into station #4. This information is used to adjust the measured flows of ventilation air from gross values to net values. Because the measurements are made on the ventilation ports external to the AIMS, specific details concerning the internal flow paths inside the AIMS are not required.

The ventilation airflow test described above shall be repeated with the settings for the space heating/ventilation air distribution system operating at the manufacturer's maximum recommended speed setting for space heating, but with no space heating enabled.

Comment: Space heating for all tracer gas tests shall be disabled by disconnecting power to the water circulating pump and by shutting off and isolating the water loop to the fancoil to ensure that no water flow through the space heating coil can occur. The accuracy of the tracer-gas test results can be compromised by thermal transfer during the test.

The results of the tracer gas tests will be used to adjust measured gross ventilation rates to net values. For operating conditions different from the two test conditions described above, interpolation of the measured leakage shall be used, based on the measured gross flowrates in stations #1 and #4.

1.4.2 Energy Recovery Performance:

Background

Tests are required to develop ratings data which can be compared with data provided by the current CSA C439 test in order to ensure that the AIMS prototypes meet the performance requirements (60% sensible recovery efficiency at 30 l/sec for both 0°C and -25°C).

Comment: The existing CSA 439 test method provides for a steady-state test of HRV performance with an outdoor temperature of 0°C. Unlike a conventional CSA C439 test at 0°C, the ventilation/energy recovery system of an AIMS may never actually operate at a steady-state condition for the required one hour time for laboratory data collection because the 0°C temperature will be associated with a space heating load. It is likely that the existence of a space heating load will directly influence the flowrates, flow balance, and energy recovery performance of the system. For energy rating purposes, however, it is necessary to operate the ventilation/energy recovery system independent of space heating.

1.4.2.1 Non Freezing Steady-State Energy Recovery Performance Test (0°C Test)

The AIMS shall be installed in a laboratory in accordance with the manufacturer's standard installation instructions using recommended installation procedures and accessories in the same manner as for the tracer gas test described above

The energy recovery performance shall be tested under the following conditions:

- The AIMS shall be set to the “continuous operating condition” as specified by the manufacturer.
- Supply and exhaust flowrates shall be balanced per the manufacturer’s instructions and to the same condition used for the tracer gas test. If no mass balance ratio is specified the air mass flow ratio shall be balanced so that the supply/exhaust flow ratio is 1:1.
- A temperature sensor shall be installed to monitor the supply air temperature from the heat recovery module before any mixing with the AIMS space heating supply flow. This temperature shall be used as T2 for calculations.
- The resistance of the ventilation inlet and outlet ducts (stations #1 and #4) shall be adjusted so that the external static pressure at the connections to the AIMS is a minimum of 50 Pa at each duct (minimum 100 Pa differential pressure) when the system is adjusted to produce the required net ventilation capacity of 70 l/s. Once this has been done, the system shall be returned to the “continuous operating condition” settings without further adjustment of the system resistance.
- If the AIMS is not capable of providing the required net ventilation of 70 l/s with 50 Pa external static pressure applied to each of the two ventilation ducts, the manufacturer shall be notified and the test shall not be performed.

Comment: The AIMS RFP specifies a minimum ventilation capability of 70 l/s. In the event that the AIMS fails to meet this specification, the deficiency must be corrected before continuing testing.

Thermal effectiveness and heat-recovery efficiency shall be determined for the heating mode. For the heating mode, the tests shall be performed with a return air temperature (Station 3) of 22°C, and a humidity ratio of 0.0065 kg/kg dry air (40% RH). Supply-air conditions (Station 1) shall be at a temperature of 0°C and a humidity ratio of 0.0028 kg/kg dry air (75% RH).

Comment: Tests in cooling mode are not required for current AIMS products, but are included for future use. Cooling mode tests are performed with a return air temperature (Station 3) of 24°C and a humidity ratio of 0.0092 kg/kg dry air (50% RH). Supply-air conditions (Station 1) shall be at a temperature of 35°C and a humidity ratio of 0.0178 kg/kg dry air (50% RH). Total recovery efficiency is reported for cooling tests.

The test duct, measuring equipment, and the equipment under test shall be operated until equilibrium conditions are attained, but for not less than 1 h. After equilibrium is indicated, at least one hour of data shall be recorded for each test. Data shall be recorded with a maximum interval of ten (10) minutes between measurements during the test.

A test of energy recovery performance shall be performed with outdoor entering temperature set to 0°C at the AIMS entry collar, and with the AIMS set to the normal “continuous operating speed”.

A test of energy recovery performance shall be performed with outdoor entering temperature set to 0°C at the AIMS entry collar, and with the AIMS adjusted to the normal “space heating speed” for the design heating output of 14 kW.

A test of energy recovery performance shall be performed with outdoor-entering temperature set to 0°C at the AIMS entry collar, and with the AIMS set to normal “continuous operating speed”, with the resistance of the supply and exhaust ducts adjusted to produce net ventilation capacity within ten percent of the AIMS program rating point of 30 l/s.

Comment: The AIMS project requires 60 % minimum sensible recovery efficiency with net ventilation flow of 30 l/s. A test at 30 l/s is therefore required for verification of the performance requirement. However, a separate test is not necessary if the test at the “continuous operating speed” setting of the AIMS unit produces net ventilation flow within ten percent of 30 l/s.

Calculation of Energy Recovery Efficiency

The performance of the energy recovery system shall be determined using the basic formulae from the CSA C439 standard (reference Appendix A). For the calculations, fan energy shall be attributed as follows:

1. If a separate fan or fans are used for provision of ventilation airflows, the fan power(s) shall be monitored and attributed to the supply or exhaust airflow of the energy recovery system based on the location of the fan(s) in the airstreams.
2. If an integrated circulating air blower is used to provide ventilation airflow, the fan power shall be determined and attributed to the supply and exhaust airflows in proportion to the flowrates.

Example: If the circulation-fan power is measured at 400 W and the supply air from the space heating module is measured at 300 l/s, with net ventilation air balanced and equal to 30 l/s, the total airflow provided by the circulation-fan is 330 l/s (300+30: The 300 l/s supply air includes 30 l/s ventilation air). The supply

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- fan energy and exhaust fan energy shall each be set equal to $30/330 \times 400$ W or 36 W for sensible recovery efficiency calculations.
3. If the energy recovery module of the AIMS uses both a circulating air blower and a supplemental fan or fans to provide airflow through the energy recovery core, both 1 and 2 shall apply.

Comment: This treatment of fan energy is consistent with a simplified installation of an HRV, where furnace fan energy is not charged to the HRV for calculation of recovery efficiency. However, the total system electrical energy input will be measured and compared with the maximum AIMS electricity allowance for periods with no call for space heating.

1.4.2.2 Low Temperature Energy Recovery Performance Test

No separate test for low temperature energy recovery performance is required. A procedure for testing integrated functions at low temperature is described in section 2.

Comment: The ventilation flowrates and energy recovery performance may change as the operating speed of the system blower changes during on-off heating cycles. Also, low temperature operation of the ventilation system may directly or indirectly utilize available energy from the space heating system for defrost or frost prevention, and actually require combined mode operation for proper operation with low outdoor temperatures. The actual interactions between the ventilation and space heating systems depend on many parameters, which will be product-specific.

For these reasons, it may not be possible to directly determine the low-temperature performance of the ventilation heat recovery subsystem on its own. This information can be derived from an integrated mode test wherein the AIMS is subjected to a space and DHW heating requirement as well as ventilation. An integrated mode test is also necessary to verify that the AIMS is capable of satisfying the combined ventilation, space, and DHW loads for which it is designed, and to verify that system priority logic controls perform as intended.

2 Integrated Space Heating, DHW Heating and Ventilation Design-Day Test

As noted in section 1.3, the ASHRAE standard 124 provides a method for calculating combined annual efficiency (CAE) from the AFUE and water heating test data. However, tests of the combined functions shall also be performed through implementation of a combination space heating, DHW heating and ventilation laboratory test. This is the only way to determine that the system actually operates properly at system design condition. For this test, the AIMS project design loads shall be used to produce an hour-by-hour simulation of space and DHW requirements. This will be implemented in the laboratory with temperature at the ventilation supply-air inlet at the AIMS maintained at -25 °C. The water use profile for the test is the standard simulated use test from the DOE Appendix E protocol, with the total daily DHW load supplied in six consecutive hourly draws, commencing at 7AM.

Comment: The DOE SUT draw profile is a slightly more severe test of the DHW delivery system than an alternative draw schedule from the F379.1 solar DHW test standard. The

DOE profile has been selected by the AIMS consortium since the ability to satisfy the DHW draw over a six hour period, combined with coincident design-day space heating, demonstrates some system reserve for situations with less aggressive DHW draws. (One area of concern with conventional “combo” systems has been their response to morning thermostat recovery combined with simultaneous DHW draws for showers etc.). The DOE SUT also provides an extended time period with no water draw that is normally used to determine the system standby loss. This portion of the SUT will allow for analysis of the performance of the heating and ventilation systems of the AIMS units.

Hourly space-heating load shall be calculated and simulated based on a design-heating load of 14 kW. The test facility shall provide a contact closure to simulate a thermostat call for heat, monitor the space-heating output from the system and terminate the thermostat call as appropriate. System priority-logic controls for the AIMS system shall be allowed to operate normally to direct the system capacity to the appropriate loads.

Ventilation system performance shall be monitored using the external ports (stations #1 and #4), and the tracer gas test results from 1.4.1 shall be used to adjust the gross airflow measurements to net airflow.

The overall system performance shall be determined by running the hour-by-hour simulation and directly monitoring AIMS inputs and outputs. This data shall be tabulated to determine hourly energy totals. Daily energy totals shall also be determined and reported using a format similar to that shown in figure 1 (Appendix B).

It is anticipated that the simulation will have to be run for three days to obtain consecutive days of data with acceptable (within five percent) agreement (i.e. it is anticipated that day two data will approximate day three data).

The test loads for the integrated space heating, domestic water heating, and ventilation test are specified in the next section.

Comment: A 72-hour time period is consistent with the existing CSA F379.1 SDHW test, which requires that SDHW energy data for consecutive days are repeatable within five percent, and is also the same duration as specified in the current CSA C439 HRV standard for a low temperature performance test. The final 12 hours of the CSA C439 HRV test are used to determine HRV performance ratings.

2.1 Test Setup

The AIMS shall be installed and setup in accordance with the manufacturer’s instructions. The AIMS shall be setup so that all systems (space heating, DHW and ventilation) are active, and shall utilize any controls provided with the unit for the test.

Ventilation Load

The system shall be operated in the “continuous” ventilation condition, and the ventilation duct system resistance shall be adjusted to provide the net ventilation rate specified by the AIMS manufacturer, but not less than 30 l/s. During the course of the test, the ventilation rate shall be allowed to change as the AIMS controls operate. The

supply air temperature at the inlet collar to the AIMS ventilation/energy recovery module shall be maintained at -25°C for the duration of the simulation test.

AIMS controls shall be adjusted to deliver DHW at 135°F, with inlet water temperature adjusted to 58°F. Inlet water temperature to the AIMS shall be maintained at 58°F throughout the test.

The resistance of the air ducts, fan speed settings and other operational parameters shall be adjusted according to the manufacturer's specifications so that airflow through the space heating system is within specifications.

Water Use Profile

The water heater system shall have the water draws implemented from the following table. Draws shall be at 10 litres/minute, and shall be implemented at the start of the specified time interval. For instantaneous water heaters, the draw rate shall be at V_{max} (the maximum water flowrate which produces 77°F rise on a continuous basis in the standard test described in section 1.2)

Time of Day	Water Draw (l)
0 to 7AM	0
7 to 8 AM	40.5
8 to 9 AM	40.5
9 to 10 AM	40.5
10 to 11 AM	40.5
11 to 12 AM	40.5
12 to 1 PM	40.5
1PM to 12 PM	0
Total (litres)	243

Space Heating Load

The space-heating load for the integrated load test shall be 14 kW. The return-air temperature shall be 22°C.

Comment: It has been decided by the AIMS project consortium that the specified AIMS project design space-heating load of 14 kW includes an energy allowance for the sensible heat load associated with continuous ventilation at 30 l/s with -25°C outdoor air temperature and 22°C indoor air temperature.

Test Procedure

Instrumentation shall be installed to monitor the airflow and temperature supplied by the space heating coil of the AIMS, the ventilation airflow, temperature, and humidity ratio in stations #1 and #4, space heating return air temperature and humidity ratio, and the supply air temperature delivered by the heat recovery core. Instrumentation shall be installed to monitor water flow in the space heating loop, and water temperature at the inlet and outlet of the space heating coil. Instrumentation shall be installed to monitor domestic water flow, domestic water inlet and outlet water temperatures, flue temperature

and composition (CO, CO₂, NO_x), natural gas and electrical energy consumption of each fan or pump motor.

Instrumentation shall be monitored with a frequency adequate to characterize the performance and emissions of the system. It is recommended that all measurements be taken and stored at least every minute, with more frequent readings of critical parameters as necessary (for example DHW temperatures during the draws).

Comment: Although not mandatory, if available, directly recording energy meters may be installed to monitor the outputs from the space heating and DHW loops. Energy meters can serve as a check on the laboratory measurements and are useful for field measurements.

Loads:

System loads for the test are identified above. The ventilation load and the DHW load are directly implemented as described above. The space heating load shall be implemented by directly operating a contact closure to represent a thermostat call-for-heat. The contact shall be closed at the start of each one-hour interval to initiate the heating demand. The space heating thermal output from the system shall be monitored continuously by measurement of space heating airflow and temperature difference between space heating supply air and return air. The space heating call shall be continued until the space heating output totaled during the one-hour interval equals the design space heating load plus any sensible load associated with ventilation exceeding 30 l/s. The space heating load (L_V) corresponding with ventilation V exceeding 30 l/s for each hour is calculated in MJ as follows.

$$L_V = (V - 30) \text{ l/s} / 1000 \text{ l/m}^3 * 1.20 \text{ kg/m}^3 * (47^\circ\text{C } \Delta T) * 1 \text{ kJ/kg-}^\circ\text{C} * 3600 \text{ s/h} / 1000 \text{ kJ/MJ}$$

If the continuous ventilation rate V does not exceed 30 l/s, L_V shall be zero.

The design space heating load is 14 kW (50.4 MJ/h)

The required space heating output from the system is therefore $50.4 + L_V$ MJ for each hour of the simulation. The call-for heat shall be maintained until the measured space heating output for the hour is within 5 % of the calculated requirement. If the space heating system is not capable of providing the required output in the one-hour period, any deficit shall be added to the space heating requirement for the next one hour interval.

Comments:

- *The 5% factor is intended to allow the residual energy in the system to complete the call for heat in much the same way as a thermostat heat anticipator acts to shut off a thermostat prior to the call for heat being completed.*
 - *If the actual heating system stored energy results in overshoot or undershoot of the output requirement, the 5% allowance for determining when to terminate the call for heat may be varied at the discretion of the testing laboratory so that the amount of*
-

space-heating energy delivered by the system more closely approximates the simulation requirements.

- *The sensible heating load associated with ventilation is calculated with no energy recovery. The energy recovery module of the AIMS will directly contribute to the measured space-heating output from the system.*
- *This simulation approach is based on the understanding that the space-heating system will be closely matched to the design load, as required by CSA F280 and the HRAI UCG criteria for integrated (combo) heating systems. If the system space heating capacity is significantly oversized for the space heating load, different load packets corresponding with shorter time intervals such as ½ hr shall be calculated to reflect the actual system oversize factor and more closely approximate the design number of heating cycles per hour.*

Reporting

The performance of the system during the integrated load test shall be documented. The actual ventilation rate during the test will be determined and compared with the nominal “continuous” ventilation rate determined at the outset of the test. Any ventilation reduction or increase shall be documented in the test report.

Deficiencies in providing the required outputs (space-heat and DHW) as well as any system failures or control system issues that are identified during the test shall be noted in the report.

The system performance in the design-day test shall be determined by tabulating and summing the hour-by-hour measured system outputs and inputs. The performance shall also be reported using a specification sheet similar to Figure 1 (Appendix B). The combined cycle efficiency shall be calculated and reported by adding the useful outputs (space and DHW heating) and dividing by the energy inputs in consistent units (including the thermal equivalent of all electrical energy used).

3 Other Requirements and Tests

3.1 Hot Water Delivery Requirements (from AIMS RFP)

Tests shall be performed to ensure that the AIMS is capable of meeting the following DHW delivery requirements when operating with all AIMS functions and controls active, but with no space heating load or ventilation.

The tests shall be performed with inlet water temperature to the AIMS maintained at 14.4°C (58°F), and with any water thermostats or temperature controls adjusted to the same settings specified by the manufacturer for the design-day simulation tests.

The DHW flow shall be adjusted within 0.1 l/min of the value specified in the “Flow Rate” column of the table below, and DHW flow shall be continued for the time specified in column 2 of the table.

The DHW outlet temperature from the AIMS shall be monitored to ensure compliance with the requirements listed in the following table.

Water Outlet Temperature (Minimum)	Time (Minimum)	Flow Rate
57°C (135°F)	Continuous (see comment)	2.6 l/min (0.7 gpm)
57°C (135°F)	30 minutes	5.3 l/min (1.4 gpm)
57°C (135°F)	10 minutes	11.7 l/min (3.1 gpm)
42°C (108°F)	10 minutes	18.9 l/min (5.0 gpm)

Comment: For the purpose of determining compliance with the requirements, “continuous” shall be deemed to be met when the requirement is satisfied for a period of one hour without degradation of system storage temperature. For systems that cycle the heat generator during DHW draws to reheat a storage vessel or tank, the “continuous” requirement shall be deemed to be satisfied when the storage vessel is fully recharged during two complete cycles with the DHW draw operating at the specified flow and temperature.

3.2 Steady-State Space-Heating Output

Steady-state space-heating output and supply air temperature shall be determined for three combinations of heat generator/storage tank temperature, space loop water flow and blower speed to characterize the space heating capability of the system. The combination of settings will be specified prior to the tests. Tests shall be performed to collect steady-state data for a minimum of one hour for each combination of the above parameters to determine space heating output and system performance for steady-state heating modes with the system setup (water temperature, fan speed etc) to the manufacturer’s specifications.

The test duct, measuring equipment, and the equipment under test shall be operated until equilibrium conditions are attained, but for not less than 1 h. After equilibrium is indicated, at least one hour of data shall be recorded for each test. Data shall be recorded with a maximum interval of ten (10) minutes between measurements during the test

3.3 Filtration

Requirement: All air being circulated through the house or into a house by an AIMS must pass through a filter which meets one or both of the following criteria:

- Minimum of 50% average atmospheric dust spot efficiency when tested to ASHRAE 51.1, or
- Minimum MERV (Minimum Efficiency Reporting Value) of 10 when tested to ASHRAE 52.2

Method of Test:

No performance tests will be undertaken at this time. The AIMS manufacturer will submit product ratings for the filter(s) used in their AIMS to demonstrate compliance with this requirement.

3.4 Acoustics

Requirement: AIMS shall be quiet relative to typical HVAC equipment

Method of test:

No test will be performed. This requirement will be investigated during testing at CCHT.

3.5 Diagnostics

Requirement: A simple main-floor display must be provided to inform dwelling occupants when a primary function is no longer operating appropriately. This applies to a minimum of space heating, DHW heating and ventilation.

Method of Test:

No functional testing of the diagnostics is required. The test laboratory will indicate in a checklist on a specification sheet to be included with the test report whether the required diagnostics were included with the laboratory test sample or not.

Comment: Because of the short product development timelines, it is possible that the laboratory test prototype sample may not have all diagnostic functions fully operable in time for laboratory tests.

3.6 Footprint

Requirement: All AIMS and any vertical plenum ducting and piping surrounding them must fit within a rectangular closet with a floor space of 1.5m². Total height must not exceed 2.34 m (7.7 feet).

Method of Test:

No testing is required. The test laboratory will indicate in a checklist on a specification sheet to be included with the test report whether the AIMS satisfies the requirement, based on direct measurement.

3.7 Water Circulation

Requirement: Non-Segregated water heating equipment (i.e. where DHW is used directly for space heating equipment) must have automatic provision to circulate water through the space heating system at least once every 24 h when the heating system is not operational.

Method of Test:

The system shall be monitored over a period of several days (e.g. a weekend) with power connected but with no call for space heating to determine if the space heating circulating pump operates. This shall be determined using a flowmeter installed in the space heating loop or by direct monitoring of the electrical power of the space heating pump. The test laboratory will indicate in a checklist on a specification sheet to be included with the test report whether the AIMS satisfies the requirement.

Comment: If the AIMS uses segregated water for space heating, this test is not required.

4 General Tests:

It is suggested that wherever possible, these tests be performed early in the test cycle to permit repair of any problems that are identified prior to the detailed performance tests.

4.1 Thermosyphon Test

A standby loss test shall be performed with the airhandler operating at its “continuous operating speed” to provide ventilation airflow through the heat recovery module, but with no call for heat. For this test, the ventilation flows and the space heating return air conditions shall be at the ambient conditions in the laboratory. The system shall be operated at the same condition as the standby period from the standard water heater tests described in 1.2 above, but with the isolating valves for the space-heating coil opened. The test shall be performed for a period of 18 h. and the energy inputs to the system shall be monitored using the same test protocol and adjustments as the SUT test. Standby losses shall be calculated using the procedures identified in the DOE appendix E. If this test indicates greater standby losses than found in the water heater test described in 1.2, the difference shall be attributed to the space-heating coil, and the manufacturer shall be alerted. This test shall be performed prior to the Integrated Space Heating, DHW Heating and Ventilation Test to allow for correction of problems prior to the test.

Comment: This test is intended to determine whether thermosyphon thermal energy losses are occurring in the heating coil.

4.2 Short-Cycle Test

This test shall be undertaken with the AIMS setup in accordance with the manufacturer's instructions. The test shall be performed with a fully recovered system, and a storage tank (if used) shall be allowed to reach setpoint.

A space-heating load shall be implemented by closing the thermostat contact terminals. The system shall be monitored. As soon as the system burner activates, the space-heating load shall be terminated by opening the thermostat contacts.

When the burner shuts off, the space-heating contact shall be closed, and the process repeated.

This shall be repeated for at least four cycles to investigate any problems with the heat generator, venting system or other system components.

Comment: One specific area of concern that has been identified for integrated mechanical systems is the potential for a low mass water heater to short-cycle with an associated risk of premature product malfunction.

4.3 Trickle DHW Draw

A trickle DHW draw test shall be performed to investigate problems that might result from a tap not properly shut off, excessive standby losses or equivalent low loads. This test entails a continuous DHW draw at a low rate (approximately 0.2 l/min). For a flow-activated instantaneous water heater, the draw shall be at the minimum flowrate that will allow the water heater to operate.

The trickle draw shall be maintained for a period of at least one-hour with the supply water temperature maintained at 58°F.

The system shall be carefully examined during the test and any abnormal or unusual operating conditions that are observed shall be documented in the test report.

5 Function/Safety Tests

Introduction

These requirements relate primarily to the heat generation component of the AIMS. Specific test requirements are identified to verify safe operation of the combustion venting system, as well as control of delivered DHW temperature within acceptable range. These requirements have been developed specifically to enable early testing of the prototype AIMS being developed in response to the AIMS RFP, and are not intended to be a replacement for existing industry-recognized procedures.

These test requirements have been largely drawn from the ANSI Z21.10.3-1998 / CSA 4.3-M98 bi-national standard for Gas Water Heaters. It should be noted that the ANSI / CSA standard also contains other test requirements which might apply to AIMS for certification. Where specific clauses from the ANSI/CSA standard have been summarized, the clause number from the CSA 4.3 standard is given in square brackets for reference.

If the manufacturer provides a copy of a certification report which demonstrates that the AIMS uses only certified components or subsystems (e.g. heat generator component) that complies with these requirements, the tests described in sections 5.1 to 5.5 do not need to be performed, provided that the manufacturer provides written documentation that identical components and venting systems are used in the AIMS as were used for the original certification reports.

5.1 General Construction Requirements

5.1.1 Gas Ignition Systems

Automatic gas-ignition systems shall comply with the applicable construction provisions of the Standard for Automatic Gas Ignition Systems and components, ANSI Z21.20 or CAN1-6.4. [CSA 4.3-1.10.1]

5.1.2 Thermostats

A thermostat shall have no setting higher than 190°F (88°C). Thermostats on instantaneous water heaters are optional. [CSA 4.3-1.18]

5.1.3 Automatic Gas Shutoff Systems

Each AIMS shall be provided with an automatic gas shutoff system actuated by high water temperature as an integral part of the appliance. [CSA 4.3-1.21]

5.1.4 Relief Valves

Relief valves shall be readily accessible for servicing and shall comply with Standard CAN1-4.4 "Temperature, Pressure, Temperature and Pressure Relief Valves and Vacuum

Relief Valves”. Devices having pressure relief features shall not have a relieving pressure exceeding the maximum working pressure of the AIMS. [CSA 4.3-1.22]

5.1.5 Electrical Equipment and Wiring

Electrical equipment and wiring shall comply with CAN/CSA C22.2, No 3, “Electrical Features of Fuel Burning Equipment” [CSA 4.3-1.28]

5.1.6 Vent and Air-Intake Pipes of Direct Vent Systems

The design and specifications of a direct vent system shall be such that the vent and air-intake pipes are supplied as parts of the AIMS. Exterior grilles, vent caps and vent and air-intake piping shall be constructed of corrosion-resistant material or have a corrosion-resistant finish. [CSA 4.3-1.29]

5.2 Combustion

5.2.1 An AIMS shall not produce flue gases which contain carbon monoxide (CO) in excess of 0.04 percent on an air free basis, in a sample of the flue gases when adjusted to have an input rate of 106.25 percent of the manufacturer’s specified input rate, and tested in an atmosphere having a normal oxygen supply, and not more than .02 percent operating at reduced inlet test pressure. [CSA 4.3-2.4.1]

Method of test:

A water draw shall be initiated at 130°F to produce continuous burner operation. After 15 minutes of burner operation at normal gas pressure, a flue gas sample shall be drawn from the flue outlet. The gas pressure shall then be increased to produce an input of 106.25 % of the manufacturer’s specified firing rate, and a second flue gas sample shall be drawn after five minutes of operation at this input rate. The gas supply pressure to the AIMS heat generator shall then be reduced to 3.5 inches water column, and a second sample of flue gases shall be taken after five minutes.

5.2.2 An AIMS shall not produce flue gases which contain carbon monoxide in excess of .04 percent, on an air-free basis in a sample of the flue gases when tested in an atmosphere having a normal oxygen supply, when operating at normal inlet test pressure (seven inches of water column) and with supply voltage reduced to 85 percent of the manufacturer’s voltage rating. [CSA 4.3-2.4.2]

Method of test:

The AIMS burner shall be operated continuously by implementing a DHW draw as outlined in 5.2.1. After 15 minutes of burner operation at normal input rating and at normal test pressure, with supply voltage adjusted to 85 percent of the manufacturer’s rating, a flue gas sample shall be obtained and analysed for carbon monoxide and carbon dioxide.

5.2.3 Burner and pilot operating characteristics

Burners and pilots shall operate without flash back or depositing of carbon during conduct of all specified tests. Yellow tipped flames are acceptable as long as carbon is not being deposited. [CSA 4.3-2.5]

Comment: CSA 4.3 provides a number of specific tests for this stipulation. For the AIMS prototypes, it is considered appropriate to apply this requirement to all tests performed in the laboratory. The combustion chamber of the AIMS heat generator shall be visually examined at the start and end of laboratory testing for any evidence of carbon deposition during the tests. If carbon deposition is observed at the conclusion of the laboratory tests, the manufacturer shall be advised and it shall be documented in the laboratory test report.

5.2.4 Automatic adjustment of input based on water flow

AIMS having controls to automatically provide multi-rate control of the input rate through adjustment of DHW flow shall comply with the following when adjusted to the minimum input rate permitted by the controls. [CSA 4.3-2.5.9]

Method of test:

At normal gas inlet pressure (seven inches WC), and with the AIMS installed as specified by the manufacturer, the water flow rate through the appliance shall be reduced to the point just before the gas flow to the burner is automatically shut off by the controls. The appliance shall be examined for carbon deposits, accumulation of explosive gas-air mixtures, and safe operation.

5.3 Temperature Control

5.3.1 The DHW outlet water temperature of an AIMS prior to any mixing valve shall not exceed 200°F (93.5°C) at any continuous water flow rate. [CSA 4.3-2.14.3]

Method of test:

The AIMS shall be supplied with water at 70°F ± 2°F. Thermostats shall be adjusted to their maximum setting, and a water flow sensing device (when provided) shall be adjusted to minimum flow. With the appliance operating at normal inlet test pressure, the outlet water supply shall be gradually restricted to provide different water flow rates, and the outlet water temperature shall be measured as close to the outlet connection as practicable. At no time shall the measured outlet water temperature exceed 200°F during this test.

Comment: This test should not be interpreted in the context that 200°F would be a safe operating temperature for DHW. The test is intended to ensure that steam cannot be produced in the AIMS heat generator under any circumstances where it contains water. For this reason, the water temperature from the AIMS heat generator shall be measured prior to any tempering for this test.

The AIMS RFP specifies maximum DHW temperature of 140°F (60°C) after any anti-scald mixing valve, which must be supplied with the AIMS, if it is required in order to comply with the maximum temperature requirement.

5.3.2 DHW Temperature Limit

The AIMS DHW temperature shall not rise more than 30°F (16.5°C) above the initial water temperature when subjected to the following test. [CSA 4.3-2.15]

Method of test:

The DHW thermostat for consumer adjustment of discharge temperature shall be set to its maximum setting. Thermostats not intended for consumer adjustment shall be tested with their settings adjusted according to the manufacturer's specifications or "as received" by the test laboratory. A quick acting on-off valve shall be installed at the DHW outlet connection of the AIMS. A flow-restricting valve shall be installed at the outlet of the on-off valve and adjusted to maintain a flow rate of $5 \pm .25$ USGPM ($18.9 \pm .25$ l/min) during test draws, with inlet water pressure maintained at 40 psi. (275.8 kPa) for the DHW draws. Inlet water temperature for the tests shall be maintained at $65^\circ\text{F} \pm 5^\circ\text{F}$. The AIMS shall be operated at the normal inlet test pressure until the thermostat reduces the gas supply to a minimum. Water shall then be withdrawn at the specified rate until the thermostat functions at which time the DHW draw shall be terminated, and the water outlet temperature shall be recorded. This shall be repeated until a constant outlet water temperature is attained. The maximum water outlet temperature shall not be higher than 30°F above the initial temperature, and must not exceed 190°F.

Comment: This clause addresses "stacking" in a DHW storage tank due to thermostat deadband, thermal stratification etc. The test is useful since it is anticipated that the majority of AIMS will utilize some form of thermal storage, either in the form of a DHW storage tank, or in the heat generator or potable-water heat exchanger.

5.4 Draft Tests

5.4.1 General Requirement

The construction of an AIMS shall be such that its performance is not impaired by wind effects or vent blockage. This provision shall be deemed to be satisfied when the AIMS complies with all requirements in sections 5.4 and 5.5. [CSA 4.3-2.25]

Comment: The AIMS RFP requires that combustion equipment be direct vent or induced draft. AIMS are also required by the RFP to have "no spillage of combustion products into the living space when the living space is depressurized relative to outdoors. Induced draft vented appliances must be capable of positive shutdown in the case of a venting blockage."

The following clauses, derived from CSA 4.3, are intended to ensure that the combustion product venting requirements from the RFP are satisfied. The methods are consistent with the ANSI Z21.13/CSA 4.9 proposed draft standard for gas-fired low-pressure steam and hot water boilers.

5.4.2 Vent Blockage

With the flue outlet or vent outlet blocked to any degree up to and including complete closure, the concentration of carbon monoxide in an air-free sample of flue gases shall not exceed .04 percent when the AIMS is tested in an atmosphere having a normal

oxygen supply. Should burner outage occur, raw gas shall not be forced into the combustion chamber on reopening the venting system. [CSA 4.3-2.25.1]

Method of test:

When the appliance incorporates a control to automatically shut off the main burner gas supply under blocked flue conditions, the test shall be performed with the control setting which will allow main burner operation with the greatest degree of blockage, as specified by the manufacturer.

The AIMS shall be operated at normal inlet test pressure for at least 15 minutes. The area of the flue outlet shall then be gradually decreased to the lowest point at which the control will allow main burner gas flow. A sample of flue gases shall be taken and analysed for CO and CO₂.

In case of flame outage, the blocked condition shall be maintained for 3 minutes to allow for operation of safety devices, and then removed and observations made.

Comment: This clause is essentially identical to CSA 4.3-2.25.1, edited to remove references to draft diverting devices, since it is unlikely that a draft diverting device would be capable of satisfying the AIMS requirement for no spillage with a minimum depressurization of 30 Pa.

5.5 Wind Test

5.5.1 Ignition

Installation:

The AIMS shall be installed with its venting system and air supply in place. Tests shall be conducted at normal gas test pressure and system voltage.

Requirement:

The burner system shall be capable of being ignited in accordance with the manufacturer's instructions and shall not become extinguished when the AIMS is placed in operation in a normal manner while exposed to a wind of 40 mile per hour (17.88 m/s) [CSA 4.3-2.28.2]

Method of test:

A 40 mile per hour wind {0.66 in. (164 Pa) static pressure}, measured in a vertical plane 18 inches (457 mm) from the windward surface of the AIMS shall be directed over the area of the air intake and vent terminal of the AIMS. At the discretion of the testing agency, the wind test may be repeated with the wind targeted in other directions.

A DHW draw shall be implemented to cause the AIMS heat generator to operate. The pilot and main burner shall ignite under the above wind condition, and the main burner shall not become extinguished during a five minute period. The gas supply to the main burner shall then be shut off. After a period of at least 30 seconds, the main burner shall be turned on and the main burner gas shall be ignited by the AIMS without excessive delay.

Comment: This is developed from two clauses in the CSA 4.3 standard which require a pilot to be capable of being ignited with a 10-mph wind, but then be capable of igniting the main burner with a 40-mph wind. In view of the AIMS RFP requirement that systems shall not use a standing pilot, the entire ignition system must be capable of igniting with a 40-mph wind load.

5.5.2 Combustion Characteristics

The operating characteristics of an AIMS heat generator shall not be adversely affected when exposed to winds from zero to 40 miles per hour (17.88 m/s)

Method of test:

A DHW draw shall be implemented to cause the AIMS heat generator to operate. The burner shall be operated at normal inlet test pressure and system voltage, and the burner firing rate shall be adjusted in accordance with the manufacturer's instructions to produce the rated input. The system shall be operated until a constant flue temperature (within 10°F in five minutes) is obtained, with the venting system operating in a still-air condition. A flue gas sample shall be obtained and analysed for CO and CO₂ (normal test pressure result).

The gas pressure regulator shall then be adjusted to produce an input rate of 106.25 % of the rated input and the heat generator shall be operated at this condition for at least two minutes with the vent system operating in still air. Following this time, a flue gas sample shall be secured and analysed for CO and CO₂ (increased manifold pressure result).

The gas pressure regulator shall be readjusted to produce the manufacturer's rated input. The vent system shall be subjected to a range of wind loads between zero and 40 mph. (measured as described in 5.5.1) and the AIMS heat generator shall be operated until constant flue temperature is obtained for each step of wind load. A flue gas sample shall be obtained and analysed for CO and CO₂ for each test.

Requirements:

The CO₂ concentration for any of the tests with the venting system subjected to wind loads shall not be less than 50% of the CO₂ produced at normal test pressure and with still air.

The CO₂ concentration for any of the tests with the venting system subjected to wind loads shall not exceed by more than 0.3 % the CO₂ produced by the heat generator when operated at increased manifold pressure.

The CO concentration in an air-free sample of flue gas shall not exceed 0.04 % for any of the tests described in 5.5.2

Comment: This is based on CSA 4.3, clauses 2.28.3 and 2.28.4. The number of discrete steps of wind tests are not specified in the CSA standard. For AIMS prototypes, a minimum of three wind load tests at approximately 10 mph, 25 mph and 40 mph directly onto the combustion air/venting system terminations are required.

5.6 Hydrostatic Test

A hydrostatic test is required to ensure that the AIMS does not leak, rupture or become damaged.

Test Requirement: Water carrying parts of an AIMS shall withstand without rupture or visible permanent deformation a hydrostatic test pressure of two times the manufacturer's rated maximum working pressure, but not less than 300 psi (2.07 MPa), [CSA 4.3-2.31.2] Water carrying parts of an AIMS stamped with an ASME symbol indicating compliance with the ANSI/ASME Boiler & Pressure Vessel Code are exempt from this requirement.

Method of test:

The DHW portion of an AIMS shall be connected to a water supply through a pump system incorporating a calibrated pressure gage graduated in increments of not more than 5 psi. (34.5 Pa), a check valve, and shutoff valves. All tapped openings shall be sealed by use of threaded fittings. If the system is equipped with a pressure relief valve, it shall be removed, and the opening sealed. The DHW system shall be filled with water at 70°F ±5°F at atmospheric pressure, taking care to avoid any pocketing of air in the system.

Hydrostatic pressure in the system shall be gradually raised by means of the pump until the required hydrostatic or rated line pressure is reached. This pressure shall be maintained for 30 minutes. At the end of this time, the pressure in the system shall be reduced to atmosphere and the system shall be examined for evidence of rupture or visible permanent deformation. At no time during the application of the hydrostatic pressure during the test shall any leakage of water from the storage vessel be observed

Comment: This is a blend of several clauses in CSA 4.3. Later in their development cycle, AIMS may require a further hydrostatic pressure test for their DHW storage vessels, if these components are not ASME stamped. For this reason, a description of the more rigorous but inherently invasive hydrostatic pressure test for storage vessels is included in this comment, for information purposes only. If all potable DHW components (including storage tank, if used) are ASME approved and stamped, no hydrostatic test is required, according to both the CSA 4.1 and 4.3 standards. Conventional natural gas and electric DHW storage tanks are pressure tested to 300 psi. pressure, but are not ASME marked.

Hydrostatic test for storage vessel (for information only)

Unless the DHW storage vessel of an AIMS is marked with an appropriate ASME symbol, and a working pressure no less than the marked maximum working pressure of the AIMS, the storage vessel shall withstand a hydrostatic test pressure of two times the manufacturers rated maximum working pressure, but not less than 300 psi. (2.07 MPa), without developing leakage or permanent deformation. [CSA 4.3-2.31.1]

Method of test:

The storage vessel shall be connected to a water supply through a pump system incorporating a calibrated pressure gage graduated in increments of not more than 5 psi. (34.5 Pa), a check valve, and shutoff valves. All tapped openings shall be sealed by use of threaded fittings. If the vessel is equipped with a pressure relief valve, it shall be removed, and the opening sealed. The storage vessel shall

be filled with water at 70°F (21°C) at atmospheric pressure, taking care to avoid any pocketing of air in the vessel.

Prior to imposing hydrostatic pressure on the vessel, measurements of the storage tank shall be obtained to determine its physical dimensions. These measurements shall include circumferential measurements taken at intervals along the vessel of not more than twelve inches (305 mm), taken using a method that permits measurement to be made directly to 0.001 inch. Extensometers reading to 0.001 inch shall be placed with the movable spindles against the top and bottom heads of the storage vessel.

Hydrostatic pressure in the system shall be gradually raised by means of the pump until the required hydrostatic or rated line pressure is reached. This pressure shall be maintained for 30 minutes. At the end of this time, the pressure in the system shall be reduced to atmosphere and the dimensional measurements shall be repeated. Circumference measurements shall not vary by more than 0.2 percent of the corresponding measurement taken prior to the application of the test pressure. Top or bottom head deflections as shown by the extensometers shall not exceed 0.5 percent of tank diameter. At no time during the application of the hydrostatic pressure during the test shall any leakage of water from the storage vessel be observed.

5.7 Vent Leakage Tests

Combustion Vent and Air Supply Leakage

Test Requirement: Joints in combustion air and vent systems shall be tight. This shall be deemed met if leakage from the system is not in excess of the limits specified in the following method of test. For AIMS which do not use sealed combustion systems, the maximum air leakage requirement for the air intake section shall not apply.

Method of test:

The vent and air intake terminals shall be removed and the entrance of the air intake section sealed at the point at which it enters the combustion chamber. The entire system, including the combustion air and intake sections shall be installed and sealed in accordance with the manufacturer's instructions.

The flue outlet and combustion air inlet shall be sealed at the point at which they would normally be connected to the vent and air intake terminals. The sealing means shall incorporate fittings suitable for introducing air to the combustion chamber vent and air intake sections and shall include provisions to determine the air static pressure in each section.

The internal static pressure in each section shall be determined using a pressure measurement instrument with measurement accuracy of at least .01 inch water column (2.5 Pa).

A suitable supply of clean air shall be introduced into the combustion vent system through a calibrated metering device. The fitting for the other section shall be open during this test.

The air supply into the section shall be adjusted to produce an internal air pressure of 0.1 inch water column (25 Pa) greater than the normal system operating pressure, and the air flow rate required to produce this pressure shall be recorded as the section leakage (in cubic feet per hour).

This procedure shall be repeated for the air intake section.

Test Requirement

The maximum air leakage for each section shall not exceed the following:

$$L_C = .02 * 15 * I$$

$$L_A = .08 * 15 * I$$

Where:

L_C is the allowable leakage rate from the combustion chamber-vent section, in ft³/h

L_A is the allowable leakage rate from the air intake section, in ft³/h

The factor 15 is based on formation of approximately 15 ft³ combustion products (including 50% excess air) per 1000 Btu/h input

I is the AIMS burner input (in thousands of Btu/h)

The calibrated accuracy of the air-metering device shall allow measurement of the maximum allowable leakage flows for each section within $\pm 2\%$ of reading for these tests.

Comment: This test is a blend of clause 2.35.3 from CSA 4.3 and clause 2.30.7 from the current draft of CSA 4.9, both intended for application to direct vent systems. The test as described verifies that the combustion air supply and venting system (including the combustion chamber) are tight. The allowable leakage for the combustion venting section is less than for the air supply section.

6 Depressurization Spillage Test

Rationale: The AIMS RFP identifies that systems shall have no combustion spillage when depressurized to at least 30 Pa. A review of published appliance standards did not reveal a suitable test to verify this requirement. The test protocol that follows is based on a 1993 research report prepared by CGRI entitled "Resistance of side-wall vented appliances to combustion product leakage when operating within depressurized structures".

Depressurization test requirement:

AIMS shall have no more than 2% spillage of the combustion products into a test room when operated in accordance with the following method of test.

Method of test:

The AIMS shall be setup in a test room that is equipped with an exhaust fan and is sufficiently sealed to allow the test room to be evacuated to produce 30 Pa (0.12 in water column) depressurization with the AIMS combustion module operating. The space-heating supply air and return air ducts and ventilation air ducts shall be removed from the AIMS for this test if required to install the AIMS inside the test room. The combustion air inlet and vent terminals shall be installed at the wall of the test room and connected to bring combustion air from the adjacent space and discharge the vent products into the adjacent space.

The adjacent space shall be adequately ventilated to ensure that the combustion products do not contaminate the space. A supplemental gas-capture and exhaust apparatus may be used to remove the combustion products from the space adjacent to the test room,

provided that the CO₂ content and flow of the combustion products in the AIMS venting system is not affected by the operation of the apparatus.

A sampling port shall be installed to monitor the CO₂ level inside the test room

The test room fan shall be operated and adjusted to produce a static pressure in the test room of 30 Pa below the surrounding area. This pressure shall be monitored in a location determined by the test laboratory but within 1 m of the AIMS combustion module. The pressure shall be maintained at -30 Pa within ± 2 Pa for the duration of the depressurization test by adjusting the flow through the test-room exhaust fan. The airflow through the test-room exhaust fan shall be measured during the test.

A DHW draw shall be implemented to cause the AIMS burner to operate. The DHW flowrate shall be adjusted as necessary to maintain steady firing of the AIMS combustion module. If the AIMS firing rate is capable of modulation, adjustments shall be made according to the manufacturer's instructions to maintain the system at high firing rate for the duration of the depressurization test.

The AIMS fuel input rate and CO₂ content and temperature in the combustion venting system at the vent termination discharging to the adjacent space shall be monitored during the test.

The CO₂ level in the test room and the adjacent space shall be monitored during the test. The test shall be continued until steady state is obtained. Steady state shall be accepted when the firing rate, net vent temperature, vent CO₂, test room CO₂, adjacent area CO₂ and test room exhaust fan flow do not vary by more than $\pm 2\%$ for three sets of readings taken over a fifteen minute period.

Calculations:

The CO₂ volume leakage into the test room shall be calculated in CFM as follows

$$\text{Leakage} = (\text{CO}_2 \text{ (test room)} - \text{CO}_2 \text{ (adjacent room)}) * \text{Exhaust Fan Flow} * \text{Scaling Factor}$$

[The scaling factor is required to convert units to produce the leakage in CFM]

The CO₂ generated by the combustion process, in SCFM shall be determined as follows

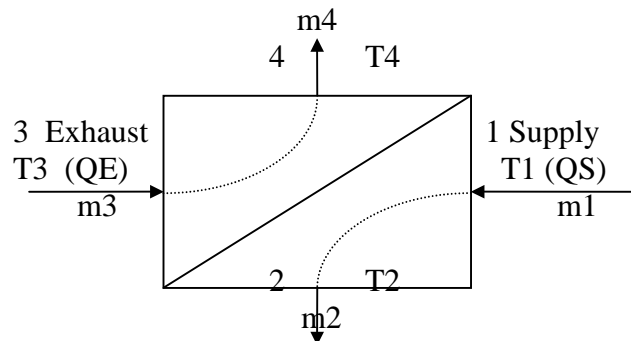
$$\text{CO}_2 \text{ generated by AIMS} = \text{Input rate (BTU/h)/1000} * .0167 \text{ SCFM/1000 Btu/h}$$

$$\text{Spillage} = \text{Leakage} / \text{CO}_2 \text{ generated by AIMS}$$

Comment: While the RFP specifies no spillage with 30 Pa depressurization, it is considered impractical to validate this requirement. The limit of 2% spillage for this test is consistent with the allowable leakage for the combustion-venting portion of the existing vent-leakage test described above (note, however that the tests are performed at different pressures).

Appendix A
Simplified Schematic of an HRV and Calculation Procedure
(Calculations from CSA C439)
Two pages

Simplified schematic of a Heat Recovery Ventilator (HRV)



This schematic illustrates a simplified heat recovery ventilator. For the sake of simplicity, defrost energy, casing energy transfer and leakage have been ignored in the diagram. As seen in the schematic, all measurements are performed in the ducts external to the unit. The designations 1 to 4 represent the measurement location identifications used in the CSA standard.

- Station 1 is “fresh” air from outdoors to the heat recovery module.
- Station 2 is “fresh” air after conditioning by the heat recovery module
- Station 3 is exhaust air from indoor space to the heat recovery module
- Station 4 is exhaust air to outdoors after passing through heat recovery module

The formula for sensible energy recovery efficiency from equation 11 of the CSA 439-88 standard is as follows:

$$E_{SHR} = \frac{\left(\sum_{i=1}^n M_{s,i} \times C_p \times (t_{5,i} - t_{1,i}) \times \Delta\theta \right) - Q_{SF} - Q_{SH} - Q_C - Q_D - Q_L}{\left(\sum_{i=1}^n M_{max,i} \times C_p \times (t_{3,i} - t_{1,i}) \times \Delta\theta \right) + Q_{EF} + Q_{EH}}$$

Where:

- E_{SHR} = sensible heat-recovery efficiency
 - n = number of times that data are recorded
 - i = i^{th} time that data are recorded
 - M_s = mass flowrate of outdoor air at Station 2 = $M_2 \times (1 - R)$
 - M_2 = mass flowrate of air measured at Station 2, kg/s
 - R = exhaust-air-contamination ratio as calculated in Clause 9.3.1.1
 - C_p = specific heat of air, kJ/kg-°K
 - t_1, t_3 = dry-bulb temperature at Stations 1 and 3 respectively, °C
 - t_5 = net outdoor airflow temperature at Station 2, as calculated in Clause 9.3.3.7, (corrected for leakage) °C
 - M_{max} = maximum of M_s or M_e
-

Appendix A
HRV Calculations and Numbering Convention from CSA C439

$$M_e = \text{mass flowrate of exhaust air at Station 4} = M_4 \times \left(\frac{B'_4}{B'_3} \right)$$

M_4 = mass flowrate of air measured at Station 4, kg/s

$\Delta\theta$ = time between flow measurements, s

Q_{SF} = energy input into supply airstream attributed to fan(s), kJ

Q_{EF} = energy input into exhaust airstream attributed to fan(s), kJ

Q_{SH} = energy used by heater in supply airstream, kJ

Q_{EH} = energy used by heater in exhaust airstream, kJ

Q_C = casing heat transfer, as calculated in Clause 9.3.3.4, kJ

Q_D = defrost energy use, as described in Clause 9.3.3.5, kJ

Q_L = heat loss due to casing leakage, as calculated in Clause 9.3.3.6, kJ

For calculation of sensible energy recovery efficiency for an AIMS, this formula can be used (refer to section 1.4.2 of this document for AIMS fan energy allocation).

Appendix B

Example of AIMS Specification Sheet

1 page

Figure 1: AIMS SPECIFICATION SHEET (Preliminary)

Testing Agency: _____	Model Designation: _____
Date Tested: _____	Serial Number: _____
Manufacturer: _____	Options Installed: _____
Address: _____	_____
Tel & Fax: _____	Nameplate Requirements: _____ Volts _____ Amps
	Internet: _____

Energy Performance

Space Heating: AFUE _____ % PE _____ W Eae _____ kWh/year
DHW Heating: First Hour (77°F Rise) _____ USGal. First Hour (90°F Rise) _____ USGal.
Standard Test (77°F Rise) EF _____ Standby _____ % _____ W Recov. _____ %
Application Test (90°F Rise) EF _____ Standby _____ % _____ W Recov. _____ %

Other Tests

DHW Outlet Temperature (Minimum)	DHW Flow Rate	Time (Minimum)	Complies	
			Yes	No
57°C (135°F)	2.6 l/min (0.7 gpm)	Continuous		
57°C (135°F)	5.3 l/min (1.4 gpm)	30 minutes		
57°C (135°F)	11.7 l/min (3.1 gpm)	10 minutes		
42°C (108°F)	18.9 l/min (5.0 gpm)	10 minutes		

Summary:

Complies with DHW Requirements Yes No
 Complies With Space Heat Requirements Yes No
 Combined Space and DHW: CAE _____ %

Ventilation

Ventilation Capacity: Continuous: _____ l/s _____ Pa Fan Power _____ W
Intermittent: _____ l/s _____ Pa Fan Power _____ W
Ventilation Energy Recovery Rating (SRE at 0°C) _____ % at _____ l/s _____ W
Ventilation Energy Recovery Rating (SRE at 0°C) _____ % at _____ l/s _____ W
Ventilation Energy Recovery Rating (SRE at 0°C) _____ % at 30 l/s _____ W

Design-Day Load Simulation (data from final day)

Energy Outputs: Satisfies Loads ?
Space Heating Provided _____ MJ/day _____ kW Yes No
DHW Provided _____ l/day _____ MJ/day _____ kW Yes No
Ventilation provided _____ l/s with _____ °C Inlet Yes No

Energy Inputs

Natural Gas _____ m³/day _____ MJ/day
Electricity _____ kWh/day _____ MJ/day _____ W

Overall Performance: (Outputs/Inputs *100) _____ % Min. Space Heating Supply Temp. _____ °C
 Min. DHW Supply Temp. _____ °C Delayed fan-startup? Yes No

Function/Safety Tests -----Pass ----- Fail

Test Agency Comments:

Checklist

Filter Performance Verified ----- Yes ----- No
 Footprint Verified ----- Yes ----- No
 Diagnostics Verified ----- Yes ----- No
 Water Circulation Verified ----- Yes -----No ----- N/A
 DHW Priority Verified ----- Yes ----- No

Conversions:
 249 Pa = 1" of Water : 0.47 l/s = 1 cfm : 1 kW = 3412 Btu/h

Reference Report: xxx-xxxx
 Sample No: ZZ-ZZZZ

Testing has been performed in accordance with approved AIMS testing protocols and was conducted in accordance with normal professional standards. Operation with different air delivery systems, thermal loads or control system settings may result in different performance. Consult the full test report for detailed performance information.