U. S. NUCLEAR REGULATORY COMMISSION
REGION I

Report No. 50-320/89-09

Docket No. 50-320

License No. DPR-73

Licensee: GPU Nuclear Corporation
P. O. Box 480
Middletown, PA 17057

Facility Name: Three Mile Island Unit 2

Inspection At: Middletown, Pennsylvania

Inspection Conducted: September 28 and October 12-13, 1989

Inspectors: S. Sherbini
S. Sherbini, Senior Radiation Specialist
Facilities Radiation Protection Section
10/26/89
date

Approved by: W. Pasciak
W. Pasciak, Chief, Facilities Radiation Protection Section
10/26/89
date

Inspection Summary: Inspection on September 28 and October 12-13, 1989 (Report No. 50-320/89-09)

Areas Inspected: A reactive inspection to review the circumstances connected with an apparent exposure of two workers in excess of the limits specified in 10 CFR Part 20.

Results: Two apparent violations were identified: exposure of two workers in excess of the limits specified in 10 CFR 20.101 (Section 5.0 of this report) and failure to make a 24-hour notification in accordance with the requirements of 10 CFR 20.403(b) (Section 4.0 of this report).

DETAILS

1.0 Personnel Contacted

* J. Bevelacqua, Director, Radiological Controls Unit 2
* J. Byrne, Licensing, Unit 2
* B. Frantz, Sergeant, Site Protection
* S. Levin, Defueling Director
* G. Lodde, Manager, Radiological Health
* W. Marshall, Manager, Plant Operations Unit 2
  D. Merchant, Radiological Engineer, Unit 2
  C. Opalack, Site Physician
  B. Parfitt, Radiological Engineer, Unit 1
  A. Paynter, Lead Group Radiological Controls Supervisor Unit 2
* C. Pollard, Manager, Radiological Controls Field Operations Unit 2
* M. Roche, Director, Unit 2
* R. Rogan, Director, Licensing and Nuclear Safety
* E. Schrull, Licensing, Unit 2
* R. Shaw, Director, Radiological Controls Unit 1
  J. Steiner, Nuclear Security Agent
* M. Wells, Manager, Media Relations

1.2 NRC Personnel

* S. Young, Senior Resident Inspector
  T. Moslak, Resident Inspector

* Denotes attendance at the exit meeting

2.0 Description of the Facility

The work area in which the incident occurred was the Decontamination/Burn/Flush Facility (Decon facility) located on the 347' elevation of the Unit 2 Reactor Building (RB). The facility is a stand-alone steel frame enclosure (shack) used to repair, disassemble and decontaminate equipment involved in the defueling operation. The facility consists of two work rooms: the burn area and the decontamination and flush area. The burn area contains welding and gas cutting equipment and is constructed with a metal floor for fire protection. The decontamination room is provided with a raised grating for flushing purposes. The grating is made of steel sections and is raised about 15" off the floor of the room. Below the grating is a coarse mesh wire net designed to catch items

that fall through the grating but that are large enough to clog the drain below the grating. The drain leading from the area below the grating goes to the RB sump. The grating area is separated from the rest of the decontamination room by a plastic curtain that is cut into vertical sections to facilitate access to the grating. The curtain is designed to minimize splashing into the room during flushing.

Each of the two rooms in the facility opens up, via a doorway, into an ante-room. The access points between the ante-room and the two work rooms are provided with stepoff pads. The ante-room is maintained at a lower contamination level (150,000 dpm /100 sq. cm) than that in the work areas (250,000 dpm/100 sq. cm). Access to the facility is via a doorway that leads into the ante-room, and the access point is also provided with a stepoff pad. The access door to the facility is posted as a high radiation and high contamination area. Upon leaving either of the work areas to enter the ante-room, personnel must remove their booties before crossing the stepoff pad. When leaving the ante-room to the outside of the facility, personnel remove their plastic protective clothing.

Access to the Decon facility is controlled by an RWP with a thirty day expiration period. All work in the facility must be done under this RWP (RWP # 018286, "Activities In The Burn/Flush/Decon Facility On Defueling Items"). The RWP in effect during the incident was established on September 1, 1989 and expired on September 30, 1989. Protective clothing specified in the RWP included, for the hands, cotton liners, surgeon's gloves, and rubber gloves. Foot protective clothing included plastic booties, rubber boots, and then plastic booties. Respirators were also required (powered air purifying respirators (PAPRs) were used). A wet suit and plastic hood were required for flushing work. The surveys used to generate the RWP showed 15-50 mR/hr general area with 400 mR/hr maximum located at the flush grating, and 20-40k dpm/100 sq. cm general contamination levels with a maximum of 240K dpm/100 sq. cm at the grating. Airborne activity was of the order of 6E-10 uCi/cc. The RWP required radiation and contamination surveys at least once per shift when work is performed in the facility.

The dosimetry worn by the workers during this entry consisted of what the licensee refers to as the standard defueling set. This set included TLDs on top of the head, on both wrists, and on the right thigh just above the knee. Self reading dosimeters were also used with the head and thigh TLDs. The licensee stated that their experience in defueling work showed that these are the locations most likely to receive the highest doses.

3.0 Description of the Incident

The sequence of events and the details were obtained by attending a critique held after the incident, interviews with site personnel, and

reviewing an investigation report generated by site security. Site security became involved as a result of significant discrepancies in the accounts of the incident provided by the workers involved. The description provided in this inspection report represents the most likely sequence of events as determined by the licensee. Inconsistencies are noted at the appropriate points in the description.

The incident occurred on the morning of September 25, 1989 (Monday). Work had been done on September 22 (Friday) in the Decon facility and it was decided at that time not to clean the area since it was the end of the day and there was no work scheduled in the facility over the weekend. The work on September 22 involved flushing a highly contaminated pump in the flushing facility. On the morning of September 25, a crew of four people was sent in to clean the Decon facility. The crew consisted of three contractor laborers and one licensee senior Radiological Controls Technician (RCT). The crew entered the Reactor Building (RB) at 9:10 in the morning. The RCT had to cover two jobs: the Decon facility cleanup and a cutting job in a room close to the Decon facility. The decon workers will be referred to as 'A', 'B', and 'C'. 'A''s job was to clean up the grating area and then flush it to lower the contamination levels. Flushing is done using high pressure hot water supplied by a machine located just outside the Decon facility. Worker 'C''s job was to operate that machine from outside the facility, and worker 'B' was to clean the walls and floors in the area adjacent to the grating. This was to be done by spraying the walls and floor with a household cleaner and then wiping with terri cloth (paper towels). Radwaste trash bags were provided for discarding these towels and other radioactive debris collected during the cleanup. All members of the team had hand-held radios to facilitate communications

The RCT surveyed the area to be cleaned before work started and told the workers that the radiation levels were a little high. The crew then started their work. 'A' first misted the area to keep airborne contamination low and started flushing, but then lost water pressure. He asked 'C' to adjust the machine and, while waiting, he picked up debris from the grating and put it into the radwaste bags. These bags were located on the floor just outside the plastic curtains covering the grating area. When pressure returned he started flushing to decontaminate the area. Meanwhile, 'B' had started wiping the walls and floor of the adjacent area. The RCT left to check on the other job he was covering and returned before the flush was finished. He surveyed the area and told 'A' that the radiation levels were lower but still high and that he should continue decontaminating the area. 'A' then proceeded to flush the area a third time. While flushing, he noticed an object on the grating that he said looked looked like a nut (as in nut and bolt). He picked it up in his left hand and continued to flush the grating. When he approached the edge of the grating, he reached through the plastic curtain and tossed the object toward one of the trash bags. He missed and the object landed on top of some terri towels on the floor. 'A' stated that the area over the grating had become very steamy as a result of the hot water flushing and that visibility was not very good. He therefore

did not see the object clearly when he picked it up. However, when he tossed the object toward the trash bag, he noticed that it was not a nut. He continued flushing the grating.

In the meantime, 'B' continued to wipe down the walls and floor. His work took him close to the trash bags at the edge of the grating area and he moved the bags to the side to clean the area around them. He noticed an object that was lying on a terri towel and wrapped in the towel in a manner similar to a "Hershey Kiss". He stated that he picked up the object to put it in the trash bag but 'A' noticed this and told him to leave it alone because he wanted the RCT to survey it. 'B' put it down and continued to decontaminate the walls. Contrary to this description by 'B', 'A' stated that he did not see 'B' pick up the object nor did he tell him to put it down.

When 'A' finished flushing, he called for the RCT to survey the object he had found. He then got off the grating, picked up the object in his right hand, transferred it to his left hand, and took it to the other side of the room and put it on a terri cloth on the floor near the grating. He again asked the RCT to survey the object.

The RCT stated that he found the object on the edge of the grating and not on the floor. He surveyed it with an RO-2A (ionization chamber with a 0-50 R/hr range) at a close distance (not specified but considered a contact reading) and found it to read 24 R/hr closed window and off scale open window. The RCT then called the Command Center on his radio and told them about what was now believed to be a piece of fuel from the reactor. The Command Center asked if he can push it through the grating and the RCT said he could not. The Command Center then asked if he could break it into smaller pieces. The RCT put the object in a plastic bag using a long-handled tool and then hit it with the tool but it did not break. He then asked to speak to his supervisor, a Group Radiological Controls Supervisor (GRCS) who was in the Command Center at that time. The GRCS instructed him to locate a bucket, place the object in the bucket, and throw it back into the reactor vessel. The RCT found a bucket, placed the object in it, and took another RO-2A reading from the lip of the bucket (about 15" from the bottom). He found 1.6 R/hr closed window and 14 rads/hr beta. He then threw the object into the reactor vessel. The crew completed their decontamination work and they all exited the RB at 10:30 am. The total stay time in the RB was 80 minutes. Transcripts of the conversations that went on between the persons involved in the incident show disagreement between the different versions regarding what was said.

The licensee has not been able to resolve the inconsistencies in the descriptions of the events given by the worker involved, nor the inconsistencies in their reports of the conversations that took place during that period. The inconsistencies between the accounts given by 'A' and 'B' are relatively minor, but those between the accounts given by 'A' and the RCT are significant. 'A' 's account implies that the RCT knew that at least 'A' had handled the fuel fragment. The RCT's account implies that

the fuel fragment was found by the RCT on the lip of the grating and that it was not put there or handled by 'A'. In an attempt to resolve this inconsistency, the licensee considered what they refer to as the 'multiple-particle' hypothesis. According to this hypothesis, the object handled by 'A' and 'B' was not the same object that was surveyed by the RCT. In support of this hypothesis, the licensee pointed to the fact that when asked to choose a rock of about the same weight as the object they handled, 'A' and 'B' picked rocks of nearly equal weight but the RCT picked a rock that was nearly a factor of four lighter. However, there is little to support this hypothesis, and it is inconsistent with available dosimetry data. The difference in weights of the rocks selected may be due to the fact that 'A' and 'B' actually handled the fuel fragment directly whereas the RCT handled it only using a long-handled tool.

The origin of the fuel fragment, that is, how it got to the grating, could not be determined by the licensee. The pump that was decontaminated in the facility the previous Friday (September 22) was partially disassembled in the Decon facility but the licensee stated that the fuel fragment was probably too large to have come from the pump. The RCT who covered the pump job also stated that he had surveyed the pump and the work area during the work but did not find any unexpectedly high radiation fields.

4.0 Response of the Licensee and Reporting

The licensee stated that they had initially not considered the incident to be anything unusual that warranted any followup action, and that it was not unusual to find fuel fragments in the Decon facility. The licensee also stated that they did not initially know that anyone had handled the fuel fragment. During investigation of the incident, a senior contractor RCT stated that on the day following the incident, September 26 at 7:30 am, 'A' had approached him and told him that he had picked up a piece of fuel on the previous day and wanted to know if there were any adverse health effects to be expected. The technician advised him to talk to his supervisor. Another RCT also stated that on that day, September 26 at 8:00 am, 'A' had also spoken with him about an incident that happened in the Decon facility, and asked him about the health effects to be expected as a result of handling a piece of fuel. The RCT notified his supervisor at 9:00 am on September 26 of the conversation with 'A'. The supervisor then recalled 'A' from the RB where he was working on another job. He pulled his dosimetry and restricted his access until further notice. The licensee held a critique that afternoon to discuss the situation. The RCT who had covered the Decon facility during the incident was called at his home at 4:00 pm and told of the situation. He stated that that was the first time he had heard that anyone had handled that fuel fragment.

On September 27, the Manager, Radiological Controls Field Operations Unit 2 interviewed 'B' about the activities on September 25 and learned at that point that 'B' had also handled the fuel fragment. The NRC resident was notified by the Director, Radiological Controls TMI Unit 1 on September 27 at 1:30 pm. On the morning of September 28, a mockup of the Decon facility was used to help re-enact the activities of September 25 and to estimate the length of time 'A' and 'B' had the fuel fragment in their hands. On the afternoon of September 28, a full scale critique was held to discuss the incident. It was attended by the workers involved (except 'B'), members of site and corporate management, representatives from the departments involved, and the NRC.

'A' and 'B' were referred to the site physician following discovery that they may have been exposed to relatively high radiation doses. They were both given complete physical examinations and were counselled by the physician and by the Director of Radiological Controls Unit 2 on the health effects of radiation. Their medical conditions were found to be normal. They were informed of the estimated doses and of the expected health effects at these levels. The licensee stated that their medical consultant did not expect any negative observable health effects to develop. Both workers remain under observation by the physician. A medical consultant is scheduled to examine the workers on site.

The licensee made an official notification of the incident to the NRC on October 6, 1989. The notification was made per the requirements of 10 CFR 20.403, "Notification of incidents", subpart (b), "Twenty-four hour notification", and was made to the NRC Operations Center over the Emergency Notification System (ENS). The licensee stated that they made the notification as soon as the dose assessments clearly indicated that the dose to the extremities would exceed 75 rems, which is the trigger level for the 24-hour notification requirement. However, NRC evaluation of the information available at the critique of September 28 shows that the data clearly indicated that the dose to the hand of at least 'A' would be well in excess of 75 rem. Also, 10 CFR 20.403(b) requires the 24-hour notification to be made after "...any event involving licensed radioactive material possessed by the licensee that may have caused or threatens to cause....exposure to the feet, ankles, hands, or forearms to 75 rems or more of radiation...". Therefore, delaying the required notification until October 6 constitutes an apparent violation of the requirements of 10 CFR 20.403(b) (50-320/89-09-01).

As of the date of this inspection, the licensee had not submitted a Licensee Event Report (LER), as required by 10 CFR Parts 20.405 and 50.73.

5.0 Dose Assessment

Following discovery that the workers had handled the fuel fragment, the licensee initiated a dose assessment effort to estimate the dose to the workers. A review of the dosimetry readings for the workers involved did not show any unusually high readings on any of the dosimeters worn during the entry in question. However, this result is not wholly unexpected because the fuel was held in the worker's hand and the closest dosimeter was on the wrist. The wrist dosimeter, however, is not well placed to measure the dose to the palm of the hand from an object grasped in the hand. Therefore, a dose assessment based on dose calculations was necessary.

The dose assessment performed by the licensee was based on the reading taken by the RCT with the RO-2A with the source in the bucket before it was returned to the reactor vessel. That reading showed 1.6 R/hr closed window and 14 rad/hr beta. The licensee did not use the beta reading in the dose assessment because its interpretation involved many assumptions that would diminish the validity of the analysis. The closed window reading was considered to be a combination of gamma radiation and some penetration by the high energy beta radiation from Y-90, which was known to be present in the fuel. This penetration was estimated, based on measurements and theoretical considerations, to contribute about 0.15 R/hr to the reading, which left 1.45 R/hr as the measure of the gamma exposure rate at the point of measurement. This point was at the lip of the bucket, which was measured to be 15.5" from the fuel fragment. To this distance was then added 1 3/16" for the distance between the front face of the instrument window and the center of the detector's active volume. The basis of the licensee's assessment was thus an exposure rate of 1.45 R/hr at a distance of 16 11/16" from the fuel. The source was assumed to be spherical in shape.

The licensee then asked workers 'A', 'B' and the RCT, who had handled the fuel, to go out on site and select a piece of rock that they believed weighed about what they recalled the fuel felt like when they handled it. 'A' and 'B' selected rocks that agreed within less than 10% of each other and the mean weight was about 90 gm. The RCT selected a much smaller weight, less than one quarter of the weights selected by 'A' and 'B'. The licensee decided to use a weight of about 90 gm for the fuel fragment. The licensee then estimated the density of the fuel fragment based on the selected weight and the estimated size. The estimate was a density of 2.9 gm/cubic cm. The licensee stated that this value is reasonable based on the description given of the fragment, which was apparently porous, and also based on considerations of the likely composition of the fragment material, which is thought to have been fuel that had melted and then solidified in a composition that included material other than fuel, such as some structural materials. The estimated density was used in the calculations to make allowance for self absorption in the fuel fragment. The licensee then used

isotopic analysis data of fuel that had previously been done at the Idaho National Engineering Laboratory (INEL). This analysis provided specific activities in uCi/gm of each radionuclide in the fuel. The specific activity multiplied by the estimated weight of 90 gm gave the activity of each isotope in the fuel fragment. This data was then used as input to a shielding computer code, and the dose rate from the fragment at the detector was calculated. The result was 0.2 R/hr, instead of the expected 1.45 R/hr, which is the measured gamma ray exposure rate.

The licensee stated that they do not know the reason for the difference between the calculated exposure rate of 0.2 R/hr and the measured rate of 1.45 R/hr, a difference of a factor of about seven. However, in order to accommodate the available measurement, which is considered to be the most reliable data for use in the dose estimates, the licensee scaled the activities in the fuel fragment by a factor that resulted in the correct calculated exposure rate. The activities were therefore increased from the original estimate by a factor of about seven, giving a total estimated activity of 11.1 Ci. The isotopic composition of the fuel was estimated to be almost entirely Cs-137 and Sr-90, with Y-90 in equilibrium as a daughter product of Sr-90. Other radionuclides were identified but their concentrations were at least two orders of magnitude less than those of Cs and Sr. Since Sr-90 and Y-90 are both pure beta emitters, the measured gamma exposure rate was due almost entirely to Cs-137 gamma rays, with possibly some contribution from beta penetration through the detector closed window and some bremsstrahlung generated in the fuel fragment by the Sr and Y beta radiation. Using the calculated total activity, the contact gamma dose rate to the skin was calculated to be about 0.2 rads/sec.

The beta dose rates to the hands of the workers were estimated on the basis of the total activity calculated to be in the fragment, namely 11.1 Ci. The workers were wearing cotton liners, surgeons gloves, and rubber gloves at the time they handled the fuel. The licensee measured the thickness of the items worn by the workers and found a total absorbing layer between the fuel and the skin of the palm of 86 mg/sq. cm. A skin thickness of 7 mg/sq. cm was used in the calculations, giving a total thickness for penetration of the beta rays to the basal skin layer of 93 mg/sq. cm. The beta dose was calculated using Loevinger's equation for the depth dose distribution of beta rays. The source geometry was assumed to be that of an infinite plane source of infinite thickness. The dose rates were also calculated using the VARSKIN computer code assuming the same infinite plane geometry. Since this code cannot be applied directly to an infinitely thick plane geometry, the code was used to calculate the dose rates from a series of thin planes and the results were then added. The two methods were found to be in good agreement, and the dose rate calculated for the beta component was found to be 5 rads/sec. The total calculated skin dose rate is thus 0.2 gamma plus 5 beta for a total of 5.2 rads/sec. The beta component for worker 'B' will be somewhat smaller than that for worker 'A' because 'B' picked up the fuel fragment in a piece of terri cloth, which provided an additional 19 mg/sq. cm of shielding over the 93 mg/sq. cm total used for worker 'A'.

The licensee conducted two sets of re-enactments of the activities that took place in the Decon facility on the day of the incident. A mockup of the flushing area with the grating was used, and the second re-enactment was recorded on video tape. The first re-enactment was conducted with the workers wearing only respirators and gloves, but the second was conducted in full protective clothing, including the respirators. The results of these re-enactments showed the following contact times with the fuel fragment:

	Contact Time, seconds	
	Worker 'A'	Worker 'B'
First re-enactment	18	7
(done three times for	26	7
'A' and twice for 'B')	28	
Second re-enactment	42	5

Despite the fact that the second re-enactment was somewhat more realistic than the first because the workers were dressed in full protective clothing, the licensee believes that the second re-enactment produced an unrealistically long time for worker 'A' because there were several interruptions and conversations with the team of observers. The licensee is currently of the opinion that 30 seconds represents a reasonable average time for 'A' and 7 seconds for 'B'. Based on these values, the dose to the extremities were found to be as follows:

Worker 'A':

Mean dose to the left hand (30 sec) = 156 rads
Based on minimum time of 18 sec = 94 rads
Based on maximum time of 42 sec = 220 rads

Worker 'B':

Dose based on 7 seconds = 35 rads

The doses assessed to the hands of 'A' and 'B' are in excess of 18.75 rem per quarter and therefore constitute two instances of an apparent violation of the requirements of 10 CFR 20.101 (50-320/89-09-02).

Following discovery of the incident, the dosimetry worn by the workers involved were read and the doses obtained are shown below. The readings represent doses received over the period from September 11 to September 26, 1989 and therefore include doses received during the incident as well as from other jobs previous to the incident. Self reading dosimeter measurements for each entry during that period are also available but they do not show any trends that are significantly different from those indicated by the TLD results.

TLD Doses, millirem

	Worker 'A'		Worker 'B'	
	Beta	Gamma	Beta	Gamma
Top of head	871	427	53	179
Right wrist	365	429	61	151
Left wrist	517	487	52	156
Right thigh	715	393	64	146

The doses for the quarter for both workers, not including the doses to the hands from this incident, are for 'A', 1057 mrem whole body and 2198 mrem extremity and for 'B' 238 mrem whole body and 291 mrem extremity.

The licensee considers the dose assessments done to date as preliminary and in need of refinements. Although the general order of magnitude of the doses is not expected to change as a result of these refinements, the licensee expects the final doses assigned to the individuals to be somewhat lower than the current values. Efforts to refine the dose assessments include the following:

. Perform calculations to estimate the doses received by other parts of the body, particularly the torso, since that area was close to the source held in the worker's hand and it was not monitored by a dosimeter.

. Refine estimates of the density of the fuel fragment to improve the estimate of self absorption for gamma dose calculations.

. Repeat the beta dose calculations for skin thickness other than 7 mg/sq. cm, which is the thickness used to obtain the currently available dose estimates. Specifically, the licensee intends to do the beta calculations for skin thicknesses of 40 and 65 mg/sq. cm, which the licensee believes better reflect the actual skin thickness in the palm of the hand.

. Review the video tape of the re-enactment in an attempt to refine the time estimates for source handling.

. Repeat the beta dose calculations for worker 'B' to include an extra 19 mg/sq. cm of shielding provided by the terri cloth in which the source was wrapped when 'B' picked it up. The initial calculations did not include this shielding.

. Perform beta measurements on the RO-2A to determine its response to beta radiation from the fuel. In particular, these measurements should indicate the degree of penetration of the beta radiation through the closed window of the detector, thus affecting the gamma measurements. These measurements will be done both on site and also at INEL.

. Perform angular dependence measurements on the TLDs in gamma and beta fields. The licensee intends to use this data to calculate the dose rate to be expected at the location of the wrist TLD due to holding the fuel fragment in the palm. This dose rate may supply additional information regarding contact time. The TLD readings shown above show that, for worker 'A', the left wrist TLD registered about 60 mrem higher gamma dose than the corresponding right wrist TLD and 152 mrem higher beta dose. This difference is presumed to have been caused by handling the fuel fragment. The wrist TLDs of worker 'B' do not show any significant difference between the left and right wrists. This may be due to the fact that worker 'B' handled the fuel for only 7 seconds whereas worker 'A' handled it for 30-42 seconds. Preliminary calculations by the licensee show that the difference in dose between the left and right wrist TLDs for worker 'A' are of the magnitude expected to result from handling the fuel fragment.

. Measurements are to be made of the response of the TLD when placed on an arm phantom in a geometry similar to that of holding a fuel fragment in the palm. These measurements are to be made at INEL using core debris material. Similar measurements will be made on site using Sr-90.

. The final dose assessment will be subjected to review by site and corporate engineers and also by an expert in the field of radiation dosimetry.

. The licensee will contact other licensees who have had similar past experiences to benefit from their experience in dose assessment.

. The dosimetry records for all personnel who worked in the Decon facility during the two week period prior to the incident will be reviewed for any unusual results. The licensee stated that the previous two weeks mark the start of use of the Decon facility for work on highly contaminated items.

7.0 Corrective Actions

As a result of reviews of the incident, the licensee identified a set of corrective actions designed to minimize the probability of recurrence. These corrective actions include the following:

. The design of the Decon facility and the flushing method is to be reviewed in order to improve the visibility in the grating area during flushing. One of the problems identified in the review of the incident was that the visibility was very poor during flushing because of the steam generated by the hot water used in flushing. The licensee has already modified the ventilation flow path in the area to improve the air flow. Other measures being considered include the use of a demister and lowering the temperature of the flushing water.

. The area is to be cleaned and all unnecessary material and equipment cleared out and the facility will be decontaminated to acceptably low levels. Housekeeping will be improved and the RCTs will be instructed to ensure the area is in good condition and will shut down the facility if conditions are not satisfactory.

. Workers will be trained not to pick up any items before they are surveyed by the RCT.

. A review of jobs that took place in the facility prior to the incident will be made in an attempt to determine the likely source of the fuel fragment. The review will also include a search through the dosimetry data for any unusual dosimetry readings for people who had worked in the facility that may point to unsuspected exposures to personnel.

. The adequacy of the following items will also be reviewed:

- . Dosimetry requirements and placement.
- . Frequency and type of RCT job coverage.
- . The RWP and the ALARA review.
- . Job briefings and turnovers.
- . Administrative controls of the facility.
- . Methods used to flush equipment.
- . Methods used to survey the facility.

8.0 NRC Evaluation

The methods used in calculating the doses to the hands of the workers are appropriate in view of the available data. The calculation of the gamma dose is based on the measurement taken by the RO-2A with the fuel in the bucket. This measurement is subject to two main errors: the detector is

close to the source and the field may therefore not be uniform over the detector's active volume. This may cause the detector to give an incorrect or at least a difficult to interpret reading. Also, the reading may include contributions from bremsstrahlung generated in the fuel and from energetic beta particles penetrating to the detector's active volume through the closed shield window. The latter effects will cause the detector to record a higher apparent gamma exposure rate than is actually the case, which would in turn lead to overestimating of both the gamma and beta skin dose rates. The licensee is investigating these effects.

Another source of uncertainty in the dose estimate is the weight of the fuel fragment and the specific activity of the fuel. The product of these two quantities gives the total activity estimated to have been in the fuel fragment. Although this quantity may involve large uncertainties, its effect on the final dose estimate is small because the results of the computer dose calculations are normalized to give the observed exposure rate reading. This normalization process in effect changes the total activity in the fuel fragment until it yields the known exposure rate.

The remaining factor in the gamma dose estimate is the validity of the computer model. The licensee assumed a spherical source geometry, but this may not be an appropriate shape. The licensee did not know the effect of the choice of geometry on the final result. Following discussions with the inspector, the licensee decided to perform a sensitivity analysis to determine the effect of changes in geometry on the calculated dose rate. If the effects are found to be small the spherical geometry would be considered adequate. Otherwise, a more refined geometry may be needed.

The beta dose calculations are based on the results of the gamma dose calculations and any errors introduced in those calculations will be propagated to the beta dose. The use of an infinite plane of infinite thickness is appropriate in view of the small range of the beta particles and the comparatively large size of the fuel fragment. The models used are those currently available for use in beta dose calculations and should yield reasonably accurate results. Refinements in the calculations would include use of a skin thickness other than 7 mg/sq. cm that is more appropriate for the palm of the hand, which is often taken to be 40 mg/sq. cm.

A review of the circumstances surrounding the incident suggests that the incident was probably precipitated by neglect of good housekeeping practices in the Decon facility. The descriptions provided by the workers involved in the incident show that the flush facility was in a state of considerable disarray. This included high levels of contamination as well as a variety of debris, lead shielding blankets, paper towels, tape, etc. scattered over the work area. The licensee stated that these were left over from work performed the previous Friday and that it had been decided to postpone cleaning the area until the following Monday since the facility was not to be used during the weekend. However, there are indications that

housekeeping problems existed in the facility before the job on Friday, and that at least some of the debris and other items were left over from earlier jobs. There are no indications to suggest that the survey performed by the RCT prior to start of work on the day of the incident was not properly done. In view of this, the conclusion reached by the licensee is that the fuel debris must have been shielded by one of the items in the flush area, otherwise it would have been easily detected because of its high activity. The licensee indicated that the fuel fragment found on September 25 was probably too large to have come from the pump that was being flushed in the facility the previous Friday. The licensee speculated that the fuel must have been brought into the area on a previous job and that it had remained shielded and thus escaped detection until the area was cleared on September 25.

The RWP controlling work in the Decon facility states that "Upon completion of each team's work activities, the work area shall be cleaned of all generated waste." The RWP also states that "Task supervisors (have the responsibility) to ensure the work area is cleaned up upon completion of each team's task". It appears that these RWP requirements were not being strictly adhered to in the operation of the Decon facility.

The licensee stated that the workers are trained not to pick up items in the RB before having them surveyed by a RCT. However, both 'A' and 'B' picked up the fuel fragment without first having it surveyed. 'A' picked the fragment in his hand twice, once in the grating area and the second time outside the grating area. The first time he stated that he thought it was a nut and so he picked it up. But he picked it up the second time even though at that point he had doubts about its identity since he could see that it was not a nut but an irregularly shaped object. That also applies to 'B' when he picked it up. It should be noted that 'A' had demonstrated earlier during the work an appreciation of the hazards involved in picking up debris: he used beta gloves when he was picking up debris and trash from the grating area before flushing the grating. The policy regarding picking up nuts and similar machine components is not clear. The RWP states that "No individual shall handle tools or equipment that has not previously been surveyed by Rad Con (this excludes hand tools, flush tools, etc...)". Although this clearly requires survey of certain items such as tools and equipment, it does exclude hand tools etc. It is not clear whether nuts, bolts and similar are also excluded or not. This situation is made even more ambiguous for the worker by the manner in which health physics coverage was provided. When the team entered the Decon facility on September 25, the RCT surveyed the area. One of the purposes of the survey is to make sure that conditions were safe to proceed with the decontamination work. Since part of the work involved picking up debris that was left from previous jobs, it is logical for the workers to assume that the survey allowed them to pick up the debris without further surveys. This is particularly true since much of this cleanup work was done in the presence of the RCT. There does not appear to be a clear policy regarding

what the worker should do when cleaning up an area such as the Decon facility.

A number of problems were known to exist in the Decon facility before the incident on September 25 but the licensee had not initiated corrective actions. One of the problems was mentioned above, namely the poor housekeeping practices in that facility. Another problem was the fact that visibility during flushing was known to be very poor due to the presence of steam from the hot water, but also aggravated by condensation of the steam on the lens of the respirator required for work in this area. Finally, it was known that the very high humidity in the area caused the absolute particulate filters in the respirators to become wet, which may interfere with the correct functioning of the filter and may invalidate the respirator's certification if the filter is not certified to maintain its efficiency under such high moisture conditions.

The response of the licensee to the fact that a highly radioactive fuel fragment was found in the Decon facility while people were working in the area does not appear to have been adequate. It is not clear why the Command Center asked the RCT to push the fuel through the grating. This would only have resulted in the fuel being caught in the wire net immediately below the grating and would have defeated the purpose of the work crew, which was to decontaminate the area and reduce the radiation and contamination levels as much as possible. The direction from the Command Center to attempt to break the fuel fragment was presumably dictated by the idea of trying to push the fuel through the grating. However, attempting to break the fragment is not ALARA: it causes some exposure to the RCT and also poses the danger of creating hot particles. Finally, it is not clear why the GRCS, who was present in the Command Center at the time, was not immediately consulted regarding such a radiologically hazardous situation.

The licensee did not look into the matter or investigate the possibility that the workers may have been exposed until the matter was brought to a supervisor's attention as a result of concern on the part of one of the workers about his health. The licensee stated that the investigation was not initiated earlier because finding a piece of fuel in the Decon facility was not an unusual occurrence. Although small fuel fragments had been found before, a review of survey data for the facility showed that no fuel fragment was previously found with a radiation field approaching that produced by the fragment found on September 25. The dosimetry worn by the workers was such that the hand exposures would not have been identified in a survey of the dosimeter readouts. The exposure received by the workers may have remained unrecognized had it not been for the fact that 'A' realized that he had done something that may prove detrimental to his health and expressed this concern to health physics personnel. The licensee stated that on September 25 (Monday), a debriefing was scheduled for September 27 (Wednesday) to comply with Standing Order Memo 16, which requires that a documented debriefing be held whenever loose fuel debris is

found outside the immediate area of the reactor vessel (the work slot over the vessel).

Notification of the NRC of the incident was not sufficiently prompt. The licensee knew that they had a potentially very serious exposure problem by the afternoon of September 26 yet the NRC resident was not notified until the afternoon of September 27. The licensee's reason for the 24 hour delay was that there were no personnel on site at that time who realized that the NRC should be notified of such incidents as soon as possible. Furthermore, the licensee made the formal ENS 24-hour notification on October 6, nearly two weeks after the incident. The licensee gave as a reason for this delay that they were not sure the dose to the hand would exceed 75 rem, which is the trigger for the 24-hour notification. However, 10 CFR Part 20 states that "Each licensee shall, within 24 hours of discovery of the event, report any event involving licensed material possessed by the licensee that may have caused ...". By September 28, the licensee knew that at least one of the workers had handled the fuel fragment for at least 30 seconds. It was also known that the exposure rates close to the source was 24 R/hr gamma and at least 50 rad/hr beta using an RO-2A and 1.6 R/hr closed window at 15". NRC evaluation of the data available on September 28 indicated that a quick calculation showed that there was a high probability that the dose to the hand of at least one of the workers would be well in excess of 75 rem.

9.0 Exit Meeting

The inspector met with licensee representatives at the end of the inspection on October 13, 1989. The inspector reviewed the purpose of the inspection and presented and discussed the findings.