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# A PREVIEW OF THE NATIONAL RADON/THORON TEST FACILITY

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# A PREVIEW OF THE NATIONAL RADON/THORON TEST FACILITY

by

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## ABSTRACT

A radon/thoron test facility of the walk-in type has been designed for testing and calibration of radiation instrumentation, for studying plate-out of radon and thoron daughters on surfaces (e.g., walls), for testing and comparing radiation measuring techniques, and for a variety of dynamic simulation studies of practical and theoretical relevance. The conditions in the test facility can be varied externally within a wide range of values. The test facility described in this report can operate as a flow-through system, thereby enabling a variety of dynamic studies to be undertaken, or as a closed-loop with recirculation.

The test facility is relevant to the establishment of radiation reference standards for calibration purposes in Canada for radon, thoron and their short-lived decay products. The radon/thoron test facility should prove useful for the calibration of instrumentation and the simulation of uranium mine and mill atmospheres.

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Key words: Radon; Radon daughters; Thoron; Thoron daughters; Calibration.

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Avant-goût de l'installation nationale d'essais sur le radon et le thoron

par

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RESUME

Une installation d'essais sur le radar et le thoron, dans laquelle il est possible d'entrer, a été conçue pour mettre à l'essai et étalonner des instruments de mesure des rayonnements, étudier les produits de filiation du radon et du thoron piégés sur des surfaces (ex. murs), mettre à l'essai et comparer des techniques de mesure des rayonnements, et faire diverses études de simulation dynamique d'intérêt pratique et théorique. Les conditions dans l'installation peuvent être réglées de l'extérieur dans une vaste gamme de valeurs. L'installation peut fonctionner en circuit ouvert, ce qui permet de mener diverses études dynamiques, ou en circuit fermé avec recirculation.

L'installation s'inscrit dans le cadre de l'établissement d'étalons de rayonnement en vue de l'étalonnage au Canada du radon, du thoron et de leurs produits de désintégration. Elle devrait s'avérer utile pour l'étalonnage des instruments et la simulation des atmosphères des mines et des usines d'uranium.

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Mots clés : Radon, produits de filiation du radon; thoron; produits de filiation du thoron; étalonnage.

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# INTRODUCTION

Radon gas ($^{222}Rn$) and its short-lived decay products (radon progeny) found in uranium mines and tailings piles are radionuclides whose accurate quantification is of great importance from the occupational, health physics and ventilation standpoints. Furthermore, ores found in some uranium mines also contain thorium ($^{232}Th$) in variable amounts, an isotope which upon a series of radioactive decays gives rise to thoron gas ($^{220}Rn$). Radioactive decay of thoron gas leads in turn to its short-lived decay products or thoron progeny.

Accurate determination of both radon/radon progeny and thoron/thoron progeny activity concentrations is instrumental in assessing the biological hazards and health impact of these radioisotopes on uranium mine and mill workers.

The measurement of environmental radiation levels depend on the accuracy of sophisticated instrumentation and analytical techniques and procedures. Hence, reliable radiation measurements depend on accurate instrument calibration, which must be conducted under strictly controlled conditions.

Facilities designed to calibrate and test radon and radon progeny instrumentation have been built and are commonly known as 'radon boxes'. Examples of such facilities can be found in the United States, England, Canada, Australia, and other parts of the world, e.g., Environmental Measurements Laboratory (E.M.L.), New York; U.S. Bureau of Mines (U.S.B.M.), Denver, Colorado; Environmental Protection Agency (E.P.A.), Alabama; Department of Energy (D.O.E.), Grand Junction, (CO), operated by Bendix Field Engineering Corporation; National Radiological Protection Board (N.R.P.B.), U.K.; Australian National Laboratory (A.N.L.), Australia; and Elliot Lake

Laboratory (CANMET, E.M.R.), Elliot Lake, Canada.

However, it is also of interest to design test facilities which enable the use of thoron/thoron progeny atmospheres, and arbitrary mixtures of radon and thoron, and their respective progeny. Furthermore, in the interest of simulating uranium mine atmospheres, it is important to design facilities that also allow long-lived radioactive dust (LLRD) and trace and noxious gases to be mixed with radon (thoron) progeny atmospheres.

Essentially, a radon (or thoron) 'box' consists of a container where a radon (or thoron)/air mixture is injected at one end of the box and exhausted at the other end. During the time the radioactive gas remains inside the container, it partially decays into its short-lived decay products, i.e., progeny, resulting in a radioactive gas/decay product mixture. The concentration level of radioactive gas and its progeny, and the ratios of the different decay products can be controlled by: varying the input and output air flow rates; the addition of aerosols, and water vapour, which also regulate the relative humidity; and by other means, as discussed below.

Because of its mandate and the close proximity to several underground (U/G) uranium mines, the Elliot Lake Laboratory has long been interested in: testing and calibrating radiation instrumentation; building facilities to such end; and simulating U/G uranium mine atmospheres. Because Ontario U/G uranium mines have appreciable amounts of thorium in their ores, the Elliot Lake Laboratory has been particularly interested in the measurement of thoron and its progeny.

A radon/thoron test facility of about 3 $m^3$ volume was designed and built and has been in operation since late 1980 (1). This small facility has proved to be quite useful in the calibration of radiation instrumentation of several kinds, including environmental monitors and personal dosimeters, and in the investigation of plate-out phenomena and other phenomena of great practical and theoretical interst (2,3).

Although quite useful for research purposes, this facility was not practical for certain activities such as parallel testing and calibration of a large number of instruments and reasonably realistic simulation of mine atmospheres. With this purpose in mind, a much larger radon/thoron test facility (~26 $m^3$) was designed and completed in 1982. This large facility operated from 1982 to 1985 (4), and served as the basis for the final design of the National Radon/Thoron Test Facility (NRTTF) for radon, thoron, and their progeny for testing and calibrating radiation instrumentation used for AECB compliance purposes.

This report presents a brief preview of the newly designed Radon/Thoron Test Facility (RTTF), its operating conditions and characteristics, and other relevant information.

## DESCRIPTION OF THE RADON/THORON TEST FACILITY

For simplicity, the description of the Radon/Thoron Test Facility (RTTF) will be divided into the following main sections:

a) Radon/Thoron chamber;

b) Air conditioning system and associated monitoring system;

c) Air flow system and associated monitoring system;

d) Aerosol and radiation injection systems; and

e) Aerosol and radiation monitoring system;

f) Systems control.

### RADON/THORON CHAMBER

The radon/thoron chamber consists essentially of two chambers, one inside the other. The inner chamber is the radon/thoron chamber proper, i.e., it contains the radioactive aerosol atmosphere.

The space between the inner chamber and outer chamber is used as an isothermal enclosure to thermally isolate the inner chamber from the laboratory room. This enclosure contains air at a temperature close to the operating temperature of the inner chamber. To improve the insulating characteristics of the enclosure its inner walls are lined with thermal insulating material.

The inner chamber is a parallelepipedon shaped enclosure of about 30 $m^3$ volume. The chamber is lined with stainless steel panels; it is leak proof and has electrical continuity for grounding purposes.

The inner chamber is equipped with a leak proof double door with about 3 $m^3$ volume between doors to serve as a 'buffer zone'. The buffer zone is pressure compensated in order to enable easy transfer from the inner chamber to the laboratory room.

Two windows symmetrically located on each side of the double-door permits easy visual inspection of the inner chamber. The latter is provided with 16 double electrical outlets to operate instrumentation placed inside.

The inner chamber is equipped with 37 stainless steel sampling and injection ports of about 10 mm diameter terminated with on/off stainless steel valves of the ball type. In addition, the chamber is provided with 12 stainless steel ports of about 40 mm diameter. Three of these ports are used to drive communication cables from instrumentation placed in the inner chamber to data loggers and microcomputers, located outside, for data storage, display, and analysis purposes. The other 9 large sampling ports are used mainly for grab-sampling purposes. This is done by fitting a length of 10 mm diameter stainless steel tubing to a rubber stopper fitting snugly into the sampling port. One end of the stainless steel tubing is terminated by an open-face sample holder/filter system. The other end of the tubing is connected to a sampling pump whose exhaust is fed to the inner chamber so that sampling is conducted in a close-loop fashion. Figures 1 to 3 show some details of the Radon/Thoron Test Facility.

The length of the stainless steel tubing inside the inner chamber can be changed by sliding it through the rubber stopper to reach different locations inside the chamber. A few of these sampling port arrangements is all that is needed for almost complete radiation 'mapping' of the chamber by grab-sampling.

The inner chamber is connected to the small radon/thoron box (3 $m^3$), indicated above, by means of 19 mm tubing and a 5 L/min pump. This unique arrangement (see Figure 4) allows simultaneous operation of the two facilities for independent purpose under the same environmental and radioactivity conditions.

B. AIR CONDITIONING SYSTEM AND ASSOCIATED MONITORING SYSTEM

The RTTF air conditioning system has been designed to handle an air flow rate in excess of 30 $m^3$/min at any combination of temperature and relative humidity ranging, respectively, from 10°C to ~35°C, and from ~5% to >99%. Air conditioning is done by means of a heater/drier/humidifier system and associated fan and ducting system.

The temperature (T), and relative humidity (RH) are fully programmable. A microprocessor-controlled air conditioning control unit enables T and RH to be programmed independently. Up to 99 sequential sets of values for T and RH can be programmed to operate at different times and for variable lengths of time.

Temperature and relative humidity sensors located in the RTTF permit continuous monitoring of T and RH by means of a rotating chart recorder located outside the RTTF. The air conditioning control unit has alarm capabilities to indicate when a given condition has been reached.

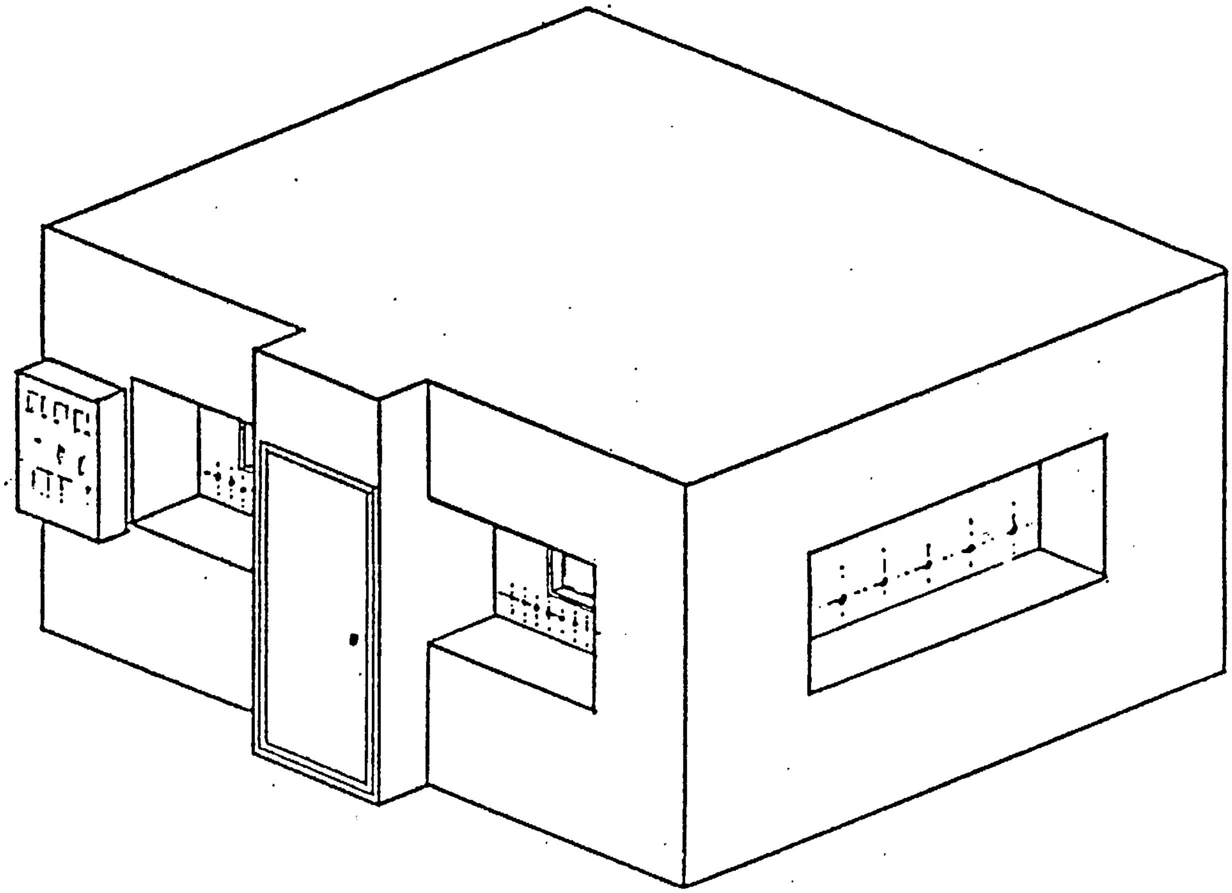


Fig. 1 - View of the Radon/Thoron Test Facility (RTTF).

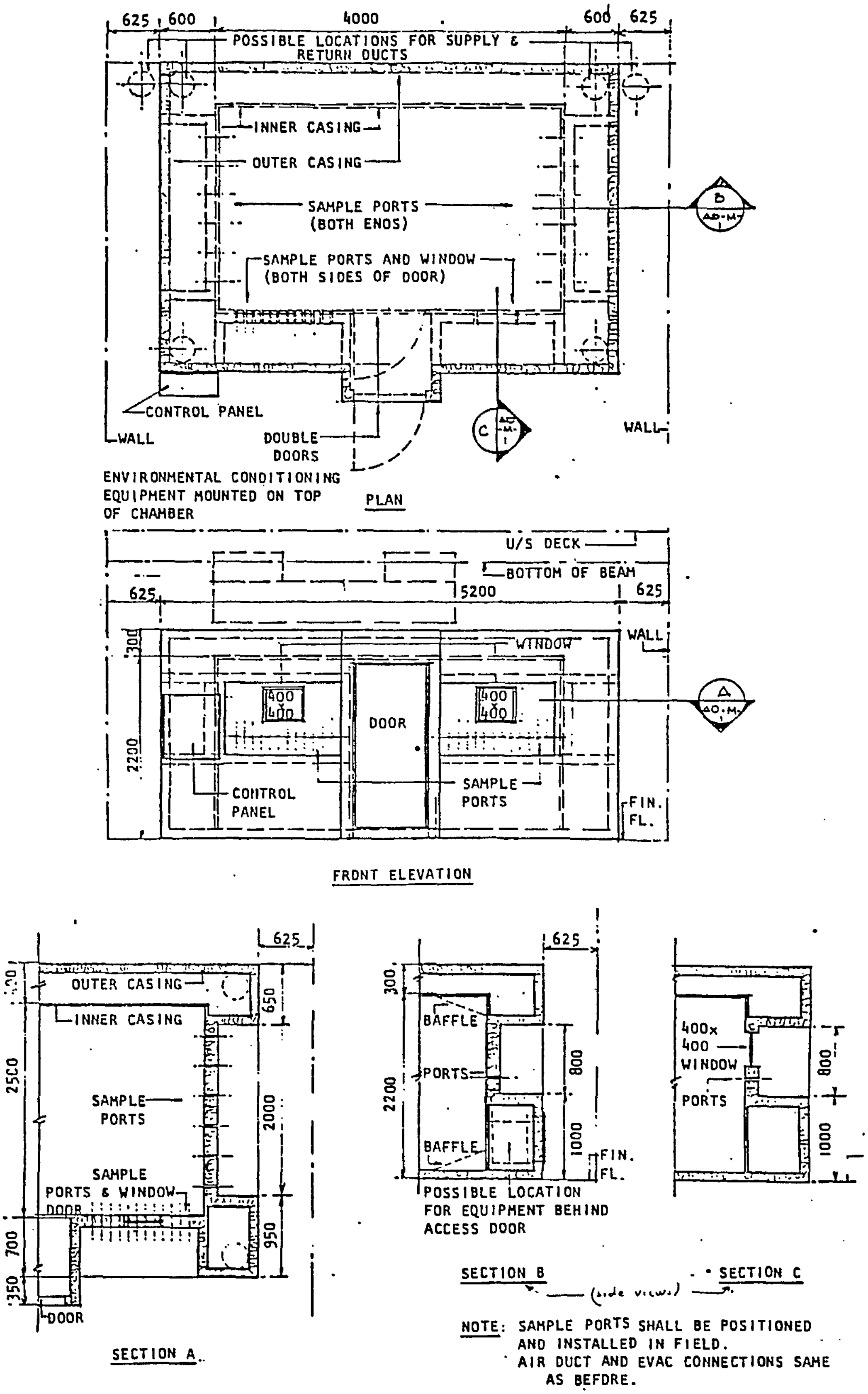
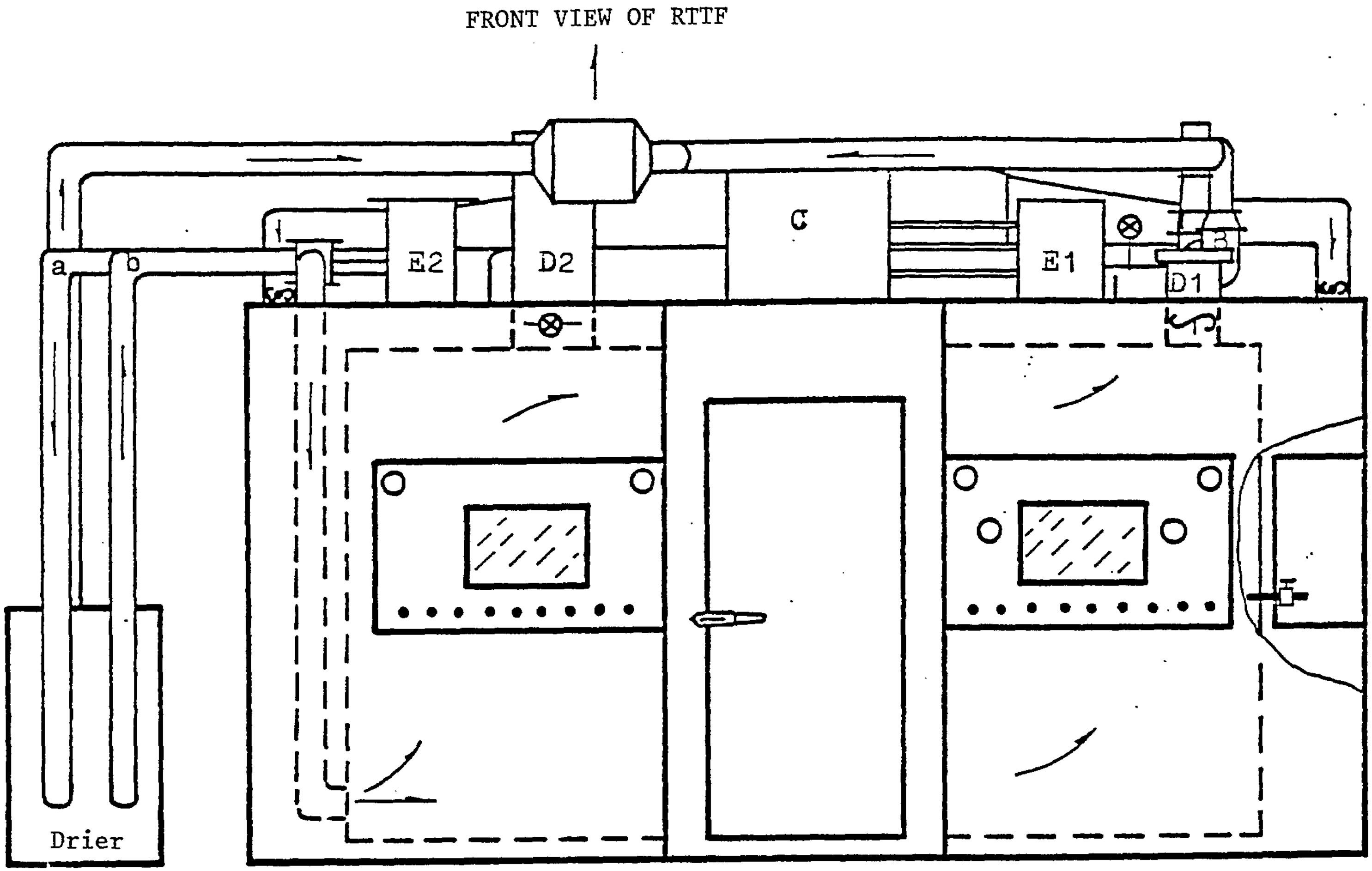



Fig. 2 – Plan, front elevation and several sections of the Radon/Thoron Test Facility.




| | | | |
|---|---|---|---|
| | Anemometer | B : | Inner room air exhaust fan |
| | Automatic control damper | C : | Outer room ventilation fan |
| | Manual control damper | E1, E2 : | Compressor |
| | Sampling port | D1, D2 : | Emergency air inlet and exhaust |

Fig. 3 - Front view of the Radon/Thoron Test Facility.

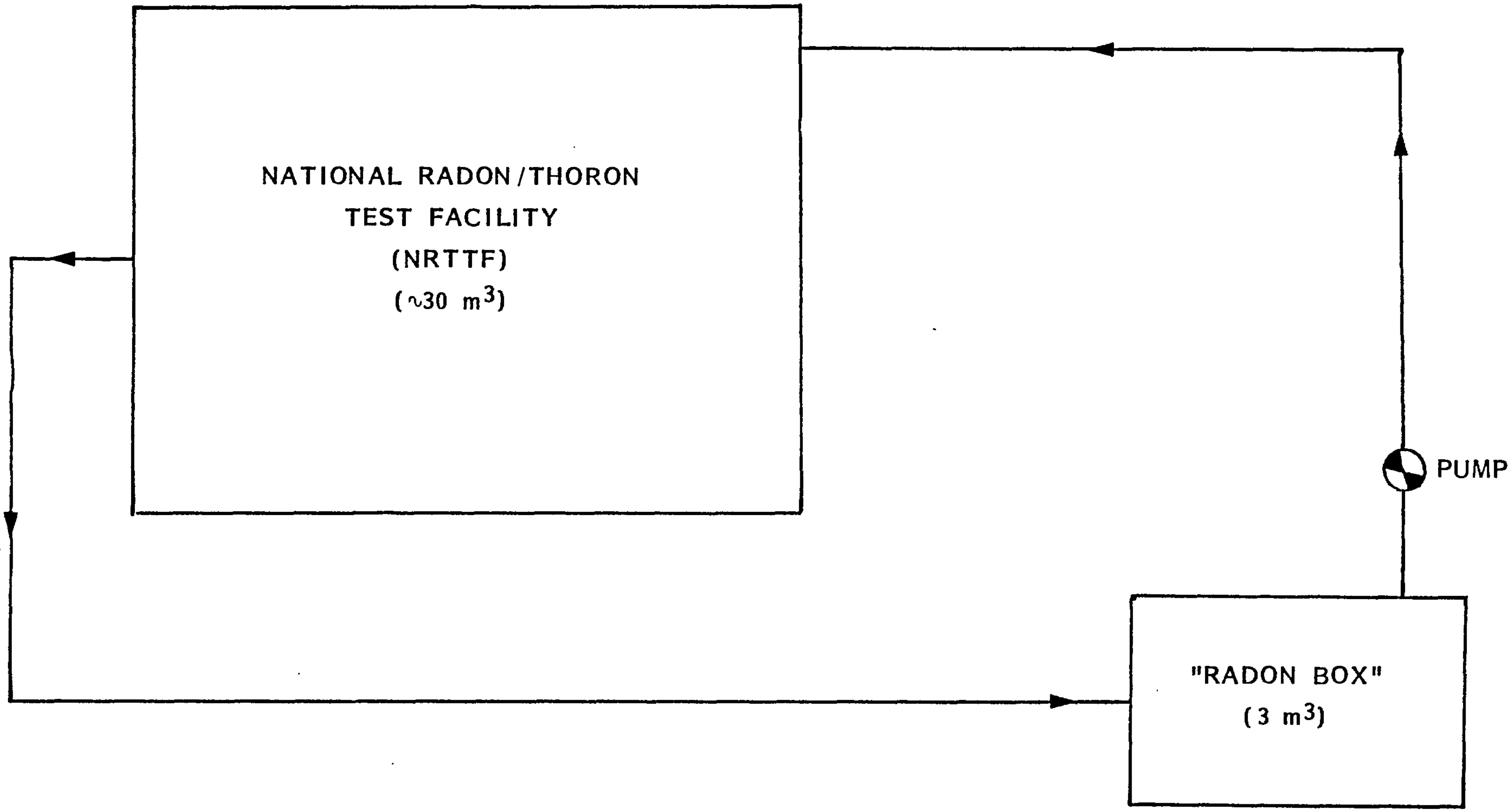



Fig. 4 - Radon/Thoron Test Facility connected to Radon Box.

C. AIR FLOW SYSTEM AND ASSOCIATED MONITORING SYSTEM

The air flow system has been designed to operate under the following conditions:

a) Total recirculation, i.e., no air intake or air exhaust; the air is recirculated continuously in the RTTF;

b) Total flow-through, i.e., no air is recirculated. In this modality fresh air is taken into the RTTF and exhausted at the opposite end of the RTTF and outside the building after passing through a filtering system to remove the decay products of radon and thoron;

c) Partial recirculation/partial flow-through. In this modality any combination of air recirculation and fresh air flow-through can be chosen from 0% recirculation and 100% flow-through to 100% recirculation and 0% flow-through. Items a) to c) are shown in Figure 5.

Items a), b) and c) allow the change of:

i) the radon (thoron) progeny disequilibrium ratio;

ii) the F-value, i.e., ratio of radon progeny Working Level to radon gas concentration; and

iii) the radon, thoron, and their progeny, concentration.

Total air flow through the RTTF is variable from practically 0 $m^3$/min to >30 $m^3$/min by means of air flow 'controllers'.

The RTTF is equipped with an air emergency system to evacuate the chamber in a few seconds should the need arise, e.g., because of excessive radioactive levels, leaks or any other reason.

Air flow-rate is measured and monitored at three locations in the air flow system by means of air velocity probes Model 1610-4 by TSI Systems (U.S.A.) located at the air intake, air exhaust and recirculation ducting. Air velocity readings are converted into air flow rate readings in the air

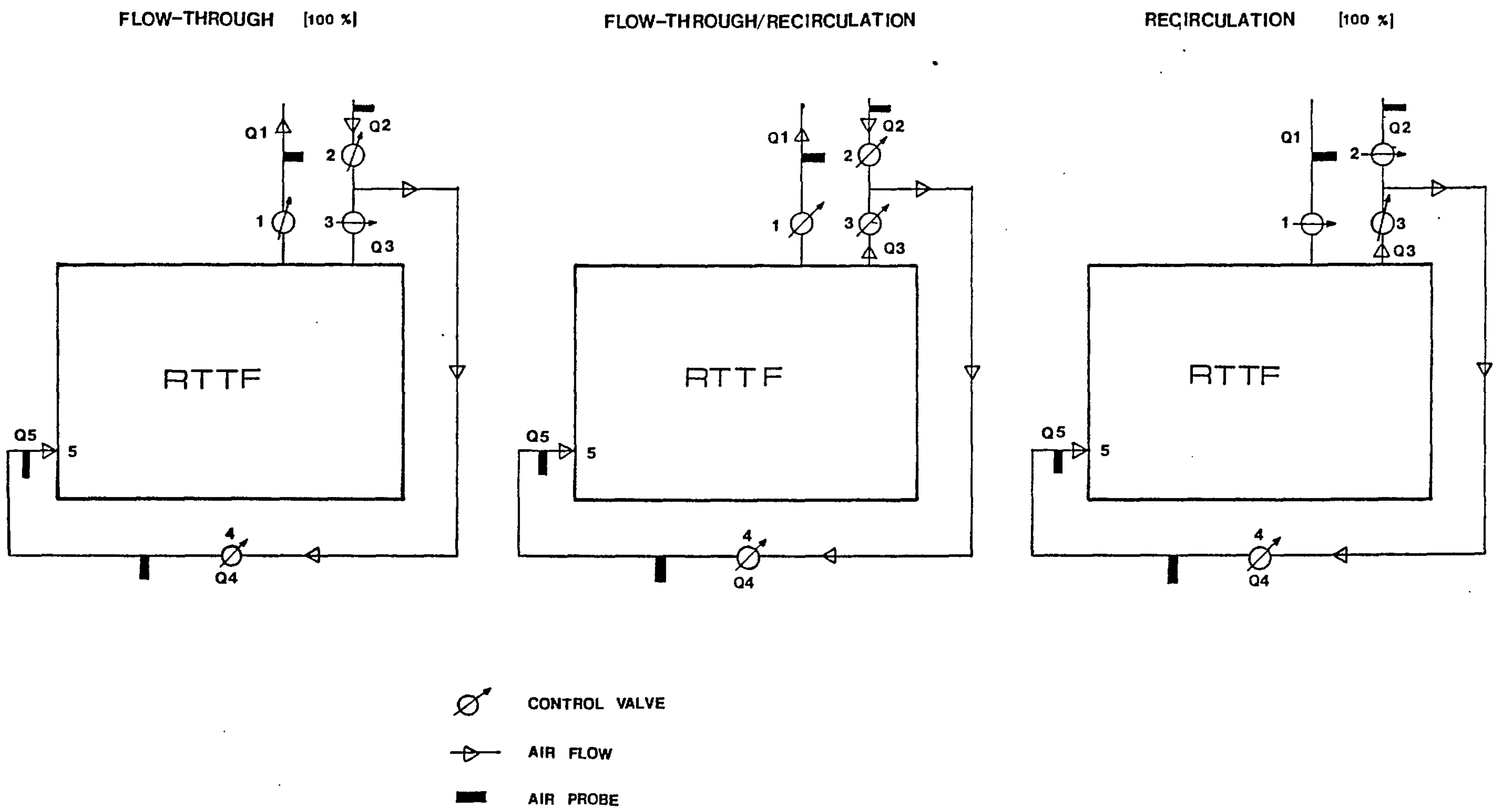



Fig. 5 - Air flow configurations of the Radon/Thoron Test Facility.

flow control/monitoring system. Air flow rates are displayed by a LED digital read-out system and plotted in a strip chart recorder.

Provision has been made to filter the intake air to control and/or remove atmospheric aerosols before entering the RTTF. Furthermore, air distribution systems have been designed for injecting air to and exhausting air from, the RTTF. The air distribution systems are aimed at attaining a uniform air distribution in the RTTF.

Several baffles are being designed to eliminate 'dead' air spots and unwanted eddies in the RTTF. In addition, several air fans in the RTTF can be operated, if so desired, to improve air mixing and to increase the Reynolds number.

D. AEROSOL AND RADIATION INJECTION SYSTEMS

Aerosols are injected into the RTTF for a twofold purpose:

a) To provide a substrate for the attachment of the recently formed radon and thoron decay products. Without aerosols, the radon and thoron progeny would readily attach themselves to the room walls, i.e., plate-out, resulting in a considerable loss of these decay products in the room atmosphere; and

b) To simulate field conditions for instrument calibration.

Aerosols are produced mainly by means of a:

i) Constant Output Atomizer Model 3076, or a Six Jet Atomizer Model 9306, in conjunction with an Air Supply System Model 3074 and other associated instrumentation, all manufactured by TSI Systems (U.S.A.);

ii) Vibrating Orifice Aerosol Generator Model 3450 from TSI Systems.

The systems indicated in item (i) are suitable for the generation of submicron aerosol whereas the system in item (ii) is only used to generate aerosol in the micron range. These systems generate polydisperse clouds.

When monodisperse aerosol of a given size or size range is required, the above systems are operated in conjunction with either an automatic switching valve/diffusion battery system Model 3042 from TSI Systems, or a Differential Mobility Particle Analyzer Model 3071, also from TSI Systems.

A variety of aerosols may be used such as aqueous solution of NaCl, uranine, methylene blue, and $NH_4Cl$. Furthermore, several types of smoke, kerosene, DOP and other chemical substances can be used depending on particular applications. Aerosol concentration in the RTTF is usually controlled by varying the concentration of the chemical substance in the solution.

Aerosols can be injected into the RTTF:

a) directly through any sampling/injection port;

b) in a mixing chamber where aerosols and radon and/or thoron gas are mixed before entering the RTTF; and

c) through the main RTTF air intake ducting system.

The mode of injection used depends on the particular application and the efficiency and mixing effect desired.

The RTTF is equipped with a total of 8 'dry' radium ($^{226}Ra$) and thorium ($^{232}Th$) sources manufactured by Pylon Electronic Development (Ottawa), Models Rn-1025 and Th-1025, respectively. The sources are of the flow-through type. Dry sources are more convenient than liquid sources as the danger of a spill is greatly minimized. Furthermore, the routine handling, in-line operation and installation, and maintenance of dry sources is considerably simpler than for example, the more conventional radium chloride aqueous solution.

The Pylon sources operate by suction, i.e., air is drawn first through silica gel, to remove air moisture, then through a glass fibre filter, to eliminate airborne particulate matter from the air stream, and finally through the radium or thorium source and into the RTTF. Variable flow rate pumps are used in conjunction with the sources. The amount of radon and thoron gas injected into the RTTF is inversely proportional to the pump flow rate which is regulated by means of precision needle valves. The sources operate in the range 0-10 L/min. The sources can be arranged to operate either independently, in series, or in parallel. The following $^{226}$Ra and $^{232}$Th sources are available:

a) Four $^{226}$Ra sources with the following activities: 35 $\mu$Ci, 50 $\mu$Ci, 100 $\mu$Ci, 100 $\mu$Ci. Hence, a total of about 300 $\mu$Ci of $^{226}$Ra is available;

b) Four $^{232}$Th sources with the following activities: 30 $\mu$Ci, 40 $\mu$Ci, 105 $\mu$Ci and 98 $\mu$Ci. The total activity available being again in the order of 300 $\mu$Ci.

As for the case of aerosols, radon and thoron gas can be injected directly into the RTTF, or premixed with aerosols in a mixing chamber before injection into the RTTF, or injected into the main air intake system of the RTTF.

## E. AEROSOL AND RADIATION MONITORING SYSTEMS

A number of instruments operate in conjunction with the RTTF to monitor its overall performance and the different environmental variables of interest.

The aerosol concentration and aerosol size distribution in the RTTF are monitored continuously by means of a diffusion battery TSI Model 3040 in conjunction with an automatic switching valve TSI Model 3042, and a condensation nucleus counter (CNC) TSI Model 3020. Furthermore, a CNC Model Rich 200, manufactured by Environment One (U.S.A.), is also used as an independent back up aerosol counter. Both CNCs, i.e., TSI Model 3020 and Rich 200, are interfaced to a programmable data logger and a bubble memory to operate the instruments and display and store the data.

Aerosol concentration and size distribution is also monitored by means of a Differential Mobility Particle Sizer (DMPS) Model 3071 by TSI operated in conjuction with an IBM XT computer.

Radon gas concentration is monitored by means of a variety of instrumentation such as:

a) A continuous radon gas monitor Model RGM-2 manufactured by Eberline (U.S.A.);

b) Two continuous monitors employing pulsed ionization chambers manufactured by Oberhoff and Associates (U.S.A.);

c) A radon gas continuous monitoring system designed by Pylon Electronic Development consisting of a multi-purpose programmable Scaler Model AB-5 and a passive radon detector (PRD), or a large scintillation cell with enhanced sensitivity by electrostatic means; and

d) Several units with operating principles based on the two-filter method (5,6). One of the units is fully automated and programmable directly interfaced to a microcomputer for data display and data storage.

Radon progeny is measured by a variety of instrumentation such as:

i) Continuous radon daughter monitors Models WLM-300, RGA-400 and WLM-30 manufactured by EDA Instruments (Toronto), Model alpha-PRISM manufactured by Alpha-NUCLEAR (Toronto), and Model AB-5/APD-47 manufactured by Pylon Electronic Development (Ottawa);

ii) A $\beta$-particle detector of the pancake type Model HP-260 in conjunction with a Scaler Model MS-2, both manufactured by Eberline (U.S.A.);

iii) A diffused-junction detector and a silicon-barrier detector in conjunction, respectively, with a multichannel analyzer by Canberra (U.S.A.), and an IBM XT microcomputer with digital to analog converter, and other associated electronic circuitry that effectively replaces the functions of the multichannel analyzer; and

iv) A radon daughter/thoron daughter continuous monitor with dual detector system Model Rn/Tn-750 manufactured by Alpha-NUCLEAR (Toronto).

All instruments indicated above can be used for radon or thoron, and for radon progeny or thoron progeny. Radon and thoron progeny monitoring instrumentation is placed inside the RTTF and data is retrieved from the outside by means of interface cables linking the monitors to a microcomputer. Radon and thoron monitoring instrumentation is placed outside the RTTF.

Other instrumentation of the active and passive type, automated or grab-sampling are available according to needs and purpose.

## F. SYSTEMS CONTROL

The RTTF has been designed to operate automatically by means of a multiplexer/computer/controller system. However, the system is used for a twofold purpose:

a) As a data acquisition, display and storage system; and

b) As a control system to maintain the radon progeny or thoron progeny activity concentration in the RTTF constant.

Radiation, aerosol and meteorological sensors are interfaced to the computer via a multiplexer. Some of the radiation sensors are used for control purposes whereas other sensors are used to acquire relevant RTTF data, e.g., aerosol, meteorological and radiation sensors.

The control function of the system operates as follows:

a) The desired value for the radiation level is programmed in the computer by the operator.

b) The actual value for the radiation level in the RTTF is transmitted to the computer where it is compared with the pre-programmed value. Radiation levels in the RTTF are continuously monitored by several radiation monitors which send data in real-time to the computer via communication cables. (Monitors and sensors are placed inside the RTTF;

the computer/ multiplexer/controller system is located outside the RTTF. Communication between the system and monitors and sensors is effected by communication cables through communication ports in the RTTF walls.)

c) If the difference between the desired radiation level and the actual level exceeds a given percentage of the pre-programmed value, the rate of injection of radon or thoron in the RTTF is changed by means of a variable flow rate sampling pump controlled by the computer via the systems controller.

d) The steps in items (b) and (c) are repeated until the desired radiation level is achieved.

## OPERATING CONDITIONS OF THE RTTF

The RTTF has not yet been thoroughly tested. Hence, the values given in Table 1 for the range of operating conditions are only approximate. Higher and lower values than those quoted can be achieved depending on the number of radioactive sources used, the aerosol system employed, and the air flow conditions in the RTTF, e.g., percentage recirculation, and flow-through.

## APPLICATIONS OF THE RADON/THORON TEST FACILITY

The test facility described in this paper is relevant to the establishment of radiation reference standards for calibration purposes in Canada for radon, thoron and their short-lived decay products.

The RTTF should prove useful for the calibration of instrumentation and the simulation of uranium mine and mill atmospheres.

## REFERENCES

1. Bigu, J., "The design of a radon/thoron calibration facility"; Division Report MRP/MRL 81-46(TR), CANMET, Energy, Mines and Resources Canada;

1981.

2. Bigu, J., "On the effect of a negative ion-generator and a mixing fan on the plate-out of radon decay products in a radon box"; Health Physics, vol 44, No. 3, pp 259-266; 1983.

3. Bigu, J. and Grenier, M., "On the effect of a negative ion-generator and a mixing fan on the attachment of thoron decay products in a thoron box"; Health Physics, vol 46, No. 4, pp 933-939; April 1984.

4. Bigu, J., "A walk-in radon/thoron test facility"; Am Ind Hyg Assoc J, vol 45, No. 8, pp 525-532; 1984.

5. Thomas, J.W. and LeClare, P.C., "A study of the two filter method for radon-222"; Health Physics vol. 18, pp 113-122; 1970.

6. Mayya, Y.S. and Kotrappa, P., "Modified double filter method for the measurement of radon or thoron in air"; Ann Occup Hyg, vol 21, pp 169-176, 1978.

Table 1 - Approximate operating conditions for the radon/thoron test facility (RTTF)

| Variable | Range of Values |
|---|---|
| Radon gas concentration | <5 pCi/L (0.18 Bq/L) to >$10^3$ pCi/L (37 Bq/L) |
| Thoron gas concentration | <5 pCi/L (0.18 Bq/L) to >$10^3$ pCi/L (37 Bq/L) |
| Radon progeny Working Level | <0.02 to several WL |
| Thoron progeny Working Level | <0.02 to several WL |
| Aerosol concentration | <$10^3$ $cm^{-3}$ to >$10^6$ $cm^{-3}$ |
| Relative humidity | ~5% to >99% |
| Temperature | <10°C to ~35°C |
| Air flow | 0 to >30 $m^3$/min |
| Air circulation | 0 to 100% |
| Air flow-through | 0 to 100% |