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# ASHRAE Research Contract 862

# Development of a Methodology to Accurately Design and Predict the Part Load Performance of an Energy Recovery Ventilator/Energy Recovery Device

## Final Report Summary and Introduction

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## Executive Summary

ASHRAE Research Project 862 "Development of a Methodology to Accurately Design and Predict the Part Load Performance of an Energy Recovery Ventilator/Energy Recovery Device" had as its objectives:

1. to propose field testing procedures for air-to-air energy exchangers,
2. to monitor accurately the inlet and outlet properties and calculate the performance of four different types of air-to-air energy exchangers,
3. to analyze the collected data for errors or uncertainty for each system,
4. to compare the results with theoretical results,
5. to correlate the results in a form useful to industry, and
6. to report on the findings and write papers.

This report contains a comprehensive and critical review of the literature, field and laboratory data and their analyses for several air-to-air heat/energy exchangers, a new theoretical/numerical model for a rotary energy wheel, and its validation for a wide range of operating conditions, and recommendations for changes to ANSI/ASHRAE Std. 84 "Method of Testing Air-to-Air Heat Exchangers" so that it can be adopted for both laboratory and in situ field systems installed in buildings.

It is evident from the literature, measured data, and analysis that uncertainty analyses must be added to ASHRAE Std. 84 if this standard is to be used for both laboratory and field testing where the costs of field testing large systems may be only a small fraction of laboratory testing. For most air-to-air heat exchangers the performance factors measured at one operating condition can be extrapolated to other operating conditions using widely available correlations and heat exchanger theory. For rotary energy wheels, the relationships among the operating conditions and performance factors are complex so a new theoretical/numerical model was developed and validated using laboratory data. New design equations are presented for rotary energy wheels based on the numerical model. The report is concluded with a chapter on the part-load performance and control for various types of air-to-air heat/energy exchangers.

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## Introduction

Air-to-air heat exchangers, such as heat wheels, plate, heat pipe and run-around coil loop, have been commercially available for many decades and have been used for industrial energy recovery applications such as exhaust-to-supply air preheating for electrical power plant boiler system and gas turbine power generators or waste heat recovery from industrial processes, diesel engines or heat pumps. Similar air-to-air heat exchangers have also been used for ventilation air energy recovery from exhaust to supply air in buildings where the temperature differences across the heat exchanger is often much smaller than many of the industrial applications. Ventilation air energy recovery is the focus of this research. Two general problems are considered in this report. These are:

1. Performance rating of air-to-air heat recovery exchangers can be very expensive if it is done under laboratory conditions because expensive, moderate or large capacity facilities must be dedicated to the testing along with the necessary instrumentation and data acquisition and analysis systems. The current standard for testing air-to-air heat exchangers, ANSI/ASHRAE Standard 84-1991 "Method of Testing Air-to-Air Heat Exchangers", requires this type of dedicated laboratory test facility. Most manufacturers have been reluctant to contract out the testing of their air-to-air heat exchangers to independent laboratories because of the large cost of testing small-sized units for only a few test data. Such laboratory test results would likely need modifications for large sized units installed in commercial buildings. The procedures required to extrapolate laboratory test and

performance data for small units to those used in commercial buildings are not specified. Finally, owners and users of these air-to-air heat/energy recovery systems are given few assurances of expected performance and return on their investment and no validated procedures to monitor and challenge actual systems performance after they are installed.

2. Over the past decade, several manufacturers have developed air-to-air energy recovery wheels, which include a desiccant coating on the surfaces of the porous wheels on which water vapor is transferred directly between the exhaust and supply air streams. These devices that combine both heat and water vapor transfer on the same regenerative wheel raise questions about the direct applicability or accuracy of the current test standard, which was developed in the first instance for sensible heat exchangers, later modified to accommodate condensation and perhaps frosting, and finally extended to include desiccant coated energy wheels. The validity of the definitions and testing procedures specified in Standard 84 had not been established for energy wheels.

## Objectives

The objectives stated in the original research contract proposal on May 18, 1994 are as follows:

1. to propose field testing procedures for air-to-air energy exchangers,
2. to monitor accurately the inlet and outlet properties and calculate the performance of four different types of air-to-air energy exchangers,
3. to analyze the collected data for errors or uncertainty for each system,
4. to compare the results with theoretical results,
5. to correlate the results in a form useful to industry, and
6. to report on the findings and write papers.

## Scope of Research Carried Out

The above research objectives, although very broad, have been by and large met. The research has involved a thorough analysis of existing literature, field and laboratory testing of several air-to-air heat/energy rotary energy wheels.

The research work includes not only a review of ASHRAE Std. 84 but several other related test standards for air-to-air and air-to-liquid heat exchangers. It was evident that Standard 84 had several short comings even for laboratory testing so that using it as a basis of field testing required significant modifications.

A large research effort was directed toward selecting the method of uncertainty analysis that could be used with the least ambiguity for both laboratory and field testing. ANSI/ASME PTE 19.6 "Measurement Uncertainty" was identified as the most comprehensive and unambiguous standard for uncertainty analysis and was used for all test results. For field testing, even this standard needed certain modifications that are described in this report.

The research work required for energy recovery wheels was both comprehensive and theoretically much more complex than was first envisaged when the research proposal was put forward. These complications arose through the coupled nonlinear heat and moisture transfer processes in the energy wheel, its wide range of operating conditions and the inadequacies of the effectiveness definitions used in Standard 84. This report includes a full presentation and discussion of the findings for energy wheels.

During the research, energy wheels were the main focus of the theoretical and experimental research. In addition, heat-pipe and plate type heat exchangers were tested. Heat-pipe and energy wheel exchangers were tested both in the laboratory for one field test but only laboratory testing was done for the plate type heat exchanger. Originally, it was planned to include additional testing of another heat exchanger such as the run-around system. The benefits of additional testing of a run-around system would be very small because we had thoroughly examined such systems in the past and reported it in the ASHRAE Transactions. The only thing we could add would be the uncertainty analysis which is reported in great detail in this report.

## Overview of the Report

In this report, it is both convenient and instructive to present the results through a series of chapters where each one represents a research paper that has been submitted for review. These chapters are somewhat independent in that each one is self contained with some cross references to earlier papers or, in this case, chapters. They are arranged in nearly the sequence in which they were written starting with laboratory testing and validation of a numerical model of an energy wheel and ending with recommendations for modifications to ASHRAE Std. 84. The final chapter on the part-load performance and control of various types of air-to-air heat/energy exchangers points to the need for further research.

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