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AN ADVISORY SYSTEM FOR INDOOR RADON MITIGATION

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ABSTRACT

An advisory system for providing information on indoor radon mitigation and practice has been developed. The advisory system is intended to assist Pacific Northwest mitigation contractors in the selection and design of mitigation systems for existing residential homes. The advisory system uses an interactive mode to query the user on the characteristics of the home that may undergo radon mitigation; it then offers one or several recommendations to the user on what techniques should be used. In addition, the needed computations for a cost analysis and a fan selection for the ventilation system are performed. It also advises the user on other tasks such as the sealing of cracks and system performance.

We believe that this system will provide mitigators with increased quality assurance, and rapid and consistent fan sizing and cost estimation. Besides aiding professional mitigators, the advisory system has the potential to be employed as a tool for training novice mitigators.

AN ADVISORY SYSTEM FOR INDOOR RADON MITIGATION

INTRODUCTION

In 1986 the Environmental Protection Agency began publishing information to educate the public about the risks of radon exposure, and what they could do about it. The EPA publication "Application of Radon Reduction Methods" (Mosley and Henschel 1988) and "Practical Radon Control for Homes" (Brennan and Galbraith 1988) explains and illustrates many radon mitigation strategies. These strategies can be grouped into two main classifications; those that attempt to prevent radon from entering the home, and those that dilute the radon once it has entered the home. The selection of a radon reduction system depends upon a wide collection of information such as initial radon level, geological factors, climate, house and site characteristics, driving forces, and possible entry routes. After a system is selected, the design and installation depends upon the method that was selected, diagnostic measurements, and homeowner preference. While a vast amount of literature on radon reduction is available, there are relatively few experts around to provide their judgement for each individual who needs a practical and cost effective means to reduce their indoor radon level. Also, as new methods become available, knowledge of them may not be widespread. Radon reduction is a new field, and since the need for it varies regionally, not all contractors will have sufficient expertise in dealing with a radon problem. One solution is to provide the mitigator with a knowledge-based advisory system capable of disseminating the knowledge in the present literature and assisting them in various aspects of radon mitigation work.

Knowledge-based systems have emerged as the most applied branch of Artificial Intelligence (AI). These systems capture the knowledge of human experts in the areas where expertise can be readily obtained and coded via symbolic knowledge processing languages (such as Lisp or Prolog) or expert systems development shells (such as LEVEL5, OPS83, and others). Knowledge-based systems applications have proliferated in the fields of diagnostics, monitoring, planning, trouble shooting, and design. Of these categories there have been several attempts in the application of knowledge-based systems to building design (Hitchcock 1991 and Mayer et al. 1991). Efforts in applying expert system technology to radon mitigation have also been reported (Mosley 1987, Brambley et al. 1990, and Brennan and Gillette, 1990). An initial attempt was made by Mosley in 1987, and a demonstration system on a Macintosh computer was developed by Brambley in 1990. In addition, an interactive system was developed for a Macintosh by Brennan in 1990. The interactive system was designed to assist in the training of mitigation contractors. These ventures demonstrated the capability of expert systems in dealing with radon mitigation.

This paper describes the development of a prototype hybrid knowledge-based advisory system for indoor radon mitigation. The advisory system is intended to assist Pacific Northwest mitigation contractors in the selection and design of mitigation systems for existing residential homes. The advisory system makes a recommendation as to which mitigation method should be used. In addition, any required computations for a cost analysis and a fan selection for the ventilation system are performed. Additional potential benefits of mitigation contractors utilizing the advisory system are verification of approved radon reduction technologies, uniform record keeping for a regional database, and consistency in computational processes. It is our intent to distribute the advisory system at this conference to experienced professional mitigators for their review. Upon return of the software we will incorporate the recommendations and distribute the advisory system to interested mitigators at no charge.

APPROACH

The prototype advisory system has been developed employing knowledge obtained from existing publications on radon mitigation. Some portions of the knowledge are well defined, such as the fan selection process, and can be easily implemented in a computerized environment. The computer program has been developed using an expert system shell. Using a shell (versus a pure symbolic processing language) greatly reduces the development time since the knowledge processing subprogram is built-in and can be readily activated without the need for further programming. Another advantage of the advisory system is that it is developed around a graphical user interface, which enhances the presentation of information to the end user and makes it possible to incorporate graphical as well as textual information.

SYSTEM MODULES

The system is composed of six modules. The House Investigation Summary module extracts the characteristics of the house. This module was designed to be analogous to the house investigation summaries that mitigators often use to gather data about a particular house. The Data Conversion and Mitigation Selection module converts the data from the previous module into a form that is usable by the system and then recommends an appropriate mitigation method. These first two modules are the most essential and constitute the mitigation determination process. The Suction Point Determination module assists in the point selection for soil suction techniques (the number of needed suction points), the Fan Selection module performs a fan selection and ducting analysis for soil suction techniques, and the fifth module is the Cost Estimation. The modules are activated hierarchically, but once the mitigation determination modules have been executed for a particular case, subsequent modules such as the Fan Selection or the Cost Estimation can be repeatedly executed without invoking the previous modules (See Figure 1). This arrangement makes it possible for the user to reactivate individual modules as many times as necessary. An additional and completely independent module is the Fan Tutorial, which provides some guidance for new users. In the prototype, every module provides a utility for the users to make comments and suggestions for each step of the system. This utility is to be employed for the testing phase of the software as a method to collect a wide spectrum of expert opinion and enhance the robustness of the system.

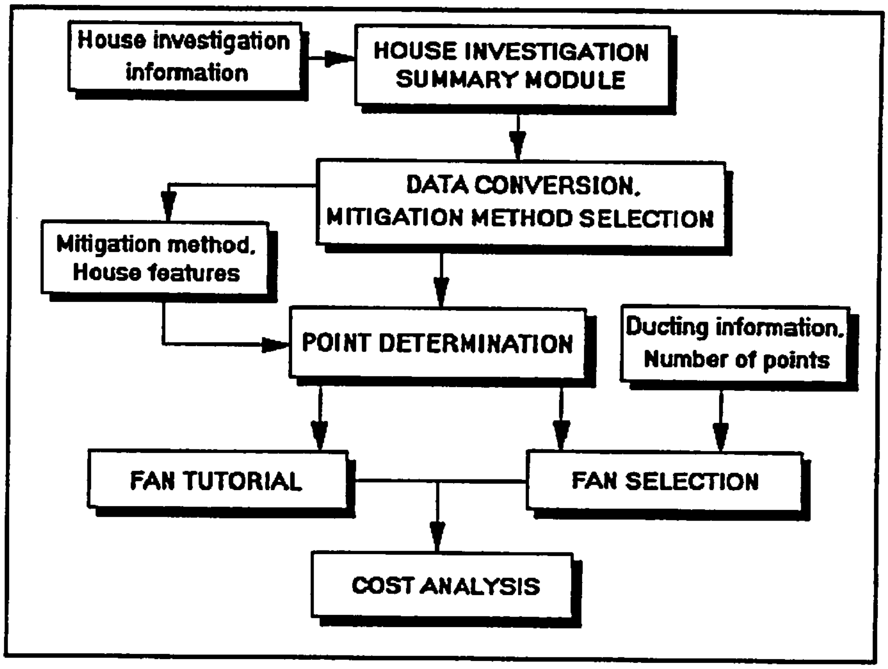

Figure 1.

House Investigation Summary

In the House Investigation Summary module of the advisory system, the user is queried about the characteristics of the house (See Figure 2). The information sought by the module is identical to that requested by house investigation summaries used by professional mitigators. An advantage of this approach is that the mitigator can fill out house investigation forms while in the field, and can use the system at a later time. In addition, only relevant questions will be asked. For instance, if a house is specified as a full-basement type, there will be no questions asked about crawlspace features. The data is stored in a text file which is referred to by the Data Conversion and Mitigation Selection module (See Figure 3). This file can be accessed by the user for viewing and slight modifications, but a strict format must be followed in order to maintain its compatibility with the following module. For major changes, it is recommended that the user rerun the module and create a new text file.

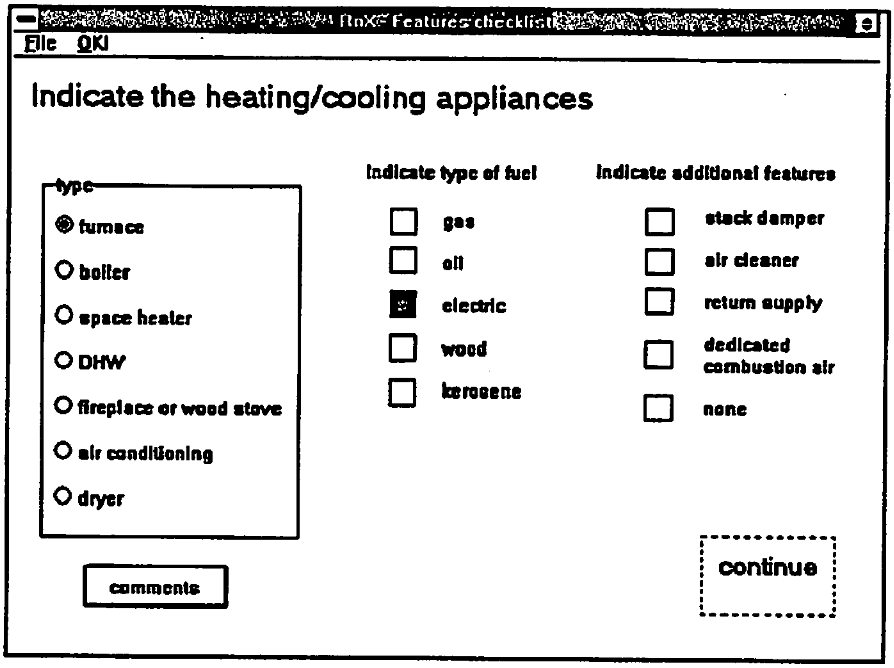

Figure 2.

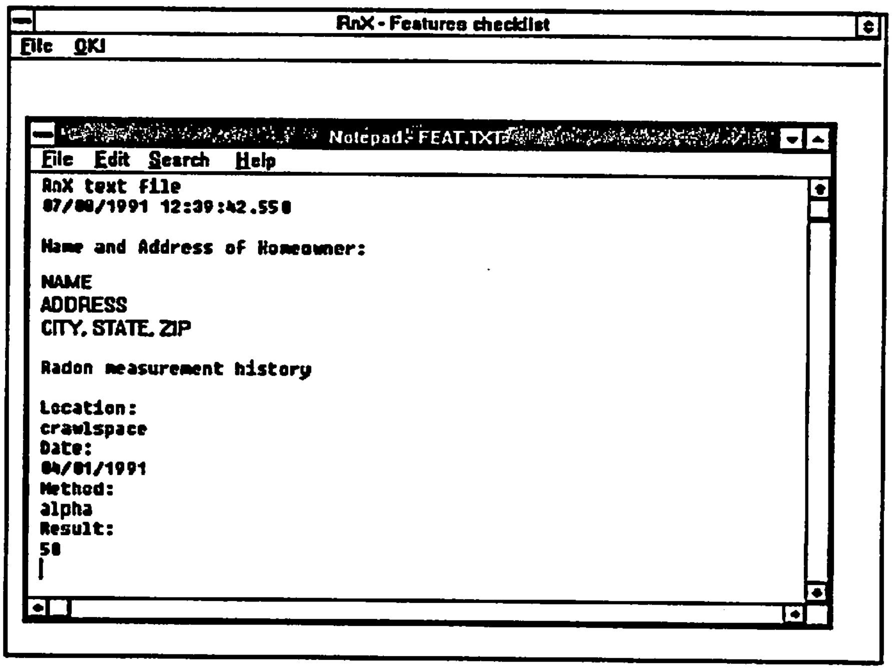

Figure 3.

Data Conversion and Mitigation Selection

The Data Conversion and Mitigation Selection module reads the text file created by the House Investigation Summary module and assigns appropriate values to the objects of the knowledge base. Rule processing is activated only after all of the data has been converted into objects. The rules of the system are based upon information contained in radon mitigation literature. Additional information such as the nature of the climate or the accessibility of the crawlspace may be requested to complete rule processing. A mitigation method is recommended only after conditions for its applicability are met and rule processing is completed. Several mitigation methods may be recommended, especially in the case of a foundation consisting of a combination of pure foundation types, such as a basement adjoined to a crawlspace. (See Figure 4).

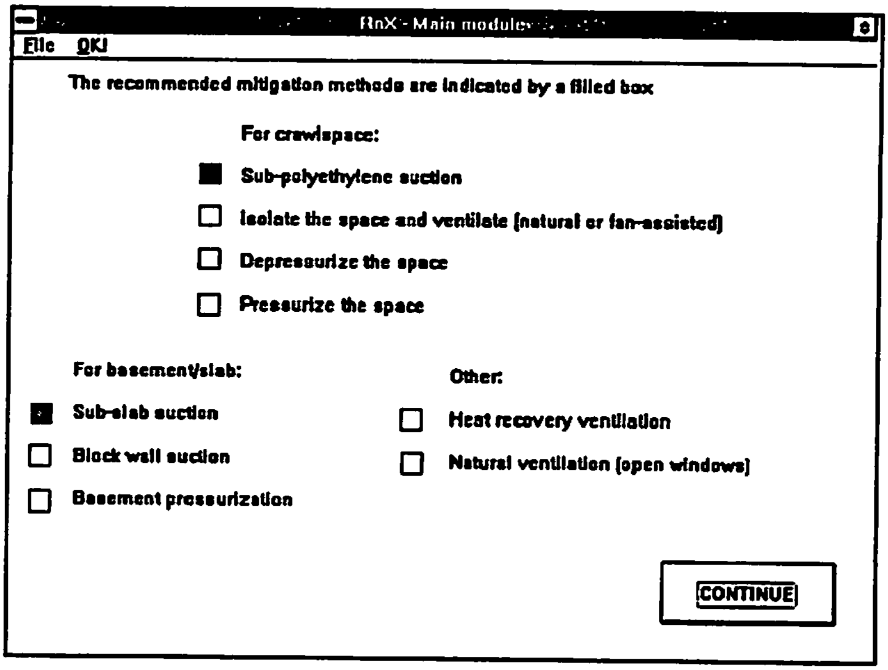

Figure 4.

At this point, the user may select one of the recommended methods based upon an intangible factor, such as aesthetics. If all relevant data has been collected and processed, and the module fails to find a method, the user is notified of the condition. The user is also informed about the floor penetrations that were indicated from the house investigation summary and need to be sealed and is reminded of the appliances that are present and may be contributing to a stack effect in the house. If any of the recommended mitigation methods included a soil suction technique, the user may continue with the next module.

<u>Suction Point Determination</u>

The advisory system is capable of recommending the number of suction points that should be installed for soil suction techniques. The recommendation is based on data from radon mitigation publications. This data was based upon the foundation type, the area of contact with the soil, and soil communication. As an example, for a sub-slab suction mitigation method employed where the soil communication has been proven to be fair to poor, the system would recommend one suction point for every 600 square feet of slab area. If the soil communication had been excellent and extended over the entire slab, the system would recommend a single suction point (See Figure 5).

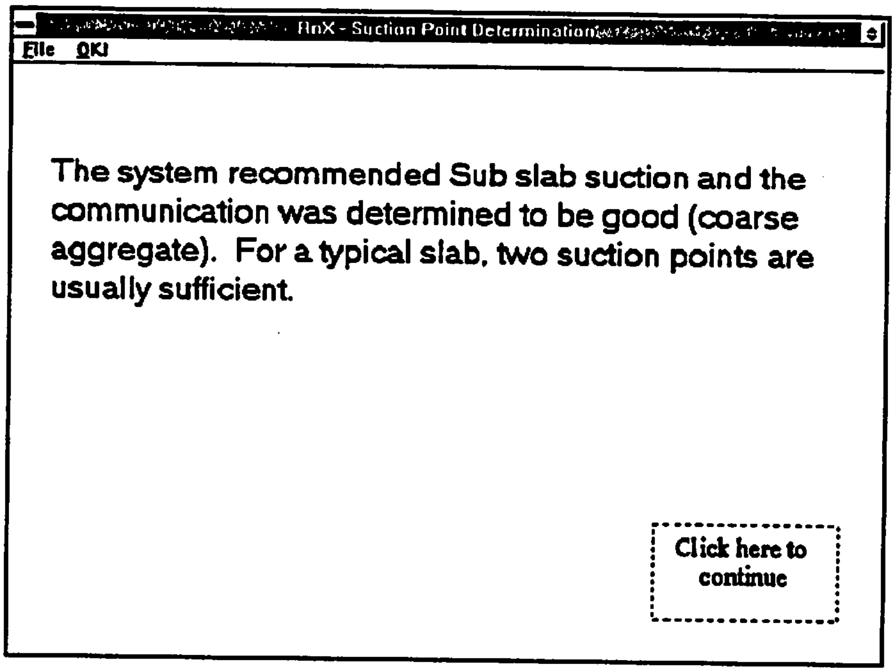

Figure 5.

Fan Selection

The fan selection module performs a piping analysis and selects an appropriate fan. It is currently limited to systems with three or less ducting branches (suction points), and duct diameters of 3, 4, or 6 inches. This module requires that the user has diagnostic measurements available (Prill 1989) and a preconception as to how the ducting will be configured. If not, the user can invoke a fan tutorial module, which is described later. The system passes the data obtained pertaining to the number of needed suction points (determined from the previous module), and the user is given the option of overriding the information and entering a different number. The number of suction points corresponds directly to the number of branches in the ducting system. The module requests information concerning the ducting, such as the diameter, length, and the number of fittings that are used (See Figure 6). For single branch systems, the module assumes that the diameter of the ducting remains constant and that no reducer/expander type fittings are used. For multiple branch systems, different diameters may be used for the different branches. Usually the main trunk has a larger diameter than the branches in order to accommodate their combined flow without increasing the velocity too much. For three-branch systems, the module assumes that branches one and two form an intermediate junction, and this intermediate branch joins with the third branch to form the main trunk which goes to the fan.

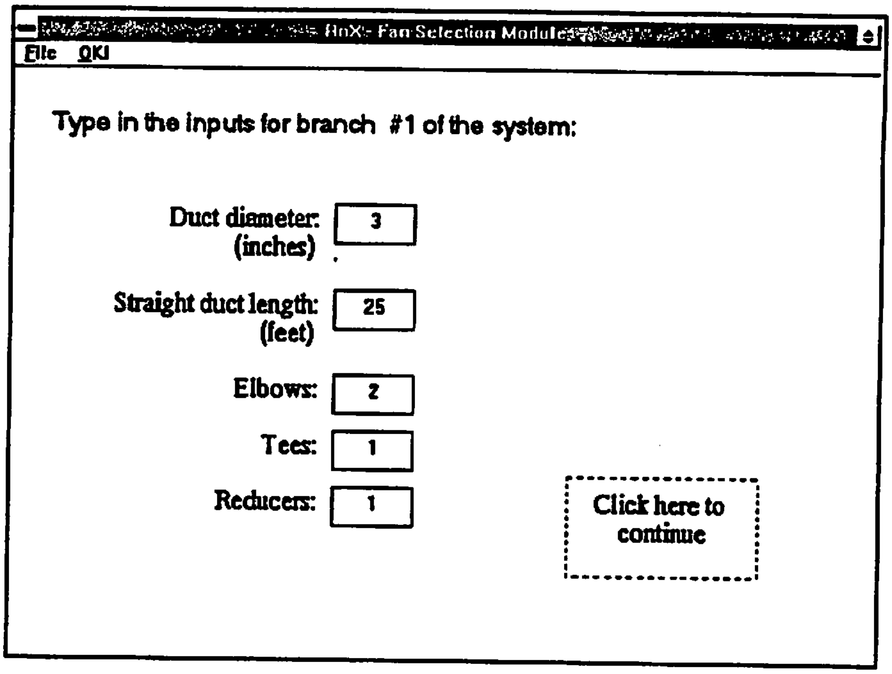

Figure 6.

Diagnostic measurements of pressure drop and flow rate are also requested from the user (See Figure 7).

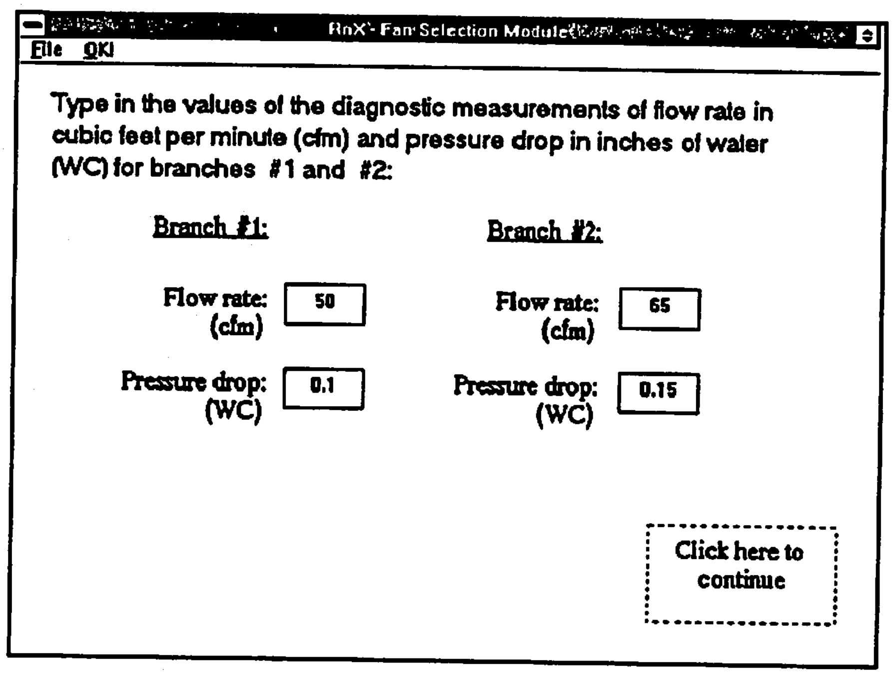

Figure 7.

The module proceeds to determine the total system friction loss and airflow. It uses this data to recommend a fan in terms of pressure drop, flow rate, and brand name (See Figure 8).

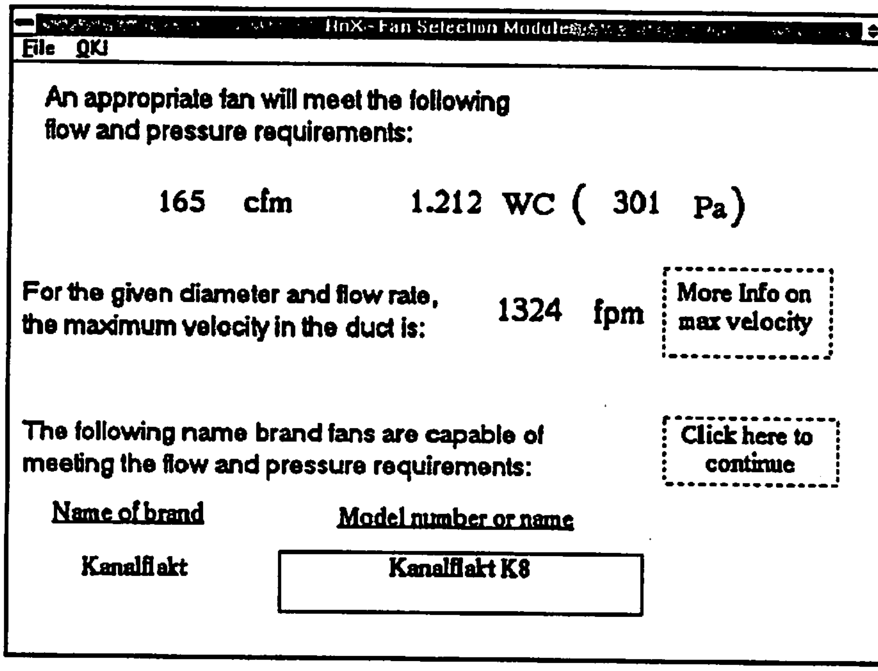

Figure 8.

The module also shows the maximum air velocity achieved, and in which branch of the system it occurs (See Figure 9).

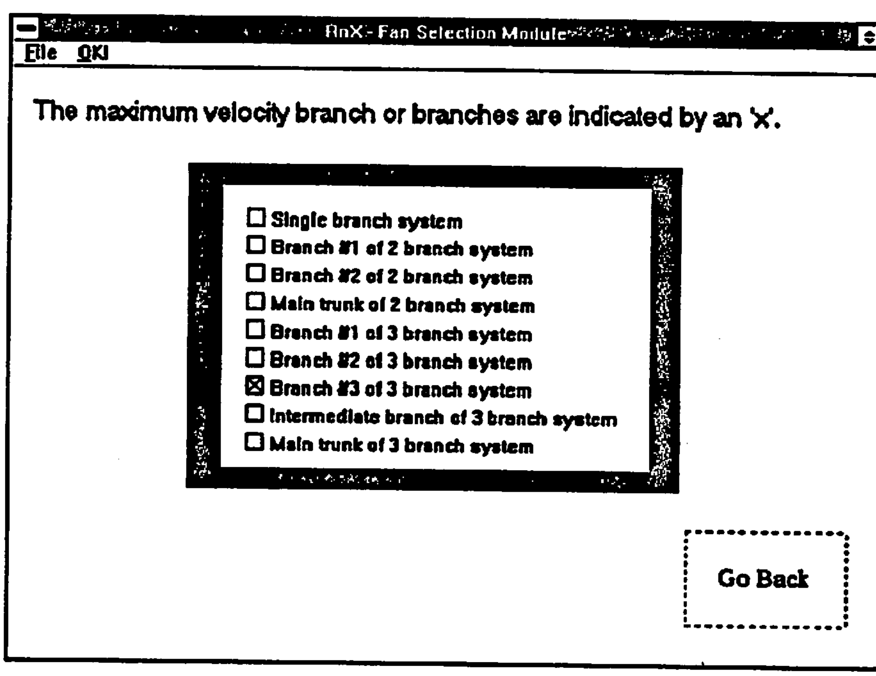

Figure 9.

The information on air velocity is provided in order to notify the user in the case of a high velocity flow. This makes the user aware of a potential noise problem and identifies the portion of the system that may need to be redesigned. The Fan Selection module may be repeatedly executed to allow the user to experiment with the design of the ducting system. For instance, if a high velocity value is detected in a branch with a three inch diameter, and the value is perceived by the user to be capable of causing excessive noise, the system can be redesigned using four inch diameter or larger ducting. This process can be repeated until an acceptable design has been accomplished. Future work may include the capability of the module to detect the occurrence of noise-causing flow, instead of having the user make this determination. Furthermore, the Cost Estimation module can be invoked to determine the impact on the total system cost due to changes in system design.

Cost Estimation

Once the Fan Selection module has obtained the data concerning duct lengths, diameters, and the number of fittings, and the type of fan has been determined, the Cost Estimation module can be used to determine the cost of the mitigation system. The Cost Estimation module uses the data from the Fan Selection module and applies it to unit costs. The user may either apply the default unit costs or may override the defaults and enter different unit costs (See Figure 10).

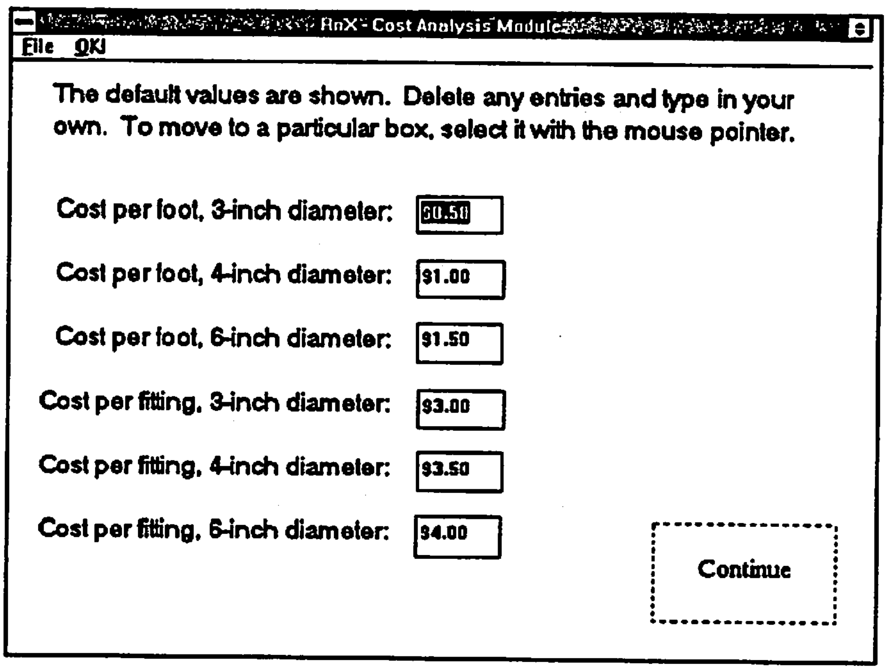

Figure 10.

This utility is provided to allow for regional and quality variations in cost. The current default values for materials used in the cost estimation were obtained as off-the-shelf prices from a local home improvement store. An energy cost is based on the power consumption of the fan, the cost per kiloWatt hour, and the assumption that the fan will operate continuously. The power consumption of the fan is obtained along with the fan type from the fan selection module. In addition, the user is prompted for a labor cost and the number of hours worked. The default values for labor are a single eight hour workday at $30.00 per hour. All of the default values may be changed by the user. The cost estimation sums up the material cost for the ducting and the fan along with the labor cost and presents it as the installation cost. The energy cost is included in an annual maintenance cost, which includes the heating/cooling penalty due to the year-round operation of the fan, and the cost of miscellaneous items such as sealants, manometers, and alarms.

Fan Tutorial

A fan tutorial module is also available to assist users who are unfamiliar with the format of the regular fan selection module. This module does not depend upon output from a previously executed module; it is completely independent. The rule base of this module is identical to the regular fan selection module, but is limited in that it can only analyze systems with up to two branches. It contains more in terms of graphics, user interface and online explanation referring to diagnostic measurements, fittings, and the ducting configuration (See Figure 11). The fan tutorial module illustrates the potential for a knowledge-based system as a training tool.

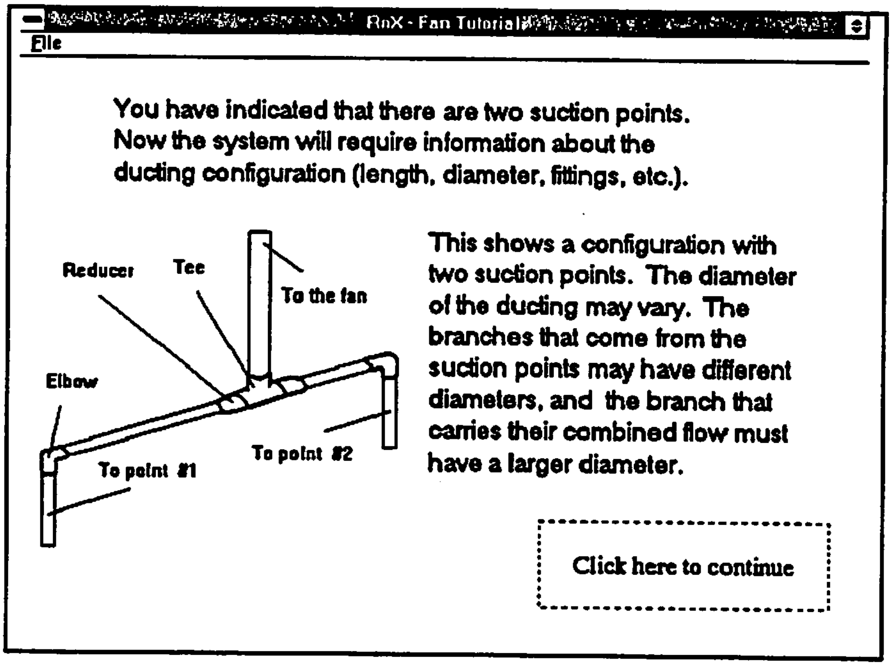

Figure 11.

SYSTEM SPECIFICATIONS

Hardware requirements

IBM compatible PC, 386 or higher family of processors.
Microsoft or compatible Mouse
2 Megabytes of RAM (minimum)
5 1/4" 1.2M or 3 1/2" 720K Floppy disk drive
Hard disk drive with at least 3 Megabytes free space
VGA graphics

Software Requirements

PC or MS-DOS version 3.0 or higher
Microsoft Windows version 3.0 or higher
LEVEL5 OBJECT Run-Only version 2.2
RnX modules

LEVEL5 OBJECT Run-Only and the RnX modules will be supplied on one 5 1/4" 1.2M or one 3 1/2" 1.44M floppy disk. The software will also be available on two 3 1/2" 720K floppies. Due to the size of the LEVEL5 OBJECT Run-Only program files, the software will not be available for 5 1/4" 360K floppies.

BENEFITS TO MITIGATORS

The advisory system writes the house investigation information to a text file. This text file may be recorded on a computer diskette and stored for future use. The mitigator may wish to retain both the actual house investigation forms and their corresponding text files as a type of back-up system for their business records. Furthermore, the advisory system has the potential to be interfaced with a database. This would facilitate data management and would make it possible for mitigators as well as health and regulatory agencies to keep a database of cases for a particular region. The information contained in the database may be of use to planners and researchers involved in radon related studies.

The advisory system provides a form of quality assurance for mitigators just entering the field. The advisory system in its final form will have incorporated the suggestions of field experts, and will reflect their collective opinion. Therefore, the novice user will have the assurance of the expert opinion, and the client will be reassured that the recommended mitigation method complies with established protocol and professional practice.

The Fan Selection module alleviates the amount of computation that must be performed during the design of a ducting system. Since the module also informs the user of potential noise problems, it encourages fine-tuning of the ducting system before the actual installation. This may help to manage the amount of time that is spent on installation, and could possibly eliminate the need for follow-up corrections to ducting systems. Another benefit of the module is that it provides consistent results for similar cases and will prevent possible oversizing of the fan.

The Cost Estimation module is an efficient way for the mitigator to provide a quick estimate to the client. It will also assure the client that the quoted price is justified. The module is flexible enough to include unforeseen costs involved in the installation and maintenance of a mitigation system. When used in conjunction with the Fan Selection module, the cost estimations for several different designs may be presented to the client. This would also be a benefit to the client who is deciding between several possible ducting configurations.

The advisory system can conceivably enhance the professional image of radon mitigation contractors and help to build public trust. It may be compared to the well-known energy audits performed at residences.

Besides assisting established professional mitigators, the advisory system illustrates the potential for a knowledge-based system to serve as an interactive training tool for novice mitigators. A successful training tool should have an uncomplicated and highly visual method of communicating the knowledge to the novice, and a graphical user interface such as the one employed in the advisory system is a good representation of this technique. An additional consideration is that the effectiveness of a computerized training tool is reasonably dependent upon the availablility of the computers needed to run the software. In small busineses, PC systems have emerged as somewhat more prevalent than their counterparts, and current trends in the PC market are evidence that advanced technology is becoming increasingly available at a lower cost.

ACKNOWLEDGEMENTS

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