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Solar Radon Reduction and Air Quality Management System

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Solar Radon Reduction and Air Quality Management System

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Technical Summary

The patented and award winning Solar Radon Reduction/Air Quality Management System (SRR/AQMS) incorporates proven ventilation and pressurization techniques, in conjunction with captured solar energy, to provide cost effective indoor air quality improvement. Outdoor air is heated in a conventional, flat plate solar collector and discharged into the dwelling via an induced draft fan. The discharged air pressurizes the structure, reducing soil gas infiltration, and dilutes existing contaminants through simple dilution. Two years of field demonstrations proved the SRR/AQMS competitive with other mitigation systems in terms of radon reduction and superior in terms of energy efficiency.

The initial project involves marketing to do-it-yourselfers and distributors/professional installers. Manufacturing capabilities will also be established. Research and development efforts will continue to optimize energy efficiencies and mitigation effectiveness.

Marketing activities will be provided by Doug Sevey, an experienced consultant with 20 years of marketing and product commercialization experience. Manufacturing will be under the supervision of the product patent holder and project applicant Richard J. Klein; 20 years HVAC experience. Jim Olson, initial project researcher, will provide ongoing research and development activities supported by 10 years of engineering experience.

The current research and development facility is located at the University of Northern Iowa. In addition, two field demonstration sites are located in Waterloo/Cedar Falls, IA.

I. Technical (Element I)

Element I.A. Identification and Description of the Proposed Project

Product Concept: Solar Radon Reduction and Air Quality Management System (SRR/AQMS)

Enviromiser's Solar Radon Reduction and Air Quality Management System (SRR/AQMS) is an energy efficient fresh air system designed to introduce solar-heated fresh air for diluting indoor air pollutants through ventilation. The system also creates slight positive pressurization of the structure to prevent radon gas and other soil or exterior air pollutants from entering through basement foundations and exterior surfaces. Outside air is drawn through a solar panel using a thermostatically controlled induced draft fan. The heated air is then discharged into the structure to reduce indoor air pollutants by dilution and/or reduced infiltration. The obvious energy advantage of the SRR/AQMS over conventional ventilation systems is the addition of make-up/ventilation air at above in-door ambient temperatures. The amount of fresh air provided by the system is dependent on the number and capacity of panels installed on the building. This feature allows the flexibility to use the SRR/AQMS in residential, commercial, and manufacturing facility settings.

Development Status. The SRR/AQMS was originally developed as a "solar radon reduction system" and a patent was issued to Richard J. Klein, II, inventor, on February 16, 1993 (U.S. Patent #5,186,160). In 1991, before the final patent was approved, Klein's SRRS was the second place winner of EPA's **1991 Innovative Radon Mitigation Design Competition**. This application is intended to support Klein's current efforts in seeking capital investment to manufacture and commercialize his company's SRR/AQMS in its application as a "solar radon reduction system" and to further develop and market the SRR/AQMS as a solution to the broader problems associated with the "sick house" and "sick building" syndrome where pollutants come from cleaners, paints, solvent, carpet, and air fresheners. The SRR/AQMS will still serve as a supplementary heating and fresh air supply system to deter seepage of gases, such as radon, into a building's interior (by pressurizing the building's interior), but its applications are also being marketed to address airtight efficient homes and buildings, where indoor winter air, is more polluted with organic chemicals, molds, pesticides, carbon monoxide, etc. than outside air.

Operability. The SRR/AQMS consists of a flat plate solar panel, induced draft fan, duct work to route heated air into the structure, and simple electrical circuitry to monitor panel temperature and operate the fan. In the solar only mode, a thermostat activates the system fan to draw outside air through the solar panel during times of sufficient solar insolation. The heated outside air is then forced into the dwelling to provide fresh air ventilation. Indoor air pollutant levels are lessened by dilution and/or reduced infiltration resulting from a slight pressurization of the structure. Other operational modes can be accomplished using indoor air quality monitors, timers, operating equipment relays, etc. As opposed to conventional systems, including direct ventilation fans and air-to-air heat exchangers, the SRR/AQMS operates at a net energy gain by introducing above ambient temperature, solar-heated fresh air into the structure. System components can be fabricated for specific applications or, as in the case of the demonstration project, purchased "off-the-shelf".

Technical Viability. The technical viability of the system seems assured.

The SRR/AQMS interfaces with existing heating and air return systems in building structures. As commercial and residential structures become more air tight to reduce heating demands, ventilation air is necessary to control the accumulation of indoor air pollutants. Even with air-to-air heat exchangers, which recover some of the indoor heat that is forced from the structure, ventilation is accomplished at a net energy loss. Direct ventilation fans result in even more severe energy losses. The SRR/AQMS affords fresh air ventilation at a net energy gain.

In manufacturing facilities, significant volumes of ventilation/make-up air are necessary to maintain safe working environments. In cold climates, this make-up air must be preheated using expensive fossil fuels. Installation of an appropriately sized SRR/AQMS will provide solar heated make-up air during daylight hours; traditionally the most active industrial period. Energy savings afforded by this type of system will likely increase with time as OSHA guidelines for employee safety become more stringent. An even more likely trend has been predicted by a coalition of environmental and business groups in a report called, *U.S. Energy Trends and Policies: Past, Present and Future.* It states that renewable sources of energy are the only steadily increasing energy technology. Because of dramatic declines in the cost of renewables and the prediction of further substantial declines (as compared to gas, oil, coal, and nuclear energies), it is predicted that renewables will triple their contribution to our nation's energy mix from about 7 quads in 1993 to about 20 quads in 2013.

The mechanical reliability of the SRR/AQMS is directly related to the reliability of the fan and simple electrical circuits, which is easily documentable and considered quite good. The amount of solar insolation that can be utilized by the system can be optimized by panel location, number, and capacity based on ventilation needs and the facility's geographical location.

As stated previously, a residential SRR/AQMS system can be installed using commercially manufactured solar panels, duct work, and fans. Larger applications can be designed using multiplies of above equipment or custom fabricated using standard manufacturing practices (i.e. sheet metal forming and glazing).

Replicability and Reliability. The SRR/AQMS is currently in its second year of demonstration testing, supported by a University of Northern Iowa, Recycling and Reuse Technology Transfer Center grant. Begun during the winter of 1992/1993, this grant allowed testing of the system (a.k.a. Solar Radon Reduction System - SRRS) in two single family homes, using radon concentration as the system efficiency measurement parameter. During its first year of demonstration testing, as compared to background concentration levels, the SRR/AQMS achieved 24% to 29% radon level reductions during periods of solar only operation (ventilation/pressurization during periods of adequate solar insolation). Extended operation of the system (solar only and during operation of the dwelling's heating system) accomplished a maximum radon level reduction of 56%. Due to the introduction of solar heated air into the dwelling, radon reduction was accomplished at a net energy gain. Results from the second year of demonstration testing follows.

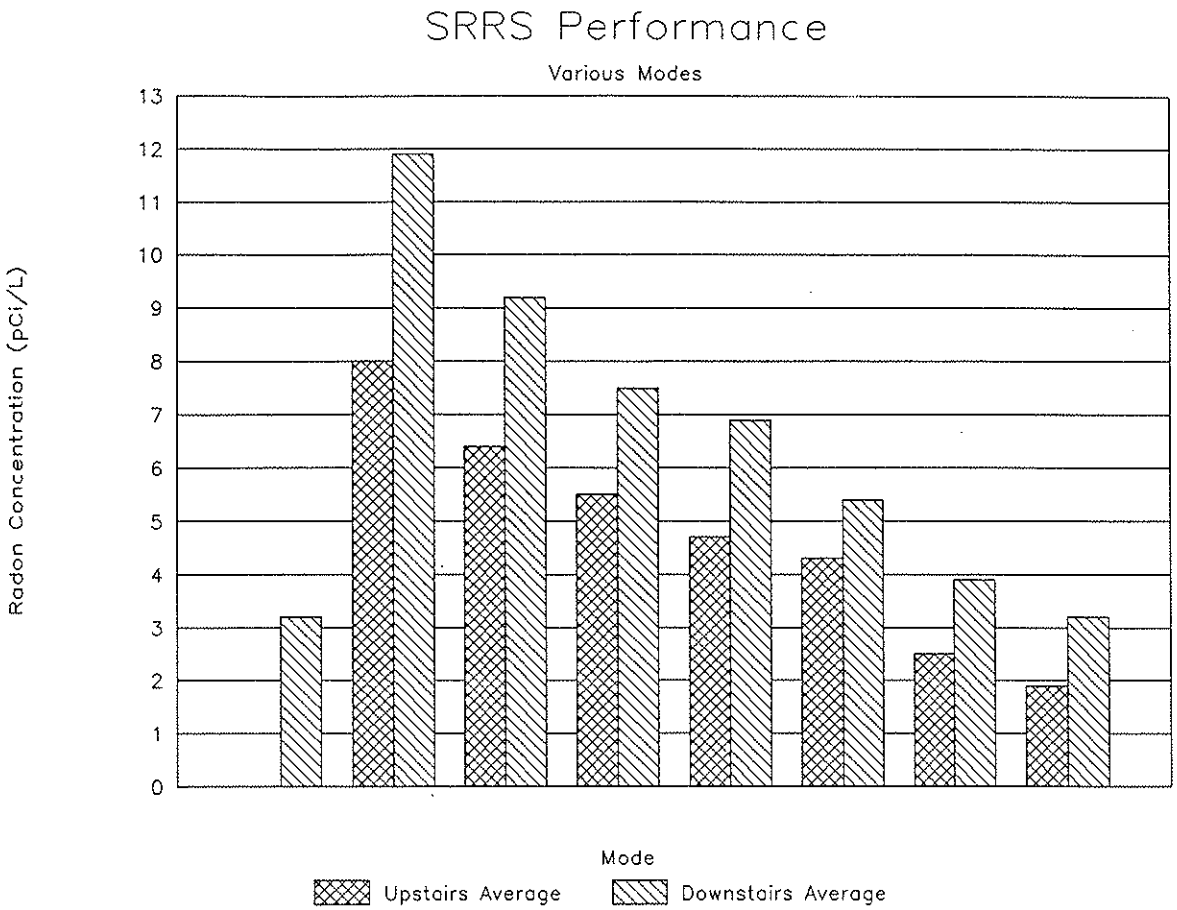
SOLAR RADON REDUCTION SYSTEM DEMONSTRATION PROJECT - YEAR TWO

Introduction. Solar Radon Reduction System (SRRS) testing conducted during the winter of 1992/1993 yielded encouraging initial results. In order to evaluate the flexibility of the SRRS in other modes of operation and determine the optimum SRRS operational mode and resulting radon reduction efficiencies, a second year demonstration was designed using original test home #2 equipped with continuous radon monitors in both the basement and living areas of the home. Table 1 lists the modes of operation. Figure 1 shows the average radon levels obtained for each operational mode.

Table 1

Mode	Time Interval	Description
1	9/10/93 - 10/7/93	SRRS off, periodic open house conditions including basement windows open.
2	10/8/93 - 11/8/93	SRRS off, closed house conditions.
3	11/9/93 - 11/26/93	SRRS discharging upstairs during times of adequate solar insolation, Foundation sump pump pit sealed and naturally vented.
4	11/27/93 - 12/29/93	SRRS discharging upstairs during times of adequate solar insolation, Foundation sump pump pit sealed and forced vented using a 45 CFM fan.
5	1/1/94 - 1/9/94	SRRS discharging upstairs during the following timer mode (3 times per day, 2 hours per time) and continued sump pit forced venting.
6	1/10/94 - 2/6/94	SRRS discharging upstairs during times of adequate solar insolation, One basement window opened slightly, and continued sump pit forced venting.
7	2/7/94 - 2/22/94	SRRS discharging upstairs during the following timer mode (2 times per day, 6 hours per time) discharging upstairs and continued sump pit forced venting.
8	3/25/94 - 4/17/94	SRRS discharging downstairs during the following timer mode (2 times per day, 6 hours per time) discharging upstairs and continued sump pit forced venting.

Figure 1



Results

As can be seen from Figure 1, both upstairs and downstairs open house conditions (Mode #1) resulted in an average downstairs radon concentration of 3.2 pCi/L. This radon concentration is assumed to be the minimum level achievable through natural dwelling ventilation. Mode #2 represents a closed house background radon concentration of 8.0 (pCi/l) and 11.9 (pCi/l) respectively for upstairs and downstairs. (Please note: the 8.0 (pCi/l) level was the dwelling background level obtained during year one testing, (winter of 92/93). With these baseline levels established, the foundation sump pump pit was sealed and naturally vented to the outside of the dwelling and the SRRS system was activated in a mode that induced outside air into the upstairs of the dwelling during periods of adequate solar energy (Mode #3). The resulting ventilation/pressurization during this mode of operation resulted in an average radon concentration of 6.4 (pCi/l) and 9.2 (pCi/l) in the upstairs and downstairs areas respectively. In relation to closed house background levels, SRRS mode #3 operation achieved and upstairs radon reduction of 20% and a downstairs reduction of 23%. These values are relatively consistent with the first year, "solar only mode" reduction efficiencies of 24% and 29%.

In order to evaluate the affect of further, active, and low cost radon mitigation options, the SRRS system operation remained in the solar only mode while the sump pump pit natural ventilation system was replaced with a forced draft fan (Mode #4). This operational mode resulted in average upstairs and downstairs radon levels of 5.5 (pCi/l) and 7.5 (pCi/l) respectively; an 11% radon reduction level improvement upstairs and a 14% downstairs improvement as compared to natural sump pit ventilation.

During optimum solar insolation conditions (i.e. non-cloudy days) the SRRS introduces outside air for approximately 6 hours (9:00 am to 3:00 pm). In order to evaluate the effect of the SRRS during maximum solar insolation conditions and to spread the radon reduction benefits of the system through the day, the SRRS was connected to a timer set to operate the system at two hour intervals, evenly space three times throughout the day (Mode # 5). Figure 1 shows an average upstairs radon level of 4.7 (pCi/l) (41% reduction) and a downstairs level of 6.9 (pCi/l) (42% reduction) in this mode.

As would be expected, the downstairs radon concentration consistently remained higher than that recorded upstairs. In order to evaluate the effect of additional downstairs ventilation, Mode #6 was designed to return the SRRS to solar only operation with one basement window slightly opened. While lower radon levels were obtained both upstairs and downstairs (4.3 (pCi/l) and 5.4 (pCi/l) respectively) due to this additional, natural ventilation, additional performance was desired to obtain an EPA action level of 4.0 (pCi/l).

Based on data obtained from the previous year's SRRS demonstration, operation the SRRS for 12 hours obtained a upstairs radon level of 4.0 (pCi/l) in this demonstration's test home (See Figure 4 of the attached "SOLAR RADON REDUCTION SYSTEM DEMONSTRATION PROJECT" report). With this in mind, the SRRS was connected to a timer set to operate the system two times daily, six hours per time (i.e. 9:00 am to 3:00 pm and 10:00 pm to 4:00 am). The 9:00 am to 3:00 pm interval coincides with the optimum daily solar insolation period, thus achieving maximum energy gain. As shown in Figure 1, this mode of operation resulted in an upstairs radon concentration of 2.5 (pCi/l) and a downstairs level of 3.9 (pCi/l). Corresponding percent reductions were 69% upstairs and 67% downstairs as compared to background levels.

Here-to-fore the SRRS has been set up to discharge fresh air into the upstairs area of the dwelling. In the final reported mode of operation (Mode #8), the SRRS was modified to discharge fresh air into the downstairs area of the dwelling. In this mode, upstairs radon levels averaged 1.9 (pCi/l) while downstairs levels were reduced to 3.2 (pCi/l). Versus background, the SRRS achieved 76% and 73% upstairs and downstairs radon reduction efficiencies.

Figures 2 and 3 show detailed Mode #8 data (upstairs and downstairs respectively) over a 3 week period. Upstairs radon levels ranged from 0.1

pCi/L to 4.5 pCi/L during the test period. More important is the average radon level of 1.9 pCi/L. Likewise, basement radon levels ranged from 0.5 pCi/L to 7.1 pCi/L, with an average of 3.2 pCi/L. While lower radon levels could likely be achieved by extended SRRS operation (i.e. more or longer operational time intervals), the radon levels obtain in this mode were acceptable to the home owner and no additional timer operated test modes were conducted.

Figure 2

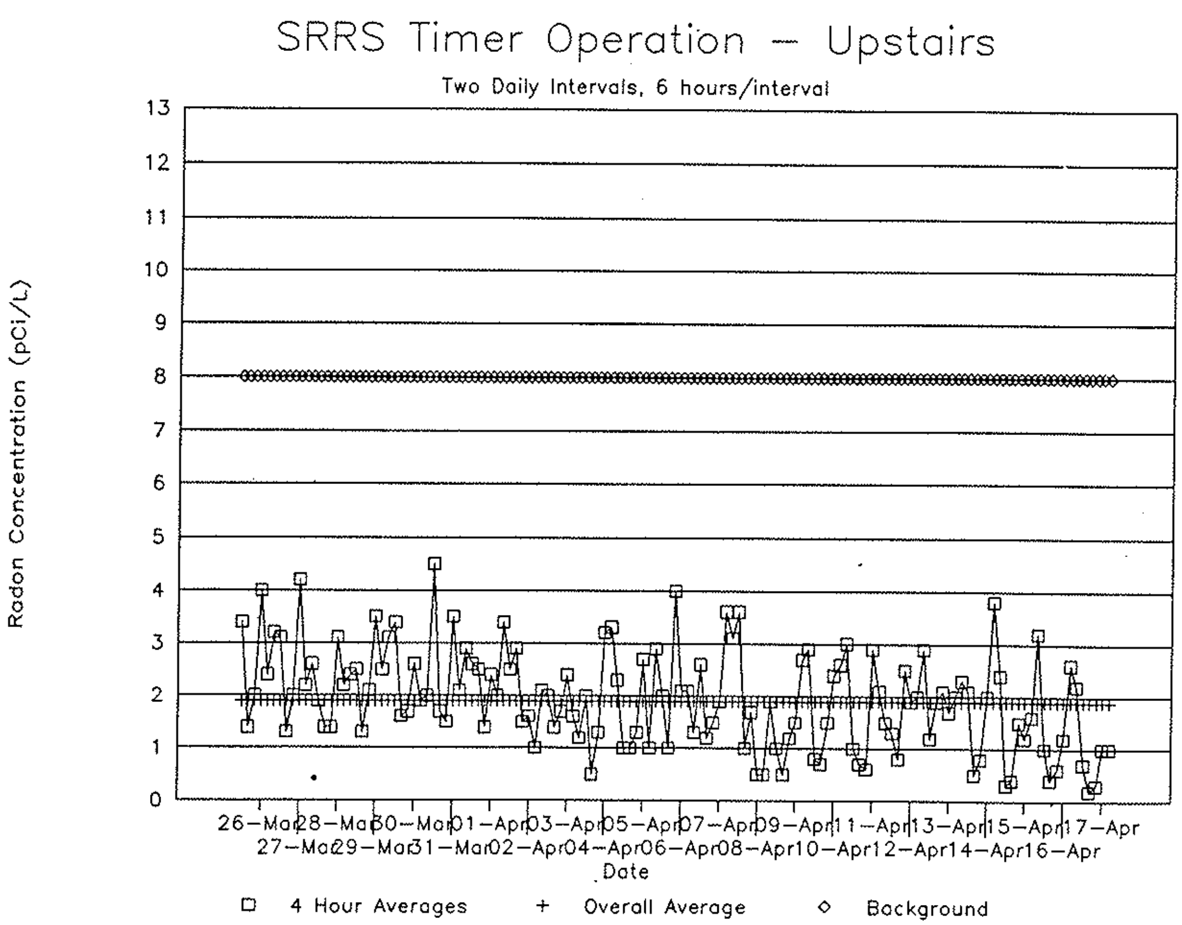
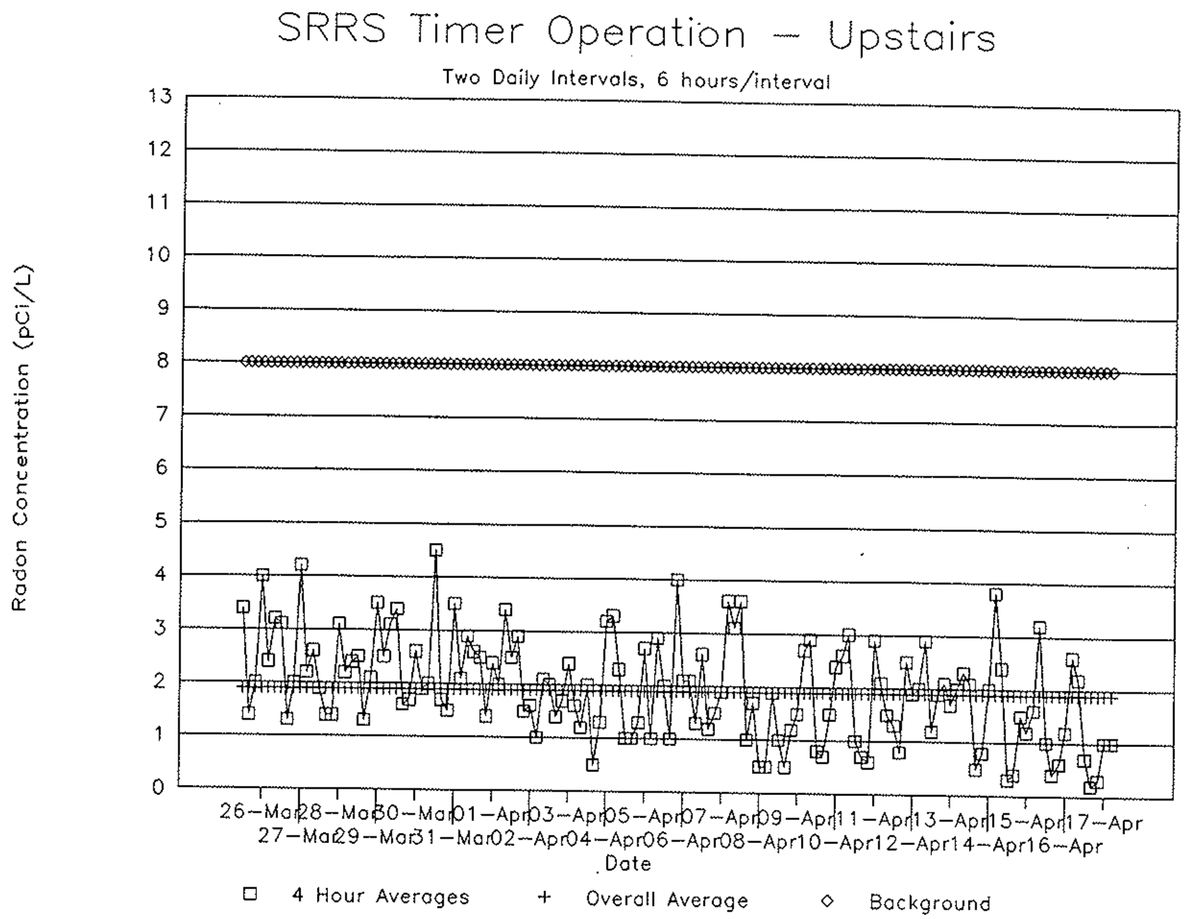


Figure 3



Conclusions

First year SRR/AQMS demonstrations proved the system effective in reducing indoor air radon concentration levels. As would be expected for a ventilation/pressurization system, the effectiveness of the SRR/AQMS (i.e. percent radon reduction) was related to the volume of air the system introduced into the dwelling (i.e. time of operation). The objective of this study was to develop other modes of SRR/AQMS operation that would accomplish consistent radon reduction at levels below the EPA standard of 4 pCi/L.

Timer operation of the SRR/AQMS system during optimum solar insolation periods (i.e. 9:00 am to 3:00 pm) and an additional six hour period during the night, resulted in average radon concentrations of 1.9 pCi/L in the living area of the home. This concentration is well below the recommended EPA action level.

A major advantage of the SRR/AQMS over other radon mitigation systems is its ability to introduce solar heated air into the home. This energy gain is optimized when the system is allowed to operate only during periods of adequate solar isolation. The only possible drawback to operation of the SRR/AQMS in a timer mode is the introduction of non-heated outside air during cloudy days and night time operation. To quantify this aspect, the following calculations are provided:

- The month of March had:
  - 10 clear days
  - 11 partly cloudy days
  - 10 cloudy days
  - an average temperature of 36°F
  - an assumed relative humidity of 50%

- Assuming a SRR/AQMS input to the house of:
  - 100°F for 4 hours and 68°F for 2 hours on clear days
  - 68°F for 6 hours on partly cloudy days
  - 36°F for 6 hours on cloudy days
  - 36°F for all 6 hour night time operational intervals

The enthalpy (i.e. energy of input air) of SRR/AQMS air = 1,688,015 BTU for the month of March

The enthalpy of the 72°F, 25% relative humidity in door air replaced by the SRR/AQMS input = 2,699,325 BTU

In other words, it took 1,101,310 (2,699,325 - 1,688,015) BTU of make up heat to adjust the SRR/AQMS input to indoor ambient levels. At $8.10/MBTU, the energy expense attributed to the SRR/AQMS during March was $8.20. Assuming 6 months of operation per year at $8.20 per month, the annual SRR/AQMS operating expense would be approximately $50 (This value excludes the cost of operating the 1 amp induced draft fan.)

Assuming the installed cost of the SRR/AQMS is $1,000 versus an alternative $2,500 subslab radon reduction system, negating the costs of operating the subslab fans (as was done above for the SRR/AQMS) and negating the time value of money, the energy payback on the subslab system would be 30 years, well beyond the working life of the subslab system and the time most people reside in a home.

Additional Research

The above SRR/AQMS demonstration steps involved progressively more aggressive system operation/intervention. To obtain acceptable levels of radon (i.e. 4 pCi/L or less) in other dwellings, similar trials and radon recording instrumentation would likely be necessary. In order to simplify subsequent SRR/AQMS installations, incorporation of newly available and affordable continuous radon monitors equipped with fan start/stop electrical relays ("radon-stats") is being planned. In this test mode, the SRR/AQMS will operate, independently, during times of adequate solar insolation to provide maximum energy gain ventilation/pressurization. If the "radon-stat" senses radon levels above a predetermined, maximum acceptable level, the SRR/AQMS will be activated. When levels drop, the SRR/AQMS will revert back to the solar only mode of operation. This SRR/AQMS/"radon-stat" incorporation should assure desired radon reduction in most applications without the time and expense of trial and unpredictable modeling. Results of the SRR/AQMS/"radon-stat" testing on new installations will be made available as soon as possible.

Manufacturability:

The solar panel of the SRR/AQMS will be manufactured out of metal and plastic. The frame will be manufactured at Enviromiser utilizing the shear and brake press stated in the equipment list. The plastic glazing used on the solar panels will be purchased and cut to size on the shear. These components will be assembled at Enviromiser for packaging. The blower and controls will be purchased and modified by Enviromiser technicians and packaged to ship with the solar panels as a completed system and sold in kit form for installation by the consumer or distributors/installers.

Element I.B. Statement of Work

Enviromiser, which has a U.S. patent on a Solar Radon Reduction System, is now ready to focus on the latter stage of product refinement and market penetration/commercialization. Existing test facilities have proven that the system reduces radon concentrations, and results in a reduction in energy consumption. This makes the SRR/AQMS the only system on the market that is an energy saving device rather than an energy consuming device.

At present, Enviromiser is ready to move into a start-up phase of marketing and commercialization. The SRR/AQMS has already demonstrated market readiness as a renewable energy technology that reduces radon and energy consumption. This start-up phase is to market the system for use by "do-it-yourselfers" and distributors/professional installers.

Step 1: Marketing/Commercialization

This step involves developing a 2-phase marketing plan. The first phase is an emphasis in market penetration for the "do-it-yourselfer" and the second phase towards distributors/professional installers.

Step 2: Manufacturing

The second step is developing a manufacturing facility capable of producing the solar panels, blowers, controls, and assembly hardware. In addition, a complete packaging system will be used to ship the system complete in kit form.

Step 3: Research and Development

Continuing research and development will be performed to improve the efficiency of the system. Development will be towards creating a system that can be used where solar heat is not required, but cooling is. There will also be implementation of solar water heating, heat storage systems for use when the solar panel is not active, and better monitoring and controls built into the system.

The above steps are required to move the project from a research-oriented project to a commercialized product. A marketing study has been completed and demonstrates the locations best suited for market penetration. This market survey has shown our system to be the lowest cost system available at this time which has the ability to save energy versus using energy to accomplish the same goal of radon reduction and indoor air quality improvement. Enviromiser is confident that marketing the product for these reasons will allow easy access to the market with a high degree of success.

A manufacturing facility is required to produce the product and control the quality. Enviromiser believes that by manufacturing its own product, the result will be a high quality and cost-effective system available to the end consumer.

In the present design, existing technology and manufacturing processes are available for in-house manufacturing. The research and development department will allow for improvements, to develop new technology and to incorporate other technology into the system. This will lead to expansion and market growth, and allow movement into commercial applications.

At present, there are no foreseeable technical or business related problems or obstacles that would keep Enviromiser from being successful in the indoor air quality market, using solar power as a component to reduce the energy consumption needed to increase air quality.

Element I.C. Applicant and Key Personnel Capabilities

Owners/Applicants

Richard J. Klein, II

President, Enviromiser

4028 North Ave.

Waterloo, Iowa 50702

Research Technician, Iowa Waste Reduction Center, University of Northern Iowa, 1990-present

Owner, Enviromiser (trademarked name)

Inventor, "Solar Radon Reduction System", U.S. Patent Number 5,186,160

Winner of EPA's 1991 Innovative Radon Mitigation Design Contest

Recipient of 1989 Iowa Governor's Waste Reduction Award

Board of Directors, Iowa Renewable Energy Association

James A. Olson

2928 Lovejoy Dr.

Cedar Falls, Iowa 50613

Waste Management Specialist, Iowa Waste Reduction Center, University of Northern Iowa, 1988-present

Certified Hazardous Materials Manager, Senior Level

Engineer in Training (EIT)

M.S., Thermal and Environmental Engineering, 1984, Southern Illinois University

B.A., Biology/Business, 1977, University of Northern Iowa, Iowa

Marketing Consultant

Douglas L. Sevey, President

Innovative Designs, Inc.

325 Locust Street

Waterloo, Iowa

Product Design/Development Consultant and Business Broker, Innovative Designs, Inc., 1990-present

Founding Member, Venture Resources of Northeast Iowa, 1992

Hawkeye Institute of Technology

University of Northern Iowa

University of Lowell

RELEVANT BACKGROUND INFORMATION FOR DOUGLAS L. SEVEY

JAN 1990 TO PRESENT: President, Innovative Designs, Inc.

RESPONSIBILITIES: Management of company; develop new product ideas for our company and our clients; evaluation of new markets and products; conceptual designs of new products; presentations to clients; development of new products; estimate costs of products; and project budgets for expenses. Patent, trademarks and copyright applications.

MAJOR ACCOMPLISHMENTS INCLUDE:

* Development of Custom Medical Products Inc., sold to local investment group.
* Sold and relocated two companies to New Hampton and Parkersburg, Iowa.
* Development/production/patented LEVEL GUARD, sold to Johnson Level & Tool.
* Development/production of THE SIDER, patented, trademarked, and assigned.
* Development and design of plastic lumber, patented and assigned.
* Development and design of car door protector, patented and assigned.
* FEA and design of Frigidaire's new inner tube for a new line of washers.
* FEA/thermal analysis/design of explosion proof lab equipment for DOW.
* Concept of cordless electric caulking gun for Black & Decker.

JAN 1980 - JAN 1990: Waterloo Industries Inc. (Subsidiary of American Brands)

TITLES HELD: Senior Research & Development Engineer, Market Specialist, Product Development Engineer, Design Engineer.

ENGINEERING RESPONSIBILITIES: To implement long range product and marketing strategies; evaluation of product lines and new market areas; conceptual design of new products; presentations to Executive Committee; development of new products; and yearly budgets for capital and expenses for product development.

MARKETING SPECIALIST RESPONSIBILITIES: Evaluation of new markets to be used for development of new divisions for company expansion.

MAJOR ACCOMPLISHMENTS INCLUDE: One of a three member venture team assigned to develop a new division to generate sales of $12 million in three years.

Holder of U.S. Patent #4,681,381 for a medical device.

Preliminary development of a high end product line leading to a 3% increase in market share. Developed new home office product line for Sears. Assisted in development of medical accessory line.

DEC 1975 - DEC 1979: Pentech/Houdaille Industries

TITLES HELD: Standards and Product Development Coordinator, Production Coordinator, Designer.

RESPONSIBILITIES: Establish standard design of new methods of manufacturing to improve product quality and cost. Investigate sources for new methods of manufacturing.

MAJOR ACCOMPLISHMENTS INCLUDE: Development and construction of a $250,00.00 R&D portable pure oxygen water treatment plant. Development and manufacturing of aeration product line for updating existing treatment plants. Set up and started manufacturing center for in house manufacturing.

Project Work Locations. Current location of research and development and ongoing testing is located at a University of Northern Iowa test facility. In addition, two demonstration locations are located in Waterloo, Iowa. With the infusion of start-up capital and DOE grant funds, an office and manufacturing facility will be leased in the Waterloo-Cedar Falls, Iowa area.

Organizational and Individual Responsibilities The three principals will share overall company management and financial-related decisions. More specific roles are outlined below.

Step 1: Marketing/Commercialization Doug Sevey will be heading up the marketing division of the company and will be responsible for all tasks associated with marketing and commercialization of the SRR/AQMS.

Step 2: Manufacturing Richard J. Klein will be heading up the manufacturing operations division of the company and will be responsible for all tasks associated with site selection, acquisitions, and production management.

Step 3: Research and Development Jim Olson will be heading up the research and development division of the company and will be responsible for all tasks associated with on-going development and testing of Enviromiser's SRR/AQMS.