UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

August 21, 1987

NRC INFORMATION NOTICE NO. 87-39: CONTROL OF HOT PARTICLE CONTAMINATION AT NUCLEAR POWER PLANTS

Addressees:

All nuclear power reactor facilities and spent fuel storage facilities holding an NRC license or a construction permit.

Background and Purpose:

IE Information Notice 86-23 (Reference 1) provided information on events involving excessive skin exposures resulting from skin contamination by small, highly radioactive particles with high specific activity (hot particles). Since that information notice was issued, there have been more of these events, and a recent report by the Institute of Nuclear Power Operations (INPO) (Reference 2) provides additional information on this subject. This information notice provides information on some of the subsequent events and discusses degraded fuel and a lack of proper radiological control during fuel reconstitution as major sources of hot particles. Generic licensee lessons learned also are included.

It is expected that recipients will review this information for applicability to their facilities and consider action, if appropriate, to preclude a similar problem occurring at their facilities. However, suggestions contained in this notice do not constitute NRC requirements; therefore, no specific action or written response is required.

Discussion:

During the first 6 months of 1987, events involving hot particle exposures were reported at nine different nuclear power stations. Two events in late 1986 (at V.C. Summer and San Onofre) involved exposures apparently exceeding NRC regulatory limits. Attachment 1 provides summary descriptions of eight of these events. More detailed descriptions can be obtained from the referenced inspection reports for each event. (Copies of NRC Inspection Reports are available from the NRC Public Document Room, 1717 H Street N.W., Washington, D.C.)

Hot particles come primarily from two major sources: degraded fuel and neutron-activated corrosion and wear products (e.g., Stellite). While much of the information in this notice is pertinent to both neutron-activated corrosion and wear product particles (hereafter referred to as activated particles) and

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irradiated fuel particles (hereafter referred to as fuel particles), a major concern of this notice is extended facility operation with degraded fuel and the resulting problems with fuel particle contamination. On the basis of an NRC review of licensees' corrective actions, discussions with licensees' operating staffs, and information obtained by NRC inspectors, the lessons learned and licensee good practices resulting from the events summarized in Attachment 1 are as follows:

1. Extended power plant operation with degraded fuel (leaking fuel pins) can result in widespread dispersal of fuel particles. Some plants continue to experience fuel particle contamination problems long after leaking fuel pins have been removed because of the residual contamination of plant systems. Some plants with these problems have started programs to account for missing fuel pellets and fragments and to identify measures to recover this material.

2. Considerations concerning the handling of leaking fuel include the following:

   a. Special techniques and precautions for handling leaking fuel bundles are necessary to prevent aggravating the spread of fuel particles. For example, containment devices should be used when reconstituting fuel. The lack of proper radiological controls and oversight of the fuel reconstitution process in the San Onofre 3 fuel pool led to loss of control and dispersal of numerous fuel particles into the pool. Fuel particles then spread through the plant spent fuel systems and to the liquid radwaste systems.

   b. A damaged, leaking fuel pin that is not properly contained and segregated from the common fuel pool area could be a significant, long-term source of fuel particle contamination.

   c. Plants should be aware that NSSS vendors' special refueling tools and equipment could be a source of fuel particle contamination. These tools and equipment should be carefully surveyed before they are used and before they are shipped to other facilities.

3. Some plants that have operated for extended periods of time with degraded fuel and plants with activated particle problems now have instituted specialized, comprehensive training programs for plant system maintenance workers and general employees. These programs are designed to better inform and prepare the plant staff to cope with the continuing fuel particle problems. Additionally, as part of comprehensive contamination control programs, special new procedures to improve surveys for detection

of hot particles have been prepared and health physics technicians have been trained in their use. Decontamination and dose evaluation methods and procedures that focus on hot particles have been implemented. (See summaries of events at Trojan and San Onofre in Attachment 1.)

4. In general, licensees have upgraded their programs for contamination monitoring of "clean," laundered anti-contamination protective clothing (PC). However, PC continues to be a means of transferring both fuel particles and activated particles. Some facilities need to consider making their PC monitoring programs more sensitive. For example, some licensees that are using contractor laundry services found the contractor's alarm on the radiation monitor (used to screen PC) too high to detect 0.4 microcurie (μCi) particles. Moreover, when commercial laundry services are used, it is possible that PC from a "particle-free" plant can be mixed with PC from a plant with hot particle problems. Finally, at least one licensee was relying solely on monitoring of large bundles of washed PC (bulk surveys) and was not monitoring samples of individual PC. For plants with identified particle problems, individual PC items may have to be checked before they are reused after cleaning.

5. Except for the Trojan event discussed in Attachment 1, to date, no licensee has reported detecting hot particles during airborne sampling. However, as a precaution, some licensees have elected to provide workers with respiratory protection for performing maintenance on plant systems known to be a source of hot particles. No plant has reported inhalation or ingestion of hot particles by any worker.

6. Hot particles in contact with skin produce very high dose rates. Diligent personnel contamination surveys performed as soon as practical after completing work involving contamination are needed to minimize potential exposure times.

7. Approximately 75 percent of the U.S. power reactor facilities are currently using new high-sensitivity whole-body contamination monitors. These state-of-the-art contamination monitors increase the probability of detecting hot particles on plant personnel while reducing the likelihood of inadvertently releasing particles from the plant site. To date, most of the particles found on personnel have been detected by these new monitors. Even with use of the new monitors, a few instances have occurred where hot particles have inadvertently been carried home by workers and have been detected in the home or on the worker returning to the site. No significant public exposures have been reported to date.

8. In a recent study for the NRC (Reference 3), it was reported that a plant operating with 0.125 percent pin-hole fuel cladding defects showed a general five-fold increase in whole-body radiation exposure rates in some

areas of the plant when compared to a sister plant with high-integrity fuel (<0.01 percent leakers). Around certain plant systems the degraded fuel may elevate radiation exposure rates even more.

9. Maintenance on valves with Stellite components can cause introduction of cobalt-containing debris with Co-60 as the resultant neutron activation product. Some plants have instituted work controls (e.g., use of containment and post-maintenance cleaning) to minimize this input into reactor systems (Reference 4).

Health Implications and Radiation Protection Criteria for Hot Particle Exposures of Skin:

A hot particle on the skin gives a high beta dose to a small area. Any radiation dose to the skin is assumed to result in some increased risk of skin cancer, although this type of cancer is rarely fatal. Experiments with animals indicate that highly localized irradiation of the skin by hot particles is less likely to cause skin cancer than more uniform irradiation by the same quantity of radioactive material.

In addition to any increased risk of cancer, large doses to the skin from hot particles also may produce observable effects such as reddening, hardening, peeling, or ulceration of the skin immediately around the particle. These effects appear only after a threshold dose is exceeded. The doses from hot particles required to produce these effects in the skin are not known precisely; however, it appears likely, except for a point reddening, that these effects will only be seen for doses of hundreds of rems or more. No such effects have been seen to date on any workers who have been exposed to hot particles, even though one exposure has been measured or calculated as high as 512 rem.

Recent reviews of radiobiology and radiation protection criteria for skin, including considerations of hot particle exposures, have been provided by Wells (Reference 5) and Charles (References 6 and 7).

The NRC staff recognizes the need for more information on the effects of radiation on skin and particularly the effects of hot particle irradiation. The staff has requested the National Council on Radiation Protection and Measurements (NCRP) to study the health significance of hot particle exposures and to provide recommendations based on the findings of this study. These recommendations may result in changes in NRC requirements with respect to hot particle exposures. However, until these requirements are changed, IE Information Notice 86-23 (Reference 1) contains current information for use in evaluating doses to skin resulting from hot particles.

No specific action or written response is required by this information notice. If you have any questions about this matter, please contact the Regional Administrator of the appropriate regional office or this office.

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References

1. IE Information Notice 86-23, "Excessive Skin Exposures Due to Contamination With Hot Particles," April 9, 1986.

2. Institute of Nuclear Power Operations, Significant Event Report 18-87 (Rev. 2), "Radiation Exposure From Small Particles," July 16, 1987.

3. Moeller, M. P., G. F. Martin, and D. L. Haggard, "The Impact of Fuel Cladding Failure Events on Occupational Radiation Exposures at Nuclear Power Plants. Case Study: PWR During Routine Operations," NUREG/CR-4485 (PNL-5606), January 1986.

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7. Charles, M. W., "Skin, Eye, and Testis: Current Exposure Problems and Recent Advances in Radiobiology," J. Soc. Radiol. Prot. 6 (No. 2), pp. 69-81 (1986).

Attachments:
1. Event Summaries
2. List of Recently Issued NRC Information Notices

EVENT SUMMARIES

San Onofre 3, Events During November 1986 - March 1987, Inspection Report No. 50-362/86-37

Background:

At the onset of the first fuel cycle, significant fuel degradation was evident. The plant continued to operate with approximately 105 defective fuel pins. In late 1985 during the first refueling outage, a fuel pin was inadvertently pulled apart during the fuel reconstitution process. Several fuel pellets fell and dispersed throughout the fuel pool. Fuel particles had previously been detected early on during reconstitution on fuel handling tools and on the refueling floors. All the severely damaged fuel pins were then grouped into one fuel bundle and stored in the pool without any containment.

Event Specifics:

From January 2 through February 20, 1987, the licensee's aggressive hot particle inventory and tracking system indicated that 92 "new" fuel particles (recently neutron irradiated), 155 "old" fuel particles, 51 ruthenium, 84 crud, and 42 cobalt particles had been found and analyzed. Before 1987, no formal tracking program existed.

Several incidents involving hot particles have occurred, including an apparent worker extremity exposure (hand) of 512 rem during November 1986. As a result, appropriate NRC enforcement actions are currently underway. Three events involving the inadvertent release of hot particles from the plant site occurred in February 1987. In two of these events, the radiation dose to the public was determined to be negligible. However, the third event involved a 0.2 μCi particle found by a worker at his home during a self-initiated radiological survey. The licensee has not yet estimated the potential dose to the worker's family as a result of this occurrence.

In the licensee's licensee event report (LER No. 86-015, Revision 1) of February 22, 1987, the following program improvements for detecting hot particles and controlling personnel exposures from hot particles were described:

Extensive, mandatory use of exceedingly sensitive fixed instrumentation (frisking booths) for the detection of personnel contamination;

Special training (including hands-on laboratory exercises) in radioactive particle characteristics and survey techniques for all Health Physics Technicians;

Oral and written indoctrination of all managers, first line supervisors and workers in the special problems associated with radioactive particles, including the methods each person must employ to protect himself;

Special procedures to assure detection and control of radioactive particles which feature the establishment of a clearly identifiable zone, to demark and contain such particles, surrounded by clearly identified buffer zones (or solid physical barriers) which are surveyed frequently to verify that control is being maintained;

Maintenance and wide publication of a radioactive particle census during outages to maintain station awareness;

The establishment of a Task Force to recommend and implement action to minimize the future production and movement of radioactive particles.

Trojan, April, 1987, Inspection Report No. 50-344/87-15

Background:

The facility has operated since July 1982 with an estimated 112 fuel pellets unaccounted for throughout the reactor and support plant systems. The licensee recovered or located about 264 pellets of the estimated 376 missing after the 1982 refueling outage, which occurred because of the baffle jetting problems of the 1981 fuel cycle. (See IE Information Notice 82-27, "Fuel Rod Degradation Resulting From Baffle Water-Jet Impingement," August 5, 1982.)

Event Specifics:

Shortly after the start of the 1987 refueling outage in April, a significant increase in personnel skin contaminations occurred. On April 9, high surface contamination (up to 300,000 dpm/100 cm^2) and high airborne activity levels (2E-7 µCi/cc, mixed fission products) in containment resulted from the dispersal of fuel fragments during reactor vessel stud removal and stud-hole plugging operations. The workers in the reactor cavity were wearing respirators and no excessive uptakes of radioactive materials were detected during followup whole-body counting. Because of the spread of contamination to the spent fuel building, the licensee stopped all reactor building cavity work and all personnel evacuated the area that afternoon.

On April 10, a licensee radiation survey located a hot spot on the cavity floor near a reactor vessel stud hole (>100 rad/hr beta and 30 R/hr gamma contact reading using a portable ion-chamber survey instrument). On April 11, another worker located what appeared to be about one-half of a fuel pellet in the flange area at the stud hole. This partial fuel pellet was removed on April 12.

On April 17, a radiation protection technician, after performing a survey of the lower refueling cavity, discovered a fuel particle lodged in his protective rubber shoe cover. This particle was later determined to be composed of approximately 50 mCi of mixed fission product activity; showed readings of 1200 mR/hr with the window open and 250 mR/hr with the window closed. After a careful time-and-motion study of the technician's activities, the licensee determined that no NRC regulatory dose limits were exceeded. (Licensee estimates were 1.2 rem to whole body; 4.6 rem to skin; 9.6 rem to extremities.)

In general, it appears that the licensee experienced a programmatic breakdown that resulted in several workers receiving significant, unnecessary radiation exposures from fuel particle contamination. In LER No. 87-08 dated May 8, 1987, the licensee identified the following additional concerns and corrective actions. The LER stated in part:

> Workers entering containment on April 9 were not aware of the fuel particle hazards. As a corrective measure, all personnel with access to radiological control areas were retrained to be informed of the fuel particle problem and perform hands-on training to demonstrate competence in anti-contamination clothing use. Daily reports are being provided to workers on the status of containment activities.
>
> Radiation surveys and record keeping were inadequate. As a corrective measure, new procedures were developed to specifically address discrete radioactive particles. All radiation protection technicians have been trained on these new procedures.
>
> There was insufficient extremity monitoring and no procedures for particle control. As a corrective measure, procedures have been prepared to address particle control. Additional extremity monitoring is being utilized.
>
> Evaluation of radiological events needs to be improved. A new procedure will be prepared for documenting and evaluating radiological events.
>
> Review of radiation protection activities is insufficient. A new separate onsite review committee will be established to evaluate radiological events and to routinely review the performance of the Radiation Protection Department.
>
> Insufficient staffing existed. Increasing the manpower in both the onsite Radiation Protection Department and the corporate Radiological Safety Branch of the Nuclear Safety and Regulation Department is being pursued.

Problems existed due to insufficient radiation monitoring and surveying equipment. Additional equipment including new portal monitors and radiation monitoring equipment has been procured.

There was the potential for radiation exposure to individuals from fuel particles on anti-contamination clothing. An evaluation for potential exposure is in progress.

V. C. Summer, November 1986, Inspection Report No. 50-395/86-22

After working in a "clean" area where no protective clothing was required, contamination was detected on the hand of an electrician who had worked on a control panel for the overhead crane in the fuel handling building. After measuring the dose rates (window open and window closed) with a portable survey instrument the worker's hand was decontaminated. The contaminant was not retained for further analysis. Based on the survey instrument readings, the dose to the workers hand was calculated to be about 420 rems (at a depth of 7 mg/cm^2 averaged over an area of 1 cm^2).

Salem Unit 2, April 1987, Inspection Report No. 50-311/87-11

A fuel particle was detected by a whole-body contamination monitor on a worker's arm. The particle was identified as a fuel particle (about 225 days since in core) by using a gamma-ray spectrometer [Ge(Li) detector]. The licensee believes that the source of the particle was from the last refueling outage about 8 months earlier.

Yankee Nuclear Power Station, May 1987, Inspection Report No. 50-29/87-10

A potential skin exposure of 7.6 rem to a worker's scalp occurred from an activated particle. The apparent source of the particle was the worker's PC hood. After its discovery, the particle remained on the worker's scalp for about 78 hours, awaiting medical assistance to remove the particle. Prior to medical assistance arriving on site, the particle was removed by shaving the hair. Earlier in May, the licensee reported that, during fuel assembly movement, pieces of fuel rods were seen to have fallen away from the assembly and land on top of the reactor core and in the refueling cavity area. Fuel reconstitution was in progress.

Indian Point Unit 3, May 1987, Inspection Report No. 50-286/87-18

A maintenance foreman exiting the containment after helping to replace steam generator manway covers received an estimated 4 rem dose to the skin (in back of neck) from an activated zirconium particle. It appears the particle dislodged from his PC hood and fell on his neck during temporary removal of the hood during a work rest-break.

Quad Cities/Dresden/Zion, 1986 and 1987

A special program to investigate hot particle incidents has been in place at these Commonwealth Edison Company facilities for the last 1-2 years. A total of approximately 100 individual hot particles were found on workers' skin or clothing in 1986. Approximately 130 particles were found in the first six months of 1987. The particles have been predominantly Co-60 with activities ranging from about 0.01 to 1 μCi. Those particles were analyzed for physical size; the smallest was 20 microns. The licensee investigated each event and calculated skin doses. No overexposures have been reported. The transfer mechanism of the particles to the workers has not been positively identified.

Callaway Station, 1986 Period, Report No. 50-483/8700 (DRSS)

The licensee experienced ten hot particle skin contamination incidents primarily during the refueling outage early during the year. No NRC dose limits were exceeded. Ineffective frisking (hand-held pancake GM-tube) of laundered PC and potentially degraded dry-cleaning fluid quality (leading to cross-contamination of PC during cleaning) were identified by the licensee as possible contributors to this contamination problem.

LIST OF RECENTLY ISSUED
INFORMATION NOTICES 1987

Information Notice No.	Subject	Date of Issuance	Issued to
87-38	Inadequate or Inadvertent Blocking of Valve Movement	8/17/87	All nuclear power reactor facilities holding an OL or CP.
87-37	Compliance with the General License Provisions of 10 CFR Part 31	8/10/87	All persons specifically licensed to manufacture or to initially transfer devices containing radioactive material to general licensees, as defined in 10 CFR Part 31.
87-36	Significant Unexpected Erosion of Feedwater Lines	8/4/87	All nuclear power reactor facilities holding an OL or CP.
87-35	Reactor Trip Breaker, Westinghouse Model DS-416, Failed to Open on Manual Initiation from the Control Room	7/30/87	All nuclear power reactor facilities holding an OL or CP employing W DS-416 reactor trip breakers.
87-34	Single Failures in Auxiliary Feedwater Systems	7/24/87	All holders of an OL or a CP for pressurized water reactor facilities.
87-33	Applicability of 10 CFR Part 21 to Nonlicensees	7/24/87	All NRC licensees.
87-32	Deficiencies in the Testing of Nuclear-Grade Activated Charcoal.	7/10/87	All nuclear power reactor facilities holding an OL or CP.
87-31	Blocking, Bracing, and Securing of Radioactive Materials Packages in Transportation.	7/10/87	All NRC licensees.

OL = Operating License
CP = Construction Permit

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*SEE PREVIOUS CONCURRENCES

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