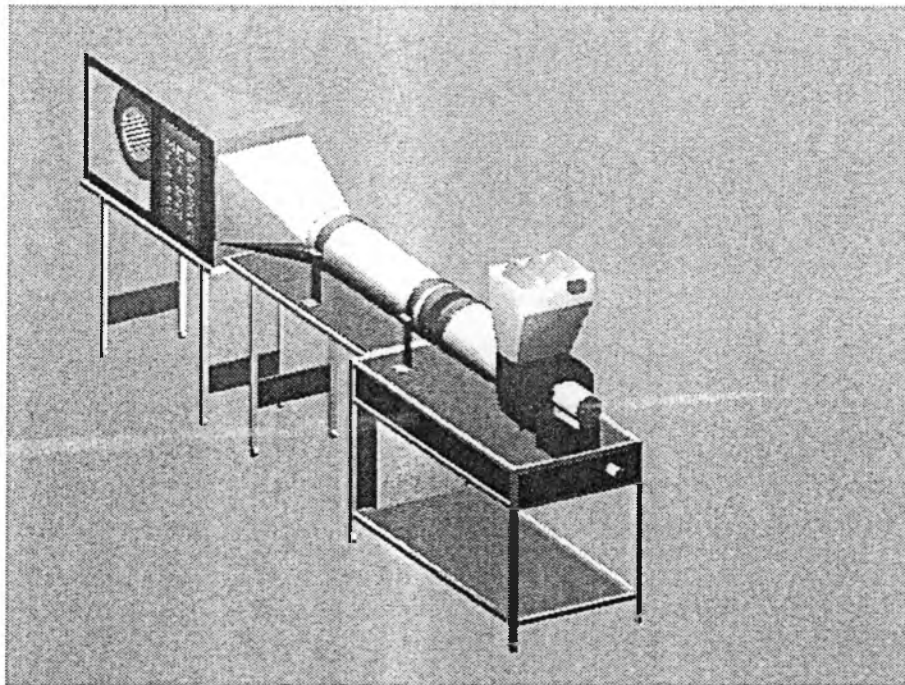


# *FANalyzer*

An Automated Portable Test  
Bench for Analyzing the Performance of  
Fractional Horsepower Fan-Motor Sets



Submitted to:  
Research Division  
Canada Mortgage and Housing Corporation

Submitted by:  
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February 96

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This publication is one of many item of information published by CMHC with the assistance of federal funds.

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## Summary

Early in 1995 Sheltair Scientific Ltd. began work on a CMHC contract to design and construct a system for performance testing of the motor and fan components of residential heating & ventilation appliances. The next year and a half involved an ambitious prototyping effort to produce a compact, easy to use, multi-purpose test bench for assisting manufacturers in developing more efficient ventilation equipment. The final product was named a "FANalyzer"

The research objective was to design, construct and pilot-test a prototype test rig capable of testing fans for both performance and efficiency; measuring the performance characteristics of small electric motors (from about 1/60 hp to 1/2 hp); and, producing performance reports.

A device like the FANalyzer was thought to be needed because increased use of ventilation appliances in homes is certain to occur, the existing systems have extremely low efficiency, and new standards will place demands on manufacturers for rating efficiency and energy use. Once created, it was hoped that the rig could be offered on loan or lease to Canadian manufacturers, or used directly by CMHC and/or contractors to provide more comprehensive test data on specific by energy utilities. It might also be used by associations & research institutes to help develop in-house test facilities of comparable or superior quality. It could also provide independent testing of commercially available products in order to create more stringent energy efficiency standards for DSM programs and building codes and regulations. Finally the rig could be used as a teaching aid in many types of HVAC courses.

The design and construction of the FANalyzer was conducted in four phases:

1. An industry Survey of 30 manufacturers and testing agents in Canada and the US, followed by a design criteria workshop with experts in Vancouver;
2. Concept design, followed by procurement of equipment for a motor testing system, an air flow measurement system, a data acquisition system, and data analysis and reporting software.
- 3: Construction and testing of a prototype;
- 4: Trials at Powertech labs and at a manufacturer's facility, and submissions to CMHC.

An analysis of the industry survey results is included in the report, along with descriptions of visits made to manufacturers and training and testing facilities in Southern Ontario. The design workshop concluded that the FANalyzer should be designed as a "Design Tool" rather than a "Standards or Product Certification" tool.

Data acquisition software and hardware was purchased from National Instruments, because of their excellent graphical programming language and user interface, the affordable, fast DAQ Hardware; the potential for compiling the test applications for protection and low cost reproduction; and the ease of customizing applications for other purposes.

A Reaction dynamometer torque-table was selected as a method for testing motors, and designed for auto calibration. It is possible to test the motor separately, or as part of the fan motor set, depending upon configuration. The table is fastened to a height-adjustable back plate, which is mounted on a bearing pillow block.

Air flow measuring methods were carefully researched and tested. Eventually a Hot-wire Anemometer Grid was chosen, using six constant current-temperature corrected thermistors.

LabVIEW Data acquisition software was purchased for processing and analyzing sensor signals. A virtual instrument (sub vi) was created for each component of the test rig including: power meter, damper control, speed control, load cell, tachometer, hot-wire flow grid, temperature sensors, and static pressures.

The FANalyzer provides a user-friendly interface with options for completing a wide variety of single point tests, or a fully automated fan efficiency or motor efficiency test. Outputs are graphically illustrated on standardized reporting forms. The forms permit analysis of all key variables, including speed, pressure, flow, torque, power, temperature, voltage & power factor.

The FANalyzer is presently most easily used for testing fan efficiency in a Type B configuration, (from ASHRAE Standard 51-85), which involves putting the test fan through a number of operating points at a single speed setting. Other configurations are also possible. The FANalyzer Operating Manual shows how the test routines are conducted, including location of the various sensors and pressure taps. This test can be conducted automatically, using the LabVIEW test routines to control the fan and dampers, and collect, analyze and present the data. By choosing the appropriate transition connector, the FANalyzer can be used to accurately test everything from bathroom fans blowing 25 L/s to furnaces blowing 550 L/s.

For purposes of motor testing the operating manual indicates the precise means of supplying loading to the motor for the efficiency test. Three loading impellers are provided, each of different size and diameter. In this fashion, motors can be tested over the range of 1/60 HP to ¾ HP, at RPMs from 1000 to 2500.

The FANalyzer disassembles and packs away into its own bench, and then rolls into a shipping crate measuring 1m by 0.7 m by 1.6m. The crate weighs 39 kg. and the bench and test equipment weigh 90 kg.

Prior to completion of the FANalyzer, the unit was subjected to a critical evaluation by Powertech Labs, and to field trials by a local manufacturer/distributor of residential ventilation equipment. The trials indicated a large degree of enthusiasm for the versatility and sophistication of the FANalyzer. Technicians and engineers were especially impressed with the integration of all the sensors and components into a single, automated man/machine interface.

The rig provides extremely visual feedback to operators during automated motor-an set testing. This makes it especially effective when used to show manufacturers, builders, code officials and utility personnel the range of performance that can be expected from different types of equipment now available. By clarifying the opportunity for improved performance, it is expected that the FANalyzer will help drive requirements for, and delivery of, better ventilation technology.

Additional work could improve the functionality of the device, including: improved training support; redesign of the prototype to produce a simpler, more robust, production unit; design of a system for 3 phase motors and for larger systems up to 10,000 CFM; and development of a library of custom applications with software utilities and schematics to assist in test configuration.

## Résumé

Au début de 1995, la firme Sheltair Scientific Ltd., engagée à contrat par la SCHL, s'est attaquée à la conception et à la fabrication d'un appareil destiné à mesurer la performance des groupes moto-ventilateurs des installations résidentielles de chauffage et de ventilation. L'année et demie qui a suivi a été consacrée à un ambitieux projet visant la réalisation d'un prototype devant mener à la production d'un banc d'essai compact, convivial et polyvalent dont les fabricants pourraient se servir pour concevoir de l'équipement de ventilation plus efficace. Le produit fini résultant de ces efforts a été baptisé le «*FANalyzer*».

La recherche avait donc pour objectif de concevoir, de fabriquer et de mettre à l'épreuve un banc d'essai prototype pouvant tester à la fois la performance et le rendement des ventilateurs, mesurer les caractéristiques de performance des petits moteurs électriques (entre 1/60 H.P. et 1/2 H.P. environ) et produire des rapports de performance.

On estimait avoir besoin d'un dispositif comme le *FANalyzer* parce qu'on savait que les appareils de ventilation seraient de plus en plus utilisés dans les habitations, que les appareils en service sont très peu efficaces et que les nouvelles normes exigeraient des fabricants qu'ils tiennent compte du rendement et de la consommation énergétique de leurs produits. Une fois ce banc d'essai créé, on espérait qu'il pourrait être prêté ou loué aux fabricants canadiens ou bien utilisé directement par la SCHL ou des entrepreneurs dans le but de produire des données d'essai plus complètes et plus spécifiques pour les divers services publics d'énergie. Le banc d'essai pourrait aussi être utilisé par les associations et les instituts de recherche dans l'élaboration d'installations d'essai internes de qualité comparable ou supérieure. Il pourrait également permettre la tenue d'essais indépendants sur des produits vendus dans le commerce de manière à favoriser la mise en place de normes d'efficacité énergétique plus rigoureuses pour les programmes de gestion axée sur la demande de même que pour les codes et règlements touchant le bâtiment. Enfin, on envisageait que le banc d'essai pourrait servir d'aide à l'enseignement dans bien des cours sur le chauffage, la ventilation et la climatisation.

La conception et la fabrication du *FANalyzer* se sont déroulées en quatre phases :

1. sondage mené auprès de 30 fabricants et organismes d'essais du Canada et des États-Unis suivi d'un atelier tenu à Vancouver au cours duquel des experts ont discuté des critères de conception;
2. élaboration du concept, suivie de l'acquisition de l'équipement requis pour faire l'essai de moteurs, pour mesurer le débit d'air, pour acquérir et analyser les données ainsi que pour produire un rapport informatisé;
3. fabrication et essai du prototype;
4. essais chez Powertech Labs et aux installations d'un fabricant, puis présentation à la SCHL.

Le rapport renferme une analyse des résultats du sondage mené auprès de l'industrie ainsi qu'une description des visites effectuées chez les fabricants et des installations d'essai et de formation du

sud de l'Ontario. L'atelier de conception a permis de conclure que le *FANalyzer* devrait être conçu pour servir d'«outil de conception» plutôt que d'«outil normatif ou d'homologation de produit».

Le logiciel et le matériel d'acquisition de données a été acheté chez National Instruments parce que son équipement offre un excellent langage de programmation graphique et une très bonne interface, que son système d'acquisition de données est rapide et abordable, qu'il permet de compiler les applications d'essai de manière à en assurer la protection et à en faire la reproduction à faible coût et qu'il est facile de personnaliser les applications pour d'autres usages.

Pour tester les moteurs, on a retenu une table de couple de réaction que l'on a conçue de manière à permettre un étalonnage automatique. Il est possible de mettre à l'essai le moteur séparément ou en association avec le ventilateur, selon la configuration choisie. La table est fixée à une plaque d'appui à hauteur réglable montée sur un palier à semelle.

Les méthodes de mesure du débit d'air ont fait l'objet de recherches et d'essais approfondis. Finalement, on a choisi un anémomètre à fil chaud associé à six thermistances électriques corrigées à une température constante.

Nous avons acheté le logiciel d'acquisition de données LabVIEW dans le but de traiter et d'analyser les signaux émis par les capteurs. Un instrument virtuel («*sub vi*») a été créé pour chaque composant du banc d'essai, soit le wattmètre, le régulateur des volets, le régulateur de la vitesse, la cellule de charge, le tachymètre, l'anémomètre à fil chaud, les capteurs de température et les pressions statiques.

Le *FANalyzer* offre une interface conviviale dotée d'options permettant de réaliser une grande variété d'essais ponctuels ou alors un essai entièrement automatisé du rendement d'un moteur ou d'un ventilateur. Les résultats sont présentés graphiquement sur des formules de rapport uniformisées. Ces formules permettent l'analyse de toutes les variables clés, y compris la vitesse, la pression, le débit, le couple, la puissance, la température, la tension et le facteur de puissance.

Actuellement, le *FANalyzer* se prête le mieux à l'essai du rendement des ventilateurs possédant une configuration de type B (conformément à la norme ASHRAE 51-85) qui consiste à faire fonctionner le ventilateur à un certain nombre de points de fonctionnement à une même vitesse. D'autres configurations sont aussi possibles. Le manuel d'utilisation du *FANalyzer* explique comment effectuer les programmes d'essai et montre l'emplacement des divers capteurs et des prises de pression. Les essais peuvent être automatiques, les programmes d'essai de LabVIEW étant utilisés pour régler le ventilateur et les volets, puis pour recueillir, analyser et présenter les données. En choisissant le connecteur de transition approprié, on peut utiliser le *FANalyzer* pour réaliser des essais précis de toutes sortes d'installations, du ventilateur de salle de bains produisant un débit d'air de 25 L/s aux générateurs de chaleur soufflant 550 L d'air à la seconde.

Pour les essais de moteur, le manuel d'utilisation indique la façon précise de charger le moteur en vue d'un essai de rendement. Trois rotors de charge sont fournis, chacun possédant sa taille et son diamètre propres. De cette façon, il est possible de mettre à l'essai des moteurs de 1/60 H.P. à 3/4 H.P., à raison de 1 000 à 2 500 tr/min.



Le *FANalyzer* peut être démonté et rangé dans son propre banc, puis roulé dans une caisse d'expédition de 1 m sur 0,7 m sur 1,6 m. La caisse pèse 39 kg et le banc et l'équipement d'essai pèsent 90 kg.

Avant sa mise en service, le *FANalyzer* a été soumis à une évaluation critique par Powertech Labs et à des essais en service par un fabricant et distributeur local d'appareils de ventilation résidentiels. Lors de ces essais, la polyvalence et le degré de perfectionnement du *FANalyzer* ont suscité beaucoup d'enthousiasme. Les techniciens et les ingénieurs ont notamment été impressionnés par l'intégration de tous les capteurs et composants au sein d'une même interface homme-machine automatique.

Le banc d'essai offre des résultats très visuels aux utilisateurs durant l'essai automatique d'un groupe moto-ventilateur. Cette caractéristique est particulièrement efficace pour montrer aux fabricants, aux constructeurs, aux responsables des codes et aux représentants des services publics les gammes de performance que l'on peut attendre des divers types d'équipement actuellement offerts sur le marché. Étant donné que le *FANalyzer* montre clairement dans quelle mesure il est possible d'améliorer la performance, on s'attend à ce qu'il contribue à l'élaboration et à l'atteinte d'exigences devant favoriser une meilleure performance des installations de ventilation.

De plus amples travaux pourraient rendre l'appareil plus fonctionnel, notamment en ce qui concerne le soutien à la formation, le remodelage du prototype de façon à produire une version finale de l'appareil qui soit plus simple et plus robuste, la conception d'un système destiné aux moteurs triphasés et à des systèmes plus importants pouvant développer 10 000 pi<sup>3</sup>/min et l'élaboration d'une banque d'applications personnalisées munie d'utilitaires logiciels et de schémas facilitant la configuration des essais.

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# CONTENTS

1. INTRODUCTION .....	1
1.1 BACKGROUND.....	1
1.2 OBJECTIVES .....	1
1.3 RATIONALE.....	1
2. METHOD .....	3
3. CONCEPT DEVELOPMENT.....	5
3.1 ESTABLISHING INDUSTRY NEEDS.....	5
3.1.1 Visit to Manufacturing Plants and Test Facilities .....	5
3.2 PROBLEM SOLVING THROUGH A DESIGN WORKSHOP .....	7
4. COMPONENT DESIGN.....	10
4.1 MOTOR TESTING SYSTEM.....	10
4.1.1 Force Measurement Using Reaction Torque Dynamometer .....	10
4.1.2 Motor Loading with "Air" .....	10
4.2 AIR VELOCITY MEASUREMENT SYSTEM.....	12
4.2.1 System Design Rationale.....	12
4.2.2 Calibration of Hot-Wire Grid in Wind Tunnel.....	12
4.2.3 Construction of Air Flow Measurement System .....	13
4.3 TACHOMETER .....	14
4.4 TEMPERATURE SENSORS.....	15
4.5 POWER MEASUREMENT .....	15
4.6 INSTRUMENTATION & METER BOX .....	17
5. DATA ACQUISITION HARDWARE AND SOFTWARE .....	18
5.1 AT-MIO-16E-10 DATA ACQUISITION HARDWARE .....	18
5.2 DATA ANALYSIS AND REPORTING SOFTWARE .....	18
5.3 HARMONIC ANALYSIS.....	19
6. TEST ROUTINES .....	20
6.1 FAN EFFICIENCY TEST: TYPE B, FREE INLET, DUCTED OUTLET.....	20
6.2 MOTOR EFFICIENCY TEST (CSA C747).....	20
7. FIELD TRIALS .....	21
8. CONCLUSIONS .....	22
APPENDIX 1: INDUSTRY SURVEY .....	23
APPENDIX 2: OPERATING & MAINTENANCE MANUAL (PRINTED SEPARATELY) .....	

# 1. Introduction

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## 1.1 Background

In December 1994, Sheltair Scientific Ltd. was awarded a contract from Canada Mortgage and Housing Corporation to design and construct a system for performance testing of the motor and fan components of residential heating & ventilation appliances. This report presents the results of this research and introduces the main components of the resulting design.

The terms of reference for this research included detailed performance specifications for the device, written by Jim White, CMHC's project officer. Sheltair expanded these criteria, in consultation with industry representatives and CMHC. The result was an ambitious prototyping effort to produce a compact, easy to use, multi-purpose test bench for assisting manufacturers in developing more efficient ventilation equipment. From this point forward the system will be referred to as the "FANalyzer".

Sheltair was assisted by Powertech Labs Inc., a Vancouver-based research facility, formerly a wholly owned subsidiary of BC Hydro. Powertech had been involved in power quality measurement and motor efficiency testing for a number of years. The skill and experience they contributed to this project proved extremely valuable during the design workshop, and throughout the prototype development stages for motor efficiency testing.

The remainder of this report describes the research objectives, rationale for creating a new type of test system, the methods employed, the design features, and the results of field testing of the device.

The prototype FANalyzer was completed and delivered to CMHC in February, 1996. A User's Manual accompanied the equipment.

## 1.2 Objectives

The intention of this project was to design, construct and pilot-test a prototype test rig capable of:

- testing fans for both performance and efficiency;
- measuring the performance characteristics of small electric motors (from about 1/60 hp to 1/2 hp); and,
- producing performance reports that are of use to a variety of audiences.

## 1.3 Rationale

The value of the FANalyzer is best understood in the context of the changes that have been occurring in residential ventilation technology. These changes are briefly discussed below.

- ***Increased Use of Ventilation Appliances in Homes***

Canadian building codes are accelerating a trend towards increased numbers of mechanical ventilation systems in houses. Many of these systems are expected to be

operated continuously much of the year. Furnace blowers may also become part of the continuous ventilation systems in houses.

- *Low Efficiency of Presently Used Systems*

Unfortunately, much of the ventilation equipment that is being used in houses is not appropriate for this new role. Fans are extremely inefficient, averaging between 2 and 10 percent efficiency in terms of the electrical power used to move air. Much of the residential ventilation equipment is likely to suffer from unacceptably short lifetimes when used frequently for long periods. In aggregate, the ventilation systems are likely to represent a major new electrical end use for electrical utilities, increasing the peak load and creating an unacceptable ongoing capital, maintenance and operating expense for householders.

- *New Standards and Initiatives are being Introduced for Energy Efficiency*

To minimize these negative impacts a number of measures are being considered to facilitate a more rapid evolution of residential ventilation technology. A new CSA standard has been developed for testing the energy efficiency of small motors. A research and development program has been proposed by CMHC. Reports have already been prepared, under the auspices of CMHC, to identify options and to educate the industry. One of the CMHC report examined barriers to the use of energy efficient residential ventilation devices, and proposed a number of strategies<sup>1</sup>. The current project is a key part of these strategies.

The proposal was to develop a portable fan/motor test rig to be used by various groups in the industry to provide reference information on how existing products are performing, and to facilitate the design and development of more suitable products. Making such a rig available to the industry is especially important at this time, since most manufacturers are not well informed in this area at present, and do not all have the facilities to conduct such testing. A test rig, properly designed, has the potential to serve a multitude of important roles over the next several years. All the following scenarios are possible:

1. The rig could be offered on loan or lease to Canadian manufacturers to assist them in:
  - constructing a similar or better facility that can be used in house;
  - developing specifications on their existing product line;
  - educating designers and others about new performance variables; and,
  - experimenting with design options when prototyping new products.
2. The rig could be used directly by CMHC and/or contractors working on CMHC's behalf to provide more comprehensive test data on specific equipment that is important to other housing research projects.
3. The rig could be loaned or leased to energy utilities in Canada, or industry associations, or associated research institutes, to:
  - help develop in-house test facilities of comparable or superior quality;

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<sup>1</sup> Barriers to the Use of Energy Efficient Residential Ventilation Devices - A Survey of Industry Opinion, and A review of Strategies for Change, Sheltair Scientific Ltd., for CMHC, June 1992

- provide independent testing of commercially available products in order to create more stringent energy efficiency standards for DSM programs and building codes and regulations.
4. The rig could be used as a teaching aid and learning tool if combined with seminars and training exercises for the industry. The equipment could provide very effective lessons to designers and practitioners about the importance of specifications and the impact of installation practices.

## 2. Method

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The design and construction of the FANalyzer was conducted in four phases, as outlined below:

### Phase 1: Industry Survey and Design Criteria Development

In the first phase of the project, Sheltair identified the needs of industry by designing and distributing a fax survey to 30 manufacturers and testing agents in Canada and the US. A visit was made to an Ontario Manufacturer of residential heating and ventilating appliances. Two testing facilities were also visited. Finally a design workshop was held in Vancouver, at the Powertech Labs Facility in which the design team met with the CMHC Project Officer present, to review the findings of the survey and visits and to brainstorm on possible design solutions.

Also during Phase I, many relevant testing standards were obtained and reviewed to ensure compatibility of the test methods. These test standards have been adhered to as well as possible and have proved an important tool for test specification and system design.

### Phase 2: Concept Design and Equipment Procurement

Phase 2 included a conceptual design and the selection of many key components. Equipment and software was purchased for each of the four main systems:

1. Motor Testing System
2. Air flow Measurement System
3. Data Acquisition System
4. Data Analysis and Reporting Software

These separate systems are illustrated in Figure 1.

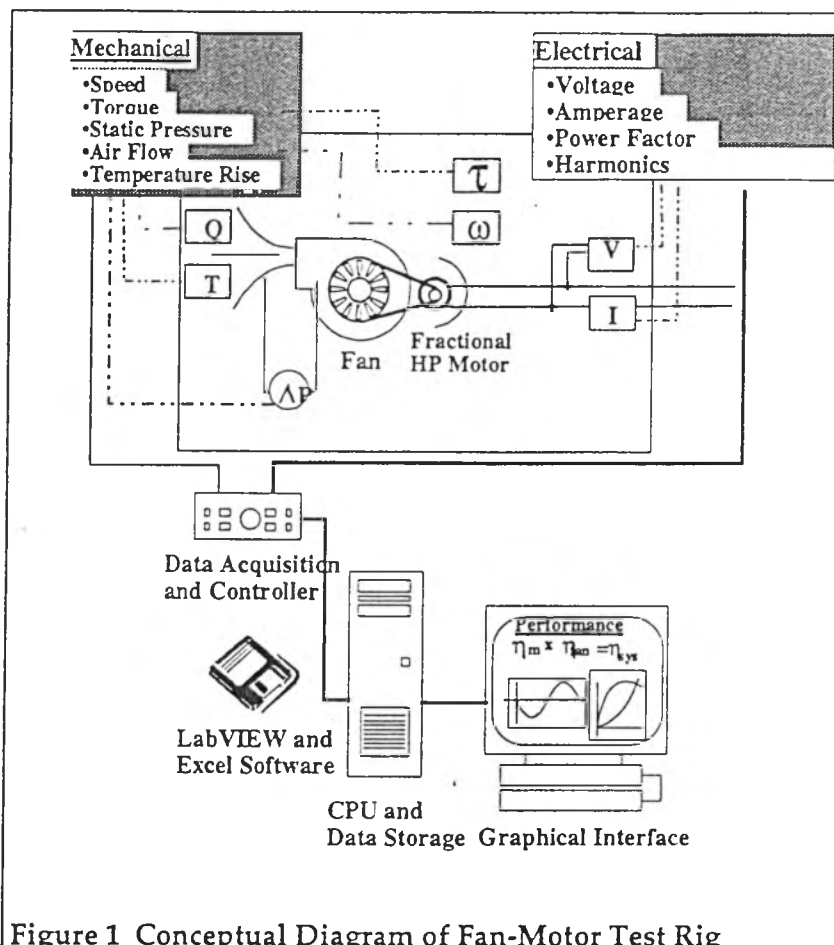


Figure 1 Conceptual Diagram of Fan-Motor Test Rig

### Phase 3: Construction and Testing of Prototype

The prototype construction Phase was the longest phase of the project and spanned several months. Each system was brought from concept to reality. The components were tried and tested, multiple times. Because of false starts and new insights, more time was spent on this phase than expected. The Data Acquisition system played a key part during this period - obtaining trial data, testing sub-routines, and calibrating the Motor Test System and Air Flow Measurement Systems.

### Phase 4: Trials and Submission of Prototype and Final Report

After the prototype reached a stage where comprehensive fan system testing was possible, testing and trials began using several appliances including a 150 cfm Utility blower, and 250 cfm multi-port ventilator, and a 1300 cfm residential furnace. The Motor-Test System was initially calibrated using a ½ hp Fasco PSC motor. The same motor was later tested under identical conditions using a CSA approved Motor Test System developed and used by Powertech Labs to confirm the validity of results.

## 3. Concept Development

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### 3.1 Establishing Industry Needs

A Fax survey was used to obtain input from the HVAC industry in Canada and the United States. The survey was designed with the following specific objectives:

- to raise awareness among residential heating & ventilation appliance manufacturers of CMHC's project;
- to discover which procedures are currently being used by industry to monitor the performance of its products, - and what improvements are desired;
- to obtain sample ventilation appliances to test during the design of the rig; and,
- to obtain feedback from industry on some of the design features that could be included in the test rig.

Lists of manufacturers, test agencies, and technical committees were reviewed. Ultimately the survey was distributed to 19 manufacturers and 11 research and standards groups. Fourteen questionnaires were returned, for a response rate of approximately 50%.

The results of the survey have been compiled and are included with a copy of the questions in Appendix I. The number of responses for each question is tabulated beside each question or data entry field. As well, any key comments made by individual manufacturers or agents were have been summarize with the results.

#### 3.1.1 Visit to Manufacturing Plants and Test Facilities

During the first week of January 1995, a visit was made to a Manufacturing plant and to some training and testing facilities in Southern Ontario including, Ontario Hydro Technologies, ORTECH International Labs, and Consumers Gas. The objectives of the visits were:

1. to observe the testing facilities that were being used to perform testing of motors, fans, and furnace blowers,
2. to discuss any design issues that might influence the motor FANalyzer design, with those that might be affected or gain from its adoption; and,
3. to get ideas for the test rig design and use a video camera to capture images of cooperating test facilities for use during the subsequent design workshop.

The highlights of these visits are discussed below:

**ORTECH Labs:** Several hours were spent in the ORTECH labs with members of the Energy and Environment Group representatives Peter Edwards and Paul Geisberger. These gentlemen have been responsible for testing and development of air flow/thermal performance testing (AMCA/ASHRAE 210-85, CSA 439 ASHRAE 37, 40) and motor efficiency testing (CSA C390 and C747) respectively. Some of the chief concerns raised during the visit were related to the accuracy of motor testing, especially in the case of



small torque measurement, and the error potential when conducting efficiency testing of air-over<sup>2</sup> motors under over-ventilated conditions.

**BROAN Manufacturing:** A visit to BROAN was made in January 1995 under the supervision of Barry Lo, Engineering Manager. BROAN has maintained an interest in the performance testing of their products and had built a 500 CFM ANSI/AMCA 210-85 fan testing chamber several years ago. In the summer of 1994, Barry Lo hired a summer student to help develop a more advanced testing

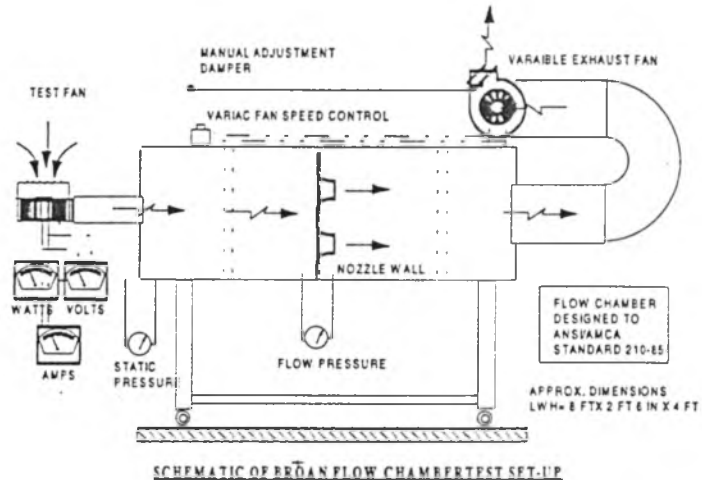


Figure 2 Schematic of Manufacturers Air Flow Chamber

system that would incorporate state of the art data acquisition and sensor technologies. The parallel between the FANalyzer and Broan's own R&D initiatives was instrumental in maintaining a keen interest in the project.

The diagram in shows approximately the configuration of the BROAN fan test facility. All measurements are taken manually and charts are used to determine the air flows through the test fans. BROAN uses the data collected to publish in house performance specifications and reports some of the data in its product literature. However, the facility does not serve as a substitute for HVI certification of ventilation appliances

**ONTARIO HYDRO TECHNOLOGIES:** A tour was taken of the Ontario Hydro Technologies (OHT) research and testing facilities, hosted by Dave Vellekoop, the Technical Services Coordinator. OHT had developed four separate testing facilities including a Heat pump test Lab, a Ventilation Test Room, a Motor Test Facility, and a Blower Test Facility. Unfortunately, due to budget restraints, and a changing focus in research initiatives and other reasons, OHT was not operating its Blower Test Facility or its Motor Test Facility and they had been partially dismantled. The Blower Test Facility was non-operational but the components were still assembled. Some of the features of the OHT test facilities are:

- *Full torque/speed control* not available in most constant torque dynamometers;
- *Neutral-buoyancy bubble flow visualization technology* used to assess how blower design changes affect flow regimes; and,
- *Tribology Labs* for testing of motor and fan bearing wear.

<sup>2</sup> Air-over implies motors that are installed in an active airstream. They do not require additional cooling using integral cooling fins, and are often much more compact in their design than other types of motors. Special consideration may be required when testing air over motors according to the CSA C747 Standard since thermal equilibrium must be reached before test data can be collected. (All types of motors require T.E. be reached.)

## 3.2 Problem Solving through a Design Workshop

Prior to completing a conceptual design for the FANalyzer, a workshop was organized to help focus design efforts. Eight individuals participated, including Sebastian Moffatt and Brian Sikorski from Sheltair, Jim White from CMHC, George Pinch from BC Hydro, Ian Theaker from Integral Engineering, Rick Slamka from QUESTEK R&D, and Bruce Nielson and Chris Morton of Powertech Labs Inc.. Many suggestions were received from the workshop. Some of the key decisions reached by the group are summarized below:

### 1. "Design Tool Vs Certification Tool"

The test rig was decided to be built as a "Design Tool" or a "Pre-Certification Tool" rather than a "Standards or Product Certification tool. This resolution relaxes the precision requirements slightly and allow the FANalyzer to be built with some tolerance to the problems of high accuracy at very small loads and torques, which is difficult to do within the budget constraints. The manufacturers survey placed a realistic price tag on the FANalyzer to be no more than \$10,000, which ruled out the use of expensive packaged motor test apparatus such as the MAGTROL HD 705 Dynamometer and Power Analyzer used by Ontario Hydro for its motor test facility which together can cost more than \$30,000.

### 2. Choice of LabVIEW Data Acquisition Software and Hardware

The Data Acquisition Software and Hardware was purchased from National Instruments at a cost of about \$4,000. The LabVIEW Base Analysis package, which was purchased for \$1,500 (plus Taxes), can be used for subsequent versions of the MFSA. Data acquisition will consequently reduce significantly in software cost for each FANalyzer version that is built. The NI LabVIEW Software and NI Hardware has been decided unanimously to be the product of choice for several reasons. Some of these reasons are:

- The graphical programming language and user interface are ideal for test bench systems and give the user a real-time sense of the system interactions during a test.
- Affordable DAQ Hardware allows extremely fast sampling (compared to standard data logging equipment) of 100,000 Samples/sec which allows for *real-time* voltage and current waveform analysis from which power and harmonic distortion values can be derived. The actual acquisition of waveforms requires only inexpensive current and voltage transformers;
- Once programmed, testing applications they can be compiled for protection so that users cannot modify them. Compiled applications can be produced at a low cost and upgraded from a single source;
- LabVIEW applications are relatively easily developed for custom needs to automate or monitor other processes in any manufacturing plant.

### 3. Low-Cost Reaction Torque Measurement System

A Reaction Torque-Table was originally chosen to be used which incorporated a force transducer (or load cell) using of a full-bridge strain gage arrangement. It was suggested during the design workshop that the motor test procedure should include an automated calibration routine to allow the user to check calibration of the system using known test weights. The Torque measurement design that was finally selected does include an auto-calibration routine and in fact, it was found that it was critical because the conditions changed each time a different type of motor was installed, or even the same motor was removed and replaced.

*Removal of Motor from Fan Assembly for Testing* The difficulty of motor torque measurement in installed fan motor sets was realized and, because of this, a consensus was reached that in order to perform the efficiency test, the motor would usually need to be detached from the blower assembly and removed from the appliance housing. A separate test would need to be performed on the motor. Motor efficiency curves would later be transferred to the fan testing routine to establish the fan efficiency.

### 4. Air-Flow Measurement by Differential Pressure Not Required

The air flow measuring method was discussed at length and it was concluded to be unnecessary to design the flow chamber entirely based on AMCA/ANSI 210-1985, which limits the possibilities for flow measurement to either mass flow measurements using flow nozzles, or velocity pressure measurement using a traverse with a Pitot tube. Some of the key disadvantages identified of using  $\Delta P$  measurement systems for the Test Rig were as follows:

- a) For Air Flow nozzles the power requirements would have increased the Test Rig estimated total power draw to above the 15 Amp limit set by typical circuit breaker size;
- b) These methods would require the uses of multiple flow ranges to cover the wide range of flows anticipated; and,
- c) Pressure based velocity measurements place practical limitations of about 2 m/sec on minimum air velocity.

Some of the alternatives to AMCA 210-85 flow measuring techniques that were considered were:

- *Ultrasonic flow measurement:* the use of transmitters and receivers to measure small changes in sound velocity caused by the moving air stream. A preliminary calculation estimated that time changes in the order of 1/100,000th of a second would required to be measured accurately.
- *Variable Flow Area Meter:* the use of an adjustable sharp-edged orifice to measure flow based on known pressure drop and cross sectional area. This would require real time adjustment of the orifice size based on static pressure and flow pressure feedback.

- *Hot-wire Anemometer Grid:* the use of constant current-temperature corrected anemometers to measure air velocity, based on heat transfer from a platinum wire to the airstream.

After some trial and experimentation the Hot-wire grid proved to be the most acceptable method. Concerns with large fluctuations caused by air turbulence at low velocities were not realized because the software had capability to average large numbers of samples. Ideally a grid with as many measurement points as economically possible needed to be used in order to characterize the velocity profile.

## 4. Component Design

### 4.1 Motor Testing System

#### 4.1.1 Force Measurement Using Reaction Torque Dynamometer

Motor Torque is measured using a reaction torque dynamometer method. As illustrated in Figure 3, the motor is mounted on a flat table and strapped tightly into place using a ratcheting clamp (not shown). The table is fastened to a height-adjustable back plate, which is mounted on a bearing pillow block. The back plate and table are allowed to rock freely around the central pivot point which is aligned with the center of the motor shaft. When the motor turns against a load, the reaction force causes the table to spin freely around the axis. There is some resistance to movement from static friction but this is negligible in the intended range of torque measurement. A force transducer or "Load Cell" is used to measure the reaction force.

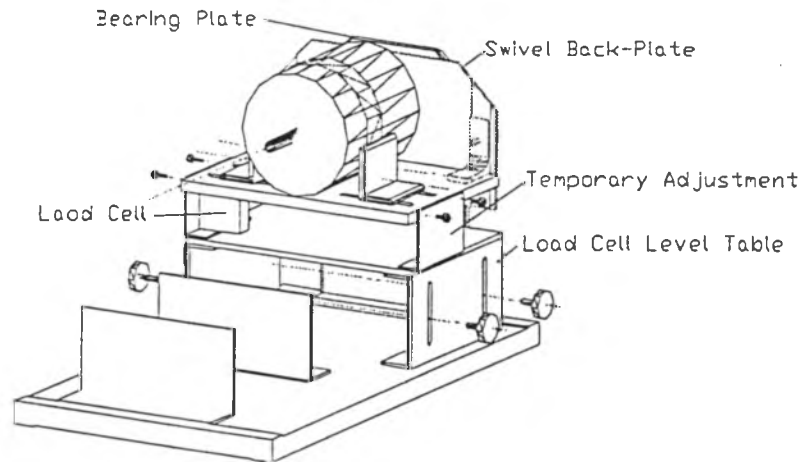


Figure 3 Motor Test Cradle Dynamometer

The motor test system has been calibrated to measure torque accurately ( $\pm 1.5\%$ ) from about 0.05 N-m (0.4 in-lb) to about 4.5 N-m (22.0 in-lb). This corresponds to a range of motors from 1/60 to 3/4 hp @ 1140 rpm. The torque arm length is adjustable from approximately 50 mm to 250 mm, in increments of 19 mm.

#### 4.1.2 Motor Loading with "Air"

CSA C747 Test standard for small motors requires that a motor efficiency test be performed within a range from "no load" to about 125% of rated load. For a 1/2 hp motor this would be 0.635 hp. In many motor efficiency measurement systems, a second motor or an alternator, an electronic brake, or possibly a friction clutch is used to bring the test motor through a series of load points. In the case of a loading motor, this may require the addition of armature current to the loading motor to increase its resistance to rotation. This leads to two technical problems that have been avoided with the use of fan-impeller loading. Firstly, these motors act as generators, so they develop energy in the form of heat,

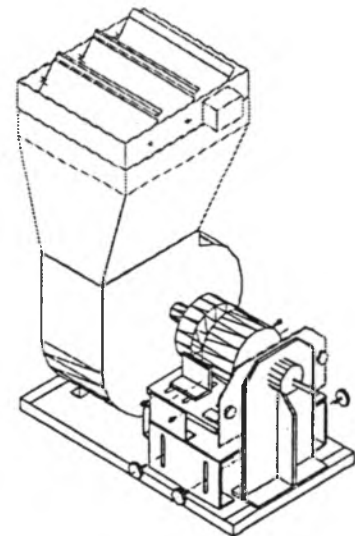


Figure 4 Torque Cradle Coupled to Control Blower

which must be dissipated using a water cooled resistor bank or some other method. Secondly, automatic control of the motor test sequence is difficult and rarely attempted. Each data point must be obtained manually, usually from several instruments.

*“two technical problems were avoided with the use of fan-impeller loading”*

Motor Loading for the Fan-Test Rig system is achieved by using the existing variable speed exhaust blower and the automatic control damper. By connecting the test motor shaft to the FANalyzer blower and impeller, variable loading is easily provided. This simplifies the testing and allows for a completely automated motor test, within the loading range of the installed impeller. The motor dynamometer system has been designed around the control fan blower, which has in turn been customized for this purpose. Details of the motor test are discussed in more detail in the Operation Manual.

While some blower motors can be tested in their “factory” blower configurations, most motors will require removal of the test motor from their native fan assembly and remounting with a dummy impeller on the torque table. For the prototype testing, only two dummy impellers were needed for adequate test results and are provided with the first prototype. The FANalyzer’s own blower assembly and automatic control damper are used to vary the loading.

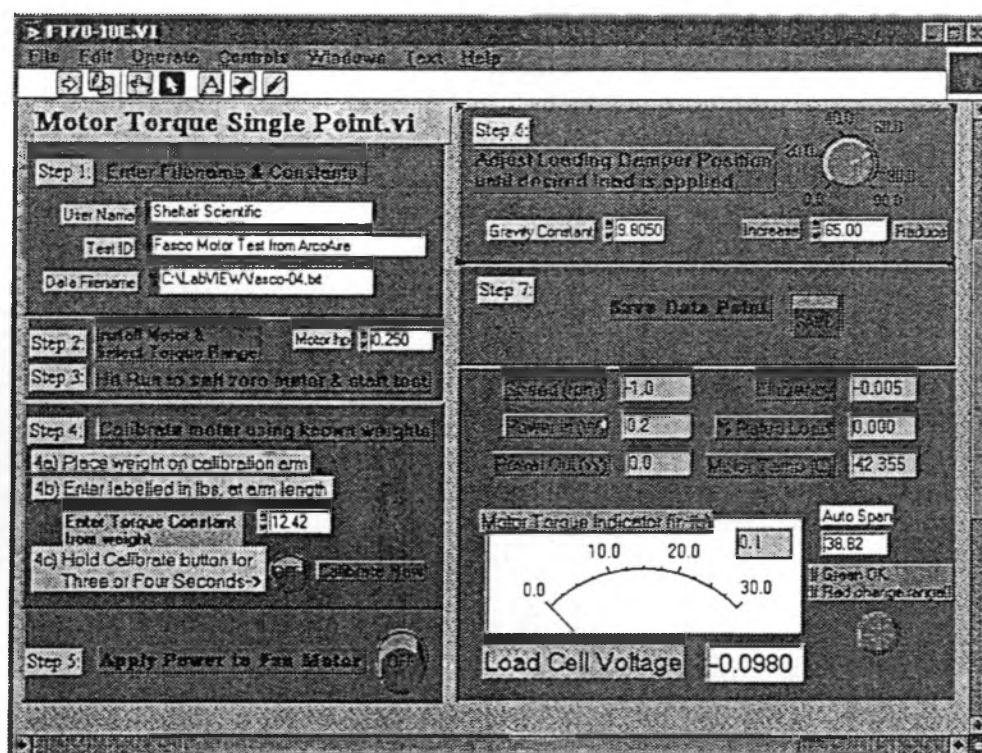


Figure 5 Front Panel of Motor Efficiency Single Point Save.vi

After the test is completed, the test data can be transferred into a spreadsheet matrix and accessed, after a fan efficiency test, to establish the intermediate system losses. Using a polynomial fit of the data acquired during the motor test, any combination of motor speed, motor torque, or Power input can be used to estimate the motor efficiency at any given fan test condition.

Motor Temperature rise has a significant effect on motor winding resistance and resultant efficiency, as indicated by equation in Section 5.7 of the CSA C747 standard. For this reason, the test procedure requires the motor reach thermal equilibrium at full load before making test measurements. When performing the test using the LabVIEW test routine provided, this is done automatically once the test set up is properly configured as per the Operating Manual specifications.

## 4.2 Air Velocity Measurement System

### 4.2.1 System Design Rationale

Air Velocity, and implied air flow measurement, is achieved using a combination of wind tunnel and six point hot-wire anemometer grid. Advantages and disadvantages of other measurement systems were considered and this was selected as the method of choice for a several reasons including:

- high nozzle or orifice pressures (i.e. up to 500 Pa across a nozzle walls) and the associated losses are eliminated when using velocity measurement; and,
- a smaller exhaust fan can be used to achieve the static pressure control;
- the flow chamber diameter can be reduced to about 11" or 12";
- velocity can be measured quickly and at very low air speeds (i.e. 0.3 m/sec); and consequently,
- the flow can be measured over the entire 20 L/s to 600 L/s span using one single flow range. This will simplify construction, use, and many other problems; and,
- Cost is low at about \$40/hot-wire or \$240 for the entire grid.

Some disadvantages to the system are:

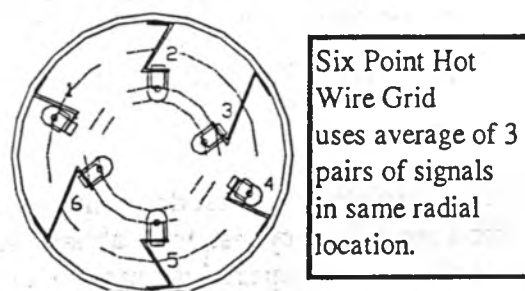
- A long entrance length to the measurement grid resulting in a slightly longer overall flow chamber length. ASHRAE suggests a 10 duct diameter overall length (i.e. 100 in. for a 10 in diameter duct).
- Low velocity measurements, below 1 m/sec, are somewhat unstable and fluctuate require statistical averaging of hundreds of measurement points.

The use of a multi-point traverse was needed to obtain a proper velocity profile. It was found that a six point grid was adequate. Spacing of the grid points was selected based on a quadrature procedure<sup>1</sup> for improving the accuracy of velocity measurement in round ducts. A schematic diagram of the Hot-wire grid is provided in Figure 6.

### 4.2.2 Calibration of Hot-Wire Grid in Wind Tunnel

Although the hot-wire anemometers are delivered with calibration curves, it was necessary to calibrate the hot-wire grid in installed conditions. For this purpose, a Flow Chamber was built according to the AMCA 210-85 Fan Test Standard<sup>2</sup>. Sheltair's calibration chamber used six ASME flow nozzles ranging from 25 mm to 175 mm diameter with a flow range from 10 L/sec to 650 L/sec (175 mm

Figure 6 Hot Wire Grid Configuration



nozzle and a 450 Pa flow pressure differential). Calibration was done under controlled conditions. A fluid manometer was used to all calibrate pressure transducers prior to hot-wire grid calibration.

The DAQ system was used to sample sensors, Pressure and Temperature, with typical sampling rates of 1000 samples per second with 2000 time-averaged samples per measurement. Over 3000 data points were collected over the range of 15 L/sec to 650 L/sec (not all really needed, but easy to obtain and analyze). A polynomial regression was made that relates the entire flow regime to a single 4<sup>th</sup> order curve as presented in Figure 7. At the very low flows (less than 20 L/sec), nozzle air flow and Hot-wire grid air flow began to diverge to +/- 10% of each other. It is suspected that the Hot-wire Grid results may be more accurate than the ASME nozzle results in the low flow ranges, primarily due to downstream air leakage and suspected nozzle precision error.

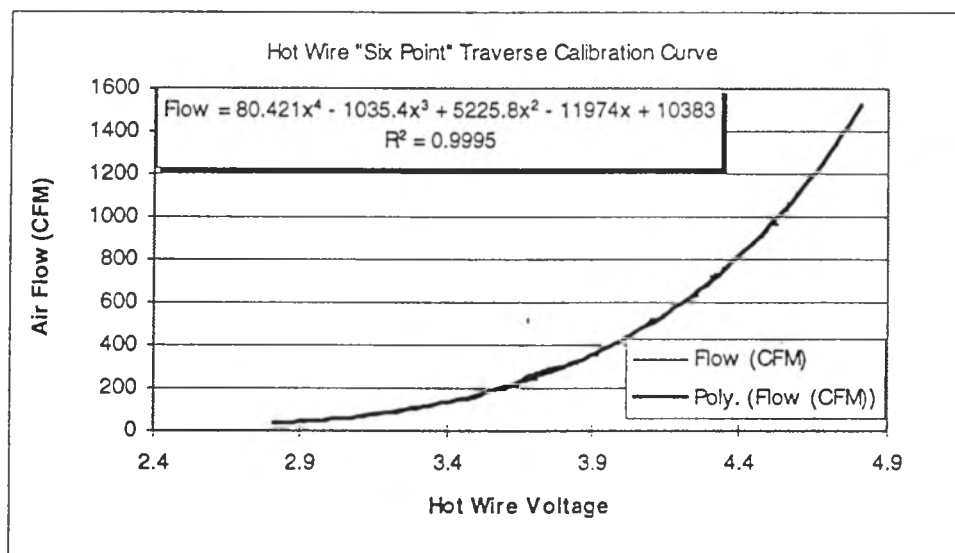


Figure 7 Hot Wire Grid Calibration Curve & Equation

#### 4.2.3 Construction of Air Flow Measurement System

The design of the flow measurement system was based, to some degree, on the ASHRAE/AMCA 210-85 Pitot in Duct arrangement. However, the similarities end after the selection of duct length, traverse position, and flow straightener location. In particular, the test rig has been designed to incorporate a significantly different flow measurement method and control method than has been previously used for such an application.

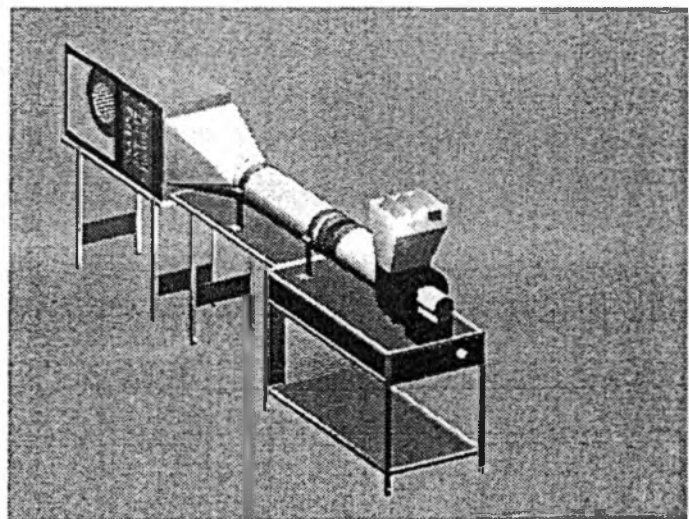


Figure 8 Test Rig Set-up with Typical Furnace



A six-point grid of inexpensive hot-wire anemometers was used in the place of the pitot traverse measurement system. The key advantage of the use of hot wires is the ability to obtain relatively accurate measurement over a wide range of air velocities (0.3 m/sec to 15 m/sec) using a single flow range.

The main components of the flow measurement system are as follows:

1. Air Flow Chamber or Wind Tunnel;
2. Hot Wire Flow Grid;
3. PC Speed Controllable Fan;
4. Automatic Control Damper;
5. Static Pressure measurement;
6. Tachometer;
7. Temperature Sensors; and,
8. Duct Transition Fittings.

Figure 8 gives an idea what the test rig set-up might look like for a residential furnace fan test .

### 4.3 Tachometer

A tachometer for measuring motor speed has been constructed using a *reflective infrared sensor* mounted at the end of a shielded cable and placed in a section of flexible chrome tubing. A small section of reflective film is attached to any rotating part of the fan impeller, or motor shaft. Only a single pulse per revolution is needed which is analyzed through LabVIEW and related to speed using a pulse counter. The tachometer is mounted on a flexible coupling that can be easily positioned during the test. The sensor must be placed approximately 1/2" from the reflective surface target.

It is important that the operator take some care in the placement of the tachometer to ensure proper results. This requires some trial and verification of measured readings with expected readings. A typical procedure for tachometer set up might be as follows:

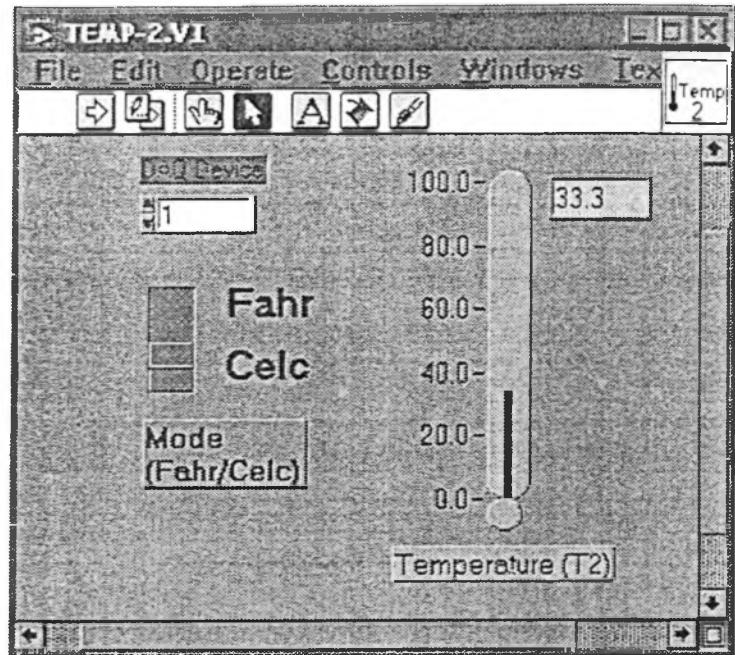
1. Install tachometer in place ½ " (12 mm) from flat reflective Mylar™ film and make sure it is perpendicular to surface. **CAUTION make sure fan or motor is de-energized if possible during Tachometer set-up.**
2. Use Tachometer-Test.vi or a Voltmeter to measure the voltage at terminal (Ctr Gate 0 in SCB68 connector board).
3. Spin the motor/impeller so that the Tachometer passes over the Mylar film.
4. If Voltage drops to near zero Vdc from 5.21 Vdc then placement is OK.
5. Start motor and read speed from Tachometer vi. If speed does not register then start over from Step 1 and adjust position until speed readings are steady.

This procedure is repeated in more detail in the Operation Manual.

#### 4.4 Temperature Sensors

Two LM35 high precision ( $\pm 0.5$  K) temperature sensors are supplied for winding and ambient air temperature measurement. The motor winding temperature can be obtained roughly by placing the temperature sensor as close as possible to the windings. The sensor has been immersed in a heat shrink shield to protect it from direct contact to windings and offer some electrical noise attenuation.

As a convention, different functions have been assigned to each of the three sensors: Temp 1 is Ambient Temperature; Temp 2 is Winding Temperature; Temp 3 is normally used for air stream temperature. For example, Temp 1 and Temp 3 can be used for a temperature differential measurement across a fan-motor set, from which energy losses to the air can be estimated. This can be used as a rough check on Fan efficiency



#### 4.5 Power Measurement

Power measurement is done using direct analysis of voltage and current waveforms in LabVIEW. The voltage and current waveforms are sampled at over 30,700 samples/sec each

$$p(t) = v(t)i(t)$$

$$I_{rms} = \sqrt{\frac{1}{T} \int_0^T i^2 dt} \quad (\text{equations 1, 2, and 3})$$

$$V_{rms} = \sqrt{\frac{1}{T} \int_0^T v^2 dt}$$

and 1524 samples each are multiplied together. Power is calculated as the instantaneous product of voltage and current (see equation (1) above), however the Power vi averages the values over 4 or 6 cycles to obtain an average power consumption. The rms (root mean square) Current and Voltage (equations (2) & (3)) are calculated exactly as shown in the equations. The integration is performed by summing up the samples over the sampling period.

Power factor is calculated exactly from the following relationship:

$$pf = \frac{P}{V_{rms} I_{rms}} = \cos(\theta)$$

Where pf is the power factor (phase angle is not normally reported).

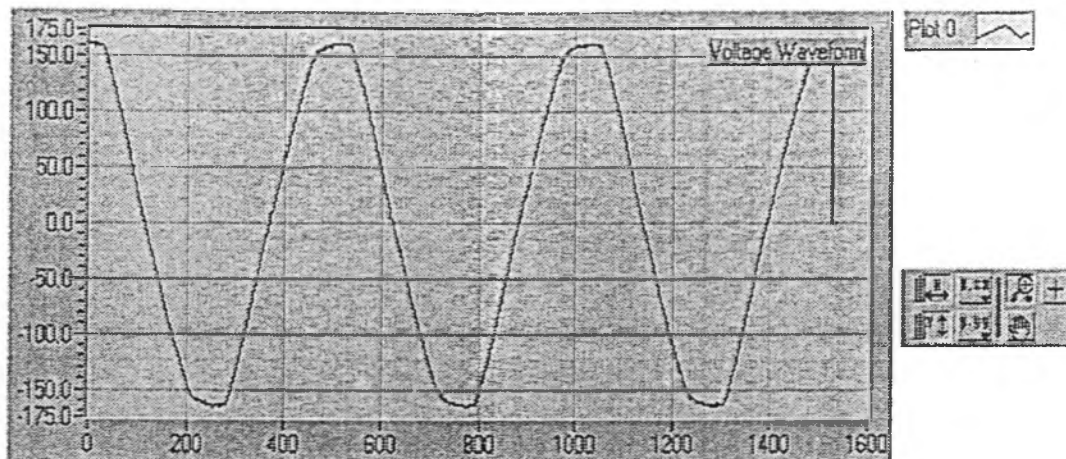


Figure 9 Voltage Waveform from Power Chart vi

The measurements are extremely accurate, more accurate in fact than those obtained from most off-the-shelf power meters. This can lead to some confusion and mistrust of the results as the measured power from the Power vi may differ from motor manufacturer specified power, dependent upon the current waveforms harmonics, and the power measurement method used. In general, low cost triac fan speed controls cause a very distorted waveform that has a high rms value but results in a low power factor.

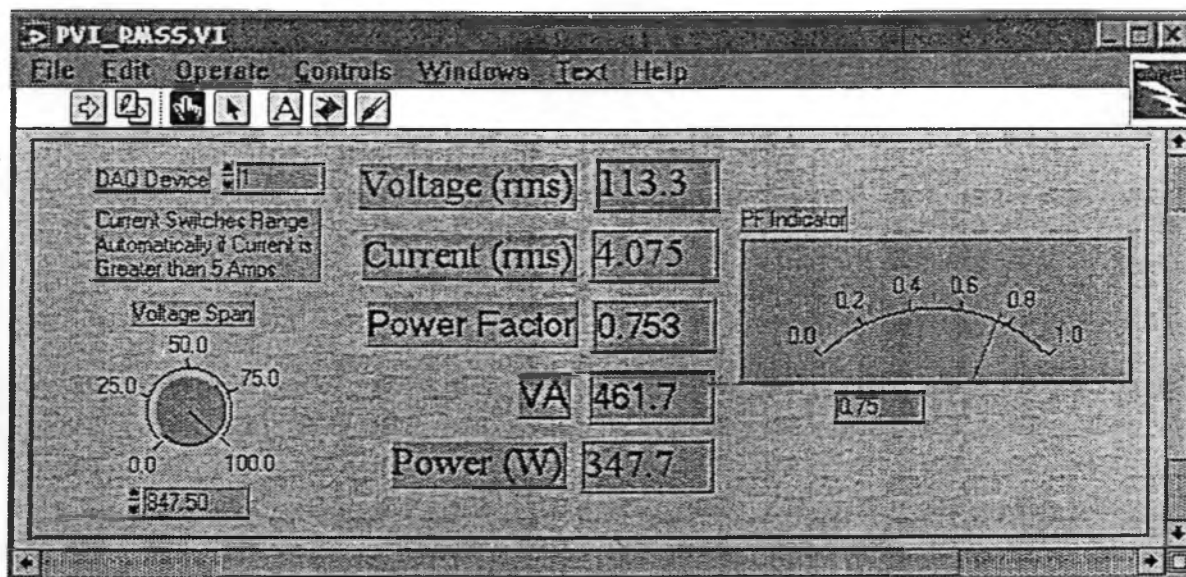


Figure 10 Digital Power Measurement vi

The graph in Figure 9 is an output from the Power Chart vi and shows a typical 115 VAC voltage 60 cycle waveform. Note that the rightmost tail of the voltage waveform has an anomaly in that it drops to zero. This is a result of an array shift that was required as a correction for a constant phase shift (approx. 2.4 electrical degrees). Despite efforts to avoid the phase shift, which in fact slows down the vi operation by about ½ second, the array shifting was found to be the most practical compromise. Figure 10 shows the front panel for the Power vi

#### 4.6 Instrumentation & Meter Box

The instrumentation box is a rather large aluminum hinged electrical box which was donated by BC Hydro & Power from their Metering Department in Vancouver. The box is 18" x 25" x 8" in depth. Although the box seems slightly oversized, it was originally intended to contain the Control fan Variable Frequency Drive. However, it was soon found that RF noise from the frequency drive effected sensors very negatively, and the speed drive was removed to a new location under the main test bench away from any instrumentation.

The Operation Manual includes a schematic drawing of the instrumentation box contents, as well as a table of cable routing, and a Data Acquisition connector box channel listing. The following table lists the main components of the instrumentation box.

##### *Instrumentation Box Contents*

<i>Qty</i>	<i>Description</i>
1	120 Volt AC Terminal and Power distribution Block
1	+/- 12 VDC and 5 VDC Instrument power supply
1	Frequency drive signal isolator board
1	115 to 12 VAC transformer and resistive divider for low voltage signal
2	MAMAC 50/5 Amp Current transformers
2	MAMAC "range selectable" low pressure differential transducers
1	MAMAC 0 to 24 VDC at 1 amp power supply for pressure transducers
1	Custom PC Board with Tachometer, Load Cell, Hot wire, AC voltage, and AC current circuitry, components, and terminal blocks.
1	Low voltage dc terminal block1
1	24 VAC transformer
1	24 VAC relay with power transistor circuit for remote switching of test motors.
1	Power supply and signal wiring to/from temperature sensors
*	Misc. wiring terminations (*as required)

## 5. Data Acquisition Hardware and Software

### 5.1 AT-MIO-16E-10 Data Acquisition Hardware

The was purchased from National Instruments (NI). The hardware includes electronics with a 100 kHz sampling rate, making it ideal for accurately measuring voltage and current.

The DAQ board is being utilized to about 85% of its capacity with 13 of 16 analog input channels, 2 of 2 analog output channels, and 1 of 2 pulse counters used. There are also 8 digital I/O channels unused that can be applied to switching on/off relays, and measuring status of devices. The resolution of the DAQ board is 12 bit or  $2^{12}$  bits = 4096 bits which means that for a 0 - 5 Volt signal input, the resolution is 1.22 mV. As an example, for a pressure reading from 0 to 500 Pa, the accuracy of the voltage measurement would be 0.122 Pa - which is more than adequate.

A virtual instrument (sub vi) was created for each component of the test rig including:

- power meter,
- damper control,
- speed control,
- load cell,
- tachometer,
- hot-wire flow grid,
- temperature sensors, and
- static pressures.

A copy of the AT-MIO DAQ board manual is included with the test rig.

### 5.2 Data Analysis and Reporting Software

LabVIEW Data acquisition software was purchased for processing and analyzing sensor signals, and providing a graphical user interface for input of test parameters, and output of results. The software has performed extremely well in the development of automated test routines such as AC waveform analysis and high speed signal processing. It has also performed well as a tool for creating spreadsheet ready data products. Though programming time during the project has been significant, the automated test routines should prove to be well worth the time investment.

Figure 11 shows a sample of the data output from LabVIEW for a fan air flow and efficiency test. Once exported to Excel, this data can be automatically formatted into a graphical presentation for whatever information desired. The Air Flow and Efficiency Test Data

Brian Sikorski  
Sheltair-001  
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Total Pressure	Static Pressure	Air Flow	RPM	Current	Power	Power Factor	Ambient Temp	Motor Temp	Efficiency
216.533	216.337	64.318	2765.9	0.638	72.1	0.971	28.1	28.0	9.10%
198.366	198.102	74.829	2713.7	0.656	74.3	0.973	28.1	28.5	9.40%
185.141	184.826	81.721	2678.6	0.663	75.1	0.974	28.1	28.5	9.50%
167.243	166.858	90.225	2643.2	0.674	77.0	0.976	28.1	28.4	9.20%
154.559	154.107	97.689	2617.8	0.678	76.9	0.974	28.1	28.5	9.20%
141.326	140.767	106.772	2595.7	0.684	77.9	0.977	28.1	28.3	9.10%
124.687	124.05	115.999	2569.3	0.689	78.1	0.976	28.1	28.1	8.70%
108.241	107.489	126.058	2553.5	0.693	78.9	0.977	28.1	28.7	8.10%
94.795	93.97	132.053	2542.9	0.694	78.9	0.977	28.1	28.8	7.40%
79.248	78.341	138.435	2532.4	0.695	78.9	0.976	28.1	28.0	6.50%
63.452	62.414	148.122	2526.1	0.699	79.9	0.979	28.0	28.9	5.50%
50.628	49.483	155.536	2516.5	0.699	79.4	0.976	28.0	28.2	4.60%
35.816	34.492	167.355	2507.6	0.703	79.7	0.975	28.0	27.6	3.40%
20.01	18.412	183.786	2517.3	0.701	79.1	0.972	28.7	28.2	2.00%

Figure 11 Sample of Data Output from LabVIEW

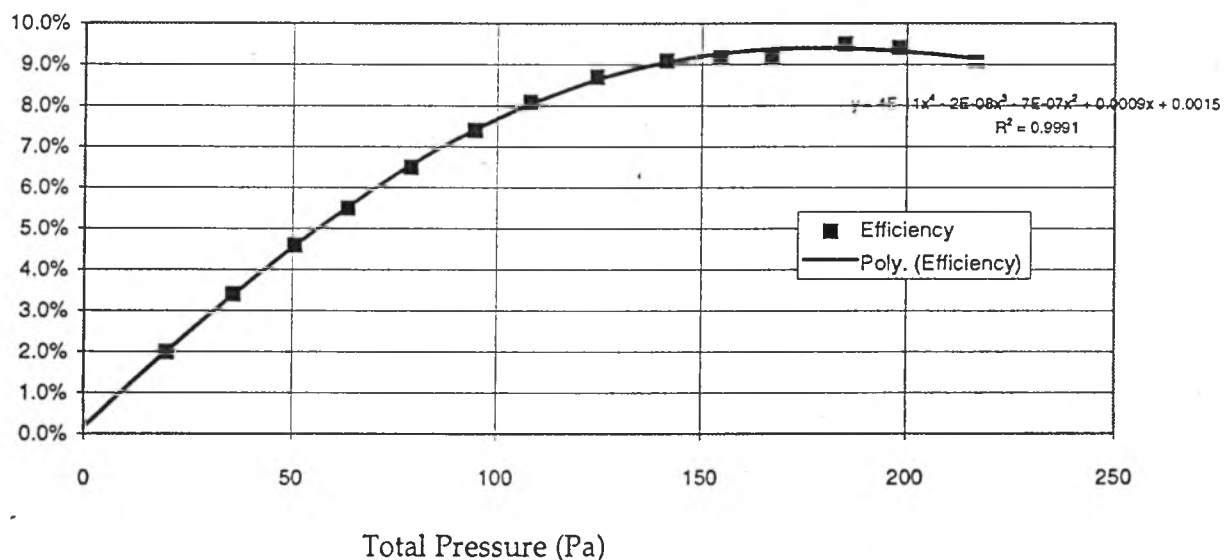


Figure 13 Graphical presentation of LabVIEW Fan Pressure and Efficiency Data

The Excel spreadsheet provided with the FANalyzer presents an efficiency vs. pressure curve as illustrated in Figure 13.

### 5.3 Harmonic Analysis

It is expected that the FANalyzer will be used for performance measurement of many different motor systems including systems with integral speed controllers. If it is found that these speed controllers behave in a predictable way, and that the harmonics are not having a significant effect on the system performance, then it may not be necessary to measure harmonics routinely.

## 6. Test Routines

### 6.1 Fan Efficiency Test: Type B, Free Inlet, Ducted Outlet

The FANalyzer is presently most easily used for testing fan efficiency in a Type B configuration, as illustrated in the ASHRAE Standard 51-85, Figure 7. The test involves putting the test fan through a number of operating points at a single speed setting. Initially the fan is operated at the shut-off position, with maximum static pressure and zero flow. The conditions are then altered through a series of at least ten points, culminating in maximum air flow rate and zero static pressure. The FANalyzer, as currently designed, does not actually permit a zero flow condition, due to duct leakage, but the results are still adequate for this purpose.

The FANalyzer Operating Manual shows how the test routines are conducted, including location of the various sensors and pressure taps. This test can be achieved in two ways:

1. an automated test routine can be selected, which will result in the fan being cycled through all conditions, from shut off to full flow, by first modulating the control damper, and then, if necessary, increasing the control fan speed to achieve a condition of zero static pressure.
2. A manual routine, which allows the user to pick any point on the fan efficiency curve, by manually modulating the control damper and control fan speed. Through a search process, the user can find the efficiency for any point on the fan efficiency curve.

### 6.2 Motor Efficiency Test (CSA C747)

The motor efficiency test procedure uses a typical percent of rated motor output method. At least six points are required, beginning from 125% of rated load, to no load. In accordance with procedures contained in the C747 standard, the rated voltage and frequency are applied to the motor and the motor is run until a condition of thermal equilibrium is reached. For typical  $\frac{1}{4}$  to  $\frac{1}{2}$  HP motors, this steady state condition requires two hours of operation. Monitoring of the motor temperature the user can measure the temperature until the rise is less than 0.5 degree C over a 15 minute period.

The operating manual indicates the precise means of supplying loading to the motor for the efficiency test. Three loading impellers are provided, each of different size and diameter. In this fashion, motors can be tested over the range of 1/60 HP to  $\frac{3}{4}$  HP, at RPMs from 1000 to 2500.

## 7. Field Trials

Prior to completion of the FANalyzer, the unit was subjected to a field trial involving use and evaluation by a typical user.

The FANalyzer was shipped to a manufacturer/distributor of residential ventilation equipment - ENERREADY Products of Vancouver. It was fully assembled at ENERREADY's facility, and used to test a VanEE 7000 series Heat Recovery Ventilator. ENERREADY's senior technologist assisted in the setup and operation of the equipment. An engineer from POWERTECH Labs also participated in the field trials.

Field testing included fan efficiency tests, and motor efficiency tests. Much of the time was spent refining test procedures and diagnosing wiring problems. In this sense, the field trials were successful in revealing problems with the prototype that might otherwise have been overlooked.

After resolving equipment problems and software bugs, the testing of ENERREADY's HRV was successfully completed. One of the most interesting and valuable results of the field tests was the recognition of a need for easier and more regular calibration of the motor torque cradle. Based on the difficulties experienced by the technician, a decision was made to require a new calibration after each motor test, using a single point calibration with a known weight. The relationship is sufficiently linear that the single point test is all that is required.

ENERREADY was surprised to learn that the 1/6 HP motor on their HRV was less efficient than expected, averaging less than 10%.

Discussion with the staff at ENERREADY following the trials indicated a large degree of enthusiasm for the versatility and sophistication of the FANalyzer. Technicians and engineers were especially impressed with the integration of all the sensors and components into a single, automated man/machine interface. ENERREADY was provided with a complete fan and motor analysis of their HRV as part of the trials.



## 8. Conclusions

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In general, the final prototype has successfully achieved or exceeded all of the design specifications.

The design process was especially productive, since the unit has incorporated several highly innovative and valuable features.

FANalyzer is now ready for use by manufacturers of residential ventilation equipment, as well as CMHC and other research organizations.

The rig is provides extremely visual feedback to operators during automated motor-an set testing. This makes it especially effective when used to show manufacturers, builders, code officials and utility personnel the range of performance that can be expected from different types of equipment now available. By clarifying the opportunity for improved performance, it is expected that the FANalyzer will help drive requirements for, and delivery of, better ventilation technology.

Additional work could improve the functionality of the device. Some of the best opportunities for improvements in the near future include:

1. Improved training support, for example a training video, or an expanded tutorial session in the manual, or personal demonstrations to manufacturers at trade shows or other venues.
2. Redesign of the prototype to produce a simpler, more robust, production unit.
3. Design of a system for 3 phase motors and for larger systems up to 10,000 CFM.
4. A library of custom applications with software utilities and schematics to assist in test configuration.

# Appendix 1: Industry Survey

## Industry Survey with Completed Responses and Comments

1. What types of fan/motor products does your company Manufacture ☐ or Test ☐?

	<u>M, T</u>		<u>M, T</u>
1. None		7. Whole-House Ventilators	<input checked="" type="checkbox"/> 1,1
2. Gas or Electric Forced-Air Furnace: Blowers and Assemblies	<input checked="" type="checkbox"/> 2,1	8. Air or Ground Source Heat Pump systems with forced-air fan	<input checked="" type="checkbox"/> 2,1
3. Ducted Heat Recovery Ventilators (HRV's)	<input checked="" type="checkbox"/> 6,2	9. Kitchen Range Hood fans	<input checked="" type="checkbox"/> 4,1
4. Ceiling/Wall Exhaust Fans	<input checked="" type="checkbox"/> 5,1	10. Kitchen Range Down Draft fans	<input checked="" type="checkbox"/> 1,1
5. Exterior Mount Room Ventilators	<input checked="" type="checkbox"/> 3,1	11. Bathroom Fans	<input checked="" type="checkbox"/> 4,1
6. Power Attic Ventilators	<input checked="" type="checkbox"/> 2,1		

Other (please specify) Remote-mount multi-point ventilators (ALDES) 1

2. What compliance standards, or product performance guidelines that your products are required to meet or adhere to, and name the organizations responsible for quality assurance? Acronyms, and abbreviations will suffice. This information will help us to design an appropriate reporting structure for the test rig.

Product	Standard/Guideline Name	Testing Agency
HRV's	CSA C260, CSA 439, UL1812, ASHRAE 84	ORTECH UL
Exhaust Fans	ANSI/ASHRAE AMCA 210-85, CSA 260, HVI 916 (Sound Testing), HVI 915 (Air Flow Testing), ANSI/ASHRAE AMCA 210-85,	HVI
Blowers	ANSI/ASHRAE AMCA 210-85, AMCA 300-85	AMCA, HVI
Range Hoods, Whole House Ventilators	ANSI/ASHRAE AMCA 210-85, CSA 260 HVI 916 (Sound Testing), HVI 915 (Air Flow Testing)	HVI
Bath fans, Power Attic Ventilators	ANSI/ASHRAE AMCA 210-85, CSA 260 HVI 916 (Sound Testing), HVI 915 (Air Flow Testing)	HVI
Heat Pumps; All Types	ARI 210/240, 370; ASHRAE 37	Ontario Hydro Technologies Division
Ceiling Exhaust Fans/Remote Mount	HVI CSA C22.2 No. 113-M1984	TEES - Texas A&M University

Multipoint Ventilators		/CSA
All Ducted Fans/Hoods	HVI Certification Program	Texas A&M
All Non-ducted Fans and Hoods	C22.2 No.113, CSA C260	CSA, HVI

3. Do you have an in-house test facility to measure the performance? Yes ☒ 3,2 No ☒ 3  
If so what type of information does your test facility provide? Please explain:

CONSERVATION ENERGY SYSTEMS (Saskatoon Sask.): Measure airflow using AMCA type flow chambers with nozzles to measure air flow, also static pressure, voltage, current, power, speed, are measured at various conditions of external static pressure.

VENMAR (Drummondville Que.): Have an HRV test rig similar to that used by ORTECH. Also have an automatic test procedure for measuring flow vs. static pressure of Kitchen Range fans. An automatic damper is used in combination with air flow and static pressure measurements to performance curves.

BROAN MFG. (Mississauga Ont.): Uses an AMCA type flow chamber with nozzles. The flow chamber has a capacity of 500 CFM and is used to test and rate its own fan systems. Also measured are temperature rise, static pressure, motor speed, current, true power, and voltage. Power factor can be estimated from the VA and Watt measurements.

ENVIRO INDUSTRIES (Etobicoke Ont.): Uses a data acquisition system tied into a computer to measure performance of their HRV's (no more information given). Suggests contact Emerson about Test Rig

AMERICAN ALDES (Sarasota Florida): Use a test facility in Lyon France. The facility measures Flow, pressure, air power, total efficiency at each point in the fan curve. They are interested in a test rig for their Sarasota Plant.

DELHI INDUSTRIES (Delhi Ont): Use an AMCA (fig 12 in ANSI/AMCA 210-85) flow chamber for measuring flow but also measure SP, Volts, Amps, Watts, RPM, Temperature, and Barometric Pressure.

4. What minimum level of technical experience should be required to operate the test rig?  
Please consider that the simpler the test rig is to use, the more time and cost must go into it's development.

engineer	<input checked="" type="checkbox"/> 1	technologist	<input type="checkbox"/>
technician	<input checked="" type="checkbox"/> 9	assembly worker	<input checked="" type="checkbox"/> 1

5. What reasonable training period should be needed in order for an operator to learn to use the test rig well enough to perform most common tests?

1 day	<input checked="" type="checkbox"/> 2	2-3 days	<input checked="" type="checkbox"/> 6
one week	<input checked="" type="checkbox"/> 2	more than a week	<input type="checkbox"/>

6. Given the floor space limitations that you have in your facility what physical dimensions (assembled plan area) would be reasonable for the test rig?

2.5 ft x 8 ft	<input checked="" type="checkbox"/> 1	3.5 ft x 10 ft	<input checked="" type="checkbox"/> 2
5 ft x 12 ft	<input checked="" type="checkbox"/> 6	fill a 10 x 12 room	<input checked="" type="checkbox"/> 1

7. If you are using an in-house test facility, would you be willing to receive a compact video camera - loaded and charged - as a means of showing us what it looks like? You would simply have to walk around your facility describing the set-up, while pointing and

operating the camera. We would then courier the camera back at our expense. Yes ☒ 2  
No ☒ 7

8. If the test rig proves to be a valuable tool and your company decides to acquire a version for its own use, what would you expect to be your preferred option? Purchase ☒ 4, Lease ☐ 0, Construct from plans ☒ 6, n/a ☒ 1.
9. The cost to construct the rig is presently estimated between \$8,000 and \$12,000 including operating software, hardware, and a 386 or higher PC (without spreadsheet or WP software). Leasing costs might be about \$150/day. If your company decided to use the test rig, what budget could you allow for its purchase or construction?

less than \$5,000	<input checked="" type="checkbox"/> 4	Purchase <input type="checkbox"/> or construct <input type="checkbox"/>
\$5,000 to \$10,000	<input checked="" type="checkbox"/> 4	Purchase <input type="checkbox"/> or construct <input type="checkbox"/>
more than \$10,000	<input type="checkbox"/> 0	Purchase <input type="checkbox"/> or construct <input type="checkbox"/>
n/a	<input checked="" type="checkbox"/> 2	Purchase <input type="checkbox"/> or construct <input type="checkbox"/>

8. What design features should be incorporated into the test rig that will make it easy to use and versatile:

(Please select 1. Very useful, 2. Moderately Useful, 3. Not needed)

- |   | 1                                     | 2                                     | 3                                     |
|---|---------------------------------------|---------------------------------------|---------------------------------------|
| i. Instantaneous readout of air flow, pressure, temperature and fan speed;  | <input checked="" type="checkbox"/> 7 | <input checked="" type="checkbox"/> 1 | <input checked="" type="checkbox"/> 0 |
| ii. Instantaneous readout of voltage, current, power and power factor;  | <input checked="" type="checkbox"/> 5 | <input checked="" type="checkbox"/> 3 | <input checked="" type="checkbox"/> 0 |
| iii. Measurement of Broad-Band Sound Power levels (extra cost);   | <input checked="" type="checkbox"/> 0 | <input checked="" type="checkbox"/> 3 | <input checked="" type="checkbox"/> 4 |
| iv. Continuous measurement of Total Harmonic Distortion on voltage and current wave forms;  | <input checked="" type="checkbox"/> 7 | <input checked="" type="checkbox"/> 0 | <input checked="" type="checkbox"/> 1 |
| v. Use of a PC interface that measures, analyzes, and records test results (user supplies PC, we provide peripherals and software); | <input checked="" type="checkbox"/> 0 | <input checked="" type="checkbox"/> 1 | <input checked="" type="checkbox"/> 7 |
| vi. Use of PC interface as in (iv) but we supply the PC;  | <input checked="" type="checkbox"/> 1 | <input checked="" type="checkbox"/> 4 | <input checked="" type="checkbox"/> 3 |
| vii. Provide a printer with rig;  | <input checked="" type="checkbox"/> 4 | <input checked="" type="checkbox"/> 3 | <input checked="" type="checkbox"/> 1 |
| viii. Provide automated test sequences that perform motor and fan tests with minimal user interaction;                              | <input checked="" type="checkbox"/> 1 | <input checked="" type="checkbox"/> 5 | <input checked="" type="checkbox"/> 2 |
| ix. Instantaneous readout of motor running torque (question not included in survey version 1.0);                                    | <input checked="" type="checkbox"/> 0 | <input checked="" type="checkbox"/> 1 | <input checked="" type="checkbox"/> 0 |

Other (please specify)

AMERICAN ALDES: Measurement of motor and bearing temperatures to show life expectancy.

CONSERVATION ENERGY SYSTEMS: Software to calculate airflow, static efficiency, total fan efficiency, motor efficiency, - from the data collected in testing - preferably on a full feature, customizable spreadsheet.

HOME VENTILATING INSTITUTE: Sound measurement (to date) requires a reverberation chamber of specified dimensions.

ONT HYDRO TECHNOLOGIES: Some measurement of relative humidity is necessary.

9. Would you be willing to lend us a sample of one or more of your products (in the fan/motor set category) on the possibility that we may use the product to ensure compatibility with the test rig, and to generate information for your own confidential use? Yes ☒ 4, No ☒ 4

If Yes please specify sample product and provide us with authorization details so that we can arrange for shipping, or pick up from a local product distributor. Product would be returned undamaged by June 1995 or earlier if requested.

Sample Product Details:

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HRV's, Range Hoods, Multi-point ventilators, Bath Fans, Utility blowers

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10. Can you suggest ways in which your industry (or yourself directly) could become more involved in the design and development of the test rig? For example,  
Would you like to receive updates on how the rig is being built? Yes ☒ 7  
No ☒ 3

Would you be willing to try out the rig at your facility, at no cost, as part of a field trial?  
Yes ☒ 8  
No ☒ 1

Other Suggestions or Ideas Please:

CES: ASHRAE TC5.5 is developing a test standard for measuring field performance of energy recovery ventilation systems. The "test rig" might be developed in consideration of what requirements this new standard may have.

BROAN: CMHC should buck up in aid of manufacturers who can't afford the rig but would like to use it. Need to develop a program.

ALDES: Multi-point exhaust fans present some difficulty in test protocols because of intentional leakage to provide motor cooling - so discharge airflow exceeds air intake on the duct ports. For airflow certification only intake airflow is meaningful.

ALDES: Bathroom fans should not be used as continuous ventilators and should only be used as spot vent.. Mfg. should not have to increase efficiency of Spot units just because some codes allow their use as continuous...

ALDES: Performance measurements should take into account Pressure Head as well as Air Flow. Some mfg. produce appliances with good pressure characteristics but lower CFM/Watt efficiencies.

HVI: When asked about FHP motor test facility they replied that it consisted of ... " Absorption dynamometer, electric brake, torque transducer, torque motor, speed counter, watt meter, PC, and Software."

DELHI: Test rig should be constructed as per AMCA 210-85. Many motor manufacturers already have "test rigs" to serve this purpose.