ALARA RADIATION CONSIDERATIONS FOR THE AP600 REACTOR

Fred L. Lau
Radiation Engineering and Analysis
Westinghouse Electric Corporation
Nuclear Technology Division
P.O. Box 355
Pittsburgh, PA 15230-0355

INTRODUCTION

The radiation design of the AP600 reactor plant is based on an average annual occupational radiation exposure (ORE) of 100 man-rem. As a design goal we have established a lower value of 70 man-rem per year. And, with our current design process, we expect to achieve annual exposures which are well below this goal. To accomplish our goal we have established a process that provides criteria, guidelines and customer involvement to achieve the desired result. The criteria and guidelines provide the shield designer, as well as the systems and plant layout designers with information that will lead to an integrated plant design that minimizes personnel exposure and yet is not burdened with complicated shielding or unnecessary component access limitations. Customer involvement is provided in the form of utility input, design reviews and information exchange. Cooperative programs with utilities in the development of specific systems or processes also provides for an ALARA design. The results are features which include ALARA radiation considerations as an integral part of the plant design and a lower plant ORE. It is anticipated that a further reduction in plant personnel exposures will result through good radiological practices by the plant operators.

The information in place to support and direct the plant designers includes the Utility Requirements Document (URD), Federal Regulations, ALARA guidelines, radiation design information and radiation and shielding design criteria. This information, along with the utility input, design reviews and information feedback, will contribute to the reduction of plant radiation exposure levels such that they will be less than the stated goals.

RADIATION GUIDELINES AND CRITERIA

The URD is an important part of the design package, as this document contains the customers requirements for future nuclear plants. The document is several volumes in size and addresses plant features that current plant operators prefer in nuclear plant designs. An example of the URD requirements for reducing personnel radiation exposure is the stipulation that an ORE assessment of maintenance activities must be made to confirm that man-rem requirements and objectives can be met. Robotic analyses for key maintenance activities, in conjunction with a maintainability evaluation program that includes consideration for in-service inspections, are also required.

ALARA guidelines also provide information to aid the systems and plant layout designers in the implementation of methods that will maintain radiation doses ALARA. The guidelines provide typical radiation fields adjacent to plant components and systems and various methods to avoid or reduce the radiation exposure to workers during plant or system maintenance or repair. The guideline for each plant component provides guidance and recommendations regarding component accessibility, maintainability, material impurities, location and good design features. A checklist can be used by the designer to judge whether the design meets the requirement of ALARA.

A check on the effectiveness of the process and the ALARA guidelines is provided by periodic evaluations of the expected annual radiation dose from planned AP600 plant operational activities. A compilation of the predicted doses in 1991 indicated that the average annual ORE will be less than 70 man-rem per year. Much of the shielding arrangements and systems information available at that time has since been upgraded, thus this estimated dose has now become an upper limit (goal) for radiation exposure from plant operation and maintenance activities. An upgrade of the evaluation is in progress in order to reflect the more recent incorporation into the shield and arrangements design of additional design features and methods which will reduce the estimated ORE.

Radiation design information for the AP600 includes design basis radiation source values for the various plant components and for postulated accident scenarios. The source values are also used in design efforts for waste handling and disposal and in planning to minimize associated radiation exposures to plant personnel. The plant parameters and assumptions used to develop the source terms are chosen such that calculated results are realistic without being over conservative. It is important that the design basis data contain some margin for unforeseen future considerations, but it is also important that the plant costs not be greater than necessary because of unidentified conservatism.

The radiation and shielding guidelines and criteria for the AP600 includes the requirements of the Code of Federal Regulations, Regulatory Guides, the URD and the ALARA guidelines. The plant specific radiation zone and access requirements and the access control criteria also are a part of the designers guidelines and criteria.

CUSTOMER (UTILITY) INPUT AND FEEDBACK

Utility input and feedback is an important part of our ALARA program as it provides insight into the actual operation and maintenance of plant systems and components. It is provided, in part, through the URD, and also through the effective involvement of the Advanced Reactor Corporation (ARC). This type of information is also provided through utility participation in design reviews, solicited input regarding system designs and area layout efforts and through joint programs for the development of process and procedure improvement.

An example of a joint program is one currently in progress with a utility to develop an improved process for handling waste such as contaminated filters, resins and other contaminated articles. The extensive use of robotics and remote operations is an expected result of this program. Another example of utility involvement is their participation in the maintainability evaluation of plant equipment on a cubicle by cubicle basis. This evaluation will include the use of robotics and consideration for in-service inspections. Utility participation in plant area access control is also a vital part of the plant arrangement effort which will minimize exposure in a cost effective manner.

Although not a customer, the Architect Engineering Firms involved in the plant design also provide significant input to the ALARA program through their participation in design reviews, planning sessions and general comments.

PROCESS RESULTS THAT SUPPORT THE ALARA GOAL

Plant Simplification

Several considerations have been designed into the AP600 which will reduce radiation exposures to plant personnel in a cost effective manner. This includes a larger containment which allows space for equipment laydown without crowding. This will reduce or eliminate the need to perform tasks where radiation from adjacent equipment is contributing to the worker dose. It has also allowed the use of a clearly defined clean area which is distinctly separate from the radiation control area (RCA). The containment design also provides an equipment hatch such that a truck can be driven directly into containment, thus simplifying the removal or return of equipment or plant components.

The plant buildings are close coupled so that the movement of equipment is simple and direct. One unique feature in the Annex Buildings is the inclusion of a "hot" maintenance shop which is designed to accommodate reactor coolant pump repair as well as other tasks on contaminated equipment. The layout of this facility as well as of the building has been reviewed by the ARC and utility personnel to insure optimum locations for the various rooms and functions of the building.

Other simplifications of note is the significant reduction in the number of valves in the plant (by 60%), as well as a reduction in the feet of piping (by 75%) and the reduction in the number of pumps used in the plant (by 35%). The chemical and volume control system (CVS) has also been simplified to operate on differential pressure across the reactor coolant pump, thus eliminating high pressure pumps in the system. The only pump required will be to inject plant make-up water. All of these simplifications will result in reduced maintenance efforts and radiation doses.

Waste Handling Considerations

Extensive effort has been spent to reduce and minimize the radiation exposure from waste handling operations required for the AP600. This includes the robotic and remote operation processes being developed with a utility as well as the planned use of cameras and mirrors to avoid and minimize exposure. Resin transfer operations will be through piping using air handlers with the ability to flush the lines if local "hot spots" develop. The ability to install temporary shielding over local "hot spots", should they occur, will also be available.

Component Considerations

The use of bent piping in the reactor coolant system has eliminated welds which must receive in-service inspections, thus reducing a source of exposure in the plant. The reactor coolant pumps have also received significant attention with respect to minimizing exposure. This has resulted in the use of two pumps per loop, the use of highly reliable canned motor pumps and the specification of polished impeller and flow vanes, which will reduce crud buildup as well as improve pump efficiency. The pump considerations also include the design of a quick removal and transport system which will minimize personnel exposure if pump repairs are required.

The steam generators have also received attention to increase reliability and in-turn to reduce radiation exposure. This includes the specification of Inconel 690 tubing and the specification that the cobalt impurity in the tubes be less than 0.015 percent by weight. The minimization of cobalt in other plant materials has also been specified with consideration given to the cost benefit expected for the amount of cobalt allowed. Allowable values were based on the expected amount of cobalt that might be input into the plant by the component as well as the cost to reduce the amount of the impurity.

Air operated pumps will be used for various waste tank applications; however, the rupture of a pump diaphragm could result in room contamination. The solution for this concern was to pipe the air vent path back into the top of the tank being served. Other components that have received special attention are the plate type heat exchangers planned for use in the spent fuel cooling system (SFS) and the heat exchanger in the CVS. The SFS heat exchangers typically do not provide significant self shielding, thus local shielding was placed adjacent to this component. The CVS heat exchanger could require replacement during plant life, thus an equipment hatch was added above this component to facilitate removal with minimal radiation exposure.

Fuel Considerations

Several features have been considered with respect to the fuel and its effects on radiation exposure throughout plant life. One considerations for the fuel is the use of gray rods for reactivity control. These reduced rod worth, control rods can be moved to provide daily load follow without changes in the soluble boron concentration. This greatly simplifies the auxiliary systems used in processing the borated coolant.

In addition to the use of gray rods, the fuel will be assembled using zirconium grid straps to eliminate the input of cobalt from these components. A reduced power density will also be utilized which will reduce the activation of components and also the exposure for various component handling operations.

Another core related consideration to reduce radiation levels in the plant is the planned use of non-cobalt bearing material in the control rod latch mechanism. This component is one of the higher wear items which can introduce cobalt into the primary system.

Shielding Considerations

In order to minimize the exposure to workers performing maintenance on equipment adjacent to radiation sources such as other pumps, valves or waste tanks, various shield walls and local shields have been provided between the radiation emitting components. The means to install temporary shielding is also being provided where access requirements for adjacent equipment preclude the use of a permanent shield. The addition of temporary shielding is contingent on the ability to provide adequate space for equipment disassembly and reassembly.

A laydown area has been provided just outside the steam generator compartment. In order to reduce dose rates in the laydown area, steel shielding has been added above the reactor coolant piping in the steam generator compartment. This will also allow low dose access to the compartment for maintenance work. Steel shielding has also been added in the area of the north steam generator compartment to shield the pressurizer surge line and valve gallery outside the compartment. This is in addition to the shielding in the CVS to separate the valves and other components for maintenance purposes.

Initial primary shield design analysis has shown that significant neutron streaming will occur through the relatively large annuli around the reactor coolant piping and in the reactor cavity. A detailed primary shield analysis using three-dimensional techniques will be used in the final design of local shields which will address these and other concerns.

During a review of the plant shielding it was noted that access to some areas for maintenance requires passing by or through areas of higher radiation fields. Alternate routes will be identified or shielding provisions (permanent or temporary) are being provided so that exposures when accessing all areas of the plant will be minimized.

Since SECY-93-087 defined post accident sampling system (PASS) requirements for advanced light water reactors, the AP600 PASS requirements differ than those for existing plants. This system is currently being reviewed to insure that the final design will meet the requirements for sample time and frequency as well as for personnel dose limits.

Plant access control has been evaluated as part of a review of the plant radiation protection system. Access requirements were based on expected radiation levels rather than on the design basis values assumed for shield design analysis. In order to allow the plant operator as much flexibility as possible, doors have been provided at all locations which could require personnel exclusion or controlled entry. The decision of whether or not to install locks on these doors is left to the plant operator should plant radiation levels require locked barriers. In addition, if ventilation air flow was considered and most of the doors will be constructed of wire mesh rather than being solid.

CONCLUSIONS

Based on the ALARA considerations presented here and on the process identified for the design of the AP600 Plant it is concluded that the plant design will meet the requirement of ALARA and will have an annual average ORE which is less than the current goal.

Author Biography

Fred Lau is Manager of Radiation Engineering and Analysis for the Westinghouse Nuclear Technology Division. In this position he is responsible for the many aspects of radiation evaluation, attenuation and control as it applies to both personnel and equipment radiation exposure. He has 28 years of experience in the design and evaluation of reactor shielding through his assignments at the Bettis Atomic Power Laboratory. This included the design and evaluation and testing of shielding for nuclear powered ships and the design of the shielding for the Shippingport Atomic Power Station for both Core 2 and for the Light Water Breeder Core. Prior to his assignment at NTD in 1984, Mr. Lau was the Manager of Shielding Design and Manager of Core Mechanical Design for naval nuclear plants.

Fred L. Lau, Manager
Radiation Engineering and Evaluation
Westinghouse Nuclear Technology Division
Energy Center East 473A
P.O. Box 355
Pittsburgh, PA 15230

Phone: 412 374 5482
Fax: 412 374 4697

PAPER 3-4
DISCUSSION

Wood: Do you have any plans to put fine filters in the system? We heard this morning from Tas Khan that filters seem to work to reduce exposures in the German plants, and I wondered if you had plans to put them in.

Lau: Are you talking about the .4 and below micron filters?

Wood: Yes.

Lau: There are plans to do that.

Wood: Just in the CVS system?

Lau: As it stands right now, that is about all we have talked about, but I'm sure that those kind of things can be fitted to the customer's desires.

Borst: The 70 rem/yr -- how many outage days does that include? Does that include standard refueling outage or is that normal operations?

Lau: That includes the standard refueling outages. We have allowed 25 days for refueling and our goal is to refuel in 17 days. As a matter of fact, I believe that better than 90% of the dose comes from refueling and maintenance work during a refueling outage.

Borst: You mentioned shielding component cubicles. I know Ringhals Unit 1 has short walls as their shielding cubicles. Were you having something like that or were you envisioning a complete cubicle with a door and/or labyrinth surrounding each component?

Lau: What we have in a lot of the tank rooms that I showed are complete walls that surround the tank except for a doorway or a labyrinth-type door; in some cases there is a ladder that would get you to an area where you need to do work.

Borst: What about smaller pumps and things as opposed to large tanks?

Lau: For the small pumps, we are planning a head-height, half-height if you will, shield wall made out of either steel or concrete. In some cases that is not going to be easy because you have to be able to get to the components to work on them, and if you put the wall between two of them it may just impede that. So we are making plans for temporary shielding that could be put in semi-remotely to allow work on one component or the other.

Ferguson: Does the AP-600 design require any kind of vital access post-accident? If so, do you have any type of ALARA features designed to protect post-accident operators?

Lau: With regard to post-accident, we have been reviewing our post-accident sample requirements and some of those requirements have changed in recent times. One of the things that we have done is to discuss this with about fifteen different utilities and have just spent some time at Commonwealth Edison reviewing with them their post-accident sampling systems and those kinds of requirements. What we hope to do is to design a system that will answer the questions and concerns all of the utilities that we have talked to have in regard to minimizing the radiation exposure. As a matter of fact, we performed a dose assessment for sampling after an accident, and came up a little bit over the 5 rem that we had planned. We would really like to be below that, so we are back to the drawing board.

Ferguson: Would the shielding requirements then be reflecting the new source terms from NUREG 1465 or staying with the GID 14844?

Lau: We are using the draft NUREG-1465.

Baum: I have three questions. This morning we heard from Mr. Terada from Japan that they are using automatic control for the chemical and volume control systems. I am wondering if you are considering that. Secondly, I believe at our international workshop five years ago the Japanese were speaking about using monorails to transport tools and equipment and perhaps surveillance equipment around a plant. Has any consideration been given to that. Thirdly, those of us who are parents and grandparents know how useful and cheap the camcorder and remote surveillance systems are. How much of that sort of things are being built into these newer plants? Do you have cameras all over the plant? How many remote cameras would there be in a typical plant?

Lau: With regard to automatic pH control, we've not gone as far as the Japanese in our thinking, however, we do have, and I forgot to mention this, our chemical and volume control systems designed to operate on differential pressure, there are no pumps in that system. That doesn't answer the question in regard to pH, but I wanted to bring out the fact that the system is very simplified and certainly the idea of automatic pH control is something that we would consider. I have not heard about the automatic pH control feature, but I am sure that some of my other people have. In regard to monorails, yes there are areas which will be equipped with monorails, especially in the waste handling building, and as I mentioned, with regard to coolant pumps other areas that lend themselves to the monorail or other kinds of remote handling. I don't have first-hand knowledge of all of those things at the moment, but I would say yes, we are designing for remote handling such as monorails. Thirdly, we plan to have a lot of cameras in the waste handling building and we also plan to have electrical circuits that would allow multiplexing the camera, and other radiation dose monitoring throughout the plant. We are not going to dictate to the customer what he has to put where, but we are going to provide him with the capability to put things wherever he needs them.