U. S. NUCLEAR REGULATORY COMMISSION

REGION V

Report No. 50-362/86-37

Docket No. 50-362

License No. NPF-15

Licensee: Southern California Edison Company
2244 Walnut Grove Avenue
Rosemead, California 91770

Facility Name: San Onofre Nuclear Generating Station - Unit 3

Inspection At: San Onofre Nuclear Generating Station

Inspection Conducted: December 15, 1986, January 12-16, 1987, and March 16-20, 1987

Inspectors: J. Russell — 4-9-87
J. Russell
Radiation Specialist, C.H.P.
Date Signed

H. S. North — 4/10/87
H. S. North
Senior Radiation Specialist, C.H.P.
Date Signed

G. P. Yuhas — 4/10/87
G. P. Yuhas, Chief
Facilities Radiological Protection Section
Date Signed

Approved by: F. A. Wenslawski — 4/10/87
F. A. Wenslawski, Chief
Emergency Preparedness and Radiological Protection Branch
Date Signed

Summary:

Inspection on December 15, 1986, January 12-16, 1987, and March 16-20, 1987 (Report No. 50-362/86-37)

Areas Inspected: This was a special inspection in response to the licensee's December 12, 1986, report of a potential exposure to the hand of a worker in excess of the regulatory limit. The inspection included an onsite visit by the Chief, Facilities Radiological Protection Section; subsequent site inspection effort by regionally based Radiation Specialists, NRC Headquarters Staff and the Resident Inspection Staff; extensive in office review; and independent technical evaluations by NRC consultants. The purpose of the inspections was (1) to determine if the worker received the exposure and (2) to establish the adequacy of the radiation protection controls imposed by the licensee to minimize the potential for unplanned exposures to workers from

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small particulate sources of radioactive material. Inspection procedures addressed were 83729, 90712, 92700 and 93702.

Results: Of the areas inspected, apparent violations involving failure to control licensed material to maintain exposure within regulatory limits; failure to perform required surveys; failure to provide immediate notification of events to the NRC; and failure to control licensed material to prevent release to unrestricted areas were identified.

DETAILS

I. Persons Contacted

Licensee Personnel

+*H. Ray, Vice President - Site Manager
+*H. Morgan, Station Manager
+ M. Wharton, Deputy Station Manager
+*P. Knapp, Health Physics (HP) Manager
+*R. Warnock, HP Engineering Supervisor
+*W. Zintl, Compliance Manager
 *C. Couser, Compliance Engineer
+*D. Schone, Site Quality Assurance (QA) Manager
+*E. Donnelly, HP Engineer
  Maintenance Worker A
  R. Dickey, Dosimetry Supervisor
+ J. Reilly, Station Technical Manager
+ A. Brough, Station Technical Engineer
+ S. Stilwagen, Refueling Supervisor

Licensee Contractors

  HP Technician A
+ P. Plato, Professor of Radiological Health, University of Michigan

NRC Contractor

  F. Attix, Consulting Physicist, Department of Medical Physics, University of Wisconsin
  R. Brown, M.D., School of Medicine, University of California
  M. Moeller, Senior Research Scientist, Health Physics Department, Battelle Pacific Northwest Laboratories

NRC Representatives

+ R. Huey, Senior Resident Inspector
+ J. Tatum, Resident Inspector
  P. Stewart, Resident Inspector
+ R. Paulus, Health Physicist, Operating Reactor Programs Branch, IE
  A. Johnson, Enforcement Officer
  S. Block, Region V, Health Physicist, C.H.P.

*Denotes individuals present at the exit interview on January 16, 1987.

+Denotes individuals present at the exit interview on March 20, 1987.

In addition to the individuals identified above, the inspectors met and held discussions with other members of the licensee's and contractor's staff.

II. Background

On December 12, 1986, at 11:30 a.m. (PST), Southern California Edison Company (SCE) made a report pursuant to 10 CFR 50.72(b) of a potential dose to a worker's right hand of 511,990 mrem. The dose to the worker's left hand and whole body, as read from his other TLD badges, was 160 mrem and 114 mrem, respectively. In response to this notification, the Region V Chief, Facilities Radiological Protection Section conducted an initial, onsite inspection on December 15, 1986, to determine if the licensee was dedicating sufficient resources to evaluate the potential exposure and to verify that the licensee was in the process of implementing additional radiation protection measures to control potential exposures from radiation sources.

In anticipation of the licensee's submittal of a Licensee Event Report (LER), two regionally based radiation specialists reported to the site on January 12, 1987, to perform an independent evaluation of the event. LER 86-015 was issued on January 12, 1987, but indicated that the licensee had not completed their investigation and that a revision to the LER would follow.

The licensee issued LER 86-015, Revision 1, on February 22, 1987, reporting their conclusion that the overexposure did not occur. The basis for the licensee's conclusion was to be contained in a report to follow.

On March 3, 1987, the licensee issued a final report, Evaluation of the reported high exposure to extremity TLD #80365 in October, 1986, describing the investigation and providing the bases for their conclusion that the overexposure did not occur. After review of the licensee's final report, the Region V Facilities Radiological Protection Section Chief, an headquarters Inspection and Enforcement Health Physicist, the Region V Enforcement Officer and a regionally based Radiation Specialist reported to the site on March 16, 1987, to complete independent onsite investigation of the event. During this same period, the Region V Emergency Preparedness and Radiological Protection Branch Chief and a NRC consulting physicist and dosimetry expert visited the facilities of the licensee's dosimetry vendor to review the vendor's processing of the TLD badge in question.

As a result of NRC comments made during the exit interview on March 20, 1987, the licensee submitted LER 87-003 on March 24, 1987, pursuant to 10 CFR 20.405(a)(1)(v) in which the licensee provided information regarding three occurrences in which small particles of licensed material had apparently been released from the site.

III. Licensee Evaluations

1. Initial Investigation of 512 Rem Exposure

In LER 86-015, the licensee described the initial information available to them as follows:

"On December 12, 1986, SCE determined that sufficient preliminary information existed to believe that an extremity exposure to one individual's right hand in excess of the regulatory limit of 18 3/4 Rem/Quarter may have occurred in October 1986 during maintenance work at Unit 3. Subsequent investigations are not complete and thus have not established whether the extremity exposure actually occurred. The individual was restricted from further exposure for the remainder of the Fall 1986 quarter. He resumed his normal activities on January 1, 1987.

"During October 1986, an SCE Maintenance individual wore two ring TLDs, one on the ring finger of each hand, provided by...(the)... (TLD Service), on five occasions during maintenance work on a Liquid Waste Management System (LWMS) Crud Tank Pump...and the Reactor Coolant System (RCS) reactor coolant pump seals...removal and reinstallation. The dates of the maintenance work were October 6, 8, 9, 20 and 21, 1986. On October 30, the rings were removed from use and routinely forwarded to the TLD Service for analysis.

"The TLD Service reported to SCE via electronic data transmission to the SCE computer system, all October TLD results on November 13, 1986. Due to an error in the SCE computer data reformatting program, a reading above 9.999 Rem was truncated, dropping any digits above the first place to the left of the decimal point. As a consequence, the computer program feature to automatically identify excessive exposure data failed and SCE remained unaware of a high reading for one of the Maintenance individual's ring TLDs.

"On or about November 17, 1986, the TLD Service, as is customary, provided the backup printed listing of the electronic data transmission to SCE. On December 11, 1986, SCE dosimetry personnel checked the October dosimetry records and noted a reading above the 18 3/4 Rem/Quarter regulatory limit for extremities. After confirming the data with appropriate vendor personnel on December 12, 1986, NRC notification was made and a comprehensive investigation was initiated."

The licensee summarized the status of their investigation by stating:

"Ongoing investigations thus far have been unable to establish whether the extremity exposure actually occurred. However, if it did actually occur, the only plausible mechanism would be from a small fission fuel fragment (FFF). At present, it appears equally likely that the TLD reading was anomalous or was caused by tampering. The ongoing investigations should be completed in February."

In regard to the problem with fuel fragments, the licensee stated:

"During the first fuel cycle of Unit 3, Fuel degradation occurred which resulted in small (size from approximately 0.18 cm down to less than 1 micron) Uranium Dioxide FFFs being liberated to the RCS and spent fuel pool. As a result of liquid radwaste processing, FFFs could also be transported to the LWMS. The activity of FFFs ranges from E-3 to E+3 microcuries. Considering the makeup of the radioactive parent/daughter nuclides from an FFF, these small fragments are characterized as a significant Beta (1.5 Mev average energy) source and a relatively insignificant gamma component...

"Due to the presence of FFFs at Unit 3, SCE had previously instituted a program to minimize personnel contamination and exposure, and spread of the FFFs at the time that FFFs were identified during the initial refueling of Unit 3. This program was further enhanced in November 1986 to upgrade training and indoctrination of supervision and personnel regarding the hazards, special health physics coverage of ongoing work in areas and systems known, or suspected of being contaminated with FFFs, and frequent beta monitoring. For the January 1987 Unit 3 refueling outage, SCE initiated enhanced monitoring which included a "stop work" requirement if the presence of an FFF is detected in an area which is not already under special FFF controls."

The licensee conducted a medical examination on December 18, 1986, of the individual in question and reported that they did not expect or observe any health effects associated with the extremity exposure. In addition, the licensee reported that the individual stated that he had observed no erythema or epilation.

The licensee reported that radiation surveys performed prior to and immediately after the individual's work activities did not indicate radiation or contamination levels which would have resulted in the exposure. Personnel frisking and personnel monitoring booths had not detected any contamination on the extremities of the individual involved. The licensee reported that, although their investigation was not complete, they were investigating the TLD response, potential tampering and deliberate exposure of the individual ring and that a final report would be submitted.

During the January 12-16, 1987, visit, the inspectors confirmed that, due to errors in the licensee's computer programming, the initial TLD reading of 511,990 mrem was truncated to 1,990 mrem. As this figure was below the licensee's administrative limit, it was not flagged by the programming. The inspectors also verified that a hard copy report of the exposure had been received on or about November 17, 1986, but had not been reviewed by the licensee's staff. The hard-copy report was not reviewed until December 11, 1986, when a dosimetry clerk, performing the routine end-of-month comparison of multiple dosimeters, began investigating the difference between the whole body TLD reading, 114 mrem, and the Pocket Ionization Chamber (PIC) reading, 162 mrem, of the individual in question. The hard-copy report indicated a dose of 511,990 mrem to the right hand. The staff member brought the report to the

attention of the Dosimetry Supervisor who informed the HP Engineering Supervisor and he informed the HP Manager at approximately 4:00 p.m., December 11, 1986. The HP Engineering Supervisor contacted the dosimetry vendor at approximately 5:35 p.m. and again at approximately 6:25 p.m. and confirmed that the report was valid and had been reviewed by the vendor Health Physicist. The HP Manager notified the Station Manager shortly thereafter. After contacting the vendor Health Physicist the next morning to further verify that the reading was not incorrect, the licensee notified the NRC at 11:30 a.m., December 12, 1986.

Based on a review of records, the TLD was read on November 10, 1986. Although the TLD vendor's procedures would normally require telephone notification of the exposure to the licensee, no notification was made. The licensee representative informed the inspectors that the contract with the TLD Service did not specifically require a telephone notification. The inspectors were informed by the licensee that the computer software, implemented in February 1984 to expedite the handling of dosimetry data, had not been validated, verified or documented. Specifically, these programs are:

GENCOM - Receives electronic data transmission from the vendor

LNDXMIT - Reformats data and creates file in mainframe

SRPRCS - Takes information from LNDXMIT created file and updates dosimetry file

SCERJE - Updates file on mainframe from lab

TLDOSE - Extracts data from SCERJE fcr reports

With respect to reporting overexposures, the inspectors brought to the licensee's attention that 10 CFR 20.403(a), Immediate notification, states: "Each licensee shall immediately report any event involving byproduct, source, or special nuclear material possessed by the licensee that may have caused or threatens to cause: (1)...exposure of the feet, ankles, hands or forearms of any individual to 375 rem or more of radiation." Since the licensee had sufficient information available on November 17, 1986, to enable him to recognize and report the potential overexposure yet failed to do so, this is considered a violation of the reporting requirement. Failure to immediately notify the NRC of an event that may have caused or threatens to cause an exposure to the hand of an individual to 375 rem or more is an apparent violation of 10 CFR 20.403(a). (86-37-01)

The dosimetry supervisor informed the inspectors that all written reports from the TLD vendor since implementation of the defective programs had been reviewed and no other extraordinary exposures were identified. The licensee staff informed the inspectors that they had instituted action to validate, verify and document the software.

2. Licensee Conclusion Relative to the 512 Rem Exposure

With respect to the apparent overexposure of a maintenance worker's right hand, the licensee's final report, Evaluation of the reported high exposure to extremity TLD #80365 in October, 1986, provided the bases for their conclusion that the exposure report was invalid. These were:

A. "The residual reading (on the TLD) was unreasonable and unreproducible in the dose range reported;

B. "No sources capable of delivering such a dose were available within a vanishingly small probability;

C. "Extensive radiation and contamination surveys failed to detect any such sources; and

D. "No conclusive medical evidence of such an exposure was found."

The licensee's report documented their investigation and conclusion that it was unreasonable to attribute the TLD reading to tampering or inadvertent exposure, citing the trackable control history of the TLD rings and procedural controls instituted by the licensee and their vendor.

The licensee's report describes visits by their consultant Health Physicist to the vendor facility and a number of experiments which were performed at the licensee's request. The consultant's report to the licensee documents his investigation into vendor procedures and the handling of the TLD in question. The consultant's report documents that, when the TLD in question was initially read on a reader designated "AA" by the vendor, it provided a high initial light output, 5.12E6 nanocoulombs; and that, in accordance with vendor procedures, the TLD chip was irradiated to 350 mrem with a Sr/Y-90 source and reread on a reader designated "BB" by the vendor and provided a higher than expected second output, 5.63E5 nanocoulombs. The consultant documented that the vendor performs the irradiation and second reading to determine a unique calibration factor for each chip, that the readers used were recently put into use and that the chips are heated by a laser rather than hot gas.

The licensee's report centers around the premise that if the exposure is real, the reading on the badge including what the licensee terms the "residual" should be reproducible. The licensee documents numerous experiments involving irradiation of TLD chips with different types of radiation, with different levels of exposure, and at different exposure rates. The licensee documented experiments involving reading TLDs with different readers, both laser heated and gas heated. The licensee documented experiments involving contaminating TLD chips with physical and chemical agents and chip overheating. The licensee documented experiments that could involve variations in reader calibration over a two-month period.

The licensee's experiments were unable to produce an initial light output equivalent to a 500 rad dose by any means other than irradiation of a TLD. Of the experiments conducted, the licensee reported that only very high exposures, those greater than 65,000 rem, duplicated the large "residual" seen when the badge in question was read. The licensee conducted no experiments to investigate the effect of inadequate heating of the TLD chip as a method of producing a similarly high "residual" reading. The licensee's inability to reproduce the exposure by the undertaken experiments precipitated their conclusion that the TLD reading was invalid.

In addition, the licensee concluded that no sources of radiation capable of delivering such a dose were available within a vanishingly small probability by analyzing the distribution of irradiated fuel fragments and Co-60 particles found outside the fuel handling building, the majority of which had been found after January 2, 1987. The analysis failed to consider numerous higher activity particles found within the fuel handling building and other particles found before January 2, 1987.

The licensee's report stated that extensive radiation and contamination surveys did not detect any sources capable of delivering such a large dose. No records were made of any radiation or contamination surveys performed during actual work activities while the ring was being worn. The licensee documented two air samples taken during the work activities and also documented the radiation and contamination levels as recalled by the involved workers and technicians two months subsequent to the time the ring was worn.

The licensee's report documents that no conclusive medical evidence of such an exposure could be found based on examination of the worker's hands and blood samples two months after the potential occurrence.

3. Investigation of Released Particles

Following the January 12-16, 1987, inspection, two events involving control of fuel fragments were brought to the NRC's attention by the licensee by telephone. LER 87-003, submitted on March 24, 1987, describes these occurrences as well as an additional occurrence not previously brought to the NRC's attention. The two events, previously brought to NRC's attention, were reviewed during the March 16-20, 1987, inspection. In addition, the Senior Resident Inspector documented his observations regarding implementation of the fuel fragment control program in Inspection Report No. 50-362/86-38.

The licensee reported that the first event involved a contract worker on February 2, 1987. The worker's protective clothing became contaminated and, after removing them and while wearing only modesty garments, the worker was surveyed by a whole body contamination monitor, a PBM-200. The worker repeatedly alarmed the monitor but hand frisking of only the suspect area with a E-140 detected no

contamination. A whole body frisk was not performed. The worker was eventually released from the restricted area and upon his return on February 3, 1987, he again alarmed the PBM-200. On this occasion a HP technician conducted a full body frisk of the individual and located a particle on the sleeve of his jacket. The particle was found to be a 0.08 microcurie irradiated fuel fragment which produced a calculated contact dose rate of approximately 400 mrem/hr. The licensee surveyed the worker's residence and automobile and found no further contamination. The licensee concluded that they had recovered all the radioactive material that could have left the site on the worker's body. The licensee estimated that the dose to the worker was 1.77 rem to the skin of the whole body and 1.20 rem to the extremity and that the worker's family received no appreciable exposure. This was based on their conclusion that the particle was transferred from the individual's upper arm, where it was initially located when the PBM-200 alarmed, to the worker's jacket during his drive home, that the particle was removed from contact with the worker's body when he removed his jacket at his residence, that the other members of the worker's family did not contact the jacket and that the particle was again put in contact with the workers lower arm when he donned his jacket the next day.

The licensee reported that the second event involved a site HP technician on February 19, 1987. The HP technician found that his shoe was contaminated on the outside as he was entering the facility restricted area at the beginning of his shift. The shoe was discarded, so the activity of the particle and its composition could not be determined. The licensee determined that a radioactive particle may have been embedded in the technician's shoe and might have been previously removed from the site. The licensee is continuing the investigation.

The licensee reported that the third event involved a site HP technician on February 21, 1987. The technician discovered what was later determined to be 0.2 microcurie irradiated fuel fragment in the carpet of his residence during a self-initiated survey of his home with an E-140. The technician stated that he had been concerned that irradiated fuel fragments might have gotten offsite as these fragments had been found outside restricted areas and that the sensitive instrumentation used to detect these particles, the PBM-200 personnel monitoring booths, had only recently been put into use. The contact dose rate produced by the particle at the time it was found was calculated to be approximately 1200 mrem/hr. The licensee determined by isotopic distribution that the particle was approximately one year old. The licensee has not yet assigned a dose to the technician or estimated the dose to which the technician's family was exposed as a result of this occurrence.

10 CFR 20.301 and 10 CFR 30.41 require that no licensee shall dispose or transfer licensed material, except as authorized. In addition, 10 CFR 20.105(b) requires that, except as authorized by the NRC, no licensee shall possess, use or transfer licensed material in such a manner as to create, in any unrestricted area,

radiation levels which, if an individual were continuously present, could result in his receiving a dose in excess of two millirem in any one hour or 100 millirem in any seven consecutive days.

The inspectors noted that the 0.2 µCi source could result in a dose of 1200 mrem/hr to the skin of an individual or 27 mrem/hr to the limiting organ if it were continuously present on the individual. For example, if the speck were to become embedded in an individual's clothing (as previously observed in SCE modesty garments) a member of the public could receive a localized dose well in excess of acceptable limits within a few hours.

The release of licensed material from the licensee's restricted area to offsite areas is an apparent violation of 10 CFR 20.105(b), 20.301 and 30.41. (86-37-02)

10 CFR 20 states, under Precautionary Procedures in 20.201, Surveys, that:

> "As used in the regulations in this part, "survey" means an evaluation of the radiation hazards incident to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions. When appropriate, such evaluation includes a physical survey of the location of materials and equipment, and measurements of levels of radiation or concentrations of radioactive material present.
>
> "(b) Each licensee shall make or cause to be made such surveys as (1) may be necessary for the licensee to comply with the regulations in this part, and (2) are reasonable under the circumstances to evaluate the extent of radiation hazards that may be present."

During the inspection of March 16-20, 1987, the inspectors reviewed the licensee's investigation of the February 2, 1987, and February 21, 1987, events. This review included discussions with the individuals involved.

The licensee's staff determined that, in regard to the February 2 event, the individual had been working immediately adjacent to a fuel fragment control area established in accordance with licensee health physics procedure SO123-VII-7.12. The individual's protective clothing became physically dirty and the individual suspected he had become contaminated. The worker went to the control point and requested the assistance of the HP technician. The licensee representative stated that the HP technician determined that the protective clothing was contaminated without determining the extent, level or type of contamination. The technician surveyed the individual and observed that the instrument was pegged. The individual was directed to remove the contaminated clothing without special precautions. Specifically, in order to assess the dose to the worker and to minimize the potential for personnel contamination during removal of the protective clothing and to prevent

distribution into the laundry pool, a survey to identify the extent, location and type of contamination would have been appropriate. Failure to make such surveys as are reasonable to evaluate the extent of radiation hazard that may be present is an apparent violation of 10 CFR 20.201(b)(2). (86-37-03)

After the individual removed his protective clothing, he performed whole body monitoring in the PBM-200 beta booth and repeatedly alarmed the monitor. The HP technicians responding to the alarms, performed frisking type measurements of the individual but failed to identify the radioactive material present. The HP technician allowed the individual to leave the site in spite of the fact that the worker continued to alarm the PBM-200. Failure to make such surveys as are reasonable to evaluate the extent of radiation hazard that may be present is an apparent violation of 10 CFR 20.201(b)(2). (86-37-04)

In response to this event, the licensee terminated the HP technician's employment, discussed the event with the staff and instituted a policy that requires management approval for release of any individual that continues to alarm a PBM-200 monitor.

The licensee evaluated the dose to the skin of the whole body of the individual to be 1.77 rem and to the skin of the extremity of the individual to be 1.20 rem by postulating that the only contamination present on the individual during the event was the particle found the next day on the individual's jacket and that that particle had been removed from the workers upper arm and attached to the cuff of his jacket when the jacket was removed after the individual arrived at his residence.

The inspectors, employing a conservative scenario that the particle remained on the worker's skin until it was located on February 3, 1987, calculated that a dose to the skin of the whole body of the individual on the order of 7 rem could have occurred. This dose together with the individual's cumulative whole body exposure for the first quarter of 1987, would not have been in excess of the 7.5 rem limit.

IV. NRC Evaluation of 512 Rem Exposure

(Note: The following paragraph designations A., B., C., and D. are intended to coincide with the paragraph designations 2.A., B., C., and D. on page 6 of this report.)

A. Dosimetric Indications

The Emergency Preparedness and Radiological Protection Branch Chief and a Consulting Physicist, expert in the field of thermoluminescent dosimetry, visited the vendor's facility to review the processing of the TLD badge. The team reviewed the vendor's TLD handling procedures from the time the TLDs are obtained from the supplier until the time they are discarded, specific information relative to the TLD in question, and the hardware used by the vendor.

The team found that the TLD chip in question was composed of lithium fluoride (LiF), commonly termed TLD-100, obtained from the vendor's supplier. They found that after receipt from the supplier, the chips are annealed and response checked by exposing the chips to a known dose of radiation. The chips must respond within a certain range or they are discarded. The chips are then cleaned and sealed in plastic rings under a welded polyethylene cover. The rings are individually labelled and sent to the users with appropriate controls. When the rings are returned they are surveyed for contamination and then processed. The processing involves removing the label, noting any damage to the ring, cutting the ring in half to release the chip, loading the chip into a carousel with other returned chips and controls, noting any damage to the chip, reading the chip on the vendor's laser heating system, reirradiating each chip to 350 mrem from Sr/Y-90, rereading the chip to determine a unique calibration factor, annealing and cleaning the chips and reloading them into rings. The vendor's procedures require that the chip be read several times if the chip indicates a high dose and that the chip then be discarded. The vendor's procedures also require that the vendor contact the user to report a high dose. The team found that the vendor had not performed any rereadings of the 512 rem chip after the second read and that the vendor had not contacted the licensee by telephone when the exposure was discovered.

The use of lithium fluoride, TLD systems is a standard dosimetric technique widely used throughout the industry. (See: Personnel Thermoluminescence Dosimetry Systems - Performance, ANSI N13.15 1985). LiF systems respond primarily to ionizing radiation but can provide a false indication if the chips are contaminated with a substance which could burn or luminesce or if the chip is heated to too high a temperature and it incandesces.

The team observed, relative to the possibility of incandescence causing the high initial light output, that none of the other 45 user chips in the carousel during the first reading of the chip in question produced a high light output and that the chip in question produced a high output during the second read on a different reader. The NRC consultant dosimetry expert observed that it was not reasonable to attribute he large light output of the TLD to overheating as this woul. have had to occur only for the chip in question and sequentially on two different machines.

The team observed the vendor's records of the chip in question, relative to the possibility of contamination having caused the high initial light output, and noted there was no record of any contaminant being observed on the badge by the technician, that no foreign or charred material was observed in the carousel after the read, and that the laser heating is done in a nitrogen atmosphere which would not be conducive to burning. The team also noted that the licensee performed experiments in which they contaminated TLD chips with various chemicals and agents and that these failed to produce any response greater than that equivalent to a dose of 50 mrem. The team also noted that, after a search of available

literature, such false-light outputs had been observed but that their magnitude was a factor of 100 less than the light output noted in this event. (See: Hoots, S. S. and Landrum, V., Glow Curve Analysis for Verification of Dose in LiF Chips, Health Physics 43, 905-912).

The team investigated the question presented by the licensee of the second large light output, or "residual," observed during the calibration cycle of the chip in question. The NRC consultant noted that there are varying opinions as to what the second light output might and might not indicate and the magnitude of which might be expected in certain situations. The vendor provided data to the team from a two chip badge recently processed by the vendor which provided an initial reading of about 10,000 rad, a second reading of 60% of the first reading, a third reading of 10% of the first reading and fourth through seventh readings of from 1% to 5% of the first reading. The vendor also performed an experiment at the request of the team in which they varied the heating time with the laser, thereby inadequately heating the chip. The vendor informed the team that the heating time of the chip in question was 1 second and that the experiments demonstrated that a reduction of the heating time to 0.95 second resulted in light output, during the second reading, of from 10% to 30% of the initial reading when the chips had been exposed to about 500 rem.

This finding clearly indicates that the "residual" effect was reproducible and process parameters seem to indicate it was the most likely source of the observed response of the SCE chip in question.

The vendor representative, after having reviewed their records and after having performed numerous experiments stated:

> "I believe in light of these tests, we will continue our position, which is that we have not seen any data that would cause us to qualify our original dose reported to Southern California Edison."

The NRC's consultant and dosimetry expert stated:

> "It is not only possible, but seems probable that TLD #80365 received a dose of ionizing radiation approximating that which was reported."

In view of the findings presented above, it appears that the licensee's conclusion that: "The residual reading was unreasonable and unreproducible in the dose range reported" is invalid.

B. Sources of Exposure

During the December 15, 1986, initial NRC inspection, the Section Chief examined the licensee's investigation plan; contacted the involved HP Engineering and Plant Maintenance personnel; and reviewed available records. The Section Chief determined that the potential exposure could not easily be attributed to a particular

job or event. However, the most likely source of exposure that could have resulted in a dose of this magnitude would have involved direct contact of the worker's hand with a small particle of irradiated fuel. Particles of this type were known to exist at Unit 3 following operation during cycle one with 105 defective fuel pins.

The Section Chief suggested to the licensee that their evaluation carefully consider those systems which could contain fuel fragments and involved maintenance performed by the worker.

On March 18, 1987, the licensee's staff informed the inspectors that the site Health Physics organization had not been involved in the planning phase of the fuel reconstitution effort following cycle 1 and that the Health Physics input was provided as a supplement to the reconstitution plan. The reconstitution/refueling supervisor stated that highly radioactive particles were found early during the reconstitution effort, in late 1985, and that this problem was greatly exacerbated when, during reconstitution of the final fuel bundle, a fuel pin was pulled apart. The supervisor recalled that this necessitated greatly increased radiological control requirements, isolation of the Fuel Handling Building from normal access and the training of a special team of HP technicians in order to locate these fuel fragments and decontaminate the building, further details are contained in Inspection Report No. 50-362/86-02. The Refueling Supervisor further informed the inspectors that all the damaged fuel pins were grouped into one bundle and stored in the Spent Fuel Pool without further containment.

The Refueling Supervisor informed the inspectors that the Fuel Pool Cleanup System, which draws suction from below the racks in which the reconstitution was performed, was run both during and after reconstitution. Based on a review of the FSAR and plant system diagrams, the inspectors noted that the Fuel Pool Cleanup System contains a backflushable filter, designed to remove particles greater than 5 micrometers in size, and that these filters are routinely backflushed into the Crud Tank system. The inspectors also noted that the Crud Tank liquid is circulated through shielded disposable filters which, as indicated by a review of licensee survey records, produced external gamma dose rates as measured with a teletector of up to 120 R/hr. The inspectors also noted that similar backflushable filters of other primary systems are routinely backflushed into the Crud Tank. The inspectors also reviewed the design of the Reactor Coolant Pump Seals and Heat Exchangers and noted that these provide areas which could trap circulating particles. A review of licensee surveys revealed that the seal areas have elevated dose rates due to accumulation of particulate material on the seals.

The inspectors reviewed a memorandum issued by the HP Manager on November 15, 1985, requesting the assistance of the Station Technical organization to identify probable pathways for system contamination, actions needed to ameliorate future problems, and indications of fission product contamination in various liquid samples. The inspectors noted the response from a licensee Senior

Engineer on February 4, 1986, which identified numerous systems potentially contaminated with fuel fragments, specifically:

- "Spent Fuel Pool Cleanup System
- "Spent Fuel Pool Cooling System
- "Fuel Handling Building Sumps and Drains and Contaminant Sump
- 'Reactor Coolant Radwaste System
- "Reactor Coolant Chemical Volume and Control System
- "Containment Spray
- "Nuclear Plant Sampling System"

The inspectors also noted a memorandum from the Unit 2/3 HP Supervisor to the HP Manager dated April 24, 1986, which observed that an extensive number of plant systems might contain fuel fragments, that no controls specific for dealing with fuel fragments were being implemented for work on these systems, and called for a task force to address and eliminate the fuel fragment problem.

The inspectors were informed by the licensee's staff that a task force to address the fuel fragment problem was not instituted until December 1986, that a formalized program to control fuel fragments during work on potentially contaminated systems was not instituted until January 5, 1987, and that the majority of HP technicians did not receive training in the specialized techniques needed for detecting fuel fragments until December 1986 and January 1987.

The inspectors reviewed shipping documents which recorded the transfer of ten fuel fragments from the licensee to a contract laboratory on March 25, 1986. The ten fuel fragments, ranging in size from 220 microcuries to 6800 microcuries, were recovered from the fuel handling building. A fuel fragment of 100 microcuries will produce a contact dose rate of about 300-900 rad/hr depending upon the beta energy, age of the particle and calculational technique. Discussions with the licensee's staff also revealed that 20 to 25 other large fuel fragments, whose activities were not determined, were removed from the floor of the Fuel Handling Building (FHB) during the cleanup after fuel reconstitution. The inspectors were also informed by the licensee's staff that perhaps hundreds of smaller fragments whose activities were not determined were also found at this time in the FHB. The inspectors noted that the statistical analysis, presented by the licensee to support their conclusion that no fuel fragment sufficiently large to produce the exposure in question was present in the areas which the worker entered, neglected to include the large particles removed from the FHB and to consider the communication between the Reactor Coolant System and the Reactor Coolant Pumps and the Spent Fuel Pool and the Crud Tank System. The inspectors also noted that a formal tracking

system to document the number and size of fuel fragments was not established until January 2, 1987.

In view of the findings presented above, it appears that the licensee's conclusion that: "No source capable of delivering such a dose were available within a vanishingly small probability" is invalid.

C. Work Activities and Surveys

The inspectors reviewed the Radiation Exposure Permits (REPs), numbers 76234, 90253 and 90254 which controlled entry of the workers to the restricted area while wearing the TLD in question. The REPs were found to be routine in nature, they contained no instructions which would alert the worker or technician to the potential for fuel fragments within the systems being worked and they provided no special instructions which would ameliorate the hazard from fuel fragments.

When questioned by the inspectors, technician "A," who had been the responsible technician on October 6, 20 and 21 covering the jobs of the worker in question, stated that he had not received, at the time of the potential event or subsequently, the specialized instructions, which had been provided to others, needed to detect fuel fragments; that no specialized controls had been employed during the jobs which recognized the hazard from fuel fragments and that the special survey techniques, needed to distinguish a fuel fragment from activation product contamination, were not employed. Although the licensee's staff could locate records of radiation and contamination surveys taken before and after the jobs in question, they could produce no records of surveys taken of the areas or components on which the mechanic worked during the period he was wearing the TLD. The licensee's staff located the records of two air samples taken during the period at the jobs in question. Based on their recollections, the workers and technicians involved stated that only teletector measurements were taken during actual work on the Reactor Coolant Pump seal and heat-exchanger/gasket replacement and that these indicated maximum gamma levels between 5 and 10 rem/hr. They also stated that open and closed window RO-2 measurements were taken during the Crud Tank Pump repair and that, as best the technician could recall, the meter never went off scale on the 0-500 mR/hr range when components were surveyed and that the meter never went off scale on the 0-50 mR/hr range when the workers' gloved hands were surveyed.

The inspectors note that a teletector is a rugged, high range geiger-muller survey instrument with a telescoping probe used for measuring high gamma radiation fields and that it is insensitive to beta radiation on the higher ranges. The RO-2 is a general use ionization chamber survey instrument with a thin window which allows detection of beta radiation and is equipped with a sliding metal shield which can be used to eliminate the low energy beta contribution from the response. The RO-2 can thus be used to estimate the beta or surface dose rate as opposed to the deep dose

rate by taking a window opened and a window closed reading and applying a correction factor. The correction factor is dependent on the energy of the beta particles being measured, the distance from the source to the detector and the physical size of the radiation source.

At NRC's request, a consultant laboratory made a series of measurements of a fuel fragment, identified as No. 7, provided by the licensee on March 25, 1986. This approximately 80 micrometer speck of irradiated fuel was found to contain about 153 microcuries of mixed fission products on April 6, 1987. The major isotopes included Ce-144, Pr-144, Ru-106, Rh-106, Sr-90, Y-90, Cs-137, Ba-133, Pm-147 and Nb-95. The laboratory calculated the dose rate to one square centimeter of skin through 7 mg/cm^2 to be 432 rem/hr if the speck were in contact with the skin. The dose rate measured by an exo-electron technique was 215 rad/hr as close to the speck as possible.

Using a large volume ion chamber (Eberline Model RO-2A), the following measurements were made and the instrument response recorded:

	Unshielded		Shielded through Two Pairs of Rubber Gloves and One Cotton	
Distance	Window Open	Window Closed	Window Open	Window Closed
Contact	6.0 R/hr	1.2 R/hr	2.8 R/hr	0.56 R/hr
10 cm	500 mR/hr	130 mR/hr	420 mR/hr	94 mR/hr
30 cm	61 mR/hr	15 mR/hr	56 mR/hr	11.7 mR/hr

The diameter of the RO-2A and RO-2 is about 7.6 centimeters. Measurements were made as the instrument was moved in 0.5 centimeter increments from directly over the speck, at contact, to one side. The results are shown below:

Displacement of Source from the Center of the Detector in Centimeters	Window Open R/hr	Window Closed R/hr
0	6.2	1.0
0.5	6.2	1.0
1.0	6.0	0.98
1.5	5.9	0.95
2.0	5.8	0.88
2.5	5.5	0.80
3.0	4.5	0.67
3.5	2.0	0.3
4.0	0.2	0.08

This experimental data indicates the extreme position and distance dependence to be expected when using a hand held ion chamber to survey for irradiated fuel specks.

If specks are located in areas of high background radiation, only deliberate and careful survey techniques could be expected to identify irradiated fuel fragments of this size.

The inspectors observed that the licensee's final report contains an analysis of the maximum size of fuel fragments that could be present during the work in question based on survey record data taken before and after the work and the radiation levels as remembered by the technician involved. The licensee's evaluation fails to take into account that beta radiation from fuel fragments can be easily shielded by small thicknesses of metal from piping or by a worker's hand and that the presence of fuel fragments within a system or on a worker's hand would not be observable, as noted above, unless extraordinary surveys were made during the work and the technician involved had the knowledge and skill to detect them.

In view of the findings presented above, it appears that the licensee's conclusion that: "Extensive radiation and contamination surveys failed to detect any such sources" is not a valid basis for concluding that sources of radiation sufficient to cause the exposure were not present.

10 CFR 20.201(b)(1), Surveys, requires that each licensee shall make or cause to be made such surveys as may be necessary to comply with the regulations in this part.

During the work on October 6, 8, 20 and 21, 1986, involving the reactor coolant and crud tank pumps performed by worker "A" while wearing the TLD in question, the licensee failed to make such surveys as were necessary to comply with the dose limit expressed in 20.201(a), in that worker "A" received a dose to the right hand on the order of 512 rem.

Failure to make such surveys as are necessary to comply with the regulations is an apparent violation of 20.201(b)(1). (86-37-05)

D. Medical Evaluation of the Worker

When the licensee first brought this event to the attention of the NRC, the NRC's medical consultant contacted the licensee's physician to confer on what physiological effects might be observable from large radiation exposures to the hand of an individual. As the worker involved was not examined until more than eight weeks after the potential event, the window of opportunity had passed for observation of physical effects such as erythema, which can occur due to doses to the skin of 200-600 rem between 1 and 2 weeks after exposure and dry desquamation (flaking) which can occur due to doses between 800-1100 rem, see: Extremity Monitoring: Considerations for Use, Dosimetry Placement and Evaluation, NUREG/CR-4297 PNL-5509. The licensee's examining physician observed no physiological effect, that would have been indicative of an exposure greater than 1300 rem such as moist desquamation or ulceration. When questioned by the inspectors, worker "A" stated that he did not recall any reddening of his hand but that he did recall an episode of dry scaling on his

hand in about November 1986 but that he does occasionally experience periods of dry scaling and took little notice of it.

The licensee's final report documents that the licensee's physician obtained a blood sample from worker "A" which was analyzed by a nationally recognized authority for anomalies that might be observed as a result of a large radiation exposure. The blood sample report stated:

> "We observed only two cells with dicentric chromosomes in our cytogenetic analyses of 500 metaphases from lymphocyte cultures from...(worker "A")....The distribution of dicentrics was "overdispersed" in that one of these two damaged cells contained two dicentric chromosomes. Such findings could be observed if the majority of...(worker "A"s)...circulating lymphocytes had not been exposed to radiation, while a small proportion had received an excessive radiation dose. Thus our cytogenetic findings corroborate exposure data from his physical dosimeters which indicate that he may have received a localized over-exposure of one hand, but that he did not receive a clinically significant whole body dose."

When a noted authority on the hematological effects of radiation was contacted by a Region V health physicist, the authority stated that the noted dicentrics were not inconsistent with a large localized exposure but such anomalies would have had an extremely small chance of being observed due to the small volume of blood in the hand.

In view of the findings presented above, it appears that the licensee's conclusion that: "No conclusive medical evidence of such an exposure was found" fails to recognize that the window of opportunity for physiological observations was missed and that the cytogenetic findings, although inconclusive, are consistent with a partial body exposure of this magnitude.

E. Dose to the Worker

10 CFR 20.101(a) limits the total occupational radiation exposure to the hands of an individual in a restricted area to 18.75 rem per calendar quarter.

The Branch Chief and the consultant dosimetry expert determined, from their visit to the dosimetry vendor, that there was no reason to conclude the TLD in question did not function properly and that the light output observed was consistent with a large dose of ionizing radiation.

The inspectors determined that small intense sources of radiation, fuel fragments, were present at the licensee's facilities; that some of these particles exhibited sufficient activity to produce a dose of the magnitude observed in a very short period of time; and that the components on which worker "A" labored could have been contaminated with such particles.

Lacking radiation or contamination survey records, the inspectors determined, from extensive discussion with the workers and technicians involved, that the surveys taken, as recalled, do not provide conclusive evidence that a fuel fragment was not present during the reactor coolant and crud tank pump work. In addition, the technicians involved had not received the training needed to detect such particles and the technicians did not have sufficient understanding of the properties of fuel fragments to determine if they were present and to take action to protect the workers from them.

Therefore, it appears that a maintenance worker received during the fourth calendar quarter of 1986 a cumulative dose to the right hand on the order of 512 rem while performing maintenance activities in the restricted area.

Failure to comply with dose limits is an apparent violation of 20.101(a). (86-37-06)

V. Licensee Actions in Response to the Fuel Fragment Problem

As previously noted in this report, as a result of the Unit 3 Cycle 1 refueling outage, the licensee had, prior to identification of the 512 rem exposure, begun to establish a formal radiation protection control program specifically to address the fuel fragment issue for the Unit 3 outage scheduled to begin in January 1987.

On December 22, 1986, the Health Physics Manager issued a memorandum to site management titled: A Station-wide Program for Irradiated Fuel Particle Control. This memorandum identified specific points to be addressed by the Technical, Operations and Maintenance Support, Maintenance, Operations, Planning and Control, Training and Health Physics Divisions. The key points included: identification of all systems containing fuel particles; determination of actions to prevent further addition of fuel particles, transfer of existing particles to other systems and cleanup strategy; improved fuel performance and reconstitution programs; specialized maintenance planning; specialized training; and additional radiation protection controls.

A general employee education handout titled: Facts About Irradiated Fuel Fragments and How to Protect Against Them, was issued to all workers on December 26, 1986, and incorporated into the formal General Employee Training program performed as a requirement for restricted area access.

During the first week of January 1987, the specific radiation protection procedures establishing a three-zone control approach were issued.

In the licensee's February 22, 1987, revision of LER No. 86-015, the licensee stated in part:

"Notwithstanding that we conclude that the overexposure did not occur, action has been taken as if it did occur. This action includes the following measures:

"1. The 512 rad extremity exposure report will be included in the individual's record as a special entry. In order to avoid penalizing the worker in his future employment, the record will also reflect the existence of the referenced report.

"2. The SCE program for detecting small radioactive particles and for controlling exposure to them, already considered by SCE to be one of the strongest in the industry, was further enhanced. This program includes:

"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 clearly identifiable zones, 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.

"3. Action has been taken to eliminate deficiencies in the vendor's system for reporting anomalous exposures and in the Station's procedures for receiving and verifying routine electronic data transmissions from the vendor. A change to our contract with the vendor now mandates vendor compliance with previously existing reporting procedures and that TLD chips which exhibit anomalous high readings be promptly isolated, identified and delivered to SCE with a full report of the results obtained."

During the NRC March 16-20, 1987, visit, the inspector confirmed that the General Employee Training includes a handout and video presentation on fuel fragment issues. The inspector observed that two PBM-200 frisking booths were being put into operation just outside the main restricted area access point and all individuals were being provided a handout titled: Information About Personnel Contamination and Frisking. The handout explained actions workers should take to ensure they are free of

contamination; why the voluntary PBM-200s had been made available outside the restricted area; the establishment of a "Radiological Concerns Phoneline;" and the safety significance of personnel exposure to irradiated fuel fragments.

The inspectors met with the Irradiated Fuel Particle Task Force Chairperson and reviewed the action item status report of the March 10, 1987, meeting. The task force is composed of first line supervision and engineer level personnel from the various divisions. The chairperson stated that he spends about one half of his time on task force activities. Twelve action items were considered closed and eighteen open at the time of this inspection. The closed items included six directly related to training and the radiation protection procedures as described above. The remaining involved use of a spent fuel pool skimmer during refueling; increasing availability of the spent fuel pool cleanup system; participation in the Combustion Engineering Fuel Users Group; and consideration of irradiated fuel fragments in planning work activities. Several key open items include: identification of systems containing fragments; preparation for future fuel reconstitution; and identification of systems to be cleaned.

Review of the licensee's fragment inventory and tracking report for the period from January 2, 1987, through February 26, 1987, indicated 92 new fuel fragments (composed of isotopes indicating recent exposure in the core), 155 old fuel fragments, 51 ruthenium particles, 84 crud and 42 cobalt particles had been found and analyzed. One hundred and forty of the specks were found on personnel or their clothing. The activity of these 140 specks ranged from 0.001 microcuries to 1.249 microcuries. Nineteen of the specks were detected with hand held friskers and ranged from 0.002 to 1.249 microcuries, the remaining 121 were detected by the PBM-200s. Sixty-two specks ranging from 0.199 to 21.53 microcuries were detected from non-personnel sources.

The inspectors discussed the irradiated fuel particle control program with several workers including six Health Physics Technicians. All the workers seemed familiar with the program. Several workers were concerned with the consistent discovery of specks outside the zone controlled areas. The workers felt that discovery of specks on personnel at the PBM-200s indicated that the control program is not fully effective.

Based on the discussions with the six Health Physics Technicians, the inspector advised licensee management that one technician exhibited excellent knowledge of the program and techniques to identify and control specks. Three technicians demonstrated an acceptable level of knowledge and two technicians appeared to require additional training on survey procedures.

The inspectors requested to review the dosimetry record for the individual with the 512 rem hand exposure. The computer record did not reference the 512 rem dose. The licensee representative stated that they plan to footnote the file indicating a copy of the evaluation is available for review but not to show a dose of 512 rem for the fourth quarter 1986 hand exposure.

Based on the above observation, the inspectors found the licensee's program to be adequate. Three areas were presented for the licensee to consider:

- There appears to be a significant mismatch in resources allocated to the problem. It appears a great deal of effort is being spent providing radiation protection measures while far less effort is going into the task force effort to remove the source of activity.

- More comprehensive radiation surveys need to be considered in work areas and for people leaving work zones when they believe they are contaminated.

- The licensee should evaluate the effectiveness of training provided to the radiation protection technicians.

These points were discussed at the exit interview on March 20, 1987.

No violations or deviations were identified in this area.

VI. Exit Interview

The inspectors met with the licensee representatives denoted in Paragraph 1 at the conclusion of the site visit on March 20, 1987. The scope and findings of the inspection were summarized. The licensee representatives were informed of the apparent violations of NRC requirements discussed in this report.

In regard to the apparent violations noted, the Vice President and Site Manager stated that the Commission bears the responsibility to reasonably enforce their Regulations and that the good faith efforts of SCE should be recognized. The Vice President and Site Manager continued that SCE's evaluation of the 512 rem exposure represents a large allocation of resources and that their conclusion is the most reasonable that could be reached based on the extensive research performed. Additionally, he stated his belief that the SCE fuel fragment control program represents the state-of-the-art in the industry today and that their extraordinary efforts should not be rewarded with Notices of Violations when other programs, which probably have similar problems, are not being cited because they are not as diligent as SCE.