CHAPTER 12

RADIATION PROTECTION

SECTION 12.1

CONTENTS

RADIATION PROTECTION

12.1 ENSURING THAT OCCUPATIONAL RADIATION EXPOSURES ARE AS LOW AS REASONABLY ACHIEVABLE (ALARA)

12.1.1 Policy Considerations

Administrative programs and procedures, in conjunction with facility design, ensure that the occupational radiation exposure to personnel will be kept As Low As Reasonably Achievable (ALARA).

12.1.1.1 Design and Construction Policies

The ALARA philosophy was applied during the initial design of the plant and implemented via internal design reviews. The design was reviewed in detail for ALARA considerations and was reviewed, updated and modified as necessary during the design phase as experience was gained from operating plants. Engineers reviewed the plant design and integrated the layout, shielding, ventilation and monitoring instrument designs with traffic control, security, access control and health physics aspects to ensure that the overall design is conducive to maintaining exposures ALARA.

All pipe routings containing radioactive fluids were reviewed as part of the engineering design effort. This ensured that lines expected to contain significant radiation sources are adequately shielded and properly routed to minimize exposure to personnel.

Operating plant results were continuously integrated during the design phase of the Nuclear Island. Review by and input from various utilities was used in such areas as TIP drive and control rod drive maintenance, and the incorporation of the suppression pool cleanup system.

12.1.1.1 Design and Construction Policies (Continued)

(Description on onsite inspections to determine that the design and operation keeps radiation exposures ALARA is, where required, the responsibility of the Applicant.)

12.1.1.2 Operation Policies

(Description of operational policies to maintain occupational doses ALARA is the responsibility of the Applicant.)

12.1.1.3 Compliance with 10CFR20 and Regulatory Guides 8.8, 8.10 and 1.8

Compliance of the Nuclear Island design with Title 10 of the Code of Federal Regulations, Part 20 (10CFR20), is ensured by the compliance of the design and operation of the facility within the guidelines of Regulatory Guides 8.8, 8.10 and 1.8.

12.1.1.3.1 Compliance with Regulatory Guide 8.8

The design of the Nuclear Island fully meets the intent of Revision 1 of Regulatory Guide 8.8, and reflects the commitment of General Electric and its subcontractors. Examples of compliance with all items in Section C.3 of the regulatory guide are delineated in Subsection 12.3.1 of this SAR. Design features of the Nuclear Island allow the Applicant to comply easily with the recommendations of Subsection C.4 of the guide. For instance, provisions are made in systems such as the Reactor Water Cleanup System (RWCS) to allow flushing of the piping in shielded cubicles before entry, and to use remote reach rods. Breathing air headers are provided in areas where past experience indicates airborne radioactivity has been a problem. Design provisions allow for remote operation of fuel handling and radwaste cask filling.

12.1.1.3.1 Compliance with Regulatory Guide 8.8 (Continued)

(Further discussion of compliance with the regulatory guide, if required, is the responsibility of the Applicant.)

12.1.1.3.2 Compliance with Regulatory Guide 8.10

(Description of compliance with this regulatory guide is the responsibility of the Applicant.)

12.1.1.3.3 Compliance with Regulatory Guide 1.8

(Description of compliance with this regulatory guide is the responsibility of the Applicant.)

12.1.2 Design Considerations

This subsection discusses the methods and features by which the policy considerations of Subsection 12.1.1 are applied. Provisions and designs for maintaining personnel exposures ALARA are presented in detail in Subsections 12.3.1 and 12.3.2.

12.1.2.1 General Design Consideration for ALARA Exposures

General design considerations and method employed to maintain inplant radiation exposures ALARA, consistent with the recommendations of Regulatory Guide 8.8, have two objectives:

(1) minimizing the necessity for and amount of personnel time spent in radiation areas, and

(2) minimizing radiation levels in routinely occupied plant areas in the vicinity of plant equipment expected to require personnel attention.

12.1.2.1 General Design Consideration for ALARA Exposures (Continued)

Both equipment and facility designs are considered in maintaining exposures ALARA during plant operations. Events considered include normal operation maintenance and repairs, refueling operations and fuel storage, inservice inspection and calibrations, radioactive waste handling and disposal, etc.

12.1.2.2 Equipment Design Considerations For ALARA Exposures

12.1.2.2.1 General Design Criteria

The engineering design procedures require that the component design engineer consider the applicable regulatory guides as a part of the design criteria. This includes Regulatory Guide 8.8. In this way, the radiation problems of a component or system are considered. A summary survey of the components designs was made to determine the factors considered. The following paragraphs cite some examples of design considerations made to implement ALARA.

12.1.2.2.2 Equipment Design Considerations to Limit Time Spent in Radiation Areas

(1) Equipment is designed to be operated and have its instrumentation and controls in accessible areas both during normal and abnormal operating conditions. Equipment such as the Reactor Water Cleanup (RWCS) System and the Fuel Pool Cleanup (FPCCU) System are remotely operated, including the backwashing and precoat operations. Other equipment has been redesigned in order to lengthen service life. For example, seal water is applied to the recirculation pump seals to keep them clean. This increased the maintenance interval from

12.1.2.2.2 Equipment Design Considerations to Limit Time Spent in Radiation Areas (Continued)

approximately 1 year to more than 3 years. Changes in the LPRM design changed the expected life from 1 to 3 years.

(2) Equipment is designed to facilitate maintenance. Equipment such as the RHR heat exchanger is designed with an excess of tubes in order to permit plugging of some tubes. The heat exchanger has drains to allow draining of the shell side water. Some of the valves have stem packing of the cartridge type that can be easily replaced. The recirculation pipes have blocking valves in order to isolate the pump. The BWR/6 Mark III has a CRD maintenance machine that reduces manhours for removal or replacement by a factor of 5. Refueling tools are designed for drainage and with smooth surfaces in order to reduce contamination. Vessel and piping insulation is of an easily removable type.

(3) The materials selected for use in the system have been chosen to fulfill the environmental requirements. Valves, for example, use grafoil stem packing to reduce leakage and maintenance.

(4) Past experience has been factored into current designs. The steam relief valves have been redesigned as a result of inservice testing. Access for inservice inspection has been changed.

12.1.2.2.3 Equipment Design Considerations to Limit Component Radiation Levels

(1) Equipment and piping were designed to reduce the accumulation of radioactive materials in the equipment. The piping, where possible, was constructed of seamless pipe as a means to reduce radiation accumulation on the seam. The control rod drive volume tanks are sloped for drainage and flushing capability to reduce accumulation of radioactivity. The filter demineralizers in the RWCS and FPCCU Systems are backwashed and flushed prior to maintenance.

(2) Equipment designs include provisions for limiting leaks or controlling the fluid that does leak. This includes piping the released fluid to the sumps and the use of drip pans with drains piped to the floor drains.

(3) The materials selected for use in the primary coolant system consist mainly of austenitic stainless steel, carbon steel and low alloy steel components.

(4) The system design includes a RWCS and a Condensate Demineralizer System on the reactor feedwater. These systems are designed to limit the radioactive isotopes in the reactor system. The systems are described in Subsections 5.4.8 and 10.4.6.

12.1.2.3 Facility Layout General Design Considerations for Maintaining Radiation Exposures ALARA

12.1.2.3.1 Minimizing Personnel Time Spent in Radiation Areas

Facility general design considerations to minimize the amount of personnel time spent in radiation areas include the following:

12.1.2.3.1 Minimizing Personnel Time Spent in Radiation Areas (Continued)

(1) locating equipment, instruments, and sampling stations, which require routine maintenance, calibration, operation, or inspection, for ease of access and minimum of required occupancy time in radiation areas;

(2) laying out plant areas to allow remote or mechanical operation, service, monitoring, or inspection of highly radioactive equipment; and

(3) providing, where practicable, for transportation of equipment or components requiring service to a lower radiation area.

12.1.2.3.2 Minimizing Radiation Levels in Plant Access Areas and Vicinity of Equipment

Facility general design considerations directed toward minimizing radiation levels in plant access areas and in the vicinity of equipment requiring personnel attention include the following:

(1) separating radiation sources and occupied areas where practicable (e.g., pipes or ducts containing potentially high radioactive fluids not passing through occupied areas);

(2) providing adequate shielding between radiation sources and access and service areas;

(3) locating equipment, instruments, and sampling sites in the lowest practicable radiation zone;

12.1.2.3.2 Minimizing Radiation Levels in Plant Access Areas and Vicinity of Equipment (Continued)

(4) providing central control panels to permit remote operation of all essential instrumentation and controls from the lowest radiation zone practicable;

(5) where practicable for package units, separating highly radioactive equipment from less radioactive equipment, instruments, and controls;

(6) providing means and adequate space for utilizing moveable shielding for sources within the service area when required;

(7) providing means to control contamination and to facilitate decontamination of potentially contaminated areas where practicable;

(8) providing means for decontamination of service areas;

(9) providing space for pumps and valves outside of highly radioactive areas;

(10) providing remotely operated centrifugal discharge and/or backflushable filter systems for highly radioactive radwaste and cleanup systems;

(11) providing labyrinth entrances to radioactive pump, equipment, and valve rooms;

(12) providing adequate space in labyrinth entrances for easy access; and

(13) maintaining ventilation air flow patterns from areas of lower radioactivity to areas of higher radioactivity.

12.1.3 Operational Considerations

(Description of operational considerations to maintain doses to operators ALARA is the responsibility of the Applicant.)

SECTION 12.2

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SECTION 12.2

TABLES

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ILLUSTRATIONS

12.2 RADIATION SOURCES

12.2.1 Contained Sources

12.2.1.1 Source Terms

12.2.1.1.1 General

With the exception of the vessel and drywell shields, shielding designs are based on fission product and activation product sources consistent with Section 11.1. For shielding, it is conservative to design for fission product sources at peak values rather than an annual average, even though experience supports a lower annual average than the design average (Reference 1). It should be noted that activation products, principally Nitrogen-16, control shielding calculations in most of the primary system. In areas where fission products are significant, conservative allowance is made for transient decay while at the same time providing for transient increase of the noble gas source, daughter product formation and energy level of emission. Areas where fission products are significant relative to Nitrogen-16 include: (1) the condenser off-gas system downstream of the jet air ejector; (2) liquid and solid radwaste equipment; (3) portions of the RWCS; and (4) portions of the feedwater system downstream of the hotwell including condensate treatment equipment.

For application, the design sources are grouped first by location and then by equipment type (e.g., reactor building, core sources). The following paragraphs represent the source data in various pieces of equipment throughout the plant. General locations of equipment are shown in the general plant arrangement drawings of Section 1.2.

12.2.1.2 Reactor Building

12.2.1.2.1 Reactor Vessel Sources

12.2.1.2.1.1 Radiation from the Reactor Core

12.2.1.2.1.1.1 General

The information in this section defines a reactor vessel model and the associated gamma and neutron radiation sources. This section is designed to provide the data required for calculations beyond the vessel. The data selected were not chosen for any given program, but were chosen to provide information for any of several shield program types. In addition to the source data, calculated radiation dose levels are provided at locations surrounding the vessel. These data are given as a potential check point for calculations by shield designers.

12.2.1.2.1.1.2 Physical Data

Table 12.2-1 presents the physical data required to form the model in Figure 12.2-1. This model was selected to contain as few separate regions as possible to adequately portray the reactor. Table 12.2-1 provides nominal dimensions and material volume fractions for each boundary and region in the reactor model. To describe the reactor core, Table 12.2-1 provides thermal power, power density, core dimensions, core average material volume fractions and reactor power distributions. The reactor power distributions are given for both radial and axial distributions. These data contain uncertainties in the volume regions near the edge of the core. The level of uncertainties for these regions is estimated at 20%.

12.2.1.2.1.1.3 Core Boundary Neutron Fluxes

Table 12.2-2 presents peak axial neutron multigroup fluxes at the core equivalent radius. The core-equivalent radius is a hypothetical boundary enclosing an area equal to the area of the fuel bundles and the coolant space between them. The peak axial flux occurs adjacent to the portion of the core with the greatest power. As shown by the data in Table 12.2-1, this point is below the core midplane. Since these data are calculated with a core-equivalent radius, the flux represents a mean flux in the azimuthal angle around the core. While the flux within any given energy group is not known within a factor of 2, the total calculated core boundary flux is estimated to be within ±50%.

12.2.1.2.1.1.4 Gamma Ray Source Energy Spectra

Table 12.2-3 presents average gamma ray energy spectra per watt of reactor power in both core and noncore regions. In Table 12.2-3, part A, the energy spectra in the core are presented. The energy spectra in the core represent the average gamma ray energy released by energy group per watt of core thermal power. The energy spectra in MeV per sec per watt (MeV/sec/W) can be used with the total core power and power distributions to obtain the source in any part of the core.

The gamma ray energy spectra include the fission gamma rays, the fission product gamma ray and the gamma rays resulting from inelastic neutron scattering and thermal neutron capture. The total gamma ray energy released in the core is estimated to be accurate to within ±10%. The energy release rate above 6 MeV may be in error by as much as a factor of ±2.

Table 12.2-3, part B, gives a gamma ray energy spectrum in MeV/sec/W in spent fuel as a function of time after operation. The data were prepared from tables of fission product decay gamma

12.2.1.2.1.1.4 Gamma Ray Source Energy Spectra (Continued)

fitted to integral measurements for operation times of 10^8 sec, or approximately 3.2 years. To obtain shutdown sources in the core, the gamma ray energy spectra are combined with the core thermal power and power distributions. Shutdown sources in a single fuel element can be obtained by using the gamma ray energy spectra and the thermal power the element contained during operation.

Table 12.2-3, part C, gives the gamma ray energy spectra in the cylindrical regions of the reactor from the core through the vessel. The energy spectra are given in terms of MeV/cm^2/sec/W at the inside surface and outside surfaces of the region. This energy spectrum, multiplied by the core thermal power, is the gamma ray source. The point on the inside surface of the region is the maximum point within the region. In the radial direction, the variation in source intensity may be approximated by an exponential fit to the data on the inside and outside surfaces of the region. The axial variation in a region can be estimated by using the core axial variation. The uncertainty in the gamma ray energy spectra is due primarily to the uncertainty in the neutron flux in these regions. The uncertainty in the neutron flux is estimated to vary from approximately ±50% at the core boundary to a factor of ±3 at the outside of the vessel. The calculations were carried out with voids beyond the vessel. The presence of shield materials beyond the vessel will cause in increase in the gamma source on the outside of the vessel.

12.2.1.2.1.1.5 Gamma Ray and Neutron Fluxes Outside the Vessel

Table 12.2-4 presents the maximum axial neutron and gamma ray fluxes outside the vessel. The maximum axial flux occurs on the vessel opposite the elevation of the core with the maximum power level. This elevation can be located using the data from Table 12.2-1. The fluxes at this elevation are based on a mean

12.2.1.2.1.1.5 Gamma Ray and Neutron Fluxes Outside the Vessel (Continued)

radius core and do not show azimuths angle variations. The calculational model for these fluxes assumed no shield materials beyond the vessel wall. The presence of shield materials will significantly alter the neutron fluxes in the lower end of the neutron energy spectrum. The gamma ray calculations include gamma ray sources from all of the cylindrical regions between the center of the core and the edge of the vessel. While the uncertainties in a given energy group flux may be a factor of ±3, the uncertainties in the total integral flux are estimated to be within a factor of two.

12.2.1.2.1.1.6 Gamma Ray Dose Rates and Fast Neutron Fluxes at the Vessel

Table 12.2-5 presents calculated fast neutron fluxes greater than 1 MeV and gamma ray dose rates in rad per hour at three points outside of the vessel. The points include a point on the radius of the vessel at the elevation of the peak power in the core, a point on the vessel centerline at the top head and a point on the vessel centerline at the bottom head. At the vessel radius, the calculated fast flux and gamma ray dose rates contain the same type of uncertainties as the total integral fluxes.

This uncertainty is estimated to be within a factor of ±2. The top head data in Table 12.2-5 have been treated in a very conservative manner. As a result, the data at the top head represent maximum conditions. It is estimated that the flux at this location could be more that a factor of 3 lower. At the centerline position on the bottom head, the neutron calculation represents an upper limit. At this point, the calculated neutron flux from the core was orders of magnitudes less than the data given in Table 12.2-5. The calculated gamma dose rate from the core is not known to better than a factor of ±2. At the bottom head, there

12.2.1.2.1.1.6 Gamma Ray Dose Rates and Fast Neutron Fluxes at the Vessel (Continued)

there will be a contribution to the gamma dose rate from accumulations of radioisotopes in the bottom of the vessel. This contribution will be dependent on the history of the plant. The radioisotope contribution is not included in Table 12.2-5.

12.2.1.2.2 Radioactive Sources in the Reactor Water, Steam and Offgas

T radioactive sources in the reactor water, steam and offgas are co red and discussed in Chapter 11 (Subsections 11.1.1 through 11.1.4). This material provides the concentrations during normal operation of the radioisotopes in the reactor vessel or leaving the reactor vessel.

12.2.1.2.3 Radioactive Sources in the Engineered Safeguard Systems

The engineered safeguard systems include the HPCS and the LPCS Systems, which are described in Section 6.3. During operation, the systems take suction from either the condensate storage tank or from the suppression pool. The radiation source in the equipment is the activity of the water transported through the system. During routine testing of the systems, the activity of the suction water is the average expected condition of the water in the suppression pool or the condensate storage tank. Following a loss-of-coolant accident, (LOCA), the activity in the suppression pool water is defined by Regulatory Guide 1.7.

12.2.1.2.4 Radioactive Sources in the Residual Heat Removal System

The radioactive sources in the Residual Heat Removal (RHR) System were calculated for the system operating in the reactor shutdown mode. In this mode, the system recirculates reactor coolant to

12.2.1.2.4 Radioactive Sources in the Residual Heat Removal System (Continued)

remove reactor decay heat (Subsection 5.4.7). The RHR System is operated from approximately 2-4 hours after shutdown until the end of the refueling period. The source in the RHR System is the activity in the volume of reactor water contained in the system. This should include the increase of activity as a result of depressurization. The sources are provided in Tables 12.2-6 and 12.2-7.

12.2.1.2.5 Radioactive Sources in Reactor Core Isolation Cooling System

The radioactive sources in the Reactor Core Isolation Cooling (RCIC) System were evaluated for the systems operating in the reactor shutdown mode. These systems may be utilized during reactor shutdown if the main condenser is unavailable. The systems are operated from the time of reactor shutdown for approximately 2 hr until a reactor pressure of 50 psig for the RCIC is achieved. Below 150 psig, the RCIC flow decreases. The source in the system is the activity in the volume of reactor water and steam contained in the system.

During routine testing of the system, the source in the equipment is the activity of the steam driving the system turbine. This activity is controlled by the Nitrogen-16. The radiation source data used in the shield design for this system is shown in Table 12.2-8.

12.2.1.2.6 Radioactive Sources in Radwaste Systems

12.2.1.2.6.1 Radioactive Sources in the Reactor Water Cleanup System

The radioactive sources are the result of the activity in the reactor water in transit through the system or accumulation of

12.2.1.2.6.1 Radioactive Sources in the Reactor Water Cleanup System (Continued)

radioisotopes removed from the water. Components for this system include regenerative and nonregenerative heat exchangers, pumps, valves, filter demineralizers and the backwash receiving tank (Subsection 5.4.8). The accumulated sources in the filter demineralizers, backwash receiving tanks and heat exchangers are given in Tables 12.2-9 through 12.2-12.

The source is present in the filters and receiving tank during all modes of operation. Therefore, backwashing capability is provided to remove the residual activity for effective radwaste handling.

12.2.1.2.6.2 Radioactive Sources in Liquid Radwaste System

The Liquid Radwaste System is composed of three subsystems designed to collect, treat and recycle or discharge different categories of waste water (Subsection 11.2.2). The radioactive sources for the components in the systems are provided in Table 12.2-13. The isotopic inventories in the liquid radwaste components were calculated assuming a fission product release rate from the fuel equivalent to that required to produce 100,000 μCi/sec of offgas following a 30-min holdup period.

12.2.1.2.6.3 Radioactive Sources in the Gaseous Radwaste System

The gaseous effluent treatment systems are designed to limit the dose to offsite persons from routine station release. The off-gases are treated through the use of a catalytic recombiner and low-temperature charcoal adsorption (RECHAR) system (Subsection 11.3.2). The system is designed to handle an annual average noble gas release equivalent to 100,000 μCi/sec after a 30-min delay. The accumulation of gaseous radioisotopes and the solid daughter products resulting from the decay of the noble gases is given in Table 12.2-14. The inventory in the components has

12.2.1.2.6.3 Radioactive Sources in the Gaseous Radwaste System (Continued)

been evaluated for several possible operating modes. In all cases, a 1-yr operating time has been used to accumulate the decay activities. This is sufficient time for most isotopes to reach equilibrium.

12.2.1.2.6.4 Radioactive Sources in the Solid Radwaste System

The solid radwaste system provides the capability for solidifying and packaging waste from the other radwaste systems (Subsection 11.4.2). The wastes are not solidified separately by type or source. The final waste is placed in a steel container. The expected average radioactivity content of the solid waste per container is given in Table 12.2-15.

12.2.1.2.6.5 Radioactive Sources in the Fuel Pool Cleanup System

The radiation source data used in the shield design of the Fuel Pool Cleanup (FPCCU) System filter demineralizer system is given in Table 12.2-16.

12.2.1.2.6.6 Radioactive Sources in the Suppression Pool Cleanup System

The radiation source data used in the shield of the Suppression Pool Cleanup (SPCU) System is given in Table 12.2-17.

12.2.1.2.7 Radioactive Sources in Piping and Main Steam Systems

12.2.1.2.7.1 Radioactive Sources in Main Steam System

All radioactive materials in the Main Steam System result from radioactive sources carried over from the reactor during plant operation. In most of the components carrying live steam, the

12.2.1.2.7.1 Radioactive Sources in Main Steam System (Continued)

source is dominated by Nitrogen-16. In components where N-16 has decayed, the other activities carried by the steam become significant. During plant shutdown, there is a residual activity resulting from prior plant operations. These data will be provided by the Applicant.

12.2.1.2.7.2 Radioactive Crud in Piping and Steam Systems

The inside surfaces of the piping and all reactor and power systems components become coated with activated corrosion products, commonly called crud. The quantity of crud on the components is dependent on a number of factors, including power history, water quality and fuel experience. The piping and components carrying reactor water are coated with higher levels of crud than piping and components carrying steam. Table 12.2-18 shows the crud accumulation data used in the design of this plant.

12.2.1.2.8 Radioactive Sources in the Spent Fuel

The radiation source for spent fuel is given in Subsection 12.2.1.2.1.1.4 (Table 12.2-3) in terms of MeV/sec/W. The design calculation is carried out for a mean element for an appropriate decay time.

12.2.1.2.9 Other Radioactive Sources

12.2.1.2.9.1 Reactor Startup Source

The reactor startup source is shipped to the site in a special cask designed for shielding. The source is transferred under water while in the cask and loaded into beryllium containers. This is then loaded into the reactor while remaining under water. The

12.2.1.2.9.1 Reactor Startup Source (Continued)

source remains within the reactor for its lifetime. Thus, no unique shielding requirements are required after reactor operation.

12.2.1.2.9.2 Radioactive Sources in the Control Rod Drive System

The control rod drive (CRD) source term data are provided in Table 12.2-19. The system is described in Subsection 3.9.4.

12.2.2 Airborne Radioactive Material Sources

This subsection deals with the source models and parameters required to evaluate airborne concentrations of radionuclides during plant operations in various plant radiation areas where personnel occupancy is expected.

12.2.2.1 Production of Airborne Sources

Design efforts are directed towards keeping contained all the radioactive material, whether it is in a solid, liquid or gaseous form; however, the unavoidable leaks from process systems and some processes of refueling and decontamination lead to airborne radioactivity.

Leakage of fluids from the process system will result in the release of radionuclides into plant buildings. In general, the noble radiogases will remain airborne and will be released to the atmosphere with little delay via the building ventilation exhaust ducts. The radionuclides will partition between air and water to approach equilibrium conditions. Airborne iodines will "plateout" on most surfaces, including pipe, concrete, and paint. A significant amount of radioiodine remains in air or is desorbed from

12.2.2.1 Production of Airborne Sources (Continued)

surfaces. Radioiodines are found in ventilation air as methyl iodide and as inorganic iodine which is here defined as particulate, elemental and hypoiodous acid forms of iodine. Particulates will also be present in the ventilation exhaust air.

The average annual release of I-131 is 1356 millicuries (mCi) in elemental form. Other forms of I-131 amount of 2782 mCi/yr. These forms of I-131 include hypoiodous acid, particulates and methyl iodide. The basis for these releases is as follows:

(1) a calendar year consisting of 300 days of power operations and one refueling/maintenance shutdown period;

(2) a concentration of I-131 in reactor water of 31.2 μCi/kg;

(3) a carryover of I-131 from reactor water to steam of 1.5%;

(4) forward-pumped heater drains;

(5) use of "clean" steam for the turbine gland seals;

(6) a noble gas release rate of 100,000 μCi at t = 30 min and an I-131 release rate of 700 μCi/sec at t = 0, and

(7) 24 drywell purges per year, 365 hours between each purge.

The airborne radiological releases from building heating, ventilating, and air conditioning and the main condenser mechanical vacuum pump have been compiled and evaluated in References 3 and 5.

12.2.2.1 Production of Airborne Sources (Continued)

Based upon the above conditions and values in References 2 and 4, airborne releases to the environment are summarized in Tables 12.2-20 through 12.2-23.

Approximately 15,800 Ci/plant/yr of noble radiogases are released; one-half of this total is released from the turbine building. Nineteen particulates have been identified. The total particulate release rate per plant is approximately 0.4 Ci/yr; the annual release of Co-60 is less than 0.03 Ci.

12.2.2.2 Airborne Sources for Relief Valve Venting

A special consideration for ventilation source terms is the activity release to the containment via relief valve discharge to the suppression pool. The different modes of this type of discharge and the frequency of occurrence are discussed in Chapter 15. From measurements, it has been established that a correlation can be made between activity release and reactor pressure change. A mathematical model has been developed which characterizes shutdown release transients to the suppression pool.

12.2.2.3 Airborne Sources During Refueling

The airborne radioactivity during refueling in the containment is expected to be similar to that observed in operating stations. Experience at operating BWR has shown that airborne radioactivity can result from the water in the reactor cavity exceeding 100°F and flaking of cobalt dioxide (CoO_2) from the dryer and separator if their surfaces are allowed to dry. Other potential airborne sources could occur during vessel head venting and fuel movement. The airborne radioactive material sources resulting from reactor vessel head and internals removal have been determined from operating plant experience. The major radioisotopes found were I-131, 12.2.2.3 Airborne Sources During Refueling (Continued)

Co-60, and Mn-54, with Nb-95, Zr-95, Ru-103, and Ce-144 at moderate concentrations, and with Ce-141, Cs-137, Co-58, and Cr-51 at low concentrations. The radioactive particulates ranged as high as 2×10^{-8} μCi/cc and the I-131 as high as 4×10^{-8} μCi/cc.

To minimize the containment airborne radioactivity contribution due to removal of the reactor pressure vessel head:

(1) the steam dryer and separator surfaces will be kept wet or covered;

(2) the fuel pools are cooled through heat exchangers of large capacity; and the

(3) ventilation system on the refueling pool is designed to sweep air from the pool surface and remove a large portion of potential airborne contamination.

12.2.3 References

1. J.E. Smith, "Noble Gas Experience in Boiling Water Reactors", Paper No. A-54, presented at Noble Gases Symposium, Las Vegas, Nevada, September 24, 1974.

2. "Airborne Releases from BWRs for Environmental Impact Evaluations", NEDO-21159-2 (1977).

3. American Nuclear Society, ANS-18.1, ANSI N237-197 (approved May 11, 1976), Table 5.

4. "Airborne Releases from BWRs for Environmental Impact Evaluations", NEDO-21159, March 1976.

5. "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors" (BWR-GALE Code) U.S. NRC NUREG-0016 Rev. 1, January 1979.

Table 12.2-1

BASIC REACTOR DATA

A. REACTOR THERMAL POWER: 3579 MW
B. AVERAGE POWER DENSITY: 54.07 W/cm^3
C. PHYSICAL DIMENSIONS*

	Radii	in.
1.	Core Equivalent Radius	92.58
2.	Inside Shroud Radius	99.90
3.	Outside Shroud Radius	101.90
4.	Inside Vessel Radius - Nominal	119.0
5.	Outside Vessel Radius - Nominal	125.0
6.	Outside Vessel Radius - Reinforced - Nominal	125.75
7.	Shroud Head Inside Radius	192.0
8.	Vessel Top Head Inside Radius	119.0
9.	Vessel Bottom Head Inside Radius	130.19

	Elevation	in.
10.	Outside of Vessel Bottom Head	-7.75
11.	Inside of Vessel Bottom Head	-0.25
12.	Vessel Bottom Head Tangent	129.94
13.	Bottom of Core Support Plate	202.56
14.	Top of Core Support Plate	204.56
15.	Bottom of Active Fuel	213.50
16.	Top of Reinforced Vessel Wall	210.00
17.	Top of Active Fuel	363.5
18.	Bottom of Top Guide	371.31
19.	Top of Fuel Channel	377.87
20.	Shroud Head Tangent	424.23
21.	Inside of Shroud Head	452.27
22.	Outside of Shroud Head	454.27
23.	Normal Vessel Water Level	566.6
24.	Top of Steam Dryer	720.63
25.	Vessel Top Head Tangent	727.0
26.	Inside of Vessel Top Head	846.0
27.	Outside of Vessel Top Head	849.0

*Figure 12.2-1 shows the relative locations of the dimensions.

Table 12.2-1 (Continued)

D. MATERIAL DENSITIES* - grams/cm^3 of REGION VOLUME

Region	Coolant	UO_2	Zircaloy	304L Stainless
A	0.740	0.0	0.0	0.178
B	0.338	0.0	0.0	4.349
C	0.318	2.334	0.978	0.056
C-1	0.597	0.0	0.166	1.697
C-2	0.234	0.0	1.099	0.255
D	0.240	0.0	1.004	1.209
E	0.390	0.0	0.0	0.0
F	0.669	0.0	0.0	0.200
G	0.036	0.0	0.0	0.0
H	0.740	0.0	0.0	0.0
I	0.740	0.0	0.0	0.26

E. TYPICAL CORE POWER DISTRIBUTIONS

Radial Power Distribution		Axial Power Distribution (Typical End-of-Life)	
Percent of Equivalent Radius	Relative Power	Elevation** (in.)	Relative Power
0	1.2	-75	0.343
20	1.2	-68	0.755
35	1.19	-60	1.055
50	1.17	-48	1.190
60	1.15	-36	1.200
70	1.12	-24	1.190
80	1.05	-12	1.170
85	0.995	0	1.155
90	0.778	12	1.140
92.5	0.590	24	1.105
95.0	0.430	36	1.055
97.0	0.375	48	0.945
98.0	0.395	60	0.715
99.0	0.432	68	0.462
100.0	0.518	75	0.212

*Figure 12.2-1 shows the region locations.

**Elevations are measured from the mid plate of the core.

Table 12.2-2

CORE BOUNDARY NEUTRON FLUXES

Energy Bounds	Neutron Flux (neutrons/cm^2-sec)
16.5 MeV	3.9 E+10
10.00 MeV	5.5 E+11
6.065 MeV	2.0 E+12
3.679 MeV	3.8 E+12
2.231 MeV	4.4 E+12
1.353 MeV	3.9 E+12
820.8 KeV	3.8 E+12
497.9 KeV	2.6 E+12
302.0 KeV	2.3 E+12
183.2 KeV	3.2 E+12
67.38 KeV	2.2 E+12
24.79 KeV	2.2 E+12
9.119 KeV	2.0 E+12
3.355 KeV	2.0 E+12
1.234 KeV	1.9 E+12
454.0 eV	2.0 E+12
167.0 eV	1.9 E+12
61.44 eV	1.8 E+12
22.60 eV	8.8 E+11
13.71 eV	8.8 E+11
8.315 eV	8.2 E+11
5.043 eV	8.4 E+11
3.059 eV	8.3 E+11
1.855 eV	8.2 E+11
1.125 eV	8.8 E+11
0.616 eV	3.2 E+13
0.00 eV	

Table 12.2-3

GAMMA RAY SOURCE ENERGY SPECTRA

A. GAMMA RAY SOURCES IN THE CORE DURING OPERATION

Energy Bounds (MeV)	Gamma Ray Source (MeV/sec-W)
16.5	
	7.8 E+8
8.0	
	7.3 E+9
6.0	
	5.9 E+10
4.0	
	5.8 E+10
3.0	
	5.2 E+10
2.6	
	6.7 E+10
2.2	
	7.2 E+10
1.8	
	8.3 E+10
1.4	
	9.1 E+10
1.0	
	7.5 E+10
0.75	
	6.8 E+10
0.5	
	6.1 E+10
0.25	
	9.8 E+10
0.003	

Table 12.2-3 (Continued)

Energy Bounds (MeV)	Region I (Jet Pumps) Inside	Region I (Jet Pumps) Outside	Vessel Inside	Vessel Outside
16.5				
	1.4	2.2 E-2	2.2 E-1	2.1 E-4
8.0				
	4.6	6.9 E-2	2.1	1.6 E-3
6.0				
	1.3	2.0 E-2	5.6 E-1	1.6 E-3
4.0				
	6.3 E-1	9.3 E-3	2.8 E-1	2.0 E-3
3.0				
	2.6 E-1	3.7 E-3	1.0 E-1	1.2 E-3
2.6				
	6.1	4.7 E-2	4.7 E-2	1.1 E-3
2.2				
	1.8 E-1	2.4 E-3	5.3 E-2	1.4 F-3
1.8				
	4.2 E-1	6.0 E-3	1.8 E-1	1.1 E-3
1.4				
	2.1 E-1	2.9 E-3	7.5 E-2	9.3 E-4
1.0				
	3.2 E-1	3.6 E-3	9.1 E-2	5.5 E-3
0.75				
	1.6 E-1	2.4 E-3	6.4 E-2	4.2 E-5
0.50				
	6.6 E-1	9.9 E-3	2.6 E-1	2.0 E-4
0.25				
	5.1 E-1	7.6 E-3	1.9 E-2	1.8 E-4
0.003				

Table 12.2-4

GAMMA RAY AND NEUTRON FLUXES OUTSIDE THE VESSEL WALL

A. NEUTRON FLUXES

Energy Bounds	Neutrons/cm^2-sec
16.5 MeV	5.8 E+6
10.00 MeV	2.9 E+7
6.065 MeV	2.2 E+7
3.679 MeV	4.5 E+7
2.231 MeV	7.5 E+7
1.353 MeV	1.1 E+8
820.8 [illegible]	1.6 E+8
497.9 [illegible]V	1.5 E+8
302.0 KeV	9.1 E+7
183.2 KeV	1.1 E+8
67.38 KeV	1.2 E+7
24.79 KeV	6.7 E+7
9.11 KeV	1.4 E+7
3.355 KeV	8.6 E+6
1.234 KeV	6.4 E+6
454.0 KeV	2.9 E+6
167.0 eV	4.2 E+6
61.44 eV	3.9 E+6
22.60 eV	1.9 E+6
13.71 eV	2.0 E+6
8.315 eV	1.8 E+6
5.043 eV	1.6 E+6
3.059 eV	1.5 E+6
1.855 eV	1.4 E+6
1.125 eV	7.9 E+5
0.616 eV	6.0 E+5
0.000 eV	

Table 12.2-4 (Continued)

B. GAMMA RAY ENERGY FLUXES

Energy Bounds MeV	MeV/cm^2-sec
16.5	
	1.0 E+9
8.0	
	3.4 E+9
6.0	
	3.3 E+9
4.0	
	1.7 E+9
3.0	
	7.0 E+8
2.6	
	1.0 E+8
2.2	
	6.9 E+8
1.8	
	6.1 E+8
1.4	
	5.3 E+8
1.0	
	3.2 E+8
0.75	
	4.2 E+8
0.50	
	4.0 E+8
0.25	
	1.5 E+7
0.003	

Table 12.2-5

FAST NEUTRON FLUXES AND GAMMA RAY DOSE AROUND THE REACTOR VESSEL*

Location	Fast Neutron Flux (>1.0 MeV) (n/cm^2-sec)	Gamma Ray Dose Rate (rads/hr)
Core - at Peak Axial Location	2.7 E+8	2.0 E+4
Above Top Head	1.0 E+2	2.2 E+1
Below Bottom Head	<0.1	1.7 E-1

*The data presented in this table are calculations of the primary and secondary radiation from the core vessel. In power plant applications, the neutron fluxes above and below the core will include contributions from radiation exiting the vessel at mid-plane and being scattered to these locations.

Table 12.2-6

FISSION PRODUCT GAMMA SOURCE STRENGTH IN RHR
HEAT EXCHANGER SHELL (MeV/sec)

(LATER)

Table 12.2-7

FISSION PRODUCT INVENTORY IN RHR HEAT EXCHANGER SHELL
FOUR HOURS AFTER SHUTDOWN (μCi)

(LATER)

Table 12.2-8

REACTOR COOLANT CONCENTRATION EQUILIBRIUM VALUES
ENTERING RCIC TURBINE (μCi/g)

Isotope	Concentration	Isotope	Concentration
N-13	6.6E-03	Kr-88	1.1E-02
N-16	4.8E-01	Kr-89	1.9E-04
N-17	1.5E-02	Xe-131m	3.7E-05
F-18	4.0E-03	Xe-133m	1.9E-04
O-19	6.9E-01	Xe-133	4.7E-03
Na-24	2.3E-06	Xe-135m	6.0E-03
Mn-56	5.2E-04	Xe-135	1.4E-02
Co-58	5.9E-06	Xe-137	7.3E-04
Br-83	5.1E-04	Xe-138	1.7E-02
Br-84	6.7E-04	Sr-91	3.4E-04
I-131	4.3E-04	Sr-92	3.4E-04
I-132	4.7E-03	Tc-99	1.6E-04
I-133	3.1E-03	Tc-101	5.3E-05
I-134	6.8E-03	Cs-138	1.4E-02
I-135	4.8E-03	Ba-139	2.8E-03
Kr-83m	2.1E-03	Ba-140	1.9E-05
Kr-85m	3.4E-03	Ba-141	5.8E-04
Kr-85	1.2E-05	Ba-142	1.3E-04
Kr-87	9.7E-03	Np-239	2.5E-04

Table 12.2-9

REACTOR WATER CLEANUP BACKWASH RECEIVING TANK SOURCES (Ci)

Source Volume = 2600 gal.
Total Curies = 2400

Halogens		Soluble Fission Products		Insoluble Fission Products		Activation Products	
Isotope	Curies	Isotope	Curies	Isotope	Curies	Isotope	Curies
BR-83	5.0E 00	SR-89	2.8E 01	ZR-95	3.7E-01	NA-24	3.0E 00
BR-84	1.8E 00	SR-90	2.2E 00	ZR-97	4.9E-02	P-32	1.9E-01
BR-85	6.0E 02	SR-91	6.4E 01	NB-95	1.2E 00	CR-51	5.1E 00
I-131	1.7E 02	SR-92	3.1E 01	RU-103	1.8E-01	MN-54	4.4E 01
I-132	1.2E 02	Y-90	2.2E 00	RU-106	2.5E-02	MN-56	1.2E 01
I-133	2.8E 02	Y-91M	4.4E 01	RH-103M	1.8E-01	CO-58	5.3E 01
I-134	2.7E 01	MO-99	1.1E 02	RH-106	2.5E-02	CO-60	5.5E 00
I-135	1.3E 02	TC-99M	4.7E 01	LA-140	8.2E 01	FE-59	8.6E-01
		TC-101	3.8E 00	CE-141	3.5E-01	NI-65	7.5E-02
Total	7.3E 02	TE-129M	3.0E 00	CE-143	9.9E-02	ZN-65	2.2E-02
		TE-132	7.4E 01	CE-144	3.3E-01	ZN-69M	4.1E-02
		CS-134	1.5E 00	PR-143	3.1E-01	AG-110M	6.7E-01
		CS-136	8.5E 01	ND-147	1.1E-01	W-187	7.1E 00
		CS-137	2.3E 00				
		CS-138	1.1E 01	Total	8.5E 01	Total	8.8E 01
		BA-137M	2.3E 00				
		BA-139	2.4E 01				
		BA-140	7.1E 01				
		BA-141	5.9E 00				
		BA-142	3.1E 00				
		NP-239	1.0E 03				
		Total	1.5E 03				

The source term in each of the filter demineralizers is one half the source term in the backwash receiving tank.

Table 12.2-10

REACTOR-WATER CLEANUP REPRESENTATIVE HEAT EXCHANGER
SHELL SIDE SOURCE TERMS (Ci)

Total 1.263E-00

3T	1.3E-03	97NBM	1.5E-03	135XEM	9.5E-01
190	4.1E-03	99TCM	1.7E-03	135XE	1.6E-01
83KRM	4.1E-02	101TC	2.0E-03	137XE	1.6E-02
85KRM	1.0E-03	102TCM	1.5E-03	137BAM	2.2E-03
87KR	2.1E-03	132I	3.0E-03	138XE	3.1E-03
89KR	4.9E-03	133I	1.7E-03	139CS	1.0E-03
91YM	4.2E-03	133XEM	1.5E-03	139BA	1.2E-03
92SR	1.5E-03	133XB	2.3E-02	141BA	2.1E-03
92Y	1.1E-03	134I	5.4E-03	142BA	1.9E-03
93SR	1.9E-03	135I	2.8E-03	239NP	2.5E-03

Table 12.2-11

REACTOR WATER CLEANUP NONREGENERATIVE HEAT EXCHANGER RADIATION SOURCES (Ci)

Total 3.582E-00

3T	1.0E-03	93SR	1.7E-01	134TE	6.7E-03
13NO*	4.3E-02	94SR	7.5E-02	134IM	1.4E-02
16NO	3.1E-03	94Y	2.1E-02	134I	4.3E-01
18F	3.7E-03	95SR	1.0E-02	135I	2.2E-01
19O	3.0E-02	95Y	2.7E-02	135XEM	6.0E-03
24NA	1.9E-03	97NBM	2.4E-02	135XE	1.5E-03
56MN	4.6E-02	97NB	4.1E-03	136TE	1.2E-03
58CO	4.6E-03	99NBM	1.3E-02	136IM	1.6E-02
83SEM	2.4E-03	99TCM	1.4E-01	136I	5.5E-02
83BR	2.6E-02	101MO	1.2E-02	137I	5.8E-03
84SE	5.8E-03	101TC	1.6F-01	137XE	1.6E-02
84BR	5.5E-02	102MO	1.3E-02	138XE	2.6E-03
85SE	1.9E-03	102TCM	1.1E-01	138CSM	5.3E-03
85BR	4.0E-02	103TC	2.3E-02	138CS	2.7E-02
87BR	2.3E-02	103RHM	1.9E-03	139XE	1.2E-03
87KR	1.5E-03	104MO	1.1E-02	139CS	8.9E-02
88RB	3.6E-03	104TC	5.5E-02	139BA	8.3E-02
89KR	5.4E-03	105MO	3.8E-03	140CS	3.9E-02
89RB	3.0E-02	105TC	2.9E-02	140BA	6.7E-03
89SR	2.1E-03	106TC	1.7E-03	141CS	6.6E-03
90KR	1.4E-03	131SB	3.7E-03	141HA	1.8E-01
90RBM	1.7E-02	131TE	4.2E-03	141LA	2.2E-03
90RB	5.1E-02	131I	1.9E-02	142HA	1.7E-01
91RB	3.7E-02	132I	2.4E-01	142LA	[illegible]03
91SR	5.3E-02	133SB	1.4E-02	143LA	1.[illegible]-02
91YM	2.4E-03	133TEM	3.5E-03	144LA	2.4E-02
92SR	1.2E-01	133TE	9.5E-03	187W	2.8E-03
92Y	1.6E-03	133I	1.4E-01	239NP	2.0E-01

*NO indicates isotopes of nitrogen as oxides.

Table 12.2-12

REACTOR WATER CLEANUP REGENERATIVE HEAT EXCHANGER
RADIATION RADIATION SOURCES (Ci)

Total 2.417E-00

13NO*	2.5E-02	94Y	1.1E-02	134I	2.5E-01
16AM**	6.3E-03	95SR	1.8E-02	135I	1.3E-01
16NO	8.0E-02	95Y	1.6E-02	135XEM	2.8E-03
18F	2.1E-03	97NBM	2.4E-02	136TE	1.7E-03
190	5.2E-02	97NB	2.3E-03	136IM	1.8E-02
24NA	1.1E-03	99NBM	9.4E-03	136I	4.5E-02
56MN	2.7E-02	99NB	3.0E-03	137I	1.1E-02
59CO	2.7E-03	99TCM	7.9E-02	137XE	1.0E-02
83SEM	2.1E-03	101MO	7.2E-03	138XE	1.6E-03
83BR	1.5E-02	101TC	9.3E-02	138CSM	3.7E-03
84SE	3.9E-03	102MO	7.5E-03	138CS	1.6E-02
84BR	3.2E-02	102TCM	7.2E-02	139XE	1.5E-03
85SE	2.4E-03	103TC	2.4E-02	139CS	5.5E-02
85BR	2.8E-02	103RHM	1.1E-03	139BA	4.8E-02
87BR	2.3E-02	104MO	8.5E-03	140CS	3.6E-02
88BR	3.0E-03	104TC	3.3E-02	140BA	3.9E-03
88RB	2.1E-03	105MO	3.8E-03	141CS	1.2E-02
89KR	3.7E-03	105TC	1.8E-02	141BA	1.0E-01
89RB	1.7E-02	106TC	2.2E-03	141LA	1.0E-03
89SB	1.2E-03	131SB	2.2E-03	142CS	1.1E-01
90RB	2.1E-03	131TE	2.4E-03	142CS	1.0E-03
90RBM	1.2E-02	131I	1.1E-02	143BA	3.7E-03
90RB	3.5E-02	132I	1.4E-01	143LA	1.1E-02
91RB	3.6E-02	133SB	9.7E-03	144BA	1.3E-03
91SB	3.1E-02	133TEM	1.9E-03	144LA	3.0E-02
91YM	1.1E-03	133TE	5.5E-03	187W	1.6E-03
92SR	6.8E-02	133I	8.1E-02	239NP	1.1E-01
93SR	1.1E-01	134TE	3.9E-03		
94SR	6.4E-02	134IM	9.3E-03		

*NO indicates isotopes of nitrogen as oxides.
**AM indicates isotopes of nitrogen ammonia, NH_3.

Table 12.2-13
LIQUID RADWASTE COMPONENT INVENTORIES

The inventory in the liquid radwaste components is provided in the following table for a deep bed system. The data in Table 12.2-13 were generated assuming a fission product release from the fuel equivalent to that required to produce 100,000 μCi/sec of offgas following a 30-min holdup period.

Table 12.2-13 (Continued)

CONCENTRATED WASTE TANK A700

Source Volume = 3000 gal. normal, 25,000 gals. full
Total Curies = 29

Halogens		Soluble Fission Products		Insoluble Fission Products		Activation Products	
Isotope	Curies	Isotope	Curies	Isotope	Curies	Isotope	Curies
BR-83	2.5E-04	SR89	9.4E-02	ZR-95	1.2E-03	NA-24	4.0E-04
BR-84	1.9E-06	SR-90	8.9E-03	ZR-97	7.5E-06	P-32	4.4E-04
BR-85	4.7E-10	SR-91	4.8E-03	NB-95	3.7E-03	CR-51	1.4E-02
I-131	2.6E-01	SR-92	2.6E-04	RU-103	5.2E-04	MN-54	1.5E-03
I-132	6.2E-02	Y-90	8.9E-03	RU-106	8.7E-05	MN-56	9.5E-05
I-133	1.5E-00	Y-91M	3.3E-03	RH-103M	5.2E-04	CO-58	1.7E-01
I-134	1.0E-04	MO-99	7.3E-02	RH-106	8.7E-05	CO-60	2.0E-02
I-135	7.3E-02	TC-99M	1.7E-03	LA-140	1.8E-01	FE-59	2.6E-03
		TC-101	2.7E-07	CE-141	1.0E-03	NI-65	5.6E-07
TOTAL	2.8E-01	TE-129M	7.9E-03	CE-143	3.1E-05	ZN-65	8.4E-05
		TE-132	5.9E-02	CE-144	1.2E-03	ZN-69M	5.0E-06
		CS-134	6.1E-03	PR-143	6.9E-04	AG-110M	2.3E-03
		CS-136	1.9E-03	ND-147	2.2E-04	W-187	1.6E-03
		CS-137	9.4E-03				
		CS-138	3.9E-06	TOTAL	1.9E-01	TOTAL	2.1E-01
		BA-137M	9.4E-03				
		BA-139	5.4E-05				
		BA-140	1.6E-01				
		BA-141	6.8E-07				
		BA-142	1.3E-07				
		TOTAL	1.0E-00				

Table 12.2-13 (Continued)

LOW CONDUCTIVITY OIL SEPARATOR D035

Source Volume = 6300 gal.
Total Curies = 10

Halogens

Isotope	Curies
BR-83	1.0E-01
BR-84	6.0E-02
BR-85	3.2E-03
I-131	3.2E-01
I-132	9.1E-01
I-133	1.0E-00
I-134	8.4E-01
I-135	1.2E-00
TOTAL	4.4E-00

Soluble Fission Products

Isotope	Curies
SR-89	2.5E-02
SR-90	1.9E-03
SR-91	4.4E-01
SR-92	5.7E-01
Y-90	1.9E-03
Y-91M	3.0E-01
MO-99	1.5E-01
TC-99M	4.8E-01
TC-101	1.3E-01
TE-129M	2.7E-03
TE-132	1.0E-01
CS-134	1.3E-03
CS-136	8.0E-04
CS-137	2.0E-03
CS-138	3.7E-01
BA-137M	2.0E-03
BA-139	6.2E-01
BA-140	6.6E-02
BA-141	2.0E-01
BA-142	1.1E-01
NP-239	1.6E-00
TOTAL	5.2E-00

Insoluble Fission Products

Isotope	Curies
ZR-95	3.3E-04
ZR-97	2.1E-04
NB-95	1.0E-03
RU-103	1.6E-04
RU-106	2.2E-05
RH-103M	1.6E-04
RH-106	2.2E-05
LA-140	7.6E-02
CE-141	3.2E-04
CE-143	2.3E-04
CE-144	2.9E-04
PR-143	3.0E-04
ND-147	1.1E-04
TOTAL	7.9E-02

Activation Products

Isotope	Curies
NA-24	1.4E-02
P-32	1.8E-04
CR-51	4.6E-03
MN-54	3.9E-04
MN-56	2.4E-01
CO-58	4.7E-02
CO-60	4.8E-03
FE-59	7.7E-04
NI-65	1.4E-03
ZN-65	1.9E-05
ZN-69M	2.1E-04
AG-110M	6.0E-04
W-187	2.2E-02
TOTAL	3.3E-01

Table 12.2-13 (Continued)

HIGH CONDUCTIVITY OIL SEPARATOR D015

Source Volume = 6300 gal.
Total Curies = 1.5

Halogens		Soluble Fission Products		Insoluble Fission Products		Activation Products	
Isotope	Curies	Isotope	Curies	Isotope	Curies	Isotope	Curies
BR-83	7.1E-03	SR-89	1.2E-02	ZR-95	1.5E-04	NA-24	1.6E-03
BR-84	2.7E-03	SR-90	9.8E-04	ZR-97	2.5E-05	P-32	7.0E-05
BR-85	1.5E-04	SR-91	4.3E-02	NB-95	4.7E-04	CR-51	2.0E-03
I-131	3.5E-01	SR-92	3.0E-02	RU-103	7.1E-05	MN-54	1.9E-04
I-132	8.0E-02	Y-90	9.8E-04	RU-106	1.1E-05	MN-56	1.2E-02
I-133	2.3E-01	Y-91M	2.9E-02	RH-103M	7.1E-05	CO-58	2.2E-02
I-134	4.0E-02	MO-99	3.3E-02	RH-106	1.1E-05	CO-60	2.4E-03
I-135	1.5E-01	TC-99M	3.8E-02	LA-140	3.0E-02	FE-59	3.5E-04
		TC-101	4.0E-03	CE-141	1.4E-04	NI-65	7.2E-05
TOTAL	8.6E-01	TE-129M	1.2E-03	CE-143	3.5E-05	ZN-65	9.6E-06
		TE-132	2.3E-02	CE-144	1.4E-04	ZN-69M	2.3E-05
		CS-134	6.8E-04	PR-143	1.1E-04	AG-110M	2.9E-04
		CS-136	3.1E-04	ND-147	4.0E-05	W-187	2.9E-03
		CS-137	1.0E-03				
		CS-138	1.2E-02	TOTAL	3.1E-02	TOTAL	4.4E-02
		BA-137M	1.0E-03				
		BA-139	2.3E-02				
		BA-140	2.6E-02				
		BA-141	6.2E-03				
		BA-142	3.5E-03				
		NP-239	3.2E-01				
		TOTAL	6.1E-01				

Table 12.2-13 (Continued)

LOW CONDUCTIVITY COLLECTOR TANK A186

Source Volume = 57,000 gal.
Total Curies = 30

Halogens		Soluble Fission Products		Insoluble Fission Products		Activation Products	
Isotope	Curies	Isotope	Curies	Isotope	Curies	Isotope	Curies
BR-83	2.6E-02	SR-89	7.6E-01	ZR-95	1.0E-02	NA-24	2.0E-02
BR-84	3.4E-03	SR-90	6.6E-02	ZR-97	3.2E-04	P-32	4.4E-03
BR-85	1.7E-05	SR-91	4.3E-01	NB-95	3.1E-02	CR-51	1.3E-01
I-131	4.6E-00	SR-92	1.6E-01	RU-103	4.6E-03	MN-54	1.3E-02
I-132	1.2E-00	Y-90	6.6E-02	RU-106	7.2E-04	MN-56	6.6E-02
I-133	2.2E-00	Y-91M	2.9E-01	RH-103M	4.6E-03	CO-58	1.5E-00
I-134	7.8E-02	MO-99	1.3E-00	RH-106	7.2E-04	CO-60	1.6E-01
I-135	9.2E-01	TC-99M	3.0E-01	LA-140	1.8E-00	FE-59	2.3E-02
		TC-101	3.4E-03	CE-141	9.1E-03	NI-65	3.9E-04
TOTAL	9.0E-00	TE-129M	7.4E-02	CE-143	7.8E-04	ZN-65	6.4E-04
		TE-132	1.0E-00	CE-144	9.6E-03	ZN-69M	2.7E-04
		CS-134	4.5E-02	PR-143	7.1E-03	AG-110M	2.0E-02
		CS-136	1.9E-02	ND-147	2.4E-03	W-187	4.9E-02
		CS-137	7.0E-02				
		CS-138	2.2E-02	TOTAL	1.9E-00	TOTAL	2.0E-00
		BA-137M	7.0E-02				
		BA-139	9.3E-02				
		BA-140	1.6E-00				
		BA-141	6.6E-03				
		BA-142	2.2E-03				
		NP-239	1.1E-01				
		TOTAL	1.7E-01				

Table 12.2-13 (Continued)

HIGH CONDUCTIVITY COLLECTOR TANKS A441

Source Volume = 18,000 gal.
Total Curies = 15

Halogens		Soluble Fission Products		Insoluble Fission Products		Activation Products	
Isotope	Curies	Isotope	Curies	Isotope	Curies	Isotope	Curies
BR-83	4.8E-03	SR-89	2.6E-02	ZR-95	3.3E-04	NA-24	1.2E-03
BR-84	1.6E-04	SR-90	2.3E-03	ZR-97	2.0E-05	P-32	1.5E-04
BR-85	4.3E-07	SR-91	2.2E-02	NB-95	1.0E-03	CR-51	4.2E-03
I-131	1.0E-01	SR-92	4.3E-03	RU-103	1.5E-04	MN-54	4.1E-04
I-132	7.4E-02	Y-90	2.3E-03	RU-106	2.3E-05	MN-56	1.7E-03
I-133	3.3E-00	Y-91M	1.5E-02	RH-103M	1.5E-04	CO-58	4.7E-02
I-134	5.3E-03	MO-99	5.4E-02	RH-106	2.3E-05	CO-60	5.2E-03
I-135	4.9E-01	TC-99M	1.2E-02	LA-140	6.3E-02	FE-59	7.4E-04
		TC-101	5.2E-05	CE-141	2.9E-04	NI-65	9.9E-06
TOTAL	1.4E-01	TE-129M	2.4E-03	CE-143	4.4E-05	ZN-65	2.2E-05
		TE-132	3.8E-02	CE-144	3.1E-04	ZN-69M	1.6E-05
		CS-134	1.6E-03	PR-143	2.3E-04	AG-110M	6.2E-04
		CS-136	6.6E-04	ND-147	8.0E-05	W-187	3.0E-03
		CS-137	2.5E-03				
		CS-138	3.3E-04	TOTAL	6.6E-02	TOTAL	6.4E-02
		BA-137M	2.5E-03				
		BA-139	1.8E-03				
		BA-140	5.5E-02				
		BA-141	1.0E-04				
		BA-142	3.4E-05				
		NP-239	5.0E-01				
		TOTAL	7.4E-01				

Table 12.2-13 (Continued)

FILTRATE TANK A287

Source Volume = 3000 gal.
Unit = Ci

TIME = 3.504E-05

TOTAL	0.
3H	6.898E-03
13N2	8.629E-12
13AM*	4.864E-12
13NO**	1.779E-10
16N2	0.
16AM	0.
16NO	0.
17N2	0.
17AM	0.
17NO	0.
18F	9.684E-05
19O	0.
24NA	1.862E-04
32P	2.237E-06
51CR	5.676E-05
54MN	4.463E-06
56MN	1.877E-03
58CO	5.666E-04
59FE	9.080E-06
60CO	5.415E-05
65NI	1.096E-05
65ZN	2.231E-07
69ZNM	2.751E-06
83AS	0.
83SEM	0.
83SE	2.330E-08
83BR	9.748E-04
83KRM	8.792E-02
84AS	0.
84SE	2.420E-26
84BRM	4.022E-17
84BR	3.122E-05
85AS	0.
85SEM	0.
85SE	0.
85BR	7.579E-29
85KRM	4.829E-03
85KR	1.894E-06
87AS	0.
87SE	0.
87BR	0.
87KR	1.786E-03
88SE	0.
88BR	0.
88KR	1.670E-03
88RB	2.686E-04
89SE	0.
89BR	0.
89KR	1.535E-25
89RB	1.535E-07
89SR	2.543E-04
89YM	0.
90BR	0.
90KR	0.
90NBM	9.852E-21
90RB	2.832E-22

3.504E-05

TOTAL	0.
90SR	1.423E-05
90YM	1.663E-10
90Y	1.233E-05
91BR	0.
91KR	0.
91RB	0.
91SR	4.828E-03
91YM	1.930E-03
91Y	7.547E-05
92BR	0.
92KR	0.
92RB	0.
92SR	4.960E-03
92Y	8.004E-03
93KR	0.
93RB	0.
93SR	2.665E-12
93Y	4.625E-04
94KR	0.
94RB	0.
94SR	0.
94Y	4.430E-07
95KR	0.
95RB	0.
95SR	0.
95Y	2.789E-10
95ZR	4.737E-06
95NBM	1.120E-07
95NB	4.221E-06
97ZR	2.632E-05
97NBM	1.238E-05
97NB	1.292E-05
99ZR	0.
99NBM	3.809E-33
99NB	0.
99MO	3.276E-05
99TCM	1.035E-02
99TC	0.
101MO	1.195E-08
101TC	1.312E-07
102MO	3.042E-10
102TCM	1.326E-10
102TC	0.
103TC	0.
103RU	2.373E-06
103RHM	1.757E-05
104MO	0.
104TC	5.137E-07
105MO	0.
105TC	1.861E-12
105RU	1.295E-04
105RHM	1.756E-05
105RH	3.605E-05
106TC	0.
106RU	1.564E-07
110AGM	6.716E-06

3.504E-05

TOTAL	0.
129SB	6.059E-06
129TEM	5.963E-07
129TE	1.282E-05
131SB	2.685E-07
131TEM	2.988E-06
131TE	1.524E-06
131I	2.482E-03
131XEM	5.565E-04
132TE	1.886E-05
132I	8.549E-03
133SB	2.280E-34
133TEM	2.076E-05
133TE	5.769E-07
133IM	0.
133I	1.573E-02
133XEM	1.505E-02
133XE	2.279E-01
134TE	1.395E-05
134IM	4.271E-24
134I	2.096E-03
134XEM	5.534E-26
135I	1.809E-02
135XEM	6.167E-04
135XE	1.383E-00
135CSM	8.974E-08
136TE	0.
136IM	0.
136I	0.
137I	0.
137XE	8.421E-21
137CS	1.439E-05
137BAM	6.402E-[illegible]
138XE	8.071E-08
138CSM	1.788E-29
138CS	4.496E-05
139XE	0.
139CS	1.084E-10
139BA	1.546E-03
140XE	0.
140CS	0.
140BA	8.205E-04
140LA	9.853E-04
141XE	0.
141CS	0.
141BA	1.855E-06
141LA	1.714E-03
141CE	2.216E-05
142XE	0.
142CS	0.
142BA	2.317E-09
142LA	8.317E-04
143XE	0.
143CS	0.
143BA	0.
143LA	1.055E-08
143CE	4.502E-05

3.504E-05

TOTAL	1.842E-09
143PR	7.824E-06
144XE	0.
144CS	0.
144BA	0.
144LA	0.
144CE	2.395E-06
147ND	2.076E-06
147PM	5.340E-07
149ND	9.339E-06
149PM	4.848E-06
187W	3.041E-04
239NP	2.285E-02

*AM indicates isotipes of nitrogen as ammonia, NH_3.

**NO indicates isotopes of nitrogen as xides.

Table 12.2-13 (Continued)

DISTILLATE TANK A776

Source Volume = 3000 gal.
Total Curies = 0.00024

Halogens		Soluble Fission Products		Insoluble Fission Products		Activation Products	
Isotope	Curies	Isotope	Curies	Isotope	Curies	Isotope	Curies
BR-83	6.9-E-08	SR-89	4.4E-07	ZR-95	5.5E-09	NA-24	2.0E-08
BR-84	1.4E-09	SR-90	3.9E-08	ZR-97	3.3E-10	P-32	2.5E-09
BR-85	0.	SR-91	3.6E-07	NB-95	1.7E-08	CR-51	7.0E-08
I-131	1.7E-04	SR-92	6.3E-08	RU-103	2.5E-09	MN-54	6.9E-09
I-132	1.2E-06	Y-90	3.9E-08	RU-106	3.9E-10	MN-56	2.4E-08
I-133	5.4E-05	Y-91M	2.4E-07	RH-103M	2.5E-09	CO-58	7.9E-07
I-134	5.9E-08	MO-99	9.0E-07	RH-106	3.9E-10	CO-60	8.7E-08
I-135	7.8E-06	TC-99M	2.0E-07	LA-140	1.1E-06	FE-59	1.2E-08
		TC-101	2.6E-10	CE-141	4.9E-09	NI-65	1.4E-10
TOTAL	2.3E-04	TE-129M	4.0E-08	CE-143	7.2E-10	ZN-65	3.8E-10
		TE-132	6.4E-07	CE-144	5.2E-09	ZN-69M	2.7E-10
		CS-134	2.7E-08	ND-147	1.3E-09	W-187	5.0E-08
		CS-136	1.1E-08				
		CS-137	4.1E-08	TOTAL	1.1E-06	TOTAL	1.1E-06
		CS-138	3.0E-09				
		BA-137M	4.1E-08				
		BA-139	2.3E-08				
		BA-140	9.2E-07				
		BA-141	6/3E-10				
		BA-142	1.3E-10				
		NP-239	8.3E-06				
		TOTAL	1.2E-05				

Table 12.2-13 (Continued)

PRECOAT TANK A275

Source Volume = 2000 gal.
Total Curies = 0.011

Halogens		Soluble Fission Products		Insoluble Fission Products		Activation Products	
Isotope	Curies	Isotope	Curies	Isotope	Curies	Isotope	Curies
BR-83	7.6E-06	SR-89	3.0E-04	ZR-95	3.9E-06	NA-24	7.3E-06
BR-84	3.7E-07	SR-90	2.6E-05	ZR-97	1.2E-07	P-32	1.7E-06
BR-85	0.	SR-91	1.6E-04	NB-95	1.2E-06	CR-51	5.1E-05
I-131	1.8E-03	SR-92	5.0E-05	RU-103	1.8E-06	MN-54	5.0E-06
I-132	4.1E-04	Y-90	2.6E-05	RU-106	2.8E-07	MN-56	2.0E-05
I-133	8.3E-04	Y-91M	1.1E-04	RH-103M	1.8E-06	CO-58	5.8E-04
I-134	1.4E-05	MO-99	5.1E-06	RH-106	2.8E-07	CO-60	6.4E-05
I-135	3.2E-04	TC-99M	1.1E-04	LA-140	7.2E-04	FE-59	9.1E-06
		TC-101	7.6E-08	CE-141	3.0E-07	NI-65	1.2E-11
TOTAL	3.4E-03	TE-129M	2.9E-05	CE-143	3.0E-07	ZN-65	2.5E-07
		TE-132	3.9E-04	CE-144	3.8E-06	ZN-69M	9.8E-08
		CS-134	1.7E-05	PR-143	2.8E-06	AG-110M	7.6E-06
		CS-136	7.6E-06	ND-147	9.1E-07	W-187	1.9E-05
		CS-137	2.7E-05				
		CS-138	2.4E-06	TOTAL	7.4E-04	TOTAL	7.6E-04
		BA-137M	2.7E-05				
		BA-139	2.3E-05				
		BA-140	6.3E-04				
		BA-141	2.9E-07				
		BA-142	2.0E-08				
		NP-239	4.5E-03				
		TOTAL	6.4E-03				

Table 12.2-13 (Continued)

DETERGENT WASTE TANKS A838

Source Volume = 1500 gal.
Total Curies = 0.000013

Halogens		Soluble Fission Products		Insoluble Fission Products		Activation Products	
Isotope	Curies	Isotope	Curies	Isotope	Curies	Isotope	Curies
BR-83	3.8E-08	SR-89	4.4E-08	ZR-95	6.0E-10	NA-24	1.7E-08
BR-84	1.7E-09	SR-90	3.4E-09	ZR-97	2.7E-10	P-32	3.2E-10
BR-85	0.	SR-91	4.0E-07	NB-95	1.9E-09	CR-51	8.6E-09
I-131	1.1E-06	SR-92	1.2E-07	RU-103	2.9E-10	MN-54	7.0E-10
I-132	4.3E-07	Y-90	3.4E-09	RU-106	0.	MN-56	5.0E-08
I-133	4.2E-06	Y-91M	2.7E-07	RH-103M	2.9E-10	CO-58	8.6E-08
I-134	4.2E-08	MO-99	2.8E-07	RH-106	0.	CO-60	8.7E-09
I-135	2.1E-06	TC-99M	2.8E-07	LA-140	1.4E-07	FE-59	1.4E-09
		TC-101	1.7E-09	CE-141	5.9E-10	NI-65	3.0E-10
TOTAL	7.9E-06	TE-129M	5.0E-09	CE-143	3.9E-10	ZN-65	0.
		TE-132	1.9E-07	CE-144	5.3E-10	ZN-69M	2.4E-10
		CS-134	2.3E-09	PR-143	5.6E-10	AG-110M	1.1E-09
		CS-136	1.5E-09	ND-147	2.0E-10	W-187	3.3E-08
		CS-137	3.6E-09				
		CS-138	1.1E-09	TOTAL	1.5E-07	TOTAL	2.1E-07
		BA-137M	3.6E-09				
		BA-139	5.6E-08				
		BA-140	1.2E-07				
		BA-141	3.3E-09				
		BA-142	1.1E-09				
		NP-239	2.9E-06				
		TOTAL	4.7E-06				

Table 12.2-14

OFFGAS SYSTEM COMPONENT INVENTORY ACTIVITIES

Calculated Offgas System component inventory activities are provided for four different sets of offgas system parameters. The inventory activities are provided as a basis of evaluating the site boundary dose rate for postulated accidents as analyzed in Section 15.7. The system parameters for the cases are shown below.

Table 12.2-14 (Continued)

CASE IDENTIFICATION

Case No.	Flow	30-Minute-Old Noble Gas Mix (μCi/sec)	Buildup Time
1	30	100,000	1 year
2	30	100,000 350,000	11 months 30 days
3	2	100,000	1 year
4	2	100,000 350,000	11 months 30 days

Case 1 (30 scfm flow, 100,000 μCi/sec mix, 1-year buildup time) - This case represents the normal design offgas system operating conditions.

Case 2 (30 scfm flow, 100,000 μCi/sec mix for 11 months plus 350,000 μCi/sec mix for 30 days; a total buildup time of 1 year). This case represents normal conditions for 11 months followed by a 30-day abnormal condition where a 250,000 μCi/sec spike is added to the normal 100,000 μCi/sec release.

Case 3 (2 scfm flow, 100,000 μCi/sec mix, 1-year buildup time). This case represents a lower limit operating condition where the main condenser air inleakage is reduced. This causes a buildup of radioactive inventory in the "front end" of the system. (Note: system design minimum air flow can be maintained 6 scfm by an auxiliary air bleed.)

Case 4 (2 scfm flow, 100,000 μCi/sec mix for 11 months plus 350,000 μCi/sec mix for 30 days; total buildup time 1 year). This case represents abnormal operating conditions of low flow and an additional activity release spike of 250,000 μCi/sec for 30 days.

Table 12.2-14 (Continued)

CASE ONE

OFFGAS PREHEAT (Ci)

13N2	1.111E-03	90KR	1.774E-01	138XE	4.008E-02
16N2	2.452E-00	91KR	1.535E-01	139XE	1.824E-01
16AM*	1.074E-02	92KR	6.591E-03	140XE	1.709E-01
83KRM	1.339E-03	133XE	2.516E-03	141XE	4.102E-03
85KRM	1.994E-03	135XEM	1.193E-02		
87KR	6.883E-03	135XE	7.480E-03		
88KR	6.713E-03	137XE	8.288E-02	TOTAL	= 3.395E-00
89KR	7.087E-02				

RECOMBINER (Ci)

13N2	3.314E-03	90RB	2.415E-03	138XE	1.197E-01
16N2	6.640E-00	91KR	4.238E-01	139XE	5.351E-01
16AM	2.909E-02	91RB	6.220E-03	140XE	4.856E-01
171N2	1.021E-03	92KR	1.389E-02	140CS	6.463E-03
83KRM	4.001E-03	92RB	2.620E-03	141XE	8.462E-03
85KRM	5.958E-03	133XE	7.518E-03		
87KR	2.056E-02	135XEM	3.562E-02		
88KR	2.006E-02	135XE	2.235E-02		
89KR	2.110E-01	137XE	2.469E-01	TOTAL	= 9.373E-00
90KR	5.183E-01				

OFFGAS CONDENSER (Ci)

13N2	9.194E-02	91KR	5.248E-00	139XE	1.217E+01
16N2	5.931E-01	91RB	1.511E-00	139CS	3.994E-01
16AM	3.036E-01	92KR	4.101E-02	139BA	1.406E-03
17N2	6.715E-03	92RB	5.880E-02	140XE	7.663E-00
190	1.384E-02	93KR	1.887E-03	140CS	2.001E-00
83KRM	1.125E-01	93RB	3.351E-03	141XE	2.335E-02
85KRM	1.676E-01	133XEM	8.682E-03	141CS	1.900E-02
87KR	5.778E-01	133XE	2.116E-01	142XE	1.066E-03
88KR	5.641E-01	134I	1.108E-03	142CS	1.707E-03
88RB	9.690E-03	135XEM	9.932E-01		
89KR	5.672E-00	135XE	6.296E-01		
89RB	1.135E-01	137XE	6.692E-00		
90KR	1.126E-01	138XE	3.334E-00		
90RBM	8.690E-02	138CS	3.161E-02	TOTAL	= 1.304E-02
90RB	1.093E-00				

*AM indicates isotopes of nitrogen as ammonia, NH_3.

Table 12.2-14 (Continued)

CASE ONE

WATER SEP (Ci)

13N2	1.276E-02	90RBM	1.215E-03	138XE	4.622E-01
16N2	1.887E-00	90RB	1.555E-02	139XE	1.317E-00
83KRM	1.580E-02	91KR	2.087E-01	139CS	5.849E-03
85KRM	2.357E-02	91RB	8.681E-03	140XE	4.813E-01
87KR	8.110E-02	133XEM	1.218E-03	140CS	1.838E-02
88KR	7.929E-02	133XE	2.968E-02		
89KR	7.566E-01	135XEM	1.378E-01		
89RB	2.059E-03	135XE	8.830E-02		
90KR	1.147E-00	137XE	8.986E-01	TOTAL =	7.681E-00

OFFGAS DELAY LINE (Ci)

13N2	1.246E-00	90RB	4.715E-00	138CS	2.921E-00
16N2	4.510E-00	91KR	6.563E-01	139XE	2.037E+01
83KRM	1.937E-00	91RB	3.409E-01	139CS	3.714E-00
85KRM	2.930E-00	91SR	1.272E-03	139BA	9.004E-02
85KR	7.510E-03	131XEM	1.551E-02	140XE	2.401E-00
87KR	9.838E-00	133XEM	1.528E-01	140CS	1.137E-00
88KR	9.799E-00	133XE	3.725E-00		
88RB	1.006E-00	135XEM	1.465E-01		
89KR	4.628E+01	135XE	1.117E-01		
89RB	5.450E-00	137XE	6.147E-01		
90KR	1.435E+01	138XE	4.851+-1	TOTAL =	2.739E-02
90RBM	4.79[illegible]E-01				

OFFGAS COOLER (Ci)

13N2	1.726E-02	90RBM	4.439E-03	138CS	5.127E-02
83KRM	3.457E-02	90RB	2.783E-02	139XE	1.054E-03
85KRM	5.301E-02	133XEM	2.789E-03	139CS	5.041E-02
87KR	1.736E-01	133XE	6.806E-02	139BA	1.651E-03
88KR	1.763E-01	135XEM	2.24.E-01		
88RB	1.671E-02	135XE	2.032E-01		
89KR	3.278E-01	137XE	5.231E-01		
89RB	8.532E-02	138XE	7.317E-01	TOTAL =	2.776E-00

Table 12.2-14 (Continued)

CASE ONE

MOISTURE SEP (Ci)

13N2	1.026E-02	89KR	1.917E-01	137XE	3.072E-01
83KRM	2.070E-02	133XEM	1.671E-03	138XE	4.360E-01
85KRM	3.175E-02	133XE	4.077E-02		
87KR	1.039E-01	135XEM	1.336E-01		
88KR	1.056E-01	135XE	1.217E-01	Total =	1.508E-00

OFFGAS PREFILTER (Ci)

13N2	5.566E-02	133XEM	9.234E-03	138XE	2.378E-00
83KRM	1.142E-01	133XE	2.253E-01	139XE	2.370E-03
85KRM	1.754E-01	135XEM	7.293E-01		
87KR	5.728E-01	135XE	6.729E-01		
88KR	5.827E-01	137XE	1.618E-00	Total =	8.138E-00
89KR	9.933E-01				

FILTER 1 YR (Ci)

88RB	6.866E-01	133I	5.532E-03	139CS	2.924E-02
89RB	1.188E-00	135I	2.777E-03	139BA	2.922E-03
89SR	1.178E-00	137CS	4.374E-02		
131I	7.024E-03	137BAM	2.060E-02		
132I	1.019E-03	138CS	2.808E-00	Total =	5.949E-00

Table 12.2-14 (Continued)

CASE ONE

OFFGAS DRYER (Ci)

13N2	2.440E-01	89KR	3.626E-00	137XE	6.162E-00
83KRM	5.436E-01	89RB	3.431E-01	138XE	1.071E-01
85KRM	8.387E-01	131XEM	4.504E-03	138CS	4.908E-01
85KR	2.181E-03	133XEM	4.430E-02	139XE	3.496E-03
87KR	2.716E-00	133XE	1.081E-00		
88KR	2.781E-00	135XEM	3.299E-00		
88RB	2.275E-01	135XE	3.233E-00	Total =	3.635E-01

CHARCOAL DELAY (Ci)

13N2	1.492E-00	89SR	9.550E-00	137BAM	1.829E-00
83KRM	3.992E+01	131XEM	4.698E+01	138XE	9.545E+01
85KRM	1.488E+02	133XEM	9.419E+01	138CS	1.057E+02
85KR	2.778E-00	133XE	5.525E+03	139CS	3.374E-03
87KR	1.354E+02	135XEM	3.180E+01	139BA	3.895E-03
88KR	3.081E+02	135XE	1.208E+03		
88RB	3.107E+02	135CS	1.823E-03		
89KR	5.918E-00	137XE	1.279E+01		
89RB	9.204E-00	137CS	2.059E-00	Total =	8.095E+03

AFTER-FILTER (Ci)

133XE	1.022E-03	134TE	0.

FILTER 1 YR (Ci)

137CS	3.360E-01	137BAM	1.582E-01	Total =	4.946E-01

Table 12.2-14 (Continued)

CASE TWO

OFFGAS PREHEAT (Ci)

16N2	2.452E-00	91RB	1.780E-03	138XE	1.202E-01
16AM*	1.074E-02	92KR	1.977E-02	139XE	5.471E-01
83KRM	4.014E-03	92RB	1.098E-03	140XE	5.127E-01
85KRM	5.978E-03	93KR	1.506E-03	141XE	1.230E-02
87KR	2.064E-02	133XE	7.429E-03		
88KR	2.013E-02	135XEM	3.574E-02		
89KR	2.126E-01	135Xe	2.240E-02		
90KR	5.320E-01	137XE	2.486E-01	Total =	5.256E-00
91KR	4.602E-01				

RECOMBINER (Ci)

13N2	3.314E-03	91RB	1.886E-02	140XE	1.454E-00
16N2	6.639E-00	92KR	4.168E-02	140CS	1.939E-02
17N2	1.0[illegible]E-03	92RB	7.860E-03	141XE	2.538E-02
83KRM	1.19[illegible]-02	93KR	2.778E-03	141CS	1.071E-03
85KRM	1.786E-02	133XE	2.[illegible]20E-02	142XE	1.634E-03
87KR	6.168E-02	135XEM	1.067E-01		
88KR	6.015E-02	135XE	6.693E-02		
89KR	6.328E-01	137XE	7.407E-01		
90KR	1.555E-00	138XE	3.589E-01		
90RB	7.245E-03	139XE	1.605E-00		
91KR	1.271E-00	139CS	2.444E-03	Total =	1.477E-01

Table 12.2-14 (Continued)

CASE TWO

OFFGAS CONDENSER (Ci)

13N2	9.193E-02	91SR	2.347E-03	139XE	3.652E+01
16N2	6.931E+01	92KR	1.230E-01	139CS	1.198E-00
16AM*	3.036E-01	92RB	1.764E-01	139BA	4.217E-03
17N2	6.718E-03	93KR	5.660E-03	140XE	2.299E+01
19O	1.379E-02	93RB	1.005E-02	140CS	6.003E-00
83KRM	3.372E-01	131XEM	2.492E-03	141XE	7.004E-02
85KRM	5.026E-01	132I	1.794E-03	141CS	5.699E-02
87KR	1.733E-00	133I	1.044E-03	142XE	3.197E-03
88KR	1.692E-00	133XEM	2.583E-02	142CS	5.122E-03
88RB	2.906E-02	133XE	6.249E-01		
89KR	1.701E+01	134I	3.322E-03		
89RB	3.406E-01	135I	1.674E-03		
90KR	3.377E+01	135XEM	2.976E+00		
90RBM	2.607E-01	135XE	1.885E+00		
90RB	3.280E-00	137XE	2.008E+01		
91KR	1.475E+01	138XE	1.000E+01	Total =	2.518E+02
91RB	4.534E-00				

WATER SEP (Ci)

13N2	1.276E-02	90RB	4.664E-02	138CS	1.782E-03
16N2	1.887E-00	91KR	6.261E-01	139XE	3.950E-00
83KRM	4.737E-02	91RB	2.604E-02	139CS	1.755E-02
85KRM	7.066E-02	133XEM	3.623E-03	140XE	1.444E-00
87KR	2.433E-01	133XE	8.766E-02	140CS	5.514E-02
88KR	2.378E-01	135XEM	4.129E-01		
89KR	2.270E-00	135XE	2.644E-01		
89RD	6.176E-03	137XE	2.696E-00		
90KR	3.442E-00	138XE	1.386E-00	Total =	5.514E-02
90RBM	3.646E-03				

Table 12.2-14 (Continued)

CASE TWO

OFFGAS DELAY LINE (Ci)

13N2	1.245E-00	90RB	1.414E+01	138CS	8.763E-00
16N2	4.510E-00	91KR	1.969E-00	139XE	6.112E+01
83KRM	5.808E-00	91RB	1.023E-00	139CS	1.114E+01
85KRM	8.784E-00	91SR	3.816E-03	139BA	2.701E-01
85KR	4.268E-03	131XEM	4.387E-02	140XE	7.201E-00
87KR	2.951E+01	133XEM	4.544E-01	140CS	3.401E-00
88KR	2.939E+01	133XE	1.100E+01		
88RB	3.016E+00	135XEM	4.388E+01		
89KR	1.388E-02	135XE	3.345E+01		
89RB	1.635E+01	137XE	1.844E+02		
90KR	4.304E+01	138XE	1.455E+02	Total =	8.097E+02
90RBM	1.437E-00				

OFFGAS COOLER (Ci)

13N2	1.725E-02	90RBM	1.332E-02	138XE	2.195E-00
83KRM	1.037E-01	90RB	8.350E-02	138CS	1.538E-01
85KRM	1.590E-01	133XEM	8.298E-03	139XE	3.162E-03
87KR	5.207E-01	133XE	2.010E-01	139CS	1.512E-01
88KR	5.286E-01	135XEM	6.713E-01	139BA	4.953E-03
88RB	5.012E-02	135XE	6.084E-01	140CS	2.214E-03
89KR	9.832E-01	137XE	1.569E-00		
89RB	2.559E-01			Total =	8.286E-00

MOISTURE SEP (Ci)

13N2	1.026E-02	89RB	2.150E-03	138XE	1.308E-00
83KRM	6.206E-02	133XEM	4.971E-03	138CS	2.311E-03
85KRM	9.521E-02	133XE	1.204E-01	139XE	1.688E-03
87KR	3.116E-01	135XEM	4.002E-01		
88KR	3.166E-01	135XE	3.645E-01		
88RB	1.017E-03	137XE	9.217E-01	Total =	4.498E-00
89KR	5.750E-01				

Table 12.2-14 (Continued)

CASE TWO

OFFGAS PREFILTER (Ci)

13N2	5.565E-02	131XEM	2.654E-03	137XE	4.854E-00
83KRM	3.424E-01	133XEM	2.747E-02	138XE	7.135E-00
85KRM	5.258E-01	133XE	6.654E-01	139XE	7.110E-03
87KR	1.718E-00	135XEM	2.185E-00		
88KR	1.748E-00	135XE	2.015E-00	Total =	2.428E+01
89KR	2.998E-00				

FILTER 1 YR (Ci)

88RB	2.059E-00	133I	1.656E-02	138CS	8.423E-00
89RB	3.563E-00	134I	2.011E-03	139CS	8.771E-03
89SR	3.535E-00	135I	8.324E-03	139BA	8.764E-03
90RB	1.023E-03	137CS	1.312E-01		
131I	2.074E-02	137BAM	4.669E-02	Total =	1.783E+01
132I	3.015E-03				

13N2	2.439E-01	138CS	1.472E-00	133XEM	1.318E-01
83KRM	1.630E-00	89KR	1.088E-01	133XE	3.193E-00
85KRM	2.515E-00	89RB	1.029E-00	135XEM	9.883-00
85KR	1.240E-03	90KR	1.086E-03	138XE	3.212E-01
87KR	8.147E-00	131XEM	1.274E-02	139CS	1.574E-03
88KR	8.341E-00	137XE	1.848E-01		
88RB	6.824E-01	139XE	1.049E-02	Total =	1.085E-02
135XE	9.681E-00				

OFFGAS DRYER (Ci)

13N2	2.439E-01	131XEM	1.274E-02	Total =	1.085E+02
83KRM	1.630E+00	133XEM	1.318E-01		
85KRM	2.515E+00	133XE	3.193+00		
85KR	1.240E-03	135XEM	9.883E+00		
87KR	8.147E+00	135XE	9.681E+00		
88KR	8.341E+00	137XE	1.848E+01		
88RB	6.824E-01	138XE	3.212E+01		
89KR	1.088E+01	138CS	1.472E+00		
89RB	1.029E+00	139XE	1.049E-02		
90KR	1.086E-03	139CS	1.574E-03		

Table 12.2-14 (Continued)

CASE TWO

CHARCOAL DELAY (Ci)

13N2	1.492E+00	131XEM	1.328E+02	138CS	3.170E+02
83KRM	1.197E-02	133XEM	2.802E+02	139XE	1.192E-03
85KRM	4.461E+02	133XE	1.631E+04	139CS	1.012E-02
85KR	1.606E-00	135XEM	9.528E+01	139BA	1.168E-02
87KR	4.060E+02	135XE	3.618E+03		
88KR	9.240E+02	135CS	1.091E-05		
88RB	9.313E+02	137XE	3.838E+01		
89KR	1.776E+01	137CS	1.295E-00		
89RB	2.761E+01	137BAM	6.146E-01		
89SR	2.846E+01	138XE	2.863E+02	Total =	2.399E+04

AFTER-FILTER (Ci)

133XE	2.679E-03	134TE	0	Total =	3.684E-03

Table 12.2-14 (Continued)

CASE THREE

OFFGAS PREHEAT (Ci)

13N2	1.178E-03	89KR	7.764E-02	135XE	8.588E-03
16N2	2.489E-00	90KR	1.877E-01	137XE	9.386E-02
16AM*	1.489E-02	91KR	1.566E-01	138XE	4.582E-02
83KRM	1.483E-03	92KR	6.670E-03	139XE	1.979E-01
85KRM	2.208E-03	133XE	2.88E-03	141XE	4.151E-03
87KR	7.620E-03	135XEM	1.364E-02	140XE	1.773E-01
88KR	7.434E-03				
				Total =	3.497E-00

RECOMBINER (Ci)

13N2	3.516E-03	89KR	2.311E-01	135XEM	4.074E-02
16N2	6.731E-00	90KR	5.484E-01	135XE	2.566E-02
16AM	2.942E-02	90RB	2.587E-03	137XE	2.796E-01
17N2	1.032E-03	91KR	4.321E-01	138XE	1.368E-01
83KRM	4.430E-03	91RB	6.423E-03	139XE	5.806E-01
85KRM	6.598E-03	92KR	1.401E-02	140XE	5.024E-01
87KR	2.277E-02	92RB	2.672E-03	140CS	6.783E-03
88KR	2.221E-02	133XE	8.630E-03	141XE	8.528E-03
				Total =	9.653E-00

OFFGAS CONDENSER (Ci)

13N2	9.752E-02	90RB	1.167E-00	138XE	3.811E-00
16N2	6.958E+01	91KR	5.305E-00	138CS	3.660E-02
16AM	3.041E-01	91RB	1.546E-00	139XE	1.318E-01
17N2	6.706E-03	92KR	4.082E-02	139CS	4.378E-01
19O	1.396E-02	92RB	5.880E-02	139BA	1.560E-03
83KRM	1.245E-01	93KR	1.875E-03	140XE	7.892E-00
85KRM	1.856E-01	93RB	3.354E-03	140CS	2.085E-00
87KR	6.396E-01	131XEM	1.011E-03	141XE	2.323E-02
88KR	6.247E-01	133XEM	9.967E-03	141CS	1.916E-02
88RB	1.087E-02	133XE	2.429E-01	142XE	1.059E-03
89KR	6.210E-00	134I	1.122E-03	142CS	1.703E-03
89RB	1.259E-01	135XEM	1.136E-00		
90KR	1.187E+01	135XE	7.228E-01		
90RBM	9.282E-02	137XE	7.575E-00	Total =	1.352E-02

Table 12.2-14 (Continued)

CASE THREE

WATER SEPARATOR (Ci)

13N2	1.852E-01	90KR	1.005E-01	135XE	1.324E-00
16N2	5.879E-00	90RBM	1.492E-01	137XE	1.231E-01
83KRM	2.359E-01	90RB	1.838E-00	138XE	6.752E-00
85KRM	3.524E-01	91KR	7.641E-01	138CS	1.288E-01
87KR	1.209E-00	91RB	3.597E-01	139XE	1.240E-01
88KR	1.185E-00	131XEM	1.851E-03	139CS	8.001E-01
88RB	4.080E-02	133XEM	1.823E-02	139BA	5.936E-03
89KR	1.023E-01	133XE	4.445E-01	140XE	2.394E-00
89RB	4.089E-01	135XEM	2.017E-00	140CS	1.058E-00
				Total =	7.255E-01

OFFGAS DELAY LINE (Ci)

13N2	2.884E-00	90RBM	5.871E-01	138XE	1.506E-02
16N2	3.153E-02	90RB	4.512E-00	138CS	5.729E-01
83KRM	2.126E-01	91KR	1.243E-02	139XE	7.987E-00
85KRM	3.836E-01	91RB	1.668E-01	139CS	7.835E-00
85KR	1.126E-01	91SR	2.691E-02	139BA	2.096E-00
87KR	9.458E-01	91YM	5.357E-03	140XE	1.659E-01
88KR	1.188E-02	131XEM	2.318E-01	140CS	6.008E-01
88RB	4.739E-01	133XEM	2.261E-00	140BA	2.798E-03
89KR	4.716E-01	133XE	5.553E-01		
89RB	2.266E-01	135XEM	4.845E-01		
89SR	9.874E-03	135XE	1.613E-02		
90KR	4.645E-00	137XE	7.025E-01	Total =	9.678E-02

OFFGAS COOLER (Ci)

83KRM	2.669E-01	88RB	1.769E-01	133XE	1.010E-00
85KRM	6.029E-01	89RB	1.215E-02	135XEM	2.670E-02
85KR	2.057E-03	131XEM	4.226E-03	135XE	2.740E-00
87KR	9.826E-01	133XEM	4.081E-02	138XE	5.995E-02
88KR	1.700E-00			138CS	2.448E-01
				139BA	2.296E-02
				Total =	7.893E-00

Table 12.2-14 (Continued)

CASE THREE

MOISTURE SEPARATOR (Ci)

83KRM	1.583E-01	88RB	4.756E-02	135XEM	1.485E-02
85KRM	3.597E-01	131XEM	2.532E-03	135XE	1.638E-00
85KR	1.232E-03	133XEM	2.444E-02	138XE	3.314E-02
87KR	5.799E-01	133XE	6.047E-01		
88KR	1.011E-00			Total =	4.47E-00

OFFGAS PREFILTER (Ci)

83KRM	8.533E-01	88RB	3.020E-03	135XEM	6.867E-02
85KRM	1.967E-00	131XEM	1.399E-02	135XE	9.007E-00
85KR	6.811E-03	133XEM	1.350E-01	138XE	1.52E-01
87KR	3.090E-00	133XE	3.341E-00		
88KR	5.498E-00			Total =	2.414E-01

FILTER 1 YR (Ci)

88RB	6.449E-00	138CS	1.832E-01	Total =	6.633E-00

OFFGAS DRYER (Ci)

83KRM	3.635E-00	88KR	2.438E+01	133XE	1.604E-01
85KRM	8.991E-00	88RB	1.761E+01	135XEM	1.471E-01
85KR	3.275E-02	131XEM	6.720E-02	135XE	4.225E+01
87KR	1.245E+01	133XEM	6.461E-01	138CS	1.549E-01
				138XE	3.064E-01
				Total =	1.267E+02

Table 12.2-14 (Continued)

CASE THREE

CHARCOAL DELAY (Ci)

14C	6.786E-03	88RB	1.758E+02	135XE	1.00E-03
83KRM	1.616E+01	131XEM	5.120E+01	135CS	1.263E-02
85KRM	1.023E+02	133XEM	9.128E+01	138XE	7.800E-02
85KR	4.157E+01	133XE	5.475E+03	138CS	2.298E-01
87KR	3.587E+01	135XEM	4.334E+02		
88KR	1.690E+02			Total =	7.164E+03

AFTER FILTER (Ci)

85KR	7.550E-03	Total =	7.562E-03

FILTER 1 YR (Ci)

Total = 1.731E-08

Table 12.2-14 (Continued)

CASE FOUR

OFFGAS PREHEAT (Ci)

13N2	1.178E-03	91KR	4.698E-01	137XE	2.816E-01
16N2	2.489E-00	91RB	1.838E-03	138XE	1.375E-01
16AM*	1.088E-02	92KR	2.001E-02	139XE	5.938E-01
83KRM	4.445E-03	92RB	1.123E-03	140XE	5.319E-01
85KRM	6.621E-03	93KR	1.524E-03	140CS	1.892E-03
87KR	2.286E-02	133XE	8.529E-03	141XE	1.245E-02
88KR	2.229E-02	135XEM	4.088E-02		
89KR	2.329E-01	135XE	2.571E-02	Total =	5.486E-00
90KR	5.632E-01				

RECOMBINER (Ci)

13N2	3.516E-03	90RB	7.761E-03	137XE	8.387E-01
16N2	6.731E-00	91KR	1.296E-00	138XE	4.104E-01
16AM	2.942E-02	91RB	1.927E-02	139XE	1.742E-00
17N2	1.033E-03	92KR	4.201E-02	139CS	2.685E-03
83KRM	1.328E-02	92RB	8.016E-03	139CS	2.685E-03
85KRM	1.979E-02	93KR	2.796E-03	140XE	1.507E-00
87KR	6.829E-02	133XEM	1.053E-03	140CS	2.035E-02
88KR	6.662E-02	133XE	2.549E-02	141XE	2.558E-02
89KR	6.933E-01	135XEM	1.221E-01	141CS	1.093E-03
90KR	1.645E-00	135XE	7.684E-02	142XE	1.644E-03
				Total =	1.543E+01

Table 12.2-14 (Continued)

CASE FOUR

OFFGAS CONDENSER (Ci)

13N2	9.751E-02	92KR	1.224E-01	139CS	1.313E-00
16N2	6.958E+01	92RB	1.764E-01	139BA	4.681E-03
16AM*	3.041E-01	93KR	5.625E-03	140XE	2.368E+01
17N2	6.710E-03	93RB	1.006E-02	140CS	6.254E-00
19O	1.391E-02	131XEM	2.860E-03	141XE	6.970E-02
83KRM	3.734E-01	132I	1.817E-03	141CS	5.748E-02
85KRM	5.566E-01	133I	1.058E-03	142XE	3.176E-03
87KR	1.919E-00	133XEM	2.965E-02	142CS	5.108E-03
88KR	1.874E-00	133XE	7.174E-01		
88RB	3.259E-02	134I	3.365E-03	Total =	2.655E+02
89KR	1.863E+01	135I	1.695E-03		
89RB	3.776E-01	135XEM	3.403E-00		
90KR	3.562E-01	135XE	2.164E-00		
90RBM	2.784E-01	137XE	2.272E+01		
90RB	3.502E-00	138XE	1.143E+01		
91KR	1.592E+01	138CS	1.098E-01		
91RB	4.638E-00	139XE	3.953E+01		
91SR	2.431E-03				

WATER SEPARATOR (Ci)

13N2	1.852E-01	90RB	5.514E-00	138CS	3.864E-01
16N2	5.879E-00	91KR	2.292E-00	139XE	3.721E+01
83KRM	7.071E-01	91RB	1.079E-00	139CS	2.400E-00
85KRM	1.057E-00	91SR	1.176E-03	139BA	1.781E-02
87KR	3.626E-00	131XEM	5.234E-03	140XE	7.181E-00
88KR	3.553E-00	133XEM	5.424E-02	140CS	3.173E-00
88RB	1.223E-01	133XE	1.313E-00		
89KR	3.068E+01	135XEM	6.043E-00	Total =	2.055E+02
89RB	1.227E+00	135XE	3.964E-00		
90KR	3.016E+01	137XE	3.693E+01		
90RBM	4.475E-01	138XE	2.025E+01		

Table 12.2-14 (Continued)

CASE FOUR

OFFGAS DELAY LINE (Ci)

13N2	2.883E-00	90RBM	1.761E-00	138CS	1.718E+02
16N2	3.153E-02	90RB	1.354E+01	139XE	2.396E+01
83KRM	6.373E+01	91KR	3.729E-02	139CS	2.350E+01
85KRM	1.150E+02	91RB	5.003E-01	139BA	6.288E-00
85KR	6.423E-02	91SR	8.074E-02	140XE	4.977E-01
87KR	2.837E+02	91YM	1.607E-02	140CS	1.803E-00
88KR	3.563E+02	131XEM	6.555E-01	140BA	8.394E-03
88RB	1.421E+02	133XEM	6.727E-00		
89KR	1.415E+02	133XE	1.640E+02	Tocal =	2.893E+03
89RB	6.797E+01	135XEM	1.452E+02		
89SR	2.962E-02	135XE	4.828E+02		
90KR	1.393E+01				

OFFGAS COOLER (Ci)

83KRM	8.001E-01	89SR	5.416E-04	138XE	1.798E-01
85KRM	1.807E-00	91SR	1.375E-03	138CS	7.343E-01
85KR	1.174E-03	131XEM	1.195E-02	139BA	6.887E-02
87KR	2.947E-00	133XEM	1.214E-01		
88KR	5.096E-00	133XE	2.981E-00	Total =	2.360E-01
88RB	5.303E-01	135XEM	7.997E-02		
89RB	3.664E-02	135XE	8.202E-00		

MOISTURE SEPARATOR (Ci)

83KRM	4.745E-01	133XEM	7.270E-02	138CS	2.597E-03
85KRM	1.078E-00	133XE	1.786E-00		
87KR	1.739E-00	135XEM	4.447E-02	Total =	1.338E-01
88KR	3.033E-00	135XE	4.904E-00		
88RB	1.426E-01	138XE	9.940E-02		
131XEM	7.158E-03				

Table 12.2-14 (Continued)

CASE FOUR

OFFGAS PREFILTER (Ci)

83KRM	2.558E-00	131XEM	3.995E-02	138XE	4.536E-01
85KRM	5.897E-00	133XEM	4.014E-01		
85KR	3.887E-03	133XE	9.864E-00	Total =	7.215E-01
87KR	9.267E-00	135XEM	2.057E-01		
88KR	1.648E-01	135XE	2.696E-01		
88RB	9.055E-03				

FILTER 1 YR (Ci)

88RB	1.934E-01	133I	1.051E-03	138CS	5.493E-01
131I	1.388E-03				
				Total =	1.989E-01

OFFGAS DRYER (Ci)

83KRM	1.090E-01	131XEM	1.900E-01	138XE	9.190E-01
85KRM	2.695E-01	133XEM	1.922E-00	138CS	4.647E-01
85KR	1.871E-02	133XE	4.734E-01		
87KR	3.734E-01	135XEM	4.406E-01		
88KR	7.311E-01	135XE	1.265E-02	Total =	3.789E-02
88RB	5.279E-01				

Table 12.2-14 (Continued)

CASE FOUR

CHARCOAL DELAY (Ci)

14C	1.037E-03	88RB	5.267E-02	138XE	2.339E-01
83KRM	4.843E-01	131XEM	1.447E-02	138CS	6.892E-01
85KRM	3.066E-02	133XEM	2.715E-02		
85KR	2.402E-01	135XEM	1.298E-01		
87KR	1.076E-02	135XE	3.009E-03	Total =	2.111E-04
88KR	5.066E-02				

AFTER-FILTER (Ci)

85KR	4.027E-03	Total =	4.029E-03

Table 12.2-15

EXPECTED SOLID WASTE AVERAGE RADIOACTIVITY CONTENT

Nuclide	Cleanup Sludge Ci/Container*	Spent Resin Ci/Container	Filter Sludge Ci/Container	Concentrated Wastes Ci/Container
Na-24	0	0	0	2.1 E-05
P-32	4.3 E-03	3.3 E-03	0	1.7 E-04
Cr-51	7.5 E-01	0	3.1 E-01	5.2 E-03
Mn-54	4.5 E-01	0	3.0 E-02	6.0 E-04
Mn-56	0	0	1.4 E-01	3.4 E-10
Co-58	3.1 E+01	0	2.5 E+00	6.5 E-02
Co-60	7.7 E+00	0	3.9 E-01	7.8 E-03
Fe-59	2.8 E-01	0	5.5 E-02	1.0 E-03
Ni-65	0	0	8.9 E-04	0
Zn-65	2.1 E-02	2.9 E-03	0	3.0 E-05
Zn-69m	0	0	0	2.2 E-07
Ag-110m	6.6 E-01	0	4.7 E-02	9.3 E-04
W-187	0	0	1.2 E-01	1.8 E-04
Br-83	0	0	0	3.8 E-10
I-131	2.4 E-01	2.4 E+00	0	7.8 E+00
I-132	2.1 E-05	0	0	1.4 E-09
I-133	0	0	0	1.1 E-01
I-135	0	0	0	3.2 E-04
Sr-89	1.1 E+01	6.9 E+00	0	3.6 E-02
Sr-90	2.8 E+00	3.6 E-01	0	3.6 E-03
Sr-91	0	0	0	8.5 E-05
Sr-92	0	0	0	1.4 E-09
Y-90	2.8 E+00	3.6 E-01	0	3.6 E-03
Y-91m	0	0	0	5.8 E-05
Zr-95	1.8 E-01	0	2.4 E-02	4.4 E-04
Zr-97	0	0	7.6 E-04	4.9 E-07
Nb-95	4.4 E-01	0	7.3 E-02	1.4 E-03
Mo-99	2.9 E-06	1.8 E-04	2.0 E+00	1.8 E-02
Tc-99m	0	0	0	4.4 E-06
Ru-103	4.9 E-02	0	1.1 E-02	1.9 E-04
Ru-106	2.6 E-02	0	1.8 E-03	3.4 E-05
Rh-103	4.9 E-02	0	1.1 E-02	1.9 E-04
Rh-106	2.6 E-02	0	1.8 E-03	3.4 E-05
Te-129m	3.2 E-01	0	1.8 E-01	3.0 E-03
Te-132	2.1 E-05	0	2.3 E+00	1.7 E-02
Cs-134	1.8 E+00	2.4 E-01	0	2.3 E-03
Cs-136	1.3 E-02	1.2 E-02	0	6.9 E-04
Cs-137	2.9 E+00	3.8 E-01	0	3.8 E-03

*Data based on a 155 ft^3 shipping container.

Table 12.2-15 (Continued)

Nuclide	Cleanup Sludge Ci/Container	Spent Resin Ci/Container	Filter Sludge Ci/Container	Concentrated Wastes Ci/Container
Ba-137m	2.9 E+00	2.0	0	3.8 E-03
Ba-140	1.0 E+00	3.0 E+00	0	5.7 E-02
La-140	1.1 E+00	0	0	6.6 E-02
Ce-141	7.0 E-02	0	2.0 E-02	3.9 E-04
Ce-143	0	0	1.8 E-03	5.0 E-06
Ce-144	5.4 E-01	0	2.2 E-02	4.4 E-04
Pr-143	5.8 E-03	0	1.7 E-02	2.6 E-04
Nd-147	8.6 E-04	0	5.8 E-03	7.9 E-05
Np-239	1.6 E-06	5.3 E-03	0	1.1 E-01
Total	61	14.3	8.3	7.5

Table 12.2-16

RADIOACTIVE SOURCES IN THE FUEL POOL FILTER
DEMINERALIZED SYSTEM

(LATER)

Table 12.2-17

RADIOACTIVE SOURCES IN THE SUPPRESSION POOL CLEANUP SYSTEM
(ACTIVITY IN THE BACKWASH TANK)(Ci)

Isotope	Activity	Isotope	Activity
85Br	1.6E-3	88Rb	7.6E-1
87Br	2.9E-4	89Rb	7.6E-1
88Rb	2.2E-1	89Sr	2.1E-2
89Rb	2.0E-1	131Te	1.2E-6
89Sr	1.5E-2	131I	1.7E-0
131I	1.1E-1	134Te	1.9E-6
132Te	1.8E-5	134I	6.4E-1
132I	1.9E-2	135I	1.5E-0
133I	8.9E-2	137Cs	4.9E-3
134Im	6.6E-4	137Bam	2.4E-3
134I	2.8E-2	138Cs	3.4E+1
135I	4.7E-2		
136Im	1.4E-4	Total	1.2E+2
136I	1.2E-3		
137I	6.6E-6		
137Cs	4.8E-3		
137Bam	2.3E-3		
138Cs	1.9E-1		
Total	9.3E-1		

Table 12.2-18

RADIOACTIVE CRUD IN PIPING AND STEAM SYSTEMS

(LATER)

Table 12.2-19

RADIOACTIVE SOURCES IN CONTROL ROD DRIVE SYSTEM

Control Rod Drive Radiation Survey Data

	Gamma Dose Measured at Contact MR/hr			
	Before Cleaning		After Cleaning	
Component	Maximum	Average	Maximum	Average
Spud	10,000	600	500	110
Filter	23,000	3,500	20,000	300
Collet Housing	3,000	1,800	4,000	700
Outer Cylinder	1,200	60	80	40
Strainer	8,000	1,800	1,000	500
Flange	1,000	200	400	150

Control Blade Principal Isotopes

	Curies (135 GWd/Te 7-Days Cooled)
Isotope	Ci/Blade
Cr51	1.4E5
Mn54	9.1E3
Fe55	1.6E5
Co58m	7.7E3
Co58	8.8E3
Co60	1.1E5
Ni63	5.0E3
Total	4.4E5

Table 12.2-20

ANNUAL AIRBORNE RELEASES OF ELEMENTAL IODINE-131 ACCORDING TO PLANT OPERATING MODE FOR ENVIRONMENTAL IMPACT EVALUATIONS ELEMENTAL I-131 RELEASE (mCi/yr)

Source	Plant Operating Mode	
Building or Exhaust	Power Generation	Refueling/ Maintenance
Auxiliary and Fuel Building	166.0	7.5
Containment Building	12.0	46.9
Turbine Building	889.0	95.9
Radwaste Building	40.2	12.2
Gland Seal Steam and Mechanical Vacuum Pump	--	85.9
Total	1107.2	248.4
Elemental	1107.2 + 248.4 = 1355.6	

Table 12.2-21

ANNUAL AIRBORNE RELEASES OF NONELEMENTAL IODINE-131 SPECIES ACCORDING TO PLANT OPERATING MODE FOR ENVIRONMENTAL IMPACT EVALUATIONS

Iodine-131 Release (mCi/yr)

Sources	Plant Operating Mode					
	Power Operation			Refueling/Maintenance		
	Species					
Building or Exhaust	Particulate	HOI	CH_3I	Particulate	HOI	CH_3I
Auxiliary and Fuel Building	69.2	83.0	31.1	3.1	3.8	1.4
Containment Building	4.1	14.0	7.1	16.1	55.7	27.8
Turbine Building	356.0	391.0	142.0	38.4	42.2	15.3
Radwaste Building	0.3	35.9	67.5	0.09	10.9	20.5
Gland Seal System and Mechanical Vacuum Pump	---	---	---	14.3	301.0	1030
Total	429.6	523.9	247.7	72.0	413.6	1095

Particulate 429.6 + 72.0 = 501.6 mCi/yr

HOI 523.9 + 413.6 = 937.5 mCi/yr

CH_3I 247.7 + 1095.0 = 1342.7 mCi/yr

Total Nonelemental I-131 = 2781.8 mCi/yr

Table 12.2-22

ANNUAL AIRBORNE RELEASE OF NOBLE GAS AND IODINE FOR ENVIRONMENTAL IMPACT EVALUATIONS (Ci/yr)

Isotope	Containment	Auxiliary	Turbine	Radwaste	Mechanical Vacuum Pump	Air Ejector Offgas	Drywell Purge
Kr-83m							0.26
85m	2	6	50			120	0.28
85						280-560	0.05
87		4	122				0.28
88	2	6	182			6	0.06
89		4	1160	58			0.07
90							0.03
Xe-131m						37	0.07
133m						0.02	0.57
133	54	166	300	440	2600	940	21.6
135m	30	90	800	1060			0.75
135	66	188	660	560	1000		6.09
137	90	270	2000	166			0.10
138	4	12	2000	4			0.21
139							0.03
I-131	0.184	0.365	1.97	0.186	1.43		0.004
132	1.29	2.56	13.82	1.32	10.05		0.0004
133	1.18	2.34	12.63	1.20	9.17		0.003
134	2.16	4.29	23.17	2.21	16.83		0.0003
135	1.59	3.16	17.05	1.62	12.39		0.002

Table 12.2-23

ANNUAL AIRBORNE RELEASES FOR ENVIRONMENTAL IMPACT EVALUATIONS (Ci/yr)

Isotope	Containment	Auxiliary	Turbine	Radwaste	Mechanical Vacuum Pump	Air Ejector Offgas	Drywell Purge
H-3	26.8		26.8				99
C-14			9.5			0.02	
15							0.02
N-13							0.19
16							4.26
17							0.0007
F-18							0.288
O-19							0.13
Cr-51	0.0004	0.0018	0.0018	0.0014			0.0017
Mn-54	0.0008	0.002	0.0012	0.008			0.00002
Fe-59	0.00018	0.0006	0.0002	0.0006			0.000009
Co-58	0.0002	0.0004	0.002	0.0004			0.000065
60	0.002	0.008	0.002	0.014			0.00014
Zn-65	0.002	0.008	0.012	0.0006			0.000069
Sr-89	0.00006	0.00004	0.012	--			0.000033
90	0.000006	0.000014	0.00004	--			0.0000025
Zr-95	0.0006	0.0014	0.00008	0.0016			0.0000026
Nb-95	0.002	0.018	0.000012	0.000008			0.0000028
Mo-99	0.012	0.12	0.004	0.000006			0.00018
Ru-103	0.0004	0.008	0.00010	0.000002			0.000006
Ag-110	0.0000008	0.000004	--	--			0.0000003
Sb-124	0.00004	0.00006	0.0002	0.00014			---
Cs-134	0.0014	0.008	0.0004	0.0048			0.00001
136	0.0002	0.0008	0.0002	--			0.000005
137	0.002	0.010	0.002	0.008			0.00003
Ba-140	0.004	0.04	0.020	0.000008			0.000096
Ce-141	0.0004	0.0014	0.020	0.000014			0.0000099
Ar-41						20.0	0.17

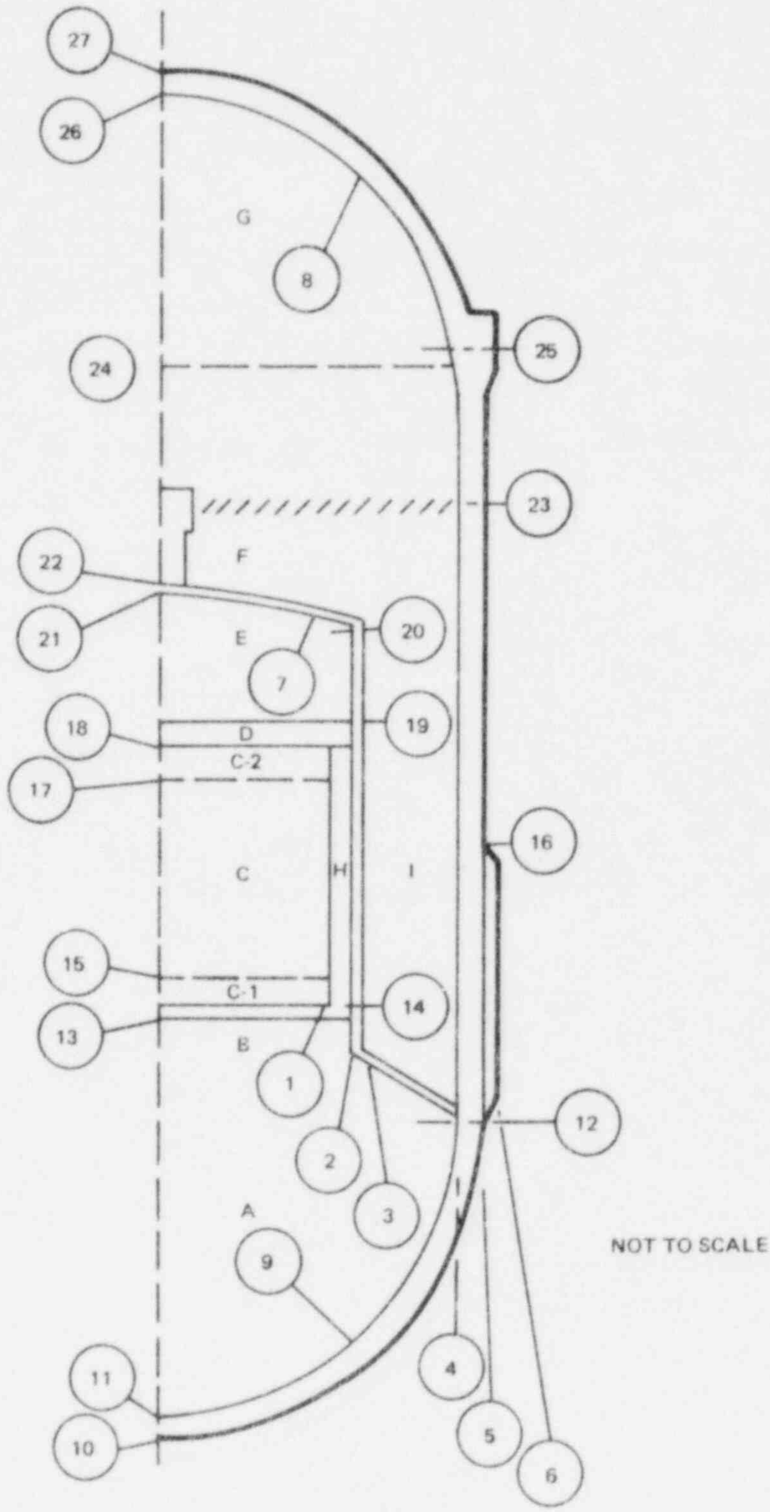


Figure 12.2-1. Radiation Source Model

SECTION 12.3

CONTENTS

CONTENTS (Continued)

TABLES

SECTION 12.3

ILLUSTRATIONS

12.3 RADIATION PROTECTION DESIGN FEATURES

12.3.1 Facility Design Features

This plant is designed to meet the intent of Regulatory Guide 8.8 [i.e., to keep radiation exposures to plant personnel as low as reasonably achievable (ALARA)]. This section describes the component and system designs in addition to the equipment layout employed to maintain radiation exposures ALARA. Consideration of individual systems are provided to illustrate the application of these principles.

12.3.1.1 Equipment Design for Maintaining Exposures ALARA

This subsection describes specific plant components as well as system design features that aid in maintaining the exposure of plant personnel during system operation and maintenance ALARA. Equipment layout to provide ALARA exposures of plant personnel are discussed in Subsection 12.3.1.2.

(1) Filter Demineralizers - Filter demineralizers are designed to provide remote removal of spent resin and filter aid material by backflushing to a shielded receiving tank through a low point drain in the filter demineralizer. Provisions are made for condensate flushing as well as chemical cleaning of these filter demineralizers prior to maintenance operations. Application of the filter aid and a new charge of resin is also accomplished remotely to eliminate the need for entering the shielded cubicle containing this equipment. A Y-strainer is provided downstream of the filter demineralizer to prevent resins and filter aid material from entering the system. These strainers are also designed to allow remote removal of entrained material.

12.3.1.1 Equipment Design for Maintaining Exposure ALARA (Continued)

(2) Demineralizers - The demineralizers are also designed to allow remote introduction and removal of resins. Provisions for condensate flushing are provided. The Y-strainer design is identical to that described for the filter demineralizer.

(3) Tanks - The tanks containing radioactive resins and fluids employed in the plant have sloped bottoms and bottom outlet connections wherever possible. For tanks containing slurries, provisions are included for recirculating the slurries prior to transfer in order to agitate settled material into suspension. Tank overflows piped directly to equipment or floor drain sumps are included to minimize contamination problems, and curbing is provided in the tank area to limit the extent of contamination should an accidental spill occur. Tanks are provided with condensate for flushing operations, and for intensely radioactive sources, they also contain water sprays to facilitate the flushing operation.

(4) Evaporators - Evaporators are designed to provide complete discharge of fluids thus eliminating stagnant pools of fluid where plateout could occur. Provisions are made for both chemical decontamination and condensate flushing of the units. For vapor bodies containing de-entrainers special spray nozzles are included to facilitate the removal of entrained material. The de-entrainers are also designed to be removed with special tools that do not require entry into the evaporator. Tube bundles are constructed of corrosion resistant stainless steel and are removable from the evaporator for repairs or replacement through equipment hatches located above the evaporator shielded cubicle. The pumps and evaporators are

12.3.1.1 Equipment Design for Maintaining Exposure ALARA (Continued)

separately shielded to reduce the exposure of personnel maintaining the pumps. Shielded valve galleries and remotely operated valves are provided to eliminate the need of entering the evaporator cubicle during operation.

(5) Waste Filters - Filters for removing sludge contained in radwaste liquids are designed to remotely apply filter aid material and remove radioactive sludge and filter aid material from a traveling belt system by mechanical and hydraulic means. Provisions are included for flushing the belt and associated components with condensate. The waste filter body is provided with a sloped bottom to facilitate draining the unit. The filters, which are in parallel operation, are in separate rooms.

(6) Pumps - Pumps located in radiation areas are designed to minimize the time required for maintenance. Quick change cartridge-type seals on reactor recirculation pumps, and pumps with back pullout features that permit removal of the pump impeller or mechanical seals without disassembly of attached piping are employed to minimize exposure time during pump maintenance. The configuration of piping about pumps is designed to provide sufficient space for efficient pump maintenance. Provisions are made for flushing and in certain cases chemically cleaning pumps prior to maintenance. Pump casing drains provide a means for draining pumps to the sumps prior to disassembly, thus reducing the exposure of personnel and decreasing the potential for contamination. The motors on certain pumps located in high radiation areas, such as the reactor recirculation pumps, are designed to be removed from their installed location to allow maintenance in lower radiation areas. Where two or more pumps conveying

12.3.1.1 Equipment Design for Maintaining Exposure ALARA (Continued)

highly radioactive fluids are required for operational reasons to be located adjacent to each other, shielding is provided between the pumps to maintain exposure levels ALARA. An example of this situation is the RWCS circulation pumps. Pumps adjacent to other highly radioactive equipment are also shielded to reduce the maintenance exposure, for example, in the radwaste system.

Whenever possible, operation of the pump and associated valving for radioactive systems is accomplished remotely. Pump control instrumentation is located outside high radiation areas, and motor or air operated valves and valve extension stems are employed to allow operation from outside these areas.

(7) Instrumentation - Instruments are located in low radiation areas such as shielded valve galleries, corridors, or control rooms whenever possible. Shielded valve galleries provided for this purpose include those for the RWCS, FPCC, and Radwaste (cleanup phase separator, spent resin tank, and waste evaporator) systems. Instruments required to be located in high radiation areas due to operational requirements are designed such that removal of these instruments to low radiation areas for maintenance is possible. Sensing lines are routed from taps on the primary system in order to avoid placing the transmitters or readout devices in high radiation areas. For example, reactor water level as well as recirculation system pressure sensing instruments are located outisde the drywell.

Liquid service equipment for systems containing radioactive fluids are provided with vent and backflush

12.3.1.1 Equipment Design for Maintaining Exposure ALARA (Continued)

provisions. Instrument lines, except those for the reactor vessel, are designed with provisions for back-flushing and maintaining a clean fill in the sensing lines. The reactor vessel sensing lines may be flushed with condensate following reactor blowdown.

(8) Heat Exchangers - Heat exchangers are constructed of stainless steel or Cu/Ni tubes to minimize the possibility of failure and reduce maintenance requirements. The heat exchanger design allows for the complete drainage of fluids from the exchanger, avoiding pooling effects that could lead to radioactive crud deposition. Connections are available for condensate or demineralized water flushing of the heat exchangers. For highly radioactive systems, connections are also provided for introducing chemical cleaning solutions for decontaminating the heat exchangers. A RWCU heat exchanger located in the containment can be removed from its shielded cubicle to the lower radiation field of the refueling floor, thus eliminating the exposure from adjacent heat exchanger units also located in the cubicle. Instrumentation and valves are remotely operable to the maximum extent possible in the shielded heat exchanger cubicles to reduce the need for entering these high radiation areas.

(9) Valves - Valve packing and gasket material are selected on a conservative basis, accounting for environmental conditions such as temperature, pressure, and radiation tolerance requirements to provide a long operating life. Valves have back seats to minimize the leakage through the packing. Straight-through valve configurations were selected where practical, over those which exhibit flow

12.3.1.1 Equipment Design for Maintaining Exposure ALARA (Continued)

discontinuities or internal crevices to minimize crud trapping. Teflon gaskets are not used.

Wherever possible, valves in systems containing radioactive fluids are separated from those for "clean" services to reduce the radiation exposure from adjacent valves and piping during maintenance.

Air- or mechanically-operated valves are employed in high radiation areas, whenever practical, to minimize the need for entering these areas. For certain situations, manually operated valves are required, and, in such cases, extension valve stems are provided which are operated from a shielded area. Flushing and drain provisions are employed in radioactive systems to reduce exposure to personnel during maintenance.

For areas in which especially high radiation levels are encountered (e.g., the RWCS filter demineralizer cubicle), valving is reduced to the maximum extent possible with the bulk of the valves and piping located in an adjacent valve gallery where the radiation levels are lower.

(10) Piping - Piping was selected to provide a service life equivalent to the design life of the plant, with consideration given to corrosion allowances and environmental conditions. Piping for service in radioactive systems such as RWCS, FPCC and Radwaste have butt welded connections, rather than socket welds, to reduce crud traps. Distinction is made between piping conveying radioactive and nonradioactive fluids and separate routing is provided whenever possible. Piping conveying highly radioactive fluids is usually routed through shielded pipe

12.3.1.1 Equipment Design for Maintaining Exposure ALARA (Continued)

chases and shielded cubicles. However, when these options are not feasible, the radioactive piping is embedded in concrete walls and floors.

(11) Lighting - Lighting is designed to provide sufficient illumination in radiation areas to allow quick and efficient surveillance and maintenance operations. To reduce the need for immediate replacement of defective bulbs, multiple lighting fixtures are provided in shielded cubicles. Consideration is also given to locating lighting fixtures in easily accessible locations, thus reducing the exposure time for bulb replacement.

(12) Floor Drains - Floor drains with appropriately sloped floors are provided in shielded cubicles where the potential for spills exist. Those drain lines having a potential for containing highly radioactive fluids are routed through pipe chases, shielded cubicles, or are embedded in concrete walls and floors. Smooth epoxy-type coatings are employed to facilitate decontamination when a spill does occur.

(13) SGTS Filters - The SGTS filters are located in separate shielded cubicles and are separated by shield walls from the exhaust fans to reduce the radiation exposure of personnel during maintenance. The dampers located in the cubicles are remotely operated, thus requiring no access to the cubicle during operation. A pneumatic transfer system is employed to remove the radioactive charcoal from the filters, requiring entry into the shielded cubicle only during the connection of the hoses to the SGTS filter unit.

12.3.1.1 Equipment Design for Maintaining Exposure ALARA (Continued)

(14) Recombiners (Applicant will supply.)

(15) Condensers (Applicant will supply.)

12.3.1.2 Plant Design for Maintaining Exposures ALARA

This subsection describes features of equipment layout and plant design which are employed to maintain personnel exposures ALARA.

(1) Penetrations - Penetrations through shield walls are avoided whenever possible to reduce the number of streaming paths provided by these penetrations. Whenever penetrations are required through shield walls, however, they are located to minimize the impact on surrounding areas. Penetrations are located so that the radiation source cannot "see" through the penetration. When this is not possible, or to provide an added order of reduction, penetrations are located to exit far above floor level in open corridors or in other relatively inaccessible areas. Penetrations which are offset through a shield wall are frequently employed for electrical penetrations to reduce the streaming of radiation through these penetrations.

Where permitted, the annular region between pipe and penetration sleeves as well as electrical penetrations are filled with shielding material to reduce the streaming area presented by these penetrations. The shielding materials used in these applications include a lead-loaded silicone foam, with a density comparable to concrete, and a boron-located refractory type material for applications requiring neutron as well as gamma shielding. There are certain penetrations where these two

12.3.1.2 Plant Design for Maintaining Exposures ALARA (Continued)

approaches are not feasible or are noc sufficiently effective. In those cases, a shielded enclosure about the penetration as it exits in the shield wall, with a 90 degree bend of the process pipe as it exits the penetration, is employed.

(2) Valve Galleries - Valve galleries are provided wherever they are necessary to reduce the radiation exposure of operating personnel. Systems employing valve galleries include the RWCU system, the radwaste waste evaporators, the radwaste cleanup phase separators, and the radwaste waste demineralizers. The galleries provide a means for operating these radioactive systems without entering a high radiation area by use of valve extension stems and remote instr tion. In addition, piping for "clean" systems required to be located in these shielded areas is routed, whenever possible, with the valves for these systems located in the valve galleries to reduce radiation exposures during valve maintenance.

(3) Sample Stations - Sample stations in the plant provide for the routine surveillance of reactor water quality in the Reactor Recirculation System and RWCS, and process fluid quality in the Radwaste System. These sample stations are located in low radiation areas to reduce the exposure to operating personnel. Flushing provisions are included using demineralized water and piped drains to plant sumps are provided to minimize the possiblity of spills. Fume hoods are employed for airborne contamination control. Both working areas and fume hoods are constructed of polished stainless steel to ease decontamination if a spill does occur. Grab spouts are located above the sink to reduce the possibility of contaminating surrounding areas during the sampling process.

12.3.1.2 Plant Design for Maintaining Exposures ALARA (Continued)

The counting room and laboratory facilities are described in Section 12.5.

(4) HVAC Systems - Major HVAC equipment (blowers, coolers and the like) for the Auxiliary, Fuel, Radwaste and Reactor Buildings are located in dedicated low radiation areas to maintain exposures to personnel maintaining these equipment ALARA. HVAC ducting is routed ouside pipe chases and do not penetrate pipe chase walls, which could compromise the shielding. HVAC ducting penetrations through walls of shielded cubicles are located to minimize the impact of the streaming radiation levels in adjoining areas. HVAC ducting penetrating Radwaste Building shielded cubicles employ backdraft dampers or isolation dampers to reduce the potential for airborne contamination. Additional HVAC design considerations are addressed in Subsection 12.3.3.

(5) Piping - Piping containing radioactive fluids is routed through shielded pipe chases, shielded equipment cubicles, or embedded in concrete walls and floors, whenever possible. "Clean" services such as compressed air and demineralized water are not routed through shielded pipe chases. For situations in which radioactive piping must be routed through corridors or other low radiation areas, an analysis is conducted to ensure that this routing does not compromise the existing radiation zoning.

Radioactive services are routed separately from piping containing nonradioactive fluids, whenever possible, to minimize the exposure to personnel during maintenance. When such routing combinations are required, however, drain provisions are provided to remove the radioactive fluid contained in equipment and piping. "Clean"

12.3.1.2 Plant Design for Maintaining Exposures ALARA (Continued)

services and radioactive piping are required at times to be routed together in shielded cubicles. In such situations, provisions are made for the valves required for process operation to be controlled remotely without need for entering the cubicle.

Penetrations for piping through shield walls are designed to minimize the impact on surrounding areas. Approaches used to accomplish this objective are described in Subsection 12.3.1.2(a).

Piping configurations are designed to minimize the number of "dead legs" and low points in piping runs to avoid accumulation of radioactive crud and fluids in the line. Drains and flushing provisions are employed whenever feasible to reduce the impact of required "dead legs" and low points. Systems containing radioactive fluids are welded to the most practical extent to reduce leakage through flanged or screwed connections. For highly radioactive systems, butt welds are employed to minimize crud traps. Provisions are also made in radioactive systems for flushing with condensate or chemically cleaning the piping to reduce crud buildup.

(6) Equipment Layout - Equipment layout is designed to reduce the exposure of personnel required to inspect or maintain equipment. "Clean" pieces of equipment are located separately from those which are sources of radiation whenever possible. For systems that have components that are major sources of radiation, such as a demineralizer or backwash tank, the most of the piping and pumps are located in separate cubicles to reduce exposure from these components during maintenance. These major radiation sources are also separately shielded from each other

12.3.1.2 Plant Design for Maintaining Exposures ALARA (Continued)

to limit the exposure from adjacent equipment. This equipment is designed with provisions for remotely flushing and, in certain systems, for chemical decontamination. When in certain cases it is not feasible to separately shield individual components, such as the individual shells of the RWCS heat exchangers, the components are designed to be individually removed to areas of lower radiation for maintenance.

Sufficient space is provided in designing equipment layout for quick and efficient inspection and maintenance of equipment. This includes providing sufficient space around equipment, free of piping and adjacent equipment, for inspecting and disassembling the equipment if required. If special equipment or temporary shielding is necessary, space is allocated with this in mind.

Radiation streaming from equipment containing radioactive material through entries of the shielded cubicle are considered in locating equipment. Locations which allow the radiation source to "see" through the entry opening are avoided. When circumstances such as the size of equipment or operational requirements prohibit this, a labyrinth (single or double bounce) or a shield door is provided. For pieces of equipment which are particularly intense sources of radiation and for which access requirements are minimal, such as the radwaste waste demineralizer, shielded vaults with shield plugs are provided.

12.3.1.2 Plant Design for Maintaining Exposures ALARA (Continued)

(7) Contamination Control - Contaminated piping systems are welded to the most practical extent to minimize leaks through screwed or flanged fittings. For systems containing highly radioactive fluids, such as the RWCU and radwaste systems, drains are hard piped directly to equipment drain sumps, rather than allow contaminated fluid to flow across the floor to a floor drain. Certain valves in the main steam line are also provided with leakage drains piped to equipment drain sumps to reduce contamination of the steam tunnel. Pump casing drains are employed on radioactive systems whenever possible to remove fluids from the pump prior to disassembly. In addition, provisions for flushing with condensate, and in especially contaminated systems, for chemical cleaning the equipment prior to maintenance are provided.

The HVAC system is designed to limit the extent of airborne contamination by providing air flow patterns from areas of low contamination to more contaminated areas. Penetrations through outer walls of buildings containing radiations sources are sealed to prevent miscellaneous leaks into the environment. The equipment drain sump vents are fitted with charcoal canisters or piped directly to the radwaste HVAC system to remove airborne contaminants evolved from discharges to the sump. Wet transfer of both the steam dryer and separator also reduce the likelihood of contaminants on this equipment being released into the plant atmosphere. In areas where the reduction of airborne contaminants cannot be eliminated efficiently by HVAC systems, breathing air provisions are provided, for example, for CRD removal under the reactor pressure vessel and in the CRD maintenance room.

12.3.1.2 Plant Design for Maintaining Exposures ALARA (Continued)

Appropriately sloped floor drains are provided in shielded cubicles and other areas where the potential for a spill exists to limit the extent of contamination. Curbs are also provided to limit contamination and simplify washdown operations. A cask decontamination vault is located in the Fuel Building where the spent fuel cask and other equipment may be cleaned. The CRD maintenance room is used for disassembling control rod drives to reduce the contamination potential. Location of the contamination control areas and equipment decontamination areas in the plant is defined by the Applicant.

Consideration is given in the design of the plant for reducing the effort required for decontamination. Epoxy-type wall and floor coverings have been selected which provide smooth surfaces to ease decontamination surfaces. Expanded metal type floor gratings are minimized in favor of smooth surfaces in areas where radioactive spills could occur. Equipment and floor drain sumps are stainless-steel lined to reduce crud buildup and to provide surfaces easily decontaminated.

12.3.1.3 Radiation Zoning

Radiation zones are established in all areas of the plant as a function of both the access requirements of that area and the radiation sources in that area. Operating activities, inspection requirements of equipment, maintenance activities, and abnormal operating conditions are considered in determining the appropriate zoning for a given area. The relationship between radiation zone designations and accessibility requirements is presented in the following tabulation:

12.3.1.3 Radiation Zoning (Continued)

Zone Designation	Dose Rate (MRem/hr)	Description
A	$\leq$1.0	Uncontrolled, unlimited access
B	>1.0 but $\leq$5.0	Controlled, limited access, 20 hr/wk.
C	>5.0 but $\leq$20	Controlled, limited access, 5 hr/wk.
D	>20 but $\leq$100	Controlled, limited access, 1 hr/wk.
E	>100	Controlled Access Authorization Required

The dose rate applicable for a particular zone is based on operating experience and represents design dose rates in a particular zone, and should not be interpreted as the expected dose rates which would apply in all portions of that zone, or for all types of work within that zone, or at all periods of entry into the zone. Large BWR plants have been in operation for over a decade and operating experience with similar design basis numbers shows that only a small fraction of the 10CFR20 maximum permissible dose is received in such zones from radiation sources controlled by equipment layout or the structural shielding provided. Therefore, on a practical basis, a radiation zoning approach as described above accomplishes the as low as reasonably achievable objectives for doses as required by 10CFR20.2(c). The radiation zone maps for this plant with zone designations as described in the preceding tabulation are contained in Figures 12.3-1 through 12.3-19.

Access to areas in the plant is controlled and regulated by the zoning of a given area. Areas with dose rates such that an individual would receive a dose in excess of 100 mRem in a period of one hour are locked and posted with "High Radiation Area" signs. Entry to these areas is on a controlled basis. Areas in which an individual would receive a dose in excess of 5 mRem up to 100 mRem with a period of one hour are posted with signs indicating that

12.3.1.3 Radiation Zoning (Continued)

this is a radiation area and include, in certain cases, barriers such as ropes or doors. The manner in which entry into high radiation areas is regulated and the control of time spent in a radiation area is addressed in Section 12.5.

12.3.1.4 Implementation of ALARA

In this subsection, the implementation of design considerations to plant radioactive systems for maintaining personnel radiation exposures as low as reasonably achievable during maintenance and operation is described for the five following systems:

(1) Reactor Water Cleanup System;

(2) Residual Heat Removal System (Shutdown Cooling Mode);

(3) Fuel Pool Cooling and Cleanup System;

(4) Main Steam; and

(5) Radwaste Treatment System (Solid, Liquid, and Gaseous).

12.3.1.4.1 Reactor Water Cleanup System

This system is designed to operate continuously to reduce reactor water radioactive contamination. Components for this system are located outside the drywell and include filter demineralizers, a backwash receiving tank, regenerative and nonregenerative heat exchangers, pumps, and associated valves.

The highest radiation level components include the filter demineralizers, heat exchangers, and backwash receiving tanks. The filter demineralizers are located in separate concrete-shielded cubicles which are accessible through shielded hatches. Valves and

12.3.1.4.1 Reactor Water Cleanup System (Continued)

piping within the cubicles are reduced to the extent that entry into the cubicles is not required during any operational phase. Most of the valves and piping are located in a shielded valve gallery adjacent to the filter demineralizer cubicles. The valves are remotely operable to the greatest practical extent to minimize entry requirements into this area. The RWCS heat exchangers are also located in a shielded cubicle with valves operated remotely from the lower radiation area of the refueling floor above by use of extension valve stems, or from instrument panels located outside the cubicle. The backwash tank is shielded separately from the resin transfer pump permitting maintenance of the pump without being exposed to the spent resins contained in the backwash tank. The pump valves are operated remotely from outside the cubicle.

The RWCU System is provided with chemical cleaning connections which can utilize the condensate system to flush piping and equipment prior to maintenance. The RWCS filter demineralizer can be remotely back-flushed to remove spent resins and filter aid material. If additional decontamination is required, chemical addition connections are provided in the piping to clean piping as well as equipment prior to maintenance. The backwash tank employs a sparger arrangement to agitate resins prior to discharge and contains a spray header to facilitate flushing the tank with condensate. The tank vent is fitted with a charcoal filter canister to reduce emissions of radioiodines into the plant atmosphere. The HVAC System is designed to limit the spread of contaminants from these shielded cubicles by maintaining a negative pressure in the cubicles relative to the surrounding areas.

Personnel access to the cubicles for maintenance of these components is on a controlled access basis whereby specific restrictions and controls are implemented to minimize personnel exposure.

12.3.1.4.1 Reactor Water Cleanup System (Continued)

Areas outside the drywell are not used exclusively for radioactive equipment or systems. However, all portions of the RWCS which contain radioactive materials are shielded, and access is controlled. Shielding is adequate to reduce radiation levels to less than 1 mR/hr in adjacent areas where normal personnel access is required. This includes areas where clean components of this system such as resin and precoat tanks, and associated pumps are located.

The system operates during all modes of power operation. System control is by remote-manual switches on a panel in the main Control Room. Therefore, this precludes radiation exposures to the control operator. Filter demineralizer panel controls for backflushing are local; however, this panel is located in a low radiation area to maintain exposure as low as reasonably achievable.

12.3.1.4.2 Residual Heat Removal System (Shutdown Cooling Mode)

In the shutdown cooling mode, the system is placed in operation to recirculate reactor coolant to remove reactor decay heat during the period of approximately 2 to 4 hours after shutdown. During power operation, the system is not in use except for flow testing to and from the suppression pool. Therefore, there is no reactor coolant flow through the system and only traces of residual radioactive contamination may exist from prior operation.

System components are located in the Auxiliary Building and include two RHR pumps and two sets of heat exchangers, which are actively used in the shutdown cooling mode. The set of heat exchangers and associated pump work independently of the other pump and heat exchangers and are located in separate concrete shielded cubicles. The cubicles are accessible through labyrinths which reduce radiation levels outside the cubicle to acceptable levels. A knockout wall constructed of vertically and horizontally

12.3.1.4.2 Residual Heat Removal System (Shutdown Cooling Mode) (Continued)

lapped concrete blocks is provided for pump removal. A concrete hatch is provided through the roof of the cubicle for heat exchanger removal. Highest radiation levels occur at the heat exchangers during the cooldown period (1/2 to 4 hr after shutdown). During all other operation and plant shutdown periods, the radiation level near these components is considerably decreased.

Process piping is routed through the steam tunnel and shielded pipe chases to avoid low radiation areas.

Access to the RHR pumps and heat exchangers for any inspection or maintenance is permitted on a controlled basis. System maintenance is performed during periods of system shutdown when no reactor coolant is being circulated through the system. Specific restrictions and controls for personnel entry into the shielded cubicles are implemented to minimize personnel exposures. Inspection of the equipment in these cubicles can be conducted from platforming about the heat exchangers to simplify inspection of this equipment and consequently reduce the exposure during inspection.

The Auxiliary Building is not used exclusively for radioactive equipment or systems. However, all components of the system, as described, are contained within shielded cubicles. This shielding is sufficient to reduce the radiation level during the shutdown mode of operation to less than 5 mR/hr in adjacent areas where clean components, materials, or equipment are located.

System control panels and instrumentation are located in the main control room. This precludes exposure to the control operator during operation of the system for plant cooldown.

12.3.1.4.3 Fuel Pool Cooling and Cleanup System

This system is designed to operate continuously to handle the spent fuel pool cooling load and to reduce pool water radioactive contamination.

The system components are located in the Fuel Building, which is not used exclusively for radioactive equipment or systems. Included are two filter demineralizer units which serve to remove radioactive contamination from the fuel pool cooling water. These units are the highest radiation level components in the system. Each unit is located in a concrete-shielded cubiclc which is accessible through a shielded hatch. Provisions are made for remotely backflushing the units when filter and resin material are spent. This removal of radioactively contaminated material reduces the component radiation level considerably and serves to minimize exposures during maintenance. All valves (inlet, outlet, recycle, vent, and drain) to the filter demineralizer units are located outside the shielded cubicles in a separate shielded cubicle together with associated piping, headers, and instrumentation. The radiation level in this cubicle is sufficiently low to permit required maintenance to be performed. Piping potentially containing resin is continuously sloped downward to the backwash tank.

The backwash tank, which receives spent resin from the filter demineralizers, also exhibits high radiation levels and is shielded in a separate cubicle. This tank is provided with spargers for agitating the spent resins prior to discharge, and a condensate spray system to facilitate flushing. The tank is provided with a high level alarm, and the overflow is piped to an equipment drain sump to reduce the potential for contamination. Ths resin discharge pump is separately shielded from the backwash tank to reduce the exposure levels during pump maintenance. The system also includes two low radiation level heat exchangers and two circulation pumps. The heat exchangers' design radiation levels are low enough to locate them in an open alcove area. The pumps are

12.3.1.4.3 Fuel Pool Cooling and Cleanup System (Continued)

located in a low radiation area adjacent to the shielded backwash tank. System piping is routed so as not to compromise zoning requirements as established in the radiation zone maps.

All of the aforementioned shielded system components are consolidated in the same section of the Fuel Building. Personnel access to shielded system components is controlled to minimize personnel exposure. Shielding for the components is designed to reduce the radiation level to less than 1 mR/hr in adjacent areas where normal access is permitted. Controlled areas where the new resin tank, filter aid tank, and pumps are located, are shielded to less than 5 mR/hr.

Operation of the system is accomplished from local control panels and instrument racks located outside the system component shielding where designed radiation levels are less than 1 mR/hr and normal personnel access is permitted.

12.3.1.4.4 Main Steam System

All radioactive materials in the main steam system, located in the main steam-feedwater pipe tunnel of the Auxiliary and Reactor Buildings, result from radioactive sources carried over from the reactor during plant operation including high-energy short-lived Nitrogen-16. During plant shutdown, residual radioactivity from prior plant operation is the radiation source.

Access to the main steam pipe tunnel in the Reactor and Auxiliary Buildings is controlled. During reactor shutdown, entry into the Auxiliary Building steam tunnel may be gained through concrete equipment hatches located at the top of the tunnel and through the blowout panels from RHR A and B rooms. Entry into the Reactor Building steam tunnel is through a controlled personnel access door shielded by a concrete labyrinth to attenuate radiation

12.3.1.4.4 Main Steam System (Continued)

streaming from the steam lines to adjoining areas. Entry into the steam tunnel within the shield building annulus is through a manway from the Auxiliary Building steam tunnel. During reactor operation, the steam tunnel is not accessible except in the hot standby condition under regulated access.

Leakage from selected valves on to surrounding areas is minimized by providing valve drains piped to equipment drain sumps. Floor drains are provided to minimize the spread of contamination should a leakage occur.

Penetrations through the steam tunnel walls are minimized to reduce the streaming paths made available by these penetrations. The blowout panels for the steam tunnel are located in the relatively inaccessible upper section of the RHR heat exchanger shielded cubicles which are controlled access areas. Penetrations through the steam tunnel walls when they are required are located so as to exit in controlled access areas or in areas that are not aligned with the steam lines. A lead-loaded silicone foam is employed whenever possible for these penetrations to reduce the available streaming area presented.

12.3.1.4.5 Radwaste Treatment Systems

12.3.1.4.5.1 Solid and Liquid Radwaste Treatment Systems

The solid and liquid radwaste system components are located in the Radwaste Building which is exclusively utilized for radioactive equipment and systems, and access to building areas is on a controlled basis.

The highest raidation level components are those which serve to remove radioactivity from solutions and those which store the concentrated radioactive sludges. These include such components

12.3.1.4.5.1 Solid and Liquid Radwaste Treatment Systems (Continued)

as the cleanup phase separators, waste evaporators, concnetrated waste tank, spent resin tank, demineralizers, and traveling belt filters. Each of these components is located in a separate concrete-shielded cubicle. Other lower radiation level components such as high and low conductivity tanks, oil separators, and filtrate tanks are also located in concrete-shielded cubicles. However, separate cubicles are not provided for each unit. Entry to all cubicles is made through shielded hatches or labyrinth shielded doors with access on a controlled basis.

Pumps and valves for these systems are located outside the shielded cubicles in separately shielded areas or corridors whenever possible, where radiation levels are sufficiently low to permit maintenance. When this is not feasible, remote means such as air- or motor-operated valves and extension valve stems are employed to allow operation without entering the equipment cubicle.

Control panels and instrumentation for the solid and liquid radwaste processing equipment are located in the radwaste control room within the Radwaste Building. This control room is shielded from processing equipment and the design radiation level is less than 1 mR/hr to permit occupancy by the control operator.

Solid waste drumming operations (i.e., drum filling, decontamination, storage, etc.) are performed remotely at local control panels placed in a shielded operating area where the design radiation level is less than 1 mR/hr. Lead-glass shield windows as well as TV equipment provide a direct view of the storage barrel filling area and cask transfer area permitting a better perspective of operations being conducted. The cask filling area is separately shielded and includes a separate sump arrangement to contain any spills that occur during the filling and decontamination operations. Filled solid waste drums are stored in a dedicated shielded

12.3.1.4.5.1 Solid and Liquid Radwaste Treatment Systems (Continued)

storage area with high and low radiation level drums segregated. The transfer of filled drums into the storage area and the loading of the filled solid waste storage drums into shielded shipping casks are also carried out remotely, using shield windows and TV.

The radwaste HVAC system is designed with an air flow pattern from areas of low contamination to areas of higher contamination as indicated in Subsection 12.3.3. The discharges from the Radwaste Building are monitored to limit environmental releases to 10CFR20 values.

The sampling stations are located in areas shielded from high radiation level components where design radiation levels are less than 1 mR/hr. Other nonradioactive waste processing support components, such as the precoat and filter aid tanks and pumps, and chemical addition tanks are located in similarly shielded areas.

Solid and liquid radwaste processing is not a continuous process operation but is scheduled and performed on a batch basis. Therefore, required personnel access controls can be preplanned. This preplanning, in addition to the shielding afforded operating and maintenance personnel, permits exposures to be maintained ALARA.

12.3.1.4.5.2 Gaseous Waste

(Applicant to supply.)

12.3.1.4.6 Standby Gas Treatment System

The Standby Gas Treatment System treats the containment, shield building annulus, ECCS equipment rooms, and Fuel Building ventilation air in the event of release of radioactivity to these atmospheres.

12.3.1.4.6 Standby Gas Treatment System (Continued)

The system contains radioactivity only in the event of an emergency of abnormal condition. However, it is a potential source of concentrated radioactivity following such an occurrence.

The system starts automatically on a high building ventilation radiation or LOCA signal and can also be manually started from the main control room. Operation of the system does not require entering the shielded filter cubicle.

The system consists of two parallel treatment trains, each train being located in its own shielded room. In addition, the fans for each train are shielded from the filter, which is the dominant source of radiation for the system. Each train includes high efficiency particulate filters and charcoal filters for removal of radioactivity prior to exhausting air to the outside environment.

All components are located in the Fuel Building, and personnel access to the shielded rooms for inspection or maintenance is on a controlled basis. A remote charcoal filter removal capability is provided to minimize exposures, which requires entry into the filter area only during the initial connection of the unit to the charcoal removal system. Sufficient space is provided around the filter unit to allow easy removal and bagging of the high efficiency filters.

In the event of a fire in the charcoal filter bed, a water spray system is employed to suppress the fire. To limit the extent of contamination in the event that this system is activated, a drain for the SGTS unit is provided which is piped directly to a floor drain sump.

The SGTS filter shielding is adequate to reduce the radiation level in adjacent areas of the Fuel Building to less than 1 mR/hr following an isolation scram event with containment purge.

12.3.2 Shielding

12.3.2.1 Design Objectives

The primary objective of the radiation shielding is to protect operating personnel and the general public from radiation emanating from the reactor, the power conversion systems, the radwaste process systems, and the auxiliary systems, while maintaining appropriate access for operation and maintenance. The radiation shielding is also designed to keep radiation doses to equipment below levels at which disabling radiation damage occurs. Specifically, the shielding requirements in the plant are designed to perform the following functions:

(1) limit the exposure of the general public, plant personnel, contractors and visitors to levels that are ALARA and within 10CFR20 requirements;

(2) limit the radiation exposure of personnel, in the unlikely event of an accident, to levels that are ALARA and which conform to the limits specified in 10CFR50, Appendix A, Criterion 19 to ensure that the plant is maintained in a safe condition during an accident; and

(3) limit the radiation exposure of critical components within specified radiation tolerances, to assure that component performance and design life are not impaired.

12.3.2.2 Design Description

12.3.2.2.1 General Design Guides

In order to meet the design objectives, the following design guides are used in the shielding design of the plant.

12.3.2.2.1 General Design Guides (Continued)

(1) All systems containing radioactivity are identified and shielded based on access and exposure level requirements of surrounding areas. The radiation zone maps described in Subsection 12.3.1.3 indicate design radiation levels for which shielding for equipment contributing to the dose rate in the area is designed.

(2) The source terms used in the shielding calculations are analyzed with a conservative approach. Transient conditions as well as shutdown and normal operating conditions are considered to ensure that a conservative source is used in the analysis.

Shielding design is based on fission product quantities in the coolant corresponding to the design basis off-gas release, in addition to activation products. This is considered an anticipated operational occurrence and hence, represents conservatism in design. For components where N-16 is the major radiation source, a concentration based upon operating plant data is used.

(3) Effort is made to locate processing equipment in a manner which minimizes the shielding requirements. Shielded labyrinths are used to eliminate radiation streaming through access ways from sources located in cubicles.

(4) Penetrations through shield walls are located so as to minimize the impact on surrounding areas due to radiation streaming through the penetrations. The approaches used to locate and shield penetrations, when required, are discussed in Subsection 12.3.1.2(a).

12.3.2.2.1 General Design Guides (Continued)

(5) Wherever possible, radioactive piping is run in a manner which will minimize radiation exposure to plant personnel. This involves:

(a) minimizing radioactive pipe routing in corridors;

(b) avoiding the routing of high-activity pipes through low-radiation zones;

(c) use of shielded pipe trenches and pipe chases, where routing of high-activity pipes in low-level areas cannot be avoided, or if these are not available and the pipe routing permits, embedding the pipes in concrete walls and floors; and

(d) separating radioactive and nonradioactive pipes for maintenance purposes.

(6) To maintain acceptable levels at valve stations, motor-operated or diaphragm valves are used where practical. For valve maintenance, provision is made for draining and flushing associated equipment so that radiation exposure is minimized. If manual valves are used, provision is made for shielding the operator from the valve by use of shield walls and valve stem extensions, where practicable.

(7) Shielding is provided to permit access and occupancy of the control room to ensure that plant personnel exposure following an accident does not exceed the guideline values set forth in 10CFR50, Appendix A, Criterion 19. The analyses of the doses to Control Room personnel for the design basis accidents are included in Chapter 15.

12.3.2.2.1 General Design Guides (Continued)

(8) The dose at the site boundary as a result of direct and scattered radiation from the turbine and associated equipment is considered.

(9) In selected situations, provisions are made for shielding major radiation sources during inservice inspection to reduce exposure to inspection personnel. For example, steel platforms are provided for ISI of the RPV nozzle welds and associated piping.

(10) The primary material used for shielding is concrete at a density of 2.3 gr/cm^3. Concrete used for shielding purposes is designed in accordance with Regulatory Guide 1.69. Where special circumstances dictate, steel, lead, water, lead-loaded silicone foam or a boron-laced refractory material is used.

(11) There is no field-routed piping in the Reactor Island design. Large and small piping, as well as instrument tubing, are routed by designers as indicated in the preceding paragraph (5).

12.3.2.2.2 Method of Shielding Design

The radiation shield wall thicknesses are determined using basic shielding data and proven shielding codes. A list of the computer programs used is contained in Table 12.3-1. The shielding design methods used also rely on basic radiation transport equations contained in Reference 1. The sources for basic shielding data, such as cross sections, buildup factors and radioisotope decay information, are listed in References 2 through 10.

The shielding design is based on the plant operating at maximum design power with the release of fission products from defective

12.3.2.2.2 Method of Shielding Design (Continued)

fuel resulting in a source of 100,000 μCi/sec of noble gas after a 30-min decay period, and the corresponding activation and corrosion product concentrations in the reactor water listed in Section 11.1. Radiation sources in various pieces of plant equipment are cited in Section 12.2. Shutdown conditions, such as fuel transfer operations, as well as accident conditions, such as a LOCA or an FHA, have also been considered in designing shielding for the plant.

The mathematical models used to represent a radiation source and associated equipment and shielding are established to ensure conservative calculational results. Depending on the versatility of the applicable computer program, various degrees of complexity of the actual physical situation are incorporated. In general, cylindrically shaped equipment such as tanks, heat exchangers and demineralizers are mathematically modeled as truncated cylinders. Equipment internals are sectionally homogenized to incorporate density variations where applicable. For example, the tube bundle section of a heat exchanger exhibits a higher density than the tube bundle clearance circle due to the tube density, and this variation is accounted for in the model. Complex piping runs are conservatively modeled as a series of point sources spaced along the piping run. Equipment containing sources in a parallel piped configuration, such as fuel assemblies, fuel racks and the SGTS charcoal filters, are modeled as parallel piped with a suitable homogenization of materials contained in the equipment. The shielding for these sources is also modeled on a conservative basis, with discontinuities in the shielding, such as penetrations, doors, and partial walls accounted for. The dimension of the floor decking is not considered in the shielding calculations are part of the effective shield thickness provided by the floor slab.

Pure gamma dose rate calculations, both scattered and direct, are conducted using point kernel codes (QADMOD or GGG). The source terms are divided into groups as a function of photon energy, and

12.3.2.2.2 Method of Shielding Design (Continued)

each group is treated independently of the others. Credit is taken for attenuation through all phases of materials, and buildup is accounted for using a third order polynomial buildup factor equation. The more conservative material buildup coefficients are selected for laminated shield configurations to ensure conservative results.

For combined gamma and neutron shielding situations, either discrete ordinates (ANISN) or Monte Carlo techniques (COHORT) are applied depending on the geometric complexity of the situation. Specifically, the bulk shielding for the reactor is accomplished by discrete-ordinate techniques, and the more geometrically complex problem of radiation streaming through the RPV shield wall penetrations is analyzed by Monte Carlo techniques.

The shielding thicknesses are selected to reduce the aggregate dose rate from significant radiation sources in surrounding areas to values below the upper limit of the radiation zone specified in the zone maps in Subsection 12.3.1.3. By maintaining dose rates in these areas at less than the upper limit values specified in the zone maps, sufficient access to the plant areas is allowed for maintenance and operational requirements.

Where shielded entries to high-radiation areas such as labyrinths are required, a gamma ray scattering code (GGG) is used to confirm the adequacy of the labyrinth design. The labyrinths are designed to reduce the scattered as well as the direct contribution to the aggregate dose rate outside the entry, such that the radiation zone designated for the area is not violated.

12.3.2.3 Plant Shielding Description

Scaled drawings indicating the plant layout of equipment containing radioactive process materials as well as shield wall dimensions

12.3.2.3 Plant Shielding Description (Continued)

are provided in the radiation zone maps described in Subsection 12.3.1.3. The general description of plant shielding in the various buildings is described below:

(1) Drywell - The major shielding structures located in the drywell area consist of the reactor shield wall and the drywell wall. The reactor shield wall in general consists of 21 in. of concrete sandwiched between two 1-1/2-in. thick steel plates. The primary function served by the reactor shield wall is the reduction of radiation levels in the drywell, due to the reactor, to values that do not unduly limit the service life of equipment located in the drywell. In addition, the reactor shield wall reduces gamma heating effects on the drywell wall, as well as providing for lower radiation levels in the drywell during reactor shutdown. Penetrations through the reactor shield wall are shielded to the extent that radiation streaming through the penetrations does not exceed the total neutron and gamma dose rates at core midplane just outside the reactor shield wall. The drywell is an E radiation zone during full-power reactor operation and is not accessible during this period.

The drywell wall is a 5-ft thick reinforced concrete cylinder, which is topped by a 4-ft thick reinforced concrete cap. The drywell wall attenuates radiation from the reactor and other radiation sources in the drywell, such as the recirculation system and main steam piping, to allow occupancy of the Reactor Building during full-power reactor operation.

12.3.2.3 Plant Shielding Description (Continued)

(2) Reactor Building - The Reactor Building is defined in this context as the area located between the drywell wall and the Shield Building. In general, the shielding for the Reactor Building is designed to maintain open areas at dose rates less than 1 mR/hr.

Penetrations of the drywell wall are shielded to reduce radiation streaming through the penetrations. Localized dose rates outside these penetrations are limited to less than 5 mR/hr. The penetrations through interior shield walls of the Reactor Building are shielded using a lead-loaded silicone sleeve to reduce the radiation streaming area made available by the penetrations. Penetrations are also located so as to minimize the impact of radiation streaming into surrounding areas.

The majority of the components of the Reactor Water Cleanup System (RWCS), except the pump, are located in the Reactor Building. Both the RWCU System regenerative and nonregenerative heat exchangers are located in a shielded cubicle separated from the other components of the system. A shielded labyrinth entry provides access to the cubicle, which need not be entered for system operation.

Process piping between the heat exchangers and the filter demineralizers is routed through shielded areas or embedded in concrete to reduce the dose rate in surrounding areas. The two RWCS filter demineralizers are located in separate shielded cubicles, which allows maintenance of one unit while operating the other. The dose rate in the adjoining filter demineralizer cubicle from the operating unit is less than 6 mR/hr. Entry into the filter

12.3.2.3 Plant Shielding Description (Continued)

demineralizer cubicle, which is infrequently required, is via a stepped shield plug at the top of the cubicle. The bulk of the piping and valves for the filter demineralizers is located in an adjacent shielded valve gallery. Backflushing and resin application of the filter demineralizers are controlled from an open corrodor, where dose rates are less than 1 mR/hr. The RWCS backwash receiving tank is also separately shielded from the other components of the RWCS, including the tank discharge pump, which allows maintenance of the pump without direct exposure to the spent resins contained in the backwash tank. A shielded labyrinth entry to the backwash tank cubicle reduces the dose rates at the entry to less than 1 mR/hr.

The fuel storage pool is shielded to maintain accessible areas around the pool at less than 1 mR/hr. Transfer of fuel from the Reactor Building to the Fuel Building is through an inclined fuel-transfer tube. A reinforced concrete structure surrounding the tube reduces radiation levels to less than 5 mR/hr during fuel transfer. Access to the fuel transfer tube is through a hatch shielded by a stepped, composite concrete and lead shield plug.

The main steamline, RWCS piping and RHR piping are routed through the shielded steam tunnel. The steam tunnel walls are designed to reduce the dose rates to less than 1 mR/hr in areas along the sides of the steam tunnel and less than 5 mR/hr both above and below the steam tunnel.

Shielding of the Traversing Incore Probe (TIP) modules is provided by wing walls and a stepped, shielded floor at the (+)11 ft 0 in. elevation above. During normal

12.3.2.3 Plant Shielding Description (Continued)

operation, radiation levels near the modules are less than 5 mR/hr due to radiation streaming through the TIP drywell wall penetrations. In the unlikely event of an inadvertent and complete TIP retraction into the TIP module, a radiation monitor attached to the interior of the wing wall alarms to initiate egress from the TIP area. The shield walls previously mentioned limit the egress exposure to less than 100 mR.

The Shield Building, which encloses the steel containment, is in general a 3-ft thick reinforced concrete structure. As a radiation shield, the Shield Building is designed to reduce the radiation levels on the plant site and at the site boundary to 10CFR100 limits following a LOCA, during which the containment and shield annulus contain a large inventory of radioisotopes released by the core. Radiation levels in open areas just outside the Shield Building during normal reactor operation are less than 1 mR/hr.

(3) Auxiliary Building - The ECCS systems are located in separately shielded cubicles in the Auxiliary Building. Shield labyrinths are provided to gain entry into the cubicles, and equipment removal doors at the (-)32 ft 0 in. elevation are shielded with removable horizontally and vertically lapped concrete block. A reinforced concrete monolith structure caps the roof hatch used for RHR heat exchanger removal. Piping to and from the ECCS System is routed through shielded pipe chases. Access into the cubicles is not required to operate the systems. In general, the radiation levels in the open corridors of the Auxiliary Building are less than 1 mR/hr, except

12.3.2.3 Plant Shielding Description (Continued)

during RHR shutdown cooling mode operation, when radiation levels may temporarily range between 1 and 5 mR/hr in areas near the RHR cubicles.

The RWCS pumps are located in a shielded cubicle designed to reduce the radiation levels in the adjoining open corridor to less than 1 mR/ hr. The pumps are separated by shield walls to allow operation of one of the pumps while performing maintenance on the other. Dose rates at this pump due to the operating pump and piping are less than 5 mR/hr. A shielded valve gallery is employed to permit manual operation of the valves associated with the RWCU pumps without entering the pump area. Piping for the pumps is directly routed from the steam tunnel to the RWCU pump area.

The CRD maintenance room walls are designed to reduce dose rates in the adjoining corridor to less than 1 mR/hr during all CRD maintenance operations except CRD transfer, when doese rates in the corridor temporarily range between 1 and 5 mR/hr. The concrete CRD storag vault located in the CRD Maintenance Room, which is used for storing clean and dirty CRD parts as well as assembled units, is designed to reduce dose rates in the room to less than 5 mR/hr.

The main steamlines, routed through the Auxiliary Building, are located in the shielded steam tunnel. The steam tunnel reduces the dose rates from the steam lines to less than 1 mR/hr in all adjoining areas except the roof of the steam tunnel, which is less than 5 mR/hr.

12.3.2.3 Plant Shielding Description (Continued)

(4) Fuel Building - The 5-ft thick walls of the fuel storage pool reduce the dose rates in adjacent open corridors to less than 1 mR/ hr. The remaining pools are similarly shielded. During fuel transfer operations, sufficient water remains in the pools to maintain dose rates on the operating floor at less than 1 mR/hr. The decontamination waste holding tank, which stores waste water from the fuel cask washdown operations, is shielded to less than 1 mR/hr in the adjacent open corridor.

The components of the Fuel Pool Cooling and Cleanup (FPCC) System, employed for removing contaminants and cooling the fuel pool water, are located in the Fuel Building. Separately shielded cubicles house the two FPCC filter demineralizers to allow maintenance of one filter demineralizer while operating the other. A stepped shield plug is employed to shield the access hatch because of the infrequent maintenance requirements of the filter demineralizers. The backwash receiving tank and the tank discharge pump are also separately shielded. Due to the relatively low activity levels of the fuel pool water, no special shielding is required for the FPCC circulation pumps, heat exchangers or drain tank.

The suppression pool cleanup (SPCU) demineralizer is located in the Fuel Building and is shielded to maintain dose rates during normal reactor operation in adjacent open areas at less than 1 mR/hr. The spent resin transfer piping, which is routed to the Radwaste Building, is embedded in the concrete floor for shielding. The SPCU circulation pumps are located in an open corridor at the (-)32 ft 0 in. elevation. During normal

12.3.2.3 Plant Shielding Description (Continued)

operation, dose rates in the pump area are less than 1 mR/hr. During an isolation transient, however, dose rates in the area temporarily increase to 700 mR/hr. Due to the nature of the event, egress from the area can be accomplished well before dose rates reach this level. Access to equipment in this area is not required during this occurrence.

The two redundant SGTS filter units are located in separately shielded cubicles in the Fuel Building. Shielding of the fan from the filter unit provides a lower radiation area for fan maintenance. Operation of the SGTS does not require entry into the SGTS filter area.

(5) Control Room - The dose rate in the control room is much less than 1 mR/hr during normal reactor operating conditions. The outer walls of the Control Building are designed to attenuate radiation from radioactive materials contained within the Shield Building and from possible airborne radiation surrounding the Control Building following a LOCA. The walls provide sufficient shielding to limit the direct-shine exposure of control room personnel following a LOCA to a fraction of the 5-Rem limit as is required by 10CFR50, Appendix A, Criterion 19. Shielding for the outdoor air cleanup filters is also provided to allow temporary access to the mechanical equipment area of the Control Building following a LOCA, should it be required.

(6) Radwaste Building - Shielding for the Radwaste Building is designed to limit radiation levels in the open corridors, control room and HVAC and Electrical Equipment

12.3.2.3 Plant Shielding Description (Continued)

Rooms to 1 mR/hr. Radioactive piping is routed through pipe chases and shielded cubicles in order to avoid compromising these areas. Highly radioactive components, such as the spent resin tank, the cleanup phase separators, the two sets of waste evaporators and heating elements, and the waste filters are shielded separately to reduce the exposure received during maintenance of adjacent equipment. Similarly, tank discharge pumps for these highly radioactive systems are also shielded from the components. Shield labyrinths are provided for all cubicles containing high-activity components to reduce the radiation streaming into other adjoining areas without restricting the accessibility of these cubicles.

Waste barrel filling operations are conducted in a shielded cubicle. Control of these operations is from areas where radiation levels are less than 1 mR/hr. The filled waste barrels are stored in a shielded area at the (-)6 ft 10 in. elevation adjacent to the truck loading area. The truck loading area radiation level is less than 1 mR/hr for all periods except during the transfer of a waste barrel from the filling station into the storage area.

(7) Turbine Building - (Applicant to supply.)

(8) General Plant Areas - (Applicant to supply.)

12.3.3 Ventilation

The HVAC systems for the various buildings in the plant are discussed in Section 9.4, including the design bases, system descriptions, and evaluations with regard to the heating, cooling, 12.3.3 Ventilation (Continued)

and ventilating capabilities of the systems. This section discusses the radiation control aspects of the HVAC systems.

12.3.3.1 Design Objectives

The following design objectives apply to all building ventilation systems:

(1) The systems shall be designed to make airborne radiation exposures to plant personnel and releases to the environment ALARA. To achieve this objective, the guidance provided in Regulatory Guide 8.8 shall be followed.

(2) The concentration of radionuclides in the air in areas accessible to personnel for normal plant surveillance and maintenance shall be kept below the limits of 10CFR20 during normal power operation.

12.3.3.2 Design Description

In the following sections, the design features of the various ventilation systems that achieve the radiation control design objectives are discussed. For all areas potentially having airborne radioactivity, the ventilation systems are designed such that during normal and maintenance operations, airflow between areas is always from an area of low potential contamination to an area of higher potential contamination. (Details of the air cleaning unit design are to be provided by the Applicant.)

12.3.3.2.1 Control Room Ventilation

The Control Building atmosphere is maintained at a slightly positive pressure (up to 0.5 in. wg) at all times, except if

12.3.3.2.1 Control Room Ventilation (Continued)

exhausting or isolation are required, in order to prevent infiltration of contaminants. Fresh air is taken in via a dual inlet system, which has an intake structure on the roof of the building and an alternate intake structure on the side of the Auxiliary Building. The inlets are arranged with respect to the SGTS exhaust stack such that a high probability exists that at least one of the intakes is free of contamination after a LOCA in the unit that the Control Building serves. Both inlets, however, can be submerged in contaminated air from a LOCA in an adjacent unit, but the calculated dose in the Control Room from such an eventuality is still below the limit of Criterion 19 of 10CFR50, Appendix A.

Outside air coming into the intakes is normally filtered by a particulate filter and a high-efficiency filter. If a high radiation level in the air is detected by the airborne radiation monitoring sytem, flow is automatically diverted to another filter train (an outdoor air cleanup unit) that has:

(1) a particulate filter;

(2) a HEPA filter;

(3) a charcoal filter;

(4) another HEPA filter; and

(5) an electric heater.

Two redundant, divisionally separated radiation monitors and filter trains are provided (See Subsection 9.4.1 for detailed description of the design.). Conservative calculations show that the filters keep the dose in the Control Room from a LOCA below the limits of Criterion 19 of 10CFR50, Appendix A.

The outdoor air cleanup units are located in individual, closed rooms that help prevent the spread of any radiation during

12.3.3.2.1 Control Room Ventilation (Continued)

maintenance. Adequate space is provided for maintenance activities. The particulate and HEPA filters can be bagged when being removed from the unit. Before removing the charcoal, any radioactivity is allowed to decay to minimal levels, and is then removed through a connection in the bottom of the filter by a pneumatic transfer system. Air used in the transfer system goes through a HEPA filter before being exhausted. Face masks can be worn during maintenance activities, if desired.

12.3.3.2.2 Drywell

Access into the drywell is not permitted during normal operation. The ventilation system inside merely circulates, without filtering, the air. The only airflow out of the drywell into accessible areas is minor leakage through the wall.

During maintenance, the drywell air is purged before access is allowed. In addition, purified breathing air is supplied via a piped distribution system and quick-disconnect fittings to the area under the reactor pressure vessel.

12.3.3.2.3 Containment

The containment air is continually circulated at the rate of 84,000 cfm by a forced air circulation system. The air is mixed in almost all areas, thus preventing localized activity concentration build-ups or stratification. Extra fans are provided for the dome, RWCS heat exchanger room and RWCS valve room to supply thorough mixing and activity dilution in those areas.

The containment air is continually purged to the outside air during normal operation by a 5,000 cfm airflow. Fresh air is drawn from

12.3.3.2.3 Containment (Continued)

outside environs, and exhaust air is drawn from the general containment and from the RWCS Valve and Heat Exchanger Rooms. Radiation monitors continually monitor the containment exhaust air, and if high radioactivity is detected, the containment isolation valves are closed and the supply and exhaust fans are stopped to prevent any significant radioactive release. The containment can then be purged through the Standby Gas Treatment System.

During normal operation, the containment air is maintained at a slightly negative pressure with respect to the outside atmosphere to prevent unmonitored venting or leakage.

Dedicated airflows are provided at sample stations to direct any airborne radiation away from personnel. A curtain of air from the dome area is provided at the upper and lower air locks to reduce airborne contamination to personnel preparing to go through the air lock during normal or abnormal conditions.

During refueling, a high containment purge rate (25,000 cfm) using fresh air is established to keep airborne radiation in containment minimal. Most of the additional airflow is directed over the upper pools to exhaust vents nearby to minimize the spread of evolution from the pools. The exhaust flow is monitored for radioactivity, and if high activity is detected, the supply and exhaust valves close, and the supply and exhaust fans stop. The containment ventilation system is described in detail in Subsection 9.4.5.

12.3.3.2.4 Shield Annulus Exhaust System

Air in the Shield Building annulus is exhausted and/or recirculated, as required, to maintain the pressure at (-)5 in. wg. This ensures that any leakage is into the building and not out of it.

12.3.3.2.4 Shield Annulus Exhaust System (Continued)

The maximum exhaust flow rate is 1,500 cfm. The exhaust is continually monitored for radiation. If a high radiation level is detected, the dampers to the plant vent automatically close, and the flow is directed to the SGTS. The annulus air pressure remains at (-)5 in. wg.

12.3.3.2.5 Auxiliary Building

The Auxiliary Building HVAC System is divided into three zones, which are separated by leaktight, physical barriers. The zones include:

(1) ECCS, RCIC and RWCS equipment rooms (These rooms contain equipment that is a potential source of radioactivity. If a leak occurs, the other accessible areas of the building are not contaminated.);

(2) electrical equipment area, cable tunnels, cable spreading rooms, CRD maintenance room and remote control panel area, and the heating and ventilating equipment rooms; and

(3) steam tunnel (This room also contains a potential source of radioactive material leakage.)

Air pressure in the rooms in Zone 1 is maintained slightly below outside atmospheric pressure by a fresh air supply and exhaust system. The supply air is filtered by a particulate filter and a high-efficiency filter. The air is distributed to the corridor and then flows into the various rooms by infiltration. The exhaust stream is monitored for radioactivity, and if a high activity level is detected, the exhaust stream is diverted to the SGTS.

12.3.3.2.5 Auxiliary Building (Continued)

Normally, exhaust air is drawn from the corridor and various rooms. The exhaust duct in the corridor has two isolation valves in series and a radiation monitor. The valves isolate the corridor area from the rest of the system if high airborne radioactivity is detected by the radiation monitor.

The area above the (-)6 ft 10 in. level of the Auxiliary Building, except for the CRD maintenance area, is maintained at a positive pressure during normal operation. The CRD maintenance area is maintained at a negative pressure and exhausted to atmosphere during normal operation.

In the CRD maintenance room, a hood exhaust system draws conditioned air across the face of the cleaning tanks. The air is drawn through ductwork, through particulate filters and high-efficiency filters and discharged to the atmosphere by the room exhaust fan. Also, a breathing air system is provided for personnel working in the room and wearing respiratory masks, helmets or suits.

For a description of the Auxiliary Building HVAC System, see Subsection 9.4.3.

12.3.3.2.6 Fuel Building

The areas within the Fuel Building are maintained at a negative static pressure, except when the railroad doors are open. One air-conditioning system is provided for the area above the operating floor, and a separate air conditioning system is provided for the area below the operating floor. Exhaust air is drawn from areas that might be contaminated and from airflow across

12.3.3.2.6 Fuel Building (Continued)

the pool. A radiation monitor is located on the exhaust flow line. If a high radiation level is detected, intake and exhaust flows are terminated, and the SGTS is started.

The filter units for the SGTS are located in the Fuel Building. The design of the SGTS meets the requirements of 10CFR50, Appendix A and the guidelines of Regulatory Guide 1.52.

Two fully redundant units are provided. The units are located in individual, closed rooms that prevent the spread of radioactivity during maintenance. See Subsection 6.5.1 for a detailed description of the SGTS.

A radiation monitor installed in the exhaust ductwork alarms on indication of high radiation. This signal isolates the building and diverts the exhaust to the SGTS, as in the Auxiliary Building ECCS, RCIC and RWCS equipment rooms.

Adequate space has been provided in the filter unit rooms for easy maintenance. Control panels for the units are located outside the rooms in a low-radiation area. The particulate filters and HEPA filters can be bagged when being removed from the unit. Before removing the charcoal, any radioactivity is allowed to decay to minimal levels, and is then removed through a connection in the bottom of the filter by a pneumatic transfer system. Air used in the transfer system goes through a HEPA filter before being exhausted.

12.3.3.2.7 Radwaste Building

The Radwaste Building is divided into two zones for ventilation purposes. The control room and unit substation are one zone, and the remainder of the building is the other zone. The air pressure

12.3.3.2.7 Radwaste Building (Continued)

in the first zone is maintained slightly above atmospheric, while the air pressure in the second zone is maintained slightly below atmospheric. Air in the second zone is drawn from outside the building and distributed to various work areas within the building. Air flows from the work areas to the tank and pump rooms and is then discharged via the radwaste vent. An alarm sounds in the control room if the exhaust fan fails. The exhaust flow is monitored for radioactivity, and if a high activity level is detected, the potentially radioactive cells are automatically isolated, but airflow through the work areas continues.

If the vent stack high-radiation alarm continues to annunciate after the tank and pump rooms are isolated, the work area branch exhaust ducts are selectively manually isolated to locate the involved building area. Should this technique fail, because the airborne radiation has spread throughout the building, the control room air conditioning continues, but the air conditioning for the balance of the building is shut down.

The silo, waste filter room, oil separator room, and the mixing and filling station exhaust air is drawn through a filter unit consisting of a particulate filter, a HEPA filter, a charcoal filter, and then another HEPA filter, before being discharged to the atmosphere. The air is monitored for radioactivity, and if a high level is detected, supply and exhaust is terminated.

Maintenance provisions for the filters are similar to those for the SGTS and Control Building HVAC System.

See Subsection 9.4.6 for a detailed discussion of the Radwaste Building HVAC System.

12.3.3.2.8 Diesel-Generator Buildings

The Diesel-Generator Buildings do not contain sources of radioactivity, nor is access required during an event involving activity release from another building. Therefore, no radiation protection measures have been taken in these buildings.

12.3.3.2.9 Turbine Building Environmental System

(Applicant to supply.)

12.3.3.2.10 Central Service Facility

(Applicant to supply.)

12.3.4 Area Radiation and Airborne Radioactivity Monitors

12.3.4.1 Control Room Ventilation Radiation Monitoring System

This system monitors the radiation level exterior to the inlet ducting of the control room ventilation system. The system consists of four channels identical to the channels in the containment and drywell ventilation radiation monitoring system. The recorder is powered from 125 VDC bus B.

Two-out-of-two upscale (high/high)/inoperative trips in channels A and C initiate shutdown and inboard isolation valve closure of the control room ventilation system and initiate startup of the emergency air filtration fan (unit A). The same condition for channels B and D initiates shutdown and outboard isolation valve closure of the control room ventilation system and initiates startup of the emergency air filtration fan (unit B).

(Additional information is to be supplied by the Applicant.)

12.3.5 References

1. N. M. Schaeffer, "Reactor Shielding for Nuclear Engineers", TID-25951, U. S. Atomic Energy Commission (1973).

2. J. H. Hubbell, "Photon Cross Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 KeV to 100 GeV", NSRDS-NBS29, U. S. Department of Commerce, August 1969.

3. "Radiological Health Handbook", U.S. Department of Health, Education, and Welfare, Revised edition, January 1970.

4. "Reactor Handbook", Volume III, Part B, E. P. Blizzard, U. S. Atomic Energy Commission (1962).

5. Lederer, Hollander and Perlman, "Table of Isotopes", Sixth Edition, (1968).

6. M. A. Capo, "Polynomial Approximation of Gamma Ray Buildup Factors for a Point Isotropic Source", APEX-510, November 1958.

7. "Reactor Physics Constants", Second Edition, ANL-5800, U.S. Atomic Energy Commission, July 1963.

8. ENDF/B-III and ENDF/B-IV Cross Section Libraries, Brookhaven National Laboratory.

9. PDS-31 Cross Section Library, Oak Ridge National Laboratory.

10. DLC-7, ENDF/B Photo Interaction Library.

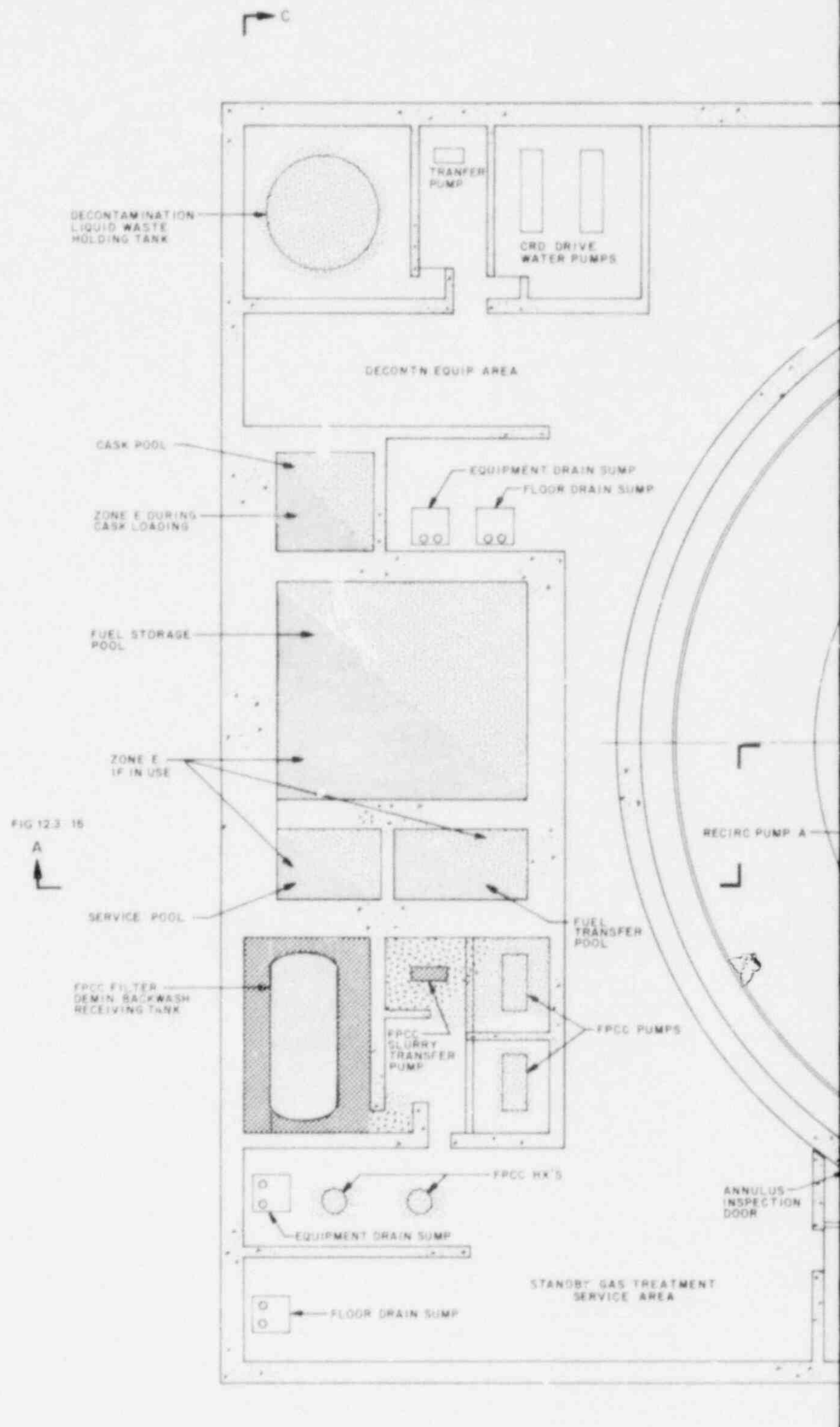
Table 12.3-1

COMPUTER CODES USED IN SHIELDING DESIGN CALCULATIONS

Computer Code	Description
RIDST*	Program for calculating radioisotope decay source terms (cumulated gamma yields in selected energy groups) for various decay times based on the input of initial isotopic activities. This program is a condensed version of ISOSHLD-III.
QADMOD*	A multigroup, multiregion, point kernel, gamma ray code for calculating the flux and dose rate at discrete locations within a complex source-geometry configuration.
GGG*	A multigroup, multiregion, point kernel code for calculating the contribution due to gamma ray scattering in a heterogeneous three-dimensional space.
ANISN*	Multigroup, multiregion code for calculating the neutron and gamma flux for a one-dimensional, cartesian, cylindrical or spherical geometry arrangement.
COHORT*	A multigroup, three-dimensional, Monte Carlo neutron and gamma ray transport code.

Additional codes to be added by Applicant.

*These computer programs meet the quality assurance standards for computer program certification described in Chapter 17 of this SAR.


C
DECONTAMINATION
LIQUID WASTE
HOLDING TANK
TRANFER PUMP
CRD DRIVE
WATER PUMPS
DECONTN EQUIP AREA
CASK POOL
EQUIPMENT DRAIN SUMP
FLOOR DRAIN SUMP
ZONE E DURING
CASK LOADING
FUEL STORAGE
POOL
ZONE E
IF IN USE
FIG 12.3-15
A
RECIRC PUMP A
SERVICE POOL
FUEL
TRANSFER
POOL
FPCC FILTER
DEMIN. BACKWASH
RECEIVING TANK
FPCC
SLURRY
TRANSFER
PUMP
FPCC PUMPS
FPCC HX'S
ANNULUS
INSPECTION
DOOR
EQUIPMENT DRAIN SUMP
STANDBY GAS TREATMENT
SERVICE AREA
FLOOR DRAIN SUMP
C FIG 12.3-17

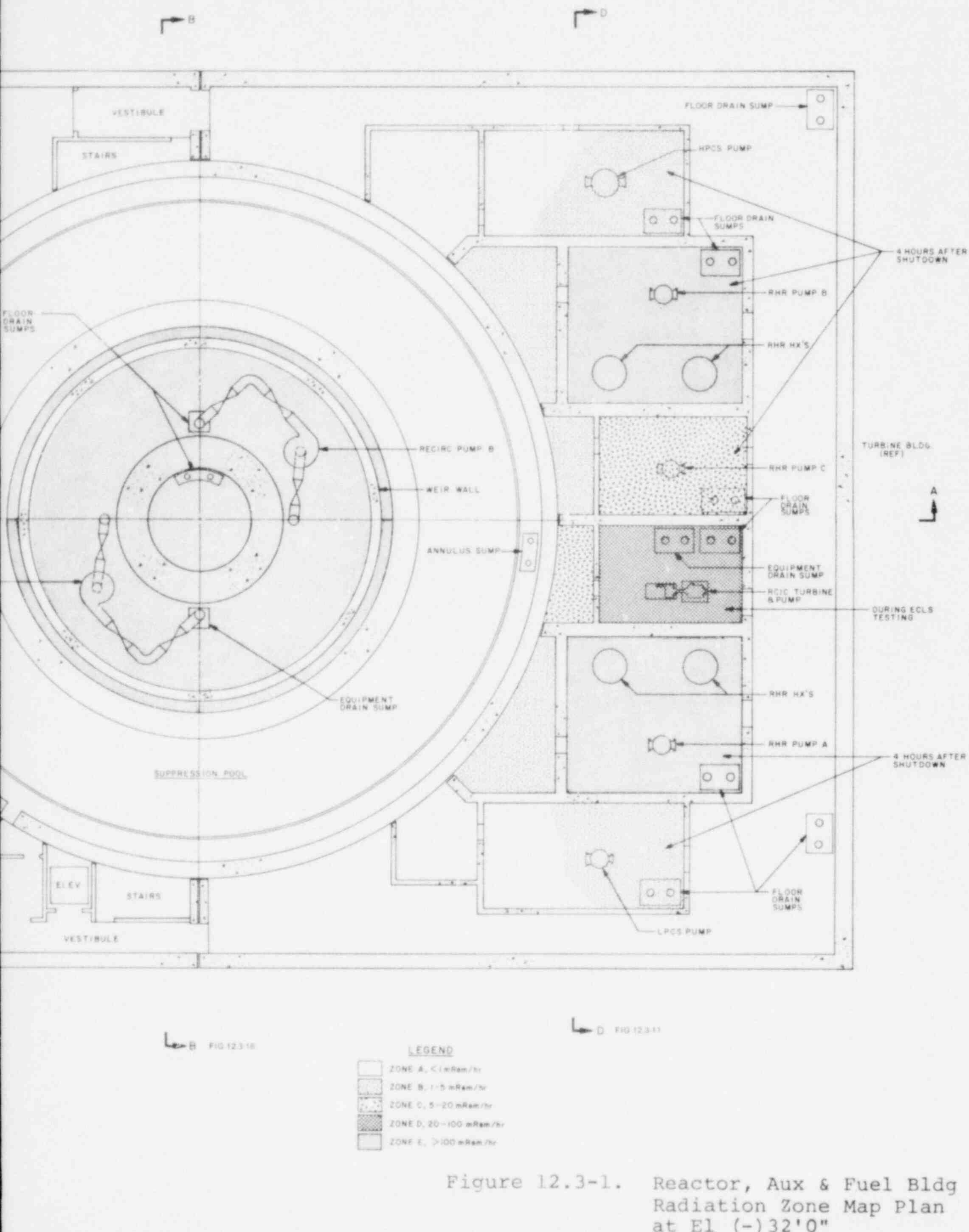
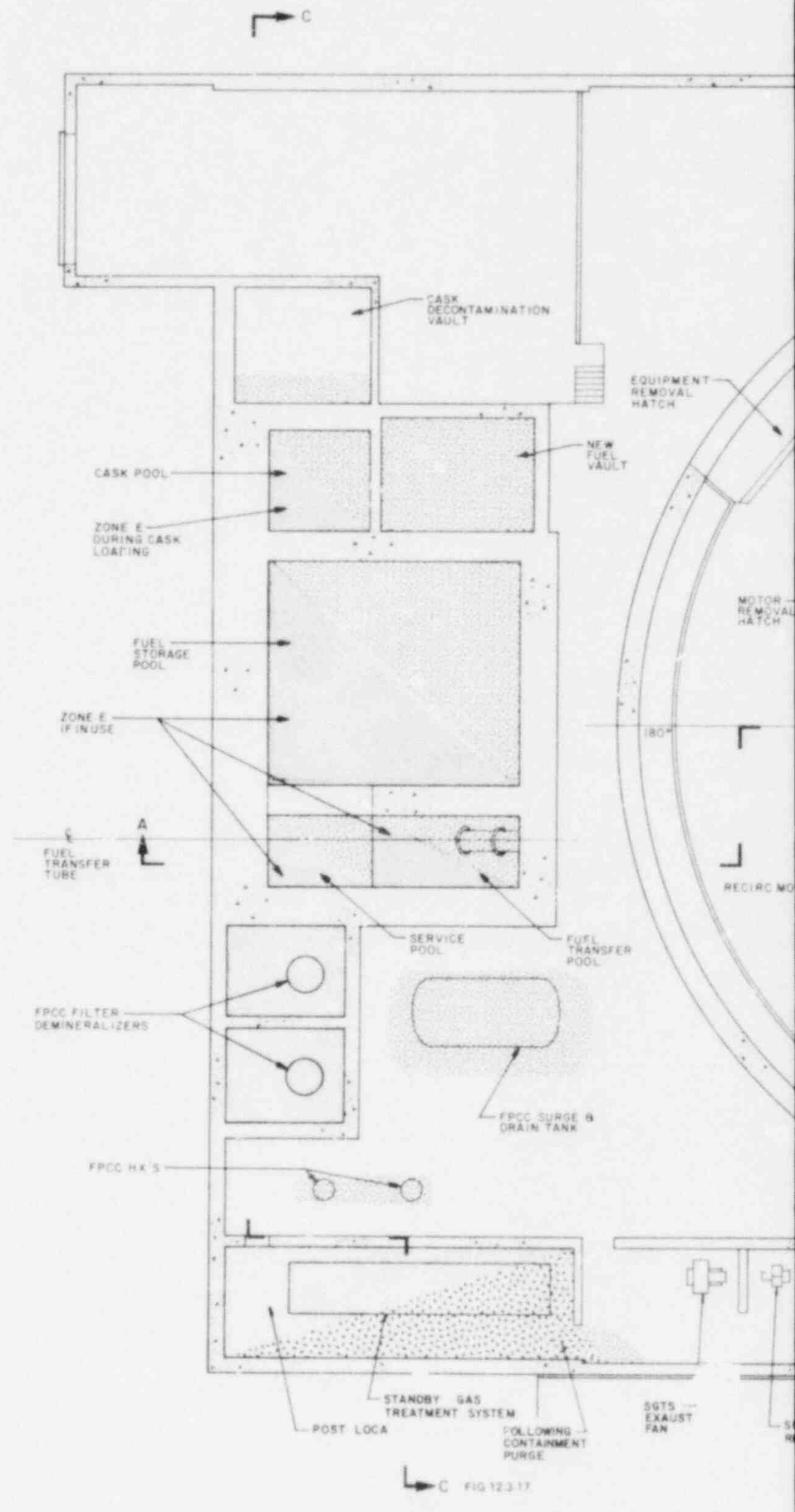


Figure 12.3-1. Reactor, Aux & Fuel Bldg Radiation Zone Map Plan at El (-)32'0"


C
CASK DECONTAMINATION VAULT
EQUIPMENT REMOVAL HATCH
NEW FUEL VAULT
CASK POOL
ZONE E DURING CASK LOADING
MOTOR REMOVAL HATCH
FUEL STORAGE POOL
ZONE E IF IN USE
180°
FUEL TRANSFER TUBE
A
RECIRC MO
SERVICE POOL
FUEL TRANSFER POOL
FPCC FILTER DEMINERALIZERS
FPCC SURGE & DRAIN TANK
FPCC H.X.'S
STANDBY GAS TREATMENT SYSTEM
POST LOCA
FOLLOWING CONTAINMENT PURGE
SGTS EXAUST FAN
C
FIG 12.3.17

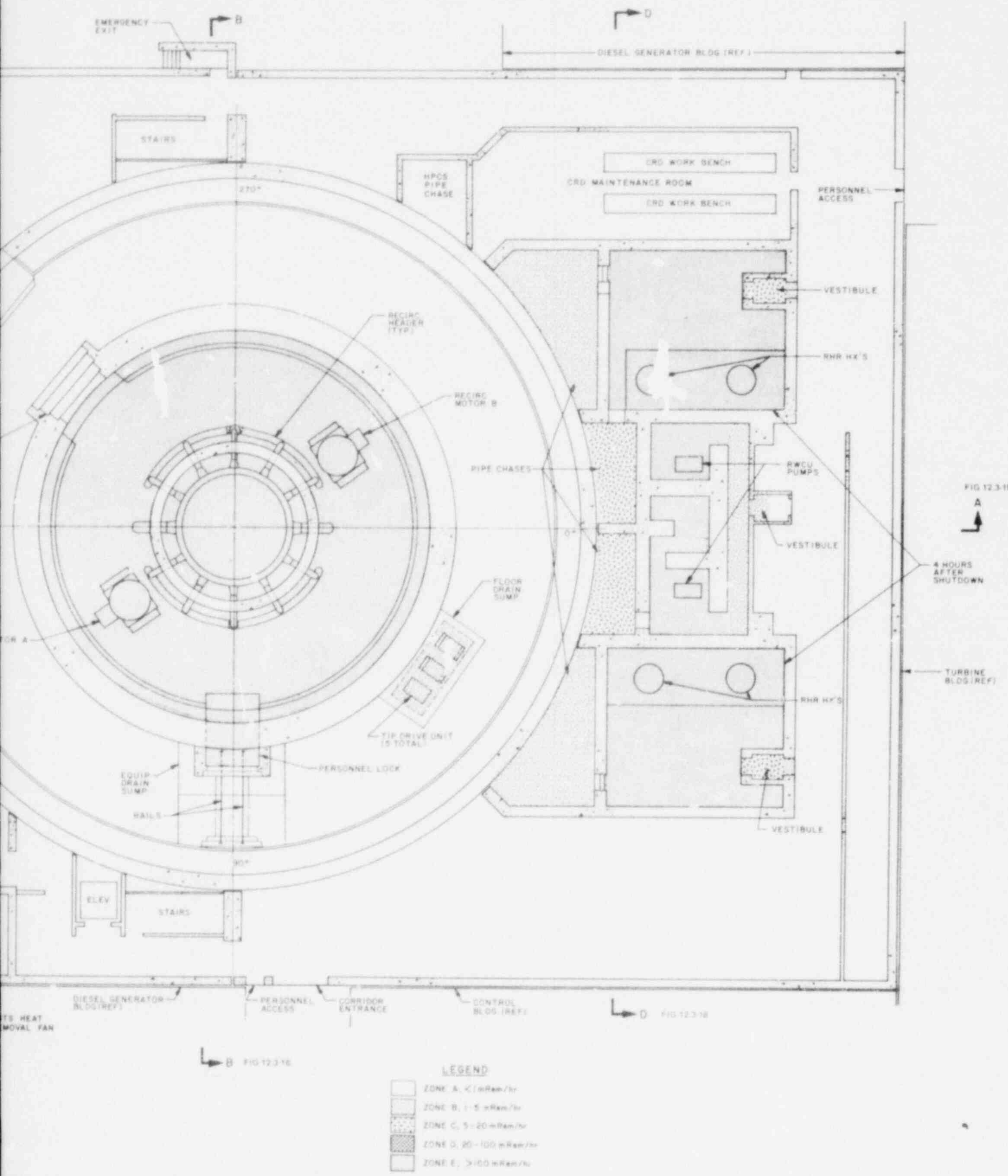
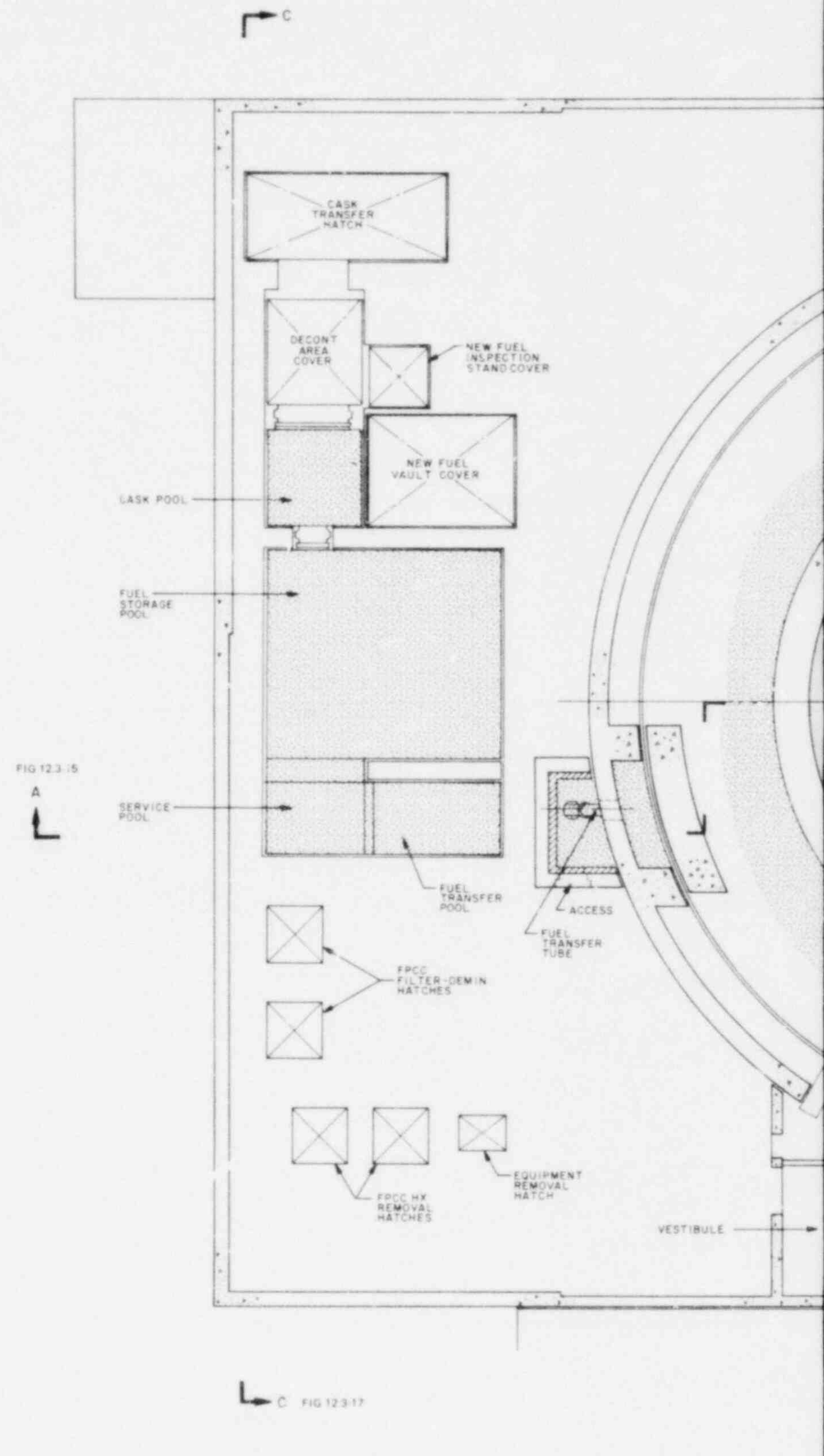


Figure 12.3-2. Reactor, Aux & Fuel Bldg Radiation Zone Map Plan at El (-)6'10"


C
CASK TRANSFER HATCH
DECONT AREA COVER
NEW FUEL INSPECTION STAND COVER
NEW FUEL VAULT COVER
CASK POOL
FUEL STORAGE POOL
FIG 12.3-15
A
SERVICE POOL
FUEL TRANSFER POOL
ACCESS
FUEL TRANSFER TUBE
FPCC FILTER-DEMIN HATCHES
FPCC HX REMOVAL HATCHES
EQUIPMENT REMOVAL HATCH
VESTIBULE
C FIG 12.3-17

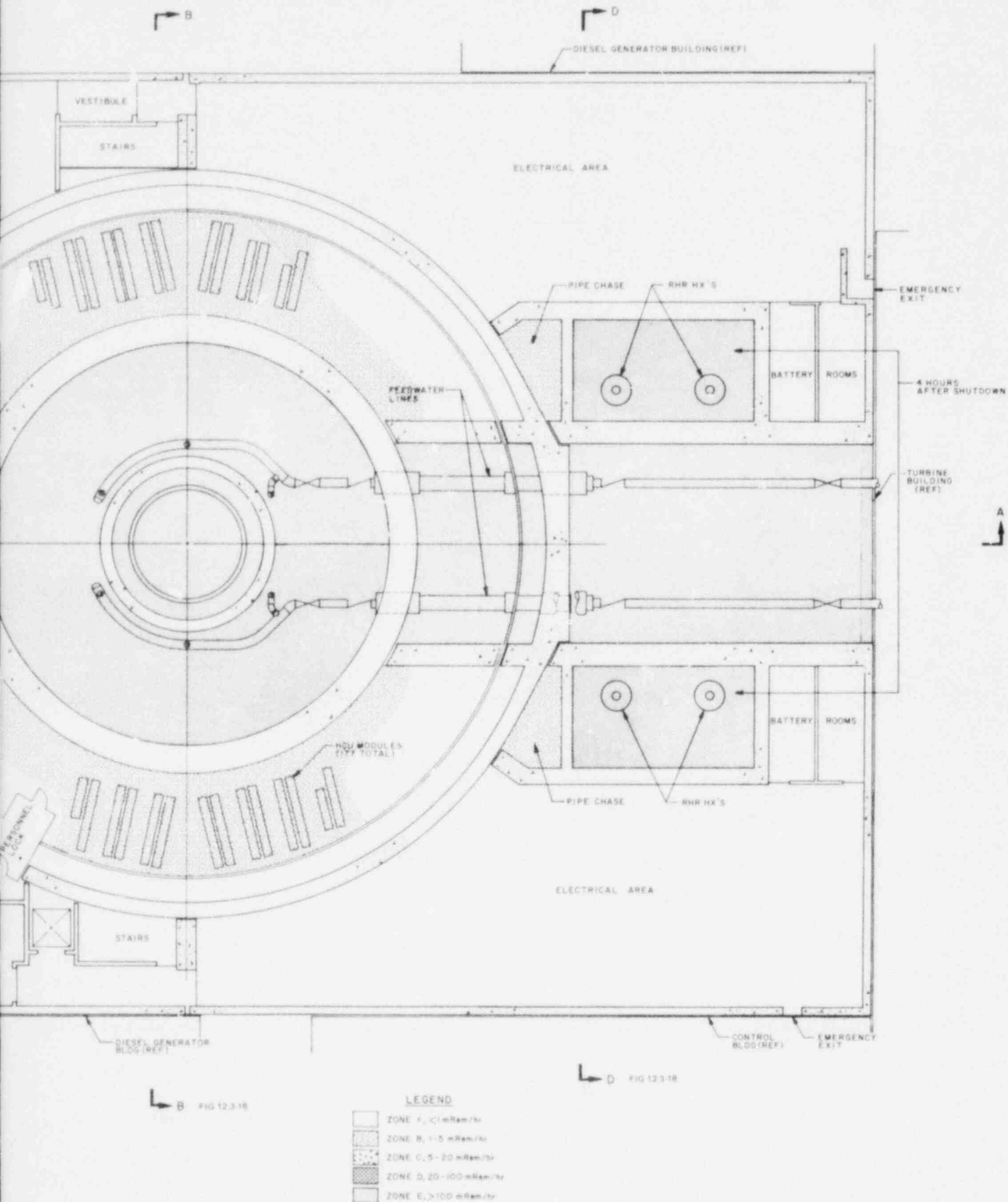
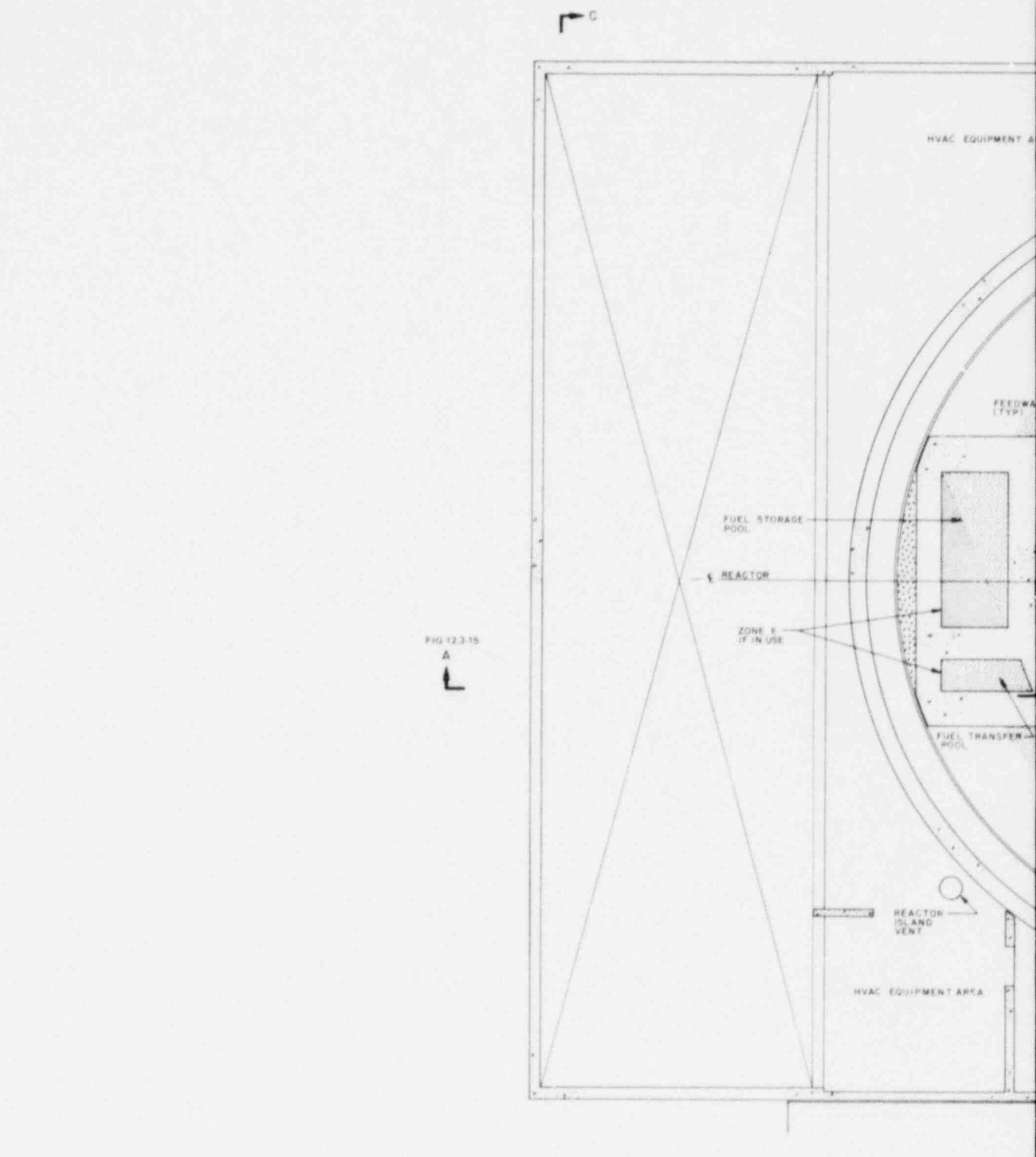


Figure 12.3-3. Reactor, Aux & Fuel Bldg Radiation Zone Map Plan at El 11'0"



C
FUEL STORAGE POOL
REACTOR
ZONE E IF IN USE
FUEL TRANSFER POOL
REACTOR ISLAND VENT
HVAC EQUIPMENT AREA
FIG 12.3-15
A
C
FIG 12.3-17

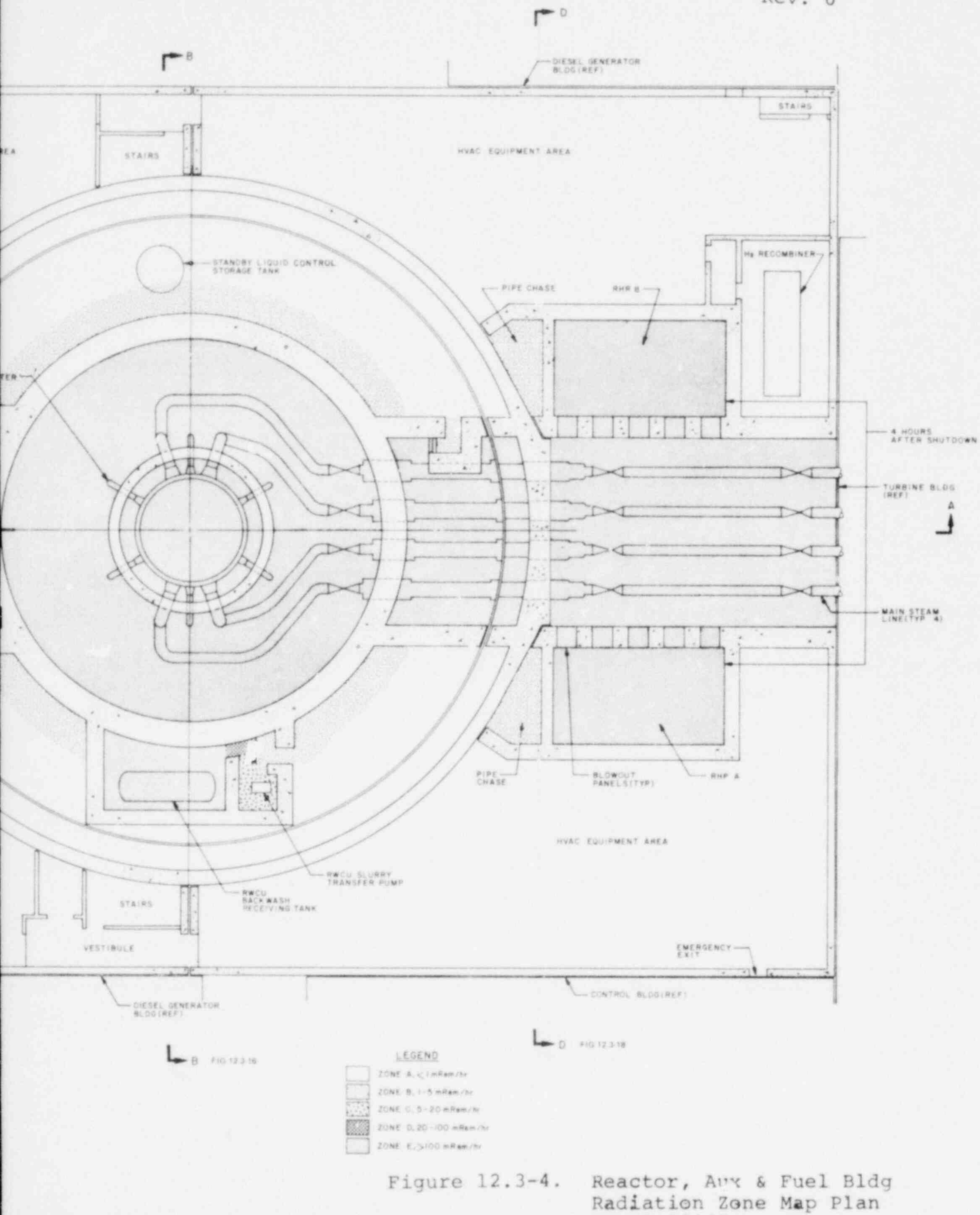
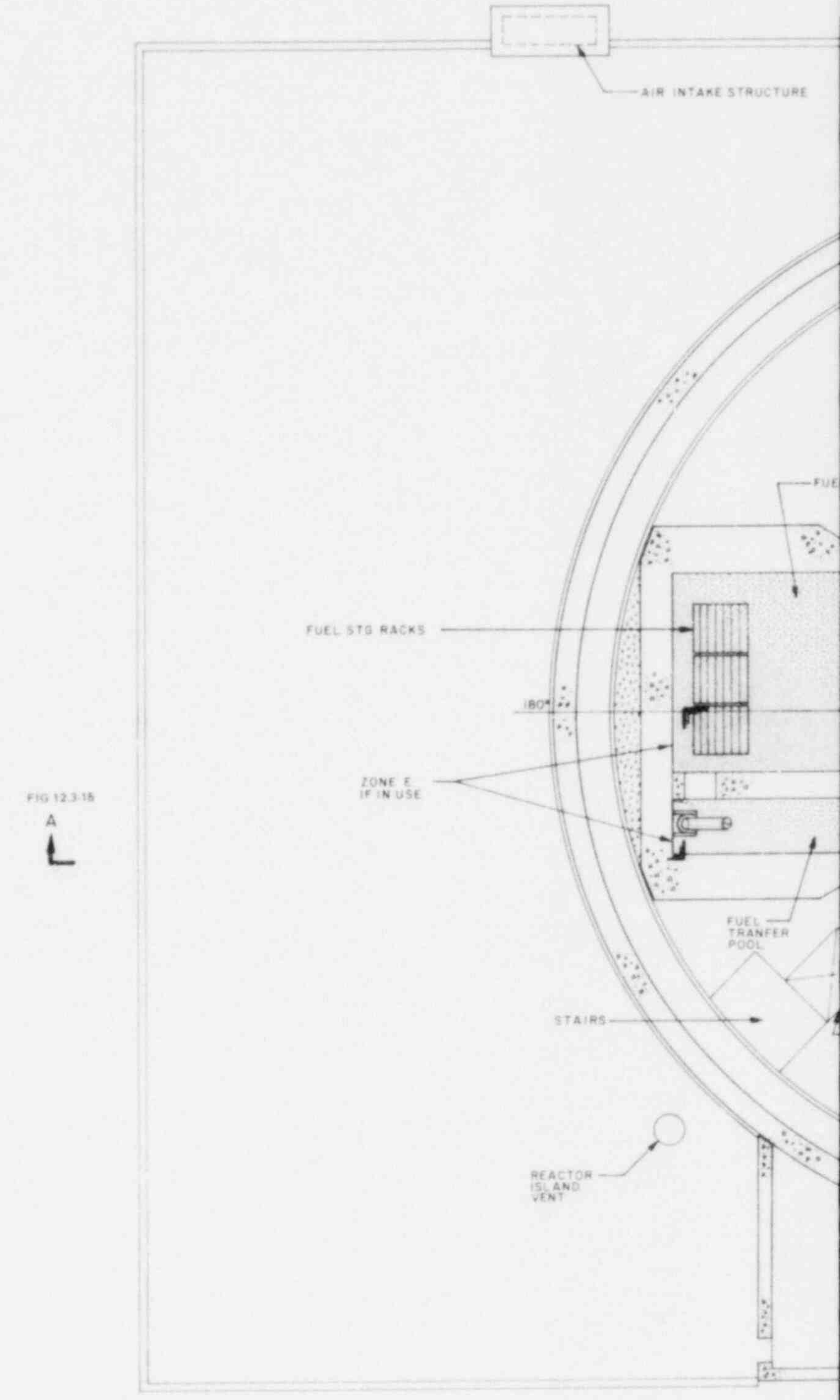


Figure 12.3-4. Reactor, Aux & Fuel Bldg Radiation Zone Map Plan at El 28'6"


AIR INTAKE STRUCTURE
FUEL STG RACKS
180°
ZONE E
IF IN USE
FIG 12.3-15
A
FUEL
TRANFER
POOL
STAIRS
REACTOR
ISLAND
VENT

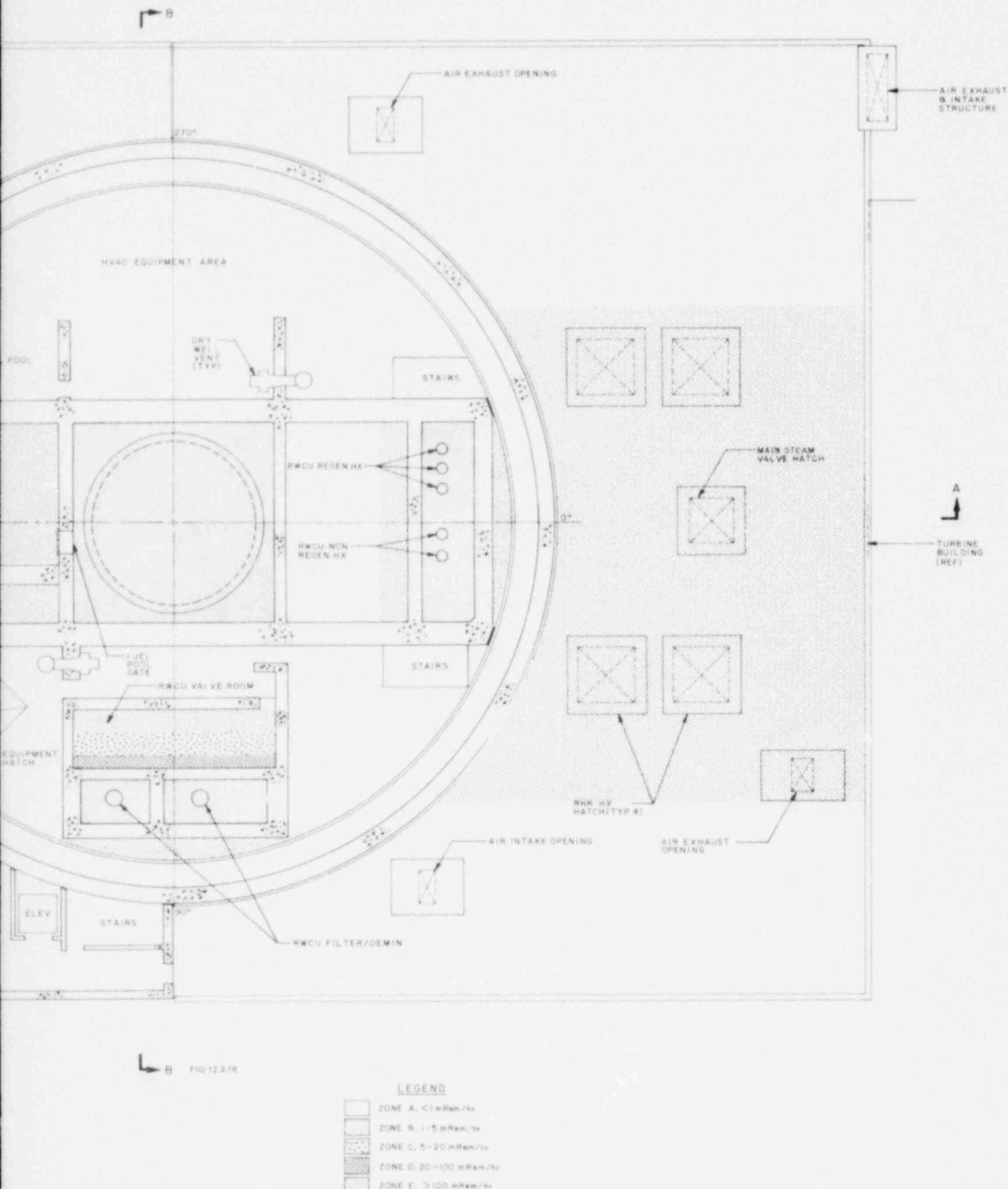
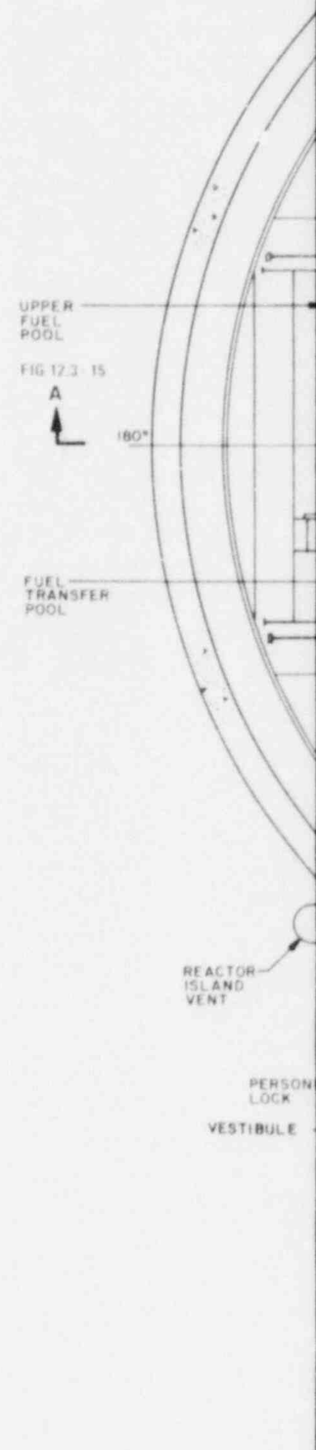


Figure 12.3-5. Reactor, Aux & Fuel Bldg Radiation Zone Map Plan at El 50'0"


UPPER FUEL POOL
FIG 12.3-15
A
180°
FUEL TRANSFER POOL
REACTOR ISLAND VENT
LOCK
VESTIBULE

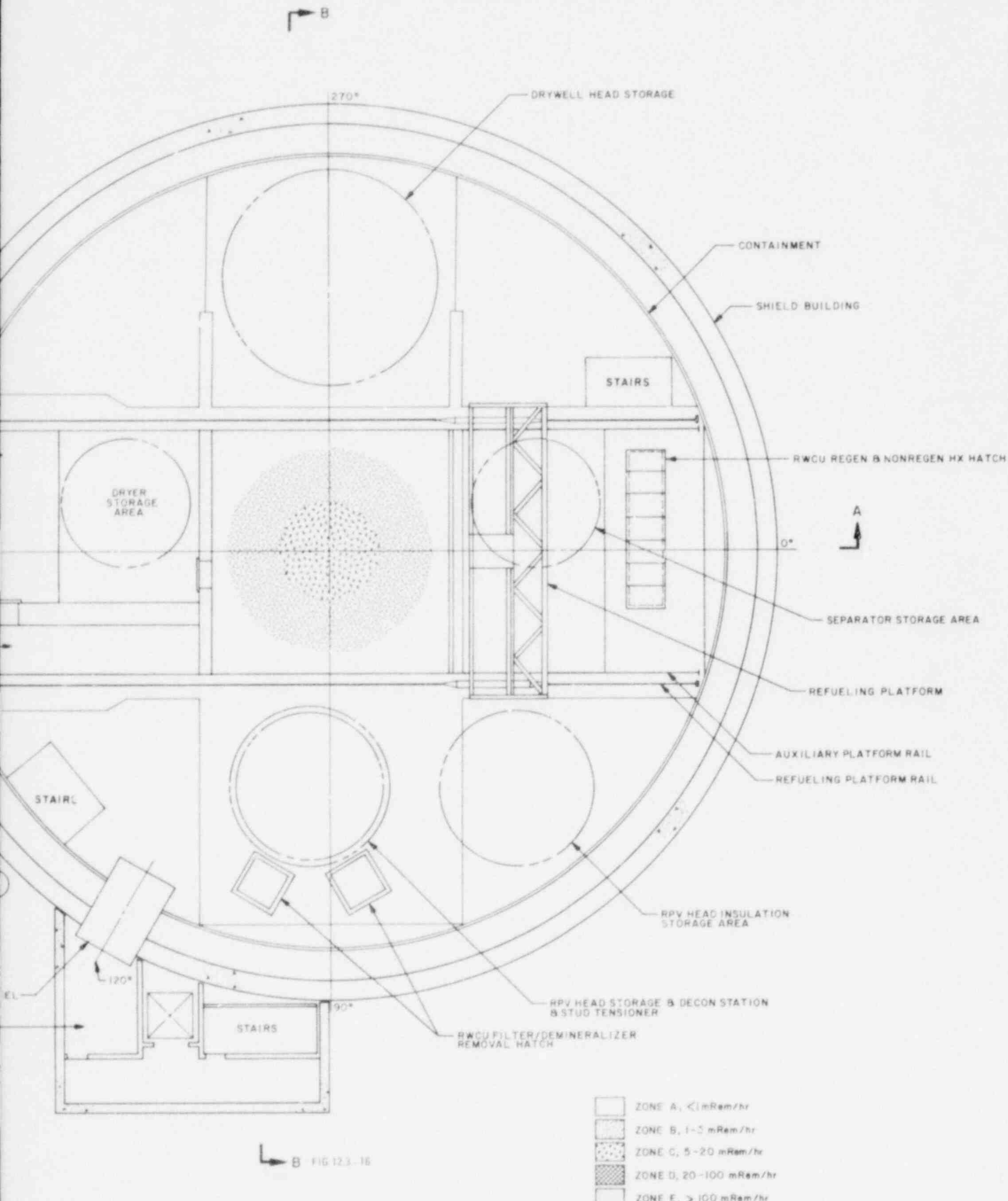
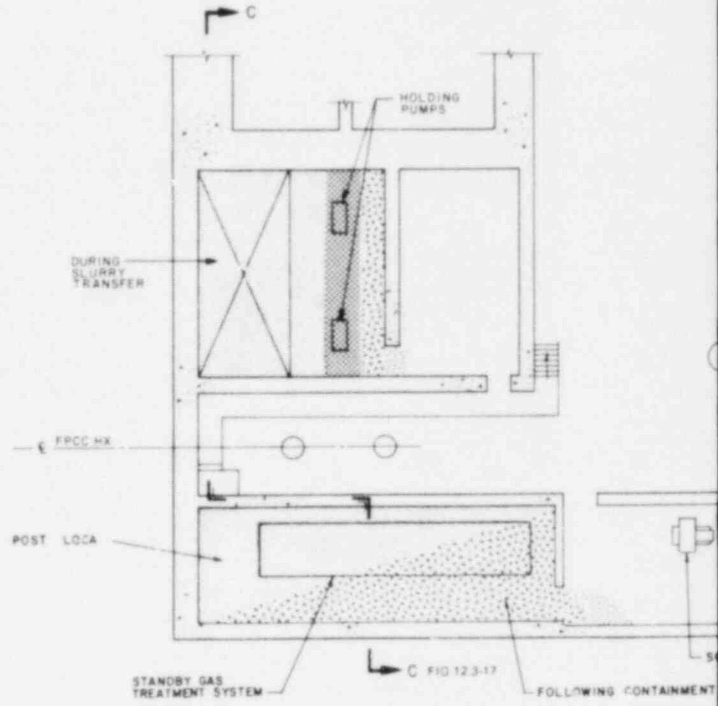


Figure 12.3-6. Reactor, Aux & Fuel Bldg Radiation Zone Map Plan El 84'7"



PARTIAL PLAN
AT EL (-) 17'-0"

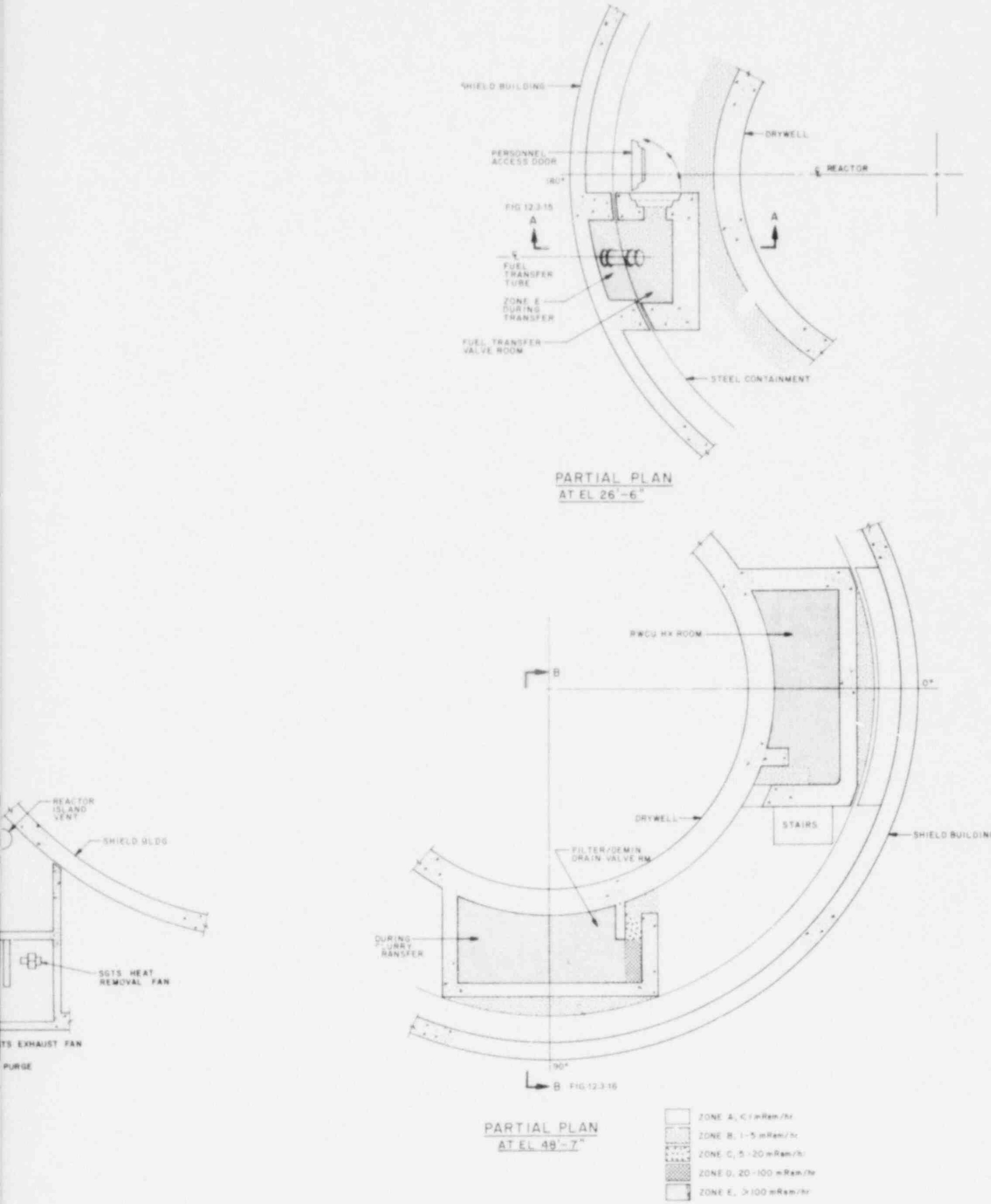


Figure 12.3-7. Reactor, Aux & Fuel Bldg Radiation Zone Map Partial Plans

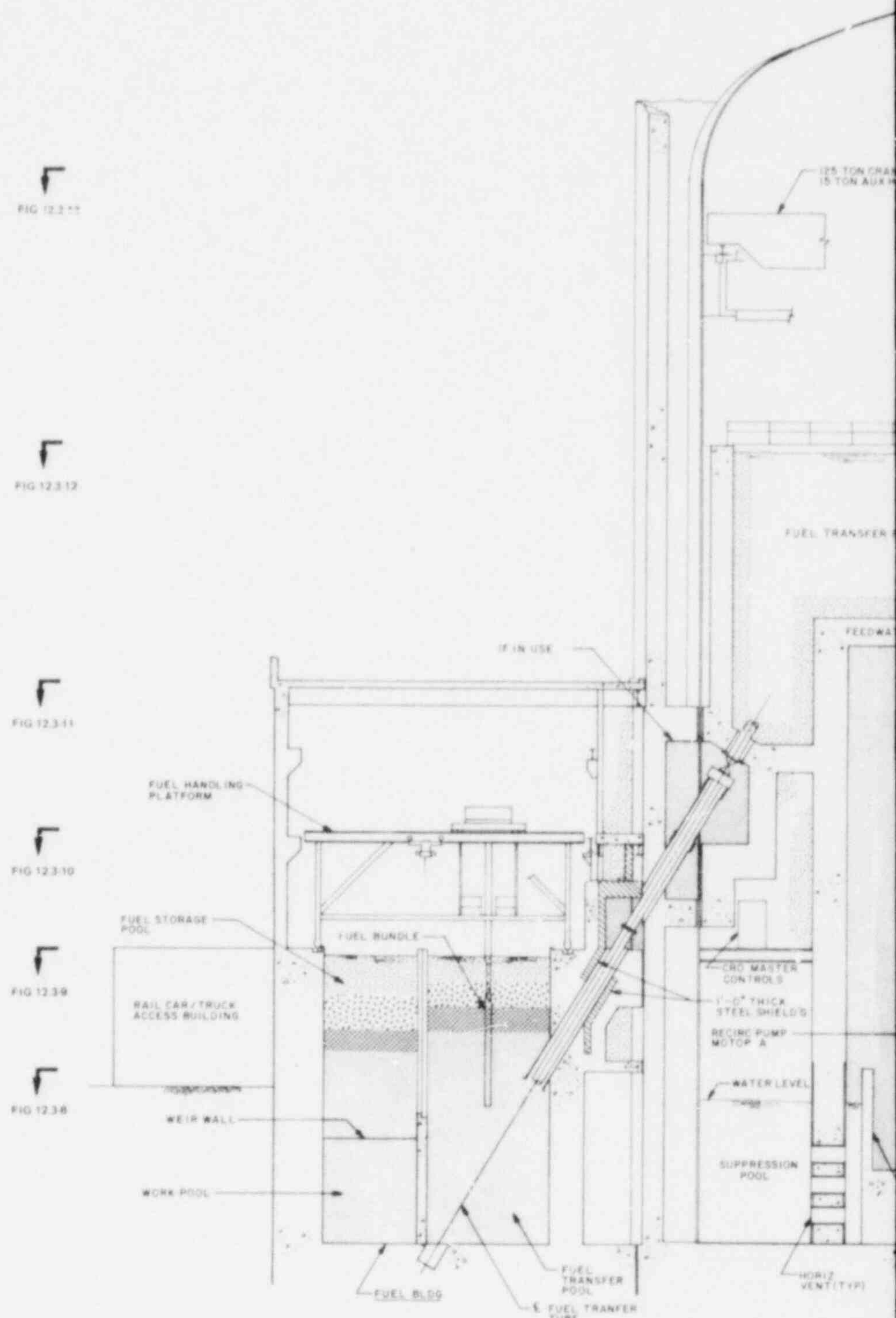


FIG 12.3-12
FIG 12.3-11
FIG 12.3-10
FIG 12.3-9
FIG 12.3-8
FUEL TRANSFER
FEEDWA
IF IN USE
FUEL HANDLING PLATFORM
FUEL STORAGE POOL
FUEL BUNDLE
RAIL CAR / TRUCK ACCESS BUILDING
CRD MASTER CONTROLS
1'-0" THICK STEEL SHIELDS
RECIRC PUMP MOTOR A
WATER LEVEL
WEIR WALL
WORK POOL
SUPPRESSION POOL
FUEL BLDG
FUEL TRANSFER POOL
HORIZ VENT (TYP)
℄ FUEL TRANFER TUBE

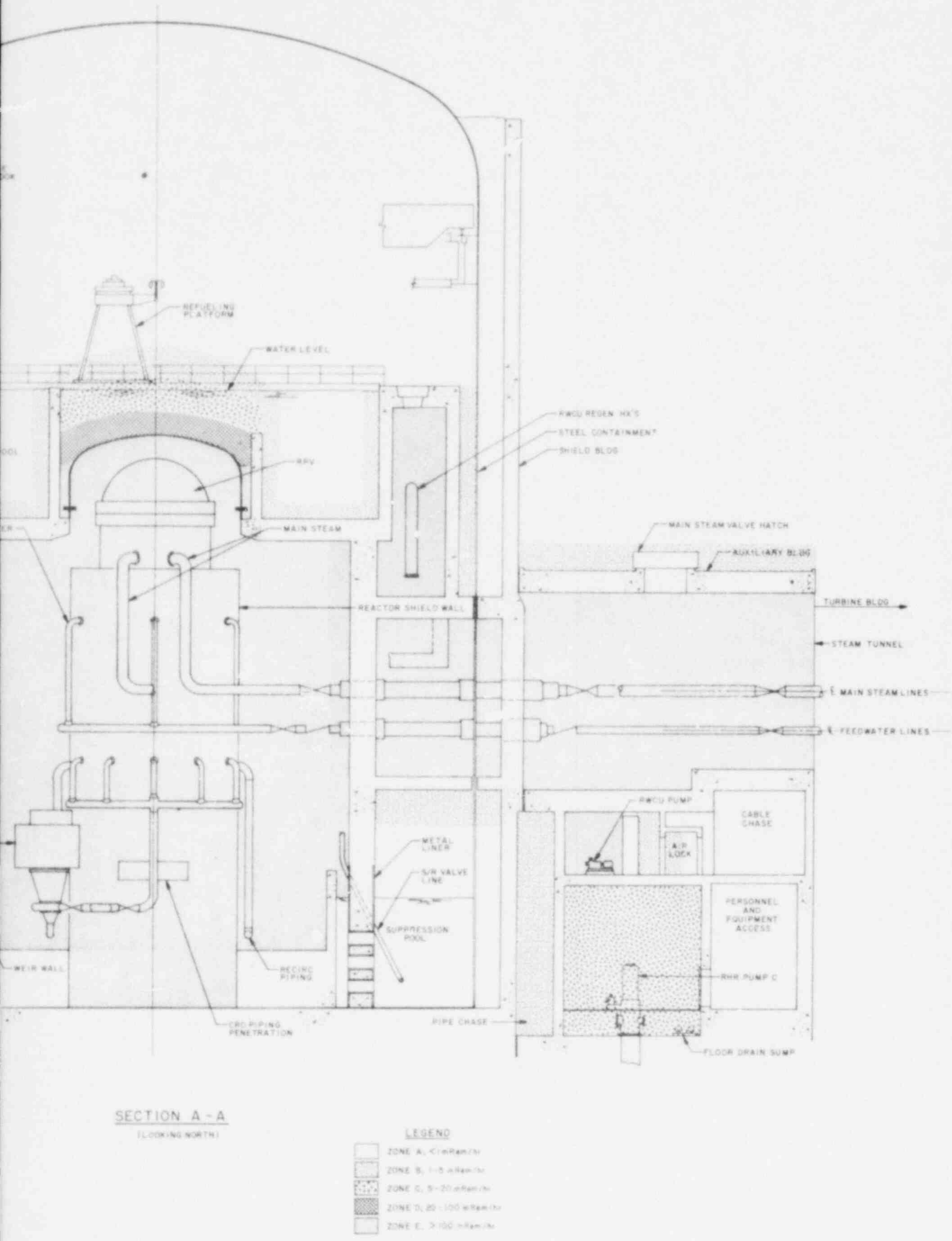


Figure 12.3-8. Reactor, Aux & Fuel Bldg
Radiation Zone Map
Section A-A

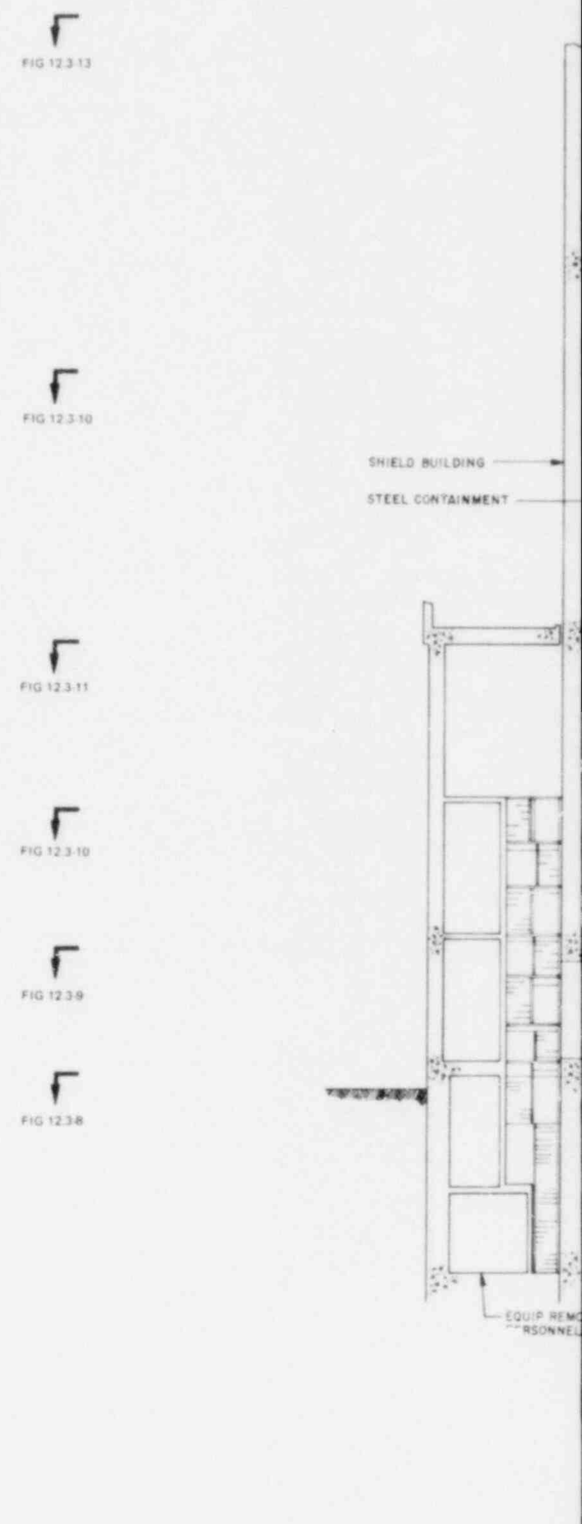


FIG 12.3-13
FIG 12.3-10
SHIELD BUILDING
STEEL CONTAINMENT
FIG 12.3-11
FIG 12.3-10
FIG 12.3-9
FIG 12.3-8

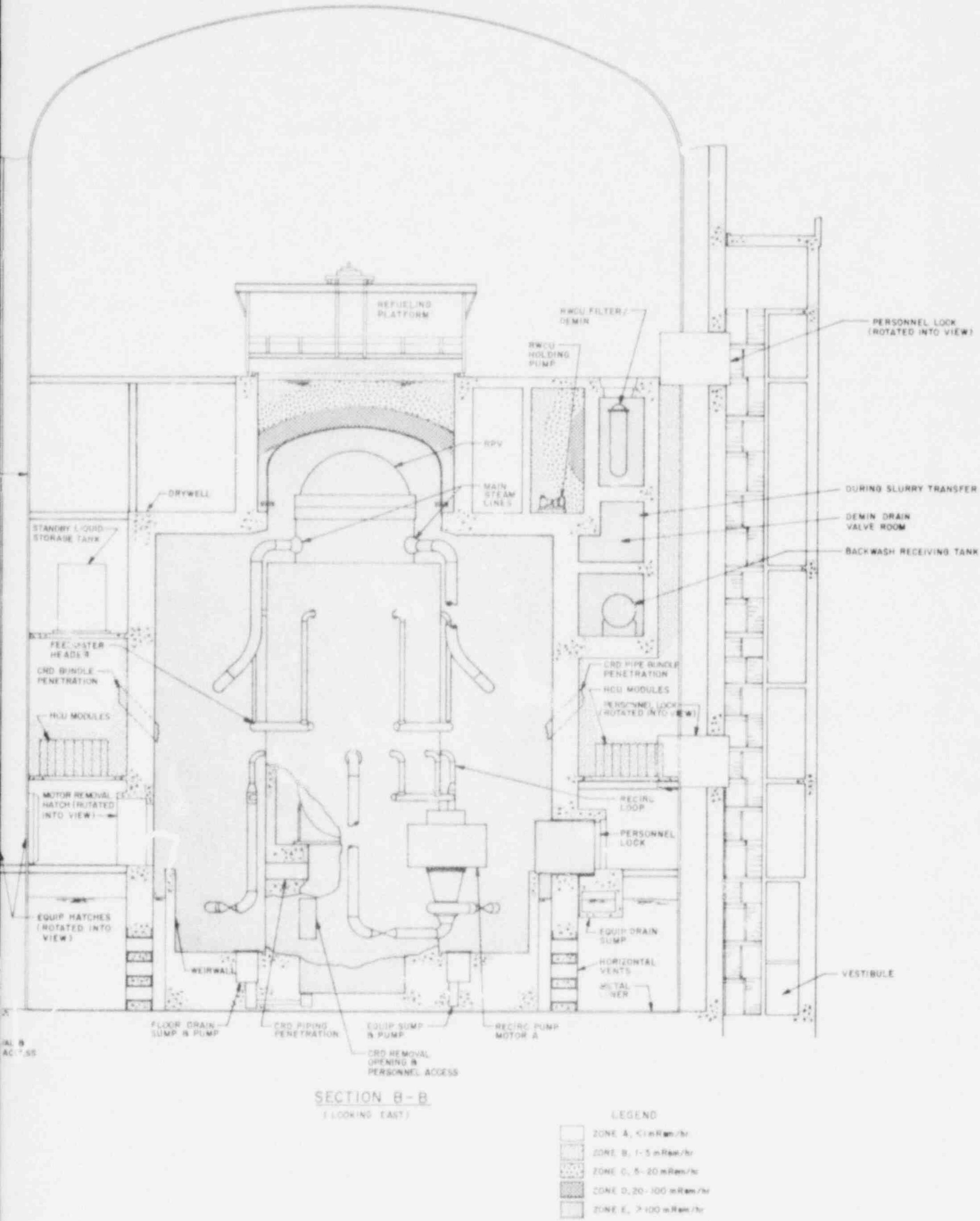


Figure 12.3-9. Reactor, Aux & Fuel Bldg Radiation Zone Map Section B-B

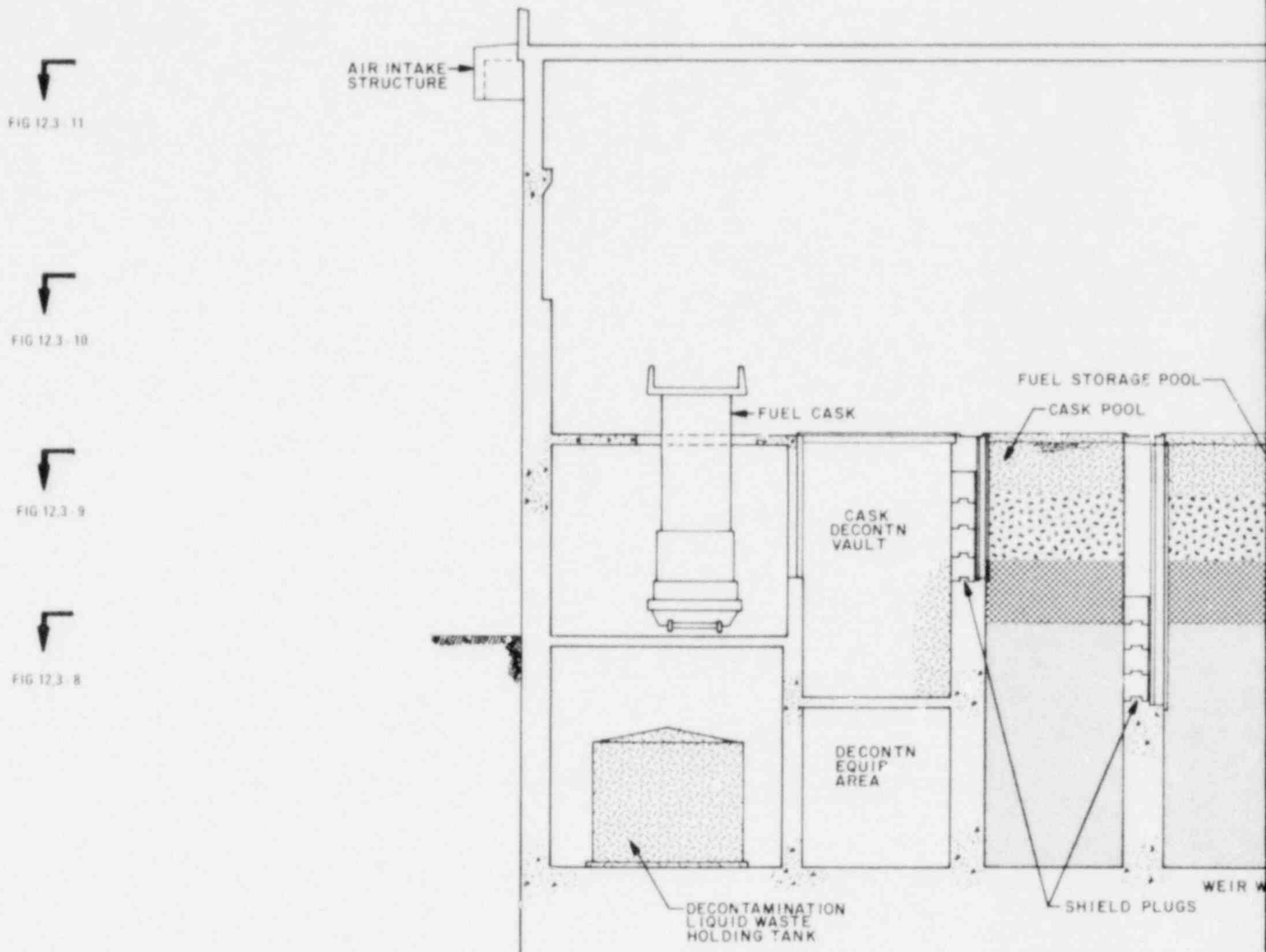
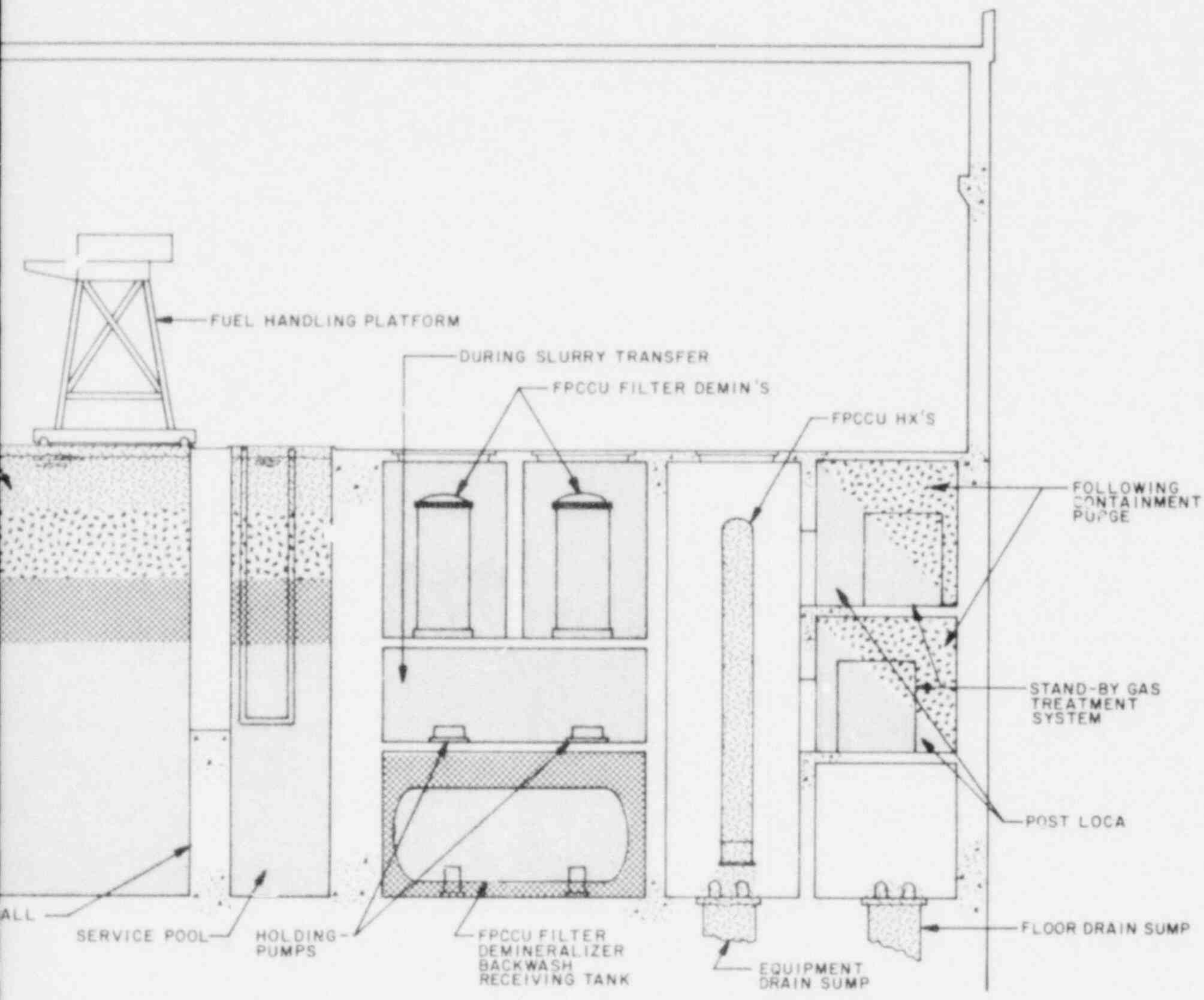


FIG 12.3-11
FIG 12.3-10
FIG 12.3-9
FIG 12.3-8
AIR INTAKE STRUCTURE
FUEL CASK
FUEL STORAGE POOL
CASK POOL
CASK DECONTN VAULT
DECONTN EQUIP AREA
DECONTAMINATION LIQUID WASTE HOLDING TANK
SHIELD PLUGS
WEIR W



SECTION C-C
(LOOKING EAST)

LEGEND

- ZONE A, <1 mRem/hr
- ZONE B, 1-5 mRem/hr
- ZONE C, 5-20 mRem/hr
- ZONE D, 20-100 mRem/hr
- ZONE E, >100 mRem/hr

Figure 12.3-10. Reactor, Aux & Fuel Bldg Radiation Zone Map Section C-C

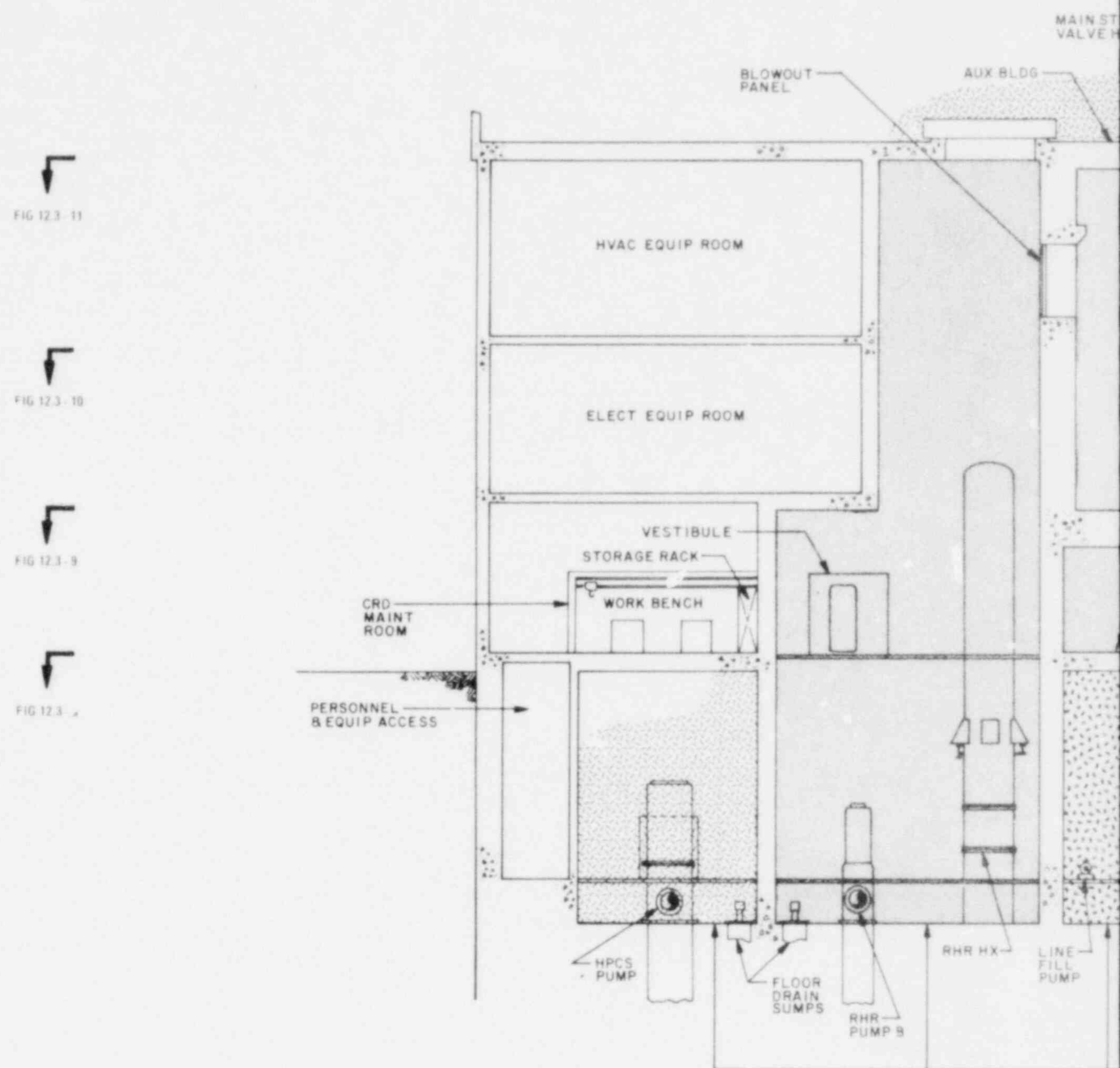


FIG 12.3-11
FIG 12.3-10
FIG 12.3-9
FIG 12.3-
MAIN ST
VALVE H
BLOWOUT PANEL
AUX BLDG
HVAC EQUIP ROOM
ELECT EQUIP ROOM
VESTIBULE
STORAGE RACK
WORK BENCH
CRD MAINT ROOM
PERSONNEL & EQUIP ACCESS
HPCS PUMP
FLOOR DRAIN SUMPS
RHR PUMP B
RHR HX
LINE FILL PUMP

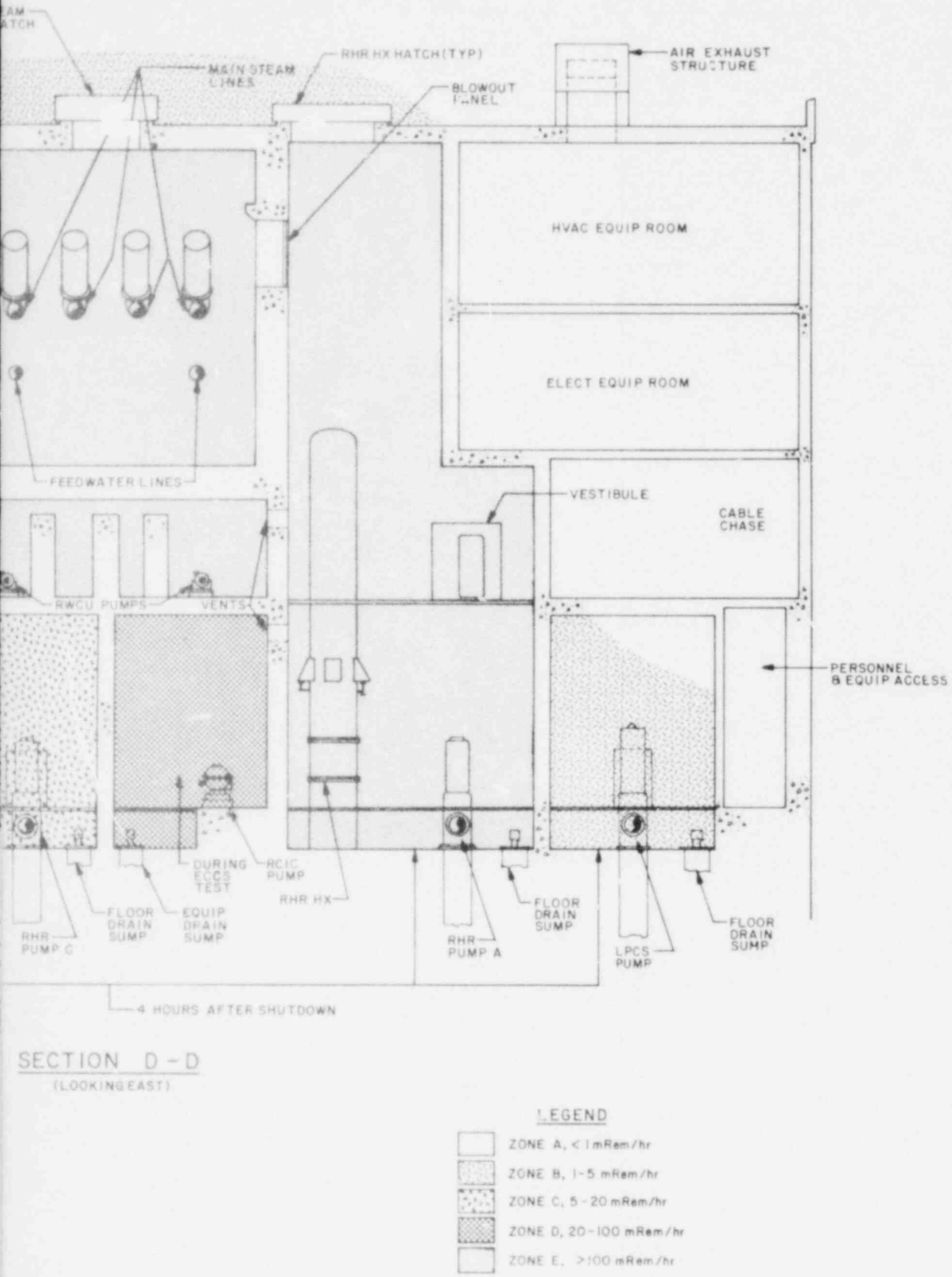
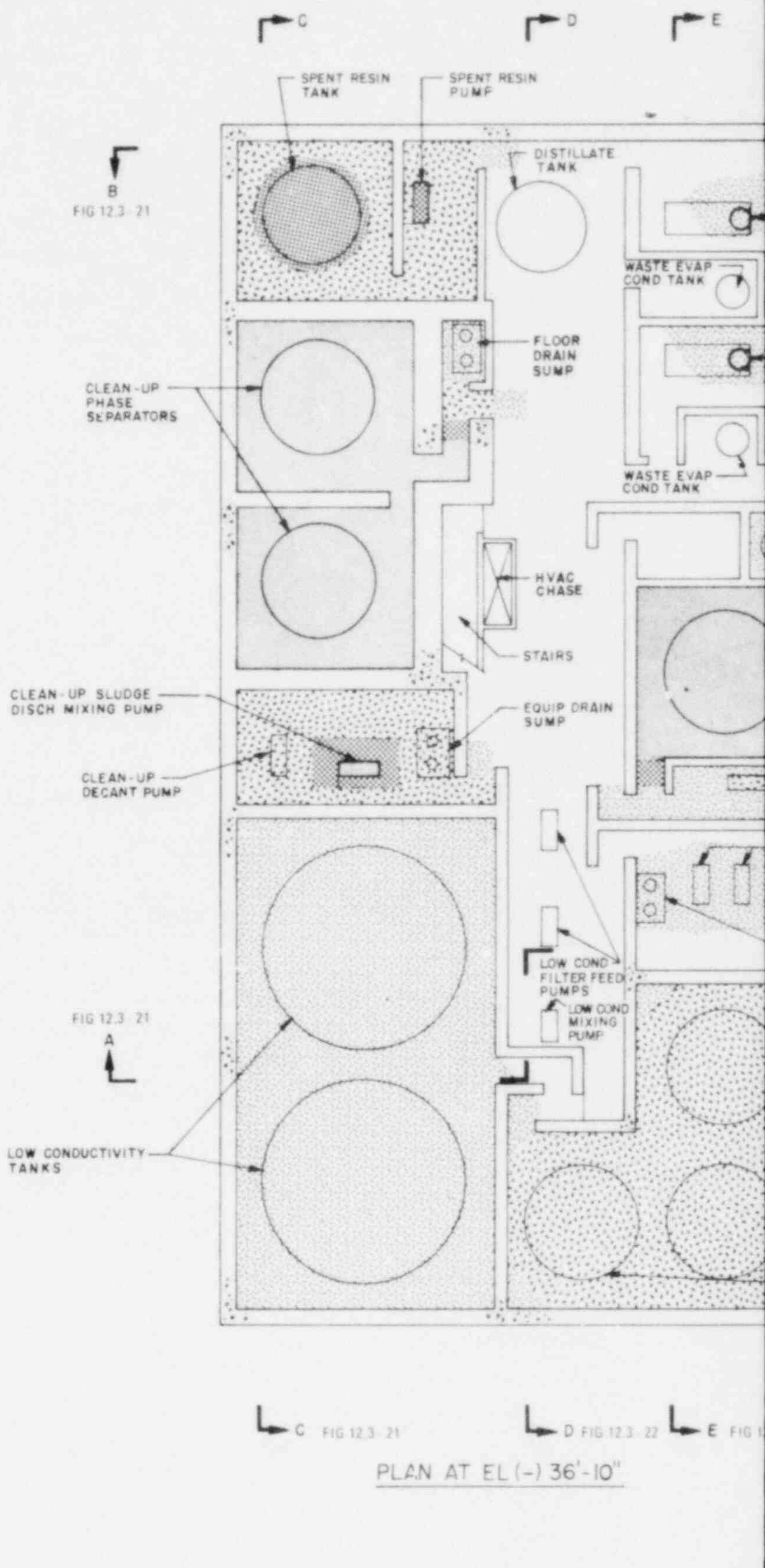


Figure 12.3-11. Reactor, Aux & Fuel Bldg Radiation Zone Map Section D-D



PLAN AT EL (-) 36'-10"

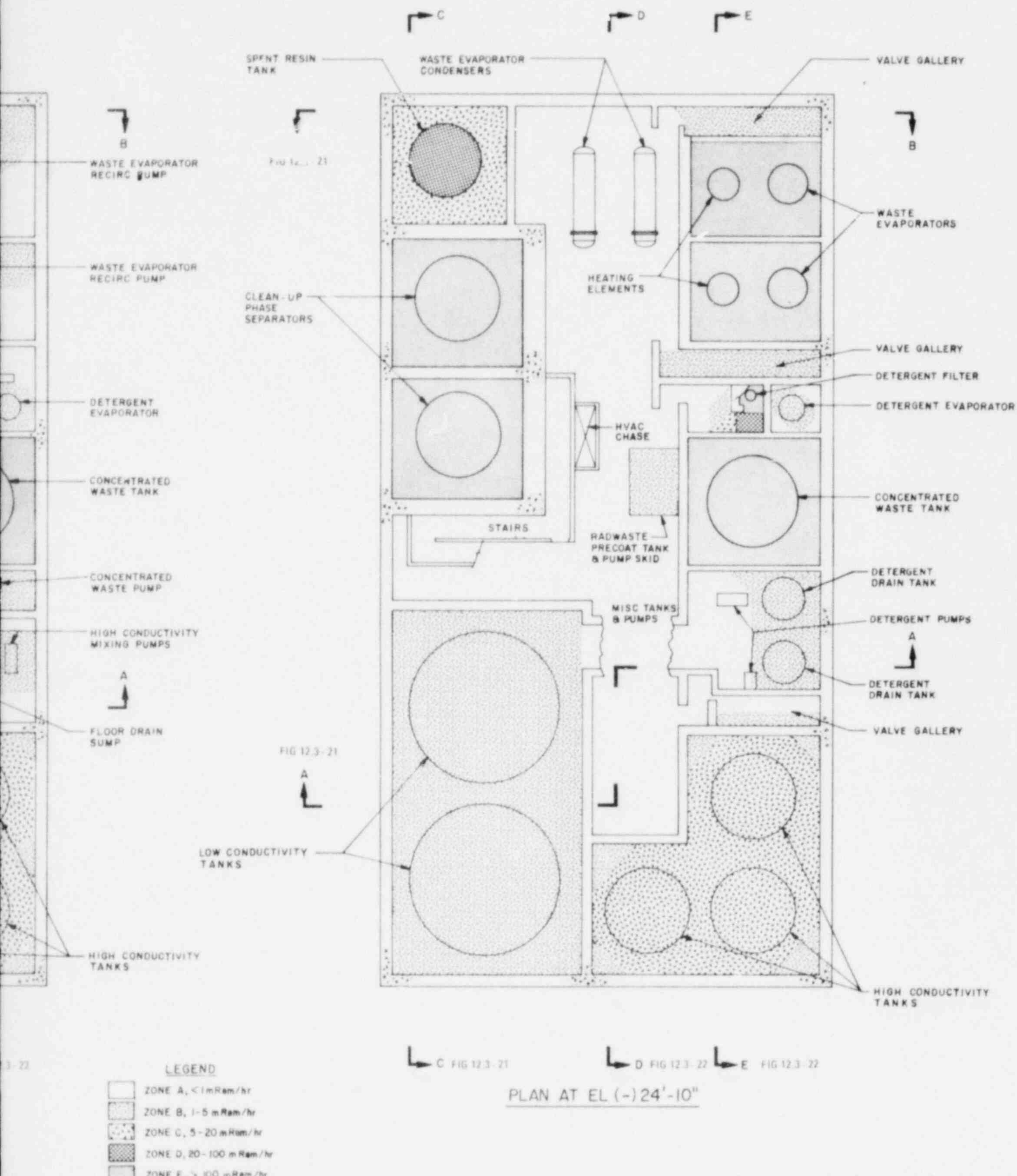
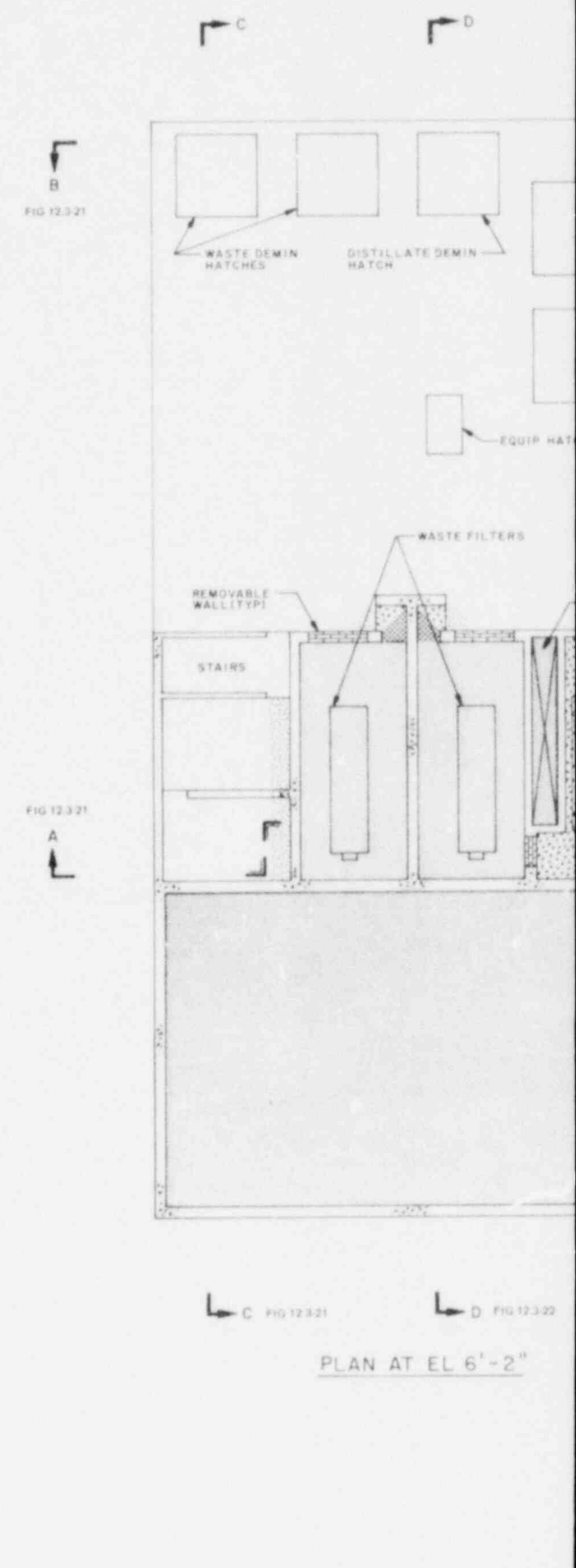


Figure 12.3-12. Radwaste Bldg Radiation Zone Map Plans at El (-)36'10" & (-)24'10"


C
D
B
FIG 12.3-21
WASTE DEMIN HATCHES
DISTILLATE DEMIN HATCH
EQUIP HAT
WASTE FILTERS
REMOVABLE WALL (TYP)
STAIRS
FIG 12.3-21
A
C FIG 12.3-21
D FIG 12.3-22

PLAN AT EL 6'-2"

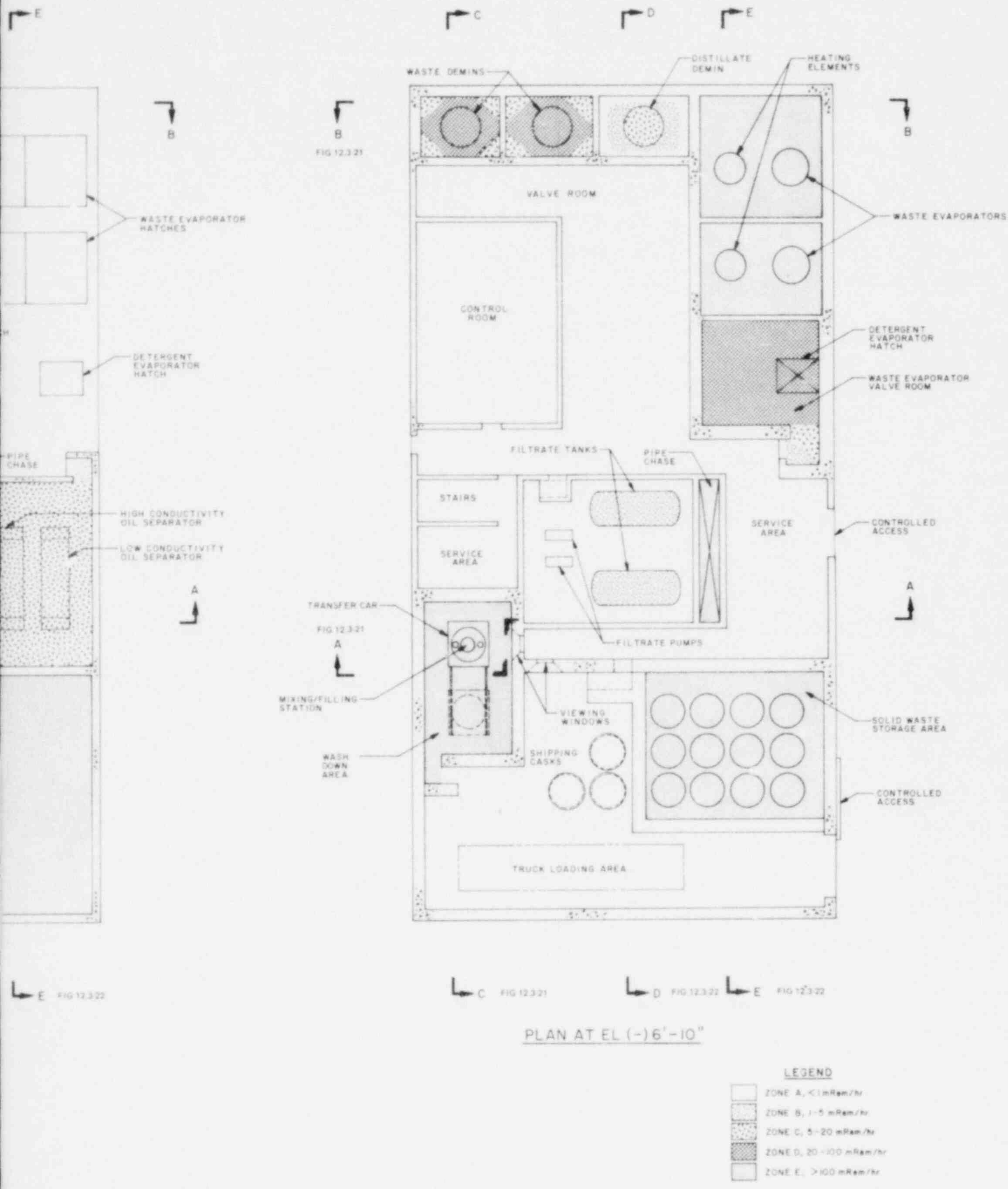
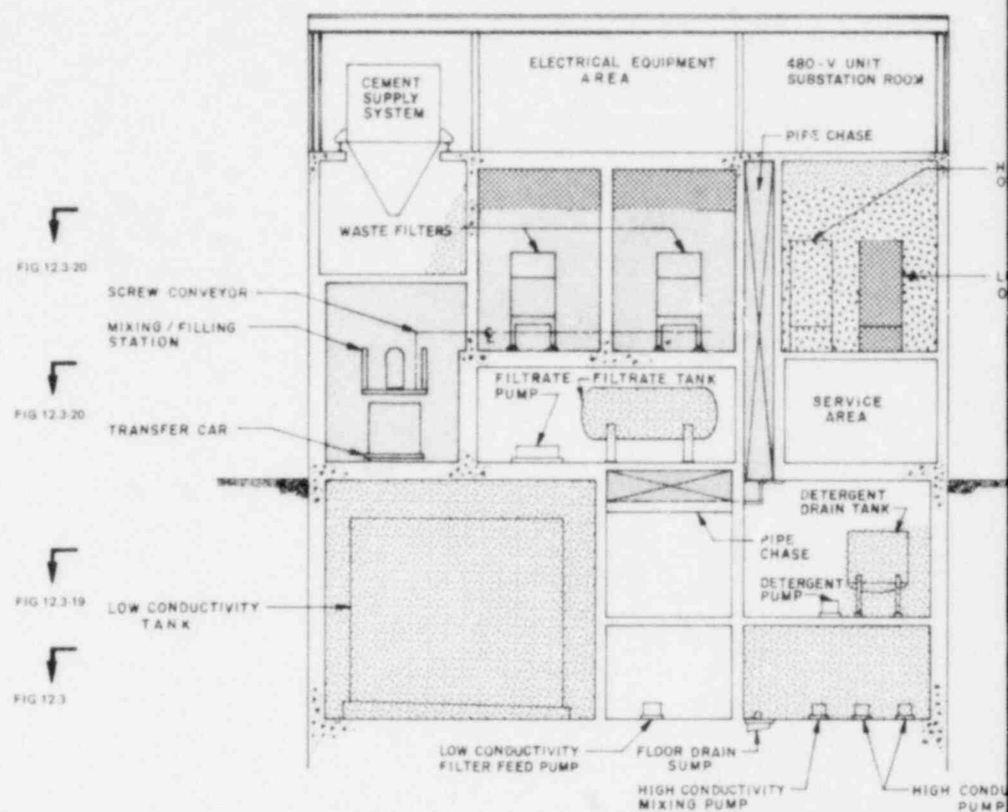


Figure 12.3-13. Radwaste Bldg Radiation Zone Map Plans at El (-)6'10" & 6'2"



CEMENT SUPPLY SYSTEM
ELECTRICAL EQUIPMENT AREA
480-V UNIT SUBSTATION ROOM
PIPE CHASE
WASTE FILTERS
FIG 12.3-20
SCREW CONVEYOR
MIXING / FILLING STATION
FIG 12.3-20
FILTRATE PUMP
FILTRATE TANK
SERVICE AREA
TRANSFER CAR
DETERGENT DRAIN TANK
PIPE CHASE
FIG 12.3-19
DETERGENT PUMP
LOW CONDUCTIVITY TANK
FIG 12.3
LOW CONDUCTIVITY FILTER FEED PUMP
FLOOR DRAIN SUMP
HIGH CONDUCTIVITY MIXING PUMP

SECTION A-A

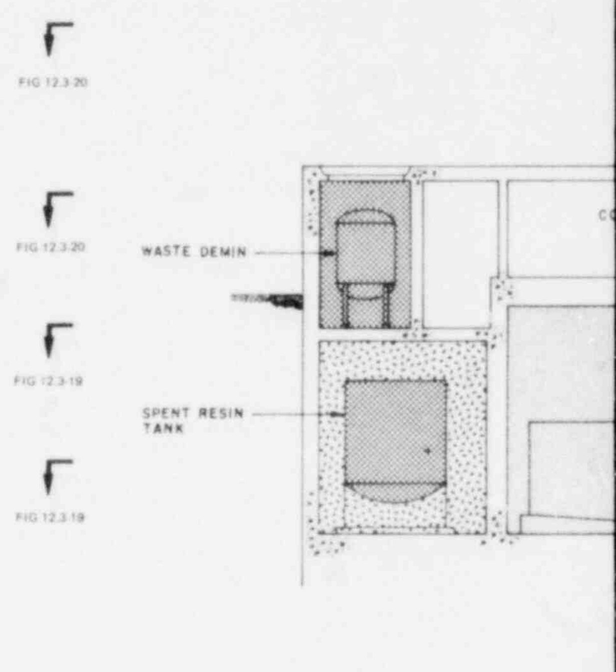


FIG 12.3-20
FIG 12.3-20
WASTE DEMIN
FIG 12.3-19
SPENT RESIN TANK
FIG 12.3-19

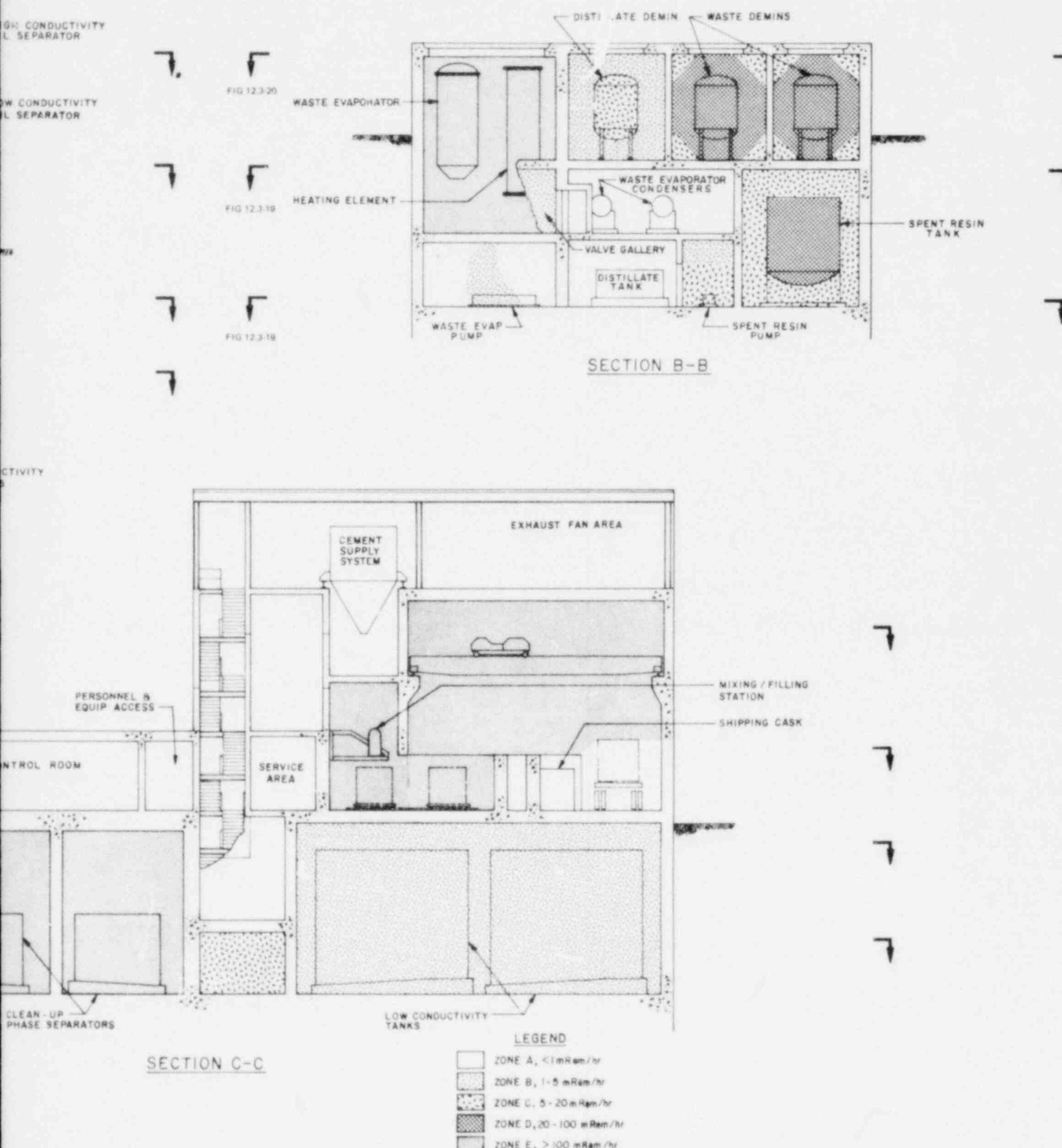


Figure 12.3-14. Radwaste Bldg Radiation Zone Map - Sections A-A, B-B & C-C

FIG 12.3-20
HE
FIG 12.3-20
WASTE EVAPORATORS
VALVE GALLERY
FIG 12.3-19
WASTE EVAP RECIRC PUMP
FIG 12.3-19
FIG 12.3-20
FIG 12.3-20
DISTILLATE DEMINERALIZER
FIG 12.3-19
FIG 12.3-19

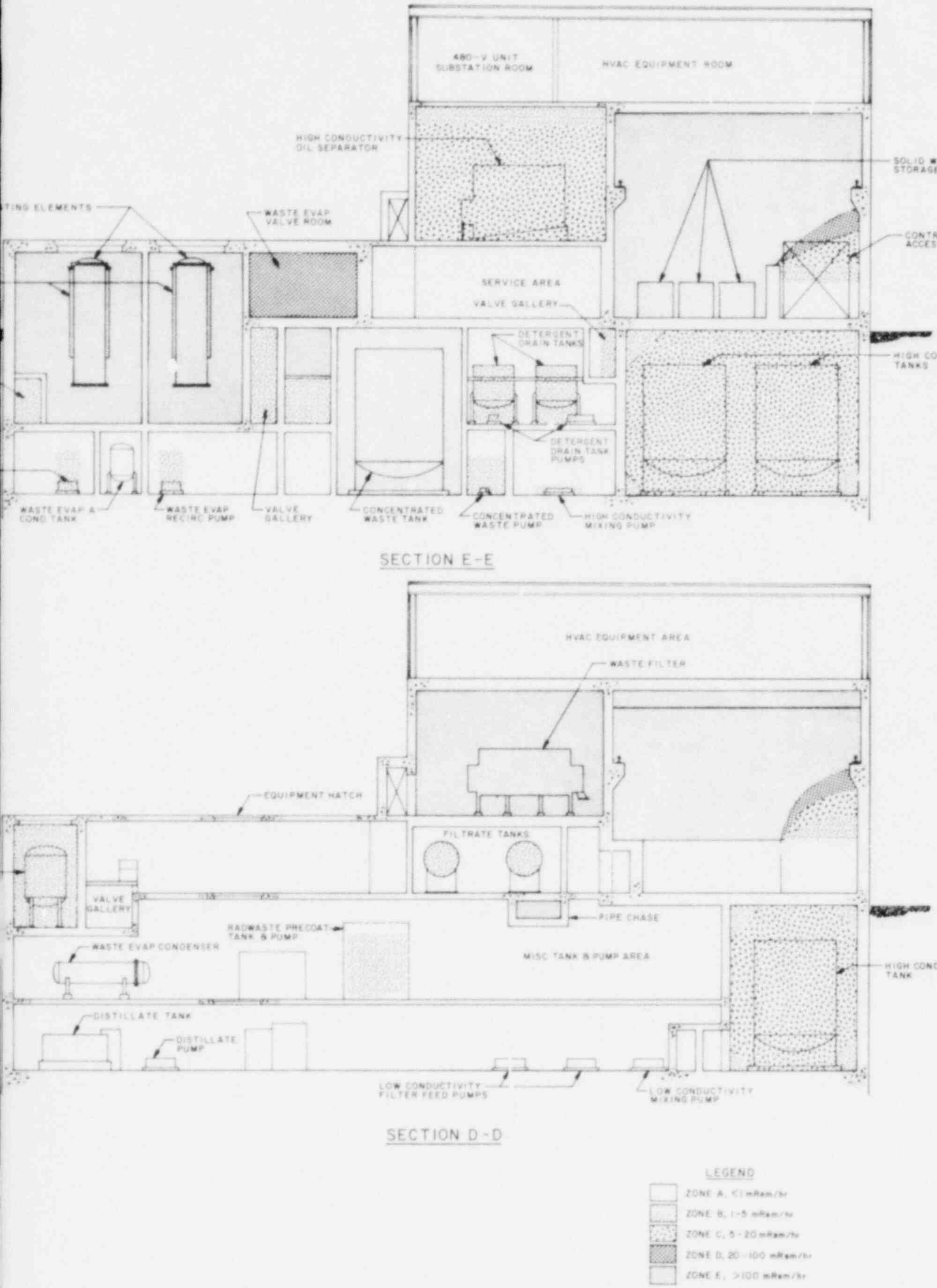
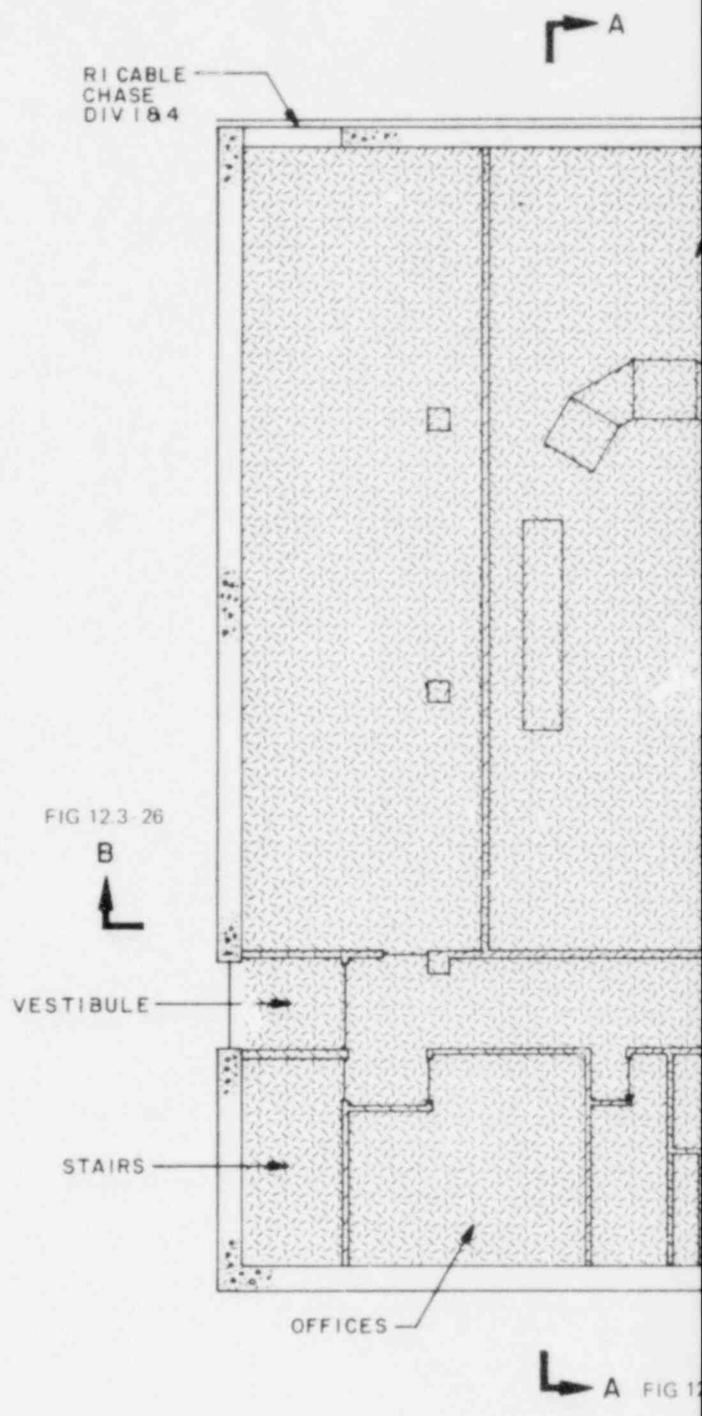
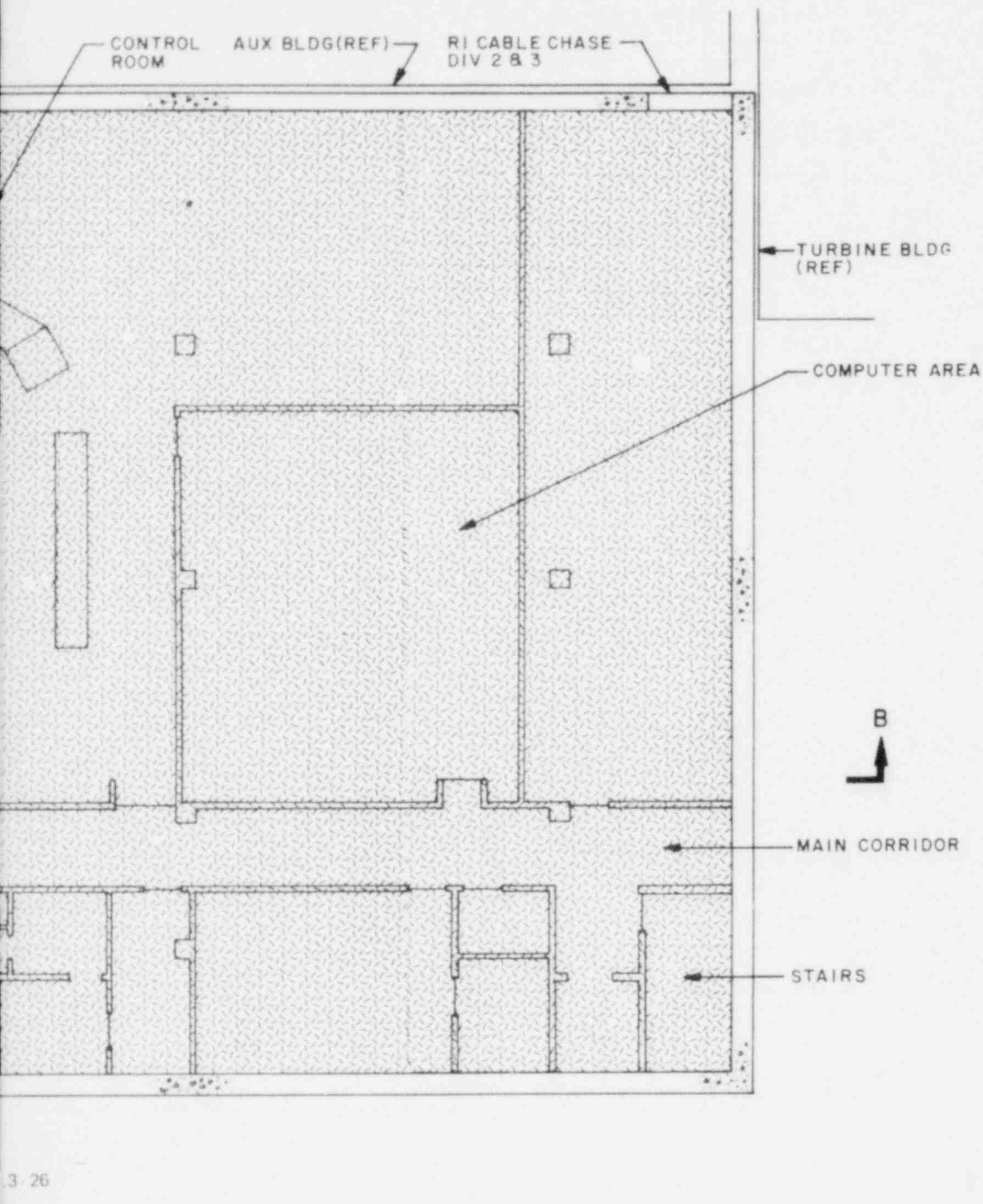


Figure 12.3-15. Radwaste Bldg Radiation Zone Map - Sections D-D & E-E


A
RI CABLE
CHASE
DIV I & 4
FIG 12.3-26
B
VESTIBULE
STAIRS
OFFICES
A
FIG 12

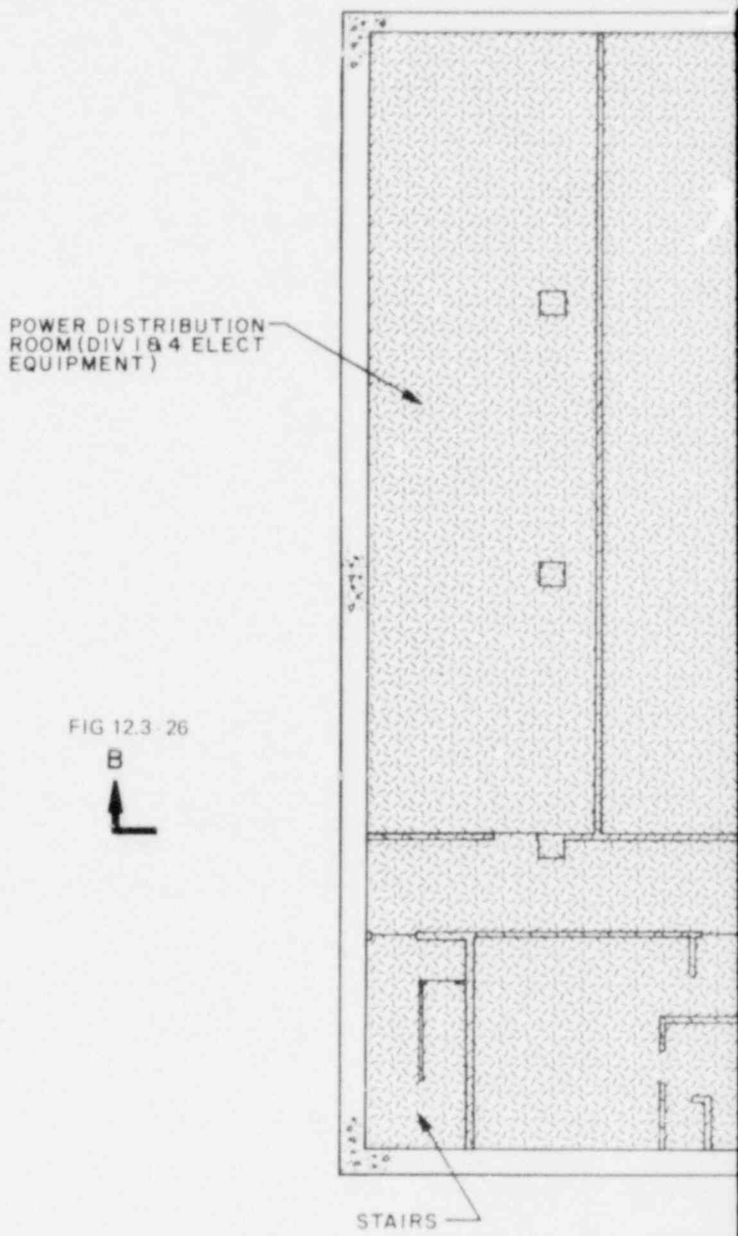


POST LOCA

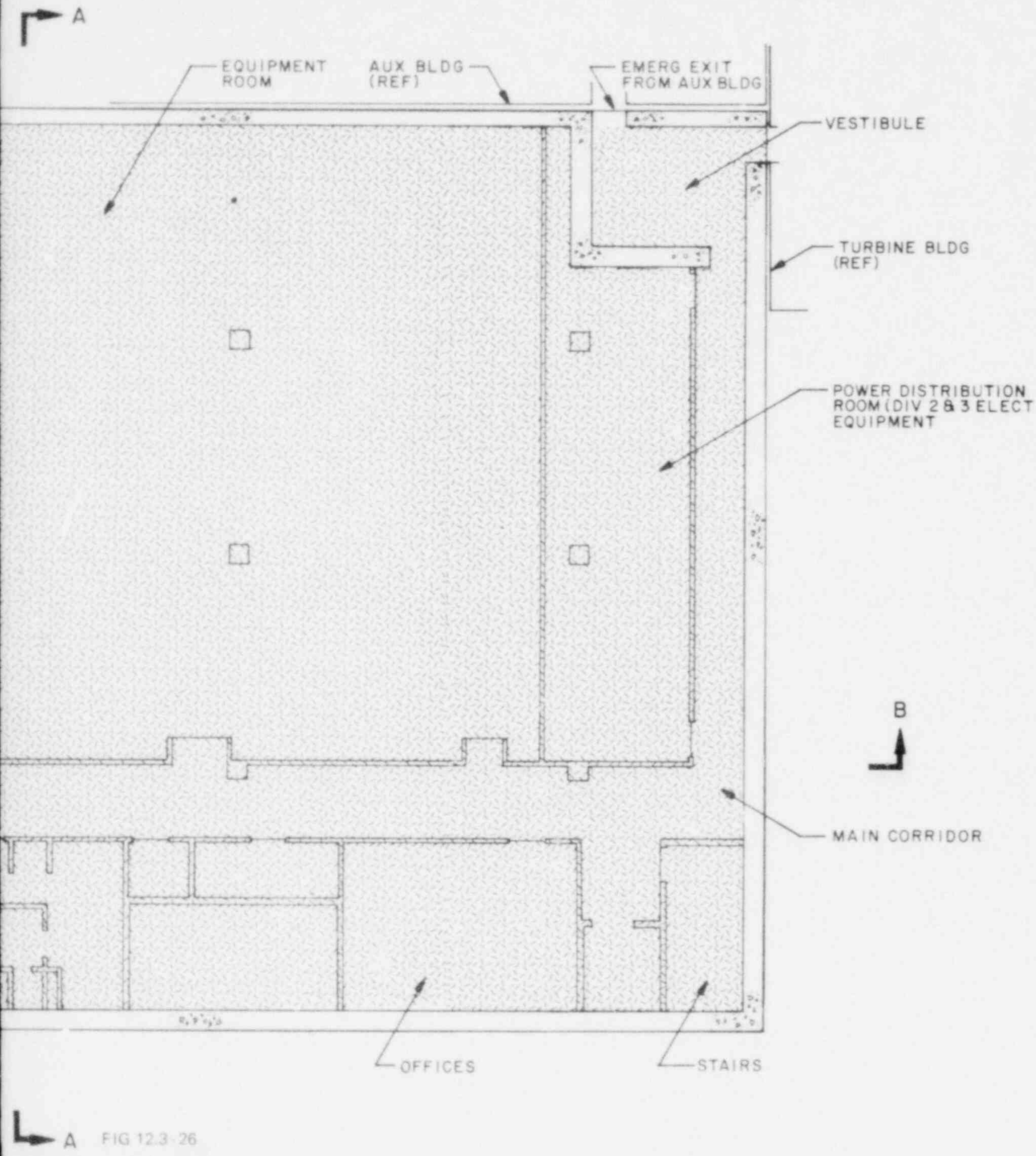
LEGEND

- ZONE A, < 1 mRem/hr
- ZONE B, 1-5 mRem/hr
- ZONE C, 5-20 mRem/hr
- ZONE D, 20-100 mRem/hr
- ZONE E, >100 mRem/hr

Figure 12.3-16. Control Bldg Radiation Zone Map Plan at El (-)6'10"



POWER DISTRIBUTION ROOM (DIV I & 4 ELECT EQUIPMENT)
FIG 12.3-26
B
STAIRS



POST
LOCA

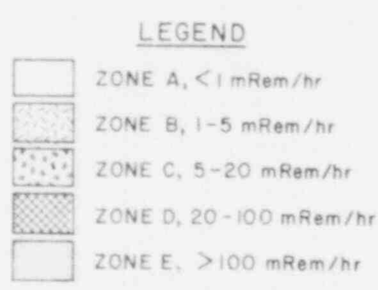


Figure 12.3-17. Control Bldg Radiation Zone Map Plan at El 11'0"

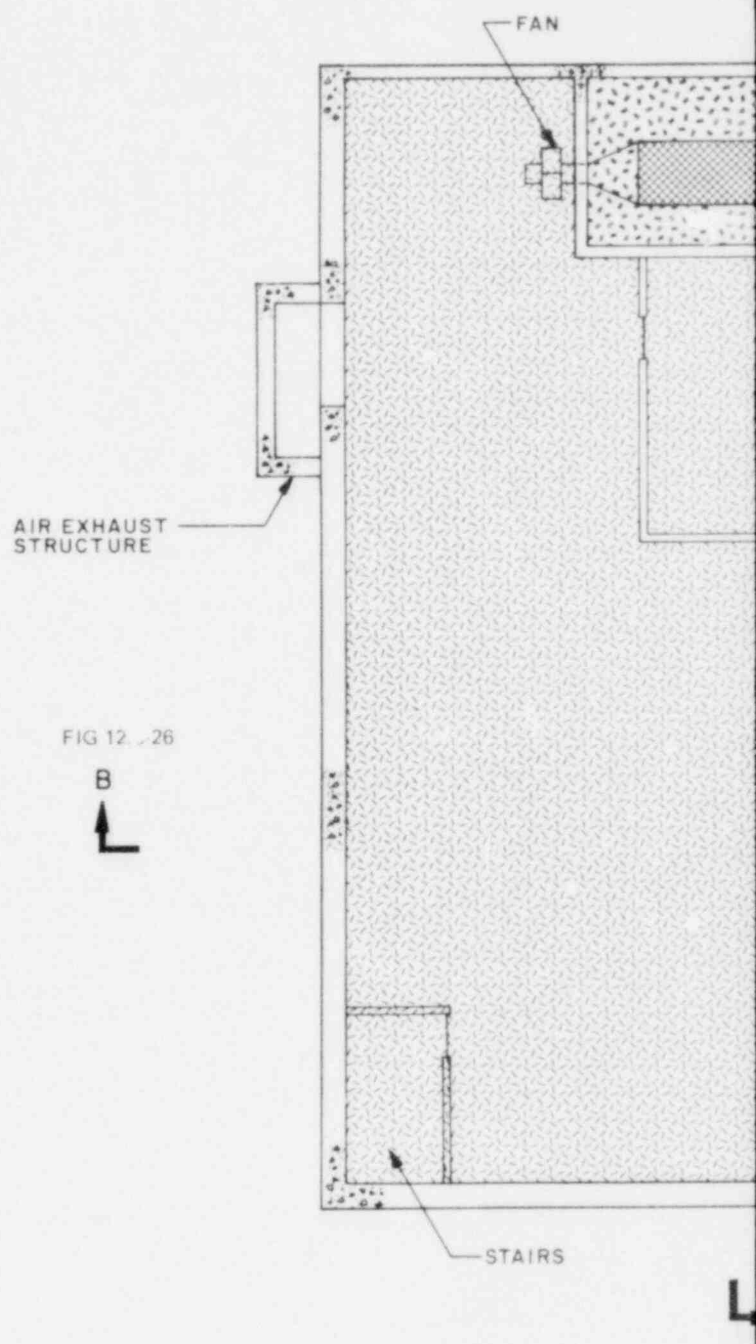


FIG 12. .26

B

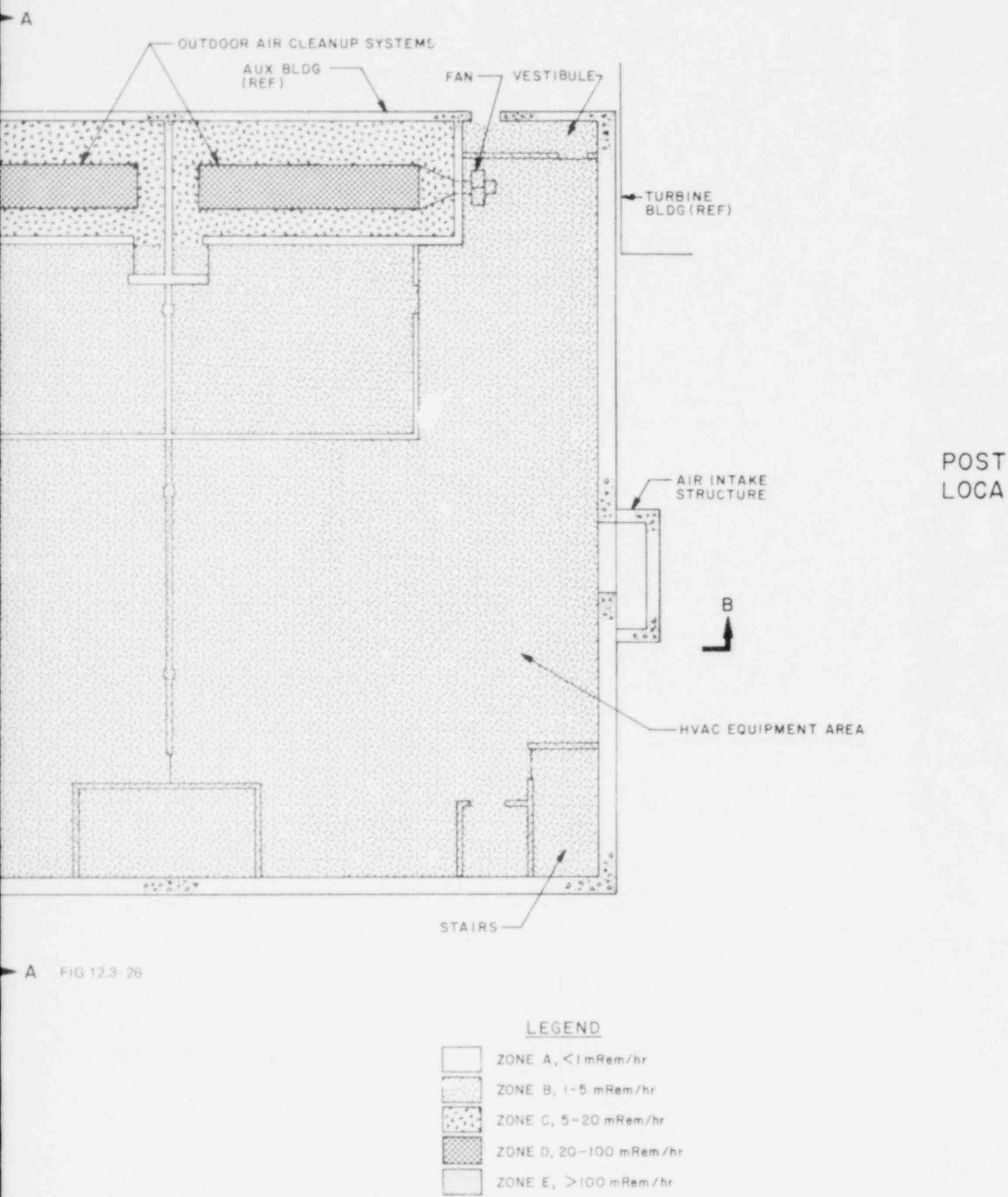
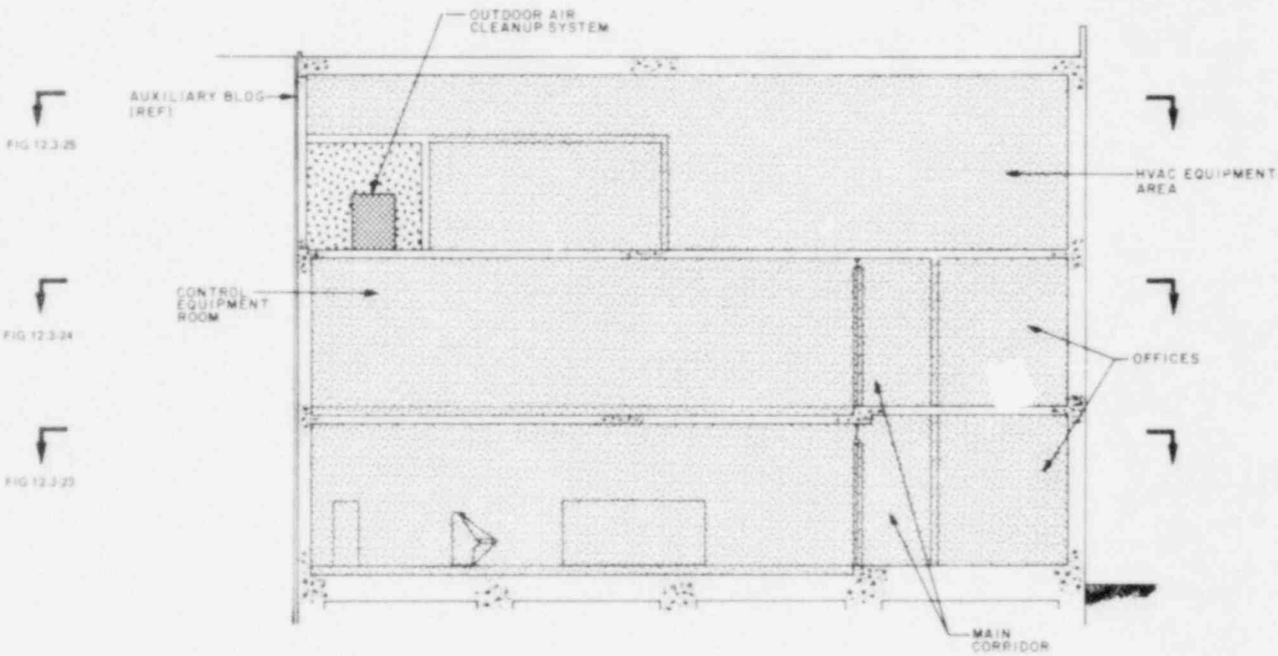


Figure 12.3-18. Control Bldg Radiation Zone Map Plan at El 28'6"

POST
LOCA



SECTION A - A
LOOKING EAST

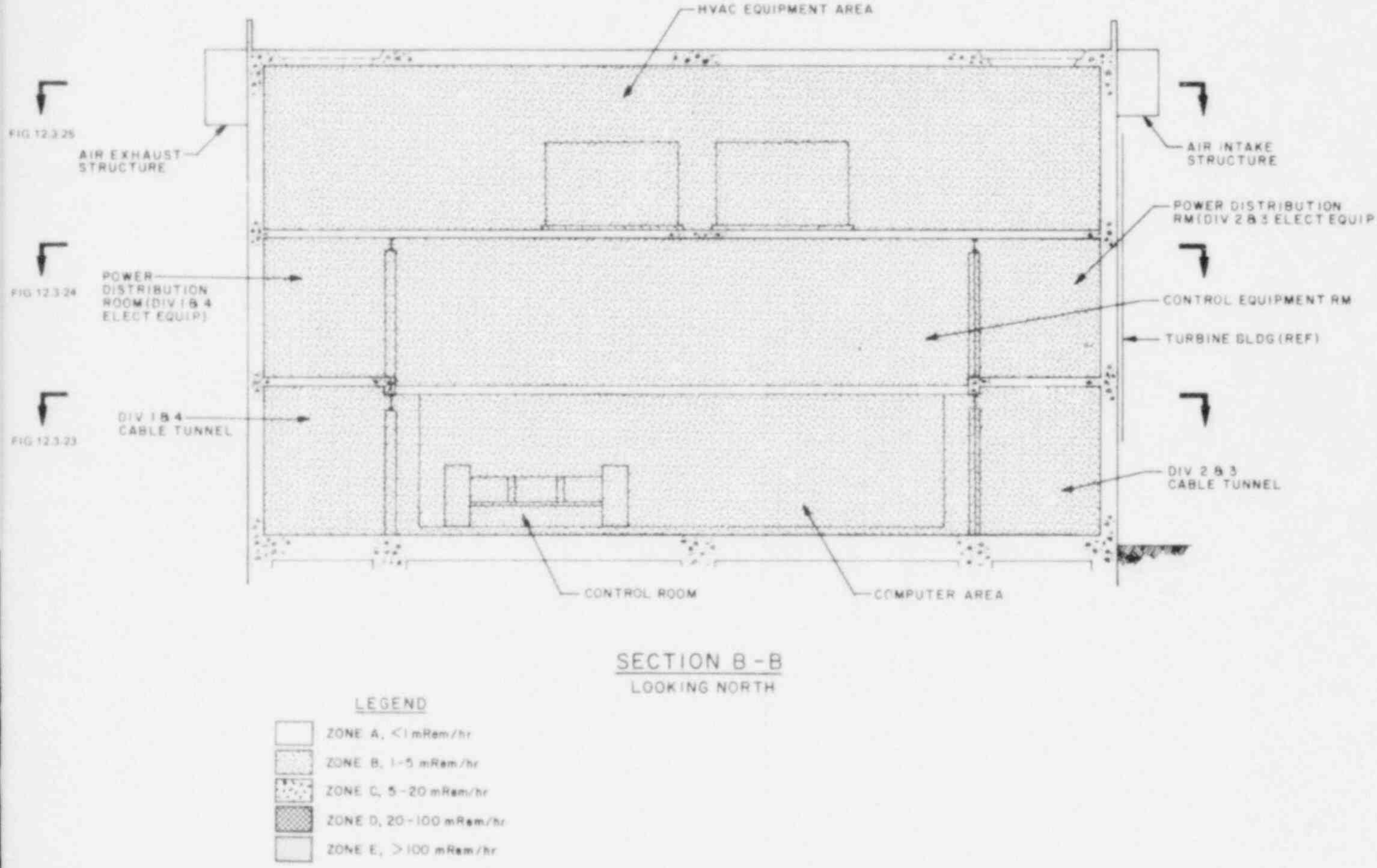


Figure 12.3-19. Control Bldg Radiation Zone Map - Sections A-A & B-B

SECTION 12.4

12.4 DOSE ASSESSMENT

(Applicant to supply.)

SECTION 12.5

12.5 HEALTH PHYSICS PROGRAM

(Applicant to supply.)