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UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

GUIDELINE TRANSMITTAL SHEET

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Herewith transmitted is the first issuance of the Cave Radiation Safety and Occupational Health Guideline.

Associate Director, Administration

CAVE RADIATION

SAFETY AND OCCUPATIONAL HEALTH

MANAGEMENT GUIDELINE

NPS-14

NATIONAL PARK SERVICE

DEPARTMENT OF THE INTERIOR

CAVE RADIATION SAFETY AND OCCUPATIONAL HEALTH MANAGEMENT
NPS-14

TABLE OF CONTENTS

INTRODUCTION

There are many hazards involved in entering natural caves. The underground environment is at once very fragile and very hostile to non-troglodytes. Radiation in caves is just one hazard - and a very subtle one.

The cave alpha radiation matter came to the attention of the Southwest Regional Office as a result of research privately conducted in Carlsbad Caverns National Park starting in 1974 and subsequent National Park Service (NPS) research starting in 1975. The presence within Carlsbad Caverns of small quantities of radon gas and its daughter decay products suggested that there might be a potential radiation hazard to employees and the public. Subsequently, the Environmental Protection Agency (EPA) determined that there was no significant health hazard to the public, but that there was enough airborne alpha radiation to pose a possible health hazard to the employee. Therefore, in order to respond adequately to this information there was simultaneous implementation of both research and management programs. Monitoring began at Carlsbad Caverns in September, 1975. Measurements continued at other NPS cave areas in 1976 and 1977 to provide baseline check data with monitoring initiated at Mammoth Cave in May, 1976 and at Cumberland Gap Caves, Lehman Caves, Oregon Caves, Round Spring Cave in Ozark, Crystal Cave in Sequoia, Timpanogos Cave, Jewel Cave, and Wind Cave after equipment had been obtained and radiation monitoring provided for NPS personnel at these areas.

Due to the unique nature of this potential airborne alpha radiation hazard in natural cave environments, no other agency has operational programs keyed to both public and employee safety and utilization of cave areas. The nearest approximation of this situation can be related to the safety regulations pertaining to uranium mining which are coordinated by the Mine Safety and Health Administration (MSHA) in the Department of Labor (formerly the Mining Enforcement and Safety Administration, MESA, in the Department of the Interior). Because of this, NPS has sought heavy input from MSHA in regard to this evolving program. Other agencies such as the Environmental Protection Agency, The Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health (NIOSH) have been involved to varying degrees. In addition, the precautionary standards published by the National Caves Association was used as a general reference. This program is a pioneering effort on the part of the Service, and as such, has required some uncommon approaches and solutions, which combine the skills and knowledge of science, safety and occupational health, public health, and natural resources management.

PURPOSE, OBJECTIVE, RESPONSIBILITIES, AND ORGANIZATION

Purpose

The purpose of these guidelines is to establish precautionary procedures for cave alpha radiation in order to minimize potential health hazards to employees and visitors in caves throughout the system.

Objectives

The objectives are:

1. Development of operating criteria to safeguard visitors and employees within a framework perpetuating natural cave dynamics.

2. Establish the relationships and basic understanding of low level radiation (radon and thoron group) and natural ventilation in cave systems.

3. Initiation of the NPS Cave Radiation Information System (CRIS) for reporting of cave radiation and exposure data for public health, management and research purposes.

Responsibilities

The Division of Safety Management of WASO will provide policy guidance and Servicewide coordination for the cave radiation monitoring. Technical advice and consultation will be supplied by the Office of Science and Technology, WASO, and will rely on the relevant servicewide expertise or outside consultants as required.

Each Regional Office shall provide coordination with WASO and shall insure that these Guidelines are fully implemented, where applicable. Regional Offices shall provide program support and guidance for the parks.

Using the criteria in Chapter 2, No. 1, each park shall carry out a review and evaluation of its caves and/or abandoned mines for radiation and shall document the findings in these using CRIS. Where monitoring is necessary, as determined using the criteria described in Chapter 5, each park shall do the following:

1. Provide personnel and funds necessary to conduct the radiation monitoring program which applies to its cave(s) and/or abandoned mine(s).

2. Fully inform the park staff of the potential health problem as described in Chapter 3.

3. Document and control employee exposure to the cave radiation by prudent, precautionary management actions.

4. Monitor employee health as described in Chapter 6.

5. Code all data on cave radiation levels and employee exposure acculations and input into CRIS.

Organization

In order to operate this overall program, the established line organization from Superintendent to Regional Director shall be used.

Monitoring will be carried out by designated Park personnel. As they deem necessary, the Region and/or parks may initiate special studies in addition to the regular radiation monitoring and medical surveillance. They are to provide funding for such work.

The Division of Safety Management, WASO, will coordinate the long-term management phase of the entire NPS Cave Radiation Monitoring and Medical Surveillance Program. Technical and scientific advice and consultative services will be provided by the Office of Science and Technology, WASO.

GENERAL REQUIREMENTS

1. All parks which have caves or abandoned mines that are used regularly by visitors or employees and where research or exploration is done shall initially test them by the Kusnetz method for the presence of airborne alpha radiation. Thereafter, sampling shall be done in accordance with the requirements in Chapter 5.

2. While underground, smoking shall be prohibited.

3. Cave air shall not be used to ventilate buildings used by employees or visitors, nor shall such air be allowed to freely enter such buildings.

4. Cave air will not be artifically ventilated.

5. The concentration of alpha radiation in caves should not be used as justification for either temporary or permanent closure of caves. This applies to both developed and wild caves. However, positive management actions designed to reduce human exposure to higher alpha radiation levels are appropriate.

6. When spelunking tours, seasonally operated tours, or new tours begin; when new caves are opened to the public; when any process or control change may increase the airborne concentration of radon daughters; or whenever the employer has any other reason to suspect an airborne increase of radon daughters, an initial environmental monitoring shall be done. Thereafter, sample in accordance with the requirements in Chapter 5.

SAFETY AND HEALTH INFORMATION

1. Employee Information:

a. The potential health hazard and effect of alpha radiation in caves must be explained to all employees who will be doing any significant underground work before they begin their employment. This explanation must be given by someone who is qualified to present a clear and careful discussion of the potential radiation health hazard.

Note: Alpha radiation hazards consist of respirable ionized particles which are emitted during the radioactive decay of certain radionuclides. Normally, the more energetic alpha radiation is stopped by the skin. However, inside the body, it produces dense ionization in the tissues. This can result in cell destruction, mutation, and uncontrolled cell growth.

b. The employer will provide the employee with a description of and explain the purpose of the medical surveillance and monitoring program.

EMPLOYEE PERMISSIBLE EXPOSURE LIMIT

1. Annual cumulative radiation exposure shall not exceed 4.00 working level months of alpha radiation for any employee.

2. When an employee receives 2.00 working level months (WLM) or more of alpha radiation in a calendar year, medical surveillance shall be made available as outlined in Chapter 6.

3. Where regular quarterly monitoring is not done, but where a few radiation measurements suggest a potential radiation health hazard, underground work shall not exceed 700 hours per year for any employee.

SAMPLING AND MONITORING FOR EMPLOYEE EXPOSURE

1. Monitor radon daughter levels by the Kusnetz method quarterly if the levels are below an average for a sample set of 0.30 working level (WL). Five minute walking and stationary samples are required along toured and all other occupied areas. Perform until the average of the sample set on the tour route and/or any occupied areas exceeds 0.30 WL.

2. When the average from one set of the samples exceed 0.30 WL, monitor by the Kusnetz method weekly and keep exposure records on all employees working underground (time underground is measured to the nearest 1/4 hour after the first 30 minutes of exposure). Record the tours and areas in which each employee worked each day and length of time spent there.

3. All such employee exposure data will be stored in CRIS.

MEDICAL SURVEILLANCE AND MEDICAL RECORDS

1. Employee Medical Surveillance:

a. An initial baseline physical examination shall be made available to all employees who work underground in the caves. This examination shall include, but not be limited to:

1) A comprehensive or interim medical and occupational work history, with special emphasis directed toward identifying preexisting disorders of the respiratory tract and history of tobacco consumption. See Appendix A.

2) An initial baseline physical examination consisting of posteroanterior and lateral chest x-rays (35 x 42 cm.) and sputum cytology.

b. An annual medical examination shall be made available to all workers who exceed exposures of 2 WLM or more per year (see Chapter 4, no. 2.). A different frequency may be indicated by professional medical judgement based on such factors as emergencies, variations in work periods and environment, and preexisting health status of the individual worker. This examination shall include, but not be limited to:

1) A yearly routine medical history and physical examination consisting of a sputum cytology done annually and chest x-rays done biennially (every two years).

Special attention and priority should be given to the following employees:

a) Each employee who smokes, who is 40 years of age or older, and who has had 5 more years of service in the caves.

b) Each non-smoking employee who is 45 years of age or older, and who has had 5 years or more of service in the caves.

c) Employees who are less than 40 years of age but have had 5 or more years of service in the caves.

c. Funding:

1) WASO will fund the initial baseline physical examination for all permanent employees who work underground in the caves for the fiscal year 1980. This will be a one time funding. Thereafter, it will be the responsibility of the appropriate Park area.

2) Funding support for the medical surveillance will be be accomplished by the appropriate Park area.

2. Medical Records:

a. Each employee's medical records should include records of occupational exposure applicable to that employee. The employee's exposure data will be stored in CRIS.

b. All medical records with supporting documents shall be retained for 25 years after the employee's last occupational exposure to radon daughters.

c. The employee, former employee or their designated representative, the medical representatives of the Secretary of Health, Education, and Welfare, of the Secretary of Labor, and of the employer shall have access to all of the employee's medical records.

EMPLOYEE RECORDKEEPING

1. The National Park Service's computerized Cave Radiation Information System, CRIS, shall maintain radon and thoron daughter concentration levels which are routinely taken in all regularly monitored cave areas and employee exposure accumulation data.

2. Where it has been determined that the employees has been exposed to 2 WLM or more per calendar year, all records of sampling and of pertinent medical examinations shall be maintained for the duration of employment plus twenty-five years after the employee's last occupational exposure to radon daughters. (Records shall indicate the type of personal protective devices, if any, in use at the time of sampling) Records shall be maintained so that they can be classified by employee.

3. When the average from one set of the samples exceed 0.30 WL, record employee exposure level, time spent underground, and tours and areas where each employee worked each day. (See Chapter 5, no. 2)

4. Each employee shall have access to information on his own environmental exposure.

PERSONAL PROTECTIVE EQUIPMENT

1. Under the provisions of Chapter 4, Employee Permissible Exposure Limit, there are no requirements for a respirator.

Note: However, when doing cave exploration or research and where hazards from respirable silica dust exists, the use of a respirator is recommended. The selection, use, and care of respirators shall adhere to the requirements of CFR 1910.134.

SAMPLING AND MONITORING FOR CAVE MANAGEMENT RESEARCH

1. When cave research activities are conducted, the following sampling and monitoring requirements are to be met:

a. Using the Kusnetz method, read thoron daughters monthly (5 to 17 hours after the radon monitoring has been performed) on selected samples having the highest radon daughter W.L. for a tour route or area. Use the same filter samples for both. However, when a radon daughter reading is extremely high at any other time also read the thoron daughter value for that air sample. Observe air flow velocity or qualitative magnitude.

b. In caves so equipped: Mammoth Cave, Carlsbad Caverns, Lehman Caves, Wind Cave, and Jewel Cave, on a biweekly interval, draw and measure one or two radon gas samples. Sample(s) should be taken where radon daughter levels are the highest along the regularly monitored tour routes or occupied areas. The purpose is to determine age of the air by knowing the radon gas concentration and radon daughter level.

c. In all caves, biweekly, at one or two points on regularly monitored routes, measure the Tsivaglou individual radon daughter concentrations. In those caves so equipped: Carlsbad Caverns, Lehman Caves, Wind Cave and Jewel Cave, (Crystal Cave in Sequoia, etc.) measure the free ion concentrations at the same time using the two pumps. Do this at the same sites where radon gas is sampled (see b. above). One pump uses standard filters; one pump uses a special wire screen. Measure at points giving the highest radon daughter concentrations on regularly monitored tour route or occupied areas.

d. Make small particle counts of cave air along with (b) above, for those caves so equipped: Mammoth Cave, Carlsbad Caverns, Lehman Caves, Wind Cave and Jewel Cave.

e. For those caves applicable: Mammoth Cave, Carlsbad Caverns, Wind Cave, Lehman Caves, and Jewel Cave, operate the meteorological equipment.

1) One set of equipment underground at a location where pressure fluctuations and other changes (i.e., temperature, humidity, and evaporation) seem to be most effectively measured in order to best characterize the cave's general behavior.

2) One set of equipment above ground where general wind patterns and frontal movements will be observed. Avoid having atypical air patterns affecting temperature, humidity, and even pressure.

3) Meteorological equipment upkeep:

a) Weekly change the paper in each piece of equipment (six pieces of equipment). Wind the clocks and fill the ink reservoirs in each.

b) Make the air velocity and flow rate (cfm) measurements as often as practical in cave areas having maximum air flows.

c) For those caves (Oregon Caves, Crystal in Sequoia, Round Spring in Ozark, Cudio's at Cumberland Gap, etc.) having non-recording equipment, observe pressure, temperature, relative humidity, etc. in the morning, noon, and night.

f. When caves are checked for airborne alpha radiation, it is advisable to do this at two different times during the year: in mid-summer when the radiation levels would be expected to be highest, and in mid-winter when the levels should be lowest. This seasonal variation holds true only for cave systems in which the natural air flow has not been altered by human management actions. The monitor checking a cave system for the first time must exercise judgment. It is best to go to the back areas of the cave and work out. Counter/scaler equipment should be placed at some convenient, central location which can be reached from the most remote sample point within 60 to 80 minutes at most. A series of moving and stationary samples, along with airflow observations should be used to characterize the cave's radiation. These data should be coded for CRIS, with new coding numbers and names created which are descriptively appropriate.

CAVE RADIATION INFORMATION SYSTEM - CRIS

1. Each employee must accurately describe and report to the supervisor the amount of time spent underground and work location(s). This data is used to compute the time weighted average daily exposure of the employee. The employee's annual exposure accumulation is also determined from this input.

2. Supervisors must make certain that the reporting is done regularly and accurately.

3. On a regular monthly basis, place all data on the appropriate coding forms for the computerized Cave Radiation Information System and until further directed, send to the Division of Safety Management, WASO, phone: Commercial (202) 523-5108, FTS 523-5108. These should be received in WASO no later than two weeks after the end of each month. All questions concerning procedures for filling out and submitting the coding forms should be directed to the Division of Natural Resources, WASO, phone: Commercial (202 343-6000, FTS 343-6000. See Appendix B.

4. The CRIS data base for which coding is to be done has four parts. These are:

a. Radon and thoron daughter data taken routinely in all regularly monitored cave areas;

b. Employee exposure accumulation data;

c. Where taken, special measurements data such as radon gas concentrations, individual radon daughter concentrations by the Tsivaglou method, free ion concentrations, small particle counts, etc.; and

d. Where taken, meteorological data.

5. CRIS will generate and forward to the parks regular monthly and annual reports as well as such _ad hoc_ reports as may become necessary.

6. Each cave monitor is to code the following data or his cave:

a. Radon daughter and thoron daughter (where taken)data which is routinely taken in all regularly monitored cave areas;

b. All personnel exposure data developed at his cave for each employee; and

c. Where taken, all special measurements data.

SCIENTIFIC INFORMATION

1. In order to make the most effective resource management decisions for caves which will be both prudent and proper in the long-term phase of the health aspects of the radiation program, it is important to continue to develop the data base. In doing this, the CRIS is fundamental to organizing all of the data. This is to be done by continued routine monitoring, where applicable, using the guidelines already discussed, at caves administered by the National Park Service.

2. In addition, managers should recognize the importance of a continuing cooperation with scientific professionals. This will insure that appropriate skills will be mustered which can assist in developing the quantitative basis for establishing sound management plans and actions, by implementing pertinent applied research efforts. Conversely, managers can provide questions, ideas, and facts useful in shaping such research so that it can produce management oriented results. Science and Technology, WASO, will provide the basis for scientific and technical determinations as required to mitigate cave radiation problems.

Actinium Series
The 14 radioactive elements commencing with U-235 and culminating in stable Pb-207.

Alpha Detector
Normally a unit consisting of an alpha sensitive scintillation crystal mounted next to a photo-multiplier tube which utilizes a preamplifier to magnify the light pulses emitted when alpha particles contact the crystal. The light pulses are converted into countable electrical pulses.

Alpha Energy
Alpha particles are emitted from atomic nuclei with varying degrees of energy, but the energy from any radionuclide is characteristic and consistent. For example, RaA emits a characteristic 6.0 MeV alpha particle and RaC' emits a characteristic 7.7 MeV alpha particle.

Alpha Particle
A positively charged particle composed of 2 neutrons and 2 protons released by some atoms undergoing radioactive decay. The particle is the same as the nucleus of a helium atom.

Alpha Standard
A calibrated alpha radiation source of known energy and activity used for the calibration and testing of radiation detection instruments. Standards are usually long-lived to preclude the need to correct for decay.

Atomic Mass
The sum of the number of protons and neutrons in the nucleus of an atom.

Atomic Number
The number of protons in the nucleus of an atom.

Background
The radioactivity which is inherent in the environment where specific radiation measurements, exclusive of the general environment, are desired. In this situation, the background radiation must be first determined and then subtracted from the total count.

Beta Particle

A negatively charged particle similar to an electron emitted by some atoms undergoing radioactive decay. Beta particles are more penetrating but less ionizing than alpha particles.

Calibration

The process of adjusting and testing the behavior characteristics of a radiation instrument so that indicated radiation intensities can be related to actual intensities.

Calibration Check

The counting of an alpha field standard provides a rudimentary method of checking instrument calibration continuity. A more involved procedure is necessary periodically to check the complete range of the instruments' counting efficiency more accurately.

Calibration Factor

The multiplier which must be applied to a count-rate to obtain total disintegrations per minute. It is the reciprocal of the decimal fraction of the gross counter efficiency.

Carnotite

The most common secondary uranium mineral found in the Uravan mineral belt. Consists of a potassium uranium vanadate.

Condensation Nuclei

The small dust and aerosol particles in the atmosphere to which the atomic size radon-daughters readily attach. Condensation nuclei are generally in the 0.2- to 0.3-micron range.

Control Sample (of air)

Samples taken to evaluate the ventilation system and to provide information for affecting improvements. Control samples are often taken at locations where men are not working, but exposure samples are always taken at work locations.

Count Rate Meter

A meter which, when attached to a radiation detector, is capable of integrating the electrical pulses created by the radioactivity into average count rates.

Counts Per Minute
The decay rate recorded by a count rate meter or scaler. To determine the true activity measurement (dpm), corrections must be made for the gross counting efficiency of the instrument. Abbreviated cpm.

Curie
A quantitative measure of radioactivity. One curie equals 2.22×10^{12} disintegrations per minute. Abbreviated Ci.

Decay Constant
The fraction of the total number of atoms of an element present decaying per unit time. Commonly designated as lambda $(\lambda) = \frac{0.693}{\text{half life}}$

Decay Series
The consecutive members of radioactive family of elements. A complete series commences with a long-lived parent such as U-238 and ends with a stable element such as Pb-206.

Disintegrations Per Minute
The radioactive decay rate, determined from the count rate on the instrument divided by the gross counting efficiency of the instrument. Abbreviated dpm.

Dose
The amount of absorbed radiant energy. Usually given in REMS, RADS, or REPS. These units are roughly 100 ergs per gram of tissue.

Dose Rate
The amount of radiant energy absorbed per unit time. Usually given in Rads per hour.

Dosimeter
A device designed to indicate cumulative radiation exposure experienced by an individual. Actual absorbed energy or dose can only be inferred from the readout of the device.

Electrons
The orbital negatively charged particles surrounding the nucleus of an atom.

Electron Volt
The amount of energy required to move one electron through a difference in potential of one volt. The unit is equal to 1.6×10^{-12} erg. Abbreviated eV.

Equilibrium
The state at which the radioactivity of consecutive elements within a radioactive series is neither increasing nor decreasing.

Exposure
The amount of radiation present in an environment, not necessarily indicative of absorbed energy but representative of potential health damage to the individual present. Working-level-hours is a good example.

Exposure Rate
The amount of environmental radiation which an individual is subjected to per unit time.

Exposure Records
Records maintained to indicate the estimated exposure of a person. Exposure records are mandatory for each employee exposed to 0.3 WL or more to assure that he does not acquire more than 4 working-level months per year. Normally, all major work areas occupied by each man are sampled weekly and a record of each man's time occupancy is used for calculating the necessary cumulative exposure records.

Exposure Sample
A representative radon-daughter sample taken in a working environment to be used in time-weighting personnel's cumulative radon-daughter exposure.

Gamma Radiation
A true ray of energy in contrast to beta and alpha radiation. The properties are similar to x-rays and other electromagnetic waves. Gamma radiation is highly penetrating but relatively low in ionizing potential.

Geiger Counter
A radiation detector of low efficiency used primarily for detecting gamma radiation.

Gross Counting Efficiency
The percentage of total radioactive decay events

detected and recorded by a radiation detection instrument.

Half-Life
The time required for one-half of the atoms of a radioactive element to undergo decay.

Ionization
The breakdown of a molecule into its unstable charged components consisting of either atoms or radicals. This breakdown can be caused by several methods, one of which is ionizing radiation.

Ionization-Chamber Counters
Relatively low sensitivity radiation counters which detect and indicate degree of ionizing radiation by the number of ion pairs produced by the radiant energy penetrating the chamber.

Ionizing Radiation
Radiation capable of providing sufficient energy to ionize or break down molecules into charged atoms.

Isotope
An atom of an element having the same atomic number (number of protons) but a different atomic mass.

Neutron
Electrically neutral particles in the nucleus of an atom.

Nucleus
The center part of an atom containing protons and neutrons.

Picocurie
A quantitative measure of radioactivity equal to $1x10^{-12}$ curie or 2.22 dpm. Abbreviated pCi.

Pitchblende
A complex primary ore of uranium consisting principally of the oxide.

Primary Ventilation
The total air which is taken underground and returned to the surface.

Protons
Positively charged particles in the atomic

nucleus. The number of protons in an atom is the atomic number of the element.

RAD

The unit denoting absorption of 100 ergs of radiant energy per gram of absorbing material. From Radiation Absorbed Dose.

Radiation Protection Guide (RPG)

An exposure limit officially recommended not to be exceeded for the protection of personnel exposed to ionizing radiation.

A radiation protection guide may be a standard but may not have the scientific backing generally associated with Threshold Limit Values.

Radioactivity

Spontaneous release of energy by the nucleus of an atom which results in a change in mass.

Radium

Generally refers to Ra-226, the parent of radon gas in the uranium decay series.

Radium A

Po-218, the first daughter of Rn-222. It emits a 6.0 MeV alpha particle and has a half-life of approximately 3 minutes.

Radium B

Pb-214, the second daughter of Rn-222. It emits beta and gamma radiation and has a half-life of about 27 minutes.

Radium C

Bi-214, the third daughter of Rn-222. It emits a beta particle and a strong gamma ray and has a half-life of about 20 minutes.

Radium C'

Po-214, the fourth daughter of Rn-222. It emits a 7.7 MeV alpha particle and has a half-life of only 164 microseconds. Because of its extremely short half-life, very few atoms of RaC' can be present and its activity is always equal to the activity of RaC.

Radium D

Pb-210, is technically not considered one of the

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short-lived daughters of Rn-222 because of the relatively long half-life of 22 years. The long half-life prevents RaD and successive decay members from contributing much activity over short periods of time.

Radon
Normally the noble gaseous element (Rn-222) in the U-238 decay series. The immediate parent of Po-218 (RaA).

Radon Daughters
The four short-lived elements which succeed radon in the U-238 decay series. These include Po-218 (RaA), Pb-214 (RaB), Bi-214 (RaC), and Po-214 (RaC'). They have an average combined half-life of about 30 minutes.

Recirculation (Ventilation)
The usually undesirable leakage of air which causes it to repeat its path of movement, through fans and connecting workings. Recirculation often results in inefficient ventilation and always results in a buildup of air contaminants which are introduced into the recirculating air.

REM
The amount of ionizing radiation that when absorbed by man is equivalent to one Roentgen of X-ray or gamma radiation. From Roentgen Equivalent Man.

REP
A dose of ionizing radiation equivalent to 93 ergs per gram of tissue. From Roentgen Equivalent Physical; the term is now nearly obsolete.

Roentgen
A primary unit of radiation exposure. Technically, it is defined as that quantity of X- or gamma-radiation that produces 1 electrostatic unit of electrical charge per 0.001293 gram of air.

Scaler
A counting instrument that is designed to integrate the electrical pulses from a radiation detector into a cumulative count, and to record this count digitally. Usually scalers can be preset to count for a specific time or to obtain a specific count and to record the time required.

Scintillation Counter
An instrument which detects activity through a crystal which emits light when contacted by radiant energy. The light pulses (scintillations) are converted to electrical pulses which are counted.

Secondary Ventilation
The air taken from primary air courses to ventilate dead-end or other areas through which primary air does not flow in sufficient quantity. The use of auxiliary fans blowing air into headings through tubing is the most common method of providing secondary ventilation.

Secular Equilibrium
Equilibrium where the parent of the radioactive series has a very long half-life compared to subsequent series members. An example is the U-238 series which requires about 1,000,000 years for equilibrium to develop.

Self Absorption
The percentage of alpha activity which is absorbed by the filter media because of penetration of the radioactive particulates into the filter fibers.

Series Ventilation
The ventilation of successive working places with the same air. This system results in an accumulation of air contaminants and allows more time for radon-daughters to develop in radon-contaminated air.

Specific Ionization
The number of ion pairs produced by radiant energy per linear depth of penetration. Allows a means of comparing the relative damage potential of radiations. The relative ratio of specific

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radiation for $\alpha:\beta:\gamma$ is about 100,000:100:1.

Thorium C"

Tl-208 emits beta particles and a strong gamma ray and has a half-life of 3.1 minutes. It is inconsequential in the thoron daughter health problem and decays directly to stable Pb-208.

Thoron

The noble gaseous element in the Th-232 decay series. Refers to Rn-220, the immediate parent of Po-216 (ThA)

Thoron Daughters

The short-lived daughters of Rn-220, part of the Th-232 decay series. Only ThB, ThC, and ThC' are of consequence in the potential health hazard. ThB, although not an alpha emitter itself, has a half-life of 10.6 hours, and is therefore the most abundant source of atoms available for decaying through the alpha emitting successors, ThC and ThC'.

Thorium Series

The 13 radioactive elements commencing with Th-232 and culminating in Pb-208.

Time Factor

The numerical factor related to the time following the end of radon- or thoron-daughter sampling which must be divided into disintegrations per minute per liter of air sampled to obtain the working level.

Transient Equilibrium

Relatively short-term equilibrium within a portion of a radioactive series where the parent has a long half-life only relative to successive series members. An example is the radon- radon-daughter series.

Uranium

Refers normally to U-238, although about 0.7 percent U-235, the fissionable component, is present in the natural state.

Uranium Series

The 14 radioactive elements commencing with U-238 and culminating in stable Pb-206.

Working Level

An atmospheric concentration of radon (Rn-222) daughters which will deliver 1.3×10^5 MeV of alpha energy per liter of air in decaying through RaC' (Po-214).

A working level of thoron (Rn-220) daughters is equal to a concentration of ThB (Pb-212) per liter of air which in decaying through ThC and ThC' will yield 1.3×10^5 MeV of alpha energy.

Working Level Hour
An exposure equivalent to 1 working level of radon daughters for 1 hour.

Working Level Month
An exposure equivalent to 1 working level of radon daughters for 173 hours.

APPENDIX A

WORK HISTORY AND HEALTH SURVEY

FOR CAVE EMPLOYMENT

WORK HISTORY AND HEALTH SURVEY FOR CAVE EMPLOYMENT

(This information is for official and medical-confidential use only and will not be released to unauthorized persons.)

HEALTH SURVEY

1. Last name-first name-middle name	2. Social security number

3. Home address (No. street, city, state, and ZIP)

4. Position (title)	5. Date of birth	6. Date of survey

7. Have you ever (check each item)	Yes	No	8. Do you	Yes	No
Lived with anyone who had tuberculosis?			Smoke?		
Coughed up blood?			If yes, how many per day?		

9. Have you ever had or Have you now (Please check each item)

	Yes	No	Don't know
frequent or severe headaches			
ear, nose, or throat trouble			
skin diseases			
tuberculosis			
asthma			
shortness of breath			
chronic cough			
heart trouble			
tumor, growth, cyst, cancer			
pneumonia			
sinusitis			
chronic or frequent colds			
hay fever			
stomach, liver, or intestinal trouble			

Yes	No	Check each item yes or no. Every item checked yes must be fully explained in blank space on right.
		10. Have you been refused employment or been unable to hold a job or stay in school because of: A. Sensitivity to chemicals, dust, etc. B. Other medical resons.
		11. Have you had, or have been advised to have any operations? (If yes, describe and give age at which occured.)

Yes	No	
		12. Have you ever had illness or injury other than those already noted? (If yes, specify when, where, and give details.)
		13. Have you ever received, is there pending, or have you applied for pension or compensation for existing disability? (If yes, specify what kind, granted by whom and what amount, when, why.)

WORK HISTORY

List place and duration of all employment done in caves and mines. Start from present and work backwards. Account for periods of nonemployment in caves and mines in separate blocks, in order.

May inquiry be made of your present employer regarding your record of employment? Yes_____ No_____

WORK EXPERIENCE

1	Dates of employment (month, year) From To present time	Exact title or position
Average hours per week	Place of employment City State and ZIP	
Supervisor's name	Name of employer and address (including ZIP, if known)	
Phone no. (area code)		
Description of duties:		

2	Dates of employment (month, year) From To	Exact title or position
Average hours per week	Place of employment City State and ZIP	
Supervisor's name	Name of employer and address (including ZIP, if known)	
Phone no. (area code)		
Description of duties:		

3	Dates of employment (month, year) From To	Exact title or position

Average hours per week	Place of employment City State and ZIP

Supervisor's name	Name of employer and address (including ZIP, if known)
Phone no. (area code)	

Description of duties:

4	Dates of employment (month, year) From To	Exact title or position

Average hours per week	Place of employment City State and ZIP

Supervisor's name	Name of employer and address(including ZIP, if known)
Phone no. (area code)	

Description of duties:

5	Dates of employment (month, year) From To	Exact title or position

Average hours	Place of employment City State and ZIP

Supervisor's name	Name of employer and address (including ZIP, if known)
Phone no. (area code)	

Description of duties:

6	Dates of employment (month, year) From To	Exact title or position

Average hours per week	Place of employment City State and ZIP

Supervisor's name	Name of employer and address (including ZIP, if known)
Phone no. (area code)	

Description of duties:

F17NB

APPENDIX B

CAVE RADIATION INFORMATION SYSTEM

CODING INSTRUCTIONS AND FORMS

CAVE RADIATION INFORMATION SYSTEM
RADIATION SAMPLE DATA CODING INSTRUCTIONS

These instructions are to be used when coding radon and thoron sample data and summary data. When coding sample data, (i.e. that data for which the W.L. concentration have not been calculated) items 1-7, 9-15 and 17-18 are required; 8, 16, 19-21 are optional. When coding summary data, (i.e. that data for which the W.L. concentration have already been calculated) items 1-7, 9-10 and 16 and 19 are required; 8, 11-15, 17-18 and 20-21 are optional. Numeric data should be right justified and alpha-numeric data should be left justified. Please reference the appropriate codes.

ITEM

1. DATA TYPE (Block 1)

Enter the appropriate one digit numeric code indicating the origin/ data type.

CODE
1 = Radiation Sample Data Sheet or Radiation Sample.
2 = Summary Radon/Thoron Daughter Concentration Data.

2. PARK (Blocks 2-5)

Enter the four digit numeric code that represents the organization number of the park. e.g. 717Ø = Carlsbad Caverns.

3. CAVE (Blocks 6-7)

Enter the two digit code that indicates the cave from which the data originated.

4. TOUR ROUTE (Blocks 8-9)

Enter the two digit code that indicates the route in the cave where the data were collected.

5. DATE (Blocks 1Ø-15)

Enter the date on which the data were collected. The first two digits represent the month, followed by the day and then the year. e.g. 072877 = July 28, 1977.

6. SAMPLE TYPE (Block 16)

Enter "W" if walking and "S" if a stationary sample.

7. SAMPLE START LOCATION (Blocks 17-19)

If a walking sample, enter the three digit code for the starting location of the sample; if stationary, enter the code for the location of the sample.

8. SAMPLE END LOCATION (Blocks 20-22)

If a walking sample, enter the three digit code for the end location of the sample.

9. WEEK OF YEAR (Blocks 23-24)

Enter the two digit integer that corresponds to the week of the year in which the data were sampled. e.g. 01 = January 1-7.

10. END TIME (Blocks 25-28)

Enter the four digit integer based on a 24 hour clock that represents the time at which the sampling ended. e.g. 1516 = 3:16 PM.

11. COUNTER EFFICIENCY FACTOR (Blocks 29-31)

Enter the three digit number (with two decimal places) that represents the efficiency of the counter. The decimal point is indicated on the coding form so do NOT enter the decimal point.

12. PUMP VOLUME (Blocks 32-35)

Enter the four digit number (with two decimal places) that indicates the pump volume. Do NOT enter a decimal point.

13. TIME OF COUNTING - RADON (Blocks 36-39)

Enter the four digit integer based on a 24 hour clock that represents the time at which the instruments were first read.

14. RADON OBSERVATION COUNTS (Blocks 40-59)

Enter the five digit integer that indicates the observed sample count of radon. Up to four separate counts may be entered.

15. MINUTES OF OBSERVATIONS (Block 60)

Enter the one digit integer that represents the length of time between each observation of radon daughter . This can be 1,2 or 4.

16. RADON WL CONCENTRATION (Blocks 61-64)

Enter the four digit number (with two decimal places) for the Radon daughter WL concentration (calculated by the Kusnetz method). Do NOT enter a decimal point.

17. TIME OF COUNTING - THORON (Blocks 65-68)

Enter the four digit integer based on a 24 hour clock that represents the time at which the instruments were first read.

18. <u>THORON OBSERVATION COUNT</u> (Blocks 69-70)

Enter the two digit interger that indicates the observed sample count of thoron.

19. <u>THORON WL CONCENTRATION</u> (Blocks 71-73)

Enter the three digit number (with three decimal places) for the Thoron daughter WL concentration (calculated by the Kusnetz method). Do not enter a decimal point.

20. <u>AIRFLOW</u>:

<u>DIRECTION</u> (Blocks 74-75)

Enter the two letter alphabetic code which indicates the direction of the airflow.

<u>MAGNITUDE</u> (Block 76)

Enter the number from Ø to 6 which accurately describes the strength of the airflow.

21. <u>INITIALS</u> (Blocks 77-80)

Enter the initials of the researcher or if the data originated from MSHA enter "MSHA".

AIRFLOW DIRECTION

CODE

UP = upcast only

DN = downcast only

IN = incast only

OT = outcast only

SL = sidecast to the left only

SR = sidecast to the right only

BK = backcast only

UD = oscillating flow, up and down reversal

IO = oscillating flow, in and out reversal

UI = upcast and incast

UO = upcast and outcast

DI = downcast and incast

DO = downcast and outcast

UB = upcast and backcast

DB = downcast and backcast

UL = upcast and sidecast left

UR = upcast and sidecast right

DL = downcast and side cast left

DR = downcast and sidecast right

IL = incast and sidecast left

IR = incast and sidecast right

OL = outcast and sidecast left

OR = outcast and sidecast right

LR = oscillating flow, left and right reversal

ST = stagnate

CODE

Ø = no airflow noted

1 = very slight airflow

2 = slight airflow, small movement

3 = moderate airflow, light breeze

4 = noticeable airflow, fairly strong

5 = strong airflow, marked wind

6 = very strong airflow, air blast

NATIONAL PARK SERVICE

ACCOUNT NO.

GENERAL PURPOSE DATA SHEET

RADIATION SAMPLE CODING SHEET

	[illegible]	PARK	CAVE	TOUR ROUTE	DATE	TYPE	START LOC.	END LOC.	[illegible]	END TIME	COUNTER EFFIC. FACTOR	PUMP VOLUME	TIME OF COUNT-RADON	OBSERVATION COUNTS-RADON	OBSERVATION COUNTS-RADON	OBSERVATION COUNTS-RADON	OBSERVATION COUNTS-RADON	MINUTES	RADON WL	TIME OF COUNT-THORON	[illegible]	THORON WL	AIR [illegible]	[illegible]	INITIALS
	1	2 3 4 5	6 7	8 9	10 11 12 13 14 15	16	17 18 19	20 21 22	23 24	25 26 27 28	29 30 31	32 33 34 35	36 37 38 39	40 41 42 43 44	45 46 47 48 49	50 51 52 53 54	55 56 57 58 59	60	61 62 63 64	65 66 67 68	69 70	71 72 73	74 75	76	77 78 79 80
1																									
2																									
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WASO-90 (5/71)

CAVE RADIATION INFORMATION SYSTEM
PERSONNEL EXPOSURE HOURS CODING INSTRUCTIONS

In order to calculate the amount of radiation to which an individual has been exposed, it is necessary to know the amount of time spent in the caves. The Personnel Exposure Hours Coding Sheet is to be completed when adding radiation exposure data to an individual's existing file(which was done by completing the Personnel Adds & Changes Coding Form).

Please supply all of the following information by having the individuals involved note the amount of time she or he spent along the particular tour routes. Please reference the appropriate codes.

ITEM

1. DATA TYPE (Block 1)

   The appropriate number has already been entered as a '5'.

2. PARK (Blocks 2-5)

   Enter the four digit numeric code that represents the organization number of the park where the individual is currently employed or located, e.g. 717Ø = Carlsbad Caverns.

3. CAVE (Blocks 6-7)

   Enter the two digit code that indicates the cave where the individual is employed or located.

4. TOUR ROUTE(Block 8-9)

   Enter the two digit code that indicates the tour route where the individual was located.

5. SOCIAL SECURITY NUMBER (Blocks 1Ø-18)

   Enter the nine digit numeric code that represents the social security number of the individual, e.g. 321-84-5870.

6. <u>YEAR</u> (Blocks 19-20)

Enter the last two digits of the year in which the data were collected, e.g. 78=1978.

7. <u>WEEK</u> OF YEAR (Blocks 21-22)

Enter the two digit integer that corresponds to the week of the year in which these data were collected, Ø1 = January 1-7.

8. <u>OCCUPANCY HOURS</u> (Blocks 23-26)

The length of time to the quarter hour during which the individual was exposed to radiation. Enter the <u>hours</u> and minutes rounded to the quarter hour, e.g. two hours and ten minutes should be recorded as 2:15.

NATIONAL PARK SERVICE

ACCOUNT NO.

GENERAL PURPOSE DATA SHEET

SHEET NO. OF

PERSONNEL EXPOSURE HOURS CODING SHEET

****

	1	PARK (2–5)	CAVE (6–7)	TOUR ROUTE (8–9)	SSN (10–18)	YEAR (19–20)	WEEK (21–22)	OCCUP. HOURS (23–26)	27–80
1	5								
2	5								
3	5								
4	5								
5	5								
6	5								
7	5								
8	5								
9	5								
10	5								
11	5								
12	5								
13	5								
14	5								
15	5								
16	5								
17	5								
18	5								
19	5								
20	5								
21	5								
22	5								
23	5								
24	5								
25	5								

WASO-70 (5/71)

CAVE RADIATION INFORMATION SYSTEM
PERSONNEL ADDS AND CHANGES CODING INSTRUCTIONS

The Personnel Adds & Changes Coding Sheet is to be used for the following purposes:

1. To add to the data base information for a person not previously in the data base. This includes 1. historic data for people who have been working in the caves but are not in the Cave Radiation Information System, as well as, 2. data for people new to the caves who have no historic radiation exposure data. In both cases the action code will be an 'A' for add. In both cases, all data on the first record (see code sheet) must be supplied except for the optional comments. However, the second record (see code sheet) is used only in conjunction with the first record to supply the cumulative radiation exposure levels for previous years and monthly exposure levels by month for the current year. These exposure levels are to be recorded in working level months with two places to the right and to the left of the decimal point. This record must not be completed if there are no historic data for the individual.

2. To change one of the following fields: park, name, sex, date of birth, smoker, occupation or employment status. For example, an individual may transfer from Mammoth to Carlsbad. If data are already in the system for this person under Mammoth, before any radiation levels can be computed for that person in Carlsbad, the park code must be changed to reflect the change in the person's location.

   Changes can not be made to an individual's data unless that person is currently in the data base (see 1 above for additions). To change one of the aforementioned data fields only the first record is used. To make changes only the action code ('C' for change), the social security number and the field to be changed must be supplied. One "first record" must be competed for each change. No "second record" is needed to make these changes. Changes to comments or social security numbers and/or deletions of a person from the files will be handled by the NRMD/WASO person in charge of the data base.

A description of each data field follows. All numeric data must be zero filled on the right. Alpha-numerics must be left justified. i.e. start in the first column on the left for that field and fill with spaces on the right. Please reference the appropriate codes.

FIRST RECORD

1. DATA TYPE (Block 1)

   The appropriate number has already been entered as a '4'.

7/7/78

22 NB

2. <u>PARK</u> (Blocks 2-5)

Enter the four digit code that represents the organization number of the park where the individual is currently employed or located, e.g. 717Ø = Carlsbad Caverns.

3. <u>ACTION</u> (Block 6)

Enter the appropriate one character code indicating whether a change or an addition to the file is being made.

<u>Code</u>
A = Addition of new individual
C = Change of information concerning the individual

4. <u>SOCIAL SECURITY NUMBER</u> (Blocks 7-15)

Enter the nine digit numeric code that represents the social security number of the individual, e.g. 321-84-587Ø.

5. <u>NAME</u> (Blocks 16-45)

Enter the name of the individual, with the last name first followed by the first name. Place a comma between the two.

6. <u>SEX</u> (Block 46)

Enter the one character code that indicates the sex of the individual.

<u>Code</u>
F = Female
M = Male

7. <u>DATE OF BIRTH</u> (Blocks 47-52)

Enter the date of birth of the individual. The first two digits must be the month, followed by the day and then the year, e.g. Ø7Ø246 = July 2, 1946.

8. <u>SMOKER</u> (Block 53)

Enter the one digit numeric code that indicates whether or not the individual is a smoker. If he/she has stopped smoking or vice versa recently, that information may be entered in the comment section.

<u>Code</u>
Ø = no
1 = yes
2 = ex-smoker

9. OCCUPATION (Block 54)

Enter the one digit numeric code that indicates the occupation of the individual. If the occupation is coded as a '5' (other), a further explanation may be entered in the comment section.

Code
1 = tour guiding
2 = maintenance
3 = research
4 = caving
5 = other
6 = administrator
7 = work projects

1Ø. STATUS (Block 55)

Enter the one digit numeric code that indicates the employment status of the individual. If he/she is not employed by the NPS enter the code '3'. Further information may be entered in the comment section.

Code
1 = Permanent
2 = Seasonal
3 = Other
4 = YACC
5 = YCC
6 = Job Corps
7 = VIP

11. COMMENTS (Blocks 56-8Ø)

Enter the medical test results and/or other comments that are appropriate.

SECOND RECORD

1. Data Type (Block 1)

The appropriate number has already been entered as a '4'.

2. Park (Blocks 2-5)

Enter the same four digit park code that was entered on the first record.

3. Action (Block 6)

The apporpriate action code has already been entered as an 'A' and the action code on the first record must also be an 'A'.

4. <u>Social Security Number</u> (Blocks 7-15)

Enter the same social security number that was entered on the first record.

5. <u>Radiation Exposure Levels By Year for Previous Years</u> (Blocks 19-36)

Enter up to three years and the individual's total exposure to radiation (in working level months) for those years. A decimal point has been indicated. Please enter both of the decimal digits on the right of the decimal point, e.g. '760070' indicates the individual was exposed to .7 wlms in 1976.

6. <u>Radiation Exposure Levels By Month for the Current Year</u> (Blocks 37-80)

Enter the individual's exposure to radiation (in working level months) by month for the current year. Only enter values for January through November. If December is available, total the figures and enter that value and the year in category #5 above. Similarly, for those caves open for only part of the year, if all the monthly data for the current year are available, total them and enter that value and the year in category #5 above.

ACTION:

CODE

A = addition of new individual
c = change of information concerning an individual

SEX:

CODE

F = female
M = male

SMOKER:

CODE

Ø = no
1 = yes
2 = ex-smoker

OCCUPATION:

CODE

1 = tour guiding
2 = maintenance
3 = research
4 = caving
5 = other
6 = administrator
7 = work projects

STATUS:

CODE

1 = permanent
2 = seasonal
3 = other
4 = YACC
5 = YCC
6 = Job Corps
7 = VIP

UNITED STATES DEPARTMENT OF INTERIOR
NATIONAL PARK SERVICE
CAVE RADIATION INFORMATION SYSTEM

PERSONNEL ADDITIONS & CHANGES
****

First Record

data type (4) 1 — park ( ) 2 - 5 — action ( ) 6 — social security number ( )-( )-( ) 7 - 15

name ( ) 16 - 45

sex ( ) 46 — date of birth ( ) 47 - 52 — smoker ( ) 53 — occup. ( ) 54 — status ( ) 55

comments ( ) 56 - 80

****
****

Second Record

data type (4) 1 — park ( ) 2 - 5 — action (A) 6 — social security number ( )-( )-( ) 7 - 15

year cum. wlms ( ) 19 - 24 — year cum. wlms ( ) 25 - 30 — year cum. wlms ( ) 31 - 36

WLMs by Month

January ( ) 37 - 40 — February ( ) 41 - 44 — March ( ) 45 - 48 — April ( ) 49 - 52 — May ( ) 53 - 56 — June ( ) 57 - 60 — July ( ) 61 - 64

August ( ) — September ( ) — October ( ) — November ( )

CAVE RADIATION INFORMATION SYSTEM
WEATHER DATA CODING INSTRUCTIONS

During the ongoing NPS study of cave radiation, weather data enter in as an important factor. Daily weather measurements for one sample location should be supplied on a monthly basis. This information is necessary for analyzing the relationships between air flow, temperature, humidity and cave radiation.

The following instructions are to be used when coding weather data both inside and outside of the cave being investigated. Data type, park, cave, date and sample location must be filled in. Please reference the appropriate codes.

ITEM

1. DATA TYPE (Block 1)

   The appropriate number has already been entered as a '6'.

2. PARK (Blocks 2-5)

   Enter the four digit numeric code that represents the organization number of the park where the weather data are being collected, e.g. 7170 = Carlsbad Caverns.

3. CAVE (Blocks 6-7)

   Enter the two digit code that indicates the cave from which the data originated.

4. TOUR ROUTE (Blocks 8-9)

   Enter the two character code that indicates the tour route where the individual was located.

5. DATE (Blocks 10-15)

   Enter the date on which the weather information was collected. The first two digits represent the month, followed by the day and the year, e.g. 072877 = July 28, 1977.

6. SAMPLE LOCATION (Blocks 16-18)

   Enter the three digit code that indicates where the information was collected inside the cave.

7. OUTSIDE AIR PRESSURE (Blocks 19-26)

   Enter in blocks 19-22 the maximum air pressure outside the cave as a four digit number with two decimal places. Enter in blocks 23-26 the minimum air pressure outside the cave as a four digit number with two decimal places. The decimal point is indicated on the coding form so do NOT enter the decimal point.

F25NB

7/7/78

8. OUTSIDE AIR TEMPERATURE (Blocks 27-34)

Enter in blocks 27-30 the maximum temperature outside the cave in degrees fahrenheit to one decimal place. Enter in blocks 31-34 the minimum temperature outside the cave in degrees fahrenheit to one decimal place. Do NOT enter the decimal point.

9. INSIDE AIR PRESSURE (Blocks 35-42)

Enter in blocks 35-38 the maximum air pressure inside the cave as a four digit number with two decimal places. Enter in blocks 39-42 the minimum air pressure inside the cave as a four digit number with two decimal places. Do NOT enter a decimal point.

10. INSIDE AVERAGE AIR TEMPERATURE (Blocks 43-46)

Enter the average temperature inside the cave in degrees fahrenheit to one decimal place. Do NOT enter a decimal point.

11. INSIDE AVERAGE RELATIVE HUMIDITY (Blocks 47-50)

Enter the average relative humidity found inside the cave as a four digit number with one decimal place. Do NOT enter a decimal point.

Release No. 1

UNITED STATES DEPARTMENT OF INTERIOR
NATIONAL PARK SERVICE
CAVE RADIATION INFORMATION SYSTEM

WEATHER DATA CODING SHEET

	PARK	CAVE	TOUR	DATE	SAMPLE LOCATION	OUTSIDE AIR PRESS. MAX	OUTSIDE AIR PRESS MIN	OUTSIDE TEMP. MAX	OUTSIDE TEMP MIN	INSIDE AIR PRESS MAX	INSIDE AIR PRESS MIN	INSIDE AVG TEMP.	INSIDE AVG. HUMIDITY
1	2 3 4 5	6 7	8 9	10 11 12 13 14 15	16 17 18	19 20 21 22	23 24 25 26	27 28 29 30	31 32 33 34	35 36 37 38	39 40 41 42	43 44 45 46	47 48 49 50
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May 1980

CAVE RADIATION INFORMATION SYSTEM
SPECIAL RADON MEASUREMENTS CODING INSTRUCTIONS

These instructions are to be used when coding special radon measurements, i.e. those measurements other than the regular Radon Samples. When coding special data, items labeled park, cave, tour route, date, sample location and end time are required. For Tsivoglou working level calculations; X1, X2, X3, counter efficiency and pump flow rate (items 8-10) must be supplied. For Free Ion calculations; X1, X2, X3, and counter efficiency (items 12 & 13) must be supplied. For Radon Gas concentration calculations; flask efficiency and volume and net count (items 14-16) must be supplied.

ITEM

1. DATA TYPE (Block 1)

   The appropriate number has already been entered as a '3'.

2. PARK (Blocks 2-5)

   Enter the four digit numeric code that represents the organization number of the park, e.g. 717Ø = Carlsbad Caverns.

3. CAVE (Blocks 6-7)

   Enter the two character code that indicates the cave from which the data originated.

4. TOUR ROUTE (Blocks 8-9)

   Enter the two character code that indicates the tour route along which the data originated.

5. DATE (Blocks 10-15)

   Enter the date on which the data were collected. The first two digits represent the month, followed by the day and then the year. e.g. 072955 = July 29, 1955

6. SAMPLE LOCATION (Blocks 16-18)

   Enter the three digit code that represents the location in the cave where the sample was taken.

7. END TIME (Blocks 19-22)

   Enter the four digit integer based on a 24-hour clock that represents the time at which the sampling ended. e.g. 1516 = 3:16 P.M.

7/7/78

FOR TSIVOGLOU WORKING LEVEL:

8. <u>X1, X2, X3</u> (Blocks 23-37)

   Enter three radon daughter counts as five digit integers.

9. <u>COUNTER EFFICIENCY</u> (Blocks 38-4Ø)

   Enter the three digit number (with two decimal places) that represents the counter efficiency. The decimal point is indicated on the coding sheet so do <u>NOT</u> enter a decimal point.

1Ø. <u>PUMP FLOW RATE</u> (Blocks 41-43)

   Enter the pump flow rate (with two decimals places) in liters per minute. Do <u>NOT</u> enter a decimal point.

11. <u>KUSNETZ W.L.</u> (Blocks 44-46)

   If the Kusnetz working level has been calculated enter it here (with two decimal places). Do <u>NOT</u> enter a decimal point.

FOR FREE IONS:

12. <u>X1, X2, X3</u> (Blocks 47-58)

   Enter three radon daughter counts (on screen) as four digit integers.

13. <u>COUNTER EFFICIENCY</u> (Blocks 59-61)

   Enter the three digit number (with two decimal places) that represents the counter efficiency. Do <u>NOT</u> enter a decimal point.

RADON GAS CONCENTRATION:

14. <u>FLASK EFFICIENCY</u> (Blocks 62-64)

   Enter the three digit number (with three decimal places) that represents the flask's efficiency factor. Do <u>NOT</u> enter a decimal point.

15. <u>FLASK VOLUME</u> (Blocks 65-67)

   Enter the three digit number (with three decimal places) that indicates the flask volume in liters. Do <u>NOT</u> enter a decimal point.

16. NET COUNT FOR FIVE MINUTES (Blocks 68-71)

Enter the radon gas net count as a right justified four digit integer. The net count is equal to gross total count (in five minutes) minus background count (in five minutes).

17. SMALL PARTICLE COUNT (Blocks 72-78)

Enter the small particle count (with two decimal places) in scientific notation. That is, the power of ten is to be entered after the "E", e.g. 33.21E66 = 33.21×10^{66}.

NATIONAL PARK SERVICE
CAVE RADIATION INFORMATION SYSTEM

SPECIAL RADON MEASUREMENTS CODING SHEET

****

data type	park	cave	tour route	date	sample location	end time
( )	( )	( )	( )	( )	( )	( )
1	2 - 5	6 - 7	8 - 9	10 - 15	16 - 18	19 - 22

Tsivoglou:

X1	X2	X3	counter effic.	pump flow rate	kusnetz WL
( )	( )	( )	( )	( )	( )
23 - 27	28 - 32	33 - 37	38 - 40	41 - 43	44 - 46

Free Ions:

X1	X2	X3	counter effic.
( )	( )	( )	( )
47 - 50	51 - 54	55 - 58	59 - 61

Radon Gas:

flask effic.	flask vol.	net count for 5 min.	small particle count
( )	( )	( )	( )
62 - 64	65 - 67	68 - 71	72 - 78

APPENDIX C

CALCULATIONS FOR EXPOSURE DETERMINATION

AND

SPECIAL MEASUREMENTS DATA

The following formulas are used in the calculation of radiation levels and for individual exposures:

1. Working Level Calculation

   a. Counts per minute (CPM from the counter) X Efficiency Factor of the Counter (EF) = Disintegrations per minute (DPM)

   b. Disintegrations per minute + Sample Volume in liters (V) = DPM per Liter

   c. Disintegrations per Liter + Time Factor of the Sample = Working Level (WL)

or

$$\frac{CPM \times EF}{V \times TF} = \text{Working Level}$$

Example: CPM = 465
EF = 3.2
V = 14.4
TF = 130 (50 minutes)

$$\frac{465 \times 3.2}{14.4 \times 130} = 0.75 \text{ W. L.}$$

2. Exposure Calculation in Working Level Months:

   Working Level x Exposure Time = Working Level Hours

   173 Working Level Hours = 1 Working Level Months

   Working Level Hours + 173 = Working Level Months

Example: Working Level = 0.75 0.75 x 8 hours = 6 working level hours
Exposure Time = 8 hours

6 WLH + 173 = 0.035 working level hour

Tsvioglou Method (Thomas Modification) of Radon-Daughter Measurement

1. Take 5-minute sample at 2 lpm or higher flowrate.

2. Obtain 3-minute count (X_1) from 2 to 5 minutes after end of sample.

3. Obtain 14-minute count (X_2) from 6 to 20 minutes after end of sample.

4. Obtain 9-minute count (X_3) from 21 to 30 minutes after end of sample.

4. Substitute these three counts (X_1, X_2, X_3) in the following equations to obtain concentrations of RaA, RaB, and RaC (C_A, C_B, C_C) in pCi/l

$$C_A = \frac{EF}{V} \left(0.16894\, X_1 - 0.08200\, X_2 + 0.07753 X_3 \right)$$

$$C_B = \frac{EF}{V} \left(0.00122\, X_1 - 0.02057\, X_2 + 0.04909 X_3 \right)$$

$$C_C = \frac{EF}{V} \left(-0.02252\, X_1 + 0.03318\, X_2 - 0.03771 X_3 \right),$$

Where EF = instrument efficiency factor and
V = flowrate, lpm

C_A, C_B, C_C may be used to determine total radon daughter concentrations by

$$WL = 0.00105\, C_A + 0.00516\, C_B + 0.00379\, C_C$$

Reference: Thomas, J.W. Modification of the Tsivoglou Method for Radon Daughters in Air. Health Physics, v. 19, 1970, p. 691.

Lucas Flask Method of Radon Gas Measurement

1. Count flask background for 5 minutes.

2. Evacuate flask with vacuum pump.

3. Sample atmosphere, using a filter on the flask inlet.

4. Count (for 5 minutes) in photomultiplier tube (Black Missile) at 3 to 5 hours after sample (if counted more than 5 hours after sample, radon concentration must be corrected for decay of more than 2 percent).

5. Subtact background countrate (cpm) from total countrate (cpm) to obtain net countrate (cpm).

6. Determine radon concentration (pCi/l) by

$$C_{Rn} = \frac{\text{net cpm}}{\text{V x Eff.}} \times \frac{1}{6.66}$$

where: C_{Rn} = radon concentration, pCi/l

net cpm = total countrate less background countrate, cpm

V = flask volume, liters

Eff. = decimal flask efficiency

Reference: Lucas, H.F., Improved Low-Level Alpha Scintillation Counter for Radon, Rev. Sci. Instruc., v. 28, 1957, pp. 680-683.

Wire Screen Method of Free Atom Measurement

1. Sample atmosphere with two pumps, one equipped with 60-mesh wire screen, the other with a standard filter. The wire screen may or may not be backed with a filter (and suitable spacer). The flowrate through the wire screen must be 2 lpm.

2. Count both wire screen and standard filter by Thomas modification of Tsivoglou Method and determine daughter concentrations indicated by screen and by filter.

3. Convert daughter concentrations indicated by screen to daughter concentrations present in air by multiplying each concentration by 1.67 (60 percent screen collection efficiency).

4. Calculate unattached daughter percentages by

$$\text{ICRP Free Atoms} = \frac{\text{RaA on screen}}{\text{RaA on filter}} \times 100$$

$$\text{Total Free Atoms} = \frac{(\text{RaA+RaB+RaC}) \text{ on screen}}{(\text{RaA+RaB+RaC}) \text{ on filter}} \times 100,$$

where RaA, RaB, and RaC are in pCi/l and the free ions (both measures) are in percent.

5. After counting, wash the screens in soap and water and allow to dry.

Equilibrium Ratio Calculation and Age of Air Determination

1. Determine equilibrium ratio by

$$E.R. = \frac{WL \times 100}{C_{R_n}},$$

where E.R. = equilibrium ratio
WL = radon daughter concentration, WL
C_{R_n} = radon gas concentration, pCi/l.

2. The equilibrium ratio is the ratio of the radon daughter concentration present in the air to the radon daughter concentration which would be present at equilibrium.

3. Determine average age of air from table. This table is derived from classical decay equations and assumes instantaneous radon introduction and no daughter removal. This age can only be used for relative comparisons; it is not the true age of air because of the above assumptions.

EQUILIBRIUM RATIOS
(Radon daughters to Radon)

Min	Ratio	Min	Ratio	Min	Ratio
0.5	0.011	15	0.238	80	0.784
1	0.022	16	0.251	90	0.824
2	0.043	17	0.264	100	0.857
3	0.062	18	0.277	110	0.884
4	0.080	19	0.289	120	0.905
5	0.097	20	0.301	130	0.921
6	0.113	25	0.360	140	0.934
7	0.128	30	0.416	150	0.945
8	0.143	35	0.468	160	0.953
9	0.158	40	0.516	170	0.959
10	0.172	45	0.561	180	0.965
11	0.185	50	0.602		
12	0.199	55	0.640		
13	0.212	60	0.675		
14	0.225	70	0.735		

RADON GAS

Two-filter chamber: 5-minute sample at 10-lpm sample rate, second (rear) filter counted for 5 minutes, starting 1 minute from end of sample (front filter may be used for radon daughter determinations).

C_{Rn} = (total counts measured in 5 min.) x chamber factor *

Radon flasks: Sample into evacuated flasks through a filter, count 3 hours ** after end of sample.

$$C_{Rn} = \frac{CPM}{f \times Vol.} \,^*$$

Age of air: Age of air may be determined with equilibrium ratio and equilibrium chart.

$$\text{Equilibrium ratio} = \frac{WL \times 100^*}{C_{Rn}}$$

* Where,
C_{Rn} = concentration of radon gas, pCi/l
CPM = average counts per minute measured
f = flask factor
Vol. = flask volume

** If sample is counted later than 3 hours after end of sample, then C_{Rn} must be corrected for decay.