19 Hot Particles

Hot particles, also called discrete radioactive particles (or DRP), can be characterized as microscopic particles of high specific activity, that may escape from the reactor coolant system and either irradiate workers' skin or are inadvertently released to the outside environment. There are two basic types of DRPs; those related to the fuel and those that result from activation of non-fuel related metals. The fuel DRPs are composed of insoluble fission products, fuel related radionuclides and some transuranic elements. The main nuclides concerned are Sr-89, Sr-90, Y-90, Nb-95, Zr-95, Ru-103, Ru-106, Rh-106, Cs-134, Cs-137, Ba-140, La-140, Ce-141, Ce-144, Pr-144 and Eu-154.[1] The fuel DRPs typically range in size from microns to millimeters and have activities in the range of nano to millicuries.[2] They are only found in PWR type plants around spent fuel pools, reactor cavity, transfer canals, steam generator channel heads and charging pumps. They may also be found on protective clothing, in the laundry and in trash sorting areas. They are produced when fuel pellets or particles escape through fuel cladding defects and enter the work environment principally during fuel handling, inspection and reconstitution.

The second kind of DRPs, the activated metal DRPs are found in both PWR and BWR type plants, the PWR ones in general being somewhat larger. They are produced when fragment from stellite and other alloys with high impurities of Co-60 and Co-58 precursors migrate to the reactor core and are activated. The predominant active nuclide in these DRPs is Co-60 though occasionally Co-58 may dominate. The activity typically in such DRPs may range from nanocuries to Curies and in size they range typically from microns to millimeters.[2]

A hot particle imparts a high beta dose and a much smaller gamma dose to a small area of tissue. Any radiation dose to the skin is assumed to result in some risk of non-melanoma skin cancer, which is rarely fatal. Moreover, experiments with animals suggest that a highly localized irradiation of the skin, such as that produced by a DRP, is less likely to cause skin cancer than a more uniform irradiation of the same quantity.[3] They could also produce acute effects such as reddening, hardening, peeling and ulceration of the skin. So far no such effects have been seen on any worker exposed to hot particles at nuclear power plants. From animal experiments, it appears that doses of hundreds of rem averaged over 1 cm^2 would be required to produce such effects. The NRC issued a notice in 1987, emphasizing the need for special control procedures for handling leaking fuel to avoid the spread of DRPs.[3] In reference 4 given below a number of basic and fundamental techniques are described to control, prevent and mitigate DRPs. These include recommendations on fuel design, on chemistry, and process controls. Here we shall confine ourselves to approaches that may be used by health physics personnel.

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[1] "Problem Assessment of Discrete Radioactive Particles", EPRI NP-5969, August 1988, EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, CA 94523.

[2] "Assessment of Discrete Radioactive Particle Dose", EPRI 5678, July 1969, EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, CA 94523.

[3] "Control of Hot Particle Contamination at Nuclear Power Plants", NRC IE INFO Notice 87-39, August 1987.

[4] B.J. Dionne and J.W. Baum, "Discrete Radioactive Particles at Nuclear Power Plants: Prevention, Mitigation and Control", Radiation Protection Management, Vol. 8, No. 5, p. 65-79, 1991.

The following are some of the causes for the hot particle problems at nuclear power plants:

- Maintenance practices which result in metal circulating in the primary coolant or reactor water.
- Failure to remove debris and corrosion from internal surfaces of a component before its installation in the primary circuit.
- Lack of adequate training in detecting leaks and responding to detected leaks.
- Failure of workers to clear DRPs from equipment, tools and components used for fuel reconstitution or maintenance of primary system.
- Failure of radiation personnel to adequately monitor the work area and the workers.
- Failure of workers to use the protective equipment prescribed by radiation protection personnel.
- Failure of the protective equipment.
- Lack of adequate training for personnel in procedures for hot particle protection.
- Inadequate equipment for monitoring and analyzing contamination.
- Lack of adequate training of radiation protection personnel in detecting the source of hot particles, and posting, containing and removing them.

Some useful suggestions to overcome hot particle problems are listed below. For more fundamental and comprehensive approaches, the reader is referred to the various references to this section[1]:

- Vacuum or wipe the valve's internals following maintenance of the valve seat.
- Develop and use spill prevention programs, including training programs.
- Perform optimal preventive maintenance on valves and pumps to prevent leakage.
- Limit fuel reconstitution operations to a confined section of the pool. Cover all surfaces in that section to collect any fuel particles or crud that may fall from assemblies.
- Use a spray down system to remove fuel particles from tools being removed from the pool, and wipe tools dry upon removal.
- Use carpets and "sticky mats" or ventilated catch basins with a grated cover plate at strategic locations to capture hot particles that may fall from equipment.
- Consider use of a glove bag or other containment device and specialized decontamination for work in hot particle zones.

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[1]"Radiation Exposure from Small Particles", INPO SER 18-87, 700 Galleria Parkway, Atlanta, GA 30339, July 1987.

- Maintain dedicated coverage by qualified radiation protection technicians for jobs in hot particle zones.
- Improve the reliability of fuel reconstitution tools to minimize the number of times equipment must be removed from spent fuel pools for repair.
- Ensure all personnel in the spent fuel pool area and other hot particle zones wear proper protective apparel.
- Use outer coveralls with reduced potential for trapping particles.
- Vacuum or wipe down the outside surface of protective clothing before their removal.
- Limit entries to hot particle zones to workers who have special training in protection against hot particles and who have a justified need for entering the area.
- Alert personnel to those activities that have a potential for hot particle contamination. Among these would be fuel reconstitution, fuel consolidation, refueling, valve and pump work.
- Increase vigilance among workers in self frisking procedures when exiting a contaminated area and when moving between frisking locations within contamination control zones.

Any amelioration measures against hot particles, however, must be taken in a balanced way, keeping in mind an overall ALARA perspective. Hot particles generally lead to a large exposure to a localized area of the skin, whereas some protective measures could involve whole body exposures to workers and radiation exposure technicians.