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Hagerman Fossil Beds National Monument, National Park Service, U.S. Department of the Interior
Hagerman, Idaho

Timothy E. Jiggens, MSPH, IHIT
John J. Cardarelli, MS
Steven H. Ahrenholz, Ph.D., CIH

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Timothy E. Jiggens, MSPH, IHIT, of the Health Related Energy Research Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Greg McDonald, Ph.D., National Park Service. Analytical support was provided by Ardith Grote, NIOSH, and by Jim L. Gale, Stephen R. Black, and Peter M Kligmann, Data Chem Laboratories. Desktop publishing was performed by Pat Lovell. Review and preparation for printing was performed by Penny Arthur.

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Health Hazard Evaluation Report 96-0264-2713
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Timothy E. Jiggens, MSPH, IHIT
John J. Cardarelli, MS
Steven H. Ahrenholz, Ph.D., CIH

SUMMARY

Hagerman Fossil Beds National Monument (HAFO) is a unit of the National Park Service. The primary activities at HAFO are the excavation, preparation, display, and storage of fossilized mammal skeletons from the Pliocine Epoch. On August 29, 1996, HAFO sent a letter to the National Institute for Occupational Safety and Health (NIOSH) requesting technical assistance because "fossil materials that we work with on a reoccurring basis have potential for radon gas and gamma radiation exposure."[1] NIOSH made two site visits in response to this request.

The first visit took place May 14-15, 1997, immediately prior to the start of the dig season. NIOSH investigated activities in the Administration Building and Visitor Center, where sampling was conducted for total airborne particulate, external ionizing radiation exposure, and surface radiation contamination. Active and passive radon monitors were installed in the two buildings, and employees were provided radiation monitoring thermoluminescent detectors (ring badges and whole body badges). Soil and fossil samples were taken from the dig site (known as the Horse Quarry) and analyzed for gamma emitting radioisotopes. The soil samples were also analyzed for silica content.

The second visit occurred July 23-24, 1997, at the peak of the dig season. NIOSH investigated outdoor work activities at the monument, particularly at the Horse Quarry. Employees were monitored for respirable airborne silica, respirable airborne particulate, total airborne particulate, and heat stress. Performance of the local exhaust ventilation in the fossil preparation laboratory was also assessed.

Sample results indicate that the soil at HAFO is not abnormally radioactive. With a specific activity of 700 ± 200 picoCuries/gram (pCi/g), the fossils at HAFO are several hundred times more radioactive than the soil, but still exhibit less than one percent of the radioactivity of some uranium bearing minerals. Exposures to external radiation at HAFO were found to be low, and no radioactive contamination of indoor surfaces was found.

The fossils at HAFO are sources of radon gas. Radon concentrations of about 8 picoCuries/liter of air (pCi/L) were found in the collections room, a poorly ventilated room where fossils are stored. Radon levels ranged from 128 to 500 pCi/L inside the collections cabinets. Radon concentrations in other parts of the Administration Building and Visitor Center were less than 2.5 pCi/L. The Environmental Protection Agency (EPA) recommends that corrective measures be taken when radon levels inside residences exceed 4 pCi/L.[20]

Some outdoor workers at HAFO may be overexposed to heat during typical summer afternoons. A formal heat stress management program is needed at HAFO due to the remote location, potential for heat overexposure, and presence of individuals not acclimated to hot conditions.

The soil at HAFO contains 20-25% silica by mass, but exposures to respirable airborne silica were low. Only one (0.04 milligrams respirable silica per cubic meter of air [mg/m^3]) of ten samples was high enough to quantify. Exposures to respirable airborne particulate (10 samples, all less than 0.22 mg/m^3) and total airborne particulate (13 valid results, all less than 0.68 mg/m^3) were also low.

The ventilation hoods in the fossil preparation lab serve to physically contain dust and projectiles generated during fossil processing. However, the hoods generate insufficient flow to remove the dust and lack air cleaners to remove dust from the exhausted air.

Results of this NIOSH Health Hazard Evaluation (HHE) demonstrate that potential health hazards exist at HAFO. Employees who work near fossil storage cabinets are potentially exposed to radon gas in excess of the EPA recommendations for private residences, while field employees are potentially exposed to hot environments beyond what is recommended by NIOSH or the American Conference of Governmental Industrial Hygienists (ACGIH). Recommendations for protecting employees from these hazards are presented on pages 20-21 of this report.

Keywords: SIC Code 3281 (Cut Stone and Stone Products), museum, excavation, paleontology, fossil, natural history specimen, uranium, radium, radon, ionizing radiation, heat stress, silica, PNOC, PNOR, particulates, National Park Service, National Monument

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INTRODUCTION

On September 5, 1996, the National Institute for Occupational Safety and Health (NIOSH) received a letter from the Hagerman Fossil Beds National Monument (HAFO), requesting technical assistance in the evaluation of gamma radiation and radon gas exposures to HAFO staff.[1] HAFO is a unit of the National Park Service (NPS) in the United States Department of the Interior, and is located near Hagerman, Idaho. Activities at HAFO include the excavation, preparation, storage, and exhibition of vertebrate fossils. The request stated that ". . . (HAFO) has recently determined that some of the fossil materials that we work with on a reoccurring basis have potential for radon gas and gamma radiation exposure."

Subsequent communications from HAFO revealed that the general public, including children, could view and handle fossils in the Visitor Center. Furthermore, during the summer dig season, HAFO staff was comprised primarily of seasonal employees, students, and volunteers, with relatively few permanent NPS employees.

In communicating with HAFO personnel prior to the initial site visit, NIOSH investigators recognized other potential occupational hazards such as heat stress and airborne silica. HAFO staff concurred, and the scope of the investigation was expanded. Two site visits (May 14-15 and July 23-24, 1997) were conducted, and an interim letter containing recommended changes in practices and hazard abatements was sent after each visit.[2,3] This final report contains the major points of those letters as well as additional information.

BACKGROUND

Site Description

The site is located in Gooding County, Idaho, about thirty miles northwest of Twin Falls. The two main HAFO buildings are located in the town of Hagerman (elev. 2960 ft), on the east bank of the Snake River.[4] Rented space in other local buildings is used for storage of equipment, materials, and raw and prepared fossils.

The Visitor Center consists mainly of exhibition space, but also includes offices and a small auditorium (Figure 1). The exhibition space and auditorium are open to the public and are often visited by groups of students.

The Administration Building contains offices, a fossil preparation laboratory, and collections (fossils) storage areas (Figure 2). Included in the preparation laboratory are two small ventilation hoods constructed by site personnel. These hoods are enclosed on all six sides, with hinged tops for placing/removing fossils and arm holes for access to the work. The hoods are used to control dust during fossil preparation and to control odors during the rendering (boiling the flesh off) of contemporary animal skeletons. A household refrigerator/freezer is used to store animal carcasses prior to rendering (as is a large chest freezer in a rented building). A 55 gallon drum of granular Butvar® (poly[vinyl butyral-co-vinyl alcohol-co-vinyl acetate]) is stored in the laboratory, as are small (< 1 gallon) quantities of isopropyl alcohol and acetone. Two collections cabinets are also present in the preparation laboratory. In the storage room (approximately 8' x 12'), adjacent to the laboratory, are twelve more collections cabinets. These airtight cabinets, approximately 34" x 34" x 30" (H x W x D), are used to protectively store fossils.

The bulk of the monument consists of 4281 acres, stretching seven miles along the west bank of the Snake River.[4] Elevations range from approximately 2800 feet (river level) to 3500 feet. There is virtually no level ground within the site boundaries and the slopes are prone to landslides. Annual average rain fall is less than 10", the soil is dusty and sandy, and sagebrush is the predominant vegetation. Rattlesnakes and scorpions are indigenous to the area. Remnants of the Oregon Trail cross the southern end of the monument. There are currently no hiking trails within the site. Most visitor and employee activity is concentrated in a small area known as the "Horse Quarry," located near Fossil Gulch at the north end of the monument.

Although the Horse Quarry is directly across the Snake River from Hagerman, the location of the nearest bridge necessitates a fifteen mile drive. A privately-owned, half-mile long two-track road terminates at a small parking lot on the canyon rim, where employees leave their vehicles. Nearby is a small trailer, occupied at night to deter vandalism. A portable restroom is also kept on the parking lot. Behind a locked gate is a narrow lane crossing a saddle to the Horse Quarry. Vehicles are sometimes used to carry equipment, but employees generally walk from the parking lot to the site, approximately 200 yards.

The Horse Quarry is a two level terrace cut into the side of a hill. The upper level, approximately 5 yards wide and 30 yards long, is the active dig area. The lower level, which dips about six feet lower than the floor of the dig area, is about 10 x 40 yards and includes a large wooden lock box for secure equipment storage. Weather is typically sunny during the May to September dig season so a tarpaulin is strung up to provide shade. The average late July high and low temperatures are 94° and 56° F, respectively.[5]

Geology & Paleontology Review

The 600 foot bluffs rising above the Snake River expose sediment layers ranging in age from 3.15 to 3.7 million years.[4] This time period is known as the Pliocene Epoch of the Cenzoic Era (dinosaurs became extinct during the Paleocene Epoch, 65 million years ago). Some sediment layers contain fossilized remains of prehistoric plants and animals. One particular layer, mined at the Horse Quarry, contains many types of fossils: plant and animal, terrestrial and marine, and amphibian and mammal. The site is famous for the large number of well preserved skeletons of the Hagerman Horse (Equus simplicidens). Due to the chemical composition of bones, they tend to concentrate certain radioisotopes during fossilization and become much more radioactive than the surrounding soil. This has been demonstrated previously in dinosaur skeletons, whale vertebrae fossils, and fossilized turtle shells.[6,7,8]

PROCESS DESCRIPTION

Excavation

The main process at HAFO can be broken down into four steps: excavation, preparation, storage, and exhibition of fossils. The first step in the process is excavation. The soil and sediment layers (overburden) on top of the fossil-bearing layer must be removed. Much of the overburden at the Horse Quarry was removed with heavy equipment, but to protect the fossils the remainder must be removed using hand tools. Soft soil is shoveled into a wheelbarrow and dumped at the edge of the dig site. Harder material is broken up with a Pulaski, a type of pickax. This work is physically demanding and care must be taken to avoid destroying fossils. Sometimes the salvage pile (previously removed overburden) is sifted through a wire mesh to retrieve small fossils or pieces of fossils. This sifter is about three feet square and mounted three feet high like a table top upon four legs.

After the overburden has been removed and target fossils are exposed, they are catalogued and their location and orientation are determined using a computerized laser transit (such as those used by land or road survey teams). Material covering the fossil is delicately removed by hand. When the matrix (rock and soil surrounding the fossil) is soft and sandy it is removed with a small paintbrush or similar brush. Firmer matrix is cleared away with a hand trowel. Harder material may require a small hammer and chisel, while dental picks and similar tools are sometimes used for the most delicate work. This excavation phase is slow and tedious. Broken bones are often glued together with a solution of Butvar® in isopropyl alcohol. (Isopropyl alcohol is used as the solvent because acetone evaporates too quickly outdoors).

Bones and other fossil materials are usually not completely extricated at the dig site. Instead, material around and underneath the target is removed until a lump of fossil and matrix sits upon a pedestal. Plaster-soaked burlap strips are then wrapped around the target to protect and strengthen it. After the plaster has hardened the lump is detached from the pedestal and transported back to the preparation laboratory.

Preparation

The second step in the process, preparation, takes place in the preparation laboratory. Here the plaster cast and the rest of the matrix are removed from the fossil. Small hammers and chisels, dental picks, and other hand tools are used to perform this work. An air scribe (a pen-sized reciprocating chipper driven by compressed air) is sometimes used as well. A table, desk, and bench top are available as work areas, as are the two ventilated hoods. The air scribe is always used in one of the hoods. A solution of Butvar® in acetone is used to fix broken bones, and is painted on the surface of all bones to improve strength and durability. (Acetone is used as the solvent indoors because isopropyl alcohol evaporates too slowly.) Fossil preparation is often performed on a sheet of cardboard, so soil and rock removed from the fossils can be dumped into a container for disposal. Alternatively the removed matrix is swept up (dry) with whisk brooms and dustpans, cleaned up with damp cloths or sponges, or removed with a vacuum cleaner.

Storage and Exhibition

The third and fourth steps in the process are storage and exhibition. Many fossils are stored in the collections cabinets in the collections room and preparation laboratory of the Administration Building. Additional collections cabinets are kept in the rented satellite building. The assembled skeletons and individual bones on permanent display at the Visitor Center are either contemporary bones or casts of fossils. The practice of not exhibiting the actual fossil bone is common to many museums.[9] The HAFO Visitor Center does keep some miscellaneous fossil bones and bone fragments available for children to handle.

Other Site Activities

Three NPS Rangers are employed at HAFO to maintain site security and to perform wildlife management tasks such as tree planting and groundwater sampling. Currently there are no hiking trails on the monument, but one is under construction. Trail building tasks include hoeing and raking by hand, tilling with a self-propelled power tiller, and installing water bars (half buried logs) to control erosion. The terrain is steep and rugged, and the worksite is reached by driving about one mile along the edge of the monument (there is no road, a 4 wheel drive vehicle is required), then walking down a steep incline to the end of the current trail. An alternative route is to take the park road along the bottom of the canyon and hike up to the worksite.

Ionizing Radiation Review

Some atoms are naturally unstable and release energy to eventually reach more stable, lower energy forms. Atoms that release energy in this way are known as radioisotopes. The Appendix shows the many steps the most common radioisotope of uranium (238U) takes to finally reach stable lead (206Pb). Each time a radioisotope undergoes a radioactive transition (also known as a disintegration or decay) it releases one or more forms of radiation. The activity of a radioisotope can be measured in Bequerels (1 Bq = 1 decay per second) or Curies (1 Ci = 3.7×10^{10} decays per second). A Curie is a large amount of activity, so smaller units like picoCuries (10^{12} pCi = 1 Ci) are sometimes more convenient to use.

Some important forms of ionizing radiation are the alpha and beta particles and gamma rays (photons) emitted from radioactive decay. These are called ionizing radiation because they can knock electrons out of atoms and molecules, creating electrically charged particles called ions. This ionization process transfers energy from the radiation particle or photon to the irradiated material. When people are exposed to ionizing radiation this energy transfer can cause chemical and physical changes in human tissue.[10] The various types of ionizing radiation differ widely in their abilities to penetrate tissue, deposit energy, and cause damage.

Alpha particles are made up of two protons and two neutrons, the same as the nucleus of a helium atom. They are much smaller than a single atom and carry a double positive charge. Alphas travel only a short distance (less than a millimeter [mm]) in living tissue, and thus cannot penetrate the skin. Beta particles (electrons) carry a single negative charge and are thousands of times smaller than alpha particles. They travel longer distances in living tissue than alpha particles, but can be stopped by a thin sheet of metal (aluminum is typically used). Gamma rays have no mass or electrical charge, so they can travel extremely long distances in human tissue, sometimes completely through the body. This means their energy is deposited over a longer path and is less likely to cause damage to living tissue.[10]

Since alpha and beta particles are not very penetrating, when outside the body they can only damage the skin and eyes. They become a concern primarily when internal exposures occur. Internal radiation exposures occur from inhalation of radioactive dust, from handling radioactive items (material rubbing off onto a person's hands, especially into cut or abraded skin), and from ingestion of this material. Internal exposures to alpha or beta particles can damage internal organs. Alpha particles are more dangerous since they deposit all their energy along a very short path. Since gamma rays are very penetrating, they are a concern when external exposures occur. An external exposure is irradiation of an object from a source located outside of the object.

External exposures are measured in units of Roentgen (R) or microRoentgen (1,000,000 µR = 1R). A Roentgen is a measure of how much ionization is produced in air by gamma or x-rays. When radiation is absorbed by a person, the quantity absorbed is referred to as the radiation dose. The units of radiation dose are the Roentgen Equivalent Man (REM) or Seivert (Sv). One hundred REM is equal to one Sv. These units were derived to account for the various types of biological damage caused by different kinds of ionizing radiations (alpha, beta, gamma, x-rays, neutrons, etc). By using REM and Sv, different kinds of radiation can be combined into one number for administrative and legal purposes such as monitoring of allowable radiation exposures. Sometimes smaller units like the milliREM (1000 mREM = 1 REM) are more convenient to use.

METHODS

Gamma Spectrometry

Six soil samples and a sample of fossils were analyzed to determine concentrations of uranium and gamma emitting uranium progeny (see Appendix). The concentrations of these elements affect the manner in which the fossils should be handled and how the waste soil might be properly discarded. The locations were selected by the investigators to represent a range of soils that could be used for both gamma spectroscopy and silica content analyses:

1 - North end of Horse Quarry floor
2 - South end of Horse Quarry floor
3 - North end of Horse Quarry back wall (fossil-bearing soil layer)
4 - Salvage pile at Horse Quarry
5 - Soil removed from fossils (soil originated at Horse Quarry, sample was gathered at preparation laboratory)
6 - Ditch near the Snake River Public Access-Hagerman side (East bank) of river.

Soil samples were collected by scooping approximately 500 cubic centimeters (cm^3) of surface soil into a wide-mouth plastic bottle. Plants, stones, and other foreign objects were excluded. The fossil sample was collected by a park ranger and consisted of fossil pieces that had washed down the hill below the Horse Quarry.

Data Chem Laboratories Inc (Salt Lake City, Utah) used their standard operating procedures WR-DC-200 and WR-EP-325 to measure and identify gamma emitting isotopes by gamma spectrometry.[11,12]

Nominal 1 gram (g) samples were counted for 240 minutes using Canberra high-purity germanium gamma spectrometry detectors with a GENIE data processing system. Canberra NID (nuclide identification) software was used for data analysis. In the practice of gamma spectrometry the limit of detection (LOD) is generally expressed relative to a reference isotope such as Cs-137. The LOD was 0.1 pCi activity per gram of sample (pCi/g) for soil samples, and 0.5 pCi/g for the fossilized bone sample.

Radon

Real-Time Measurements

Hourly measurements of radon gas concentration in the collections room, preparation laboratory, and the reception area of the Administration Building were obtained using the Pylon AB-5 Monitor (Pylon Electronics, Ottawa, Ontario). The AB-5 monitor is a portable instrument which uses a 272 milliliter (mL) volume Lucas cell coated internally with zinc sulfide.[13] The unit counts the number of radon daughter decays during a specific period (one hour in this instance), corrects for background effects, and calculates an average radon concentration. The LOD of this method is about 0.1 pCi activity per liter of air (pCi/L).

Passive Measurements

Long term average radon concentrations were obtained using alpha-track detectors provided by Landauer, Inc. (Glenwood, Illinois) and Alpha Spectra, Inc (Grand Junction, Colorado). These passive detectors contain a polymer film inside a perforated metal container. Radon diffuses into the container and decays into electrically charged daughter products, which stick to the polymer film. When the radon daughters decay, they create microscopic tracks on the polymer. These tracks were counted and converted to an average radon concentration. The LOD of this method is 30 pCi/L/day (the equivalent of 30 days at 1 pCi/L, or 15 days at 2 pCi/L, etc). The detectors were exposed for 70 days, which converts to a minimum detectable concentration (MDC) of 0.43 pCi/L.

Ten locations in the Administration Building and four in the Visitor Center were monitored between May 14 and July 23, 1997. Detectors were attached to the wall approximately five feet above the floor, except for the three placed inside fossil storage cabinets (see Figures 1 and 2).

Ionizing Radiation

Potential sources of exposure to external and internal ionizing radiation were evaluated with direct reading survey instruments. These included the Victoreen 450P (Victoreen, Cleveland, Ohio) pressurized ion-chamber and the Ludlum 2350 data logger with the Ludlum model 44-6 (pancake) and 43-65 (alpha scintillation) probes (Measurements Inc., Sweetwater, Texas). The Victoreen 450P was used because of its relatively uniform response to various gamma energies emitted by the daughter products in the uranium decay chain (Appendix). External gamma-ray dose rate measurements were performed at the Horse Quarry and other locations, and a survey was performed in the Administration Building (seven measurements) and the Visitor Center (five measurements). The Ludlum 2350 was used to measure radiation levels at the surface of the fossils. This instrument was also used to determine levels of alpha emitting and beta/gamma emitting surface contamination on desks, tables, bench and counter tops, and floors. A surface survey contamination survey was performed in the Administration Building (nine measurements) and in the Visitor Center (five measurements).

Lithium fluoride thermoluminescent dosimeters (TLDs) were used to monitor external exposures to ionizing radiation. Workers who excavated, prepared, and/or handled fossils wore two types of TLDs during their normal work schedules for up to ten weeks (May 14 to July 23, 1997). Ring badges worn on the finger were used to evaluate potential exposure to the hands. Whole-body badges worn between the neck and waist were used to evaluate potential whole-body exposures. Fifteen pairs of

TLDs were acquired from Landauer, Inc., a laboratory accredited by the National Voluntary Laboratory Accredited Program (NVLAP). The TLDs were also analyzed by Landauer, with a limit of detection for each dosimeter of about 10 mREM.

Environmental Conditions and Heat Stress

Indoor and outdoor environmental conditions were assessed with a Psychro-Dyne® psychrometer (Environmental Tectonics Corp., Southampton, Pennsylvania) which measured wet- and dry-bulb temperature. The dry bulb temperature is simply the standard measure of air temperature taken with a thermometer or similar instrument, while the wet bulb temperature is taken with a wetted-wick thermometer which allows for evaporative cooling. These data were used with a psychrometric chart to calculate the relative humidity (RH).

A Reuters-Stokes RSS 214 Wibget® heat stress meter (I&ST Canada Inc, Cambridge, Ont.) was used to measure the outdoor wet-bulb-globe temperature (WBGT). The WBGT is derived from the natural wet bulb-, dry bulb-, and globe temperatures. The globe temperature, measured with a thermometer placed in the center of a standard black-matte sphere, estimates radiant (infrared) heat load. The WBGT (external heat load), metabolic heat due to work (internal heat load), and an employee's clothing insulation value are used to estimate the amount of heat stress (environmental heat load) an employee is under. This estimate of heat stress is used to assess heat strain (physiological load) and determine what precautions are necessary to minimize the possibility of heat disorder.[14]

Bulk Samples - Crystalline Silica Content

The six soil samples described previously (Gamma Spectroscopy section) were also analyzed for crystalline silica content. These were analyzed for quartz and cristobalite by Data Chem Laboratories Inc. NIOSH Method 7500 (Silica, Crystalline, by X-Ray Diffraction) was used with the following modifications: standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure.[15] Samples were ground and screened to less than 38 micrometers (µm) in size and quantitated with 30 mm minusil standards. Polyvinyl chloride (PVC) filters, loaded with 2 milligrams (mg) portions of bulk material, were dissolved prior to analysis using tetrahydrofuran (sample preparation option c of Method 7500). The LODs were reported as 0.8% (by mass) for both quartz and cristobalite, while limits of quantitation (LOQ) were reported as 1.5% for both substances.

Respirable Airborne Crystalline Silica

Seven outdoor workers were monitored a total of ten times to assess possible exposures to respirable crystalline silica. In compliance with NIOSH Method 7500 (Silica, Crystalline, by X-Ray Diffraction), personal sampling pumps (SKC model 224-PCXR8) were used to pull 1.7 liters of air per minute (L/min) through 10 mm nylon cyclones followed by tared 5 µm PVC filters.[15] Filters were obtained from the NIOSH Measurement Research Support Branch Laboratory. Pumps were calibrated at the Hagerman Valley Inn (0.5 mile from HAFO Administration Building) before and after use with a Gilibrator® electronic bubble meter. Sampling was carried out for full shifts (approximately eight hours). The pumps were enclosed in plastic bags to minimize the potential for radioactive contamination, as sampling was carried out before the source of radioactivity was identified. For each of the 10 samples, the worker's right or left lapel was arbitrarily chosen as the location for the sampling head.

Analyses of the sample filters were performed by Data Chem Laboratories Inc. using NIOSH Method 7500 (Silica, Crystalline, by X-Ray Diffraction) with the modifications noted in the previous section.[15]

The LOD's were reported as 0.01 mg for quartz and 0.02 mg for cristobalite. These correspond to a MDC of 0.01 milligrams per cubic meter (mg/m^3) for airborne respirable quartz and an MDC of 0.02 mg/m^3 for airborne respirable cristobalite (for an ideal 8.0 hr, 1.7 L/min. sample). The LOQ was reported to be 0.030 mg for both substances, which would correspond to a minimum quantifiable concentration (MQC) of 0.037 mg/m^3 for an 8.0 hr, 1.7 L/min. sample.

Respirable Airborne Dust

The filters used with the cyclones were weighed to determine the mass of respirable dust prior to analysis for respirable silica content. NIOSH Method 0600 (Particulates Not Otherwise Regulated [PNOR], Respirable) was followed, except that the mean of two weighings was used in place of a single weighing of each filter.[16] Filters were analyzed by Data Chem Laboratories Inc. The LOD was reported as 0.02 mg, which corresponds to a respirable dust concentration of 0.02 mg/m^3 for an 8 hr, 1.7 L/min. sample.

Total Airborne Dust

Twelve personal breathing zone (PBZ) and two area samples were taken to assess exposures to total airborne dust. A wide variety of job types, activities, and work locations was included among those workers monitored. NIOSH Method 0500 (PNOR, Total) was followed, except that the mean of two weighings was used in place of a single weighing of each filter.[17] Sample collection equipment and procedures were the same as above except that no cyclones were used, and the flow rate was 2.0 L/min. Filters were analyzed by Data Chem Laboratories Inc. The reported LOD was 0.02 mg, which corresponds to a dust concentration of 0.02 mg/m^3 for an ideal 8.0 hr, 2.0 L/min. sample.

Local Exhaust Ventilation

Air velocity measurements were made using a VelociCalc® Model 8360 (TSI Inc., St. Paul, MN) Air Velocity Meter. This instrument is a constant temperature thermal anemometer which automatically compensates for changes in air density due to variations in temperature or barometric pressure. All velocity measurements are given in standard feet per minute. TSI defines standard conditions as 70° Fahrenheit (F) and 14.7 pounds per square inch, absolute.[18]

Measurements were made with the hood lids closed and no workers in place. The mean of several (6-20, depending on cross-section area) air velocity measurements was used. Volumetric flowrates were calculated using the product of the velocity and the appropriate cross-section area. Hood application, configuration and materials of construction, and appropriateness of the system fan were also evaluated using the American Conference of Industrial Hygienists' Industrial Ventilation: A Manual of Recommended Practice, 20th edition.[19]

EVALUATION CRITERIA AND TOXICOLOGY

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[20] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[14] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[21] NIOSH encourages employers to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Radon

Radon is a colorless, odorless, tasteless, radioactive gas. The chemical symbol for radon is Rn, and it has an atomic weight of 222 grams per mole. 222Rn is formed from the radioactive decay of radium (226Ra), which is part of the 238U decay chain (see Appendix). 226Ra and 238U are present in most soils and rocks, though the concentration of these radionuclides varies widely. Since radon is a gas it can leave the soil or rock where it formed and enter the surrounding air. High airborne concentrations of radon can build up when ventilation rates are low or when a large amount of 226Ra is present. As shown in the Appendix, radon decays with a half-life of about four days into a series of solid phase (particulate), short-lived radioisotopes commonly called radon daughters or progeny. These progeny can electrostatically adhere to suspended dust particles and remain airborne for extended periods of time. Two radon progeny (218Po and 214Po) emit alpha particles. If these radionuclides are inhaled the alpha radiation can damage the cells lining the airways, and the resulting cellular changes can ultimately lead to lung cancer.[22]

Cancer is the major effect of concern from the radium and radon radionuclides.[22,23] The Environmental Protection Agency (EPA) has classified radium as a Group A human carcinogen, but has not classified radon for carcinogenicity. Inhalation is the primary route of radon exposure. Exposure to radon increases a person's risk for lung cancer, and smokers exposed to radon are at greater risk for lung cancer (approximately 10 to 20 times) than are similarly exposed nonsmokers.[22] Long term exposures to high levels of radon (on the order of 100 pCi/L for 10 years) can also cause non cancer diseases of the lungs, such as thickening of certain lung tissues.[22] No information is available on the acute (short-term) effects of radon in humans. Exposure for one day to a radon concentration of 2.2×10^8 pCi/L was lethal to mice.[22]

Background levels of radon in outdoor air range from 0.003 to 2.6 pCi/L and are higher in areas with uranium and thorium deposits or granite formations.[20] Higher levels of radon are frequently present in indoor locations such as homes, schools, or office buildings. Indoor radon levels are usually about 1.5 pCi/L, although much higher levels (>200 pCi/L) have been measured in homes across the country. The EPA recommends that corrective measures be taken when in-home radon levels exceed 4 pCi/L. Outside of certain mining industries, radon is generally not considered an occupational hazard. Other than in these mining industries, no occupational exposure limit (mandatory or recommended) has been established for radon.

Ionizing Radiation

The current occupational exposure standard from the Nuclear Regulatory Commission (NRC) is 5 REM per year above background for radiation workers.[24] This limit is not applicable to the NPS for two reasons: NPS workers are not regulated by the NRC, and the exposures are from naturally occurring (and thus unregulated) radiation sources. A more appropriate NRC standard that can be applied to HAFO workers is the annual dose from ionizing radiation permitted to members of the public: 0.1 REM or 100 mREM above background. Another limit that may be applied is the International Commission of Radiological Protection (ICRP) recommended limit for protecting against ionizing radiation in the teaching of science.[25] The ICRP recommends that student doses be limited to 50 mREM per year above background.

Heat Stress

Excessive exposure to hot environments can lead to (in increasing order of severity) skin disorders, heat syncope (fainting), heat cramps, heat exhaustion, and heat stroke.[26,27] Persons at greatest risk are non-acclimatized workers, obese people, the elderly, people with cardiovascular or circulatory disorders, those taking medications that impair the body's cooling mechanisms, people performing physically strenuous work, people who use alcohol (or are recovering from recent use), and individuals recovering from illness.

Skin disorders such as heat rash and hives are caused by excessive sweating or retention of sweat.[26,27] In heat syncope, fainting results from blood flow being directed to the skin for cooling, resulting in decreased supply to the brain. This disorder often strikes workers who must stand in place for extended periods in hot environments. Heat cramps, caused by sodium depletion due to sweating, typically occur in the muscles employed in strenuous work.

Heat cramps and syncope often accompany heat exhaustion.[26,27] The weakness, fatigue, confusion, nausea, and other symptoms of this disorder generally prevent a return to work for at least 24 hours. The dehydration, sodium loss, and elevated core body temperature (above 100.4° F) of heat exhaustion are usually due to individuals performing strenuous work in hot conditions, with inadequate water and electrolyte intake. Heat exhaustion may lead to heat stroke if the patient is not quicky cooled and rehydrated.

While heat exhaustion victims continue to sweat as their bodies struggle to stay cool, heat stroke victims cease to sweat as their bodies fail to maintain an appropriate core temperature.[26,27] Heat stroke occurs when hard work, hot environment, and dehydration overload the body's capacity to cool itself. This thermal regulatory failure (heat stroke) is a life-threatening emergency requiring immediate and decisive medical attention. Symptoms include irritability, confusion, nausea, convulsions or unconsciousness, hot dry skin, and a core body temperature above 106° F. Death can result from damage to the brain, heart, liver, or kidneys.

ACGIH has developed TLV®s which represent "heat stress conditions under which it is believed that nearly all heat acclimatized, adequately hydrated, unmedicated, healthy workers wearing light-weight summer clothing may be repeatedly exposed without adverse health effects."[14] Further assumptions include an 8 hour work day, 5 day work week, two 15 minute breaks, and a 30 minute lunch break, with rest areas and work areas at the same temperature and "at least some air movement." By taking into account a workers' sources of heat (work, air temperature, radiant heat [sunlight]) and the ability of the body to cool itself (clothing insulation value, humidity, wind), a schedule of rest periods can be recommended. These work/rest regimens (Table 1) are designed to maintain workers' core body temperatures below 100.4° F.

NIOSH has developed separate RELs for workers who are not acclimated to hot environments (Figure 3) and for workers who are acclimated to hot environments (Figure 4).[27] When these work/rest regiments are followed, nearly all workers should be able to tolerate the resulting total heat exposures without substantially increasing their risk of acute adverse health effects. This statement assumes that workers are medically and physically fit for the level of activity required for their job, and are wearing at most long-sleeved work shirts and trousers.

Respirable Crystalline Silica

Silicon dioxide (SiO_2), also known as silica, occurs in both crystalline and amorphous forms. Amorphous (non-crystalline) silica is regarded as less hazardous and will not be discussed here.[28,29] Of the three primary forms of crystalline silica (quartz, cristobalite, tridymite), quartz is the most common. Quartz is commonly found in igneous rocks such as granite, as well as sedimentary rocks like sandstone. Quartz occurs in large amounts in sands and soils. Quartz has no odor and is colorless when pure. Inhalation of quartz dust has been recognized for centuries as the cause of silicosis. Only the smallest dust particles, those less than 10 µm aerodynamic diameter, can penetrate deep into the lungs to cause silicosis. Dust smaller than 10 µm is called respirable dust because of its ability to enter the deep (gas exchange region) of the lung.

Silicosis is an example of a class of dust induced lung diseases called pneumoconioses. The three clinically distinct forms of silicosis are termed chronic, accelerated, and acute.[28,29] Chronic silicosis is distinguished by the formation of characteristic lumps of scar tissue in the lungs. Initially the victim may have no symptoms of the disease, but the lumps may continue to grow and/or join together. Thus the disease may progress for many years, even after exposures to crystalline silica have ceased. Typical symptoms include cough, shortness of breath, and wheezing, and the disease is sometimes fatal. In past decades the development of associated tuberculosis killed many victims. Acute silicosis is often fatal within a year, and accelerated silicosis within a few years of exposure, but these are diseases that strike sandblasters and other highly exposed workers. All forms of silicosis occur following exposures to much higher respirable crystalline silica concentrations than observed at HAFO. Silicosis is 100% preventable.

NIOSH believes that crystalline silica should be treated as a potential occupational carcinogen.[15] The IARC includes crystalline silica in group 2A (probably carcinogenic in humans).[29] The National Toxicology Program (NTP) classifies crystalline silica as a Group 2 Carcinogen (reasonably anticipated to be a carcinogen), but has not yet studied the carcinogenicity of this substance. The ACGIH has declared that there is insufficient evidence to decide whether crystalline silica is a carcinogen, and OSHA does not regulate crystalline silica as a carcinogen.

The NIOSH REL for quartz is 0.05 mg/m^3 (respirable fraction), while the ACGIH TLV® for quartz is 0.1 mg/m^3 (respirable fraction).[28,29] The OSHA PEL for respirable crystalline silica is based on the formula:

$$PEL = (10\ mg/m^3) / (\%\ SiO_2 + 2).$$[21]

When the material is 100% silica, the PEL is 0.098 mg/m^3, nearly equivalent to the TLV®.

Respirable and Total Airborne Dust

Excessive concentrations of dust in the air can reduce visibility; mechanically irritate the eyes, ears, nose, and throat; and increase susceptibility to disease or chemical toxins by contributing to injury of skin and mucus membranes.[30] OSHA has promulgated a PEL of 15 mg/m^3 for total PNOR and 5 mg/m^3 for respirable (smaller than 10 mm) PNOR.[21] ACGIH recommends that exposures to respirable Particulates Not Otherwise Classified (PNOC) not exceed 3 mg/m^3.[14] The definitions of PNOR and PNOC exclude materials containing greater than 1% crystalline silica. Since the dusts at

HAFO are known to contain greater than 20% crystalline silica, these evaluation criteria are not directly applicable to the sample results of this survey. They are presented here to provide perspective to the total dust sampling results and to aid in assessing the overall dustiness of the workplaces at HAFO.

Local Exhaust Ventilation

Evaluation criteria were obtained from the ACGIH Industrial Ventilation: A Manual of Recommended Practice, 20th edition.[19] The hoods were evaluated as custom made enclosing type hoods, utilized to control low toxicity materials associated with work that may be described as hand grinding operations. The specific print number used to assess the application was VS-412 (Figure 8).

ACGIH recommends a minimum face velocity of 100 feet per minute (fpm), and a volumetric flow rate of 150 - 250 cubic feet per minute (cfm) per square foot of hood floor area.[19] General design considerations from the Ventilation Manual, coupled with the nature of the contaminants generated in the fossil laboratory, were also considered in evaluating the hoods' performance.

RESULTS

Gamma Spectrometry

The gamma spectrometry results indicate that the soil at the Horse Quarry was no more radioactive than the soil from the opposite (Hagerman) side of the Snake River. All soil samples contained less than 1 pCi/g 238U in equilibrium with its daughters. A reported typical range for igneous and sedimentary rocks is 0.2 - 2 pCi/g.[31] These analyses also indicated that a sample of fossilized material (drawn from the pulverized remains of many separate fossil pieces) contained approximately 700 ± 200 pCi/g of gamma emitting radionuclides. Uranium containing minerals such as uraninite (86,000 - 229,000 pCi/gm), euxenite (8400 - 19,500 pCi/g), and carnotite (18,400 - 28,100 pCi/g) have been found to be much more radioactive than this.[32] It should be noted that individual fossils may widely vary in their radionuclide concentrations, and this result was an average of several different fossils.

Radon

Real-Time Measurements

Figure 5 illustrates hourly radon measurements recorded between May 14 and July 11, 1997. The hourly average radon concentrations and standard deviations were 7.7 ± 3.4 pCi/L in the collections room, 1.0 ± 0.3 pCi/L in the preparation laboratory, and 0.9 ± 0.3 pCi/L in the reception area.

Figure 6 illustrates the mean hourly average radon concentration determined for each of the three monitored areas. Radon concentrations in the preparation and general administration areas averaged around 1 pCi/L with minimal variation (<0.3 pCi/L). The collections room data were divided into work-day and weekend average concentrations. The average work-day concentration was 7.4 ± 3.8 pCi/L and the average weekend concentration was 8.2 ± 2.1 pCi/L.

Passive Measurements

Table 2 lists the results from the passive monitoring conducting between May 14 and July 23, 1997. The three detectors placed within fossil storage cabinets measured the highest radon concentrations, ranging between 128 and 500 pCi/L. The collections room, preparation laboratory, and reception areas measured average radon concentrations of about 8 pCi/L, 1.5 pCi/L, and 1.8 pCi/L respectively. Other monitors in the Administration Building and Visitor Center measured radon concentrations from below the MDC (0.4 pCi/L) up to 2.5 pCi/L.

Ionizing Radiation

Most area survey measurements using the Victoreen 450P were at or near background radiation levels.

The background rate (about 20 µR/hr) was determined outside the Administration Building away from any known sources of radiation. The only indication of slightly above background radiation levels (between 30 and 60 µR/hr) were found in localized areas in the collections room next to fossil storage cabinets and at the Horse Quarry next to fossils being excavated. These rates quickly dropped off to background levels within a foot or two from the localized area.

The surface contamination survey found no evidence of alpha emitting contamination nor any beta/gamma contamination on work surfaces in the Administration Building or the Visitor Center (see Figures 2 and 3 for locations). Measurements with the Ludlum data logger and pancake probe showed that fossils were more radioactive than soil, a finding consistent with the gamma spectroscopy results.

Personnel exposures to ionizing radiation were monitored with ring and whole-body TLDs. Some volunteers who were monitored began work after May 14, 1997, or terminated work before July 23, 1997. Not all volunteers worked full time. The length of time the TLDs were worn could not be determined since work-shift durations varied due to weather conditions, work load, and other factors, and diaries of activities performed while wearing badges were not kept.

All ring dosimeters issued to the workers during the survey period (May 14 - July 14, 1997) were below the LOD of 10 mREM. Workers' hands are closest to the source of radioactivity (fossils) for the longest period of time, so the hands are the part of the body most likely to receive an external dose of radiation. The whole body dosimeters are farther from the source of radioactivity, so it is unlikely that any whole-body dosimeter would measure a dose greater than the ring dosimeter. One whole body dosimeter did have a slightly positive result, an inconsistency which cannot be explained. The instrument survey data, coupled with the ring dosimetry results, indicates that external ionizing-radiation is not a significant hazard at HAFO.

Heat Stress

Workers typically wore boots, long pants, light colored (sometimes long-sleeved) shirts, and a hat when outdoors. The workers generally wore light colored cotton clothing, although the U.S. Park Service Ranger uniform is made from heavy material and has dark pants. No clothing correction was made to the WBGT, since most workers wore light summer clothing as customarily worn by workers when working under hot environmental conditions.[14]

The brushing and troweling of loose soil from fossil bones or using the laser transit can be considered light work, according to the ACGIH TLV® booklet.[14] Removing hard matrix from a fossil with a hammer and chisel, or carrying equipment and fossils between the Horse Quarry and the parking lot would constitute moderately intense work. Most trail building activities such as raking, hoeing, and using the power tiller, are heavy work. Similar Horse Quarry activities, such as moving soil with a pickax, shovel, and wheelbarrow, are also heavy work.

Due to a battery problem the Wibget® was operational only on July 23, 1997. The highest dry bulb temperature measured was 94° F, which is the average high temperature for this date.[5] WBGT measurements were taken at the Horse Quarry four times that day, and these results are plotted in Figure 7. Table 1 and Figure 7 indicate that, according to the ACGIH Heat Stress TLV®, on typical summer afternoons acclimated workers performing heavy work should be allowed to rest one half hour per half hour worked. An alternative would be to perform heavy work in the morning only.

At the Horse Quarry a tarpaulin was pitched like an open tent, and this was used as a break area. The WBGT under the tarp was 5° F cooler than the rest of the Horse Quarry (74° F vs. 79° F) on the afternoon of July 23, 1997. The hiking trail was being built in an area with no trees or other sources of shade, so breaks were taken under the sun. The preparation laboratory was located in an air

conditioned building where conditions were occasionally uncomfortable but not hazardous.
There is no formal heat stress program in place at HAFO - acclimatization, work rates, rest periods, and water intake are self-paced. No formal buddy-system exists, but rangers (who have radios linked to the local fire and police departments) on security patrol are the only workers alone in the field. All field crews (Horse Quarry, trail building, ranger field work, ranger patrol) maintain radio contact with the administration building and a cellular phone is present at the Horse Quarry if needed.

Bulk Silica

The soils of the Horse Quarry contained 20-25% crystalline silica (Table 3), indicating that airborne dust likely contained silica. The decision to monitor HAFO personnel for respirable crystalline silica was based on these results.

Respirable Crystalline Silica

The respirable crystalline silica monitoring results are presented in Table 4. A quantifiable amount of crystalline silica was detected on only one of ten filters. Nothing unusual was noted about the tasks or work habits of the individual with the quantifiable silica result.

Respirable Airborne Dust

Table 4 shows that the respirable (smaller than 10 mm) airborne dust results were an order of magnitude lower than the evaluation criteria for non-silica bearing dusts (5 mg/m^3 PEL, 3 mg/m^3 TLV®).[14,21] It should be noted that the high silica content of the bulk samples are an indication that the PNOR and PNOC criteria are not applicable, since these criteria do not protect against silicosis. These criteria are indicative of dust levels which would present housekeeping and mechanical irritation problems. The highest result was from the cyclone worn next to an invalid total dust filter, so the validity of this result remains in doubt.

Total Airborne Dust

Table 5 displays the results of the total airborne dust monitoring. All results were an order of magnitude lower than the evaluation criteria (15 mg/m^3 PEL), except one invalid filter.[21] This filter cassette contained an excessive amount of loose material, and the calculated dust concentration (188 mg/m^3) would be intolerable to work in. It should be noted that the high silica content of the bulk samples are an indication that the PNOR and PNOC criteria are not applicable to this environment, since these criteria do not protect against health hazards such as silicosis. Instead, these criteria are for dusts which cause only housekeeping and mechanical irritation problems.

Local Exhaust Ventilation

The hood located along the east wall of the preparation laboratory (referred to as the east hood) is an enclosed down draft bench top hood. This painted plywood hood has a two part hinged plexiglass top, with the second panel folding down at about a 45° angle on the front of the hood. This opening facilitates the placement and removal of fossils in the hood. A sliding front panel has two arm hole cutouts and can be moved from side to side to permit access to the entire hood interior. This hood has six sides (fully enclosed) and the exhaust take-off is located in the back floor of the hood. A side exhaust takeoff beneath the hood floor is connected to the fan by a 5.5' section of 6" diameter flexible aluminum duct. The axial fan, installed in the south exterior wall, is equipped with a metal discharge cover with flexible wind flap. There is no filter or other contaminant collection device.

The hood located along the south wall of the preparation laboratory(referred to as the south hood) is also constructed of plexiglass and plywood. This hood has two interchangeable plexiglass fronts, one with two arm holes (for cleaning fossils) and a second with only a 2" slot along the top (used when rendering animal carcasses). This hood has only four sides, as the counter top and laboratory wall serve as the floor and back of the hood. An axial wall fan is installed in the wall directly at the back of this second hood. This fan also has a discharge cover and wind flap, but no filter or contaminant collection device.

The hoods serve primarily to contain dust and small projectiles produced while cleaning fossils. Fossils and fossil fragments may also be varnished or glued together with Butvar® inside of the hoods, but control of these vapors was a secondary use of the hoods. The basic design of the hoods and the incorporation of fundamental contaminant control principles is sound, within the material, space, and resource limitations existing at the time of construction. Face velocities at the access openings (arm holes) to the hoods exceeded an ACGIH recommended minimum of 100 fpm with no one at the hood.[19] (See Table 6)

The south hood has no duct to allow leaks, so the hood exhaust rate and fan exhaust rate are equal. The latter was measured for convenience in calculating system volumetric flow rate. About 10% of the air exhausted by the east hood fan is due to leakage around the hood; the fan exhausts 149 cfm, while 134 cfm are pulled from the hood. The volume of air moving through the hoods per square foot of bench area is between 17 and 40 percent of the ACGIH minimum recommended flow volume for portable hand grinding hoods.[19] The hoods adequately enclose the work process, but ineffectively collect the primary contaminant, mineral dust. The axial fans in use are not designed for this application. The low volumetric flow rate and absence of a dust collector prevent the actual capture, transport, and removal of dust generated within the system.

Other

Several HAFO employees were seen wearing earplugs, respirators, gloves, and other personal protective equipment (PPE), sometimes incorrectly. In some instances PPE was not worn when needed (e.g. safety glasses at the Horse Quarry). There is currently no established PPE program, which is necessary for effective PPE use.

A general site safety training module is currently included in the new employee orientation, but recordkeeping of who was trained and what was covered are inadequate. The Safety Officer has not received Collateral Duty Safety Officer training required by Executive Order 12196.[33] This order requires all agencies of the Executive Branch to furnish employees a workplace free of recognized hazards that may cause death or serious physical harm. Additional requirements of this Executive Order include: assurance that periodic inspections of agency workplaces are performed by personnel with equipment and competence to recognize hazards; and provision of safety and health training for supervisory employees, employees responsible for conducting occupational safety and health inspections, all members of occupational safety and health committees where these are established, and other employees.

DISCUSSION

Gamma Spectrometry

The significance of the gamma spectroscopy results is that the source of the radioactivity occurs in the fossils, not the soil. The fossil gamma spectroscopy result can not be interpreted to be representative of any particular fossil. The sample was not a random collection of fossils and only one analysis was performed.

Radon

Figure 5 and Table 2 illustrate that the highest radon concentrations occur in the collections room. Elevated radon levels were not found in other monitored rooms. Factors influencing the high radon concentrations in the collections room include: (1) the amount of radioactive material in the fossils, (2) the mass of fossils stored in the cabinets, (3) the length of time the cabinets remain closed (permitting radon build-up), (4) the frequency and duration the cabinets remain opened (allowing radon release), and (5) the lack of mechanical ventilation of the room. The monitoring data in Table 2 clearly demonstrate that radon concentrations inside the cabinets can build-up to levels exceeding 100 pCi/L.

Three observations were made concerning the daily patterns of radon concentration seen in Figure 6. First, a diurnal pattern was seen as the average hourly radon concentration increased in the early morning to mid-afternoon and then decreased into the late evening. This pattern is often seen in radon monitoring results, and is due to barometric pressure, temperature, and wind changing the rate of natural ventilation of the building. Second, the workday hourly averages show a decrease after 8:00 a.m. which is not seen in the weekend results. This change is due to the opening of doors as employees arrive in the morning, which apparently releases some of the radon to the outdoors. Thirdly, the work-day average radon concentrations exceed weekend averages for several hours in the early afternoon. This is probably due to work activities in the collections room during a typical work-day. For example, workers returning from the Horse Quarry may open storage cabinets to move, store, or retrieve fossils which releases radon into the collections room. The afternoon phenomenon did not appear to affect the reception area averages. However, the preparation laboratory, which is the only access to the collections room, did have concentrations slightly above the administration area during this period.

The real-time and passive monitoring data were consistent. In the collections room, the real-time method measured an average radon concentration of 7.7 pCi/L, while the passive detectors measured 8.1 and 8.2 pCi/L. In the preparation and reception areas the real-time measured average radon concentrations were 1.0 and 0.9 pCi/L, while the passive detectors measured 1.6 and 1.8 pCi/L respectively.

These results may not reflect radon concentrations during other times of the year, since data were collected only during a two month period between May and July 1997, and work activities at HAFO change with the seasons. This seasonal workload variation may substantially change the radon concentrations inside the administration building, especially in the collections room. Many of the workers at HAFO are visiting scientists, seasonal workers, or volunteers who work part time or for short duration. A more complete evaluation of the potential radon hazard at HAFO would require tracking when and where these transient people work as well as seasonal radon monitoring.

A comparison to the EPA recommendations regarding radon exposures can be used to illustrate the degree of hazard present at HAFO, keeping in mind that the EPA recommendations concern radon concentrations in the home. The EPA recommends that remedial actions be initiated when the average radon concentration level exceeds 4.0 pCi/L.[22] Since the collections room is the only location exceeding this limit, it would be recommended for remedial action. The source of radon in this room is from radioactive fossils in the collections cabinets, so remedial efforts should focus here.

In the practice of industrial hygiene, health hazards are abated with administrative controls, engineering controls, and use of personal protective equipment. Several mineral museums have reduced radon exposures with administrative controls such as storing uranium-bearing minerals in unoccupied areas and restricting access to these areas. While these policies may be applicable to HAFO, they rely on human behavior and only reduce the duration (not the intensity) of exposure. Engineering controls are preferred as the primary means of hazard control since they do not necessarily rely upon human behavior and can reduce the intensity of exposure.

One engineering control used in mineral museums to control radon levels would be to move all fossil storage cabinets to a dedicated room with dedicated ventilation exhausted to the outdoors.[32-38] This could be accomplished by installing a fan in the exterior wall of the collections room and an air supply grate in the door (to prevent air starvation of the fan). Lambert suggested 3-4 air changes per hour, which would be about 75-100 cfm for a collections room estimated as 6' x 8' x 30'.[34] The required ventilation rate will depend on the desired control level and the radon generation rate, which in turn will be determined by the mass of fossils stored, the amount of radium in the fossils, and the radon emanation fraction (proportion of radon that exits the fossil). The radon emanation fraction of processed fossils might be reduced by applying one or more coats of Butvar® to the surface of the fossils after all the matrix has been removed.

The most effective control would be to provide exhaust ventilation for individual storage cabinets, since this would control the radon at its source. This could be accomplished with a single fan connected to each cabinet via a manifold. A continuously running system would be simpler, but a purge system (operated immediately before opening a cabinet) might be desirable due to fossil preservation concerns. A purge-before-open system might also require an interlock system to prevent the opening of unpurged cabinets. Designing a manifold exhaust ventilation system into a new building would likely be easier and more cost effective than retro-fitting a system to the current building.

Ionizing Radiation

This initial survey was performed to determine whether external radiation exposures at HAFO present a significant health hazard. The survey instruments, ring badges, and whole body badges indicated that external radiation exposures at HAFO were low. No explanation could be found for the single positive whole body badge, since the same worker's ring badge (like all of the ring badges) did not detect any radiation exposure to the hands, and the hands are closer to the radiation sources (fossils) than the whole body badge worn on the chest.

Since the soil does not contain elevated levels of radionuclides, inhalation and ingestion of soil dust are not routes of internal radiation exposure. Workers take great care to avoid damaging the fossils while cleaning them, so matrix removed during this process contains little or no fossil material. No special precautions to minimize internal radiation exposure need be taken when handling the matrix removed from the fossils.

The fossilized bones contain radioactive elements from the uranium decay series (Appendix). Internal radiation exposures could theoretically occur from direct handling of fossils (material rubbing off onto a person's hands), from ingestion of this material, or from inhalation of airborne fossil dust. Due to the care taken when cleaning the fossils, very little fossil material is removed and airborne fossil dust is negligible. Furthermore, the hoods contain airborne dust when fossils are cleaned inside them. Also, current good laboratory practices (washing of hands after handling fossils and prohibiting food and drink in fossil handling areas) will interrupt the other internal exposure pathways. For these reasons, and since no detectable surface contamination was found, internal radiation exposures are expected to be low. Any removable radioactivity of processed fossils would be fixed by applying one or more coats of Butvar® to the fossil surface after the specimen has been cleaned.

Heat Stress

July and August are usually the warmest time of year in Hagerman, with daily high temperatures in the low 90's.[5] The number of workers, types of workers, production level, activities, and weather observed during the July site visit were considered typical for the time of year. The Horse Quarry and trail site were both staffed at normal levels, and no unusual operations were being performed. Conclusions drawn from this visit will be applied to normal conditions during the entire hot season at HAFO, even though all measurements were taken over a two day period.

The workforce at HAFO includes individuals with a known risk factors for heat disorders (i.e. lack of heat acclimatization). Volunteers, visiting scientists, and other short term workers may only stay for a week or two, which is about the time it takes to acclimatize to hot conditions. These people may come from cooler climates, lead sedentary lives, or have other known risk factors for heat disorders. Such people typically work full shifts from the start of their assignment, with no formal acclimatization schedule. It is unsafe to place them in a hot desert environment, miles away from medical help, for eight hour shifts of outdoor work. The ACGIH heat stress TLV® recommendations are for acclimatized workers, so they may not be sufficiently protective for all HAFO workers.[14]

Figure 7 and Table 1 show that typical summer afternoons at the Horse Quarry are hot enough that ACGIH would recommend workers doing heavy work receive a half-hour of break time per hour. For workers not yet adapted to hot conditions, appropriate precaution would be to lower the thresholds for heavy work by 7° F, the thresholds for moderate work by 5° F, and the thresholds for light work by 3° F.[27] Such precautions would require extra break time for new workers performing intermediate work in the afternoon, and would restrict new workers from performing heavy work in the afternoon.

The WBGT was not measured at the trail building site, but since the site is sheltered from any wind (below the canyon rim), this work site may be hotter than the hilltop Horse Quarry. There are no trees or other sources of shade. Some trail workers wore nuisance dust masks which, like any negative pressure respirator, add to heat stress by increasing breathing resistance and breath recirculation. Most of the trail building activities are heavy work, so exposures to heat at this worksite probably exceed what is recommended by ACGIH. If so, these workers have an elevated risk of suffering from one of the heat disorders described in the Evaluation Criteria and Toxicology section of this report. The remote location of this worksite would make a medical evacuation difficult and time consuming.

The hot climate, remote locations, and presence of vulnerable workers at HAFO indicate that a formal heat stress program is necessary. Current practices at HAFO, such as maintaining radio contact with field teams, allowing work to be self-paced, and dressing appropriately for hot conditions, should be written into a comprehensive heat stress program. Such a program can stand alone or exist as part of the current health and safety program.

Bulk Silica

The high crystalline silica content of the soils at the Horse Quarry demonstrates that there is potential for exposures to airborne silica. Components of soil differ in hardness, density, particle size and other properties. Therefore these results do not indicate that the airborne dust at the Horse Quarry contains the same amount of crystalline silica as does the soil.

Respirable Crystalline Silica

Airborne dust at HAFO likely contains silica, since windblown dust is often visible and the parent material of this dust (soil) is known to contain silica. The hand tools used by HAFO workers are a low energy mechanical process, and thus tend to generate large particles of dust. In contrast, it is exposure to the respirable (smaller than 10 µm) crystalline silica particles that are a health hazard. Exposures to respirable crystalline silica at the Horse Quarry seem to be low, since only one of nine measurements detected a measurable amount of silica. These results indicate that the concentration of respirable crystalline silica, averaged over the entire workday, was less than the minimum detectable concentration (about 0.01 mg/m^3)

Only one worker on the trail building crew was monitored for exposure to respirable crystalline silica, so no conclusions can be drawn. Silica exposures were not considered to be a concern at the fossil preparation laboratory. This conclusion was based upon the low total dust results from air samples taken during the May 1997 visit, the absence of windblown dust, and the use of the hoods to contain airborne dust. No sampling was performed in the preparation laboratory for airborne respirable silica.

Respirable and Total Airborne Dust

The dust concentrations measured at the Horse Quarry are unlikely to cause eye, skin, and other physical irritation. Extreme conditions could lead to dust-induced eye, throat, or other irritation. Indeed, occasionally the Horse Quarry is closed due to high winds and windblown dust. Other potential sources of overexposure are the filling/dumping of wheelbarrow loads and the sifting of soil. Most of the dust at the Horse Quarry seemed to be due to the wind, rather than due to the excavation.

Unlike the Horse Quarry, most of the dust at the trail building site seemed to result from the activities of the workers. Using the power tiller was by far the dustiest activity at HAFO. In general industry, water is often used to control dust, but this is not feasible in this remote desert location. The dust masks worn by the trail building crew are an appropriate means of preventing nose and throat irritation when worn correctly by properly trained individuals. Safety glasses stop projectiles from entering the eye, but do not protect the eyes from dust like goggles can.

The preparation laboratory was a cluttered, dusty place during the first visit, with accumulated dust that could become airborne and be inhaled. Conditions were much improved during the second visit, due to improved housekeeping and the replacement of dry cleaning methods (sweeping) with wet ones (wiping with damp cloths or sponges). As long as fossil preparation work is performed in the hoods and current good housekeeping practices are maintained, dust exposures in the preparation laboratory are not expected to be problematic.

Local Exhaust Ventilation

Two custom hoods in the preparation laboratory are used to contain dust and particulate generated during the removal of matrix from fossil bones. The hoods have inadequate capacity to actually remove dusts generated during the cleaning of fossils, and thus are suitable only for materials having negligible toxicity. Although the matrix contains a large proportion of silica, these processes most likely generate only small amounts of the respirable silica particulate thought to be a health hazard. By containing dust and projectiles, the hoods make housekeeping easier and control a potential eye hazard. It would be desirable that all fossil preparation take place inside the hoods, but the small size and number of the hoods currently prevents this. Good practice would be to use the hoods when applying Butvar® to fossils (other than small repairs), since this will at least partially control acetone vapors.

The hoods incorporate good basic design features, and function adequately as presently used to contain low toxicity particulate, but they do not fully conform to ACGIH recommended design criteria. The major shortcoming of the hoods is the use of axial fans. Axial fans are generally not suitable for use in configurations requiring air to be pulled through the ventilation system (e.g., hoods and duct work).[19] These fans are used when the objective is high volume flow rates at low pressure. The inadequacy of the fans is the primary cause of the low volumetric air flow rates in the hoods. Upgrading the hoods to meet volumetric flow criteria recommended by ACGIH would require significant modification and expense. A filter or other air cleaner, new fan (or fans), and ductwork would be required, and the south hood would need installation of a floor and rear wall.

Future facilities should include hoods of sufficient design, flexibility, and size to accommodate the array of matrix removal operations conducted in the preparation laboratory. One approach would be to start with the portable hand grinding hood configuration (VS-412, see Fig. 8) in the ACGIH Ventilation Manual.[19] The grilles in the floor of such a hood should be large enough that the fossil being cleaned does not unduly constrict air flow into the hood. A minimum duct velocity of 3500 fpm with an air flow of between 150 to 250 cfm of air per square foot of bench area is recommended. Equal air flow distribution and a clean out drawer for large particulate and fossil fragments would be required. Back and side shields would be desirable to help contain projectiles and aid in the collection of dust.

The addition of a top to the hood shown in Figure 8 would make a booth similar to those currently in use. An minimum air flow of 100 cfm per square foot of bench area or a face velocity of 100 feet per minute is recommended for the booth configuration. An enclosed booth would be most effective at controlling dust and projectiles, but would be least flexible for cleaning large fossils.

The enclosed hoods currently in use cannot accommodate large fossils, such as the three foot diameter aggregate of horse pelvis, smaller fossils, and matrix observed during the site visits. A portable chipping and grinding table configuration (VS-413, see Fig, 9) might be useful for such bulky specimens. A minimum duct velocity of 3500 fpm with air flow of 150 cfm per square foot of hood face should be maintained. Provisions for equal air flow distribution and a clean out drawer for large particulate and fossil fragments are shown in Figure 9. The addition of a transparent cover to contain stray projectiles may add significantly to the complexity and pressure drop across the system. The introduction of mandatory eye protection may be more appropriate.

Other

PPE is the least desirable method for reduction of worker exposures. It should be considered only when engineering controls are not feasible or are insufficient. Current HAFO policy is to have gloves, nuisance dust masks, ear plugs, and other PPE available to employees. This practice implies that a recognized health hazard exists in the workplace, but does not describe which hazards the equipment is to protect employees from.

Furthermore, NIOSH investigators witnessed improper use of PPE (respirator use by bearded employee, inadequate insertion of earplugs). This indicates that employees are not trained in the proper wearing and use of PPE, and that the PPE is not reducing exposures to the fullest extent possible. Use of PPE as a means of employee protection also carries risks, such as ear infections (dirty earplugs), allergic dermatitis (latex gloves) and heat stroke (respirators in hot environments). Elements of a successful PPE program are specified in 29CFR1910 Subpart I (PPE).[39]

A properly trained safety officer would have expertise and/or education in topics such as personal protective equipment, and would be accountable when decisions such as the current PPE policy were instituted. Such a person could ensure correction of the deficiencies noted in this report and could provide HAFO employees with a workplace free from recognized hazards as specified in Executive Order 12196.[33] The current staff are to be commended for their efforts to address previous NIOSH recommendations, but the lack of a trained collateral duty safety officer on site has hampered their response.

CONCLUSIONS

Gamma Spectroscopy

Normal levels of radionuclides from the 238U decay series were found in the Horse Quarry soil. Elevated concentrations of radioactive elements were found in the Horse Quarry fossils.

Radon

Radon exposure in the collections room represents the greatest radiological hazard at HAFO. The elevated radon concentrations in the collections room originate from the radioactive fossils kept in the storage cabinets.

Ionizing Radiation

External ionizing radiation exposures are at or near background levels and pose little risk to health. Current good laboratory practices limit internal exposures to negligible levels.

Heat Stress

Some workers may be overexposed to hot conditions during typical summer afternoons. All outdoor workers at HAFO are exposed to hot conditions severe enough to warrant inclusion in a formal heat stress management program.

Respirable Crystalline Silica

The high (20% - 25%) silica content of the soil means that silica exposures potentially exist. Under current conditions and practices, actual silica exposures are limited to very low concentrations.

Respirable and Total Airborne Dust

Airborne dust exposures are low under most conditions. Concentrations of dust can be high enough to cause nuisance effects during windy conditions, when loading/unloading the wheelbarrow with soil, when sifting soil at the Horse Quarry, and when using the power tiller at the trail building site.

Local Exhaust Ventilation

The custom hoods are adequate to physically contain dust and projectiles, thus contributing to housekeeping and safety. The axial fans in use provide inadequate flow rates to capture and transport dust out of the hoods and there are no dust collectors to clean the exhausted air.

Other

The current informal PPE program leads to improper usage of PPE, which in itself may lead to illness or injury. A properly trained Safety Officer is needed at HAFO.

RECOMMENDATIONS

Radon

1. Minimize the amount of fossils stored, dispose of scientifically unnecessary specimens;
2. Apply one or more coats of Butvar® to fossils after cleaning;
3. Store fossils in unoccupied, mechanically ventilated rooms;
4. Open one cabinet at a time, only open cabinets when placing or retrieving fossils, and minimize time spent in these areas;
5. Label cabinets and rooms containing radioactive fossils. Each sign should include "Caution, Radioactive Material", the trefoil radiation symbol, and "Radon Area";
6. Begin a quarterly passive radon monitoring program, including the collections room, preparation laboratory, office areas, and inside the cabinets. Other buildings storing fossils should be included in such a program, with monitors in fossil storage areas and nearby work areas;
7. Future facilities should be designed with a designated fossil storage room, with a dedicated ventilation system to exhaust the room or the individual collections cabinets.

Ionizing Radiation

1. Apply one or more coats of Butvar® to fossils after cleaning;
2. Continue to require good laboratory practices such as handwashing after handling fossils, and prohibition of food, drink, tobacco, and storage of personal items in fossil handling areas.

Heat Stress

A formal heat stress control program should be instituted to reduce the risk of heat disorders in workers. At a minimum, such a program should contain the following:[25,39]

1. Provisions for assessing heat stress and heat alerts;

2. Medical questionnaire to screen for conditions that increase heat strain;
3. Training for all field workers covering: the causes, symptoms, predisposing factors, prevention and first aid for heat disorders. Training should also include methods used by HAFO to control heat exposures;
4. Record keeping - who was trained, when, what was covered, how proficiency was tested;
5. Methods HAFO will use to control excessive exposures to heat, which may include provision of water, acclimatization schedules, work/rest regimens, radio contact and buddy systems and, heat alerts.

Local Exhaust Ventilation

Continue to use the existing hoods during fossil preparation, Butvar® application, and carcass rendering. Future facilities should be designed to meet peak seasonal demands on work space, with sufficient number and sizes of hoods. Local exhaust ventilation systems should include:

1. Hood designed to accommodate varying sizes of fossils and workers;
2. Roughing filter, screen, or trap below the work surface to capture small fossil fragments;
3. Dust collection device (filter or cyclone) upstream from fan;
4. Duct system and air handling unit designed and selected to provide sufficient capture velocity, transport velocity, and air flow volume.

Sufficient heated or cooled (depending on season) replacement air should be provided to approximate the total air flow rate removed from the laboratory by exhaust ventilation systems. Laboratory areas which share a building with other uses (e.g, office space) should be under negative pressure relative to the non-laboratory areas.

Other

A PPE program should be created in accordance with 29CFR1910 Subpart I (Personal Protective Equipment), including:[39]

1. Hazard assessment;
2. Documented rationale for choosing the selected PPE;
3. Employee training covering what PPE to use; when it should be used; donning, doffing, adjusting, and wearing; care, maintenance, and disposal; and limitations of the PPE.

The Safety Officer should receive Collateral Duty Safety Officer training, and other occupational health and safety training as needed, as specified in Executive Order 12196.[33]

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Appendix
Uranium Decay Series, ^{238}U (4n+2)†

Nuclide	Half-Life	Major Radiation Energies (MeV) and Intensities‡					
		α		β		γ	
		MeV	%	MeV	%	MeV	%
$^{238}_{92}U$ ↓	4.468 x 10^9 y	4.15 4.20	22.9 76.8			0.0496	0.07
$^{234}_{90}Th$ ↓	24.1 d			0.076 0.095 0.096 0.1886	2.7 6.2 18.6 72.5	0.0633 0.0924 0.0928 0.1128	3.8 2.7 2.7 0.24
$^{234m}_{91}Pa$ ↓	1.17 m			2.28	98.6	0.766 1.001	0.207 0.59
99.87% $^{234}_{91}Pa$ ↓ 0.13% $^{234}_{91}Pa$ IT ↓	6.7 h			22 βs E Avg = 0.224 Emax = 1.26		0.132 0.570 0.883 0.926 0.946	19.7 10.7 11.8 10.9 12.0
$^{234}_{92}U$ ↓	244,500 y	4.72 4.77	27.4 72.3			0.053 0.121	0.12 0.04
$^{230}_{90}Th$ ↓	7.7 x 10^4 y	4.621 4.688	23.4 76.2			0.0677 0.142 0.144	0.37 0.07 0.045
$^{226}_{88}Ra$ ↓	1600 ± 7 y	4.60 4.78	5.55 94.4			0.186	3.28
$^{222}_{86}Rn$ ↓	3.823 d	5.49	99.9			0.510	0.078
$^{218}_{84}Po$ ↓	3.05 m	6.00	~100	0.33	0.02	0.837	0.0011
99.98% $^{214}_{82}Pb$ ↓ 0.02% ↓	26.8 m			0.67 0.73 1.03	48.0 42.5 6.3	0.2419 0.295 0.352 0.786	7.5 19.2 37.1 1.1
$^{218}_{85}At$ ↓	2 s	6.66 6.7 6.757	6.4 89.9 3.6			0.053	6.6
$^{214}_{83}Bi$ ↓	19.9 m	5.45 5.51	0.012 0.008	1.42 1.505 1.54 3.27	8.3 17.6 17.9 17.7	0.609 1.12 1.765 2.204	46.1 15.0 15.9 5.0

Appendix (continued)
Uranium Decay Series, ^{238}U (4n+2)†

Nuclide	Half-Life	Major Radiation Energies (MeV) and Intensities‡					
		α		β		γ	
		MeV	%	MeV	%	MeV	%
99.979% ↓ $^{214}_{84}Po$; 0.021% ↓	164 µs	7.687	100			0.7997	0.010
$^{210}_{81}Tl$ ↓	1.3 m			1.32 1.87 2.34	25.0 56.0 19.0	0.2918 0.7997 0.860 1.110 1.21 1.310 1.410 2.010 2.090	79.1 99.0 6.9 6.9 17.0 21.0 4.9 6.9 4.9
$^{210}_{82}Pb$ ↓	22.3 y	3.72	0.000002	0.016 0.063	80.0 20.0	0.465	4.0
$^{210}_{83}Bi$ ↓	5.01 d	4.65 4.69	0.00007 0.00005	1.161	~100		
~100% $^{210}_{84}Po$ ↓ ; 0.00013% ↓	138.378 d	5.305	100			0.802	0.0011
$^{206}_{81}Tl$ ↓	4.20 m			1.571	100	0.803	0.0055
$^{206}_{82}Pb$	Stable						

y = Year
d = Day
h = hour
m = minute
s = second
µs = microsecond (10^{-6} s)

α = alpha decay
β = beta decay
γ = gamma decay
IT = Internal transition
MeV = million electron volts

† This expression describes the mass number of any member in this series, where n is an integer. For example: ^{206}Pb (4n+2)...4(51) + 2 = 206.

‡ Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series. Gamma %s in terms of observable emissions, not transitions.

ABBREVIATIONS AND TERMS

acclimatization
(see heat acclimatization.)
ACGIH
American Conference of Governmental Industrial Hygienists
alpha particle
Form of radiation composed of two protons and two neutrons. Stopped by a sheet of paper, won't penetrate skin.
Becquerel
(Bq) Unit of radioactivity equal to one nuclear transformation per second.
beta particle
Form of radiation identical to an electron. Stopped by a thin sheet of aluminum.
carcinogen
Agent that causes cancer.
CFM
Cubic feet per minute
CFR
Code of Federal Regulations
Curie
Special unit of radioactivity equal to 3.7×10^{10} disintegrations per second.
dry bulb temperature
Air temperature as it is usually taken with a thermometer.
EPA
Environmental Protection Agency
FPM
Feet per minute
gamma ray
Form of radiation composed of massless photons. Stopped by thick sheets of lead or concrete.
globe temperature
Temperature measured by a thermometer placed in the center of a blackened, hollow, thin copper globe. A measure of radiant (infrared) heat.
HAFO
Hagerman Fossil Beds National Monument
heat acclimatization
Physiologic changes which reduce the heat strain (of the body) caused by heat stress (of the environment). Acclimatization occurs in response to a succession of days of exposure to environmental heat stress.
heat exhaustion
Heat disorder characterized by weakness, fatigue, confusion, nausea, and continued sweating (pale, clammy skin).
heat strain
Net physiological load due to heat stress, level of heat acclimatization, degree of hydration, underlying medical conditions, and other factors.

heat stress

Net heat load on the body due to metabolic (internal) heat, air temperature, wind speed, humidity, radiant heat (sunlight) and clothing.

heat stroke

Failure of the body's temperature regulation mechanism, resulting in a dangerous rise in body temperature (above 106 °F). Symptoms of this potentially fatal medical emergency include lack of sweating (hot, dry skin), nausea, dizziness, and unconsciousness.

IARC

International Agency for Research on Cancer

ICRP

International Commission on Radiological Protection

ionizing radiation

Radiation with enough energy to remove electrons from (ionize) matter.

LOD

Limit of detection

LOQ

Limit of quantitation

MDC

Minimum detectable concentration

µm

A micrometer is one millionth of a meter. There are about 3940 µm in an inch.

mREM

A milliREM equals one one-thousandth of a REM.

Q MC

Minimum quantifiable concentration

NCRP

National Council on Radiation Protection and Measurements

NIOSH

National Institute for Occupational Safety and Health, part of the Centers for Disease Control and Prevention in the U.S. Department of Health and Human Services

NPS

National Park Service

NRC

Nuclear Regulatory Commission

NTP

National Toxicology Program

NVLAP

National Voluntary Laboratory Accreditation Program

OSHA

Occupational Safety and Health Administration, part of the U.S. Department of Labor

pCi

A pico-curie is equal to one trillionth of a curie (1×10^{-12} Ci).

PEL

Permissible Exposure Limit (OSHA)

photon

Massless form of radiant energy.

pneumoconiosis
Scarring of lungs caused by long term inhalation of dusts.
PNOC
Particulates Not Otherwise Classified (ACGIH). Dust particles that do not scar the lungs, change the architecture of the air spaces in the lungs, nor cause any irreversible tissue reaction.
PNOR
Particulates Not Otherwise Regulated (NIOSH, OSHA). Dust particles, both organic and inorganic, not governed by a specific OSHA regulation.
PPE
Personal protective equipment
PVC
Polyvinyl chloride
radiation
A way that energy is release from matter and travels through space.
radioisotope
Radioactive form of an element.
radon
Element 86 (symbol Rn), a colorless, odorless, radioactive noble gas.
radon daughter
Also radon progeny. Short-lived radioisotopes formed by the radioactive decay of radon.
REL
Recommended Exposure Limit (NIOSH)
REM
Roentgen Equivalent Man is a unit of absorbed radiation dose that takes into account different weighting factors for different types of radiation.
Sv
Seivert is a unit of absorbed radiation dose that takes into account different weighting factors for different types of radiation. 1 Sv = 100 REM.
TLD
Thermoluminescent detector
TLV®
Threshold Limit Value (ACGIH)
TWA
Time-weighted average
uranium daughter
Radioactive elements formed by the radioactive decay of uranium. (See Appendix)
WBGT
Wet-Bulb Globe Temperature is a heat stress index that takes into account the dry bulb, wet bulb, and globe temperatures.
wet bulb temperature
The lowest temperature to which ambient air can be cooled by (natural) evaporation of water. Measured with a thermometer placed in a wetted sock-like wick.

Table 1
HETA 96-0264
Hagerman Fossil Beds National Monument

Heat Stress TLV®'s (°F WBGT)[A]			
Work/Rest Regimen	Light Work[B] (150-250 kcal/hr)	Moderate Work[B] (250-450 kcal/hr)	Heavy Work[B] (>450 kcal/hr)
Continuous Work	< 86.0	< 80.0	< 77.0
15 min. rest each hr	86.0 - 87.0	80.0 - 82.5	77.0 - 79.0
30 min. rest each hr	87.0 - 89.0	82.5 - 85.0	79.0 - 82.5
45 min. rest each hr	89.0 - 89.5	85.0 - 88.0	82.5 - 86.0

[A] For each wet-bulb globe temperature (WBGT) the TLV® indicates a work/rest regimen "under which it is believed that nearly all heat acclimatized, adequately hydrated, unmedicated, healthy workers wearing light-weight summer clothing may be repeatedly exposed without adverse health effects." (Ref. 14)

[B] Brushing and troweling of loose soil from fossil bones is an example of light work. Using a hammer and chisel to remove hard matrix from a fossil bone would constitute medium work. An example of heavy work is removing overburden with a pickaxe.

Table 2
HETA 96-0264-2710
Hagerman Fossil Beds National Monument

Passive Radon Monitoring Results

Monitor #	Type	Location[A]	Results (pCi/L)[B]
Administration Building			
1	Landauer	Collections Room, Inside Cabinet 1	380
2	Landauer	Collections Room, Inside Cabinet 7	500
3	Landauer	Collections Room, Desk	8.1
4	Landauer	Collections Room, Back Wall	8.2
5	Alpha-Spectra	Preparation Room, Inside Cabinet	128
6	Alpha-Spectra	Prep. Rm. near Door to Collections Room	1.9
7	Landauer	Preparation Room, near Door to Hallway	1.9
8	Landauer	Reception Area	1.8
9	Landauer	Library	0.4
10	Landauer	Office	2.5
Visitor Center			
11	Alpha-Spectra	Office	2.5
12	Alpha-Spectra	Audio/Video Room	1.6
13	Alpha-Spectra	Auditorium	< MDC[C]
14	Alpha-Spectra	Exhibit Area	< MDC[C]

[A] See Figures 1 and 2 for diagrams of monitoring locations.
[B] Results presented as picoCuries of Radon activity / liter of air.
[C] <MDC means result was less than the Minimum Detectable Concentration (0.4 pCi/L).

Table 3
HETA 96-0264-2710
Hagerman Fossil Beds National Monument

Silica Content of Soil Samples	
Sample Site	% Silica by Mass
Horse Quarry - North end of floor	25%
Horse Quarry - South end of floor	23%
Horse Quarry - North end of back wall (fossil-bearing layer)	21%
Horse Quarry - salvage pile	24%
Horse Quarry - matrix around fossil bone[A]	20%
Snake River Public Access Site - Hagerman side of river	16%

[A] Sample was gathered at the fossil preparation lab, but was originally excavated from the Horse Quarry.

Table 4
HETA 96-0264-2710
Hagerman Fossil Beds National Monument

Cyclone Results

Date	Work Locations	Work Activities	Sample Period (minutes)	Respirable Concentration (mg/m^3) Particulate	Silica
7/24/97	Horse Quarry	digging with brush, trowel; surveying	519	0.08	< MDC[A]
7/24/97	Horse Quarry	digging with brush, trowel; surveying; earthmoving (shovel & wheelbarrow)	525	0.03	< MDC[A]
7/23/97	Horse Quarry	digging with brush, trowel; surveying	428	0.09	< MDC[A]
7/23/97	Horse Quarry	digging with brush, trowel; surveying; earthmoving (shovel & wheelbarrow)	414	0.06	< MDC[A]
7/23/97	Horse Quarry	digging with brush, trowel; surveying	420	0.13	< MDC[A]
7/24/97	Horse Quarry	digging with brush, trowel; surveying; earthmoving (shovel & wheelbarrow)	525	0.09	0.04
7/23/97	Horse Quarry	digging with brush, trowel, hammer & chisel; surveying	420	0.06	< MDC[A]
7/24/97	Field	trailbuilding with shovel, rake, hoe	481	0.22	trace[B]
7/24/97	Horse Quarry	digging with brush, trowel, hammer & chisel; surveying	510	0.02	< MDC[A]
7/24/97	Horse Quarry	digging with hammer & chisel, pickax & shovel; earthmoving (shovel & wheelbarrow)	493	0.04	< MDC[A]

A < MDC means that sample was less than the Minimum Detectable Concentration (approximately 0.012 mg/m^3).
B Trace means that sample was greater than the MDC, but less than the minimum quantifiable concentration (0.037 mg/m^3).

Table 5
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Total Airborne Particulate

Date	Work Location(s)	Work Activities	Sample Period (Minutes)	Conc. (mg/m^3)	Remarks
5/14/97	Visitor Center	handling modern bones & fossils; desk work	453	0.05	
5/14/97	Visitor Center Admin. Bldg. Field	moving fossils; desk work; capturing crawfish	500	0.52	
5/14/97	Field	hiking, collecting water samples	500	0.26	
5/14/97	Prep Lab	cleaning fossils w/dental picks, toothbrushes	421	0.20	In East hood
5/15/97	Prep Lab	cleaning fossils w/dental picks, toothbrushes	480	0.10	In East hood
5/15/97	Prep Lab	cleaning fossils w/dental picks, toothbrushes	512	0.10	Area sample, above East hood
5/15/97	Prep Lab	cleaning fossils w/dental picks, toothbrushes, hammer & chisel	469	0.68	Corner table, no hood
5/15/97	Prep Lab	cleaning fossils w/dental picks, toothbrushes, hammer & chisel	512	0.24	Area sample, above corner table
7/23/97	Horse Quarry	digging with brush, trowel, hammer & chisel; surveying	420	0.49	
7/23/97	Horse Quarry	digging with brush, trowel; surveying	420	0.35	
7/23/97	Horse Quarry	digging with brush, trowel; surveying	428	0.45	
7/23/97	Horse Quarry	digging with brush, trowel; surveying; earthmoving (shovel & wheelbarrow)	414	0.44	

Total Airborne Particulate					
7/24/97	Field	trailbuilding with shovel, rake, hoe	480	187.90	Invalid sample (Loose material inside filter cassette)
7/24/97	Horse Quarry	digging with brush, trowel; surveying; earthmoving (shovel & wheelbarrow)	528	0.54	

Table 6
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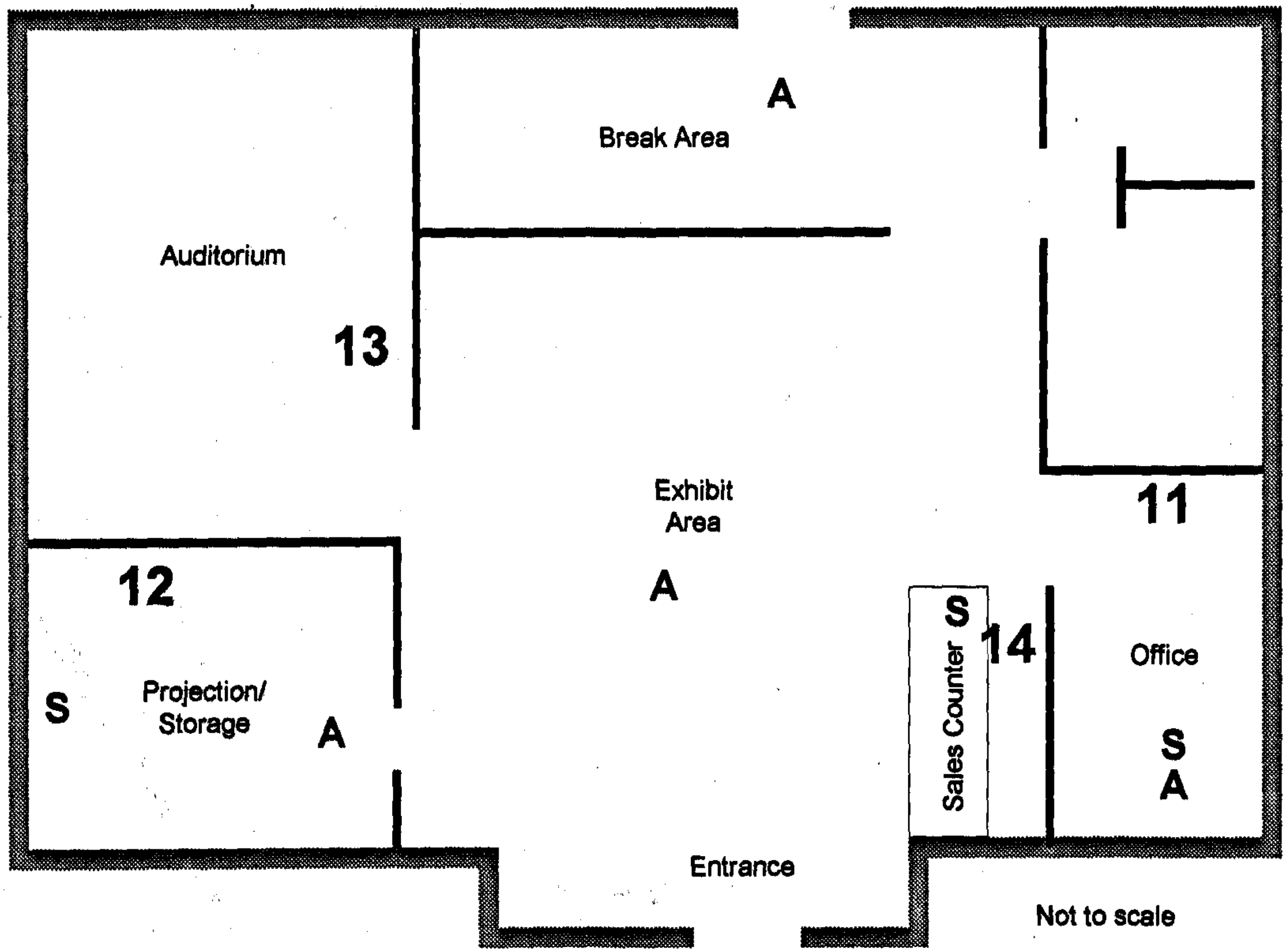
Hagerman Fossil Beds National Monument

Local Exhaust System Ventilation Measurements[A]

Hood	Front Panel Configuration	Face Velocity (fpm)[B] Left	Right	Volumetric Flow Rate (cfm)[C]	Volumetric Flow / Bench Area (cfm/ft^2)[D]
East	Arm holes	183	196	134[E]	25
	None	90		[F]	
South	Arm holes	238	193	262[G]	44
	Slot at top	220		355[G]	60
Rec.[H]		100			150-250

[A] Hood lid closed, no worker in place.
[B] Linear velocity in feet per minute of air into hood face.
[C] Volumetric flow rate in cubic feet per minute of air exhausted from hood.
[D] Volumetric flow rate (in cubic feet per minute) per square foot of hood floor area.
[E] Measured at hood discharge.
[F] Not measured; hood is not used without front panel.
[G] Measured at fan discharge; equivalent to hood discharge since system has no ductwork.
[H] Recommended ranges according to Reference 19.

Figure 1
Radon Monitoring Locations
Hagerman Fossil Beds National Monument Visitor Center
HETA 96-0264-2713
May 14 - July 23, 1997



1, 2, 3 . . .
Passive Radon
Detector

A
Area Radiation
Measurement

S
Surface Radiation
Measurement

Not to scale

Figure 2

Radon Monitoring Locations

Hagerman Fossil Beds National Monument Administration Building

HETA 96-0264-2713

May 14 - July 23, 1997

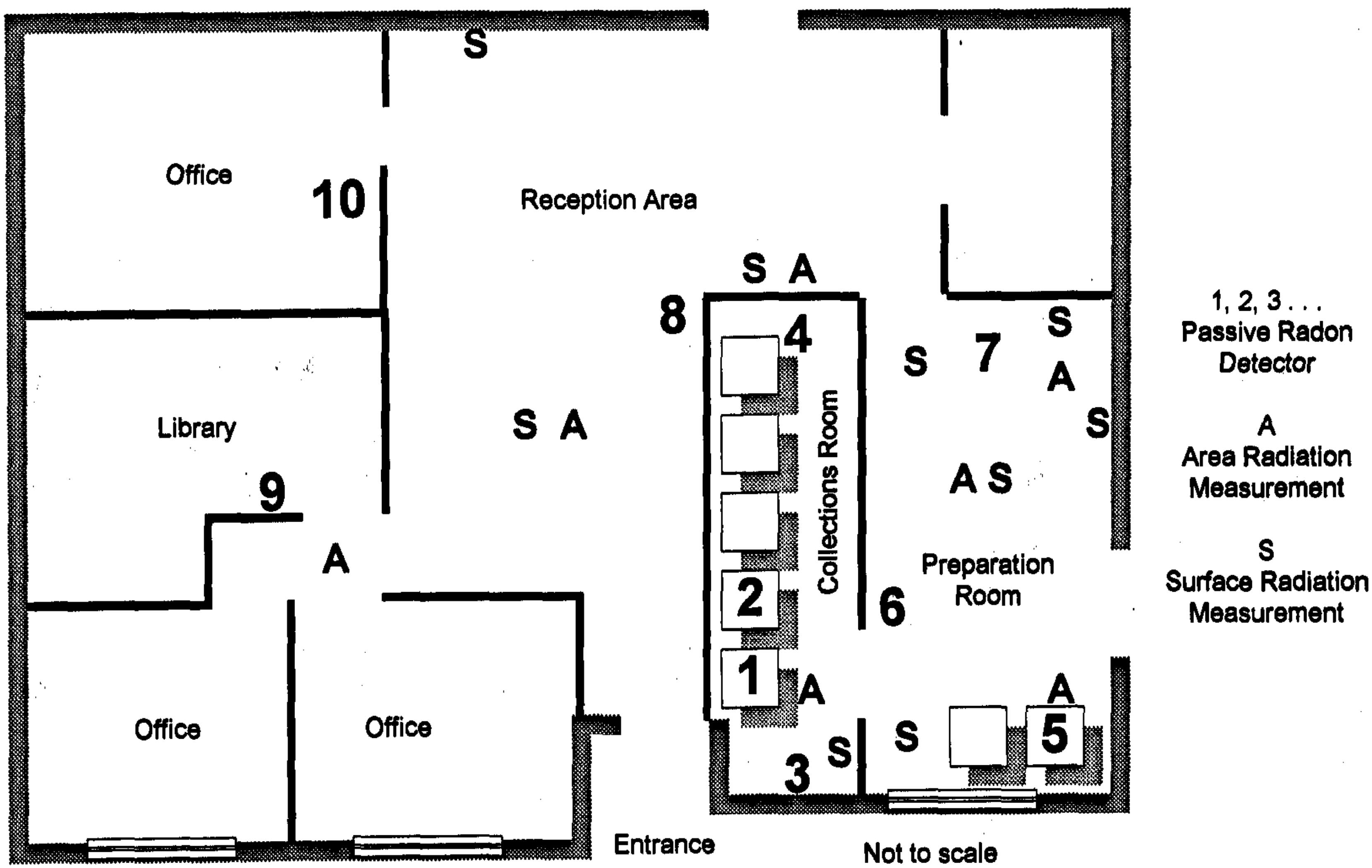
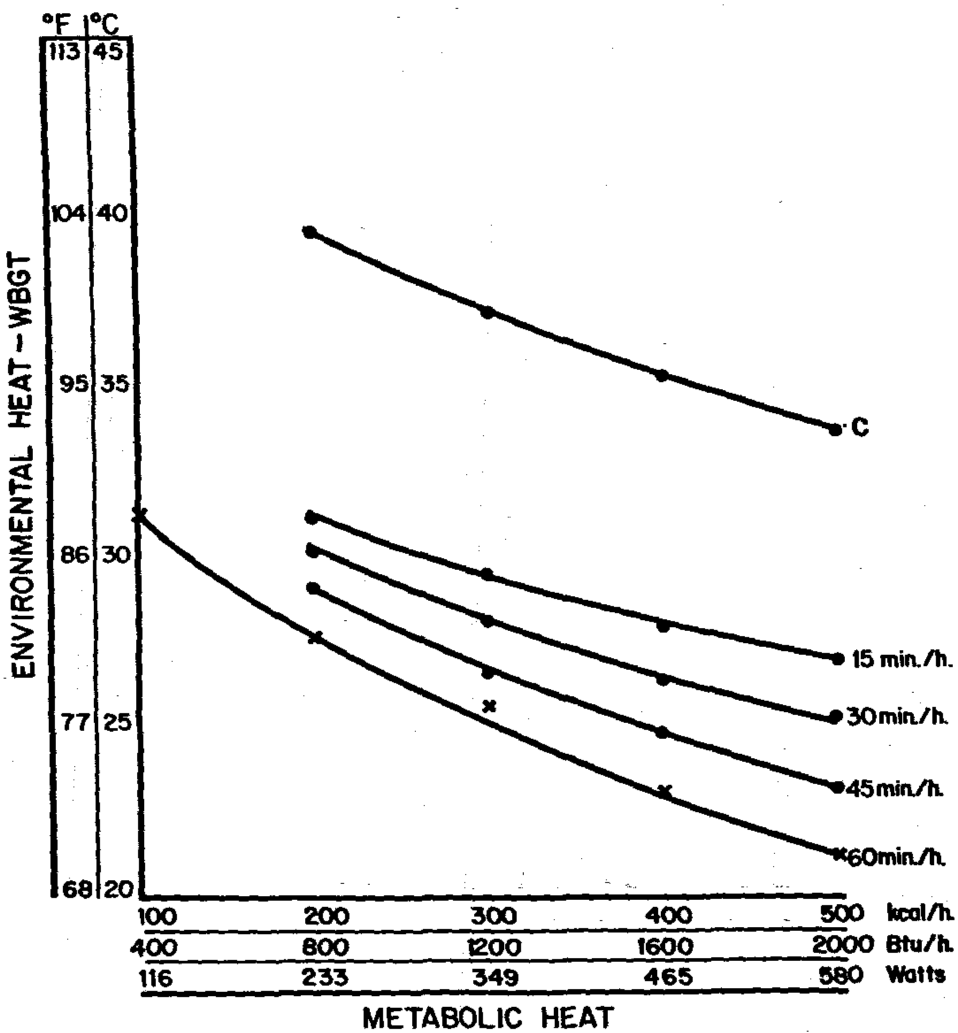


Figure 3: Recommended Heat Stress Alert Limits for Non-Heat Acclimated Workers

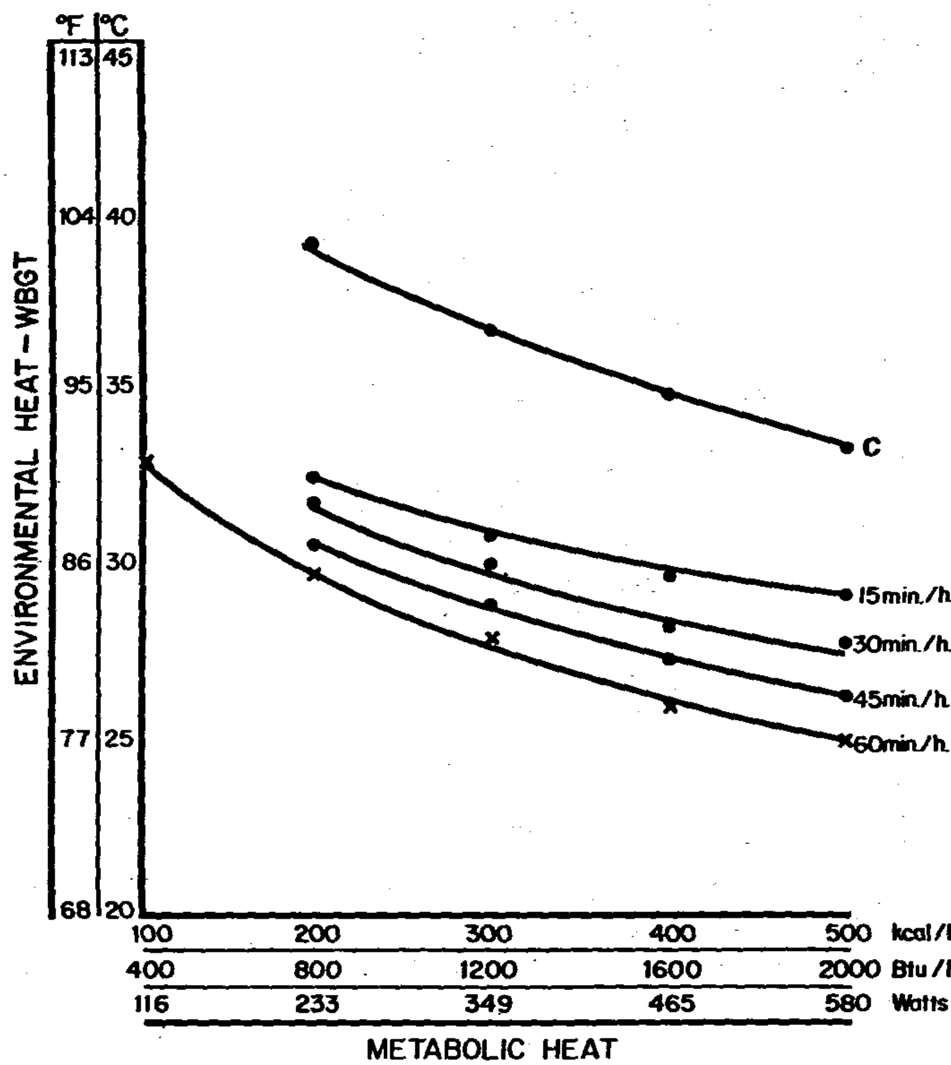
Hagerman Fossil Beds National Monument
HETA 96-0264-2713



Curves indicate recommended work/rest regimen for a combination of external heat (measured as Wet-Bulb Globe Temperature) and internal heat (metabolic heat). 'C' curve is Ceiling Limit, indicating workers should not be exposed to such conditions without adequate heat-protective clothing and equipment.

Figure 4: Recommended Heat Stress Alert Limits for Heat Acclimated Workers

Hagerman Fossil Beds National Monument
HETA 96-0264-2713

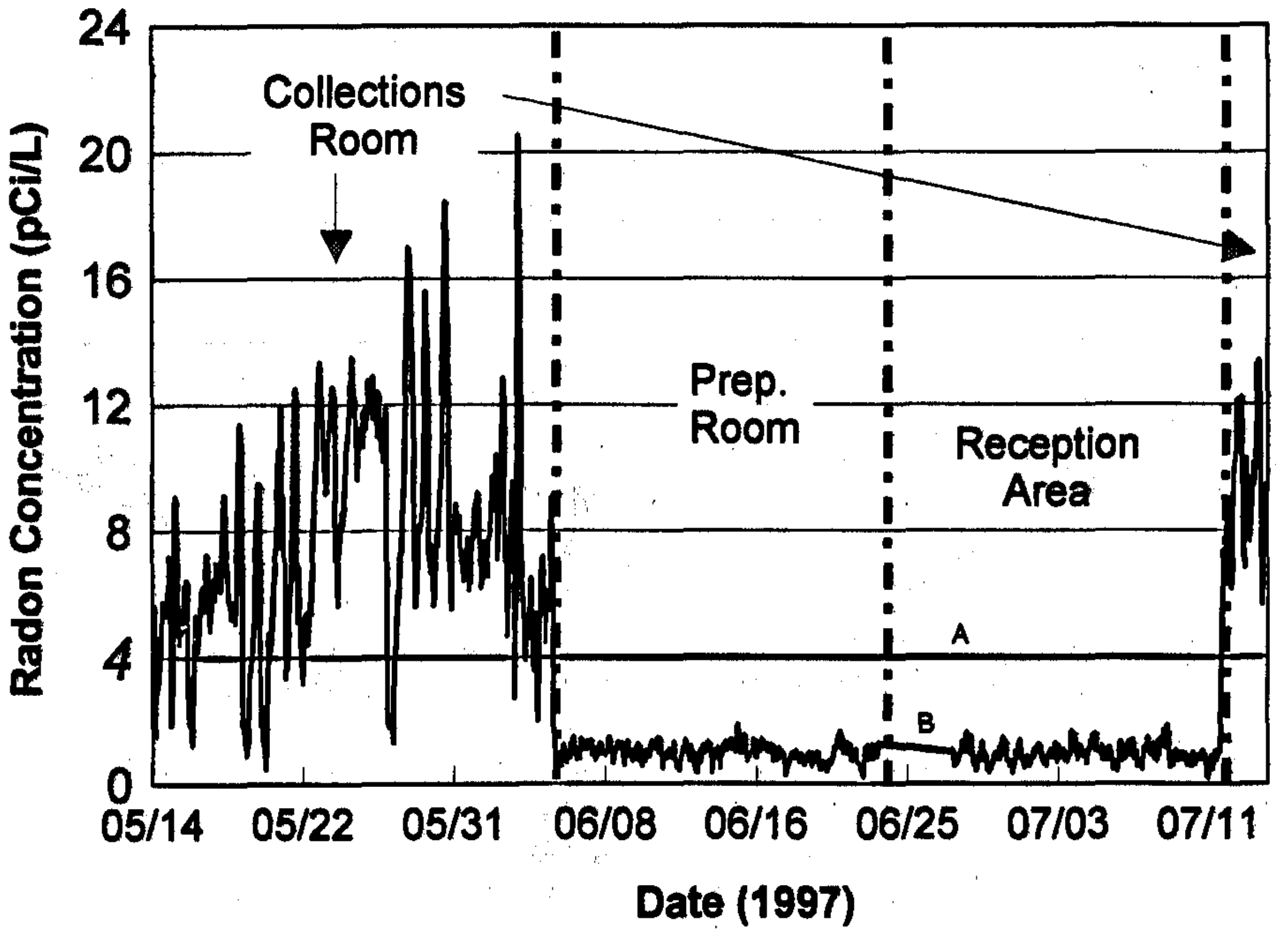


Curves indicate recommended work/rest regimen for a combination of external heat (measured as Wet-Bulb Globe Temperature) and internal heat (metabolic heat). 'C' curve is Ceiling Limit, indicating workers should not be exposed to such conditions without adequate heat-protective clothing and equipment.

Figure 5

Hourly Radon Concentrations

Hagerman Fossil Beds National Monument Administration Building
HETA 96-0264-2713



A: EPA recommends remediation in homes with radon levels greater than 4 pCi/L.
B: No monitoring was performed from 6/23 to 6/28 due to insrument malfunction.

Figure 6

Mean Hourly Radon Concentrations[A]

Hagerman Fossil Beds National Monument Administration Building
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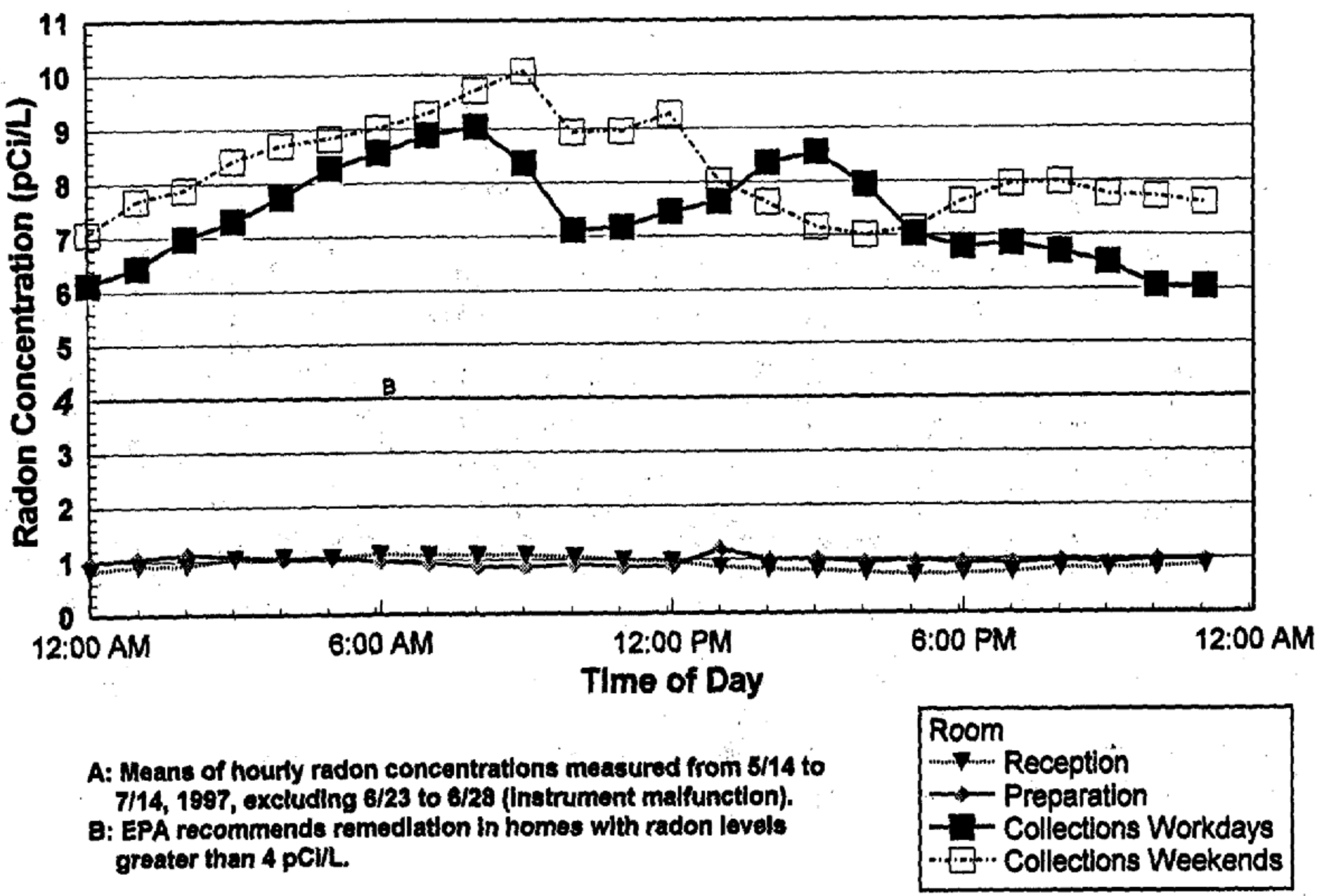
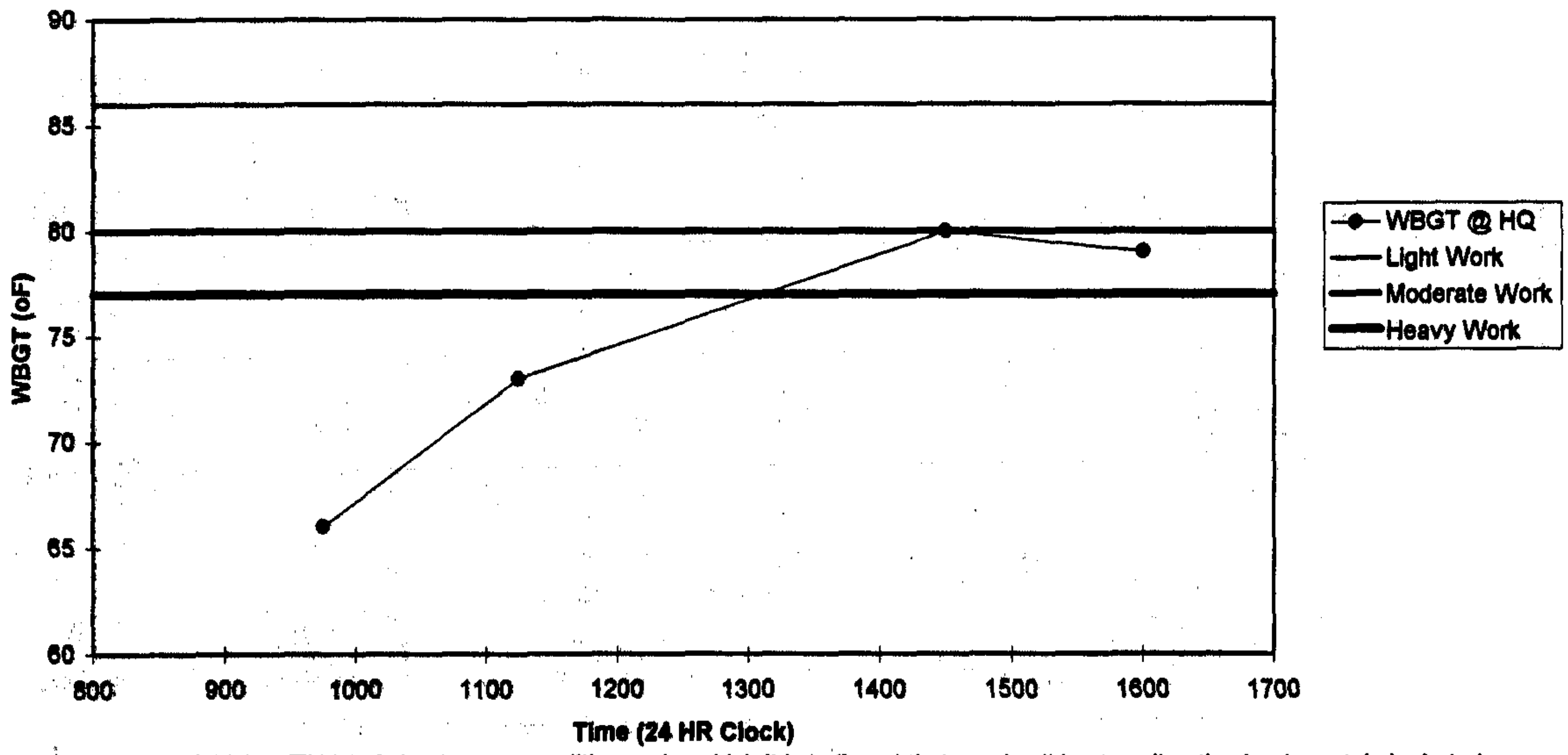


A: Means of hourly radon concentrations measured from 5/14 to 7/14, 1997, excluding 6/23 to 6/28 (instrument malfunction).
B: EPA recommends remediation in homes with radon levels greater than 4 pCi/L.

Figure 7
WBGT at Horse Quarry and Continous Work Heat Stress TLV's
Hagerman Fossil Beds National Monument
Heta 96-0264-2713
July 23, 1997



Threshold Limit Value (TLV ®) is heat stress condition under which it is believed that nearly all heat acclimatized, adequately hydrated, unmedicated, healthy workers wearing light weight summer clothing may be repeatedly exposed without adverse health effects. (Ref. 14)

Figure 8: Suggested Hood Configuration for Fossil Preparation

Hagerman Fossil Beds National Monument

HETA 96-0264-2713

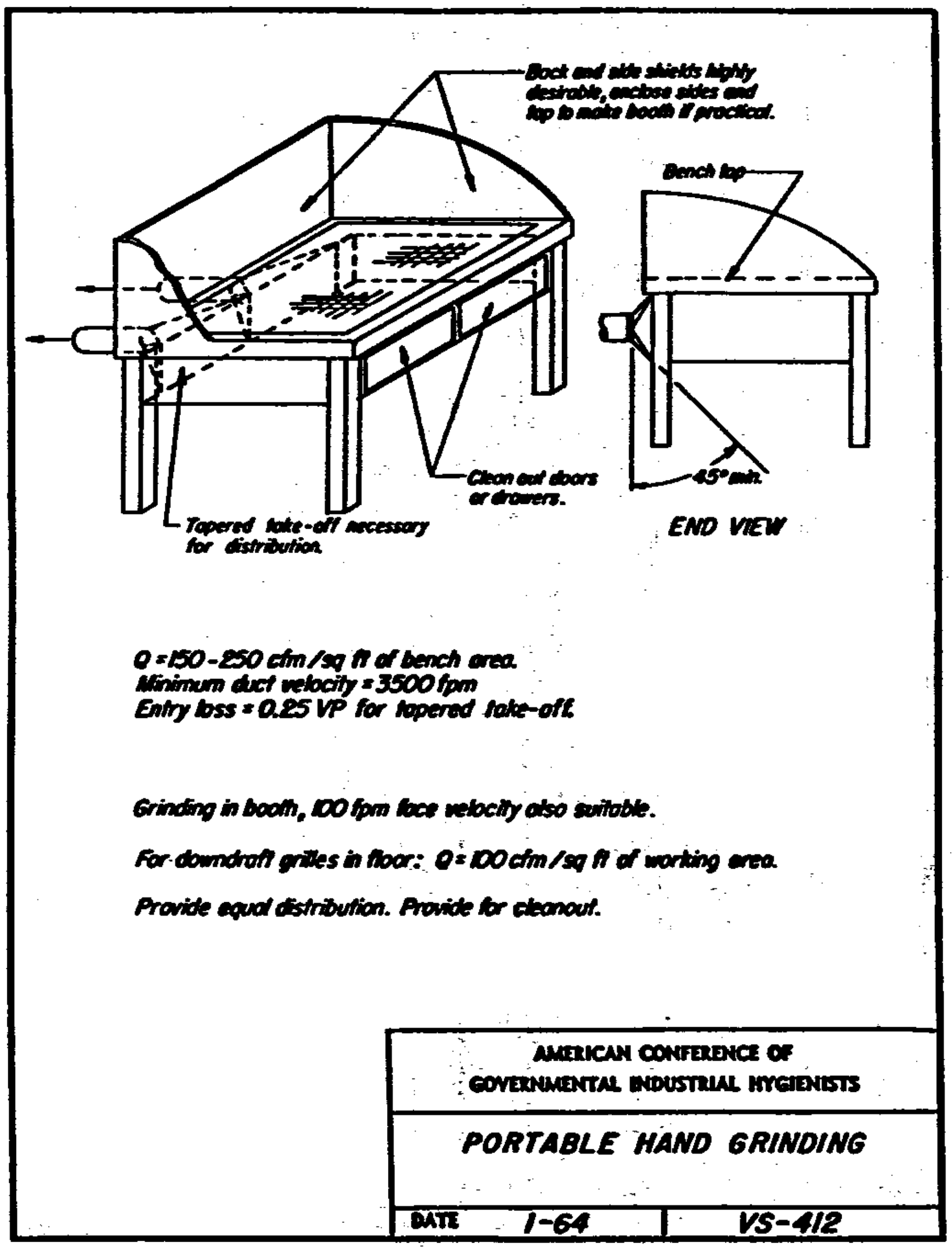
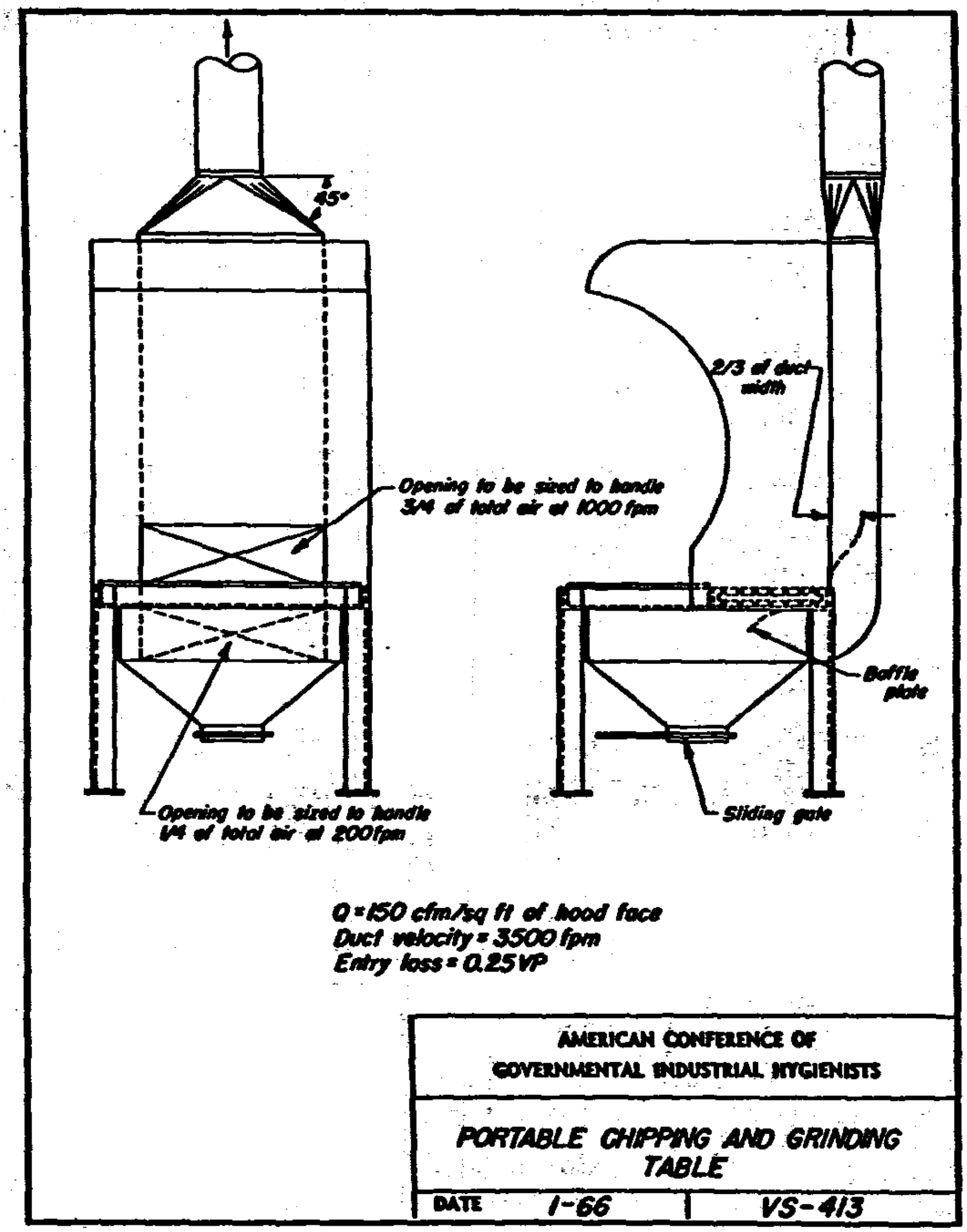


Figure 9: Suggested Hood Configuration for Fossil Preparation

Hagerman Fossil Beds National Monument
HETA 96-0264-2713



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or visit the NIOSH Homepage at:
http://www.cdc.gov/niosh/homepage.html