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HEALTH PHYSICS AND INDUSTRIAL HYGIENE ASPECTS OF DECONTAMINATION AS A PRECURSOR TO DECOMMISSIONING

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ABSTRACT

The Pacific Northwest Laboratory is conducting a comprehensive study of the impacts, benefits and effects of decontamination as a precursor to decommissioning for the U.S. Nuclear Regulatory Commission. The program deals primarily with chemical cleaning of light-water reactor (LWR) systems that will not be returned to operation. A major section of this study defines the health physics and industrial hygiene and safety concerns during decontamination operations.

The primary health physics concerns include providing adequate protection for workers from radiation sources which are transported by the decontamination processes, estimating and limiting radioactive effluents to the environment and maintaining operations in accordance with the ALARA philosophy. Locating and identifying the areas of contamination and measuring the radiation exposure rates throughout the reactor primary system are fundamental to implementing these health physics goals.

The principal industrial hygiene and safety concerns stem from the fact that a nuclear power plant is being converted for a time to a chemical plant which will contain large volumes of chemical solutions. The resulting industrial hazards include dangerous obstructions caused by insufficient storage space for decontamination equipment and chemicals, problems created because workers employed for the decontamination are not familiar with the plant layout and equipment, and the problems associated with handling toxic and highly reactive decontamination chemicals. The operation of decontamination equipment also involves risks to the decontamination worker from electrical shock, noise, airborne particulates and toxic gases. Careful planning of decontamination operations, training of the decontamination crew, and familiarization with the reactor systems significantly reduce the risks of decontamination prior to decommissioning.

I. INTRODUCTION

Decontamination of a nuclear power plant prior to decommissioning involves health physics and industrial hygiene considerations that may be quite different from those involved in restorative decontamination. Since decontamination as a precursor to decommissioning can occur years after plant shutdown, there is a possibility that few, if any, of the original operating crew will be members of the decontamination crew. The crew's general lack of familiarity with the plant can cause serious problems during decontamination operations. Another factor that requires special consideration is the extent to which the plant has deteriorated. Planning a decontamination procedure that is safe from both health physics and industrial hygiene standpoints requires an intimate knowledge of the functional limitations of all of the systems of such a reactor. An additional factor that greatly affects safety during the decontamination is the fact that less attention will be paid to preserving the integrity of the reactor systems since requalification is not a consideration. More destructive chemical and mechanical decontamination methods may be used to rapidly reduce radiation levels, even though their use might significantly increase the radiological and industrial hazards to decontamination workers. For this reason, extensive planning of the decontamination is essential to a safe decontamination program.

This paper addresses some of the major health physics and industrial hygiene issues that are critical to the implementation of a safe, successful decontamination program. Guidelines will also be given for planning decontamination efforts and training decontamination personnel in a manner that takes these issues into consideration.

II. HEALTH PHYSICS ISSUES

The radioactive inventory estimated to be present one year after final shutdown of a commercial light water reactor is approximately 10^6 Ci after coolants, sludges, fuel elements, filter resins and other wastes have been removed. From 20 to 30% of that activity is attributed to ^{60}Co. Cobalt-60 remains as the predominant source of radiation exposure in the plant until about 30 years after final shutdown.[1] After that time, ^{63}Ni, a beta emitter, becomes the predominant radionuclide. Decommissioning activities occurring within 30 years of shutdown must take into account the presence of ^{60}Co in the corrosion product film lining the primary coolant system and in neutron-activated structural material. Some of the health physics considerations essential to the safe application of decontamination techniques to a reactor prior to decommissioning include: plant radiation levels, internal exposure, external exposure, radiation protection, contamination control, and criticality control.

A. Plant Radiation Levels

Documentation of the radiation levels in the plant may not exist or may not be applicable, if there has been a considerable length of time between plant shutdown and the beginning of plant decontamination. A complete radiation survey of the plant must be performed in order to document radiation levels throughout the plant and to locate high radiation areas. At the same time, specific locations around the system should be designated in order to establish consistent survey points for monitoring radioactivity and radiation level changes during the course of the decontamination. This documentation of radiation levels should include establishing consistent sampling procedures and sampling points for the measurement of surface contamination, effluent activities, and exposure rates during both chemical and mechanical decontamination procedures. This provides a system for monitoring the radiation levels to which decontamination workers are exposed, from the initiation to termination of decontamination efforts. Such sampling also affords the decontamination management some basis for control over the decontamination process.

Lack of control over the decontamination process due to inadequate radiation monitoring was exemplified during the 1962 decontamination of the Plutonium Recycle Test Reactor. Inadequate sampling of the heavy water coolant during flush and drain procedures prior to decontamination, resulted in the assumption that much of the fuel element rupture debris still remained in the system. As a result, two fuel dissolution steps were applied to the PRTR system. Effluent sampling of each of the solutions, however, revealed little fuel debris dissolution. It was therefore assumed that most of the fuel debris had in fact been removed by the flush and drain procedures, although no analyses had been done on the effluents to confirm this assumption. Time, radiation exposure, and money might have been saved if consistent radiation monitoring and chemical assays of the effluents had been employed.

During the 1966 decontamination of the Fuel Element Rupture Test Facility[a] loop following a fuel rupture accident, thorough mapping of radiation levels prior to decontamination indicated that most of the fuel element rupture debris had settled in the loop heat exchangers. Provisions were then made to decontaminate the heat exchanger units individually in order to control the radiation levels of the waste decontamination solutions. Consistent monitoring of effluents during the application of the decontamination solution showed that a larger amount of activity than expected had been removed from the first heat exchanger decontaminated. Although mislabeling of valves controlling circulation through the heat exchanger resulted in decontamination of the hottest heat exchanger first, effluent sampling had revealed high radiation levels and the decontamination solution was rapidly drained prior to the planned recirculation time. Such monitoring not only afforded the decontamination crew some control over the decontamination process but also helped eliminate additional unnecessary decontamination steps.

B. Internal Radiation Exposure

Internal radiation exposure can result from inhalation or ingestion of radionuclides, from contamination of open wounds, or from tactile transfer of radioactivity into the mouth. Except for accident situations in which contamination enters the body through open wounds, the type of internal exposure that is of most concern during decontamination is inhalation. Many mechanical decontamination procedures produce airborne contamination. Hydrolasing, for example, is estimated to produce a 10 mg/m^3 droplet

(a) A light water test loop contained in PRTR.

concentration.[2] The level of contamination in these droplets will depend on the surface being decontaminated. Wet blasting techniques can also produce contaminated droplets while dry blasting techniques can generate significant dust. Other destructive decontamination techniques, such as the use of jack hammers, grinders, scabblers and spallers, produce airborne contamination not only for workers operating the equipment but for any workers in the vicinity of the operation. Such airborne contamination can be reduced by using wet or dry vacuum systems and water sprays. Contamination control envelopes equipped with HEPA-filtered ventilation systems can also be used to control the spread of airborne contamination. Still the potential remains for the internal exposure of workers performing these tasks. Respiratory protection equipment should be used to protect workers who are potentially exposed to airborne contamination.

The protection that each of these methods gives the decontamination workers, however, is only as good as the care with which it is applied. Improper application of protective equipment and radiation accidents are always factors that must be anticipated during the planning of decontamination operations. Manufacturer's guidelines, regulatory guidelines such as Regulatory Guide 8.15, and the limits stated in 10 CFR 20 for allowable radionuclide concentration in air and water must be used to provide adequate protection for workers during decontamination.

C. External Radiation Exposure

Decontaminating reactor systems prior to decommissioning has the same benefits as decontaminating systems in an operating reactor: 1) the direct reduction of exposure to workers by reducing the radiation levels in areas of high worker occupancy and 2) the indirect reduction of occupation exposure by removing loose outer contamination, and as a result, reducing the amount of protective equipment required and the time required for workers to be in a high radiation field. In addition to the benefits of decontamination to the performance of other decommissioning activities, the radiation exposure to the workers performing decontamination procedures must be considered when determining whether to decontaminate or which decontamination method to use. Accomplishing the overall objective of keeping occupational radiation exposures during decommissioning as low as reasonably achievable, requires the careful balancing of occupational exposure saved by decontamination and the occupational exposure expended during decontamination.

Both mechanical and chemical decontamination operations result in occupational radiation exposures during the preparatory phase when equipment is being installed and system modifications are being made. Tasks, such as the installation of fill and drain connections and component isolation, that are done in preparation for decontamination, involve major occupational dose expenditures.[2] Occupational exposure also occurs during the operational phase of the decontamination. For example, a worker performing a hydrolasing operation on the walls of a BWR suppression chamber might receive a dose equivalent of 6 to 8 rem during the 38 to 58 hours required for that decontamination operation.[4] This exposure should be weighed against the benefits of the hydrolasing operation when considering the use of such a procedure.

Mechanical and chemical decontamination involve a movement of radionuclides from the originally contaminated surface to other surfaces and configurations. This transport of radioactivity can constitute a major external radiation exposure hazard to decontamination personnel. During chemical decontamination, the dissolution or suspension of radionuclides in the decontamination solution may result in high radiation fields at new locations, such as waste tanks. Redeposition of radioactive material due to precipitate-forming chemical reactions or rapid changes in temperature or flow rate may cause unexpectedly high radiation levels in occupied areas. It is essential that the preparation for chemical decontamination of a reactor that has been shut down prior to decommissioning include not only a thorough survey of plant radiation levels but a thorough evaluation of the system configurations, such as low points and deadlegs. Such an evaluation would be conducted in order to anticipate the potentially hazardous locations. During mechanical decontamination operations, high radiation fields can be created when contaminated waste dust, slurries, or water become concentrated in wet or dry vacuum canisters, in drains leading to the radwaste system and on filters and resin columns. This buildup of radioactivity can be detected and controlled if radiation surveys are adequate and performed at sufficiently frequent intervals during the course of the decontamination.

More destructive chemical decontamination solutions might be chosen for decontaminating a reactor prior to decommissioning than for a reactor that is to be requalified for operation. Concern for the compatibility of the solution with structural materials and for control over the effectiveness of the solution might be far less than during a restorative decontamination. Leaks resulting from the destruction of pump seals and valve components pose a potential radiation hazard to workers, especially if the pumps and valves are operating at high pressure. Use of the more destructive decontamination solutions may also result in increased effectiveness and consequently an increase in the radiation exposure to workers handling the effluents.

D. Radiation Protection

Protection from sources of external and internal radiation exposure can be afforded the decontamination worker by the use of protective clothing, respirators, and shielding. In addition, techniques such as limiting worker occupancy in high radiation areas and increasing the distance between the worker and the radiation source through the use of remotely-operated equipment also lessen the radiation exposure to workers.

The use of protective clothing during decontamination efforts prior to decommissioning differs somewhat from that during decontamination of an operating plant. More of the clothing that protects workers from decontamination solution leaks, fires and radioactive vapors will be used during the pre-decommissioning decontamination than during the decontamination of an operating reactor. The major reasons for this are: 1) the uncertainty concerning the condition of reactor systems that have been out of use, 2) the use of more destructive decontamination methods, and 3) the possibility of an increased number of decontamination and demolition operations occurring simultaneously. Plastic clothing should be supplied to workers who must be near valves, piping, and components that could leak during the circulation of chemical decontamination solutions or who must operate water spray or blasting equipment. Flame-resistent clothing should be worn by workers during the decontamination operations involving welding, grinding or the use of any operation that might produce sparks, molten metal debris or the ignition of combustible material. Gases that may have accumulated in the reactor systems over time or been produced as a result of reactions between decontamination solutions and structural materials can be ignited by high temperature operations and can result in a personnel safety hazard, a radiological hazard, and a fire hazard. During the decontamination of the Shippingport reactor, a grinding operation on the outside of a contaminated stop valve resulted in the ignition of hydrogen that had accumulated in the valve. Although the decontamination worker performing the grinding operation was not seriously injured, he was extensively contaminated by radioactive crud that was expelled by the explosion.[5] Although such incidences are even more likely in a plant where the piping conditions are not known and the behavior of system components during decontamination is unpredictable, they can be prevented by careful system venting.

Respiratory protection from vapors and particulates is also essential during many decontamination operations. Such incidents as the explosion mentioned above can contaminate workers internally as well as externally if inadequate respiratory protection is not provided. Because the potentially more destructive decontamination methods such as sand and grit blasting, spalling and strong chemical solutions may be employed prior to decommissioning, the presence of radioactive particulates and vapors are of greater concern than during restorative decontamination.

Shielding is another option for providing radiation protection to workers during decontamination operations. In many instances, working space is so tight that portable shielding can not be used since it would significantly hamper accessibility to an area. However, molded lead shielding, lead bean bags and lead wool blankets, such as those used during the steam generator repair and replacement operations at the Surry Power Station, can be designed to provide shielding with a minimum of obstruction.[6] The benefit gained from the use of shielding can be determined by considering these points: the occupational exposure expended during installation of the shielding, the effectiveness of the shield to reduce radiation from the source shielded as well as from major sources of radiation in the area and the degree to which the shielding interferes with worker access, egress, and job performance.

Aside from the use of portable shields, shielding can include the use of already existing structures, such as concrete walls. In addition, the use of water to flood parts of components, such as the reactor vessel, the secondary side of the steam generator and fuel storage pools during decontamination efforts can provide shielding not only for workers decontaminating those components, but for workers in adjacent areas,

Remotely-operated equipment and long-handled tools can also be used to reduce occupational exposures during decontamination. However, the usefulness of these techniques is limited by the accessibility of the area to be worked on and the amount of exposure required during remote equipment installation and maintenance. Perhaps the best developed example of remote technology is the slurry-blasting process used to decontaminate steam generator channel heads. The control panel for such a unit can be up to 15 meters from the steam generator unit. Remotely operated electropolishing devices have also been developed for tanks and piping systems but they have not been applied to reactor system as extensively as the slurry blasting techniques.

Effective decontamination planning plays a major role in reducing occupational exposure by reducing the time spent by workers in high radiation fields. Radiation protection through exposure time reduction requires that the decontamination worker become very familiar with the task he is to perform in the high radiation field and also with the area he must be in to perform the task.

E. Contamination Control

Contamination control is a major issue during decontamination prior to decommissioning because of the use of decontamination methods that may be more rigorous then those used on operational reactor. As previously discussed, the spread of contamination from these processes can be reduced by using contamination control envelopes, water sprays, wet and dry vacuums, auxiliary ventilation and air filtering systems, and drain lines and pans for catching decontamination solutions that have leaked from components and piping systems. The prevention of explosive releases can also be accomplished by venting the piping systems prior to decontamination and not allowing spark or flame producing techniques to be used on areas where hydrogen or other potentially explosive gases have accumulated.

Contamination control also includes the prevention of recontamination of areas that have already been decontaminated. Strippable coatings and other methods for sealing clean areas from contact with radioactive materials should be adopted during the planning and scheduling of decontamination activities.

F. Criticality Control

Criticality should not be a concern during the decontamination of most nuclear reactors prior to decommissioning. However, in the case of a reactor which is being decommissioned following a massive fuel element rupture accident, criticality control may be an important issue. The uranium and plutonium dissolution capacity of potential decontamination solutions must be evaluated in order to determine whether reaching a critical concentration is possible. Other considerations that influence the potential for criticality during decontamination include: changes in pipe sizes and configurations, the likelihood of forming a precipitate that would concentrate the fissile material and the potential for reaching a critical mass on filters or a critical concentration on resin columns, in waste tanks, or waste processing equipment.

Prior to any evaluation of the applicability decontamination techniques, the amount of fuel debris in the reactor systems and the percent of fissile material expected in the debris must be well known.

Criticality concerns during the decommissioning of the SL-1 reactor prohibited the use of decontamination solutions inside the containment building. Consequently, only dry mechanical decontamination methods, such as vacuuming and using a remotely-operated electromagnet to pick up debris, were used.

III. Industrial Hygiene and Safety Issues

Decontamination personnel are exposed to many nonradiological, industrial hazards during reactor decontaminations. This is largely due to the fact that during decontamination operations, abnormal working conditions prevail within the reactor. The presence of large quantities of chemicals and equipment and changes in shift routines all contribute to the increased potential for industrial accidents. Decontamination can be even more hazardous in the case of a reactor that has been shutdown for a period prior to the start of decommissioning activities. Deterioration of the reactor and the decontamination crew's lack of familiarity with such a reactor increase the accident potential.

Some of the major industrial hygiene and safety issues that must be considered in the planning and implementation of reactor decontamination prior to decommissioning are: 1) physical conditions, including working conditions of the decontamination crew and the physical conditions of the plant; 2) chemical handling, including the evaluation of chemical toxicity, compatibility and fire hazards during storage, mixing, and waste solution handling, and 3) equipment handling, including noise levels, limits for particulate and vapor concentrations, and the impact of the use of temporary equipment on safety conditions in the plant.

A. Physical Conditions

The extent to which reactor systems have deteriorated by the time decommissioning activities begin greatly affects not only the choice of decontamination methods used but also the risks to personnel during decontamination operations. If primary system pumps are not functional or are incapable of recirculating decontamination solution at the required velocities, the decontamination procedure used may involve pipe sectioning, followed by electropolishing or the use of a temporary decontamination loop with its own recirculation pumps instead of full system chemical decontamination. The shortage of work space, complicated by the presence of temporary equipment, can increase the industrial hazards above those present during system chemical decontamination. Prior to the start of decontamination operations, the ventilation system should be evaluated to ensure that it can adequately prevent the buildup of airborne particulates and gases generated during decontamination. Evaluation of reactor systems and system components can reduce the risks to workers from leaks, pipe breaks and the accumulation of noxious fumes.

In addition to a thorough survey of system functioning, an evaluation of the physical layout of the plant should be made, paying special attention to the accessibility of areas to be decontaminated, the amount of space available for chemical storage and decontamination equipment placement, and the auxiliary circulation/ventilation, power and lighting systems present. Because most of the decontamination crew will not be familiar with the plant, efforts must be made to familiarize them with the arrangement of plant systems and the location of components to be decontaminated, lighting systems, escape routes and emergency equipment.

Consideration should also be given to the working conditions that will prevail during planned decontamination processes throughout the plant. For example, decontamination operations in locations where the potential for heat stress is high and where working space and entrance and egress routes are severely restricted should be identified. Arrangements should then be made to use alternate decontamination methods and equipment or to limit the length of time that workers must be in those locations.

B. Chemical Handling

Perhaps the major impact of chemical decontamination on working conditions and maintenance of industrial safety is the presence of a large volume of chemicals in the plant during decontamination operations. It has been estimated that for a two-step decontamination of the primary system of a commercial reactor, approximately 36,000 kilograms of chemicals would be required.[8] Unless the reactor has adequate storage space, the improvised storage arrangements made for this volume of chemicals could severely hamper accessibility to areas of the plant. Handling this volume of chemicals could also be hazardous due to the toxic or reactive nature of the chemicals and the potential for leaks. Drums of hydrogen peroxide, for example, are vented so they require special handling to prevent spillage. The highly reactive nature of hydrogen peroxide makes it a fire and explosion hazard as well as a potential eye and skin irritant.

Concentrated acids and bases also present significant hazards to decontamination workers. Sulfuric acid, for example, reacts violently with water and organic materials. Nitric acid is a strong oxidizing agent so it is also highly corrosive to the skin. It also presents a fire or explosion hazard when in contact with combustible material. Hydrofluoric, oxalic, and other concentrated acids that might be used in the decontamination of a reactor before decommissioning, are also very hazardous when injested, inhaled or allowed to contact the skin or eyes. Other chemicals, such as diethyethiourea and 8-hydroyquioline, are hazardous largely because of their suspected carcinogenic effects.

During the chemical mixing and storage operations, careful attention should be given to ensuring the adequate protection of decontamination workers with protective clothing and respiratory protection equipment. Proper chemical handling techniques should be a part of normal working procedures.

In addition to chemical hazards existing during storage and preparation of decontamination solutions, chemical hazards also accompany the decontamination process. Many strong oxidizing agents, such as concentrated acids, react with metal structural materials to form hydrogen. If allowed to accumulate to concentrations from 4.1 to 74.2%, hydrogen can become explosive.[9] The accumulation of ammonia evolved during chemical reactions can also be explosive if concentrations from 16 to 25% in air are attained.[10] At lower concentrations and under poor ventilation conditions, ammonia fumes can overcome workers. One of the instances when ammonia can form is during the addition of expended Citrox solutions to waste tanks containing expended alkaline permanganate (AP) solution. To control the rate of ammonia evolution, the procedure for mixing the two solutions should require that the AP solution be added to the Citrox solution.

In addition to radiation exposure, chemical burns and internal injury can also result from unexpected leaks and sprays of chemical decontamination solutions. Workers who must be present in areas where leaks can occur should be protected from chemicals by chemical resistant, water-proof clothing and respiratory protection. Other equipment, such as emergency showers, should be readily accessible during decontamination operations.

C. Equipment Handling

Hazards accompanying the use of mechanical decontamination equipment include the reduction of work space and entrance and egress routes, evolution of particulates, electrical shock, and other hazards normally present during the handling of heavy equipment and equipment that operates at high pressures. The application of such decontamination techniques as hydrolasing and abrasive blasting requires space for motors, hoses, tanks and the spray wand itself. The ability of workers to escape the decontamination area in the event of an accident must be an important consideration in the planning for decontamination operations. Accessibility to other parts of the reactor when the equipment is in place should also be evaluated.

The evolution of dust particles is a consideration when dry abrasive blasting equipment, scabblers, scarifiers, and grinders are used. These techniques are more likely to be used for decontamination in conjunction with decommissioning than in decontamination as a part of plant maintenance. The particulate concentration limits given in 29 CFR 1910 should be considered during the planning of decontamination operations prior to decommissioning. Dust generation can be avoided through use of water sprays, filtered ventilation systems, dry vacuums and contamination control envelopes. Normally if radiological exposure standards are met by the use of ventilation or respiratory protection, exposure to silica, asbestos and other harmful particulates will also be below established limits.

Occupational safety considerations when operating high pressure water spray equipment include the potential for the buildup of static electricity, if the equipment is not adequately grounded, and the inhalation of water droplets which could contain such chemicals as EDTA, a skin irritant and, when ingested, a potentially damaging complexer of the body's calcium.

Another occupational hazard that accompanies the use of most of the mechanical decontamination equipment is worker fatigue. This can be minimized by proper staffing and work assignments.

IV. DECONTAMINATION PLANNING AND PREPARATION

Safe, effective decontamination operations depend on careful planning which not only takes into consideration the applicability but also the radiological and industrial hygiene and safety aspects of each decontamination method. Four phases of decontamination planning are: radiological or physical survey of the plant, selection of applicable decontamination methods, identification of plant modifications necessary for decontamination operations, and training of the decontamination crew.

A. Radiological and Physical Surveys of the Plant

Surveys should document radiation levels throughout the plant and locate low flow areas, deadlegs, and areas where the system has been modified from available plant drawings. Construction materials in the plant should be noted, along with areas where poor lighting or ventilation exist. The accessibility of areas likely to be decontaminated should also be assessed in order to determine the space available for equipment operation and the emergency egress routes available for workers. High radiation areas where shielding can be installed should also be located.

The thorough plant surveys should familiarize decontamination personnel with the radiological and physical conditions present in the plant and should help the decontamination management determine which systems and system components need decontamination and to what degree the plant systems and components are functioning.

B. Selection of Decontamination Methods

Decontamination method selection involves consideration not only of the radiation survey of the plant but the physical survey as well. The potential occupational exposure and industrial hygiene risks during decontamination operations should be weighed against the potential effectiveness of the decontamination. Methods for maintaining radiation exposure as low as reasonably achievable, such as installation of shielding, use of remotely-operated equipment, limitation of worker time in high radiation areas and the use of radiation protection equipment should be incorporated into planned decontamination procedures. Another important consideration that has radiological and industrial hygiene implications is the applicability of decontamination methods to a reactor system. Selection of the most appropriate method should involve careful testing of the effect of each method on structural materials and waste management systems.

C. Modification of Reactor Systems

System modifications required for implementation of decontamination techniques should be identified and evaluated from industrial hygiene and radiological safety aspects. Risks to the decontamination worker during system modification may be outweighed by the overall decrease in radiation exposure and industrial hazards during subsequent decontamination operations. Modifications, such as the installation of a reactor vessel bypass and the sectioning of the primary loops into smaller loops that are decontaminated individually, may decrease risks to workers by making reactor decontamination more manageable.

D. Decontamination Training

The training that the crew receives prior to the start of decontamination operations has a direct impact on the radiation exposure and industrial safety during decontamination. One of the most important aspects of training should be familiarization with the plant and with the specific systems and components to be decontaminated. Access and egress routes, as well as the locations of high radiation areas, should be well known by the worker after the training course. Also included in the pre-decontamination training should be a radiation safety course which deals with the types of radiation, the biological effects of radiation and the use of monitoring and radiation protection equipment. A course in industrial hygiene and safety should be taught so that workers learn the properties, hazards, safe handling practices and emergency procedures for the chemicals and equipment involved in the decontamination effort. Decontamination workers should also become familiar with the decontamination and emergency procedures. They should receive mockup training which involves not only practicing the decontamination procedure on simulated reactor systems or models of reactor components but also practicing the use of protective clothing and equipment required during decontamination.

V. SUMMARY

Radiological and industrial hygiene issues that normally accompany the restorative decontamination of reactor systems are augmented during decontamination of a reactor prior to decommissioning. The deterioration of reactor systems, coupled with the lack of worker familiarity with the plant, result in a greater potential for radiation and industrial accidents. Careful planning of the decontamination operations requires consideration of the physical and radiological conditions in the plant, the radiation exposure and industrial safety of workers during decontamination operations, the applicability of decontamination methods to particular reactor systems, and the mechanisms available for controlling contamination.

Radiation and physical surveys of the plant should be performed prior to the start of decontamination in order to document radiation levels and physical conditions of all plant systems and components. High radiation areas and areas where radioactivity is likely to accumulate should be identified, along with deteriorated systems or components. Such surveys not only familiarize the decontamination staff with the plant but also facilitate the selection of decontamination methods appropriate to plant conditions.

Decontamination methods must be selected on the basis of effectiveness, compatibility with the reactor system or component and radiological and industrial safety. A balance must be established between these factors so that the decontamination method chosen is the most effective within the restrictions of maintaining occupational exposures as low as reasonably achievable, maintaining occupational exposure to toxic substances below accepted limits, limiting stressful working conditions, and maintaining the system integrity. Additional risks involved in modifying reactor systems prior to decontamination should be considered during decontamination planning and decontamination method selection. These risks should be weighed against the potential for making decontamination of the reactor more manageable.

Effective decontamination training can greatly influence the success of the decontamination operations. The training given to decontamination workers should prepare them to safely and effectively implement the decontamination procedures and to appropriately use protective equipment and emergency procedures. Like the other facets of decontamination planning and preparation, crew training should reflect the radiological and industrial safety conditions of the reactor prior to decommissioning.

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