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Dr. William E. Mott, Director
Public Safety Division
Office of Operational Safety, EP-323
U.S. Department of Energy
Washington, D.C. 20545

Dear Dr. Mott:

In accordance with your letter of January 27, 1981 which stated that a copy of DOE's generic plan for designation of vicinity properties under Public Law 95-604 would be provided to our office, we received a draft copy of the document entitled "Generic Radiological Characterization Protocol for Surveys Conducted for DOE/OOS Remedial Action Programs". Because this generic plan was designed for both the Formerly Utilized Sites Remedial Action Program (FUSRAP) and Uranium Mill Tailings Remedial Action Program (UMTRAP) programs my staff requested and received from your staff two additional documents describing procedures used in Salt Lake City, Utah for designation of vicinity properties under the UMTRAP program. These two documents, "Results of the Mobile Gamma-Ray Scanning Activities at Salt Lake City, Utah" and "A General Radiological Survey Plan for Off-Site Vicinity Properties in the Salt Lake City, Utah, Area", provided information concerning generic procedures applicable to the UMTRAP program. However, there is a need for additional information, especially about the screening strategy for choosing candidate properties, before we could agree that a generic procedure would meet the intent of UMTRAP. Also, we feel that there is a need for a single document, describing generic procedures for designating UMTRAP vicinity properties which incorporates screening, preliminary, and comprehensive surveys. Enclosed is a suggested outline for such a document which can probably be prepared by combining in a single report information possessed by your office. The protocols for radiological measurements used in Edgemont, South Dakota are also enclosed as an example of open lands and indoor survey techniques which the NRC has found to be satisfactory for identifying vicinity properties in need of remedial action. Please contact Kathy Hamill of my staff (427-4115) regarding this proposed course of action.

Sincerely,

Original signed by
Edward F. Hawkins
for Ross A. Scarano, Chief
Low-Level Waste Licensing Branch
Division of Waste Management

Enclosures:
1. Suggested Outline
2. Protocols for Radiological Measurements
   at Edgemont, South Dakota

cc: Robert Ramsey, DOE, ONE w/o enclosures

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DATE	82/12/06	82/12/06	82/12/6	82/12/6			

OUTLINE

I. General Discussion of Designation Approach

-Identification of candidate sites for comprehensive survey

- -preliminary screening methods
- -previous State or EPA surveys
- -other pertinent information used for site identification

-Comprehensive survey strategy

II. Decisions Regarding Screening

-What information will be used and how will it be used to determine which areas will or will not be screened.

-What is the acceptable level of false negatives (acceptable probability of failing to designate a contaminated property) and what is the rationale in choosing this level.

-What mechanisms will be available to property owners to request screening?

-Basis for selection of mobile van scan as screening approach

-Instrumentation and methodology to be used in a mobile van scan or other screening method which will assure successful identification of contaminated properties (within the acceptable level of false negatives identified)

III. Open Lands Survey Techniques

-Gamma survey protocol

- -instrumentation
- -acceptable grid
- -measurement technique
- -action levels
- -background determination

-Soil sample protocol

- -instrumentation
- -choice and number of sample locations
- -analysis techniques e.g., in situ or laboratory to determine radium content and type of contamination
- -background determination

IV. Indoor Survey Techniques

-Gamma survey

- -instrumentation
- -acceptable grid
- -measurement techniques
- -action level
- -identification of source of elevated readings(removable sources, building materials, soil)
- -background determinations

-Radon progeny measurements

- -instrumentation
- -screening measurement of working level (frequency, duration and conditions of meaurement)
- -action level
- -method for determining annual average
- -identification of source of elevated levels

PROTOCOLS FOR RADIOLOGICAL MEASUREMENTS AT EDGEMONT, SOUTH DAKOTA

I. Radiological Surveys

A flow diagram outlining the measurement and decision making process used in conducting radiological surveys at Edgemont, South Dakota is shown in Figure 13.

A. Indoor Gamma Radiation Surveys

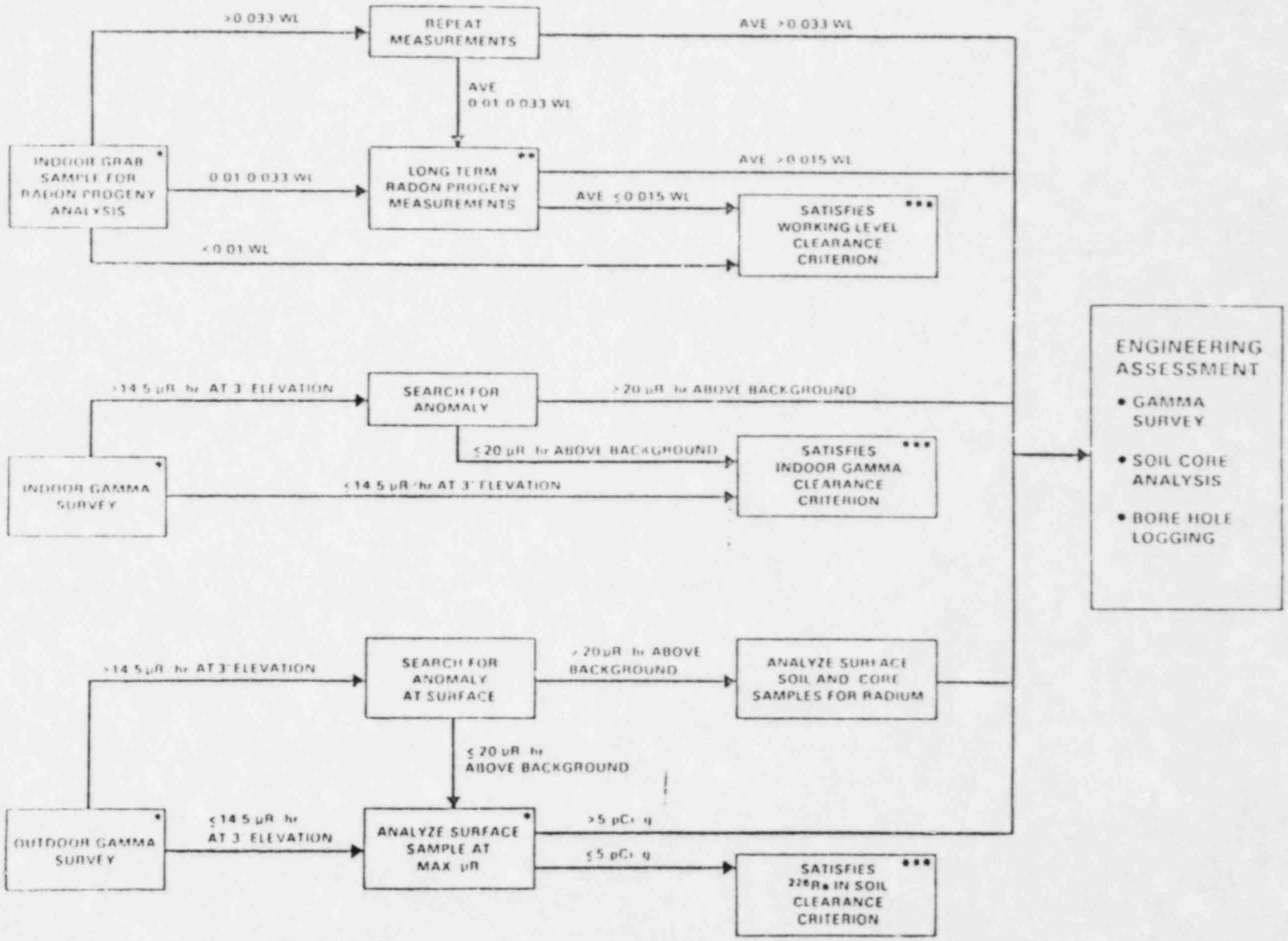
1. Homes and Businesses

Indoor gamma radiation surveys are made of all habitable floors and basements using Ludlum micro-R-scintillometers (Model 12S) that employ sodium iodide crystals for gamma-ray detection. These instruments are compared at least once a day to a calibrated Reuter-Stokes (Model S-111) pressurized ionization chamber on the ground floor of homes. The pressurized ionization chamber sensitivity is checked with a reference source daily. All instruments were calibrated at PNL prior to use and are periodically returned to PNL for recalibration. All pressurized ion chamber readings taken in the field are corrected to the standardized laboratory calibration. Micro-R-meter readings are corrected to equivalent corrected pressurized ionization chamber readings using the ratios determined in the field on the day of measurement. Indoor gamma-ray measurements are made at an elevation of about one meter at the grid points (approximately every 5 feet) of a 25 ft^2 grid starting at one wall. Measurements are also made at the far wall (unless this point is within a couple of feet of another measurement, such as in another room). The measurements are made with the survey meter set on slow response (10-11 second response time). Readings are not taken until the needle has stabilized for a few seconds. The corrected readings are recorded on a detailed drawing of the floor plan of the structure that is drawn based on measurements taken using a tape measure. If none of the readings is greater than 14.5 μR/hr, the structure is considered to pass the gamma radiation criterion for clearance. However, if readings above 14.5 μR/hr are encountered, or if the meter shows a pronounced increase in the exposure rate at any location, a search is made for elevated readings in contact with surfaces of the structure. If a corrected contact reading greater than 20 μR/hr above background is observed, this reading is recorded. The contact reading is recorded beneath a line drawn under the surface reading. Unless the object causing the elevated exposure rate can be disposed of (e.g., small rocks, radium dial clock), the structure is considered to fail the gamma radiation criterion and is scheduled for engineering assessment.

The Ludlum scintillometer produces an audible signal that clicks at a rate proportional to the exposure rate. Prior to February 1981, the audible signal was not used because it does not provide a numerical exposure rate, and because it might cause the owner or neighbor

Figure 13

FLOW DIAGRAM OF PROCEDURES FOR DETERMINATION OF PROPERTIES REQUIRING REMEDIAL ACTION



(*) PERFORMED AT EACH PROPERTY SURVEYED
(**) NOT PERFORMED UNLESS ALL OTHER CLEARANCES CRITERIA ARE SATISFIED
(***) ENGINEERING ASSESSMENT IS PERFORMED UNLESS ALL THREE CLEARANCE CRITERIA ARE SATISFIED

to fear that his building was highly radioactive. However, the audio signal does have the advantage that it provides a faster response than does the meter, so it might detect small amounts of residual radioactivity between grid points that the meter would not detect. At the Workshop on Radiological Surveys in Support of the Edgemont Clean-up Action Program (Perkins, et al., 1981), several investigators stated that the audio signal has proven very useful for locating residual activity during surveys at other locations. Therefore, following the workshop the Ludlum scintillometers were fitted with earphones that enable the surveyor to hear it without disturbing the property owner. Starting in February of 1981, the earphones have been used in addition to the meter reading to locate residual radioactivity during both indoors and outdoors surveys.

2. Garages and Nonhabitable Basements

Prior to the January 1981 workshop, gamma-ray exposure rates in garages and nonhabitable basesments were measured at an elevation of about one meter with a Ludlum scintillometer set on fast response during a slow, serpentine walk-through. Brief stops were made to allow the meter to stabilize. If readings greater than 14.5 μR/hr were encountered, or if the reading showed a significant increase at any location, a search was made for elevated contact readings. If contact readings greater than 20 μR/hr above background were observed, the building was scheduled for engineering assessment. As a result of discussions at the workshop, gamma radiation surveys in garages and nonhabitable basements have since been conducted using a 25 ft^2 grid and measurement procedures identical to those described in the previous section for other structures.

B. Outdoor Gamma Radiation Surveys

Outdoor gamma radiation measurements are made at an elevation of about one meter using Ludlum micro-R-meters (Model 12S) set at slow response. The micro-R-meters are cross-calibrated outdoors at least once a day with a pressurized ion chamber at a location that is to be surveyed. All Ludlum readings are corrected to the equivalent pressurized ion chamber reading before being recorded on the survey map.

Outdoor measurements on land with a permanent habitable building(s) are made at the grid points (approximately every seven feet) of a 50 ft^2 square grid. In the event that a lot is exceedingly large, only that portion which is within 50 ft of a habitable building is surveyed using the 50 ft^2 grid. The rest is surveyed using the procedures described below for open land containing no permanent habitable structures.

Open land containing no permanent habitable structures is divided into grids containing four survey blocks along the shorter dimension and five survey blocks along the longer dimension of the property. Measurements are made at an elevation of about one meter at the center of each survey block. On very large lots, extra rows of survey blocks are added to keep the maximum distance between measurements below 200 ft. Extra blocks may be added to irregularly shaped lots where the rectangular grid leaves unsampled areas. A serpentine walk-through between each row of sampling locations is also made with the micro-R-meters set on fast response. The highest reading is recorded.

Outdoor gamma-ray exposure rates are not recorded until the meter has stabilized for a few seconds. The corrected readings are recorded on a scale drawing of the property. Any buildings on the property are shown on the drawing. To save time, the distances between measurement points are paced rather than measured.

Gamma Radiation Levels Greater than 14.5 μR/hr

If no corrected gamma-ray exposure rate greater than 14.5 μR (including background) is observed at the one meter elevation on a property, surface soil samples are collected for ^{226}Ra analysis at two locations showing the highest exposure rates if the property contains a habitable building(s), or at one location if no habitable building is present.

In the event that it is impractical to collect a surface sample at a location of exposure rate (e.g., because of the presence of pavement or valuable shrubs), an alternate location showing a high exposure rate is sampled.

Gamma Radiation Levels Greater than 14.5 μR/hr, but no Surface Anomalies

If corrected gamma-ray exposure rates greater than 14.5 μR/hr (including background) are observed at the one meter elevation, or if the readings show a significant increase at any location, a search is made for elevated readings at the surface, and contact readings are recorded on the drawing of the property (a line is drawn beneath the one meter reading, and the contact reading is entered below the line). However, if the one meter readings are consistently greater than 14.5 μR/hr, but no anomalies are observed during the first two surface searches, no more surface searches are conducted unless a one meter elevation reading shows an increase of one μR/hr or more. If no contact reading greater than 20 μR/hr above the 14.5 μR/hr background is observed at any location, surface soil samples are taken for ^{226}Ra analysis at two locations showing maximum exposure rates if the property contains a habitable building, and at one location if no habitable building is present.

Contact Gamma Radiation Levels > 20 μR/hr Above Background

If surface gamma-ray exposure rates greater than 20 μR/hr above the maximum background of 14.5 μR/hr are observed, up to five or six surface and core soil samples are collected for ^{226}Ra analysis at locations of maximum exposure rates. The property is scheduled for a more detailed engineering assessment because it is assumed that material containing greater than 5 pCi/g of ^{226}Ra is present, even if the initial soil samples collected happened to miss it.

C. Radium-226 Concentrations in Soil

1. Soil Sampling Procedures

Surface soil samples approximately 15 cm wide by 10 cm long by 8 cm deep are collected using a shovel with about a 15 cm wide blade. Core samples are collected using a 3.8 cm diameter split tube corer that is driven into the ground to a depth of about 40 cm. Each surface or core sample is transferred to a plastic bag where it is shaken to separate materials such as leaves or grass. The soil is retained, but the other materials are returned to the hole. If insufficient soil remains, an adjacent soil sample is collected in the same manner as the original sample and combined with it.

2. Procedure for the Analysis of Soil for Radium-226

Each soil sample is homogenized, weighed and transferred to a metal can with about a 410 ml capacity. The cans are then sealed with a manually operated sealer. They are checked for leaks by immersing in nearly boiling water and inspecting for bubbles. The cans are stored for at least 10 days, and usually considerably longer, to allow radon and its short-lived daughter, ^{214}Bi, to grow in. The cans are then placed in plastic bags and the ^{214}Bi is counted for 10 minutes in a 23 cm diameter by 23 cm deep NaI(Tl) well counter. The cans used are the largest that will fit into the well. The gamma-ray spectra are stored in a multichannel analyzer. The efficiency of the detector is determined daily by counting a homogenized uranium mill tailings sample whose ^{226}Ra concentration has been established by comparison with an NBS ^{226}Ra standard. The background is determined daily by counting a can filled with distilled water. The ^{226}Ra concentrations are calculated from the measured ^{214}Bi, after correcting for the fractional ingrowth of radon from the parent ^{226}Ra during the time between sampling and counting. In making this correction, it is assumed that the radon concentration was 50% of equilibrium with ^{226}Ra at the time the can was sealed. Ten days after the can is sealed, the radon will be at 92% of equilibrium using this assumption, versus 84% if the radon concentration was zero at the time of sealing. Since most cans are allowed to sit considerably longer than 10 days before counting, the assumption of 50% equilibrium at the time of can sealing introduces little error.

If any soil sample from a property contains greater than 5 pCi/g of ^{226}Ra, that property is scheduled for engineering assessment. However, remedial action will not be undertaken if the ^{226}Ra is not due to residual radioactive materials, although for those cases the engineering assessment will still provide the property owners with an indication of the recommended procedures they may use at their own expense to remedy the problem. Therefore, soil samples that are shown by NaI(Tl) analysis to contain greater than 5 pCi/g of ^{226}Ra are shipped to Pacific Northwest Laboratory at Richland, Washington. There they are opened, homogenized, dried, re-weighed, and then counted on an intrinsic germanium gamma-ray spectrometer system. These analyses indicate (from the ratios of ^{234}Th to ^{230}Th, ^{226}Ra and ^{210}Pb) whether the ^{226}Ra is due to residual radioactivity or to natural terrestrial radioactivity. The activity of ^{234}Th, the 24-day half-life daughter of ^{238}U, should be much lower than the activities of ^{230}Th, ^{226}Ra and ^{210}Pb in residual radioactivity from mill tailings, but should be nearly equal to the activities of these radionuclides in uranium ore, whether it is from a natural deposit or has been transported from a mining or milling site. (The concentrations of ^{234}Th, ^{230}th, ^{226}Ra and ^{210}Pb are established by comparison to standards traceable to NBS or IAEA.) The resolution of the NaI(Tl) is not adequate to measure the concentrations of these radionuclides, so it cannot be used to determine whether the ^{226}Ra is due to residual radioactivity. However, its higher sensitivity permits a much more rapid screening of samples than would be possible using a germanium diode.

Visual observations of the physical characteristics of the soil samples and the deposits of the sampling sites are also used to indicate whether residual radioactivity is present. This is especially needed to differentiate between translocated ore (which is considered to be residual radioactivity) and ore in a natural, undisturbed deposit (which is not considered to be residual radioactivity).

D. Radon Daughter Concentration Measurements in Buildings

1. Five-Minute Measurements

Air filter samples are collected over five-minute intervals for radon progeny working level measurement using 47 mm diameter Millipore type AA filters with a pore size of 0.8 microns. Air is drawn through the filters at flow rates of about 40 liters per minute using Gast rotary vane pumps. One filter is collected in the main living area on the ground floor of each structure and one in any habitable basement. The home owners are asked to keep windows, doors and outside vents closed, and to turn off air fans, but not heating systems, for eight hours (three hours minimum) prior to making the grab working level measurements to minimize the dilution of the indoor radon progeny concentrations by outside air. Prior to measurement, the homes are checked for open doors, windows or vents, and for operating fans. If any are noticed, radon daughters are not measured in that home that day.

Commencing less than seven minutes after the beginning of radon daughter sampling, the filters are counted for three minutes using a ZnS scintillator covering the entire face of a 12 cm diameter photomultiplier tube to determine the sum of the alpha emission rates of the radon progeny ^{218}Po and ^{214}Po. Two 10-minute counts are then taken commencing 8-1/2 to 12 minutes and 19 to 30 minutes after the beginning of sampling to determine the change in the emission rate with time. The counts are stored in electronic scalers. These measurements are used to calculate the concentrations of the radon daughters ^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po and the working level by the general form of the method of Thomas (1972).

An air filter is collected each morning outside of the Battelle office at 107 N. 6th Avenue, because natural outdoor radon daughter concentrations in excess of 0.015 WL could cause indoor concentrations to increase to the point where structures would fail the working level criterion for clearance from remedial action. However, it has been observed that outdoor radon concentrations vary with time and location at Edgemont. Therefore, beginning in February of 1981, when the radon progeny concentrations at the Battelle office exceeded 0.01 WL, radon daughters have been measured outside of each structure before or during the indoor radon daughter measurement. If the outdoor radon daughter concentration exceeds 0.015 WL, indoor concentrations are not measured until the outdoor concentration falls below 0.015 WL. If it is found that the outdoor radon daughter concentration in any part of town is significantly below 0.010 WL on a given day, no more outdoor radon daughter concentrations are measured for the rest of that day.

The turnover times of the radon daughters in the air in structures prior to a five-minute radon daughter measurement are calculated from the degree of disequilibrium between the daughters ^{218}Po, ^{214}Pb, and ^{214}Bi using the equations reported by Morken and Scott (1966), which are given in the text of this report. These equations can be used to calculate the turnover times from the relative concentrations of any two of the three short-lived radon daughters, but in practice the turnover time is calculated from only the concentrations of the ^{218}Po-^{214}Bi pair and the ^{214}Pb-^{214}Bi pair.

Most of the time the radon daughter activities decrease in the order $^{218}Po > {}^{214}Pb > {}^{214}Bi$. However, the statistical fluctuations in the measurements and/or rapid variations in the plate-out rate (which is significantly greater for ^{218}Po than for either ^{214}Pb or ^{214}Bi) cause changes in this order, the calculated turnover times become negative. If the departure from the normal sequence is large, the calculated negative turnover time will be short.

If the turnover time calculated from either the ^{218}Po-^{214}Bi or the ^{214}Pb-^{214}Bi pair is either positive and shorter than 32 minutes or negative and shorter than 100 minutes, the radon daughter measurement is considered to be invalid because of excessive plate-out or air exchange (unless the measured concentration is >0.033 WL, in which case the measurement is considered to be a valid indication that the closed-structure concentration will average >0.033 WL).

If the radon daughter measurement in a structure is considered to be invalid because of short calculated turnover times, the structure is scheduled for re-measurement at a later date. If the re-measurement is also invalid because of short calculated turnover times, additional measurements may be made until a valid measurement has been obtained. However, in some cases after two or more invalid measurements have been made, it is decided that five-minute radon daughter measurements will not provide a sufficiently accurate estimate of the annual average working level, so the structure is scheduled for long-term radon daughter measurement. However, the measurement showing the longer turnover times is considered to be the more representative of the annual average and is reported as an interim value. It has also been observed that there is a significant reduction in the number of measured working levels above 0.010 WL when the wind speed is above 8 mph. Therefore, the wind speed is checked each morning and an attempt is made to avoid sampling when it is above 8 mph.

Working Levels Greater than 0.01 WL

If the structure average of the five-minute working level measurements is less than 0.010 WL, and if the turnover times of the radon daughters for the measurements satisfy the criterion described above, the structure is considered to satisfy the radon progeny criterion for clearance from remedial action.

Working Levels Greater than 0.033 WL

If the measured five-minute working level is greater than 0.033 WL on either floor, a second measurement is made at a later time to confirm the elevated concentrations. The valid measurements taken on each floor during the initial survey and during any repeat surveys are averaged floor by floor. (This is necessary since there may be more valid measurements available for one floor than for another.) The average for the structure is then calculated as the average of the individual floor averages. However, beginning on February 25, 1981, all indoor working levels above 0.010 WL measured on days when the outdoor working level is above 0.015 WL are being disregarded. The measurement is repeated at a later date because the elevated indoor working levels could be due to outside air, and might not be characteristic of the structure. If the structure average is greater than 0.033 WL, the structure is considered to exceed the EPA annual average working level standard of 0.015 WL and is immediately scheduled for engineering assessment.

Working Levels of 0.01 to 0.033 WL

If the structure average of the valid working level measurement is between 0.01 and 0.033 WL, it is considered that grab samples will not provide an estimate of the average annual working level that is sufficiently accurate to provide a basis for a decision on remedial action. Therefore, the structure is either scheduled for long-term radon progeny measurements or directly for engineering assessment, depending upon the availability of RPISU's. If the structure or yard fails either of the other criteria for clearance from engineering assessment (e.g., indoor or outdoor gamma-ray exposure rates 20 μR/hr above background or ^{226}Ra >5pCi/g in soil), the structure is scheduled for engineering assessment without further radon daughter measurements.

2. Long-Term Radon Daughter Measurements

Annual average radon daughter concentrations are determined from six measurements of at least 100 hours duration made approximately every other month of the year using radon daughter integrating sampling units (RPISU). A rotameter is used to measure the flow rate through the filter at the beginning and end of sampling, and the average flow rate is taken to be the average of these two flow rates. A running time meter is used to determine the total sampling time.

The filter on the RPISU tends to plug up, causing a pressure sensor to turn off the instrument. When this occurs before 100 hours have elapsed, the filter and TLD chip are replaced (they come as a sealed unit) and the measurement continued with additional sampling heads until a total sampling time of 100-hours has been obtained. The average for the total sample is taken to be the average of the concentrations measured in the individual TLD chips, weighted according to the sampling time for each chip. It requires about five hours to obtain a measurable sample, so TLD chips that have been exposed for less than this time are not included in the calculation of the average concentration for the 100-hour sample.

If the annual average radon daughter concentration calculated from six RPISU measurements is greater than 0.015 WL, the structure is scheduled for engineering assessment, but if the average is less than or equal to 0.015 WL, the structure satisfies the working level criterion for clearance from remedial action.

II. Engineering Assessment

A flow diagram outlining the measurement and decision making process used in conducting engineering assessments at Edgemont, South Dakota is shown in Figure 13.

A. Indoor Gamma Radiation Exposure Rates Greater than 20 μR/hr Above Background

Engineering assessment is performed in structures in which gamma radiation exposure rates greater than 20 μR/hr above background were measured to determine the extent of any residual radioactivity present, unless the gamma radiation was from an easily removable object. The owners or occupants of structures have been informed about the emission rates of easily removable objects that gave gamma-ray exposure rates greater than 20 μR/hr above background during the gamma-ray survey. Their disposal is at the discretion of the occupant, so no engineering assessment or remedial action is required, other than to take away items for disposal at owner's request.

In a few cases, the original gamma-ray survey has identified exposure rates greater than 20 μR/hr above background that could be clearly attributed to materials used in the construction of the structure, such as rocks used in building a fireplace. A NaI(Tl) gamma-ray spectrometer is used to confirm that the exposure rates are due to ^{226}Ra. If the gamma-ray spectrum is primarily that of ^{226}Ra and its short-lived daughters, the building material is scanned with a gamma-ray detector that is shielded with lead on the sides to determine the extent of the residual radioactive material. That area is eligible for remedial action, although remedial action is obviously performed only if it is desired by the owner. If the high exposure rates are not due to ^{226}Ra or ^{238}U decay chain members, no further engineering assessment is performed (unless required by failure of other criteria).

In cases where exposure rates greater than 20 μR/hr above background were measured in contact with outside walls, soil core samples are taken or boreholes drilled as close to the building as possible next to the location of the maximum indoor exposure rate. If the high exposure rates are measured in the basement floor, a core is drilled through the floor at the location of maximum exposure rate. Each core is analyzed or borehole logged using either a NaI(Tl) or germanium diode detector. If ^{226}Ra concentrations greater than 5 pCi/g due to residual radioactivity are measured, additional boreholes are logged to determine the extent of residual radioactivity in the deposit. If the ^{226}Ra is due to natural radioactivity, and is high enough to cause the measured exposure rates, no further engineering assessment or remedial action is performed (unless required by other criteria).

If no ^{226}Ra concentrations are measured in the soil samples that could have caused the high gamma exposure rates, samples of the building material are analyzed for ^{226}Ra. If ^{226}Ra concentrations greater than 5 pCi/g are measured, a gamma-ray detector is used to determine the extent of the source of elevated gamma exposure rates. In the unlikely event that the cause of the elevated gamma readings have not yet been discovered at this point, additional soil samples and possibly samples of the wall are analyzed for ^{226}Ra until the cause is discovered. Particular attention is given to discovering any hot rock that could be causing the anomaly.

B. Outdoor Gamma Exposure Rates Greater than 20 μR/hr Above Background and/or Radium-226 Concentrations Greater than 5 pCi/g in Soil

Engineering assessment is performed at locations where ^{226}Ra concentrations greater than 5 pCi/g due to residual radioactivity were measured in soil samples during the radiation survey. Engineering assessment is also performed at outdoor locations where gamma radiation exposure rates greater than 20 μR/hr above background were observed, because it is assumed that soil or rocks containing ^{226}Ra concentrations greater than 5 pCi/g are present at these locations even if it was not measured during the survey.

A series of boreholes is logged using NaI(Tl) detectors to determine the extent of the ^{226}Ra concentrations greater than 5 pCi/g, with one of those holes being drilled at the location of maximum gamma exposure rate. The exposure rates are measured using a NaI(Tl) detector that is shielded with lead on the sides to determine the size, shape, and density of the grid. One hole is drilled to a depth of two meters initially, but if any hole shows ^{226}Ra concentrations greater than 5 pCi/g or ^{226}Ra concentrations increasing faster than 1 pCi/g/15 cm at the bottom, that hole is extended in one meter increments until the ^{226}Ra concentration at the bottom of the hole falls to 5 pCi/g, or less. If the initial hole indicates that the deposit is shallow, each additional hole is only drilled to a depth of at least 30 cm below the maximum depth at which ^{226}Ra concentrations greater than 5 pCi/g have been measured in previous holes. A map is drawn showing the boundaries of the ^{226}Ra concentrations greater than 5 pCi/g and the depth of the deposit to provide an estimate of the quantity of soil that will have to be removed during remedial action.

C. Annual Average Radon Daughter Concentrations Greater than 0.015 WL

Engineering assessments are performed on buildings that had two five-minute air filter concentrations averaging greater than 0.033 WL or average annual radon daughter concentrations greater than 0.015 WL. Because of the lack of sufficient RPISU's to make a large number of radon daughter measurements in a reasonable period of time, engineering assessments are also being performed in many buildings that had five-minute radon daughter measurements ranging from 0.010 to 0.033 WL, or that twice failed the turnover time criterion.

The engineering assessments consist of borehole logging and soil analysis around the structures to determine the extent of any deposits of residual radioactive materials containing ^{226}Ra concentrations greater than 5 pCi/g. One borehole is drilled into the soil exterior ~~to~~ each side of the building within two meters of the building at the location showing the highest gamma radiation exposure rate, unless that location is obstructed at or below the surface by an object such as a sidewalk or a sewer pipe. In that case, the hole is drilled as close as possible to the location showing the highest exposure rates. If there is a garage, patio, or other structure attached to the side of the main building that prevents the drilling of a hole within two meters of the main building, the hole is drilled as close as possible to the point of attachment of the attached structure, and within two meters of the main building. Each hole is drilled to a depth of two meters below the surface, or to the level of the base of the foundation, whichever is deeper. If obstructions make it difficult or risky to drill the hole, it is hand-dug instead to as great a depth as practical (generally about one meter). If residual radioactivity is measured at the bottom of this hole, another hole is drilled nearby, avoiding the obstruction, to determine the depth to which the residual radioactivity extends. The ^{226}Ra concentrations surrounding the boreholes are logged every 15 cm from the surface to a depth of 45 cm, and every 30 cm thereafter. The concentrations are logged using a NaI(Tl) gamma-ray spectrometer. If the ^{226}Ra is greater than 5 pCi/g, or is increasing at a rate greater than 1 pCi/g/15 cm at the deepest level monitored, the hole is extended in one-meter increments until the concentration at the bottom of the hole is less than 5 pCi/g and is not increasing at a rate greater than 1 pCi/g/15 cm.

If gamma-ray exposure rates greater than 4 μR/hr above background are observed in contact with the ground floor of a building, boreholes are logged or soil cores analyzed through the floor at locations of maximum gamma exposure ratios. Boreholes or soil excavations are monitored to determine, if possible, whether nearby deposits pass under the foundation of the structure.

1. No Radium-226 Concentrations Greater than 5 pCi/g

If no ^{226}Ra concentrations greater than 5 pCi/g are measured in any borehole, it is assumed that the radon daughter concentrations are due to natural radioactivity, so the structure is cleared from remedial action (unless required by other criteria).

2. Radium-226 Concentrations Greater than 5 pCi/g

If ^{226}Ra concentrations greater than 5 pCi/g are logged in any hole, soil is analyzed using germanium diodes to determine whether the ^{226}Ra is due to mill tailings. The soil is analyzed at a location and depth where the ^{226}Ra concentrations are high enough to insure that reasonably accurate concentrations of the ^{238}U chain members can be obtained.

If the concentrations of ^{234}Th (24-day), the short-lived daughter of ^{238}U, is comparable to those of the other ^{238}U daughters, it is concluded that the ^{226}Ra, and the radon daughter concentrations in the building are due either to uranium ore or to local natural radioactivity. Uranium ore is likely to be present in the form of yellow (sometimes green or black) rocks or flakes that have high ^{226}Ra concentrations and are generally different in appearance from the surrounding soil matrix. If no such material is present, and the ^{226}Ra concentrations are within the range of natural radioactivity in the area (less than 10 pCi/g), it is concluded that the high ^{226}Ra concentrations are due to local natural radioactivity. Therefore, the property is cleared from further remedial action (unless required by other criteria). If the concentration of the short-lived ^{238}U daughter, ^{234}Th, is significantly lower than the concentrations of the other ^{238}U daughters, the ^{226}Ra concentration is greater than 10 pCi/g, or if there is physical evidence that uranium ore is present, residual radioactivity is considered to be present, so additional gamma-ray surveys are carried out and boreholes drilled to determine the extent of the residual radioactive materials. The holes are drilled in a grid pattern that is modified if exposure rates or visual clues provide an estimate of the size of the deposit of residual radioactivity.

When borehole logging and soil analysis has been completed, a map is drawn showing the boundaries and the depths of the ^{226}Ra concentrations greater than 5 pCi/g.