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RADIOLOGICAL DESIGN CRITERIA

BNWL-MA-3

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RADIOLOGICAL DESIGN CRITERIA

By

Staff of Radiation Standards
SAFETY AND STANDARDS DIVISION

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PREFACE

The Radiological Design Criteria Manual was prepared to assist management and design engineers in the planning and design of Battelle-Northwest buildings where radioactive materials or radiation generating machines are to be used. The criteria in this manual are intended to characterize the physical protective features which are required in the design or modification of such a building. These criteria, from a radiation protection point of view, relate to operability of the building within the rigorous protection standards applied to the work force. Since this manual will not necessarily satisfy all radiation safety requirements, the professional assistance of Radiation Standards, Safety and Standards Division, may be necessary. Requirements contained in other manuals such as BNWL-MA-6, "Radiation Protection Procedures"; BNWL-MA-25, "Criticality Safety Procedures"; BNWL-MA-43, "Safety Guides"; and BNWL-MA-65, "Special Nuclear Materials Control Procedures" are not obviated by application of requirements contained in this manual.

To incorporate a marked change in scope, BNWL-MA-3, "Radiological Design Criteria", has been completely rewritten. The previous issue of March 22, 1965 is now obsolete.

TABLE OF CONTENTS

- 1.0 PHILOSOPHY
 - 1.1 General
 - 1.2 Radiological Guides
 - 1.3 General Building Considerations
 - 1.4 Ventilation
 - 1.5 Water Supply and Sewer Systems
 - 1.6 Radioactive Work Stations
 - 1.7 Radiation Monitoring Systems
- 2.0 CRITERIA
 - 2.1 Rigor and Exceptions
 - 2.2 Radiological Guides
 - 2.2.1 Classification of Building Zones
 - 2.2.2 Exposure to Penetrating Radiation
 - 2.2.3 Exposure to Radioactive Contamination
 - 2.2.4 Classification of Radioactive Materials
 - 2.2.5 Classification of Work Stations
 - 2.3 General Building Considerations
 - 2.3.1 Site Considerations
 - 2.3.2 Stacks
 - 2.3.3 Structure
 - 2.3.4 Building Zones
 - 2.3.5 Traffic Flow and Air Locks
 - 2.3.6 Decontamination and Maintenance
 - 2.3.7 Monitoring Lab-Office
 - 2.3.8 Work Station Monitoring Facilities
 - 2.3.9 Dosimeter Storage
 - 2.3.10 Posting
 - 2.3.11 Personnel Decontamination
 - 2.3.12 Breathing Air Supply System
 - 2.3.13 Material Transfer Systems
 - 2.3.14 Solid Waste Disposal System
 - 2.4 Air Supply and Exhaust System
 - 2.4.1 Air Supply System
 - 2.4.2 Recirculating Air Systems
 - 2.4.3 Exhaust Air Systems
 - 2.5 Water Supply and Sewer Systems
 - 2.5.1 Water Supply Systems
 - 2.5.2 Waste Water Sewers
 - 2.5.3 High Level Wastes
 - 2.6 Radioactive Work Stations
 - 2.6.1 Class A Work Stations
 - 2.6.2 Class B Work Stations
 - 2.6.3 Class C Work Stations
 - 2.6.4 Storage Facilities
 - 2.6.5 Storage of Sealed Sources
 - 2.6.6 Shielded Work Stations
 - 2.6.7 Radiation Generating Machines and Large Source Installations

TABLE OF CONTENTS (Con't.)

- 2.7 Radiation Monitoring Systems
 - 2.7.1 Central Monitoring Panel
 - 2.7.2 Remote Area Monitoring
 - 2.7.3 Criticality Alarm System
 - 2.7.4 Criticality Dosimeter
 - 2.7.5 Room Air Sampler
 - 2.7.6 Hand and Shoe Counter
 - 2.7.7 Building Air Balance Alarms
 - 2.7.8 Door Alarms
 - 2.7.9 Exhaust Air Monitoring
 - 2.7.10 Liquid Waste Monitoring

3.0 APPENDIX

1.0 PHILOSOPHY

1.1 General

Radiation protection is achieved through physical protective features supplemented by administrative controls. Adequate physical protective features should be achieved in building construction so that supplemental administrative controls may be kept simple and workable. A building designed with adequate physical protective features should result in substantial operating economies resulting from the ease and efficiency of maintaining sound radiation protection practices throughout the useful life of the building. The intended use of a building, and therefore, the kinds and quantities of radioactive materials employed, may change even before the building is completed. It is common for a building which was designed with a minimum of physical protective features to be used for projects which require greatly increased emphasis on radiological safety. Within the limits of good judgment, the building should be designed for operations involving larger quantities of materials of higher radiotoxicity than initially proposed.

One of the underlying concepts in the control of radioactive materials and radiation is the use of a buffer zone between active work areas and areas which are free of radiation and radioactive materials. This intermediate area may be as small as an air lock or it may encompass a major part of the building. A buffer zone serves to minimize the consequences of occasional loss of control in the active work area by providing a second

barrier. A third barrier is sometimes used for operations involving a high potential for loss of control, particularly where the consequences of such loss would be serious. The outer barrier should receive a stress only as a consequence of a failure of the inner barrier.

Facilities containing more than 45% of a minimum critical mass of fissile material are subject to special controls in addition to those contained in this manual. Reactors, critical facilities and laboratories in which fissile materials are handled are subject to an evaluation of major accident potential. It is intended that the criteria in this manual should be applied in reactors and critical facilities to cover all normal operating conditions.

The possibility of nuclear accidents in critical facilities or buildings having very large radioactive materials inventories is well recognized. Considerable effort is expended in the design and construction of containment vessels and other engineered safeguards to protect the public from the consequences of these major accidents. Consideration also should be given to including those features which would ease problems associated with the smaller accidents periodically experienced in working with radioactive materials. Building design, for example, may have prominent effect on the ease (and cost) of recovery of normal building operations after a radiation accident not affecting the public. The following characteristics should be incorporated in building design to facilitate accident recovery:

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 2 OF 3	BNWL-MA-3	1.1
----------------------	----------------------------	----------------	-----------	-----

- ° Properly designed ventilation systems and proper zoning to prevent contamination spread.
- ° Uncluttered interior layout and surfaces which facilitate decontamination.
- ° Easy emergency access to contaminated areas.
- ° Sufficient floor loading capacity to support heavy equipment or shielding.
- ° Provisions for safe remote operation of equipment and utilities during recovery.

1.2 Radiological Guides

Radiological Design Criteria enumerates the basic design features and requirements of facilities for safe work with radioactive materials or radiation generating machines. The radiological guides contained in this section are the dose limits, contamination limits, etc., which should be met in designing the building. Criteria in other portions of the manual may result from an application of these guides. Shielding and physical protective features should be included which will facilitate operations and keep exposure of persons to radiation and radioactive materials as low as technically and economically feasible. Collectively, the building features and operating procedures must (1) keep planned exposures to radiation workers within prescribed limits and as low as possible, (2) keep casual exposure of persons not engaged in radiation work low to avoid unwarranted use of exposure needed for work, (3) keep exposure or the threat of exposure to persons not controlled by BNW as near zero as possible, and (4) maintain control in spite of operational failures or facilitate recovery of control when operational procedures fail.

1.3 General Building Considerations

The location of each new building should be chosen so that radiological hazards to the surrounding buildings and environs will be minimized. If the movement of radioactive material to and from a building interferes with normal operations in adjoining buildings, annoying, impractical and imposing controls could be necessary. For example, an unfavorable location for waste disposal will lead to increased waste treatment costs, tank storage requirements, or transport to more favorable disposal sites.

Radiological problems within a well designed building should be decreased by providing permanent shielding for some operations, by providing for the future use of temporary shielding and casks, by design for traffic control and location of various operations to minimize interference, and by design for air flow which will minimize contamination spread. One-story construction has the advantage of avoiding possible interferences, both above and below. Hazards involved in spills, breaking of process lines, contamination control, fire fighting, and cask handling favor ground floor location for Radiation Zones.

The goal of building traffic control should be to limit access to sources of ionizing radiation and contamination. Three building zones (Radiation Zone, Controlled Zone and Uncontrolled Zone) should be utilized carefully in building design to achieve this goal. Good traffic control design should minimize radiation exposure subsequent to a contamination spread, criticality or fire. The extensive use of air locks at all exits including

emergency exits as a means of contamination control should be considered. Provision should be made for isolated and locked areas that prevent unnecessary or inadvertent entry to areas where high radiation dose rates or large amounts of radioactive materials may be encountered. Consideration should be given to the ease of decontaminating work stations and to provisions for decontaminating equipment. The maintenance of a building and equipment containing Class A or B work stations may necessitate the design of special maintenance facilities. It is necessary to define the projected uses of a facility in order to determine the need for radiation monitoring facilities and equipment. A building containing Class A or B work stations should include lab-office space for resident Radiation Monitoring personnel. A building containing only Class C work stations normally will not require space for resident monitoring personnel, but does require provisions for some radiation protection equipment. Space should be provided in laboratories designed for work with radioactive materials for personal survey or dose rate instruments.

All facilities in which radioactive materials or radiation generating machines are used should include provisions for adequate posting of signs. Consideration should be given to the desirability for building radiation monitoring systems and a centralized read-out of the systems. The absolute prevention of all personnel contamination cannot be assured; hence, facilities for personnel decontamination should be provided where Class A or B work stations are present. Normally, Class C work stations will not need personnel decontamination facilities.

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 2 OF 2	BNWL-MA-3	1.3
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1.4 Ventilation

The ventilation system (supply and exhaust) of a radiological facility supplements the facility layout in controlling the movement of radioactive materials from contaminated areas toward uncontaminated areas. The ventilation rate is usually controlled by this function, and is therefore usually higher than needed solely for the comfort of the workers. Freedom from dust should be assured. The design should avoid drafts and eddies, which tend to spread contamination. It is usually desirable to design for directed smooth downflow of air across the working faces of glove boxes or hoods, so that in the event of a glove puncture or other damage, any contamination which may escape is carried away from the workers' faces and localized near the affected hood. The goal of the exhaust air treatment should be to keep the release of radioactive material to the environment to a minimum.

1.5 Water Supply and Sewer Systems

Design of water supply and sewer systems must prevent accidental contamination of supply systems and should ensure disposal of aqueous waste into the proper sewer and prevent disposal of waste materials to an improper sewer. Design should consider the following types of waste separately: (1) sanitary sewage, (2) process waste water not threatened with radioactive contamination, (3) waste water which normally meets the previous classification but which might contain radioactive material because of failure of equipment or personnel error and (4) waste water which normally contains radioactive material. The design should also provide for the disposal of liquid wastes which are not acceptable in any of the waste water systems - oil, for example.

The 300 Area is served by sewer systems which fall into each of the above four categories. The functions of the sanitary sewer, process sewer, and contaminated sewer are obvious enough. Frequent confusion regarding the retention sewer which fits the third category above may justify more explicit definition of its function. It is not intended that radioactive material should be discharged to this system. However, the system provides a means of diverting waste water to the contaminated waste system if radioactive material is inadvertently released. Connection to this system or provision of a system with similar capabilities is recommended where large volumes of normally clean water must be disposed of and where there is a

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED	PAGE 1 OF 2	BNWL-MA-3	1.5
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significant probability that the waste may infrequently contain radioactive material because of an inadvertent act or equipment failure. Since large amounts of radioactive material could easily exceed the capability of the retention waste system or any similar system, additional protection from accidental release of multicurie amounts of radioactive material may be required.

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 2 OF 2	BNWL-MA-3	1.5
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1.6 Radioactive Work Stations

This section contains criteria and guidance applicable to work stations where personnel in some way manipulate and come in contact with radiation and radioactive materials in the normal conduct of their work. The control of radioactive materials to prevent their becoming a source of internal exposure can be made easier by design and selection of proper equipment for laboratories. Because of the small quantities which are considered significant, high radiotoxicity materials may create a nuisance if they are mismanaged, but the risk of significant exposure is small. Work stations for manipulations with low radiotoxicity materials should be remote from work stations where high radiotoxicity materials are to be employed.

Shielding should be determined by the nature of the work and compliance with Section 2.0 criteria. Shielding may be provided by the construction of massive structures or the use of water-filled basins. Consideration must be given to preventing the accidental loss of water in the construction of a basin.

The shielding and safety requirements for any radiation generating machine or large radioactive source dictates the need for obtaining the services of a qualified expert early in the planning stage. Information should be provided on the type of installation, rating of the machine or source, the contemplated use of the x-ray, the expected workload and use factors, the structural details of the building and the type of occupancy of all areas which might be affected by the installation.

1.7 Radiation Monitoring Systems

Several systems are employed to insure continuous control of radiation exposures. Administrative procedures, employment of personnel whose sole job is administration of radiation protection services, use of personnel dosimeters, use of fixed and portable instruments for measurement of dose rates, and measurement of radioactivity in effluents and wastes are some of the more obvious devices employed. Fixed radiation monitoring devices are provided to assure continuous knowledge of ambient penetrating radiation dose rates and to signal significant changes in those dose rates. High radiation level and criticality alarms are provided to insure evacuation of personnel from locations where dangerous levels of radiation could possibly occur. Criticality dosimeters provide a measurement of doses which might otherwise be difficult or impossible to obtain. Air samplers provide an after-the-fact measurement of airborne radioactive materials, and air monitoring instruments provide occupants immediate warning of significant changes. Portable detection instruments and fixed personnel check stations including hand and shoe counters provide a means of detecting personnel contamination. Air balance and locked doors are devices used to control spread of contamination and to control movement of personnel. Annunciators and alarms may be required to insure prompt correction of breaches in the control system. Measurement and control of exhaust air and waste water are necessary to insure control of radiation exposures to persons outside of normal control areas.

2.0 CRITERIA

2.1 Rigor and Exceptions

Throughout these criteria four verbs have been used to indicate the degree of rigor intended by the specific criterion. "Shall" and "will" indicate that strict application of the criterion is considered necessary to assure that adequate physical protective features are included. "Should" or "would" indicate that application of the criterion is desirable.

It is recognized that the application of exacting radiological design criteria to meet the requirements of a specific building may require professional judgment and interpretation. Radiation Standards, Safety and Standards Division, upon request, will provide or secure the professional judgment and interpretation required. Exceptions to these criteria may be permitted if, in the view of Radiation Standards, the intent of these criteria and the integrity of the engineered physical protective features will not be compromised.

2.2 Radiological Guides

2.2.1 Classification of Building Zones

2.2.1.1 Radiation Zone

- ° Any location where the combination of anticipated dose rate and anticipated occupancy indicates a dose to persons exceeding 20 mrem per week.
- ° Any location where the anticipated dose rate exceeds 2 mrem/hr.
- ° Any location containing unconfined radioactive materials.
- ° Any location where the concentration of airborne radioactive materials may exceed Maximum Permissible Concentrations (MPC's) listed in AEC Manual Chapter 0524, Annex A, Table I.

2.2.1.2 Controlled Zone

- ° Any location where the anticipated dose rate exceeds 0.2 mrem/hr but does not exceed 2 mrem/hr and where the combination of anticipated dose rate and anticipated occupancy indicates a dose to persons less than 20 mrem/week.
- ° Any location where unconfined radioactive materials may be expected occasionally because of operational failure, equipment failure, or routine maintenance.

- ° Any location where the concentration of airborne radioactive materials may exceed MPC's listed in AEC Manual Chapter 0524, Annex A, Table II, but are not expected to exceed MPC's listed in Table I of the same reference.

2.2.1.3 Uncontrolled Zone

- ° Any location where no radiological control activities are required.

2.2.2 Exposure to Penetrating Radiation

- ° All persons shall be restrained from receiving radiation exposure at a rate exceeding 1000 mrem/hr by shielding or locked physical barriers.
- ° In Radiation Zones where radiation exposure is a necessary part of the work being performed, shielding shall be provided where the anticipated annual dose exceeds 4000 mrem. When shielding is provided, it shall reduce the anticipated annual dose to 1000 mrem or less. If annual occupancy time cannot be estimated, then shielding shall reduce the weekly dose to 20 mrem. If no information on occupancy time is available, shielding shall reduce the dose rate to 0.5 mrem/hr.
- ° In Controlled Zones and in Radiation Zones where radiation exposure is not a necessary part of the work being performed, shielding shall be provided, as necessary, to limit the anticipated annual dose to occupants to less

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 2 OF 6	BNWL-MA-3	2.2
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than 1000 mrem. If the annual occupancy time cannot be estimated, then shielding shall reduce the dose rate to 20 mrem/week or 0.5 mrem/hr. However, the dose rate in a Controlled Zone shall not exceed 2 mrem/hr.

- ° In Uncontrolled Zones shielding shall be provided, as necessary, to reduce the dose rate to 0.2 mrem/hr or less. In addition, where persons outside BNW control may be exposed, shielding or a fence shall be provided to insure against such persons receiving an annual dose exceeding 170 mrem.

2.2.3 Exposure to Radioactive Contamination

- ° Radioactive contamination on surfaces outside Radiation Zones shall not exceed 2000 d/m per cm^2 ($\sim 10 \text{ pCi/cm}^2$) for beta-gamma emitters nor 500 d/m per 100 cm^2 ($\sim 2 \text{ pCi/cm}^2$) for alpha emitters.
- ° The annual average concentration of airborne radioactive materials within Radiation Zones at all locations normally accessible to personnel shall not exceed one-tenth of the Maximum Permissible Concentrations (MPC's) listed in AEC Manual Chapter Appendix 0524, Annex A, Table I.
- ° All persons shall be restrained by physical barriers, locks or interlocks from entering areas where concentrations of

airborne radioactive materials exceeding 10 times the MPC's referenced above are anticipated.

- ° Persons in Controlled Zones or Uncontrolled Zones shall not be exposed to concentrations of radioactive materials in air or water exceeding Maximum Permissible Concentrations listed in AEC Manual Chapter 0524, Annex A, table 11.

2.2.4 Classification of Radioactive Materials

High Radiotoxicity Materials

Beta Emitters

⁹⁰Sr
²¹⁰Pb
²²⁷Ac
²²⁸Ra
²³⁰Pa
²⁴¹Pu
^{242m}Am
²⁴⁹Bk
²⁵³Cf
²⁵⁴Es
²⁵⁵Es

Alpha Emitters

²¹⁰Po ²⁴¹Am
²²³Ra ²⁴³Am
²²⁴Ra ²⁴²Cm
²²⁶Ra ²⁴³Cm
²²⁷Th ²⁴⁴Cm
²²⁸Th ²⁴⁵Cm
²³⁰Th ²⁴⁶Cm
²³¹Pa ²⁴⁸Cm
²³⁰U ²⁴⁹Cf
²³²U ²⁵⁰Cf
²³⁸Pu ²⁵¹Cf
²³⁹Pu ²⁵²Cf
²⁴⁰Pu ²⁵⁴Cf
 ²⁵³Es

Low Radiotoxicity

Noble Gases, Uranium, Natural Thorium and other radionuclides having a specific activity less than 1×10^{-6} curies per gram.

Medium Radiotoxicity

All other radionuclides.

2.2.5 Classification of Work Stations

Areas shall be designated as Class A, B or C Work Stations, depending on the form, quantity, and radiotoxicity of the

unconfined radioactive material to be used. The table listed below shall be used to determine the classification to be applied to the work station.

A work station where only sealed sources are used shall be classified as Class C.

Readily Dispersible as used in this table shall include radioactive materials in the form of gases, aerosols or powders, pyrophoric radioactive materials or radioactive materials associated with combustibles.

Dispersibles as used in this table shall include radioactive materials in the form of unsealed non-combustibles, liquids and solids.

CLASS OF WORK STATION

Form → Quantity ↓ ↓	Hi Radiotoxicity		Med Radiotoxicity		Low Radiotoxicity	
	Readily Dispersible	Dispersible	Readily Dispersible	Dispersible	Readily Dispersible	Dispersible
1 Ci →	Class A Work Station		Class A Work Station		Class B Work Station	
1 mCi →				Class B Work Station		
1 μCi →			Class B Work Station		Class C Work Station	
1 nCi →	Class C Work Station		Class C Work Station			

2.3 General Building Considerations

2.3.1 Site Considerations

2.3.1.1 New buildings shall be located so that normal operations, including anticipated minor accidents, do not adversely affect surrounding buildings, and conversely, so that normal operations in surrounding buildings do not adversely affect the new building.

- ° Dose rates outside a building shall not exceed the guides listed in Section 2.2.1.2 for Controlled Zones.
In an area where dose rates exceed 0.2 mrem/hr, provision shall be made (a fence) to prevent the general public or any person whose exposure is not being controlled by Battelle-Northwest from receiving dose in excess of 170 mrem in a year.
- ° No facilities for handling uncontained radioactive material out-of-doors shall be permitted.
- ° Operations that are sensitive to radiation (counting rooms, photographic operations, etc.) should be isolated from and shielded from facilities and operations which produce significant dose rates.

2.3.1.2 Buildings requiring the routine movement of high dose rate materials which require heavy shielding should be served by a railroad spur.

2.3.2 Stacks

Stacks shall be at least 20 feet higher than the roof of the facility, and shall be located at least 20 feet down wind (refer to windrose for facility location) from the air intake of the facility or at least 500 feet upwind from the air intake of an existing facility.

The height and location of a stack serving some facilities may have overriding requirements based on a specific accident analysis.

2.3.3 Structure

- ° A one-story building shall be considered. If overriding considerations dictate the need for a multi-story building every effort shall be made to locate all radioactive work stations on the ground or first floor.
- ° Heavy duty floors shall be provided to accommodate problems which may result from the transporting of casks or installation of heavy shielding.
- ° High ceilings should be avoided where readily dispersible radioactive materials will be used.

2.3.4 Building Zones

- 2.3.4.1 A building shall be divided into three zones: Radiation Zone, Controlled Zone and Uncontrolled Zone. Normal access from areas outside the building to a Radiation Zone shall be through

a Controlled Zone and a physical barrier or check point (e.g., a door or receptionist) shall be located at the point where the Controlled Zone can be entered from an Uncontrolled Zone or from out-of-doors. Exits from Radiation Zones directly to the outside shall be installed only where required as emergency exits. Specific items pertaining to each of the building zones which are defined in Section 2.2.1 are as follows:

° Radiation Zone

This category shall include all rooms and areas in which radioactive materials are stored, handled, or processed. Rooms falling into this category shall be confined to one area of the building.

° Controlled Zone

Zones that are normally free of contamination but which have a potential for becoming contaminated shall be included in this category. Change rooms and related facilities should be located in this Zone.

° Uncontrolled Zone

No radioactive materials will be permitted; therefore, no radiological considerations will be necessary.

2.3.4.2 In addition to the provision of facilities for storing and dispensing clean clothing, the change room shall contain a

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 3 OF 12	BNWL-MA- 3	2.3
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defined area near the point of exit from the Controlled Zone for the temporary storage of potentially contaminated used clothing.

2.3.4.3 Provision shall be made for locating hand and shoe counters at or near the exit from a Controlled Zone.

2.3.4.4 Provision shall also be made for storage of radiation monitoring survey instruments to be used for personal survey or release of material from the Controlled Zone.

2.3.5 Traffic Flow and Air Locks

The normal flow of traffic shall be restricted to the Uncontrolled Zone or Controlled Zone. Normal traffic patterns shall not include Radiation Zones. Areas of high potential for either contamination or radiation shall be located outside the normal flow of traffic. Air locks shall be incorporated at any exit from a high contamination area direct to an Uncontrolled Zone.

2.3.6 Decontamination and Maintenance

2.3.6.1 Future decontamination requirements shall be considered in the design of hoods, cells, glove boxes, and process equipment. Rough surfaces, square corners, cracks or crevices, and absorbent materials shall be avoided. Disposable linings, covers, coatings, or easily decontaminated surfaces shall be utilized.

2.3.6.2 Walls and ceilings in Class A or B work stations shall be non-porous and washable. Paints used to cover these surfaces shall

be of a quality that retains its original covering properties when subjected to repetitive washing with common detergents.

2.3.6.3 Class A or B work station floors shall be covered with individual tiles.

2.3.6.4 A separate decontamination and maintenance facility shall be provided for any building containing more than ten Class A or B work stations. These facilities shall be considered work stations and equipped as required in criteria for work stations. In addition, the following should be considered in designing the decontamination and maintenance facility:

- ° Remote visual inspection of radioactive components.
- ° Handling and transfer of major components.
- ° Physical separation of major activities such as decontamination, remote maintenance, contact maintenance and storage.

2.3.6.5 Consideration should be given to the provision of a utility corridor which would aid in maintenance of utilities and removal of solid radioactive wastes.

2.3.7 Monitoring Lab-Office

2.3.7.1 Each building containing Class A or B work stations shall have at least a lab-office combination to accommodate one radiation monitor.

- 2.3.7.2 For large facilities, the monitoring lab-office shall be designed to accommodate additional personnel;

Class A Work Station

Two monitors for the first 30 radiation workers plus one additional monitor for every 30 additional radiation workers.

Class B Work Station

Two monitors for the first 50 radiation workers plus one additional monitor per additional 50 radiation workers.

Class C Work Station

One monitor under some circumstances.

- 2.4.7.3 Each lab-office shall include a minimum of six lineal feet of lab bench, 12 lineal feet of open shelving, and one regulated voltage electrical outlet for every two feet of bench space. Two lineal feet of lab bench and four lineal feet of open shelving shall be added to above requirements for each additional radiation monitor provided for.

- 2.3.7.4 The monitoring lab-office shall be located at or near the exit from the Controlled Zone.

- 2.3.7.5 A readout from building monitoring systems should be provided in the monitoring lab-office. (See Section 2.7 for criteria for building monitoring systems.)

2.3.8 Work Station Monitoring Facilities

- ° Each work station in which radioactive material or a radiation generating machine is to be used shall have a bench or shelf

approximately two square feet in area located at the opening side of the door for portable or semi-portable survey instruments.

- ° A 120 volt 60 Hz outlet shall be located at the bench or shelf.
- ° A suitably sized bulletin board shall be located above the bench or table for posting procedures and instructions.

2.3.9 Dosimeter Storage

- ° Storage racks shall be provided for the radiation worker's dosimeters where special dosimeters are required.

2.3.10 Posting

- ° Fixed brackets shall be provided at each door to a Controlled Zone or Radiation Zone to attach an appropriate sign (Ref. BNWL-MA-6, Radiation Protection Procedures). The sign shall be located to the right of the door and about five feet off the floor.

2.3.11 Personnel Decontamination

- ° A personnel decontamination room shall be located near the change rooms or rest rooms in any facility containing Class A or B work stations in which unsealed radioactive materials are used.
- ° Equipment in the personnel decontamination room shall include a telephone, a work bench, an examination chair, a sink and shower connected to a monitored sewer system and a storage cabinet for decontamination supplies.

2.3.12 Breathing Air Supply System

Design of facilities should include centralized breathing air when several work stations require the occasional use of a special breathing air supply for personnel protection and when a few work stations require the use of fresh air for personnel protection for periods of several hours at a time. Special breathing air supply equipment is required under the following conditions:

- ° When gaseous radioactive materials in an occupied area may be expected to exceed the concentrations set forth in AEC Manual Chapter Appendix 0524, Table I, Column 1.
- ° When airborne particulate radioactive material in occupied areas may be expected to exceed 20 times the concentrations set forth in AEC Manual Chapter Appendix 0524, Annex A, Table I, Column 1.
- ° When high radiotoxicity materials are being handled outside enclosures such as hoods, glove boxes and cells in amounts exceeding 1 μ Ci and in a form (powder, solution, friable solids, etc.) which might readily produce airborne contamination.
- ° When maintenance or decontamination may require personnel entry into cells, or other areas where large amounts of loose radioactive material may be encountered.

When a breathing air system is provided, it shall meet applicable Hanford Standards, which specify hose coupling and manifold design.

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 8 OF 12	BNWL-MA-3	2.3
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Air supplied shall be free of oil, water and dust. Hose couplings should be provided with a plastic cover to prevent contamination from entering the system. The proposed work load will determine the number of hose couplings which should be provided at each station, but stations shall be provided near the normal entryway. In determining the location of stations, consideration should be given to the length of hose required to reach a work location. Long hoses tend to become tangled and contribute to the spread of contamination. Stations should be outside of highly contaminated areas to reduce the problems of hose coupling contamination and to facilitate "suiting up".

2.3.13 Material Transfer Systems

Material transfer systems, such as tanks and pipe lines for radioactive fluids and casks for solids or liquids, require many design considerations. In addition to other design problems, consideration should be given to radioactive contamination control and control of radiation exposure during the transfer of process materials or maintenance of equipment. Remote handling, valving and instrument readout should be designed for work operations involving high dose rates, high contamination levels and high radiotoxicity materials. Consideration should be given to the use of overhead lifting equipment such as cranes and monorails in preference to wheeled carts and carrying vehicles. Pipe lines used for transfer of radioactive materials should operate under vacuum. Design must include filtration and proper disposal of

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 9 OF 12	BNWL-MA-3	2.3
----------------------	----------------------------	-----------------	-----------	-----

waste water from jets and off-gases from the vacuum system. Filters and scrubbers should be used to protect the vacuum pump from contamination. Welded connections are preferred to screwed couplings. A double barrier (e.g., pipe inside a pipe) should be provided when it is necessary for a transfer line to pass through normal work areas; shielding may also be required. Design dose rates are discussed in another section. Fluid transfer facilities should be designed to provide positive protection against backup in valve actuating lines or instrument sensing lines. They should also be designed so that lines drain completely and to prevent inadvertent pressurization and filling of a portion of the line. Transfer systems should be designed for easy flushing and internal cleaning. Particular attention should be given to the control of radioactive materials which might be spread when temporary connections are broken. Pressurized transfer systems are to be avoided; however, when it is necessary to design a pressurized system, extreme care should be used in design to assure control of radioactive materials from leaks and at points where connections may be broken. An auxiliary protective barrier should be provided for all such systems.

Design features for the movement of solids, casks, bottles and boxes should make it convenient to keep the outside surface free of radioactive contamination. Transfer of materials into and out of a radioactively contaminated area should be designed to take place through an air lock. This not only reduces the transfer

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 10 OF 12	BNWL-MA-3	2.3
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of contamination with the parcel, but also reduces the disturbance of the air balance necessary to control contamination in the contaminated work zone. Decontamination, wrapping or coating may need to take place in the air lock to assure contamination control.

2.3.14 Solid Waste Disposal System

All radioactive wastes are buried on the 200 Area plateau in approved disposal sites. Design must, therefore, provide for the accumulation, storage and handling of solid wastes compatible with acceptable transportation to disposal sites. Design may need to include design of casks or other special equipment to facilitate handling and transport of solid wastes. Solid wastes may include small volumes of liquids made compatible with solid waste requirements by being packed in or absorbed in an absorbent material. Waste handling equipment may need to include hoists, cranes, remote handling equipment, or packaging facilities. Facilities provided for waste handling must meet the same criteria for control of radiation exposure and contamination as to all other work stations during storage, transport and disposal. Segregation of non-radioactive and radioactive waste is important to reduce operating costs.

- ° Design of facilities should provide for segregation of wastes, storage and preparation for transport and burial.
- ° Waste packages having a dose rate less than 100 mrem/hr at the surface may be handled by routine procedures. Design may need to provide shielding at the storage location.

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 11 OF 12	BNWL-MA- 3	2.3
----------------------	----------------------------	------------------	------------	-----

- ° Shielded shipping casks should be provided for waste packages having a dose rate greater than 150 mrem/hr at 10 feet.
- ° Facilities Operation will conduct all negotiations with receiving contractors. Negotiations between operators or designers and the receiving contractor which may be required to insure compatibility of shipping casks and receiving facilities shall include Facilities Operation.
- ° The outside surfaces of all waste shipments must be free of loose contamination. Design should include facilities for packaging and decontamination if these are required.
- ° Materials which may constitute an explosive or fire hazard must receive special attention and must therefore be segregated from normal wastes.
- ° Alkali metals shall not be buried with dry waste because of the hazard of fire or explosion. Special provision shall be made to react alkali metals prior to disposal.
- ° Contaminated oil and other liquids immiscible with water will normally be mixed with or bottled and packaged in an absorbent material and buried as dry waste. Design may need to provide facilities for this operation.

2.4 Air Supply and Exhaust System

2.4.1 Air Supply System

- ° The air supply rate shall be lower than the exhaust rate in Radiation and Controlled Zones. Exhaust control dampers shall fail to the open position. Supply control dampers shall fail to the closed position.
- ° Exhaust duct work shall be designed with sufficient stiffeners to withstand the full differential when the supply control dampers fail closed.
- ° The ventilation rate in Radiation and Controlled Zones where uncontained radioactive materials are handled in hoods shall be 8 to 15 air changes per hour.
- ° Adequate intake air filters shall be provided to minimize dust in work areas and to reduce dust loading on exhaust filters.
- ° Air balance shall be designed to assure air movement from non-radioactive areas to moderately or occasionally contaminated zones and then to highly contaminated or high risk zones. Supply fans should automatically cut out when there is insufficient exhaust fan capacity in service. Alarms shall be provided to signal loss of proper air balance (Ref. Section 2.7.7).

- ° Air pressure differentials between uncontaminated and contaminated areas shall be between 1/10 and 1/4 inch of water. Pressure differentials between 1/4 and 1 inch of water shall be maintained between moderately or occasionally contaminated areas and highly contaminated areas (hoods, cells). Air pressure shall be negative with respect to atmosphere in all areas except offices, areas and zones where radioactive materials are not allowed. Normally, air locks should be used to insure maintenance of proper differentials.
- ° Open faced hoods may have an adjustable front opening. The linear air velocity through the hood opening shall be 150 ± 25 ft/min. The hood front shall be designed for smooth, eddy free air flow and for protection from back drafts caused by motions of workers and objects in the room.

2.4.2 Recirculating Air Systems

- ° Particular care should be exercised in the design of recirculating air systems for areas where radioactive materials will be handled to insure removal of airborne radioactive materials. The system shall be designed to supply air at concentrations less than those listed in AEC Manual Chapter 0524, Annex A, Table II.
- ° Provision shall be made for sampling recirculated air downstream of fans and filters. Instrumented monitoring with alarms and automatic dampers to supply clean air and exhaust

contaminated air shall be provided where concentrations exceeding AEC Manual Chapter 0524, Annex A, Table I, might occur.

- ° Recirculating air systems serving rooms where high radio-toxicity materials may become airborne shall be provided with two high efficiency particulate air (HEPA) filter banks in series, one of which must be in the exhaust vent at the room where airborne activity might be introduced.
- ° HEPA and charcoal filters shall be tested in place after installation. Sample probes and injection nozzles shall be provided for this and subsequent routine testing.
- ° HEPA filters shall meet or exceed Hanford Standard HWS-7511-S.

2.4.3 Exhaust Air Systems

2.4.3.1 Auxiliary backup equipment and damper controls shall be installed to provide exhaust air flow during shutdown or power failure.

2.4.3.2 Ducts which may carry radioactive materials should not pass through Uncontrolled Zones. Special attention should be given to prevention of contamination spread from maintenance or sampling operations.

2.4.3.3 Filtration and treatment shall be designed to ensure that building exhaust air concentrations will not exceed

concentration guides listed in AEC Manual Chapter 0524, Annex A, Table II. Where high radiotoxicity materials are being handled in a way in which they might become airborne, either deliberately or accidentally, double filtration shall be provided even though a single filter would satisfy the above criterion.

2.4.3.4 HEPA Filters shall be used in exhaust systems for restraining particulate material and charcoal filters shall be used in exhaust systems for restraining radioiodine. When the nature of other air pollutants precludes the use of either type of filter, an exception to these criteria may be sought in accordance with Section 2.1.

2.4.3.5 HEPA (and charcoal, if needed) filters shall be provided in vacuum systems, cells, hoods, glove boxes and room exhausts to provide primary removal near the source, if radioactive materials are to be handled in a way in which they might become airborne, either deliberately or accidentally. Design should make replacement of such filters easy and also facilitate contamination control during replacement, especially when heavy loading with radioactive material is anticipated.

2.4.3.6 Protection of the environment should be maximized by installing HEPA (and charcoal filters, if needed) near the exhaust fans to intercept materials which may have accumulated in the duct work or which may have escaped when upstream filters were being changed or were damaged.

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 4 OF 5	BNWL-MA-3	2.4
----------------------	----------------------------	----------------	-----------	-----

2.4.3.7 HEPA and charcoal filters shall be tested in place after installation. Sample probes and injection nozzles shall be provided in original construction to facilitate this and subsequent routine testing. (See Section 2.7.9 for sampling equipment and monitoring criteria.)

2.5 Water Supply and Sewer Systems

2.5.1 Water Supply Systems

- ° Sanitary water shall be provided in Radiation Zones only for safety showers and fire protection sprinkler systems. Drinking fountains shall not be located in Radiation Zones. Drinking fountains should be located in Controlled Zones, in change rooms, in personnel decontamination rooms and in corridors where contamination can be controlled except for occasional accidents.
- ° Process water supplied to radioactive processes and Radiation Zones shall be isolated from sanitary water systems, either by separated system such as a tank and pump or by an approved back flow preventer.

2.5.2 Waste Water Sewers

2.5.2.1 General

- ° Drains, sewers, catch tanks, etc., as required shall be provided to facilitate segregation and continuous control of liquid waste streams, and to simplify sampling, monitoring and diversion. Sinks and drain lines shall be labeled to indicate to which sewer system they are linked.
- ° Backflow of air through sewer lines shall be prevented by use of seals or suction fans.

- ° Class A work stations and adjacent areas which might receive the effects of a spill or an accidental release shall be served only by a contaminated sewer or a high level waste tank.
- ° Gravity flow should be utilized for the transfer of liquid waste.
- ° Design should provide for the disposal of immiscible oils, organic wastes and other materials not readily dispersible in water in order to prevent disposal to waste water sewers.
- ° Wherever fissile materials are to be handled attention is called to the possibility that BNWL-MA-25, "Criticality Safety Procedures", may apply to the sewer.

2.5.2.2 Sanitary Sewers

- ° Radiation Zones shall not contain sinks equipped with drains connected to a sanitary sewer.
- ° The discharge of process waste to any sanitary sewer is not permitted by these criteria. When design requirements provide no satisfactory alternate, an exception to these criteria may be sought in accordance with Section 2.1.
- ° Sanitary sewer lines should not pass through areas where radioactive contamination is expected.

2.5.2.3 Process Waste Sewer

- ° Process sewers shall be equipped with a sampling system

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 2 OF 5	BNWL-MA-3	2.5
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which provides a representative sample of the waste. (In the 300 Area the chemical process sewer is sampled at the point of discharge to the 300 Area ponds.)

- ° Process sewers shall not be provided in Class A or Class B work stations or in adjacent areas which might become accidentally contaminated. Particular attention should be paid to floor drains, janitor sinks, process equipment, and personnel decontamination stations which might receive radioactive materials either through normal use or by accident.

2.5.2.4 Retention Sewer

- ° In the 300 Area, cooling water and other normally non-radioactive waste water from Class A or Class B work stations or adjacent areas should be discharged to the retention sewer.
- ° A monitored waste system with diversion capabilities similar to the retention sewer shall be provided for the disposal of normally non-radioactive waste water from Class A or Class B work stations and adjacent areas which might become accidentally contaminated.
- ° Connection to the retention sewer or other monitored waste system shall not be provided for the normal disposal of radioactive waste or where accidental release of more than 1 curie of any radionuclide might occur.

2.5.2.5 Contaminated Sewer

- ° A contaminated waste system shall be provided to receive deliberate disposal of radioactive aqueous wastes in amounts less than 200 curies and wastes from accidental spills, equipment and surface decontamination, and diversion from the monitored waste system when that is required.
- ° Where a central contaminated sewer system is not provided, facilities shall be provided to adequately handle such wastes as are generated and to preclude inadvertent disposal of contaminated waste to sewer systems not designed for proper control.
- ° Where a central contaminated sewer system is provided in the 300 Area, that system shall be discharged to the Contaminated Waste Sewer (CBWS).
- ° Fixtures, equipment, and piping used for disposal of radioactive waste shall be of materials that are highly resistant to corrosive agents, including those which may be introduced to the system for decontamination. Stainless steel should be used for piping and equipment; sinks of stainless steel or vitreous china should be used. Stainless steel pipe and fittings shall be welded at all joints. Surfaces of sinks and piping shall be smooth and free of abrupt bends or depressions which may allow accumulation of solids. Where particulate material, such as grindings and cuttings may be encountered, the waste water shall be filtered before it enters the contaminated waste system.

- ° Waste flow from source or origin to the storage or disposal location shall be by gravity. The consequences of contamination spread shall be evaluated by competent radiation protection personnel before committing the design of a radioactive waste system to the use of positive pressures in excess of 10 ft of water. The high cost of pump maintenance in high dose rate areas should also be considered.
- ° Contaminated waste lines should not pass through areas within a building which are not planned to be Radiation Zones.
- ° Normal maintenance points such as cleanouts should be designed and located with contamination control in mind. Ease of maintenance should be considered in designing a contaminated waste system.

2.5.3 High Level Wastes

- ° Special tanks or other system shall be provided for the disposal of quantities of radioactive materials exceeding 200 curies.
- ° A vacuum system (jets may be used) shall be provided to raise wastes with high dose rates into shielded casks for transport to 200 Area storage tanks. In no case shall such liquid streams be put under positive pressure.
- ° Underground pits containing waste storage tanks shall be equipped with sumps containing alarm monitors to indicate leaks or spills. Such sumps and high level systems shall not be connected to any other waste system.

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 5 OF 5	BNWL-MA-3	2.5
----------------------	----------------------------	----------------	-----------	-----

2.6 Radioactive Work Stations

2.6.1 Class A Work Stations

- ° Class A work stations shall be located inside a Radiation Zone.
- ° Materials of construction shall be corrosion resistant and incombustible.
- ° Work stations shall be equipped with a closed hood or cell.
- ° Supply air to a hood or cell shall be filtered through a high efficiency particulate air (HEPA) filter for positive prevention of spread of contamination.
- ° Exhaust air shall be filtered in the hood or cell. (See Section 2.4 for criteria for exhaust air systems.)
- ° Work stations shall be equipped with contaminated sewer connections. (See Section 2.5 for criteria for sewers.)
- ° Provision shall be made for the temporary storage of solid waste at each work station.
- ° All piping, valve stems, drive shafts, etc., shall have an air tight entrance through a rigid (metal or concrete) portion of the hood or cell. Back flow of radioactive materials into piping shall be prevented.

- ° Insertion and removal of materials through bags or sphincters shall be preferred. (See Section 3.1 - References.) Air locks may be used if necessary, but are considered less desirable.
- ° If hood gloves are provided, double ring seals shall be required. (See Section 3.1 - References.) All equipment should be within easy reach of gloves.
- ° Motors, pumps, valves, etc., shall be contained in cabinets which are easy to decontaminate.
- ° Series of hoods should be compartmentalized into several small areas so that a contamination spread is confined to a small area.

2.6.2 Class B Work Stations

- ° Class B work stations shall be located inside a Radiation Zone.
- ° Materials of construction should be corrosion resistant and incombustible.
- ° Work station shall be equipped with, at least, an open faced hood. (See Section 2.4 for criteria for air supply and exhaust from hoods.)
- ° Waste water lines shall be routed to a sewer designed to accept radioactive waste in the quantities anticipated. (See Section 2.5 for criteria for sewers.)

2.6.3 Class C Work Stations

- ° Class C work station need not be located inside a Radiation Zone. However, radioactive material shall be located within a Radiation

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 2 OF 5	BNWL-MA-3	2.6
----------------------	----------------------------	----------------	-----------	-----

Zone which, in this case, may constitute only a part of the work station.

- ° Air exhaust near the work station shall be adequate to maintain concentrations of radioactive materials in breathing zones below values listed in AEC Manual Chapter 0524, Annex A, Table I.
- ° Exhaust air shall be filtered. (See Section 2.5 for criteria for exhaust air systems.)
- ° Waste water shall be routed to a sewer designed to accept radioactive waste in the quantities anticipated. (See Section 2.5 for criteria for sewers.)

2.6.4 Storage Facilities

- ° Plans for storage of more than 300 Ci of radioactive material at a concentration exceeding 100 $\mu\text{Ci/g}$ shall be submitted to Nuclear Safety for review and approval.
- ° High radiotoxicity materials shall be stored in containers or facilities providing at least two barriers to prevent the loss of control of material. The barriers shall be designed to provide containment at all times when the material is in transit or stored outside a suitable work station as described above.
- ° Medium radiotoxicity materials shall be stored in containers or facilities presenting at least one barrier to loss of control of the material. The barrier shall be designed to provide containment at all times when the material is in transit or stored outside a suitable work station as described above.

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 3 OF 5	BNWL-MA-3	2.6
----------------------	----------------------------	----------------	-----------	-----

- ° Separate storage facilities shall be provided for all Class A work stations where more than 300 Ci of material will accumulate, and for storage of casks or other transfer vessels used outside the work stations. Storage facilities for contaminated tools and equipment should be provided if such facilities will aid in keeping work stations uncluttered.

2.6.5 Storage of Sealed Sources

- ° Encapsulated (sealed) sources shall be shielded as necessary to insure that no person is subjected to more than 0.2 mrem/hr in routinely occupied locations. Unauthorized access to shielded sources shall be prevented. Consideration should be given to detection and control of radioactive material in case of failure of encapsulation.
- ° The source storage enclosure should be located near the point of use to reduce the exposure of personnel during transfer of sources.
- ° Separate compartments should be provided for different types of sources. The shielding provided by the individual compartments and the enclosure as a whole should minimize the dose rate to a person standing in front of the enclosure.

2.6.6 Shielded Work Stations

- ° Shielded work stations shall meet the radiological criteria contained in Section 2.8.1.2, Controlled Zone, as well as other criteria pertaining to Class A, B or C work stations which apply if the radioactive material is not contained within the shield.

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 4 OF 5	BNWL-MA- 3	2.6
----------------------	----------------------------	----------------	------------	-----

- ° Water-filled canals, pools or pits may be used for handling or storage. Radioactive materials handled or stored this way shall be limited to insoluble solids or encapsulated items. Accidental siphoning or emptying of water shall be prevented. Accidental exposure to underwater items by removal of materials from the water shall be prevented by appropriate physical restraints. Basins and similar facilities should be lined or painted to facilitate decontamination. The water should be circulated through filters and ion exchange beds for decontamination and water clarity.

2.6.7 Radiation Generating Machines and Large Source Installations

- ° Design of facilities for the use of radiation generating machines, particle accelerators, or large sources shall be submitted to Radiation Standards for review and approval. Radiation generating machines and facilities in which such machines are used shall meet the requirements of Immediate Action Announcement SS-69-6. Additional guidance can be obtained from National Bureau of Standards Handbooks. (See Section 3.1 - References.)

DATE ISSUED: 3-25-70	SUPERSEDES ISSUE DATED:	PAGE 5 OF 5	BNWL-MA- 3	2.6
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2.7 Radiation Monitoring Systems

2.7.1 Central Monitoring Panel

- ° A building containing Class A or B work stations shall be supplied with a central monitoring panel for meters, recorders and annunciators.
- ° A central read-out panel for automatic monitoring instrumentation should be provided in the monitoring office unless included as a requirement for a control room (e.g., reactor control room).

2.7.2 Remote Area Monitoring

- ° Remote area radiation monitoring systems shall be provided for any area where dose rates to personnel in excess of 250 mrem/hr may occur.
- ° High level alarms shall be provided for any area where doses to personnel in excess of 10 rem may be possible.
- ° The remote area monitoring system shall meet performance criteria established by External Dose Evaluations, Radiation Protection Department.
- ° Automatic dose rate alarms shall be provided at routinely occupied work locations and shall be adjustable to alarm over the range of the detectors.

- ° The radiation monitoring system shall indicate the radiation dose rate from remote stations on a read-out panel in the Radiation Monitoring office or in a control room.
- ° The range of the radiation detectors should be 1 mR/hr to 10⁴ R/hr.
- ° The remote detectors shall be interchangeable and have in-place calibration capability.
- ° Self-checking failure alarms should be provided on all channels of the system.
- ° Continuous recorders should be provided when in the opinion of operating management, radiation exposure control would be improved.

2.7.3 Criticality Alarm System

- ° Any building where more than 45% of a minimum critical mass of fissionable material is permitted to be present shall have a criticality detector and alarm system. The system shall meet the requirements established by Nuclear Safety, Safety and Standards Division.
- ° The criticality alarm system shall include neutron detectors, an annunciator comparator unit, fail-safe relay control unit, isolated and filtered power, and howlers (see Appendix for drawing numbers and specifications).

- ° The criticality alarm system shall be connected to a continuously occupied location. Facilities located in the 300 Area shall also be connected to the BNW Area Emergency Center.
- ° There shall be a minimum of three detectors in a system, with two detectors within 300 feet of any fissionable materials with no more than the equivalent of one foot of intervening concrete. Material-detector distances shall be reduced to accommodate thicker shields.
- ° Changes in specifications, locations, etc., of criticality detectors and alarm system components, shall be reviewed by the Safety and Standards Division.

2.7.4 Criticality Dosimeter

- ° The Hanford Criticality Dosimeter shall be located according to requirements established by External Dose Evaluations, Radiation Protection Department.

2.7.5 Room Air Sampler

- ° Fixed air sampling facilities shall be provided in all rooms, work areas, laboratories, and operating areas which are to be used as Class A or B work stations.
- ° Sample heads shall be placed at selected locations, either representative of the breathing zone of the worker or indicative of room air contamination. To be representative the sampler head should be located above floor level within a three-foot radius

of the work locations. To be indicative the sampler head should be located in front of the room air exhaust. The minimum installation frequency shall be one sample head per room, area, etc.

- ° Areas occupied by personnel where concentrations of airborne radionuclides are expected to exceed values listed in AEC Manual Chapter 0524, Annex A, Table I, Column 1, shall contain a sensitive automatic alarming device which shall alarm when the airborne concentration equals or exceeds 10 MPC; the maximum allowable interval for the alarm to respond shall be less than two hours.
- ° Fixed room air samplers may be operated by vacuum furnished from a central vacuum system or by individual samplers. The capacity of the vacuum system shall be capable of providing a pressure drop equal to twenty inches of water at each sampling head when all sampling heads in the system are in simultaneous use.
- ° The central air sample vacuum system shall be separate from the vacuum system maintained for other facility services.

2.7.6 Hand and Shoe Counters

- ° Hand and shoe counter(s) shall be located near the change room and near convenient exits.
- ° Hand and shoe counters shall meet performance criteria established by External Dose Evaluations, Radiation Protection Department.

2.7.7 Building Air Balance Alarms

- ° Appropriate annunciators shall be provided to signal the loss of building air balance. These shall alarm in the building air balance operator's office or in a continuously manned location.

2.7.8 Door Alarms

- ° Except for the main entrance, annunciators should be provided on all doors leading to the outside of building containing Class A and Class B work stations. Annunciators shall signal the fact that doors are open and that a breach in the contamination control system exists. These shall alarm at a central panel which may be in the Radiation Monitoring office or a central control room.

2.7.9 Exhaust Air Monitoring

- ° Provision shall be made to sample air in all vents and stacks exhausting air from areas which include Class A, B or C work stations.
- ° Continuous air monitoring instruments shall be installed where releases exceed AEC Manual Chapter Appendix 0524, Annex A, Table II concentration guides may occur as a result of an accident.
- ° A sampling probe shall be installed where continuous sampling is required. The sampler nozzle shall be positioned parallel to the axis of the stack with its open end pointed upstream. The

access port through which the sampling probe is inserted shall be equipped to permit cross-duct sampling during initial operation to permit permanent positioning of the nozzle in the optimum location relative to the centerline of the stack. The probe nozzle and sample line shall be sized with reference to the sample size required to attain an air velocity into the probe nozzle approximately the same as in the stack (isokinetic flow).

- ° The sampling probe shall be located where a reasonable degree of mixing can be expected to occur. Normally, this shall be at least six diameters beyond the last bend or confluence.
- ° Exhaust air ducts from Class A or B work stations shall have sampling points provided in which sampling probes as described above may be inserted subsequent to building construction.
- ° Probes shall be provided both upstream and downstream of each filter or scrubber to permit routine sampling and testing of efficiency. HEPA filters shall be subjected to a DOP test after installation to check for leaks. Necessary equipment shall be provided to permit the routine measurement of pressure drop across filter banks. Readout and alarm from a continuously monitored location shall be provided at the Radiation Monitoring office or central control room.
- ° Exhaust air samplers may be operated from a centralized vacuum system or by an independent motorized pump at the sampling locations. A pressure drop of 20" of water shall be required

at each sampler. Exhaust air from a stack or duct air sample vacuum system shall be returned to the exhaust plenum via a closed system.

2.7.10. Liquid Waste Monitoring

- ° Provision shall be made for sampling all waste streams except sanitary sewers from a building containing Class A, B or C work stations.
- ° If the process sewer system is connected to the 300 Area retention waste system, the monitoring and diversion provisions of the retention waste system shall be considered adequate to satisfy the sampling and monitoring requirements.
- ° Monitoring and diversion of wastes to storage or to a suitable sewer shall be provided where there is a significant probability that accidental release of radioactive materials may exceed AEC Manual Chapter Appendix 0524, Annex A, Table I, Column 2, concentration guides.
- ° Waste monitoring systems provided for a facility shall readout and alarm in the radiation monitoring office or a control room of that facility.

3.0 APPENDIX

3.1 Equipment References

Glove Box Port Rings	Drawing H-3-12221
Criticality Alarm System	
Detectors	Drawing H-3-25962
Annunciator Comparator	Drawings H-3-29401, H-3-29402, H-3-29403
Fail-Safe Relay Control Unit, Isolated and Filter Power and Howlers	Hanford Standard HWS-8210-S
High Efficiency Particle Air (HEPA) Filter	Hanford Standard HWS-7511-S
Breathing Air System	Hanford Standard HWS-M2-14A6B

3.2 Instrument Specifications

In preparation - Contact Manager, External Dose Evaluation.

3.3 Literature References

"Protection Against Betatron-Synchrotron Radiations Up To 100 Million Electron Volts", National Bureau of Standards Handbook 55.

"Protection Against Neutron Radiation UP To 30 Million Electron Volts", National Bureau of Standards Handbook 63.

"Safety Standard for Non-Medical X-Ray and Sealed Gamma Ray Sources", National Bureau of Standards Handbook 93.

"Shielding for High Energy Electron Accelerator Installations", National Bureau of Standards Handbook 97.

"Radiation Generating Machine Procedure", Battelle-Northwest Immediate Action Announcement SS-69-6.