3024

#3024

A REVIEW OF STANDARDS AND PRODUCT CERTIFICATION
PROGRAMS FOR HEAT RECOVERY VENTILATORS

Bede W. Wellford, Airxchange, Inc.

ABSTRACT

As building envelopes are constructed with greater attention to airtightness details and infiltration is reduced to a minimum, there is an increasing need for mechanical ventilation to dilute and remove excess moisture and other contaminants in the indoor air. Heat recovery ventilators (air-to-air heat exchangers) are specified in residential applications to meet these needs without compromising the energy efficiency of the structure. Recent years have seen the rapid development of standards and product certification programs for heat recovery ventilators.

A variety of information is required for the proper selection, design and installation of heat recovery ventilation systems. This paper focuses on the development of standards to respond to this need, culminating with the Home Ventilating Institute's introduction of voluntary performance testing and product certification procedures. The evolution of the performance testing standards beginning with ASHRAE 84 is addressed, as is the development of installation standards for this equipment. An in-depth discussion of the information furnished by the Home Ventilating Institute Certification Program is provided.

Finally, the relationship of these standards and programs to other standards, codes and regulatory programs is examined. Mechanical ventilation is required by code in several states, in municipalities and in Canada. The Bonneville Power Administration publishes specifications for heat recovery ventilators installed in the Pacific Northwest and Energy Mines and Resources Canada promulgates installation guidelines for mechanical ventilation systems installed in their energy efficient buildings program. The success of industry standards and product certification will be measured in terms of how well they respond to the needs of the consumer, installer, designer, and regulatory authority specifying heat recovery ventilation.

INTRODUCTION

In the late 1970's, the custom homebuilding industry began to experiment with a variety of types of low-energy houses. Builders of active and passive solar structures quickly realized the importance of airtightness in achieving the desired energy balance. Just as quickly, they experienced the stuffy feel and moisture problems which plagued many of these early projects. As the innovators turned from complex solar designs to "superinsulation" the continuous air/vapor retarder became a primary component of a system that also included controlled mechanical ventilation. Most incorporated an air-to-air heat exchanger. Today, the air-to-air heat exchanger, packaged with fans and controls, is known as a heat recovery ventilator (HRV).

Builders and designers had recognized the need for controlled energy efficient ventilation, but they had a problem in specifying the right equipment and predicting performance. The best information available was published by William A. Shurcliff in 1981 in his book Air-to-Air Heat Exchangers for Houses. Chapter 30 on measurements contains the following statement: "Apparently there is a need to determine what sets of conditions are most pertinent and which test methods are most accurate. Meanwhile the published values of efficiency should be regarded as being tentative and subject to some revision." As one manufacturer has put it, "Performance data for this equipment was being generated in the marketing department rather than in the lab." Clearly the need for product testing standards was emerging as an issue for the infant HRV industry.

At the same time, we heard horror stories about the $3,000 HRV system installed with an airflow of 17 CFM, the well meaning homeowner who wanted to run his furnace stack through the heat exchanger, the HRV with intake and exhaust in the garage, or the installers in a non-competitive bid government contract who used as much insulated flex duct as they could. As with any "new" product there were needs for public education, installation standards, and installer training, in addition to the need for reliable performance data.

A PERFORMANCE STANDARD

First to step into the breach were the Canadians. Motivated (and funded) by the R-2000 energy efficient buildings program of Energy Mines and Resources, a number of efforts were begun which would address these needs. Much of the background was already in place; air-to-air heat exchangers had, in fact, been around for many years in commercial, industrial and process applications. The American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 84, Method of Testing Air-to-Air Heat Exchangers was available for uniform testing and rating of heat transfer capacity, thermal effectiveness and supply air contamination. The Air Movement and Control Association (AMCA) Standard 210, Laboratory Methods of Testing Fans for Rating had been in use for many years to determine the airflow versus pressure performance and efficiency of air moving devices. In addition, a significant body of work was developed at Lawrence Berkeley Laboratories, the

U.S. Department of Energy, the University of Saskatchewan and the University of Manitoba.

In this context, with leadership from Energy Mines and Resources (EM & R), and the Heating, Refrigerating and Air Conditioning Institute of Canada (HRAI), a new committee was created by the Canadian Standards Association (CSA). The first order of business for the Technical Committee on Heat Exchangers was a performance test standard. While ASHRAE 84 provided a point of departure, it did not satisfy the need to predict the ventilation performance of a system installed with ductwork, nor did it provide a means of testing the efficacy of defrost strategies for cold climates.

What information must the performance test provide about an HRV? EM and R's early experience provided many of the answers. The required information can be divided into two categories: ventilation performance and energy performance. Of these, ventilation is the more important. To design an HRV system that will provide the desired ventilation rate, the airflow versus static pressure (duct resistance) characteristics of both the intake and exhaust airstreams must be known. This permits the designer to predict the ventilation rate for a given amount and size of ductwork and to select appropriate equipment given his needs for air distribution and collection.

The designer also needs to know the amount of cross leakage from exhaust to supply airstreams. For example, if the unit delivers 100 CFM with 5% cross leakage, the effective outdoor air provided to the space is reduced to 95 CFM.

For some climates, it is also necessary to know how extremes of low temperature will affect the ventilation rate. When the heat transfer surfaces at the cold side of the HRV are below freezing, frost and ice can form in the moisture-laden exhaust airstream. Different designs employ different strategies for dealing with this, ranging from pre-heating intake air to periodic defrost with recirculating or exhaust air. Any reduction in airflow due to frosting and/or the defrost strategy used should be known.

Testing of airflow versus static pressure and cross leakage are relatively straightforward procedures, and the CSA Preliminary Standard C439-M1985 Standard Methods of Test for Rating the Performance of Heat Recovery Ventilators (C439) was able to draw on the existing AMCA and ASHRAE standards for procedures and instrumentation. The low temperature test on the other hand, was not as clear cut. Here, the CSA Committee was breaking new ground and was confronted with some constraints. What are representative conditions of indoor and outdoor temperature and relative humidity for this cold weather test? What are the capabilities of the testing laboratory?

The draft standard used for the first round of R-2000 testing in December of 1984 called for a twenty-four hour test at an outdoor temperature of $-20^{\circ}C$ ($-4^{\circ}F$) and an indoor relative humidity of 30%. The results suggested that many of the 12 units tested were beginning to build significant frost or the defrost mechanism was being severely taxed. The response of the CSA Committee, which included five or six manufacturers, was to revise the cold weather test to 72 hours at $-25^{\circ}C$ ($-13^{\circ}F$) and an indoor relative humidity of 40%. This represented the limit of the Ontario Research Foundation cold room which was being used to run the tests. The longer duration in combination with colder temperature and higher indoor relative humidity would ensure a more severe survival test. Subsequent testing demonstrated that the revised cold weather test was a veritable HRV torture track. Most units that have successfully completed the 72 hour cold test have undergone substantial redesign.

As CSA prepares to issue C439 as a full standard, the cold test is once again being reexamined. Current thinking is to establish several levels of testing which would permit greater flexibility in meeting the demands of climates milder than the $-25^{\circ}C$ design temperature, and at the same time allow testing at colder design temperatures. The test data will provide a check of the manufacturers claims of suitability for an application and permit the designer to select equipment appropriate for his climate.

Energy Performance is the other category where accurate ratings are needed. Information on energy recovered and operating cost is used to compare and select equipment and to predict the energy performance of the house as a system. It is also useful to be able to determine the temperature of the supply air in advance. The R-2000 rating sheets established three parameters in this area: sensible efficiency, apparent sensible effectiveness, and average power consumed.

Sensible Recovery Efficiency is a measure of energy recovered from the exhaust airstream. This number is appropriate for determining performance in heating applications where recovery of latent heat is not critical. Later versions of the R-2000 rating sheet and the Home Ventilating Institute Design Specification Sheet include a place for Total Recovery Efficiency which is appropriate for air conditioning applications and is tested at an outdoor temperature of $35^{\circ}C$ ($95^{\circ}F$). The Sensible Recovery Efficiency tests are carried out at $0^{\circ}C$ and can be provided for a number of different airflow rates. Sensible Recovery Efficiency is also generated from the 72 hour cold test data, providing a check on the effects of frosting and defrost strategies on the unit's energy efficiency. All the data on efficiency is corrected for cross leakage and fan energy to provide a correct measure of recovery useful in energy calculations. Preheater energy is also accounted for.

Another performance figure generated by the test procedure is Apparent Sensible Effectiveness. This is primarily useful in predicting the supply air temperature for a given set of indoor and outdoor conditions. Supply air temperature is of interest to the designer in selecting strategies for introducing this air to the conditioned space without causing drafts or discomfort. Will air conditioning type registers suffice or should the installation include a reheat coil? In an integrated heating/ventilation system, what will be the temperature of the return air to the furnace?

Average power consumed is presented in watts and provides quick insight into a unit's electrical efficiency. In general, this will play a minor role in equipment selection, but, for a device designed to run continuously, should not be ignored. The effect of preheaters and other defrost mechanisms on electric energy use during the cold test will also show up here. This energy is already accounted for in the calculation of Sensible Recovery Efficiency and thus may not be of great import. The exception would be in an area, such as Hudson Bay for example, where the cost of electric power is far greater than the common heating fuel. In such an application, it is of value to know the energy consumption during frosting conditions.

Net Moisture Transfer is also presented with the winter performance data. It is typically near 0% for fixed plate cores incorporating impermeable membranes. For permeable membrane cores, capillary blowers, and rotary designs, it is highly variable. Net Moisture Transfer provides an idea of the moisture removal capacity of the unit at the test condition. This can be important where particularly high or low moisture generation rates are expected. For example, a unit with 50% moisture transfer at a given condition would remove one half the water that is removed by a unit with no transfer operating at the same airflow. In a case of high moisture loading, the 50% unit may not have the removal capacity to hold the humidity to desired levels. On the other hand, where less moisture is generated, the unit with no transfer may dry the air too effectively, or, if controlled by dehumidistat, may experience less than the desired ventilation rate for other contaminants.

PROGRESS AND A LABELING STANDARD

In January of 1985, the first exploratory meeting between manufacturers of HRVs and the Home Ventilating Institute Division of the Air Movement and Control Association (HVI) took place in Chicago. The need for product standards for HRVs and for an industry voice to represent the manufacturers were the major topics of discussion. Prior to the publication of the C439 preliminary standard in May, the newly established HVI Heat Recovery Ventilator Committee had had several meetings and had begun work on a revision of the test standard. Several Canadian manufacturers who were members of the original CSA Technical Committee participated actively in these early meetings. Representatives from Energy Mines and Resources, the Ontario Research Foundation, and the Heating, Refrigerating and Air Conditioning Institute of Canada worked closely with the HVI Committee on what was evolving as a North American standard.

In less than one year, the HVI version, HVI Heat Recovery Ventilators Performance Testing Standard was complete. Most changes from C439 were minor or of a technical nature and the current revision of the CSA Standard has incorporated these changes. The major differences in HVI and EM & R's R-2000 testing proved to be in the information required, not in the test method itself. Because the focus of HVI's program would be product certification, a labeling standard, HVI Heat Recovery Ventilators Product Certification Procedure, was produced.

The Certification Procedure calls for a Certified Ducted Heat Recovery Ventilator Design Specification Sheet to be provided for each unit tested. This Design Specification Sheet contains the data discussed above and differs from the previous EM & R data sheets in that it requires the summer Total Recovery Efficiency Test for cooling applications, permits the manufacturer to specify the winter design temperature for his equipment (and the 72 hour cold test) and presents a graph of airflow versus static pressure for supply and exhaust rather than a table of equivalent feet of duct based on the units starting collar size (See Figure 1). Here on one sheet is all the information required to select and design HRV systems for residential application. The reverse side (see Figure 2) contains a thorough discussion of the tested parameters and their use or importance in design.

The HVI Certification Program also provides for challenge procedures designed to allow the industry to police itself and contains requirements for the proper and complete use of certified ratings. In addition, certified ratings are required for all the HRVs in a manufacturer's line following a compliance schedule which will spread the cost of testing over a period of several years. Finally, products must be tested for safety by an appropriate listing agency prior to certification by HVI.

SAFETY TESTING

Two agencies currently publish safety testing standards for heat recovery ventilators in North America: CSA and Underwriters Laboratories (U.L.). The Canadian Electrical Code Part II, C 22.2 No. 113 Fans and Ventilators incorporates a specific set of "Supplementary Requirements for Fan Type Air-to-Air Heat Exchangers." CSA certifies all HRVs acceptable for installation in Canada to this standard. U.L. has used three existing standards, 507, Electric Fans; 883, Fan Coil Units and Room Fan Heater Units; and 705, Power Ventilators in listing HRVs for safety depending on the characteristics of the device and its application. Following a meeting with HVI's HRV Committee, U.L. engineers have drafted two new standards 1812, Duct-Connected Heat Recovery Ventilators and 1815, Non-Ducted Heat Recovery Ventilators. Essentially a consolidation and reorganizing of appropriate elements from the existing documents, these proposed standards are currently in industry review. A large number of HRVs including a variety of types and sizes are available with CSA approval and/or U. L. Listing. The designer, builder or the end user can select equipment with confidence knowing that it has been subjected to the scrutiny of testing for electrical, mechanical, and fire safety.

INSTALLATION

Performance testing and listing of products for safety have taken the HRV industry rapidly from infancy to adolescence. However, before the maturing process can be considered complete, a body of knowledge and a familiarity must be developed at the level of the installation. The role of the installing contractor is critical to performance of the HRV, particularly in a ducted system. Some systems may be designed by a mechanical engineer with great attention to detail where the role of the installing contractor is reduced to execution of the plan. However, more often it is the installer or the builder who designs the system. The importance of proper installation cannot be emphasized enough. It would not be an exageration to state that the majority of problems experienced with HRVs in the field are installation related. While manufacturers attempt to refine product, making it less sensitive to installation parameters, it is recognized that standards for the installation of HRVs are required.

The same CSA technical committee which produced the C439 document felt this urgency when they promulgated C444 Installation Guidelines for Heat Recovery Ventilators (C444) several months in advance of the performance testing standard. C444, undergoing revision at this time, contains requirements for equipment, ducting, and installation of the HRV system. Evidence of the interdependence of these standards, clause 4.1.2 states, "Certification shall be provided that the equipment will perform in accordance with the manufacturers published data when tested in accordance with CSA Standard C439," and further in Clause 4.1.3 "Certification shall be provided that the equipment meets the requirements of CSA Standard C22.2 No. 113."

The Standard references the ASHRAE Fundamentals Handbook and the HRAI Residential System Design Manual with regard to duct system design. Specific requirements for 1/4 inch mesh animal screen on intake and exhaust hoods and for the location of the hoods to prevent blockage with snow, short circuiting of exhaust to intake or entrainment of other contaminants such as automotive exhaust are addressed. Insulation and vapor barriers are required on cold side ducts to prevent moisture condensation problems and preserve the efficiency of heat exchange. Additional requirements provide for installation of the HRV in conditioned space, access to the unit and filters for cleaning or servicing, minimizing noise problems through location and acoustic isolation, and a means of balancing airflow in branch ducts as well as on the unit as a whole. C444 calls for a minimum installed capacity for the HRV of 5 liters per second per room or 1/2 air change per hour for the building.

Recognizing that the proof is in the pudding, the standard provides a sample Installation Data Sheet, "Form A" (see Figure 3). Form A is the equivalent of a labeling standard for the completed installed system. The installer records measured airflows in the exhaust and supply airstreams as a check on system capacity and balance. He also certifies a check of the system controls and lists the equipment and accessories installed. Other information which may relate to HRV function is asked for (presence of bath fans, range hood, clothes dryer or type of heating system, for example) and delivery of operating, maintenance and warranty information to the purchaser is certified.

Form A is the real strength of the standard. The R-2000 Program has used several generations of this form to ensure compliance with its own installation guidelines with good success. Once the installers recognize that they will be required to measure the system performance and certify the results, good installations become the rule rather than the exception.

Other installation standards for heat recovery ventilators have been developed for specific program goals. The Bonneville Power Administration (BPA) publishes an Air-to-Air Heat Exchanger Specification for use in its Super Good Cents and Residential Conservation Demonstration Program incentive programs for energy efficient construction. In general, BPA's specifications have improved over the three years they have been in use, relying heavily on the Canadian experience and most recently involving the manufacturers in the specification review process. BPA now requires an Installation Certification form along the lines of "Form A."

The R-2000 Program of EM & R Canada publishes Design and Installation Guidelines for Ventilation Systems. The guidelines have been revised and expanded several times in an attempt to address all the ventilation systems that might be included in a home, bath fans and range hoods as well as HRVs. Methods of measuring airflow in the HRV system are specified using an averaging pitot-tube grid as the sensor. EM & R provides these grids for homes constructed in the R-2000 Program. Figure 4 pictures the sensor, a commercially available device which, when used with a standard manometer, provides an accurate reading of airflow and eliminates most of the effects of uneven flow which have plagued HRV installers in the past. The EM & R Guidelines also address the issue of make-up air for exhaust devices. Maximums of pressure across the extremely tight house envelope are specified, and make-up air ducts are required to keep the pressure within the specified limits. CSA C-444 is referenced for specifics of the HRV installation.

The R-2000 activity, the proliferation of energy efficient construction, and the recent change to the Canadian National Building Code requiring 0.5 air changes per hour of mechanical ventilation have spurred CSA to begin work on a new standard tentatively entitled "Ventilation Requirements for Houses." Like the R-2000 Guidelines, the new standard will attempt to address all aspects of a home's ventilation system(s). HRVs will be addressed along with bath fans, range hoods, clothes dryers, exhaust air heat pumps and combustion appliances. This new CSA standard may serve as the model for future U.S. residential ventilation standards. Unlike the current ASHRAE ventilation standard which treats residential units as simply another category of occupancy in a commercial/industrial standard, the CSA standard will provide a realistic framework for the design and installation of ventilation in homes. The impact of tight, energy-efficient construction and the interdependence of the various mechanical ventilation devices whichmay be utilized in modern construction are important issues for the technical committee drafting the standard.

TRAINING

Standards for product testing, labeling, and installation represent a giant step forward for the HRV industry, however, unless these standards can be put to work in the field they have little value to the consumer or regulatory authority. To bridge the gap between standards and practice it is necessary to train installers, inspectors, and code officials. This has been accomplished on alimited scale by a variety of energy efficient building seminars sponsored by groups such as the Quality Building Council of the New England Solar Energy Association, the Energy Business Association in the Pacific Northwest, the Energy Efficient Building Association in Rochester, Minnesota, and the National Center for Appropriate Technology in Butte, Montana. Newsletters, such as Energy Design Update and the now defunct Superinsulation Information Service, and individual manufacturers have offered seminars and training courses. All of these activities have helped to raise the level of knowledge of HRV system design, function, and installation.

By far the most comprehensive training program to date is offered by the Heating, Refrigerating and Air Conditioning Institute of Canada. HRAI publishes an "Installer's Manual for Heat Recovery Ventilators" which is based on the C444 Standard and accepted procedures for duct design. Originally funded by EM & R to support the R-2000 program's need for trained, certified installers, the manual and training were developed with input from manuflacturers, installing contractors, and regulatory authorities.

Beginning with background information on indoor air quality and humidity control, the course proceeds through the use of HRV performance testing data, system design, installation and maintenance. Hands on work in measuring and balancing airflow is included. Figure 4, the table of contents from the Installers Manual, provides an idea of the depth of the training. This program has produced literally hundreds of qualified installers and inspectors across Canada and has virtually eliminated the horror stories of a few years ago.

The Home Ventilating Institute is preparing a similar training program, again drawing heavily from the Canadian experience, to respond to the need for installer training in the Pacific Northwest. It is expected that HVI and BPA will oversee the training and installer certification provided by the Technical Services Division, Inc. of HRAI. If successful, this program will be available to support similar efforts elsewhere in the U.S.

BUILDING CODES AND STANDARDS

Mechanical ventilation of residential occupancies is now required by a variety of building codes and standards in the U.S. and abroad. The Nordic countries and France require mechanical ventilation capability at the rate of 0.5 changes per hour (ACH). In Canada, the CSA standard for mobile homes currently requires 0.5 ACH mechanical capability while the same requirement in the National Building Code awaits adoption by the provinces before it becomes law.

In the U.S., the states of South Dakota, Wisconsin and Minnesota have codes requiring mechanical ventilation. The California Energy Commission's Residential Building Standards require mechanical ventilation equal to 0.7 ACH with an air-to-air heat exchanger for homes incorporating a continuous infiltration barrier. The Model Conservation Standards promulgated by the Northwest Power Planning Council for homes in the Pacific Northwest states of Washington, Oregon, Idaho and Montana call for continuous air/vapor retarders and heat recovery ventilation. These standards have already been adopted by a number of local jurisdictions and promise to grow in acceptance throughout the region.

The Council of American Building Officials Model Energy Code, referenced by many state codes, allows recovered energy to be used for control of temperature and humidity while incorporating criteria for mechanical ventilation according to ASHRAE Standard 62-73 Natural and Mechanical Ventilation. Another widely referenced energy conservation standard, ASHRAE 90 is currently undergoing revision. The draft of 90.2 Energy Efficient Design of New Low-Rise Residential Buildings requires that consideration be given to the use of heat recovery in the ventilation process and allows for the use of the recovered energy in meeting space conditioning requirements.

CONCLUSION

As is often the case with standards' development, we are confronted with a chicken and egg dilemma which is further complicated by a background of rapid change in technology. Nevertheless, the speed with which the HRV industry has responded to the need for standards has been exemplary. The development of performance testing standards at CSA followed by their refinement and a product labeling standard at HVI has set the stage for rapid expansion of related standards and for the practical application of these devices in our homes.

Designers and builders of energy efficient construction now will have access to the information required to select equipment and design systems which will perform as expected in the field. Contractors can learn the ins and outs of HRV installation through education programs rather than by trial and error on the job site. And perhaps most importantly, code officials and regulatory authorities facing the inherent conflict between energy conservation and the need for ventilation for health can proceed with code development confident that the necessary standards are in place to support their efforts.

BIBLIOGRAPHY

1. Air-Conditioning and Refrigerating Institute, "ARI Standard 1060 - 1984 Standard for Air-to-Air Heat Recovery Equipment" Arlington, VA.

2. Air Movement and Control Association, Inc., "AMCA Standard 210 - 1985 Laboratory Methods of Testing Fans for Rating" Arlington Heights, IL.

3. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., "ASHRAE Standard 90A - 1980 Energy Conservation in New Building Design" Atlanta, Georgia.

4. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. "ASHRAE Handbook, 1981, Fundamentals", Atlanta, Georgia.

5. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., "ASHRAE Standard 84 - 1978 Method of Testing Air-to-Air Heat Exchangers" Atlanta, Georgia.

6. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., "ASHRAE Standard 62 - 1973 Standards for Natural and Mechanical Ventilation" Atlanta, Georgia.

7. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., "ASHRAE Standard 62-1981 Ventilation for Acceptable Indoor Air Quality" Atlanta, Georgia.

8. Besant R.W. et al, "An Air-to-Air Heating Exchanger for Residences", (1978) Extension Division, University of Saskatchewan, Saskatoon, Canada.

9. Bonneville Power Administration, "Air-to-Air Heat Exchanger (AAHX) Design and Installation Specifications for BPA's Energy Efficient New Home Programs." (revised April, 1986). Portland, Oregon.

10. Bonneville Power Administration, "Issue Backgrounder: Energy Efficient New Homes and Indoor Air Pollutants" (July, 1985). Portland, Oregon.

11. Canadian Standards Association, "CSA Standard C22.2 No. 113-M1984 Fans and Ventilators." Rexdale, Ontario, Canada.

12. Canadian Standards Association, "CSA Standard C-444-M1985 Installation Guidelines for Heat Recovery Ventilators." Rexdale, Ontario, Canada.

13. Canadian Standards Association, "CSA Preliminary Standard C439-M1985 Standard Methods of Test for Rating the Performance of Heat Recovery Ventilators." Rexdale, Ontario, Canada.

14. Canadian Standards Association, "CSA Standard fZ240.2.1-1979 Structural Requirements for Mobile Homes." Rexdale, Ontario, Canada.

15. Canadian Standards Association, "Technical Information Letter 207A, Mechanical Air Change in Mobile Homes." (October, 1983). Rexdale, Ontario, Canada.

16. Council of American Building Officials, "Model Energy Code." (1983). Falls Church, VA.

17. Electric Power Research Institute, "Manual on Indoor Air Quality." (1984). Palo Alto, CA.

18. Energy Efficient Building Association, "Energy Efficient Building Design Technical Papers" (Proceedings of the Fourth International Conference and Exposition, March, 1986). Rochester, Minn.

19. Energy Mines and Resources Canada, R-2000 Super Energy Efficient Home Program, "Design and Installation Guidelines for Ventilation Systems." (Draft Sept. 5, 1986). Ottawa, Ontario, Canada.

20. Energy Mines and Resources Canada, R-2000 Super Energy Efficient Home Program, "R-2000 Heat Recovery and Efficiency Rating Guide - February, 1986." Ottawa, Ontario, Canada.

21. Energy Mines and Resources Canada, R-2000 Super Energy Efficient Home Program, "How to Operate a Heat Recovery Ventilator." (1985) Ottawa, Ontario, Canada.

22. Energy Mines and Resources Canada, R-2000 Super Energy Efficient Home Program, "Heat Recovery Ventilator Testing - Preliminary Results." (December, 1984).

23. Fisk W.J. et al, "Freezing in Residential Air-to-Air Heat Exchangers; An Experimental Study." (Sept., 1983) LBL Report 16783. University of California, Berkeley.

24. Fisk W.J. et al, "Test Results and Methods: Residential Air-to-Air Heat Exchangers for Maintaining Indoor Air Quality and Saving Energy", LBL Report 12280. 1981. University of California at Berkeley.

25. Heating, Refrigerating and Air-Conditioning Institute of Canada, "Installers' Manual for Heat Recovery Ventilators." (1985) Islington, Ontario, Canada.

26. Heating, Refrigerating and Air-Conditioning Institute of Canada, "Residential System Design Manual." (1979) Islington, Ontario, Canada.

27. Home Ventilating Institute Division of AMCA, "Heat Recovery Ventilators Performance Testing Standard." (1986). Arlington Heights, IL.

28. Home Ventilating Institute Division of AMCA, "Heat Recovery Ventilators Product Certification Procedure." (1986). Arlington Heights, IL.

29. Home Ventilating Institute Division of AMCA, "Home Ventilating Guide." (revised 1986). Arlington Heights, IL.

30. Larson, M., South Dakota Energy Office, "Superinsulated Housing Codes - Government Takes The Lead." (1985). Pierre, South Dakota.

31. Lubliner, M. et al, "Experience With Air-to-Air Heat Exchangers In The Residential Standards Demonstration Program in Washington State" (1986). Olympia, Washington.

32. National Center for Appropriate Technology, "Conservation in Buildings: Northwest Perspective" (Proceedings of May, 1985 Conference). Butte, MT.

33. National Institute of Building Sciences, "Standards, Regulations and Other Technical Criteria Related To Indoor Air Quality." (February, 1986). Washington, DC.

34. Nazaroff, W.W. et al, "The Use of Mechanical Ventilation with Heat Recovery for Controlling Radon and Radon Daughter Concentrations", LBL Report 10222 (1980). University of California at Berkeley.

35. New York State Energy Research and Development Authority, "Indoor Air Quality, Infiltration and Ventilation in Residential Buildings NYSERDA Report 85-10." (1985) W.S. Fleming and Associates, Inc., Syracuse, NY.

36. Nisson, J.D. Ned, editor, "Energy Design Update" (published monthly by Cutter Information Corp.) Arlington, MA.

37. Nisson, J.D. and Dutt, G., The Superinsulated Home Book. (1985) Wiley and Sons, New York, NY.

38. Nordic Committee on Building Regulations, "NKB Report No. 41 Indoor Climate." (May, 1981) Stockholm, Sweden.

39. Northwest Power Planning Council, "Model Conservation Standards Equivalent Code." (1985). Portland, OR.

40. Northwest Power Planning Council, "Northwest Conservation and Electric Power Plan" (Volume 1 incorporating Model Conservation Standards Appendix 1-B). (1986). Portland, Oregon.

41. Roseme, G.D. et al, "Residential Ventilation with Heat Recovery: Improving Indoor Air Quality and Saving Energy" LBL Report 9749. (1980). University of California at Berkeley.

42. Ruth, D.W. et al, "Investigation of Frosting in Rotary Air-to-Air Heat Exchangers." University of Manitoba, Winnipeg, Manitoba, Canada.

43. Shurcliff, William A., Air-to-Air Heat Exchangers for Houses, Brick House Publishing, Andover, MA (1982).

44. State of Wisconsin, "Energy Conservation Standards for Electrically Heated Homes." (1986 amendments to Chapter ILHR22 of the Wisconsin Adminstrative Code). Madison, Wisconsin.

45. Underwriters Laboratories, Inc. "U.L. Standard 507 Electric Fans" (revised January, 1985). Northbrook, IL.

46. Underwriters Laboratories, Inc., "U.L. Standard 181 Factory Made Air Ducts and Connectors." (revised March, 1984). Northbrook, IL.

47. Underwriters Laboratories, Inc.,"U.L. Standard 883 Fan Coil Units and Room Fan Heater Units." (revised March, 1986). Northbrook, IL.

48. Underwriters Laboratories, Inc., "U.L. Standard 705 Power Ventilators." (1984). Northbrook, IL.

49. Underwriters Laboratories, Inc., "Preliminary Draft of Proposed Standard UL1812 Duct-Connected Heat Recovery Ventilators." (1986). Northbrook, IL.

50. Underwriters Laboratories, Inc., "Preliminary Draft of Proposed Standard UL1815 Non-Ducted Heat Recovery Ventilators." (1986). Northbrook, IL.

51. U.S. Department of Energy, "Heat Recovery Ventilation for Housing." (March, 1984). DOE/CE/15095-9, Washington, DC.

52. U.S. Department of Energy, "Moisture and Home Energy Conservation." (September, 1983). DOE/CE/15095-4, Washington, DC.

Home Ventilating Institute Division of AMCA
Certified Ducted Heat Recovery Ventilator Design Specification Sheet

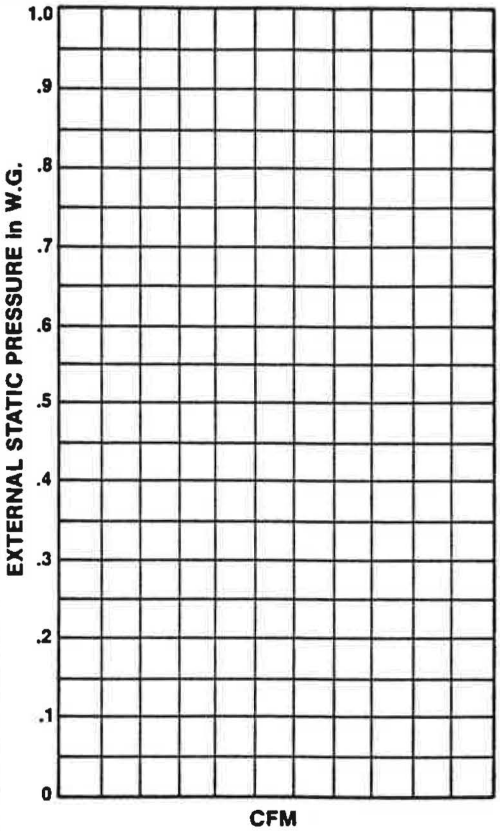
Manufacturer: Model Designation: Date:

Options Installed: Required Electrical Supply: Volts ______ Amps ______

VENTILATION PERFORMANCE

External Static Pressure In. W.G.	Net Supply Airflow	Gross Airflow	
	cfm	Supply cfm	Exhaust cfm

Exhaust Air Transfer Ratio ______ @ 0.4 in. W.G.
______ @ 0.2 in. W.G.
Low Temperature Vent Reduction Factor
Supply ______ Exhaust ______
Low Temperature Imbalance Factor ______



Gross Airflow
SUPPLY ______
EXHAUST ______

ENERGY PERFORMANCE

Supply Temp. °F Heating	Net Airflow cfm	Power Consumed Watts	Sensible Recovery Efficiency	Apparent Sensible Effectiveness	Net Moisture Transfer
+32					
+32					
+32					
+32					
−13					

Cooling	Net Airflow cfm	Power Consumed Watts	Total Recovery Efficiency
+95			
+95			

Description of cold weather wattage requirements: ______

Notice:
The test results shown here were obtained according to the methods set out in the H.V.I. standard for labelling of heat recovery ventilators at ______ an H.V.I. approved testing agency. They refer to units which carry the H.V.I. certification label appearing adjacent. To verify the applicability of these results to the equipment supplied, verify that the model designation appearing above corresponds to that shown on the equipment.

TESTED/CERTIFIED

HVI

HOME VENTILATING INSTITUTE DIVISION OF AMCA

Certified Heat Recovery Ventilator

The manufacturer of this equipment publishes HVI Certified Design Performance Specifications. Consult these specifications to ensure proper selection and installation.

FIGURE 1

EXPLANATION OF CERTIFIED DUCTED HRV DESIGN SPECIFICATION SHEET

FIGURE 2

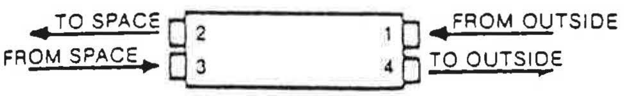
This sheet is intended primarily for the designer and contains actual results of tests and calculated values from test data. The equipment tested was supplied by the manufacturer who certifies that the equipment tested is representative of the designated model offered for sale.

Definitions and Notes Regarding the Headings Used Follow:

Model: The manufacturer's designation of the unit tested. This designation also appears on the HVI certification label.

VENTILATION PERFORMANCE[1]

A note about nomenclature: "Points" 1 through 4 are referred to. These are standardized as follows: 1 = air from outside; 2 = air from equipment to space; 3 = air from space to equipment; 4 = air from equipment to outside.



External Static Pressure: The total differential measured between points 1 and 2 (supply) or points 3 and 4 (exhaust) in question.

Gross Airflow The measured airflow rate at points 2 and 3, which may contain recirculation air (from cross leakage). These values are used only for selecting ductwork.

Net Supply Airflow The gross supply airflow reduced by measured cross-leakage (E.A.T.R.). This is the actual amount of outside air supplied by the unit and is used only for sizing the equipment for the required ventilation rate.

Exhaust Air Transfer Ratio (EATR): Ratio of the quantity of exhaust air found in the supply airstream to the gross supply air flow. When multiplied by 100, this ratio can be expressed as a percentage. Gross Supply Airflow x (1 - EATR) = Net Supply Airflow.

Low Temperature Ventilation Reduction Factor (LTVRF): The percentage reduction in flow rate of the supply and exhaust air streams at the end of the 72 hour Cold Weather Test (see −13° F supply temp. below) compared with operation under non-frosting conditions. The final flowrate is taken as the average of the last 12 hours of test. This reduction in flow results from frost and ice buildup in the core and shutdown of fans for defrosting.

Low Temperature Imbalance Factor (LTIF): The ratio of Supply Airflow to Exhaust Airflow over the last 12 hours of the 72 hour Cold Weather Test.

Net Moisture Transfer (NMT): Moisture recovered divided by moisture exhausted and corrected for the effects of cross-leakage. NMT = 0 indicates that moisture was not transferred (net of cross-leakage) from the exhaust to the supply air. NMT = 1 would indicate complete transfer of moisture. NMT is provided for the −32° F and −13° F test conditions as an indication of moisture handling characteristics and may be used to evaluate the moisture removal ability of the equipment at the test condition as well as to confirm the manufacturers published data.

The moisture removal ability should be considered when the ventilation rate is selected on the basis of moisture control. NMT may be used to approximate this ability at the 32° F and −13° F test condition by substitution into the following equation:

$RH_2O = NSA\ (1\text{-}NMT)\ (W_3\text{-}W_1)$

Where:
- RH_2O = Moisture removal rate
- NSA = Net supply airflow
- NMT = Net moisture transfer
- W_3 = Humidity ratio of indoor air
- W_1 = Humidity ratio of outdoor air

Note:

A) that if the factor (1-NMT) is removed from the equation, or if NMT = 0, then the equation becomes $RH_2O = NSA\ (W_3\text{-}W_1)$, or the equivalent of direct outdoor air supply and balanced exhaust at the conditions of test. The factor may therefore be used to evaluate the moisture removal ability of the equipment with respect to that of unmodified outdoor air at the design conditions of test.

B) Test conditions are 71.6° F and 40% relative humidity (W_3 = 0 0066) for indoor air. Outdoor relative humidity can vary from 50 - 100% giving $0.0019 < W < 0.0038$ for the +32° F condition and $0.0002 < W < 0.0004$ for the −13° F condition.

Some equipment will vary in NMT with changes in indoor and outdoor conditions. Consult the equipment supplier for performance at conditions other than those described above.

ENERGY PERFORMANCE

Values for energy performance are listed for various test points of supply (outside air) temperature and set airflow. Specific conditions of note are given below organized according to supply temperature. The corresponding airflow points are selected for test according to specific pressure or Net Supply Airflow. More or fewer test points may be listed for various units depending on their ability to meet the required Net Supply Airflow test conditions.

It is important to recognize that **for comparison of equipment only values at equivalent supply temperature and net airflow should be used.**

+32° F Supply Temp. Steady state test at one or both of 50 CFM and 117 CFM, 0.2 in. W.G. and 0.4 in. W.G. To determine corresponding external static pressure for a specific net airflow refer to the ventilation performance table. Values of pressure may not be consistent with the 50 CFM and/or 117 CFM net airflow test points as the equipment may have been operated in low speed [2].

−13° F Supply Temp. The test duration is for a fixed 72 hr. period at maximum speed and 0.4 in. W.G. differential. This is often referred to as the "72 hr. Cold Weather Test" (see LTVRF and LTIF above). The net supply airflow shown is the average of the last 12 hrs. of test and must not be reduced by the LTVRF. All other values are also the average of the last 12 hours of test. Note that the "72 hr. Cold Weather Test" may be conducted for equipment designed for higher design temperatures. If a value other than −13° F is used it will be recorded in place of −13° F.

+95° F Supply Temp. - Cooling Values for one or both of 50 CFM and 117 CFM will be listed according to the ability of the equipment to meet the test conditions [2]. Outdoor air conditions are +95° F, 50% R.H., indoor air conditions are +75° F, 50% R.H. Total Recovery Efficiency (see below) is given in place of Sensible Recovery Efficiency (see below) as the latter value is not relevant for cooling load applications.

Watts The average power consumed during the specific test. **DO NOT USE TO ASCERTAIN REQUIRED ELECTRIC SERVICE.** Refer to the electrical rating information supplied by the manufacturer. The watts shown are those recorded during the test; the equipment may be in high or low speed setting.

Apparent Sensible Effectiveness (ASEF): The measured temperature rise of the supply air stream divided by the difference between the supply temperature (point 1) and exhaust temperature (point 3) and multiplied by the ratio of mass flow rate of the supply divided by the minimum of the mass flow rate of the supply or exhaust streams. This value is useful principally to predict final delivered air temperature at a given flow rate.

Sensible Recovery Efficiency (SRE): The sensible energy recovered minus the supply fan energy and preheat coil energy, divided by the sensible energy exhausted plus the exhaust fan energy. This calculation corrects for the effects of cross-leakage, purchased energy for fans and controls as well as defrost systems. This value is used principally to predict and compare energy performance.

Total Recovery Efficiency (TRE) The total energy (enthalpy) recovered minus the supply fan energy and the preheat coil energy, divided by the total energy (enthalpy) exhausted plus the exhaust fan energy. This calculation corrects for the effects of cross-leakage and external purchased energy for fans and controls. It is used principally to predict and compare energy performance.

Footnote [1] All data are given for standard air (0.075 lb./cu. ft.) CFM may be read SCFM.

Footnote [2] If the equipment produces less than 0.2 in. W.G. at high speed or more than 0.4 in. W.G. at low(est) speed at the specific net supply airflow, the test will not be conducted.

White - Purchaser
Green - Regulatory Authority
Canary - Manufacturer
Pink - Installing Contractor

HEAT RECOVERY VENTILATOR INSTALLATION DATA
CSA Standard C444 Form A

Location of Installation
Name ______
Address ______
City and Province ______
Telephone No. ______
☐ New ☐ Existing

Installing Contractor
Name ______
Address ______
City and Province ______
Telephone No. ______

Regulatory Authority
Name ______
Registration No. ______
Permit No. ______
Certificate No. ______
Date ______

Location Description

Type of Building	Volume of Habitable Space Including Basement ft³	(m³)
Bungalow	☐	☐
Split-level	☐	☐
Multi-storey	☐	☐
Other ______	☐	☐

Air Tightness Test ☐ Yes ☐ No ☐ ELA_{10} ☐ ELA_{50}

Type of Primary Heating System
Fuel ☐ Gas ☐ Oil ☐ Electric
☐ Forced Air
☐ Baseboard
☐ Hydronic
☐ Fireplace
☐ Other ______

Outside Vented Mechanical Exhaust System
☐ Bathroom
☐ Kitchen
☐ Range Hood
☐ Central Vacuum
☐ Clothes Dryer
Other ______

Equipment Applied
Manufacturer ______
Brand Name ______
Model Number ______
CSA Rated Supply Air Volume ☐ ft³/m ☐ L/s
Required Supply Air Volume ☐ ft³/m ☐ L/s
CSA Rated Exhaust Air Volume ☐ ft³/m ☐ L/s
Required Exhaust Air Volume ☐ ft³/m ☐ L/s
Type of Operation - Continuous ☐ Yes ☐ No

Types of Control(s)
☐ Dehumidistat with or without Manual Override
☐ Interval Timer with or without Manual Override
☐ Manually Operated Switch
☐ Other ______

Type of Defrost
☐ Preheat
☐ Bypass
☐ Recirculate
☐ Not Applicable
☐ Other ______

Make-Up Heat ☐ Yes ☐ No

Applied By
Name ______
Company ______
Address ______
City and Province ______

Start-Up Check
Equipment Model No. ______ Serial No. ______

Yes	No	
☐	☐	Electrical Power Wiring
☐	☐	Control(s) Wiring
☐	☐	Control(s) Functioning
☐	☐	Defrost Setting
☐	☐	Filter(s)
☐	☐	Air Distribution System
☐	☐	Integrated With Heating System

☐ Number of Supply Outlets
☐ Number of Exhaust Points

Measuring Equipment Used - Type ______
Model ______ Accuracy ______

Results of Measurement
Supply Air Volume ☐ ft³/m ☐ L/s
Exhaust Air Volume ☐ ft³/m ☐ L/s

Pressure Differential (if applicable)
Fan On ☐ Inches of Water ☐ Pa
Fan Off ☐ Inches of Water ☐ Pa

Start-Up Check By
Mechanic ______
Company ______
Date ______

Purchaser
Proper completion and distribution of this form by your installing contractor will assure that the Heat Recovery Ventilator System is applied and installed to industry standards and will ensure you that the equipment carries the manufacturer's warranty.

☐ Received Instruction on the Operation of the Equipment
☐ Received Warranty Data
☐ Received Operation and Maintenance Manuals
☐ Received Advice and Caution Regarding Combustion Air

Purchaser's Signature ______ Date ______

Deviations or Changes from Application
Describe
______
______
______
______

FIGURE 3
HEAT RECOVERY VENTILATOR
INSTALLATION DATA

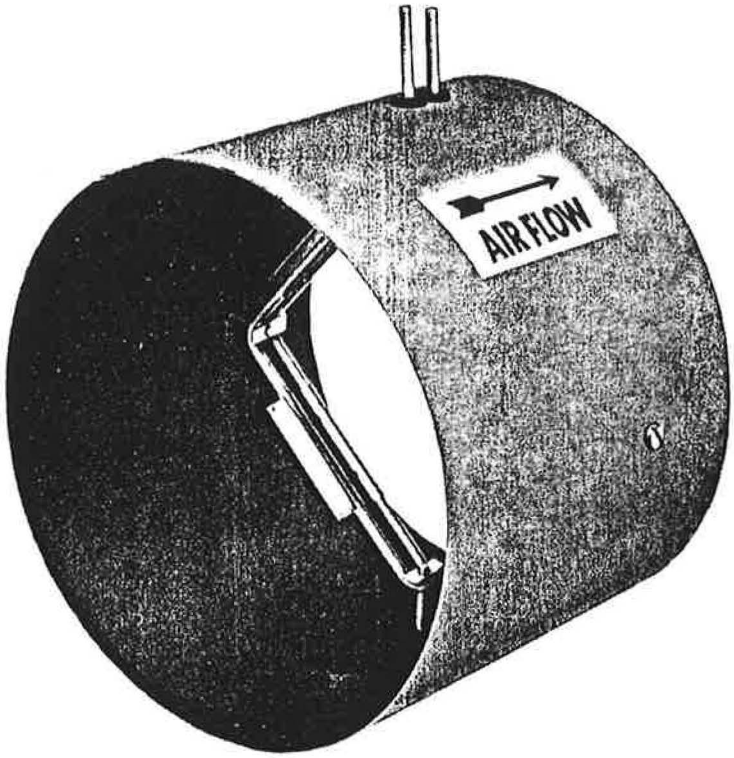


FIGURE 4
AVERAGING PITOT TUBE GRID

TABLE OF CONTENTS

FIGURE 5
TABLE OF CONTENTS FROM HRAI
HRV TRAINING COURSE