SYSTEM 80+™ STANDARD DESIGN INCORPORATES RADIATION PROTECTION LESSONS LEARNED

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ABSTRACT

Many lessons have been learned from the current generation of nuclear plants in the area of radiation protection. The following paper will outline how the lessons learned have been incorporated into the design and operational philosophy of the System 80+™ Standard Design currently under development by ABB Combustion Engineering (ABB-CE) with support from Duke Engineering and Services, Inc. and Stone and Webster Engineering Corp. in the Balance-of-Plant design. The System 80+™ Standard Design is a complete nuclear power plant for national and international markets, designed in direct response to utility needs for the 1990's, and scheduled for Nuclear Regulatory Commission (NRC) Design Certification under the new standardization rule (10 CFR Part 52). System 80+™ is a natural extension of System 80® technology, an evolutionary change based on proven Nuclear Steam Supply System (NSSS) in operation at Palo Verde in Arizona and under construction at Yonggwang in the Republic of Korea. The System 80+™ Containment and much of the Balance of Plant design is based upon Duke Power Company's Cherokee Plant, which was partially constructed in the late 1970's, but, was later canceled (due to rapid declined in electrical load growth). The System 80+™ Standard Design meets the requirements given in the Electric Power Research Institute (EPRI) Advanced Light Water Reactor (ALWR) Requirements Document. One of these requirements is to limit the occupational exposure to 100 person-rem/yr. This paper illustrates how this goal can be achieved through the incorporation of lessons learned, innovative design, and the implementation of a common sense approach to operation and maintenances practices.

INTRODUCTION

A common goal in the nuclear industry is to maintain personnel exposure as low as reasonably achievable (ALARA). The System 80+™ Standard Design has sought to incorporate those lessons learned by the current generation of nuclear power plants to achieve the EPRI ALWR Requirements Document's goal of limiting the personnel exposure to less than 100 person-rem/year.

The radiation protection philosophy of ALARA anchors a fundamental commitment to the safe operation of a nuclear power plant. This includes not only the protection of plant personnel, but also those who live and work in the surrounding communities. The concepts, outlined in Regulatory Guide 8.8, for maintaining occupational exposure ALARA are fundamental for the design, operation, and maintenance of a nuclear power plant. These concepts include time, distance, shielding and source term control.

The intent is to provide guidance for dose reduction. The concepts of time and distance are common sense. When performing an operational or maintenance activity, one should minimize the time spent in the radiation area. Conversely, one should maximize the distance between the personnel and the source of the radiation. Shielding or the placement of an absorbing material between the radiation source and the personnel should be used whenever possible.

Lastly, the control of the source term, can pay the best dividends for the reduction of dose. If the source term can be controlled through design improvements which reduce the sources of radioactivity and prevent the spread of contamination, then the exposure can be effectively reduced.

The following discussion will concentrate on these concepts and how these concepts have been implemented into the System 80+™ Standard Design.

WHERE ARE WE NOW?

Current operating nuclear power plants have developed ALARA programs for their respective plants. However, statistics have shown that the occupational exposures at Light Water Reactors such as McGuire, Catawba, and Oconee range between 167 to 310 man-rem/year on average per unit. A significant contribution to the overall occupational exposure is received while performing maintenance and station modification activities.

Reduction of occupational exposures could be achieved through the adherence to the ALARA concepts by an improved design, and better planning and execution of maintenance and operational activities. Unfortunately, redesign of the plant is not an option for most plants. However, the evolutionary plant designs ready for today's construction have implemented the wisdom from lessons learned in the current generation of nuclear power plants into their design.

DIRECTION FOR THE FUTURE

Design Features of System 80+™

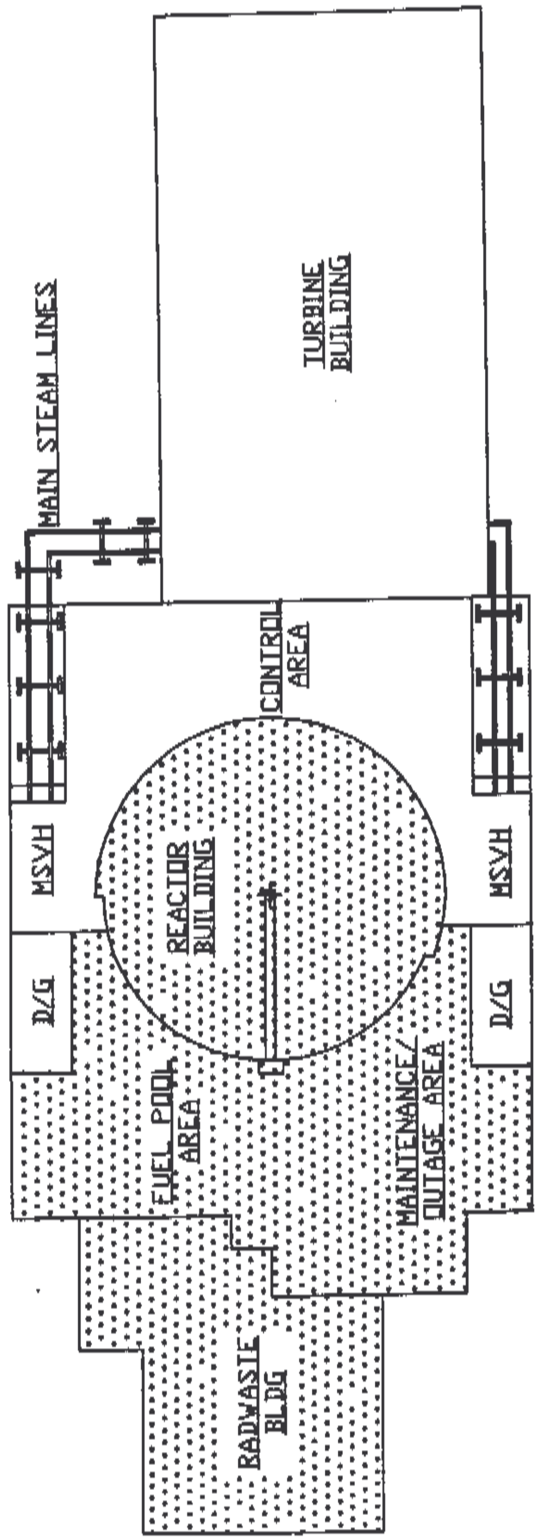
System 80+™ has incorporated many of the lessons learned by the current generation nuclear power plants. Each aspect of the ALARA philosophy of dose reduction, time, distance, shielding, and source term control has been considered in the design of the System 80+™ Standard Design. System 80+™ has unique design features that will result in a significant decrease in the occupational exposure.

General Arrangement

In the design of every plant careful consideration is given to the general arrangement of systems and their associated equipment. System 80+™ has incorporated some basic concepts into the general arrangement of the plant for dose reduction. These design features include the following:

Separation of radioactive systems from non-radioactive systems (See Figure 1) helps control the spread of contamination, minimize the necessity for routing piping containing radioactive fluids through personnel corridors, as well as the need for shielded pipe chases. It also simplifies the division of the plant into controlled and uncontrolled areas and aids in the unimpeded traffic through both the controlled and uncontrolled areas of the plant. Whenever possible, access to low radiation areas through high radiation areas is avoided; thereby, reducing the occupational exposure received.

FIGURE 1



SEPARATION OF RADIOACTIVE SYSTEMS FROM NON-RADIOACTIVE SYSTEMS

The Chemical Volume and Control System and the Fuel Pool Cleanup System are located in close proximity with the radwaste systems. This minimizes the pipe length and number of interconnections required to transfer of radioactive liquids, gases, or spent resin slurries, as well as the travel distance for transporting filters to the Solid Waste Management System. Again, this minimizes the length of piping that must be routed through access corridors.

Piping for radioactive systems is routed through shielded pipe chases. Ventilation, lighting, and adequate access area is provided for maintenance and inspection activities in the pipe chases. In addition, the number of active components located in the pipe chase has been minimized. This minimizes the frequency of access required into the pipe chase for maintenance activities.

The System 80+™ Standard Design has been designed to provide adequate spacing around equipment for easy access of equipment for maintenance. This includes provisions for an adequate laydown or equipment pull area, as well as a transport path for removal or replacement of equipment. Rigging and lifting equipment is also provided to facilitate the removal, transport, or placement of equipment or portable shielding during maintenance activities. This enables maintenance personnel to perform their task more efficiently reducing the time spent in a radiation area and therefore the dose. Space for maintenance laydown and access was one of the major reasons for selecting a large spherical containment for the System 80+™ design. The spherical containment with its 200 foot diameter provides considerable amount of floor space at the operating deck compared to cylindrical containments as illustrated in Figure 2.

Radioactive equipment are separated into compartments whenever possible. Equipment is compartmentalized based on frequency of access required, operational characteristics, and radiation level. For instance, ion exchangers containing resin beads are typically located in a separate compartment from the active components, such as pumps and valves. Valves are typically located in compartments called valve galleries.

Ion exchangers are located in pits with their associated spent resin service tanks located directly below the ion exchanger to minimize piping and the general area radiation. The compartment walls provide shielding. This enables personnel to perform operation and maintenance activities in a lower radiation area.

Hot tool cribs are located in low radiation areas adjacent to maintenance areas to minimize waiting times in high radiation areas, to help prevent the spread of contamination, and to decrease amount of decontamination work to be done; thus reducing radioactive wastes and personnel exposure.

A hot machine shop is provided adjacent to the equipment hatch (See Figure 3). This enables personnel to remove equipment from containment and perform maintenance in a low radiation area, thus reducing the radiation exposure. Access from the hot machine shop is also provided to the truck bays and maintenance areas for ease of equipment movement.

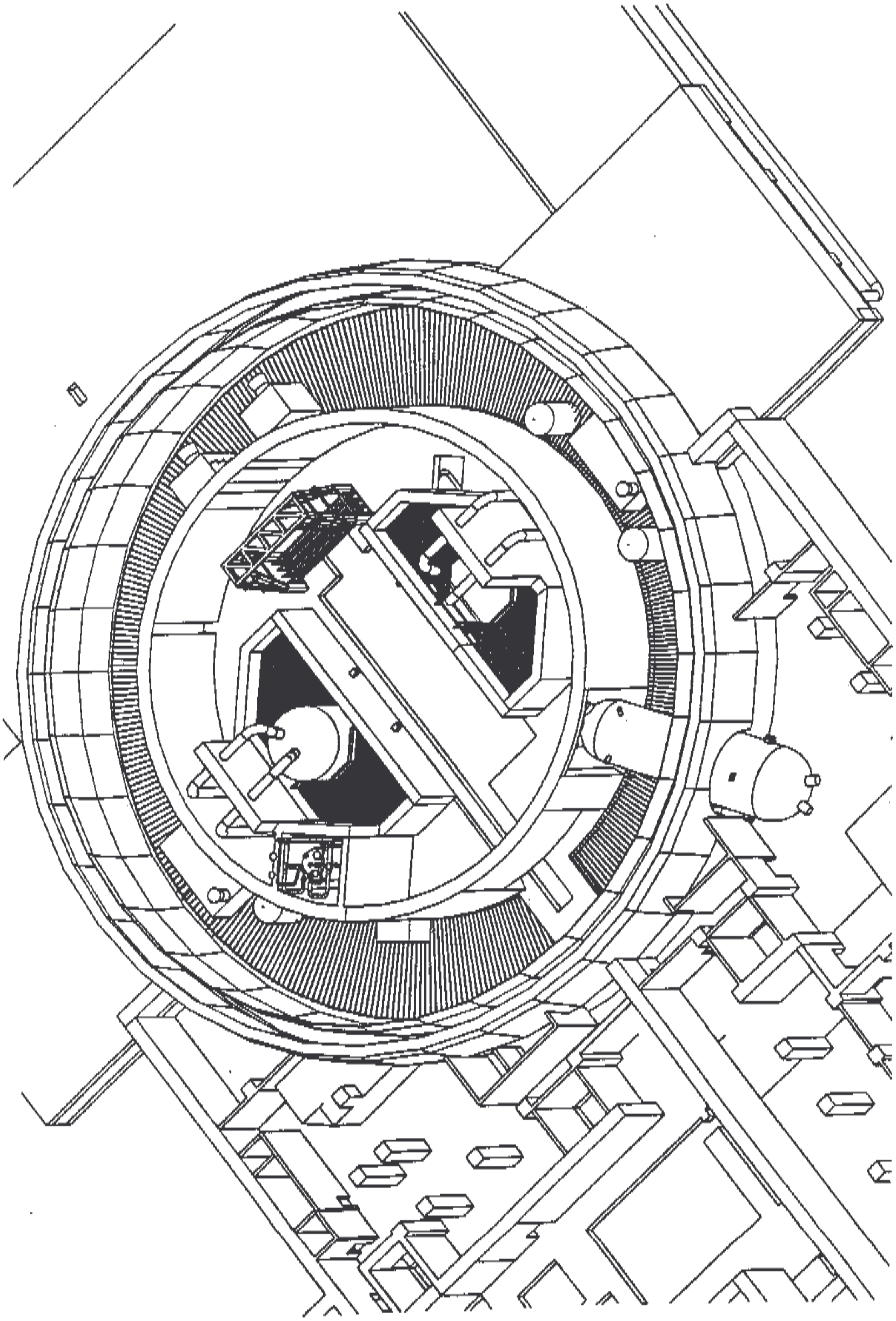
Large staging areas inside and outside the equipment hatch and personnel airlocks allow pre-staging prior to the start of an outage as well as, provide space for efficient radiation controls in moving equipment in and out of containment (See Figure 3).

Change areas are located near airlocks to minimize personnel traffic flow, distance to the work area, and the potential for the spread of contamination (See Figure 3).

The access area to the Radiation Control Area (RCA) provides a flexible and adaptable layout, a large area (40' x 100') sufficient to accommodate outage work crews and the availability of immediate interaction with radiation protection personnel. This area provides a single point of access and egress for the RCA (See Figure 4).

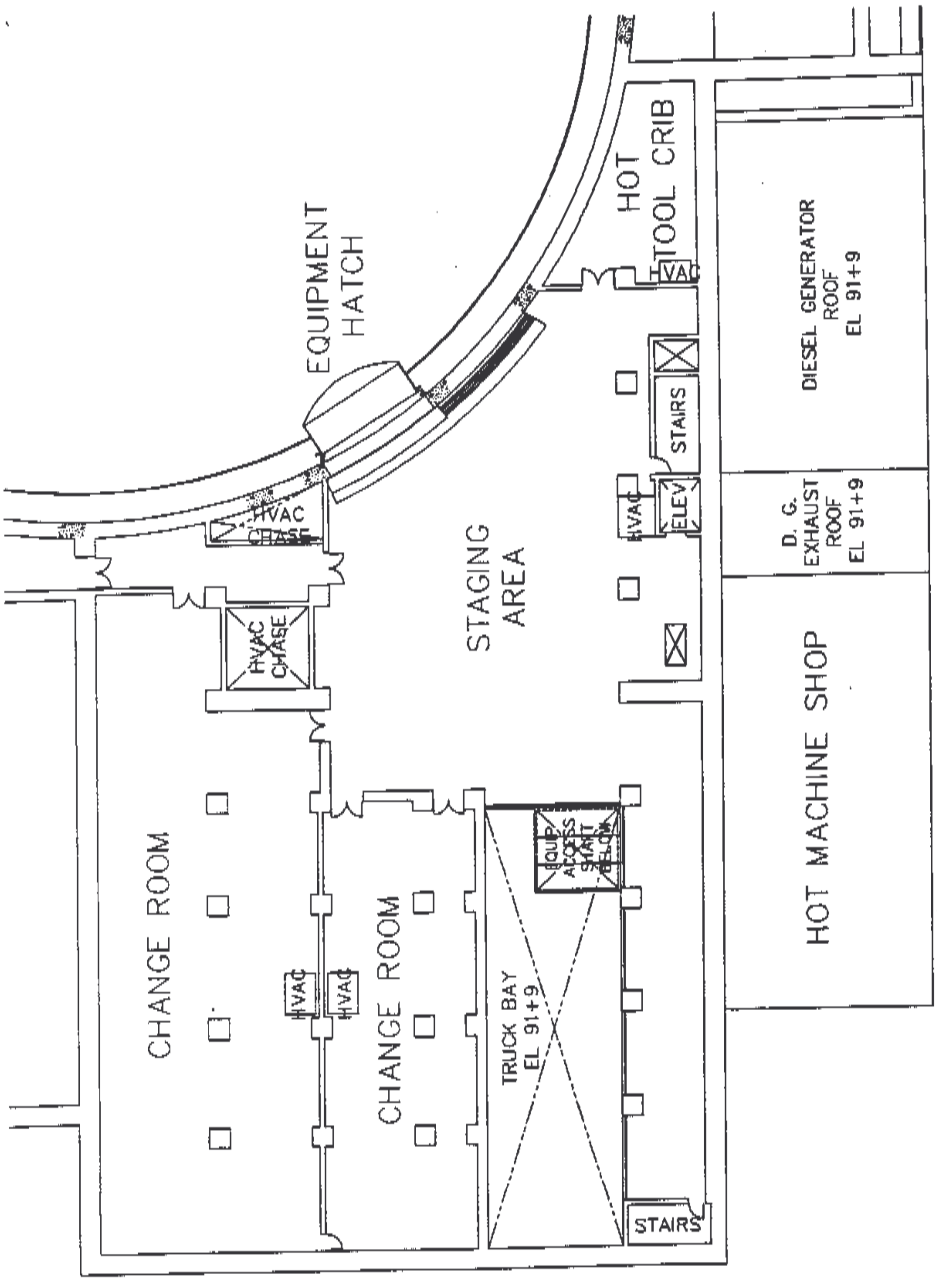
Transient sources greater than 100 R/hr are considered in the System 80+™ shielding design to ensure adequate shielding is provided. One such source is a spent fuel assembly. During transfer of a spent fuel

FIGURE 2



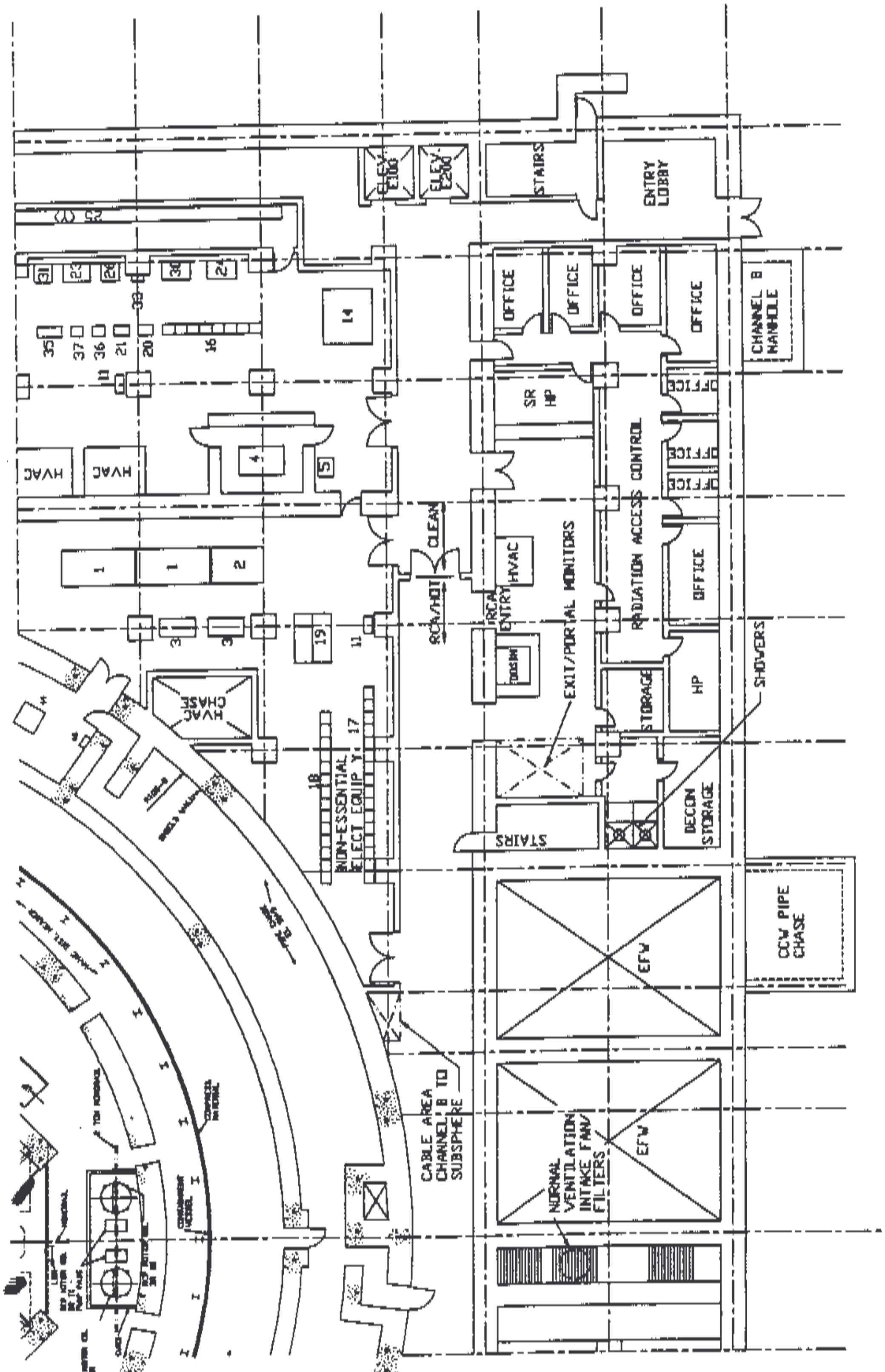
FLOOR SPACE AT OPERATING DECK
ALLOWS ROOM FOR MAINTENANCE

FIGURE 3



SYSTEM 80+ CONTAINMENT EQUIPMENT HATCH STAGING AND MAINTENANCE AREA

FIGURE 4



RADIATION ACCESS CONTROL AREA

assembly through the fuel transfer tube, adjacent corridors may experience elevated radiation levels. Streaming from this source up through the joint between the between the Reactor Building and the Nuclear Annex has been a concern for the current generation of nuclear plants. The System 80+™ design has the Reactor Building and Nuclear Annex on a common base mat which eliminates the shake space (joint) between the two buildings, thus the potential for streaming through this joint has been eliminated. In addition, a lead collar is provided around the fuel transfer tube, as well as several feet of additional concrete shielding to maintain adjacent corridor radiation level ALARA (See Figure 5). This permits personnel to perform maintenance and inspection activities in a lower radiation area and reduces the potential for adverse radiation zones from impacting refueling outage schedules.

The incore chase during incore instrumentation withdrawal is another potential area for a transient source greater than 100 R/hr. Positive access control is provided to this area during movement of the incore instrumentation. A lockable access door is provided with a warning light. During withdrawal of the incore instrumentation, the warning light illuminates providing indication that the incore instrumentation are being withdrawn. An area radiation monitor is located in the incore chase to provide indication of radiation levels and alarms when high radiation is in the area. An electrical interlock is provided between the radiation monitor and the access door to prevent access into the incore chase during withdrawal of the incore instrumentation. Emergency egress from the area is also provided.

Crud Control

Source term control is an important aspect of a nuclear power plant design. One-half to three quarters of the total dose received by personnel results from corrosion products or crud. Corrosion products result from activation of wear products or particulate in the reactor coolant as it passes through the core. Crud is then deposited in the reactor coolant system and interfacing system's piping and components.

Cobalt contributes significantly to the overall dose received during maintenance activities. Cobalt 58 and 60 are produced by the activation of materials containing cobalt and nickel impurities in primary system components.

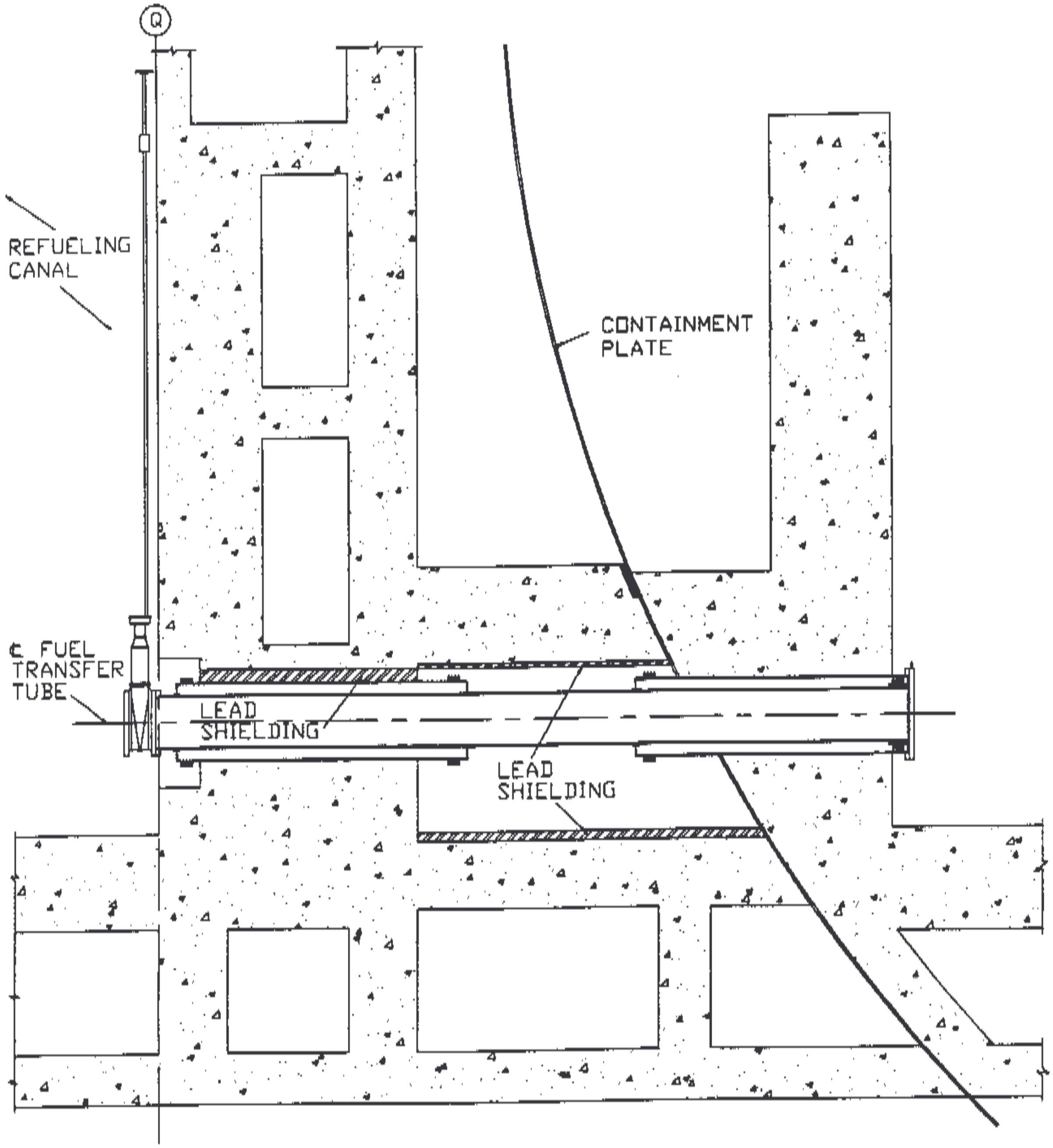
The presence of antimony in reactor coolant pump bearings has presented a problem with hot particles in the current generation of nuclear plants. The System 80+™ design minimizes the presence of antimony in the reactor coolant pump bearings.

To reduce the production of corrosion products in the primary system, System 80+™ Standard Design specifies that components in contact with the reactor coolant be fabricated from materials with low cobalt impurities ($\leq$ 0.020 w/o) and low corrosion rates. It has also been shown that an increase in reactor coolant water pH in the range of 6.9 to 7.4 reduces equilibrium corrosion rates and buildup of corrosion products on primary system surfaces. Therefore, the primary system chemistry will be operated in this range.

Equipment Selection and Design

System 80+™ specifies the use of more reliable and simplistic equipment. For instance, the use of evaporators in radwaste systems for decontamination of process flow streams in current plants has resulted in increased personnel exposure. The increase personnel exposure is primarily due to complexity of the system and the increased frequency of maintenance required by the system. The System 80+™ Standard Design has minimized the use of evaporators. With the exception of the Chemical and Volume Control System, which utilizes evaporators for boron recycle, ion exchangers are used almost exclusively for decontamination and purification of process flow streams. Ion exchangers are not only more simplistic in design, but are also more reliable and efficient. These design features reduce the frequency of maintenance and the dose received by personnel.

FIGURE 5



FUEL TRANSFER TUBE

Reactor Coolant Pump Seals

The System 80+™ reactor coolant pump seals are a cartridge type of design. This enables maintenance personnel to remove the seal as a unit and assemble and bench test it outside of high radiation areas. In addition, adequate platforms (See Figure 6) and space are provided for reactor coolant pump maintenance in addition to fixed lifting devices designed specifically for seal replacement.

Steam Generator Maintenance Improvements

Several improvements have been made in the System 80+™ design of the steam generator (S/G) to facilitate inspection and maintenance activities thus reducing the radiation exposure to maintenance and inspection personnel. These include the sizing and location of the manways, provisions for handholes and an internal hatch in the S/G, as well as the use of an improved S/G tube material.

The S/G tubes are Inconel 690 and are fabricated with the latest proven techniques to minimize residual stresses. This, along with maintaining appropriate secondary water chemistry, will greatly reduce the number of tubes required to be plugged; thus exposure time due to tube plugging is reduced.

The size of the manways are 21 inches. There are a total of four manways, two on the primary side and two on the secondary side. These manways provide access for eddy current testing and for inspection of the separator dryer, respectively. The steam generator manway locations are optimized for use of remote manipulators for inspection and maintenance. In addition, adequate platforms (See Figure 6) are provided to support S/G maintenance and inspection.

An internal hatch is also provided to access the top of the tube bundle for inspection and maintenance activities. At the tubesheet elevation, two eight inch handholes are provided. These provide access for tubesheet sludge lancing. They are also utilized to remotely inspect and retrieve loose parts. In addition, a twelve inch diameter access opening in the S/G support skirt is provided with removable insulation around that opening to facilitate inspection of the welds. Primary head draining capability is also provided which enhances accessibility for inspection and maintenance activities.

Reactor Vessel Head Vent

A vent nozzle and line is provided on the reactor vessel head to allow venting the gases to the pressurizer relief tank rather than the containment atmosphere; thus, reducing exposure during the head removal process.

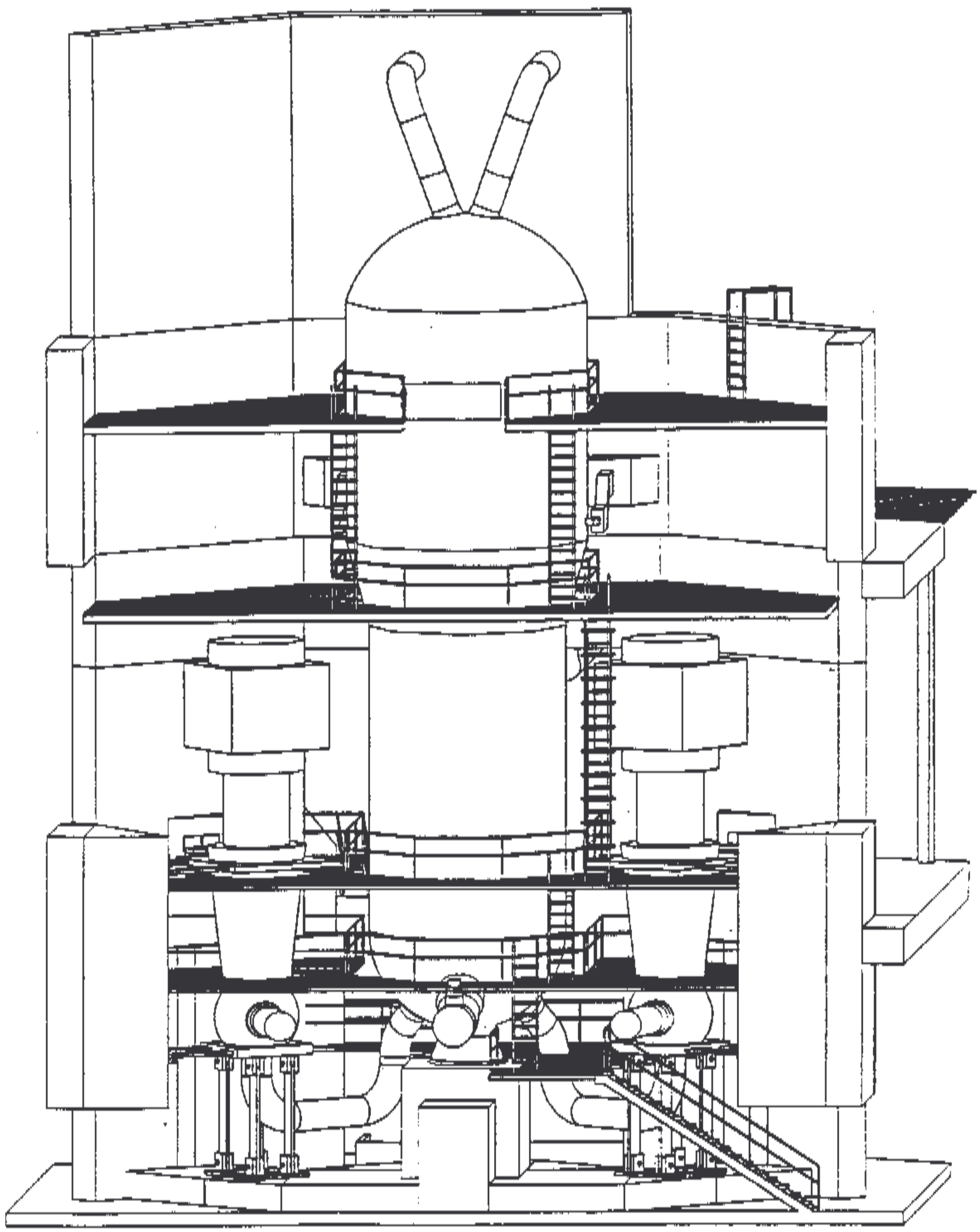
Ion Exchangers

Ion exchangers are designed for complete drainage. Spent resin removal is removed remotely by hydraulic flushing from the vessel to the Solid Waste Management System. Fresh resin addition is accomplished from a low radiation area above the shielded compartment housing the ion exchanger.

Filters

Filter housings are provided with vent connections and are designed for complete drainage. Filter housings and cartridges are designed to permit remote removal of filter elements. Cartridge filter seals are an integral part of the filter cartridge so that seal removal is accomplished during cartridge removal. Cartridge filter housing closure heads are designed to swing free for the unobstructed removal of the cartridge.

FIGURE 6



PLATFORMS FOR REACTOR COOLANT PUMP
AND STEAM GENERATOR MAINTENANCE

Tanks

Tanks are designed for complete drainage and are free of internal crevices and pockets. This is accomplished by providing either a convex or sloped bottom to the tank with the drain connection located at the lowest point. Vents are provided to facilitate the removal of potentially radioactive gases during maintenance. Non-pressurized tanks are provided with overflows, routed to a floor drain sump or other suitable collection point to avoid spillage of radioactive fluids.

Valves

Except for modulating valve applications, packless valves are used on all valves two inches and under in diameter. Modulating valves and valves greater than 2 inches in diameter use live loading of the packing by conical spring washers or an equivalent means to maintain a compressive force on the packing where possible. Double stem packing with a leak-off between the packing is used for valves four inches in diameter and larger. Stem leakage is piped to an appropriate drain sump or tank. Valves utilizing stem packing are provided with backseat capability. Radiation resistant seals, gaskets, and elastomers are utilized, when practicable, to extend the design life and reduce maintenance requirements. Fully ported valves are utilized to minimize internal accumulation of crud.

Reduction of Linear Feet of Welds

A System 80+™ Standard Design goal is to reduce the total linear feet of welds in the reactor coolant pressure boundary. This reduces the time necessary to inspect these welds in radiation areas, thus reducing the radiation exposure to personnel.

System 80+™ Standard Design eliminates the use of longitudinal welds in reactor vessel through ring forgings. The in-service inspection of these welds in the past has been quite time consuming

Seamless piping is under consideration to be utilized in the System 80+™ Standard Design of the Reactor Coolant System to minimize the number of welds requiring in-service inspection. This would reduce the amount of time required to inspect the welds located in radiation areas, thus reducing the radiation exposure to personnel.

The inspection of the reactor pressure boundary can be done with remote equipment to minimize personnel exposure. The design of welds joining the reactor vessel nozzle to the reactor coolant pipe permits in-service inspection to be accomplished from the inside diameter of the reactor vessel. Automated equipment, operated remotely normally used for reactor vessel pressure boundary inspections, can be utilized in this area.

Blanket type thermal insulation is utilized, wherever practical, held in place by Velcro fasteners. A metal jacket around the insulation is provided and held in place by quick actuation type buckle fasteners. This insulation is easily removable and will facilitate the performance of in-service weld inspections, thus reducing the time spent in contaminated areas.

Radwaste System Design

Waste is segregated by radiation level, physical and chemical characteristics, and the type of waste (solid, liquid, or gaseous). By segregating the waste streams, the processes can be tailored to the unique characteristics of each waste stream. This improves the efficiency of the process and prevents the mixing of waste streams, thus minimizing the radiation exposure to personnel.

Radiation Monitoring

Radiation monitoring in the plant is an essential part of maintaining occupational exposure ALARA. System 80+™ Standard Design's Radiation Monitoring System provides early warning to station personnel of equipment, component, or system failures which may represent a potential radiological hazard via area radiation monitors and process system monitors.

Area radiation monitors provide essential information to the plant health physics staff planning operations or maintenance activities in radiation areas.

Process flow monitors provide for the continuous monitoring capability of gaseous and liquid effluent discharges from the plant. These monitors provide necessary information to estimate the dose consequence to plant personnel and the general public in the event of a design basis accident.

The design features of the Radiation Monitoring System enable the operator to monitor, assess, and evaluate information from a central location via a digital communications network. The digital communications network interfaces the Data Processing System (DPS) and Discrete Indication and Alarm System (DIAS) with each monitor microprocessor. Via the DPS and DIAS systems the operators can obtain detailed information of monitor readings, alarm setpoints, and operating status. The digital communications network enables the operator to access information on monitor configuration and historical trends, as well as diagnose problems from operation status alarms.

In addition, the Radiation Monitoring System design enables the operator to control monitor operation from dedicated operator control modules. Dedicated operator control modules are utilized to change microprocessor database items, initiate certain monitor control functions, and change monitor alarms setpoints. These control functions include starting and stopping sample pumps, manual checksource actuations, monitor purge initiation, and moving the filter paper advance. This design incorporates state of the art technology in the design of the Radiation Monitoring System.

Adequate shielding is also provided for each process, effluent, and airborne monitor. This ensures that the required sensitivity is achieved to provide an accurate radiation level readout at the design background radiation level for the area.

Airborne Contamination Control

The primary means of airborne contamination control is through prevention of its generation. Part of the System 80+™ operational and maintenance philosophy will be to minimize the generation of airborne contamination. This is accomplished by first recognizing the sources of contamination and then implementing airborne contamination control techniques. Airborne contamination can be generated by normal leakage of valves, seals, pipe flanges, etc., as well as during maintenance activities such as welding, machining surfaces, and grinding. Control of this contamination and reduction of occupational exposure can be accomplished through the proper use of containment devices such as drip containment, glove bags, and tents.

Plant ventilation systems are designed to prevent the spread of airborne contamination and minimize the exposures to both plant personnel and the public. In the System 80+™ Standard Design, plant ventilation systems are designed so that flow is from areas of lower to areas of higher potential activity. Potentially contaminated areas will be maintained at slightly lower pressure than non-contaminated or clean areas. Areas that have a potential for high airborne radioactivity, such as fuel storage areas, will be maintained at a negative pressure to ensure no outflow of radioactivity into a clean area.

Shielding

Permanent and temporary shielding is an integral part of the System 80+™ Standard Design. Permanent shielding is used where possible. For instance, System 80+™ Standard Design provides shielding between redundant components of an operating system. This reduces the dose to personnel performing maintenance on one component while the other component is operating. The location and design of labyrinths are also considered in plant layout. Labyrinths are provided for entrances in all high radiation rooms.

Portable shields, such as lead blankets and pigs, will be used during maintenance activities if the total exposure, which includes exposure received during installation and removal of the shielding, is reduced. Removable/portable shielding in the form of bricks and concrete blocks will be avoided. Rigging and transport paths are also provided in the design of the System 80+™ Standard Design for the removal of the shielding as necessary.

INFORMATION MANAGEMENT SYSTEM

The System 80+™ design is provided on an Information Management System (IMS). This IMS provides an effective means of acquiring, storing, retrieving and manipulating the documents and data necessary to design, construct, startup, operate, and maintain the plant. The System 80+™ IMS utilizes an existing computer program that is in operation within Duke Power Company called PASCE as its base program. PASCE currently store two dimensional drawing data in a hierarchical database called PLANT-SCHEMA. Three dimensional drawing data is stored in a hierarchial database call PLANT-VIEW. The System 80+™ plant layout is currently provided on the three dimensional graphics/data model within PASCE PLANT-VIEW. This model can be used in future plant operations for entering and developing three dimensional dose maps (See Figure 7). These dose maps can be generated within PASCE which integrates the plant layout graphics with specific area information, such as dose rate and source location(s) measured and entered by health physics personnel. This information can be readily used by health physics personnel to estimate the dose, as well as by personnel in the field to effectively implement the ALARA principles of time, distance, and shielding during maintenance activities. In addition the three dimensional model can be utilized for maintenance personnel in preplanning their maintenance activities and locating electrical and service connections. This allows pre planning without entering the radiation protection area, thus reducing occupational dose.

Duke Power has modeled their McGuire and Catawba Nuclear Stations on PASCE and currently utilize PASCE for developing three dimensional dose maps and for maintenance and outage planning. PASCE also interfaces with a program called PASSPORT which allows work request to be developed including the dose information for the area, dress out and dosimetry requirements. Duke Power Company experience has found that PASCE has considerably reduced the time personnel spend in the radiation protection zone for visual inspection for planning purposes and thus has reduce operation dose.

DOSE ASSESSMENT

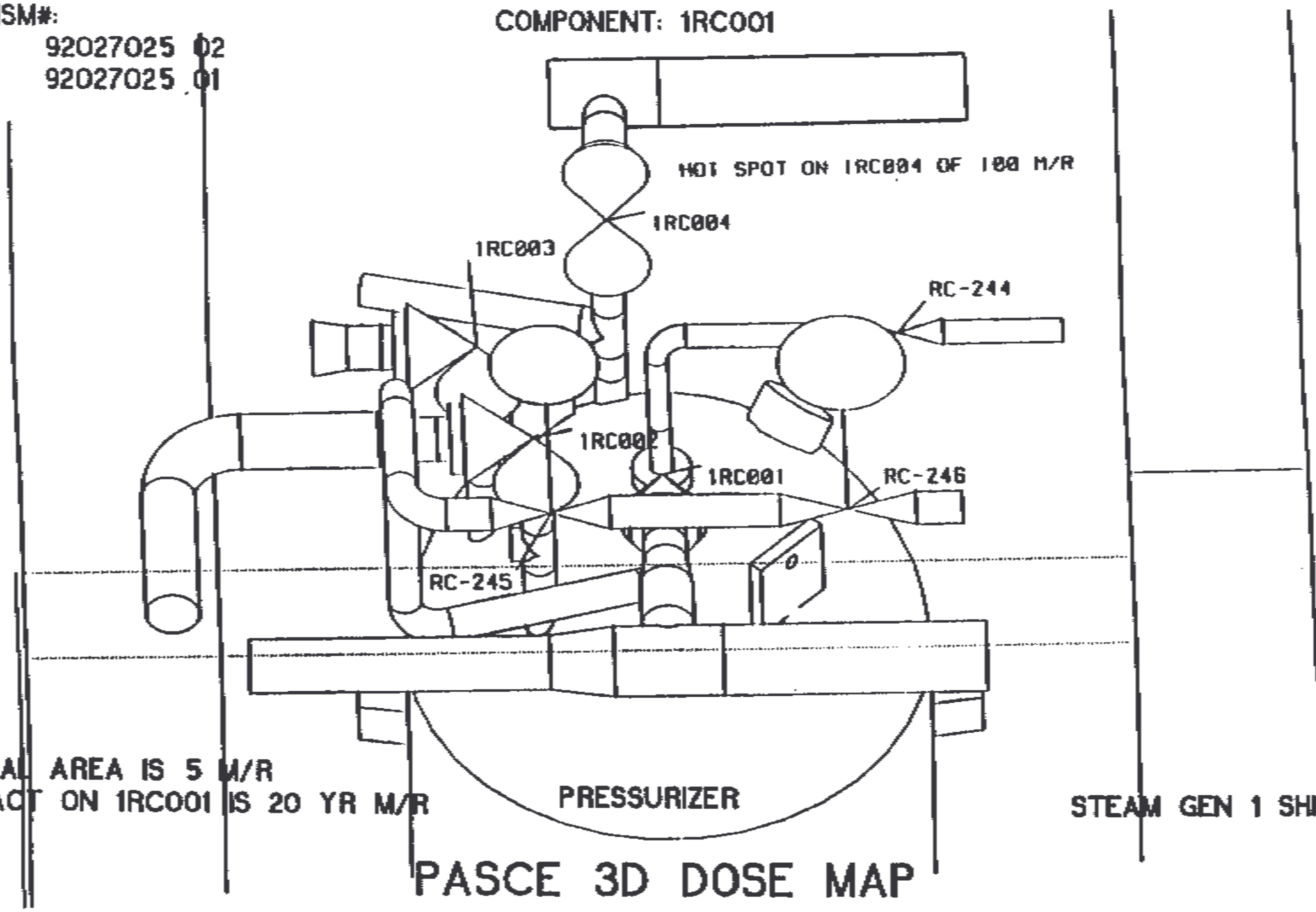
Many design features which reduce operation exposure have been discussed above and implemented into the System 80+™ design. The two most important features which will reduce the annual exposure and allow the EPRI ALWR goal of 100 person-rem/yr to be meet are source term control through the reduction of cobalt and the steam generator material, fabrication, maintenance and inspection improvements that have been incorporated into the System 80+™ design.

The annual exposure at Duke Power Company's seven Pressurized Water Reactors (PWRs) for 1989 is shown in Table 1. This results in an annual average exposure of 235 person-rem per unit. This table also shows the percentage of annual exposure resulting from each major maintenance task.

FIGURE 7

SYSTEM 80+ NUCLEAR STATION
BASIC / DETAILED ALARA PLANNING WORKSHEET

MAINTENANCE MANAGEMENT PROCEDURE 1.9
ENCLOSURE 5.1
WO#/NSM#:
92027025 02
92027025 01



PASCE 3D DOSE MAP
AND WORK OUTAGE PLAN

Table 1. PWR Reference Plant Data

	Oconee 3 Unit	McGuire 2 Unit	Catawba 2 Unit
Total Exposure (person-rem)	684	620	334
Average Per Unit (person-rem)	228	310*	167
Number of Refueling Outages	3	1	1
Refueling Exposure (% of Total)	77	67	67
Breakdown by Task (% of Total)			
Routine Operation and Maintenance	21	19	22
Steam Generator Inspection and Maintenance	20	36*	22
RV Head Inspection and Maintenance	19	5	8
Valve Maintenance	11	18	21
General Entry and Surveillance	8	5	11
Nuclear Station Modifications	5	6	1
Inservice Inspections	5	4	5
Reactor Coolant Pumps	3	3	5
Decontamination	8	4	5

*Impacted by Abnormal Occurrence, i.e., Steam Generator Tube Rupture.

One-half to three-quarters of all occupational exposures are related to exposure to activated corrosion products. Minimization of primary system corrosion and resultant dose rates will most effectively reduce total station occupational exposure, reduce effluent releases and radwaste activity. The combined effectiveness of proper material selection and chemistry control has reduced dose rate fields by as much as a factor of 5 in existing PWRs.

Leakage of fuel rod cladding accounts for the remaining one-quarter to one-half of sources of PWR occupational exposure. The fuel rod performance of the System 80+™ design is expected to reduce fuel leakage to below 0.1%. This is a factor of 2 to 4 better that average PWR fuel clad performance. This feature also is expected to reduce effluent releases and radwaste activity.

It is expected that proper material selection, chemistry control, and improved fuel cladding leakage will reduce the Annual Occupational Exposure by a factor o 2.5 compared to Duke Power Company's Oconne, McGuire and Catawba plants. These plants currently try to reduce operational exposure through pH control of the RCS and removal of fuel rods that have excessive leakage during refueling. However, these plants did not consider material selection of low cobalt content during their construction. As stated above the System 80+™ design is committed to selecting materials that have a cobalt content of less than 0.02 w/o for piping and equipment in direct contact with the RCS. The steam generator tubes will have a cobalt content of less than 0.015 w/o.

The design features described above for steam generator maintenance and inspection will greatly reduce time spent in performing this maintenance and inspection. This task represent approximately 25% of the total station dose for the average PWR system.

The dose received during an outage due to steam generator maintenance is dependent on the number of tubes requiring inspection and repair. Duke Power Company's McGuire Units 1 and 2 and Catawba Unit 1 steam generators have seen a considerable amount of primary side tube stress corrosion cracking. This results in a considerable amount of time inspecting and repairing the steam generator tubes by plugging or sleeving. In addition, McGuire had a steam generator tube rupture which has resulted in the performance of 100% bobbin coil testing of the hot leg tubes. This has also resulted in finding considerably more tubes requiring repair. The number of steam generator tubes to be inspected is dependent on the past history of the steam generator and previous problems. A plant in which the steam generators have not seen significant problems with tube cracking are only required to perform a 20% bobbin coil eddy current testing.

The McGuire and Catawba steam generator problems can be attributed to the lack of thermal treatment of the steam generator tubes and other manufacturing techniques. The System 80+™ steam generator design provides thermal treatment of the steam generator tubes and has avoided the manufacturing techniques that have caused past problems with steam generator tube cracking. In addition the steam generator tubes are fabricated from Inconnel 690 compared to Inconnel 600. Inconnel 690 has proven to be less susceptible to steam generator tube cracking.

The Palo Verde steam generator tubes are fabricated of Inconnel 600 and are thermally treated. Palo Verde has not seen the tube cracking problems experienced by McGuire and Catawba. This has resulted in a considerable difference in the annual dose received for steam generator tube inspection and repair. Palo Verde has seen an average refueling outage exposure due to steam generator maintenance of 39 person-rem compared to Duke Power Company's average of 62 person-rem. Therefore, a factor of 1.6 reduction in annual occupation exposure is expected for steam generator maintenance from these improved manufacturing techniques and material selection compared to the Duke Power Company average. The System 80+ has several additional features which are not provided on Palo Verde or the Duke Power Company units as described in Section 4.1.3.2. These features will reduce the time spent performing the steam generator maintenance and thus, are expected to reduce the annual occupational exposure due to steam generator inspection by a factor of 1.5. In addition a factor of 2.5 reduction is expected from reduction in cobalt, chemistry control and fuel performance as described above. Therefore all of the above System 80+ features will result in an overall reduction of the annual occupational exposure due to steam generator maintenance of a factor of 6.

The System 80+™ estimated annual occupational exposure is shown in Table 2. It is estimated that the System 80+™ annual occupational exposure will be 79 person-rem/yr or less with proper operational ALARA techniques. This is less than the EPRI ALWR goal of 100 person-rem/yr.

Table 2. System 80+ Estimated Annual Occupational Exposure

Task	PWR Avg. (%/man-rem)	ALARA Reduction	System 80+ Estimate (man-rem)
Routine Operation and Maintenance	21/48	2.5	19
Steam Generator Inspection and Maintenance	25/62	6	10
RV Head Inspection and Maintenance	12/27	2.5	11
Valve Maintenance	16/37	2.5	15
General Entry and Surveillance	8/17	2.5	7
Nuclear Station Modifications	4/11	2.5	4
Inservice Inspections	5/11	2.5	4
Reactor Coolant Pumps	3/8	2.5	3
Decontamination	6/14	2.5	6
Total	100/234		79

CONCLUSION

Many of the dose reductions techniques highlighted in this discussion are common sense. These dose reduction techniques are not new. However by applying these techniques early in the design stage, the cumulative effect of their implementation in the design of the System 80+™ Standard Design, as well as use of state of the art equipment, will have a long term beneficial impact on the occupational exposure and the radiation protection of the personnel and the public.

Author Biography

Thomas D. Crom is an Engineering Supervisor at Duke Engineering & Services, Inc. and is Duke Engineering's Project Manager for ABB-CE's System 80+ Design Certification Project. Mr. Crom has been directly involved with this project and the associated development of the Electric Power Research Institute Utilities Advanced Light Water Reactor Requirements Document since November 1985. Prior to working on advanced light water reactor projects he was involved in system design, pipe stress analysis and pipe support restraint design for Duke Power Company's Catawba Nuclear Station. He has a B.S. in Mechanical Engineering from Virginia Polytechnic Institute and is a registered Professional Engineer in the states of North and South Carolina.

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PAPER 3-5
DISCUSSION

Klazura: You mentioned that the System 80+ is the first plant licensed to the new source terms. Does that include the design basis normal operations source terms. In other words, is shielding designed to a quarter percent failed fuel instead of the one percent failed fuel?

Crom: Shielding design is done to one quarter percent failed fuel. We had to do effluent analysis for rad waste systems to one percent failed fuel for the 10 CFR 20 limits. The new source term I was talking about is more for the design basis accident. System 80+ is the first plant to go through the licensing process utilizing the new source term for off-site dose for Chapter 15, and is also used for the shielding design post-accident.

Na: You have made a lot of improvements to steam generators. Why don't you consider, for the future, to replace steam generators. I saw your steam generators slide down and go in. Once you made it that way, it would be nice if you could make some configuration that can bring it back for future replacement. Did you consider that?

Crom: I was showing the removal, but the replacement would go through the same means.

Na: The same out?

Crom: Yes. Through the same equipment hatch. One piece.