U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 70-36/89003(DRSS)

Docket No. 70-36

Licensee: Combustion Engineering, Incorporated Nuclear Power Systems Windsor, CT 06095

Facility Name: Hematite Facility

Inspection At: Hematite, Missouri

Inspection Conducted: August 30, 31, and September 1, 7, 8, 22, and 23, 1989 Inspection Team Leader: D. J. Sreniawski, Chief

Inspection Team Members:

Region III F. C. Sturz, NMSS

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Section 1

G. M. France, III

License No. SNM-33

10/18/84 Date 10/18/1989 Date

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Bruce S. Mallett, Ph.D., Chief Approved By: Nuclear Materials Safety Branch

Inspection Summary

Inspection Conducted August 30, 31, and September 1, 7, 8, 22, and 23, 1989 (Report No. 70-36/89003(DRSS))

Nuclear Materials Safety

Areas Inspected: An Augmented Inspection Team (AIT) composed of Region III and NMSS personnel investigated the circumstances regarding the unplanned release of enriched uranium containing approximately 4% uranium-235 and the licensee's actions to protect onsite personnel and the public. The AIT also reviewed the licensee's operating procedures, process equipment and monitoring systems.

Results: The AIT concluded, after review of information provided by CE and by direct observation, that the licensee's initial estimate of 274 grams of uranium released appears to be a valid estimate based on a stack sample and survey readings outside the building. The release was due to failure of a nitrogen valve which pressurized the conversion reactor. Prompt action was taken to assess worker exposure. Weaknesses were identified in the detection of conversion process failure, communication of inoperable equipment status and in the scope of the initial environmental surveys to characterize the release.

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DETAILS

1. Persons Contacted

- R. Betlock, Production Supervisor
- B. Pigg, Quality Control Laboratory Supervisor
- L. Deul, Manufacturing Engineer
- H. E. Eskridge, Manager, Nuclear Licensing, Safety and Accountability R. W. Griscom, Plant Engineering Supervisor

- C. Heisker, Engineering Specialist R. Miller, Manager, Administration and Production Control A. Noack, Production Superintendent
- J. A. Rode, Plant Manager
- G. Uding, Quality Assurance Engineer

During the onsite investigation members of the NRC Augmented Inspection Team (AIT) discussed the events regarding the release of uranium with the above listed members of the licensee's staff. In addition, several operators were interviewed and several members of the licensee's Radiation Protection Department assisted the AIT in the collection of environmental samples.

2. Attendees of Meeting at Region III Office which was held on September 19, 1989

Combustion Engineering

- J. A. Rode, Plant Manager, Hematite
- H. E. Eskridge, Manager, Nuclear Licensing Safety and Accountability
- C. R. Waterman, Vice President and General Manager, Nuclear Fuel Manufacturing
- A. E. Scherer, Director, Nuclear Licensing

NRC NMSS/Region III

- L. C. Rouse, NMSS, Chief, Fuel Cycle Safety Branch, Division of Industrial and Medical Nuclear Safety Branch
- F. C. Sturz, NMSS Senior Project Manager/Health Physicist, Irradiated Fuel Section, Fuel Cycle Safety Branch
- D. McCaughey, NMSS, Nuclear Process Engineer, Uranium Fuel Section, Fuel Cycle Safety Branch
- A. B. Davis, RIII, Administrator
- C. E. Norelius, RIII, DRSS Division Director
- R. Lickus, RIII, State Liason Office
- D. J. Sveniawski, RIII, Section Chief
- G. M. France, III, RIII, Fuel Facility Inspector

3. Normal Licensee Program

The Combustion Engineering (CE) facility of Hematite, Missouri, produces uranium dioxide (UO_2) fuel for the commercial nuclear power industry. Low enriched uranium (maximum 5% U-235) is received from uranium enrichment facilities as uranium hexafluoride (UF₆) in $2\frac{1}{2}$ ton, 30 inch diameter cylinders. UF_6 is converted to UO_2 powder and/or pellets.

a. Uranium Hexafluoride Conversion to Uranium Dioxide $(UF_6 \text{ to } UO_2)$

Prior to startup the conversion reactors are purged with nitrogen to remove condensation and to purge the off-gases. During startup, the nitrogen purge is replaced with steam when the operating temperature is reached. Concurrently, a cylinder of UF₆ is heated within a steam chamber until the vapor pressure allows the vaporized UF₆ to flow to reaction vessel R-1, the fluidized bed reactor (Attachment D, Incident Report, Page Five, Figure 2, Hematite Oxide Conversion Process). In R-1, the UF₆ reacts with process steam to form uranyl fluoride (UO₂F₂), hydrogen fluoride (HF) and water vapor.

Gaseous HF and H_2O (as excess steam) exit the reactor through two sets of porous metal filters. The gaseous materials are routed to the HF removal system. The HF removal system, consists of five cylindrically shaped towers each packed with about 1500 lbs of pebble sized limestone (calcium carbonate, CaCo₃). HF is removed by the reaction of F with Ca to form CaF₂. Excess H₂ in the off-gas stream is burned in an in-stack burner located after the limestone fluoride removal system.

Within the process UO_2F_2 particles which are formed in reactor R-1 pass to a second and third reactor R-2 and R-3 in series, where UO_2F_2 reacts with hydrogen (obtained from cracked ammonia) to form UO_2 .

The off-gases from R-2 and R-3 are also filtered through porous metal filters, after which the gases pass to the limestone scrubber/HF removal system and out the conversion process plant stack. This stack effluent is sampled by passing through a heat-traced stainless steel sample line at about 400 to 900 cubic centimeters per minute through two liters of KOH 10% solution which is analyzed for fluoride weekly.

Product UO_2 is removed from the R-3 reactor via pneumatic transfer to the storage silos, for subsequent use in the UO_2 pelletizing operation.

Progress of the chemical reaction (HF + $CaCo_3$) through the limestone scrubber bed is monitored by noting the scrubber bed temperature. In addition, a portion of the spent limestone is removed from one or two of the towers during each shift so that about 1 1/3 operating days complete the replacement. Each tower bed is replaced normally in sequence of one to five, by closing the selective off-gas manifold valve and dumping the contents into two 55-gallon drums per tower. The scrubber loading system is used to replace the limestone. A drum of spent limestone from every tower is rotated to mix the contents and surveyed for radiological content. The reported activity of this spent material is usually less than 150 dpm/100 cm². In normal operations, the porous metal filters (located inside R-1) along with the secondary filter (located in the off-gas stream) removes UO_2F_2 which prevents the buildup of radioactivity. However, the licensee indicated that unreacted UF₆ gas could pass through both sets of porous metal filters associated with R-1 and collect on the limestone.

b. Routine Health Physics Practices to Protect Onsite Staff

Health and safety procedures are provided to protect workers engaged in plant operations. They describe in detail how operating personnel are protected from excessive internal exposure from uranium by controlling ventilation air, sampling the air in work areas, using protective clothing and respiratory protection equipment, and surveying for and decontaminating radioactive surface contamination. In addition, workers are scheduled for bioassay and whole body counting. Process workers submit urine bioassay specimens each month (for analysis at CE's Windsor, Connecticut facility). Whole body counting is performed at least annually.

The ventilation system provides a negative pressure so that air flow is from work areas into process equipment, hoods, or glove boxes. The system is designed to move air from areas of low potential contamination to potentially higher contaminated areas. The workers breathing air is continuously sampled using fixed sampler heads mounted at various locations. These samples are changed and analyzed for each shift. Continuous air monitors (CAM) with alarms are also used to warn of high uranium air concentrations.

c. Licensee's Offsite Survey Program

Effluents are monitored to determine the amount of material released from the facility and compliance with NRC release limits. Monitoring for uranium and fluorides in air occurs at the points of discharge. In the Pellet Plant eight building stacks which exhaust process ventilation air are continuously sampled for uranium. Exhausts from laboratory fume hoods which handle wet chemicals, and two of the three room air exhausts in the Pellet Plant dewaxing and sintering furnace area are not continuously sampled for uranium. The Oxide Building (scrubber system) off-gas is continuously sampled for fluoride.

The licensee's environmental radiological monitoring program consists of collecting air, water, soil, and vegetation samples at various onsite and offsite locations. Continuous particulate air samples are taken at two locations. The air samples are collected generally north and south of the site, and are analyzed weekly and composited quarterly. Surface water is sampled monthly at Joachim Creek above and below the site creek outfall and quarterly from Joachim Creek both up and down stream of the property. Well water samples are drawn quarterly from onsite wells and one well in Hematite. Soil and vegetation samples are collected quarterly at five locations onsite surrounding the plant. Attachment E dated January 24, 1983, (location of monitoring sites around Hematite Facility) shows the sampling locations.

Description of Event

On Friday, August 25, 1989, during the midnight to morning shift after shutting the conversion process down for the weekend, the Production Supervisor observed an air leak on the solenoid that supplies air to operate the R-2 nitrogen valve. He closed the air valve to reduce plant air consumption and noted his actions on page 81 in the foreman's log. He also noted that the valve needed repair prior to system startup on Monday. August 28, 1989. Shutting the air supply caused the nitrogen valve to fail open. On Monday before 7 a.m., both the day shift Production Supervisor and Production Superintendent read pages 82 through 87 of the foreman's log, but failed to see the entry on page 81. Consequently, the air valve was not opened nor was the solenoid repaired. At 11:50 a.m. the control panel showed "normal" steam flow and normal UFe flow at 110 lbs/hour. Both nitrogen and steam have control valves on a common line. However, the flow indicator cannot differentiate between steam or nitrogen flow. With the nitrogen valve in the failed/open mode, the nitrogen pressure exceeded the steam pressure (30 vs. 25 lbs.) and permitted process steam in R-1 to be diluted with nitrogen. As a result, UF_6 was not converted to UO_2F_2 . The unreacted UF_6 gas passed through the internal R-1 and the secondary porous metal filters and reached the limestone bed scrubber system, where most of the material was trapped.

At 1:05 p.m., on August 28, 1989, the continuous air monitor (CAM) on the fourth floor of the Oxide Plant alarmed and the UF₆ flow was shut down and the upper floors were posted as respirator areas. The alarm was assumed to have resulted from loading of the bed into R-1. The bed refers to the starting material which is comprised of UO_2F_2 .

After finding no unusual conditions, at 1:40 p.m., the shift supervisor restarted the conversion process (UF₆ flow was restarted). At 2:20 p.m., the CAM alarmed again and the system was shut down. Dense fumes from the dry scrubber exhaust blower were noted to be drifting in a northeast direction disappearing into the trees. At 3:00 p.m., after hearing of the startup difficulties, the Production Supervisor who first made the log entry on Friday, August 25, had the solenoid air valve repaired.

At about the same time a heavy thunderstorm drenched the area, washing away any soluble portion of the release thus making detection more difficult. The system was inspected for leaks, purged with nitrogen, brought up to operating temperature with steam and at 8:40 p.m., the conversion process was resumed and no other problems were encountered. At 7:30 a.m., August 29, 1989, the Production Superintendent noted a low UO_2 production rate and requested Health Physics to survey the spent limestone that had been unloaded from the scrubber column. The Plant Manager was informed that the rock from three scrubbers read 30,000 to 70,000 dpm/100 cm² (normal is 150 dpm/100 cm²) and at 2:10 p.m., he ordered the Production Superintendent to shutdown the conversion process.

On August 29, 1989, the fluoride bubbler stack sample was analyzed for uranium and the results indicated a release of 274 grams of uranium. At 3:10 p.m., the Nuclear Licensing Safety, and Accountability (NLSA) Manager notified the NRC (Region III Fuel Facility Inspector) of the event. Initially, the licensee thought leakage from a break in the porous metal filters caused the unplanned release. On August 30, 1989, after a technical review of the incident, the licensee concluded that the amount of material was too high to have been caused by leakage from small breaks in the metal filter.

Meanwhile, the licensee collected initial urine bioassay samples from nine workers for emergency evaluation. Followup fecal samples (three) and urine samples (nine) were collected on August 31 and September 1, 1989.

Following the discovery (8/29) of the accidental release of uranium, the licensee collected three soil, three vegetation, and three standing water samples from seven locations outside the fence line, but within the plant site boundary. The samples were collected in the general direction (N-NE) that the exhaust plume was observed to have touched ground the preceding day. The particulate air sample from the offsite east station, as well as a sample of onsite creek water, were also collected. The area to the north east of the Oxide Building was surveyed with portable survey instruments to locate potential contamination. Additional soil, water, and vegetation samples were collected onsite and outside the fenced area by both the licensee and the AIT on September 1 and September 7.

On August 31, 1989, CE determined that the cause of the release was due to incomplete conversion of UF_6 to UO_2 because of nitrogen dilution of the process steam in reactor R-1. Nitrogen was present because the failed solenoid valve allowed nitrogen to enter R-1 through R-2. This evaluation was based on a material balance of uranium product and an analysis of the chemical and physical form of the uranium found in components of the conversion process and the HF scrubber system.

Continuing efforts were made to account for the 64.8 KgU which was fed into the reactor for the one hour and 55 minutes run time. From about August 29 to September 18, 1989, the reactor was disassembled and the components (piping, etc.) were flushed and the contents were collected and weighed for uranium accountability. As of September 19, 1989, all but 3.1 Kg were recovered. The licensee stated that such a level of entrained material would not be unusual for normal operations. NMSS (HQ NRC) concurred that it is reasonable to assume that 3.1 Kg of uranium could be retained in the hardware of the conversion process.

5. Evaluation of Event

a. Plant Operation

The AIT review of the foreman's logbook and interviews with the Production Supervisor and Production Superintendent and Plant Manager confirmed that the logbook entry as described in Section Four was not adequate to assure that repairs on vital equipment were completed. In addition, the Production Supervisor failed to recognize the safety significance of the failed solenoid in the nitrogen control valve. This resulted in management not being informed of the problem in a timely manner. It wasn't until the production superintendent noted a reduction in product output that a significant effort was made to evaluate the situation. This reduction in UO_2 product was noted between 7:30 a.m. and 9:50 a.m., on August 29, 1989.

Interviews with the Plant Manager, control room operators, and observations of the control room instrumentation showed that the flow indicator could not differentiate between steam and nitrogen. As a result, the control room operators were unaware of the degraded steam supply which in turn affected the hydrolization process which converts UF_6 into UO_2F_2 .

b. Onsite Exposure

The AIT also evaluated workers' potential internal exposure by reviewing the results from the licensee's urine and fecal bioassay samples and data with the highest results from fixed air samples located at the work stations. The highest uranium levels from the nine workers were reported as $3.1 \ \mu g/liter$ (urine) and $0.47 \ \mu g \ U/g$ (fecal). (See Pages 34, 35, Attachment D, Incident Report) The licensee has an action level of $25 \ \mu g \ U/liter$ (urine) before any formal investigation is performed. Inhalation exposure based on the fixed air sampler data showed a maximum of $22 \ MPC-hrs$ and compared favorably with exposure levels that the workers experienced during routine operating conditions. Whole body counting is scheduled for October 10, 1989, as an additional backup. Based on both the licensee's findings and the inspectors' investigation, the safety significance and/or the radiation exposure levels to workers were minor and the licensee's action to evaluate them were acceptable.

c. Environmental Activities

When the AIT arrived onsite on August 31, 1989, they were initially informed that the unplanned release was caused by a break in the R-1 filter. The licensee was also uncertain as to the duration of the release and the amount of uranium that had been released to the environment. The conversion process was shut down and had been since August 29, 1989. A plume characterized by the licensee predominantly as steam and HF had been sited drifting towards the north east on August 28, 1989. A review of the licensee's results for environmental direct surveys showed no levels greater than background. The licensee's initial soil, water, and vegetation samples also showed no evidence of any depositions from this release. After review of the meteorological data (wind speed and direction vs. time, Attachment D, Page 21, Figure 5, Page 22, Page 23, Figure 6), and discussion with the licensee additional soil, vegetation, water samples, and direct surveys were taken in other areas to account for wind shifts.

After the discovery of the unplanned release, the licensee was not aggressive in its environmental sampling efforts. At the time of the initial sampling, the time, duration, and arount of the release was not fully known. The release could have occurred over about a 26 hour period during which weather data indicated the wind to be from almost all directions. Yet the northeastern quadrant was the only one surveyed because of one observation of a plury. In retrospect, this assumption proved valid. However, more the should have been obtained in different directions around the facility to firmly establish the existence of or lack of deposited material from the release. The licensee did not pursue more sampling until directed by the AIT. The licensee's emergency procedures/radiological contingency plan should include a more comprehensive environmental sampling program.

The number and location of air sampler stations is not adequate. For example, the site boundary to the north has changed since the sampling system was implemented. Consideration should be given to adding an air sampler or relocating the existing station more to the northeast to provide better coverage of the newer site boundary and the closest resident in that predominate wind direction. Consideration should also be given to adding more air samplers to provide more directional coverage surrounding the plant. The environmental air samplers are out in the open and appeared weathered. The cffsite east air sampler was not operating.

Eventually environmental sampling and surveys were conducted at all points of the compass and at one of the nearby residents. The soil, water, and vegetation samples were 'it with the licensee. The NRC samples have been submitted to a DC. contractor for an independent analysis. Results reported by the licensee for both initial and split samples (Attachment D, Pages 26-28), do not differ substantially from the results of routine environmental samples. According to the licensee's report, the highest value ($20 \pm 7 \text{ pCi/g}$ alpha) for soil samples was not indistinguishable from background. The scrubber stack sampler is used to monitor HF, (fluoride), but not uranium releases. As a result, there is no routine evaluation of uranium releases from the conversion process stack. The direct surveys of the limestone in the scrubber served as a general indicator as to the lack of uranium in the effluent.

The principal uranium compounds that constituted the plume could not be determined. Because of the potential for a mixture of soluble and insoluble uranium compounds released, and because solubility determines the amount of inhaled uranium which is transferred and retained in a particular body organ, critical organ doses for both soluble and insoluble uranium exposure were estimated. For low enriched soluble uranium compounds inhaled, the critical organ for an acute uranium intake is the kidney, based on chemical toxicity. The critical organ for the effects from radioactivity is the osteogenic cells, particularly those on the endosteal surfaces of bone. For insoluble uranium compounds inhaled, the critical organ is the lung.

The maximum impact of the accidental release of uranium was assessed by calculating uranium concentrations at various distances towards the nearest resident and in the direction the plume traveled. The amount of uranium that could have been inhaled by an individual located at those points offsite was then estimated to determine the dose.

Fifty-year committed organ dose equivalents and committed effective dose equivalent that would occur from acute (two hour exposure in the plume) intake of uranium isotopes during the lifetime (50 years) of the individual were calculated. For soluble uranium, a bone dose was calculated; for insoluble uranium, a lung dose was calculated. The committed effective dose to the total body was also calculated for both soluble and insoluble uranium.

Approximately 300g of uranium was assumed (for calculation purposes) to be released to the atmosphere over a two hour period. The isotopic composition (activity) of the uranium was assumed to be that of uranium enriched to four weight percent of the isotope uranium-235 $(U^{2.3.5})$. A lung solubility class "D" was assumed for soluble uranium compounds and Class "Y" for insoluble compounds.

Atmospheric dispersion factors were estimated based on the equations for relative concentrations at an area boundary for two hours immediately following the accident found in NRC Regulatory Guide 1.145. (Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Flants.) These values were calculated using meteorological conditions prevailing during the accident. Numerical results for selected points in the plume path downwind at distances up to 1000 meters were estimated. The plume resulting from the accident generally traveled in a NE direction but shifted up to 60 degrees to either side. At the location of the nearest resident, approximately 400 meters NE, an individual (assumed present) would have been exposed to an estimated average uranium air concentration of about 9E-04 mg-U/m³ (or 2E-12 μ Ci/ml). This concentration is about 13 percent of the NRC's annual average permissible concentration for uranium (0.007 mg/m³) in air for unrestricted areas, listed in 10 CFR Part 20, Appendix B. Exposure to this concentration for two hours would result in an inhalation intake of about 0.002 mg of uranium.

The NRC previously reported in NUREG-1189 (Assessment of the Public Health Impact From the Accidental Release of UF₆ at the Sequoyah Fuels Corporation Facility at Gore, Oklanoma) that an absorbed dose of 25 μ g U/kg body weight (i.e., total intake of 1.8 mg) can be considered a minimal dose for inducing nephrotoxicity in the kidney. The estimated intake of 0.002 mg uranium is far below this threshold, and therefore no effects due to chemical toxicity would be detectable.

For an assumed 2 hour inhalation in the plume, the estimated maximum uranium intake for an individual is about 3 pCi. If the uranium were all soluble, then this intake would result in a maximum bone dose of about 0.1 mrem and an effective total body dose less than 0.01 mrem. If it were all insoluble uranium, then this intake would result in a maximum lung dose of about 3 mrem and an effective total body dose about 0.4 mrem. Doses due to chronic exposure to inhalation of deposited uranium resuspended in the air and to ingestion of vegetables, milk, and meat contaminated from uranium deposited in the soil would contribute only a small fraction of that calculated for the acute plume inhalation pathway. Externa? exposures from submersion in the radioactive plume and from surface contamination of the soil via uranium deposition are insignificant (less than 0.1 percent) compared to other exposure pathways. Factors such as plume meander, wake effect of wooded areas, and particle disposition would be expected to further reduce these calculated maximum doses. Regardless, no measurable radiological impacts are expected. Even if all of the uranium unaccounted for (3 kg U) had been released, any resultant offsite exposure would still not cause significant risk to an individual.

Details of the dose calculations used for this section are located in Attachments A, B, and C to this report.

6. Licensee Meeting

On September 19, 1989, Combustion Engineering and NRC staff met in Region III to discuss operational and engineering changes that were to be completed in antic vation of restart of the conversion process. CE presented three problems that were identified as a result of the event:

- Failure to recognize a potential problem in the nitrogen and steam header feed line.
- Failure in the system for communicating and documenting the need for maintenance.
- Failure in training. Operating staff was not experienced or trained to recognize the lack of UF₆ conversion.

CE also indicated that the following corrective actions would be implemented prior to start up:

- Interlocks for each nitrogen valve position have been installed to shut off the UF₆ flow automatically if the nitrogen valve is not in the closed position. The lockout mechanism for UF₆ was installed on the control panel.
- A maintenance log is maintained in the control room and requires a release of all entries by signature. It is the responsibility of the shift supervisor and/or production supervisor to confirm that maintenance service is completed prior to startup.
- Training was given to the operating staff to assure that every oxide operator is aware of complete/incomplete UF₆ conversion.
- A dual purpose off gas sampling system was installed to perform isokinetic sampling for particulates and low volume sampling for fluroide. The system will be tested in place.

CE provided a report dated September 1989 and received in Region III on September 28, 1989, describing the problems and their proposed corrective actions (Attachment D, Incident Report, Pages 36-38).

7. Pre-Startup Inspection

On September 22 and 23, 1989, a Region III inspector was dispatched to CE Hematite to observe the startup of the conversion process.

The licensee had not operated the process since the day shift on August 29, 1989. During the interim period, the licensee installed/implemented a number of engineering and/or administrative controls as part of the corrective action effort to prevent a recurrence of the unplanned release. (Discussed under Section 6, Licensee Meeting).

The inspector reviewed the licensee's procedures for preparing the conversion process for startup and observed prestart operations in the control room. The inspector confirmed that the UF_6 lock out key was in possession of the Production Supervisor and the lockout mechanism was installed on the control room panel. It was observed that the supervisor reviewed and initialed the maintenance sheet to assure that all entries had been noted and that process components were operable prior to

unlocking the value to allow UF₆ to flow into the R-1 reactor. The maintenance sheet is used as an administrative control to assure that each operating shift supervisor can identify critical items for service. The sheets are stored in the control room for viewing by maragement. The licensee noted that entries in the foreman's log will normally address the less critical items for service.

Green and red indicator lights were installed on the control panel to identify individual interlocking for each of three valves that control nitrogen to reactors R = 1, R = 2, and R = 3. By engaging the interlocking devices the appropriate indicator light will show the operator whether the nitrogen valve is opened or closed.

The Engineering Supervisor discussed the modifications that were installed to improve stack sampling of the HF gas scrubber system. The inspector observed that the licensee had added an isokinetic stack sampler for particulate uranium analysis. At least once each shift, the filter paper is exchanged and after a brief storage to eliminate decay products, is analyzed for uranium. The stack sampler has been modified to enable the licensee to determine the levels of uranium and fluoride discharged from the HF scrubber. Fluoride determinations will continue to be made on a weekly basis. The licensee agreed to monitor the stack scrubber solution for soluble uranium prior to first use and again after replacement to detect uranium vapor that may have bypassed the particulate filter. The inspector also noted that the ventilation system blower was upgraded to provide more air flow.

At about 2:00 p.m., the licensee restarted the conversion process. At 10:00 p.m., via telecommunications, the inspector was informed that the process was still ongoing. The licensee noted that the steam/HF plume that normally is visible during the conversion process seemed significantly smaller. This may have heen caused by greater air flow due to the upgraded blower. On September 23, 1989, the second cylinder of UF₆ was brought on stream. The conversion process was continued at 2:38 a.m.

The inspector also confirmed by discussion and record review that 83 plant workers received training about the safety significance and communication problems identified in the licensee's investigation of the unplanned release. The records also indicated that the oxide plant operators received training on the instrument panel in the control room to include the use of the UF₆ and N₂ locking devices, the adjusting and recording of stack sampler flow rates, and requirements of the maintenance sheet.

The inspector concluded by discussion and observation that the licensee had implemented those engineering and administrative controls which were discussed at the Region III meeting on September 19, 1989.

Attachments

- A. Calculated Source Term
- B. Atmospheric Dispersion and Meteorology
- C. Assessment of Off-Site Uranium Concentrations and Doses
- D. Incident Report, Combustion Engineering, Inc., September 1989
- E. Location of Monitoring Sites Around Hematite Facility Revision 1, January 24, 1983
- F. Confirmatory Action Letter, Dated September 01, 1989

APPENDIX A CALCULATED SOURCE TERM

The estimated amount of uranium released from the stack at the top of the Oxide Building is based on the Licensee's alpha counting analysis of the fluoride sampling solution. While questions remain about uranium particulate collection efficiency of the stack fluoride sampling system, any uranium in stack gasses passing through the bubbler sampler is considered to be retained in the 10 percent potassium hydroxide (KOH) solution. A 10 ml aliquot of the fluoride sampling solution was evaporated on a planchet and counted for 10 min in the Licensee's Tennelec low background alpha counting sytsem to determine the amount of uranium in the solution, and thus, released out the stack. This method provides a lower limit and also the best reasonable estimate on the amount of uranium released.

The following are the calculations for determining the amount of uranium released based on the licensee's 51 dpm net count rate from the sample.

Amount of uranium in the sample:

$$\frac{51 \text{ dpm}}{10 \text{ ml x } 0.275 \text{ eff}} = 18.6 \text{ dpm/ml}$$

$$\frac{18.6 \text{ dpm/ml}}{2.22 \text{ x } 10^{-6} \text{ dpm/mCi}} = 8.4 \text{ x } 10^{-6} \text{ mCi/ml}$$

$$\frac{8.4 \text{ x } 10^{-6} \text{ mCi/ml} \text{ x } 2 \text{ x } 10^{3} \text{ ml}}{2 \text{ mCi}^{2} \text{ mCi}^{2} \text{ ml}} = 8.4 \text{ x } 10^{-3} \text{ geV}$$

2 mCi/g-U

The total uranium released is proportional to the ratio of the stack flow to the sample flow:

$$\frac{760 \text{ ft}^3/\text{min} \times 28.32 \text{ l/ft}^3 \text{ (stack flow)} \times 8.4 \times 10^{-3} \text{ g-U}}{0.66 \text{ l/min} \text{ (sample flow)}} = 274 \text{ g-U}$$

The amount of uranium released was approximately 0.3 kg.

The release occurred over two periods on August 28, 1989; from 11:50 a.m. to 1:05 p.m. and 1:40 p.m. to 2:20 p.m. For assessment purposes the release was assumed to be uniform over the total 115 minutes. The uranium was enriched to 4 weight percent of the isotope uranium-235 (U^{235}) and had a Specific Activity of 2 µCi/g. The following table shows the release rates of the uranium isotopes used to assess offsite impacts.

TABLE A-1

Nuclide	Percent Activity (%)	Release Rate (Bg/sec)	Release Rate (µCi/sec)	Amount Released (µCi)	Amount Released (mg)
U-234	78.0%	2.51E+03	6.78E-02	4.68E+02	
U-235	4.2%	1.35E+02	3.65E-03	2.52E+01	
U-236	0.8%	2.70E+01	7.30E-04	5.04E+00	
U-238	17.0%	5.47E+02	1.48E-02	1.02E+02	
Total		3.22E+03	8.70E-02	6.00E+02	3.00E+05

URANIUM ISOTCPIC RELEASE RATES

APPENDIX B

ATMOSPHERIC DISPERSION AND METEOROLOGY

Meteorological conditions in the vicinity of the site on the day of the accident were typical of a hot summer afternoon with scattered heavy thunderstorms moving through the area later in the afternoon. At the time of the release, onsite meteorological measurements indicated unsteady winds. The wind was flowing generally from the southwest (resulting in plume transport to the northeast), but shifting up to 60 degrees to either side. Wind speeds were about 5-10 miles per hour (mph) (average about 3 m/s), with gusts up to 18 mph. Because of these conditions, atmospheric stability was considered to be unstable (Pasquill type "B" or "C").

Based on these meteorological conditions, atmospheric dispersion factors $(X/Q, sec/m^3)$ were estimated for Pasquill stability type "B" and "C", then averaged. X/Q values were estimated for several distances downwind in the direction of the nearest resident out to 1000 meters. The equations for relative concentrations at an area boundary for 2 hours immediately following an accident found in U.S. NRC Regulatory Guide 1.145, "Atmospheric Dispersion Models For Potential Accident Consequence Assessment At Nuclear Power Plants," were used to calculate X/Q's. Building wake effect is considered for distances out to 800 meters. The X/Q value used in dose calculations was the higher value calculated from Equations 1 or 2 shown below.

Equation 1. $X/Q = \frac{1}{U(fs_ys_z + A/2)}$ Equation 2. $X/Q = \frac{1}{U(3fs_ys_z)}$

B-1

Where

- X/Q is relative concentration, in sec/m³,
- f 3.14159,
- U is windspeed, 3 m/sec,
- sy is lateral plume spread, in m, as a function of atmospheric stability and distance,
- sz is vertical plume spread, in m, as a function of atmospheric stability and distance,
- A is the smallest vertical-plane cross-sectional area of the building, 100 m²,

The downwind atmospheric dispersion factors in the direction of the nearest resident (NE) were adjusted for the wind blowing in that direction approximately 36 per cent of the time. The calculated X/Q values and concentrations of uranium in air for that direction are shown in Tables B-1 through B-3.

Because of the wide fluctuations in wind speed and direction over the duration of the accident, a computer code was used to model the release in order to determine potential uranium air concentrations at locations not necessarily directly downwind. "TRIAD: A Puff-Trajectory Model For Reactive Gas Dispersion With Application to UF₆ Releases Into the Atmosphere," National Oceanic and Atmospheric Administration, February 1989, was used to correlate a uranium air concentration, based on an air sample, with the release. The TRIAD code is a numerical model designed to simulate the dispersion of gases that react exothermically with moisture in the atmosphere. It combines a Gaussian puff model with an objective wind field scheme. The wind speed and direction measurements during the time of the release were divided into five minute increments as input to TRIAD. The 0.3 kg of uranium were assumed to be released uniformly over a two hour time period. Uranium air concentrations

B-2

were calculated for both Pasquill stability classes "B" and "C" at several locations surrounding the facility, including the location of the Off-site East air sampling station (approximately 150 meters north of the release point). The calculated 2 hour average uranium air concentrations from TRIAD are shown in Tables C-4 and C-5 of Appendix C.

TABLE B-1

Distance (m)	Sigma y (m)	Sigma z (m)	X/Q Equation 1 (sec/m ²)	X/Q Equation 2 (sec/m ²)
1.00E+02	1.60E+01	1.10E+01	1.84E-04	7.23E-05
2.00E+02	3.30E+01	2.10E+01	5.27E-05	1.84E-05
3.00E+02	5.00E+01	3.20E+01	2.34E-05	7.96E-06
4.00E+02	6.70E+01	4.20E+01	1.34E-05	4.52E-06
5.00E+02	8.20E+01	5.30E+01	8.73E-06	2.93E-06
8.00E+02	1.25E+02	9.10E+01	3.35E-06	1.12E-06
1.00E+03	1.50E+02	1.20E+02	2.12E-06	7.07E-07

ESTIMATED DISPERSION DURING CE HEMATITE ACCIDENT RELEASE STABILITY CLASS B

TABLE B-2

ESTIMATED DISPERSION DURING CE HEMATITE ACCIDENT RELEASE STABILITY CLASS C

Distance (m)	Sigma y (m)	Sigma z (m)	X/Q Equation 1 (sec/m ²)	X/Q Equation 2 (sec/m ²)
1.00E+02	1.30E+01	7.60E+00	2.92E-04	1.29E-04
2.00E+02	2.50E+01	1.50E+01	9.39E-05	3.40E-05
3.00E+02	3.60E+01	2.20E+01	4.64E-05	1.61E-05
4.00E+02	4.90E+01	2.90E+01	2.63E-05	8.96E-06
5.00E+02	6.00E+01	3.50E+01	1.79E-05	6.06E-06
8.00E+02	9.10E+01	5.30E+01	7.87E-06	2.64E-06
1.00E+03	1.10E+02	6.50E+01	5.32E-06	1.78E-06

TABLE B-3

ESTIMATED DISPERSION DURING CE HEMATITE ACCIDENT RELEASE STABILITY CLASS B - C

	Average of B and C
Distance	X/Q a
(m)	(sec/m ²)
1.00E+02	2.38E-04
2.00E+02	7.33E-05
3.00E+02	3.49E-05
4.00E+02	1.99E-05
5.00E+02	1.33E-05
8.00E+02	5.61E-06
1.00E+03	3.72E-06

B-4

ATTACHMENT C

APPENDIX C ASSESSMENT OF OFFSITE URANIUM CONCENTRATIONS AND DOSES

Offsite concentrations of uranium in air, in the direction of the nearest resident downwind, were calculated at various distances out to 1000 meters based on the 0.3 kg uranium release calculated in Appendix A and dispersion values in Appendix B, Tables B-1 through B-3. Tables C-1 through C-3 show the calculated uranium isotope concentrations in air for Pasquill stability classes "B", "C", and an average of the two, "B-C". The closest site boundary to the north-northeast is approximately 200 meters. As can be seen from these tables, the concentration of uranium in air beyond the site boundary was not expected to have exceeded the annual average permissible concentration for uranium for unrestricted area, listed in 10 CFR Part 20, Appendix B.

Based on calculations by the "Triad" computer code, the concentrations of urar um in air at the Off-site East air sampling station (about 150 m N) would be expected to be about 8×10^{-13} mCi/ml for a 0.3 kg uranium release (Tables C-4 and C-5). Results from analysis of the licensee's particulate air sample, from this location during the period of release, indicated a uranium air concentration of about 1.3×10^{-14} mCi/ml over the sample period 10:12 a.m. on 8/25 through 3:51 p.m. on 8/29. This value is about 5 to 10 times higher than past routine air samples. If the radioactivity on the air particulate sample is assumed to have been deposited during the two hour period of release on 8/28, then a corrected uranium air concentration from the accident would be about 5×10^{-13} mCi/ml. The relatively good correlation between a measured air concentration and a calculated concentration gives additonal support that the amount of uranium released was on the order of 0.3 kg.

C-1

ATTACHMENT C

Based on the uranium air concentrations for the average of Pasquill stability Class "B" and "C", an intake of uranium was estimated for a hypothetical individual located approximately 400 meter northeast and exposed to the plume for about 2 hours. The breatning rate was taken from U.S. NRC Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases Of Reactor Effluents For The Purpose of Evaluating Compliance With 10 CFR Part 50, Appendix I" ($1.52 \times 10^{-2} \text{ m}^3/\text{min}$). The estimated amount of uranium inhaled would be about 1.5×10^{-3} mg (1.5 mg). The minimal amount considered for inducing nephrotoxicity previously reported in NUREG-1189, "Assessment of Public Health Impact From the Accidental Release of UF⁶ at the Sequoyah Fuels Corporation Facility at Gore, Oklahoma," is an absorbed dose of 25 mg U/kg body weight, or a total intake of 1.8 mg.

Based on the previously calculated air concentration for stability class "B-C" and the breathing rate above, fifty-year committed doses were estimated for this acute exposure (2 hours inhallation) for the various distance to the northeast. Dose conversion factors were taken from the Environmental Protection Agency report: "Limiting Values of Radionuclide Intake And Air Concentrations And Dose Conversion Factors For Inhalation, Submersion And Ingestion," Federal Guidance Report No. 11, September 1988. Because of the potential for a mixture of soluble and insoluble uranium compounds to have been released, and because solubility determines the amount of inhaled uranium which is transferred and retained in a particular body organ, critical organ doses for both soluble and insoluble uranium exposure were calculated. Table C-6 list the committed dose equivalents to the bone and effective whole body for soluble (Class D) uranium isotopes and to the lung and and effective whole body for insoluble (Class Y) uranium isotopes. The dose to a hypothetical

C-2

individual located 400 meter northeast would be about 0.1 mrem to the bone and an effective whole body dose less than about 0.01 mrem if the release were entirely soluble uranium compounds. If the release were entirely insoluble uranium compounds then the dose would be about 3 mrem to the lung and an effective whole body dose of about 0.4 mrem.

TABLE C-1

CONCENTRATIONS FOR STABILITY CLASS B

e	U-234 (uCi/m1)	U-235 (uCi/ml)	U-236 (uCi/ml)	U-238 (uCi/m1)	Total Uranium (mg/m3)
02	1.25E-11	6.71E-13	1.34E-13	2.72E-12	7.99E-C3
02	3.57E-12	1.92E-13	3.85E-14	7.79E-13	2.29E-03
02	1.59E-12	8.55E-14	1.71E-14	3.46E-13	1.02E-03
02	9.10E-13	4.90E-14	9.80E-15	1.98E-13	5.84E-04
02	5.92E-13	3.19E-14	6.37E-15	1.29E-13	3.79E-04
02	2.27E-13	1.22E-14	2.45E-15	4.95E-14	1.46E-04
03	1.44E-13	7.74E-15	1.55E-15	3.13E-14	9.21E-05
	2.00E-11	2.00E-11	2.00E-11	3.00E-12	7.00E-03
	02 03	(uCi/m1) 02 1.25E-11 02 3.77E-12 02 1.59E-12 02 9.10E-13 02 5.92E-13 02 2.27E-13	(uCi/m1) (uCi/m1) 02 1.25E-11 6.71E-13 02 3.57E-12 1.92E-13 02 1.59E-12 8.55E-14 02 9.10E-13 4.90E-14 02 5.92E-13 3.19E-14 02 2.27E-13 1.22E-14 03 1.44E-13 7.74E-15	(uCi/m1) (uCi/m1) (uCi/m1) 02 1.25E-11 6.71E-13 1.34E-13 02 3.57E-12 1.92E-13 3.85E-14 02 1.59E-12 8.55E-14 1.71E-14 02 9.10E-13 4.90E-14 9.80E-15 02 5.92E-13 3.19E-14 6.37E-15 02 2.27E-13 1.22E-14 2.45E-15 03 1.44E-13 7.74E-15 1.55E-15	(uCi/m1) (uCi/m1) (uCi/m1) (uCi/m1) 02 1.25E-11 6.71E-13 1.34E-13 2.72E-12 02 3.57E-12 1.92E-13 3.85E-14 7.79E-13 02 1.59E-12 8.55E-14 1.71E-14 3.46E-13 02 9.10E-13 4.90E-14 9.80E-15 1.98E-13 02 5.92E-13 3.19E-14 6.37E-15 1.29E-13 02 2.27E-13 1.22E-14 2.45E-15 4.95E-14 03 1.44E-13 7.74E-15 1.55E-15 3.13E-14

TABLE C-2

CONCENTRATIONS FOR STABILITY CLASS C

Distance (m)	U-234 (uCi/m1)	U-235 (uCi/ml)	U-236 (uCi/m1)	U-238 (uCi/ml)	Uranium (mg/m3)
1.00E+02	1.98E-11	1.07E-12	2.14E-13	4.32E-12	1.27E-02
2.00E+02	6.37E-12	3.43E-13	6.86E-14	1.39E-12	4.08E-03
3.00E+02	3.14E-12	1.69E-13	3.39E-14	6.85E-13	2.02E-03
4.00E+02	1.78E-12	9.60E-14	1.92E-14	3.89E-13	1.14E-03
5.00E+02	1.22E-12	6.54E-14	1.31E-14	2.65E-13	7.79E-04
8.00E+02	5.34E-13	2.87E-14	5.75E-15	1.16E-13	3.42E-04
1.00E+03	3.61E-13	1.94E-14	3.88E-15	7.86E-14	2.31E-04
MPC	2.00E-11	2.00E-11	2.00E-11	3.00E-12	7.00E-03

TABLE C-3

CONCENTRATIONS FOR STABILITY CLASS B-C

	Distance (m)	U-234 (uCi/m1)	U-235 (uCi/m1)	U-236 (uCi/ml)	U-238 (uCi/ml)	Uranium (mg/m3)
1	1.00E+02	1.61E-11	8.70E-13	1.74E-13	3.52E-12	1.04E-02
	2.00E+02	4.97E-12	2.68E-13	5.35E-14	1.08E-12	3.19E-03
	3.00E+02	2.37E-12	1.27E-13	2.55E-14	5.16E-13	1.52E-03
	4.00E+02	1.35E-12	7.25E-14	1.45E-14	2.94E-13	8.63E-04
	5.00E+02	9.04E-13	4.87E-14	9.73E-15	1.97E-13	5.79E-04
	8.00E+02	3.80E-13	2.05E-14	4.10E-15	8.29E-14	2.44E-04
	1.00E+03	2.52E-13	1.36E-14	2.72E-15	5.50E-14	1.62E-04
1	MPC	2.00E-11	2.00E-11	2.00E-11	3.00E-12	7.00E-03

TABLE C-4

TRIAD OUTPUT FOR STABILITY CLASS B

2.00 HR AVG. CONCENTRATION AT RECEPTORS FOR ALL SIMULATION PERIODS

	RE	CEPTORS		CONCENTRATION	
NO.	X (KM)	Y (KM)	Z (M)	(mg/m^3)	
Source	. 500	.500	20.000		
1	.550	.500	.000	1.205E-03	
2	.500	.550	.000	7.058E-04	
3	.600	.500	.000	1.376E-03	
3 4	.500	.600	.000	7.078E-04	
5	.650	.500	.000	9.663E-04	
6	.500	.650	.000	4.334E-04	
7	.700	.500	.000	6.572E-04	
8	.500	.700	.000	2.545E-04	
8 9	.800	.500	.000	3.222E-04	
10	.500	.800	.000	9.215E-05	
11	.535	.535	.000	1.609E-03	
12	.571	.571	.000	1.871E-03	
13	.606	.606	.000	1.306E-03	
14	.641	.641	.000	8.864E-04	
15	.677	.677	.000	6.121E-04	
16	.712	.712	.000	4.382E-04	
17	.747	.747	.000	3.179E-04	
18	.783	.783	.000	2.276E-04	
19	.818	.818	.000	1.614E-04	
20	.854	.854	.000	1.101E-04	
21	.571	.429	.000	3.944E-04	
22	.924	.076	.000	7.352E-06	

.

TABLE C-5

TRIAD OUTPUT FOR STABILITY CLASS C

2.00 HR AVG. CONCENTRATION A" RECEPTORS FOR ALL SIMULATION PERIODS

	RE	CEPTORS		CONCENTRATION
NO.	X (KM)	Y (KM)	Z (M)	(mg/m ³)
Source	.500	.500	20.000	
1	.550	.500	.000	6.093E-04
2	.500	.550	.000	3.091E-04
3	.600	.500	.000	1.159E-03
4	.500	.600	.000	5.223E-04
5	.650	.500	.000	9.459E-04
6	.500	.650	.000	3.609E-04
7	.700	.500	.000	6.930E-04
8	.500	.700	.000	2.201E-04
9	.800	.500	.000	3.614E-04
10	.500	.800	.000	7.896E-05
11	.535	.535	.000	8.008E-04
12	.571	.571	.000	1.579E-03
13	.606	.606	.000	1.292E-03
14	.641	.641	.000	9.439E-04
15	.677	.677	.000	6.831E-04
16	.712	.712	.000	5.011E-04
17	.747	.747	.000	3.724E-04
18	.783	.783	.000	2.749E-04
19	.818	.818	.000	1.997E-04
20	.854	.854	.000	1.368E-04
21	.571	.429	.000	3.695E-04
22	.924	.076	.000	1.044E-05

TABLE C-6 COMMITTED DOSE EQUIVALENTS

BONE DOSE (Solubility Class D)

Distance (m)	U-234 (Sv)	U-235 (Sv)	U-236 (Sv)	U-238 (Sv)	Total (Sv)
1.00E+02	1.14E-05	5.68E-07	1.17E-07	2.23E-06	1.43E-05
2.00E+02	3.50E-06	1.75E-07	3.60E-08	6.85E-07	4.40E-06
3.00E+02	1.67E-06	8.32E-08	1.71E-08	3.26E-07	2.09E-06
4.00E+02	9.49E-07	4.74E-08	9.76E-09	1.86E-07	1.19E-06
5.00E+02	6.37E-07	3.18E-08	6.54E-09	1.25E-07	8.00E-07
8.00E+02	2.68E-07	1.34E-08	2.76E-09	5.24E-08	3.37E-07
1.00E+03	1.78E-07	8.87E-09	1.83E-09	3.48E-08	2.23E-07

EFFECTIVE DOSE (Solubility Class D)

Distance (m)	U-234 (Sv)	U-235 (Sv)	U-236 (Sv)	U-238 (Sv)	Total (Sv)
1.00E+02	7.70E-07	3.85E-08	7.88E-09	1.51E-07	9.67E-07
2.00E+02	2.37E-07	1.19E-08	2.43E-09	4.64E-08	2.98E-07
3.00E+02	1.13E-07	5.64E-09	1.16E-09	2.21E-08	1.42E-07
4.00E+02	6.42E-08	3.21E-09	6.58E-10	1.26E-08	8.06E-08
5.00E+02	4.31E-08	2.16E-09	4.41E-10	8.43E-09	5.41E-08
8.00E+02	1.81E-08	9.07E-10	1.86E-10	3.55E-09	2.28E-08
1.00E-03	1.20E-08	6.02E-10	1.23E-10	2.35E-09	1.51E-08

LUNG DOSE (Solubility Class Y)

Distance (m)	U-234 (Sv)	U-235 (Sv)	U-236 (Sv)	U-238 (Sv)	Total (Sv)
1.00E+02	3.11E-04	1.55E-05	3.17E-06	6.06E-05	3.90E-04
2.00E+02	9.58E-05	4.78E-06	9.76E-07	1.86E-05	1.20E-04
3.00E+02	4.56E-05	2.27E-06	4.65E-07	8.87E-06	5.72E-05
4.00E+02	2.60E-05	1.29E-06	2.65E-07	5.05E-06	3.26E-05
5.00E+02	1.74E-05	8.68E-07	1.77E-07	3.39E-06	2.18E-05
8.00E+02	7.33E-06	3.66E-07	7.47E-08	1.43E-06	9.20E-06
1.00E+03	4.86E-06	2.42E-07	4.95E-08	9.46E-07	6.10E-06

EFFECTIVE DOSE (Solubility Class Y)

Distance (m)	U-234 (Sv)	U-235 (Sv)	U-236 (Sv)	U-238 (Sv)	Total (Sv)
1.00E+02	3.74E-05	1.87E-06	3.81E-07	7.28E-06	4.69E-05
2.00E+02	1.15E-05	5.75E-07	1.17E-07	2.245-06	1.44E-05
3.00E+02	5.48E-06	2.74E-07	5.59E-08	1.07E-06	6.88E-06
4.00E+02	3.12E-06	1.56E-07	3.18E-08	6.08E-07	3.91E-06
5.00E+02	2.09E-06	1.04E-07	2.13E-08	4.08E-07	2.63E-06
8.00E+02	8.81E-07	4.40E-08	8.98E-09	1.72E-07	1.11E-06
1.GOE+03	5.84E-07	2.92E-08	5.96E-09	1.14E-07	7.33E-07

COMBUSTION ENGINEERING, INC.

HEMATITE NUCLEAR FUEL MANUFACTURING FACILITY

SPECIAL NUCLEAR MATERIAL RELEASE

INCIDENT REPORT

September, 1989

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Attachment D

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11. CHRONOLOGY

Midnight Shift

August 25, 1985 Friday

The conversion plant is down for the weekend. Production Supervisor #1 observes an air leak on the solenoid supplying air to the actuator on the R-2 nitrogen valve, closes the air valve ahead of the solenoid to reduce plant air consumption, and notes in the foreman's log, page 81, at the bottom of the page that the valve needs to be repaired.

This action causes the loss of air to the nitrogen valve actuator and the nitrogen valve opens.

August 28, 1989 Monday

A.M.

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Production supervisors and production superintendent read pages 82 through 87 of the foreman's log, but fail to see the note on page 81 and neither open the air valve nor repair the solenoid.

7:00 Heatup of the conversion line started.

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- 11:36 Bed loaded into R-1.
- 11:40 Steam and ammonia are already on R-2 and R-3. (Nitrogen is actually being fed to R-2 and R-3 since the Nitrogen pressure exceeds the steam pressure.) Nitrogen supply valve to K-1 is switched to closed position and the steam valve to R-1 switched to open position. The flow indicator on FIC-6 (steam or Nitrogen to R-1) drops and then slowly rises. The operator assumes this indicates steam condensing in the steam lines as it enters R-1.
- 11:50 Indicated "steam" flow is normal and UF₆ flow to R-1 is started at 110 lbs/hour.
- 12:30 Operators #1 and #2 observe overflow from R-1 to the weigh hopper and collect a sample at 12:30. Size distribution is normal.
- 13:05 The continuous air monitor (CAM) alarms and the UF₆ is shutdown.
- 13:15 Health Physics posts the upper floors (2, 3, and 4) at 13:15 as respirator areas and collects samples. The highest samples are in the north end of the top floor of the oxide building near R-1. The samples are grey to black. The CAM chart shows an increase starting at about 12:00 when startup began. No leaks are found and it is assumed the release occurred during loading of the bed into R-1.
- 13:40 UF, flow is restarted. Steam flow was not changed during the shutdown interval.

<u>August 28, 1989</u> 14:20	Monday (continued) The CAM alarms and the system is shutdown with HF fumes leaking from the dry scrubber exhaust blower noted to be drifting in northeast direction disappearing into the trees. HF is also leaking into the third floor of the Oxide Building. Maintenance is called to repair the leaks in the blower housing.
15:00	Production Supervisor #1 returns, has the solenoid air valve to the R-2 nitrogen valve repaired and cycles the steam and nitrogen valves to establish they are operational.
	A heavy thunderstorm drenches the plant.
	No leaks are found.
	Samples collected look white but next morning they are yellow, indicating the possible presence of UO_2F_2 .
20:40	Conversion was resumed. No problems encountered.
August 29, 1989 1:30	Tuesday First unloading of UO_2 this week to silo, 105kg, after 6:45 hours running time.
3:30	Second unloading of UO2 to the silo: 100kg.
5:30	Third loading of UO2 to the silo: 105kg.
7:30	Fourth unloading of UO2 to the silo: 85kg.
	Production superintendent requests Health Physics check the spent limestone unloaded on midnight shift from scrubber #1.
	Meanwhile, the second and third scrubbers are unloaded.
9:50	UF flow is suspended to allow work on the $#2 R-1$ off-gas valve which is causing high pressures.
—	After the limestone unloaded from scrubbers 2 and 3 cools, the rock from the three scrubbers is counted and is hot - $30,000$ to $70,000$ dpm compared to normal levels of 150 or less dpm/100cm ² .
14:10	Plant Manager is apprised of the conditions and conversion is shutdown.
15:10	George France, Region III inspector, is advised of a suspected release to the environment. Environmental samples are taken downwind before night falls.
	The solution from the fluoride sampler is analyzed for uranium.
August 30, 1989 9:30	Wednesday Release confirmed to NRC Region III based on analysis.

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111. PROCESS DESCRIPTION

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Process Chemistry

The Hematite process for the conversion of Uranium Hexafluoride (UF_6) to Uranium Dioxide is based on two simple chemical reactions -- the reaction of steam with UF_6 gas to produce Uranyl Fluoride (UO_2F_2) and Hydrofluoric Acid (HF).

R-1 Reaction
$$UF_6(g) + 2H_0(g) \longrightarrow UO_0F_0(s) + 4HF(g)$$

Anhydrous UO_2F_2 is white, but when exposed to the moisture in the air, quickly absorbs water and develops a yellow color. UO_2F_2 is very soluble in water.

The second reaction fundamental to the Hematite conversion process is the reduction of UO_2F_2 to Uranium Dioxide, UO_2 , by hydrogen (H₂).

R-2 & R-3
$$UO_2F_2(s) + H_2(g) \longrightarrow UO_2(s) + 2HF(g)$$

A competing reaction can convert a portion of the UO_2 to Uranium Tetrafluoride (UF₄ or greensalt).

Off-gas System $UO_2(s) + 4HF(g) \rightleftharpoons UF_4(s) + 2H_2O(g)$

This reaction, however, is an equilibrium reaction and can be prevented by feeding steam into the reactor and by operating at elevated temperatures.

Under normal conditions, there is no opportunity for UF₆ to contact the hydrogen used to reduce the $U0_2F_2$. However, hydrogen will react with UF₆ to produce UF₄ and hydrofluoric acid

Potential Reaction $UF_6(g) + H_2(g) \longrightarrow UF_4(s) + 2HF(g)$ and this reaction is important in the description of this incident.

The hydrofluoric acid is removed from the reaction process off-gas stream by the reaction of the hydrofluoric acid with crushed limestone $(CaCO_3)$ in 20 foot tall scrubber towers by the reaction:

HF Scrubbing $2HF(g) + CaCO_3(s) \rightarrow CaF_2(s) + H_2O(g) + CO_2(g)$

The limestone scrubbers also function well as a trap for UF_6 under accident conditions producing a bright yellow calcium diuranate (CaU_2O_7) , carbon dioxide and calcium fluoride, an insoluble and inert white rock, by the reaction:

UF₆ Trapping $2UF_6(g) + 7CaCO_3(s) \longrightarrow CaU_2O_7(s) + 7CO_2(g) + 6CaF_2(s)$

Equipment

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The Hematite conversion process shown in Figure 2 utilizes fluidized bed reactors for conversion.

 UF_6 cylinders heated with steam feed UF_6 gas to the conversion reactor.

The reactor carries a bed of approximately 100 mesh UO_2F_2 particles fluidized by steam fed in through a bubble cap plate at the bottom of the bed. The steam reacts with the UF₆ in a surface catalyzed reaction which coats the particles with additional UO_2F_2 .

As the particles coat, the bed grows and overflows to a load cell mounted weigh hopper which unloads to R-2 reactor for 1 minute at three minute intervals metering the UO_2F_2 into the R-2 reactor.

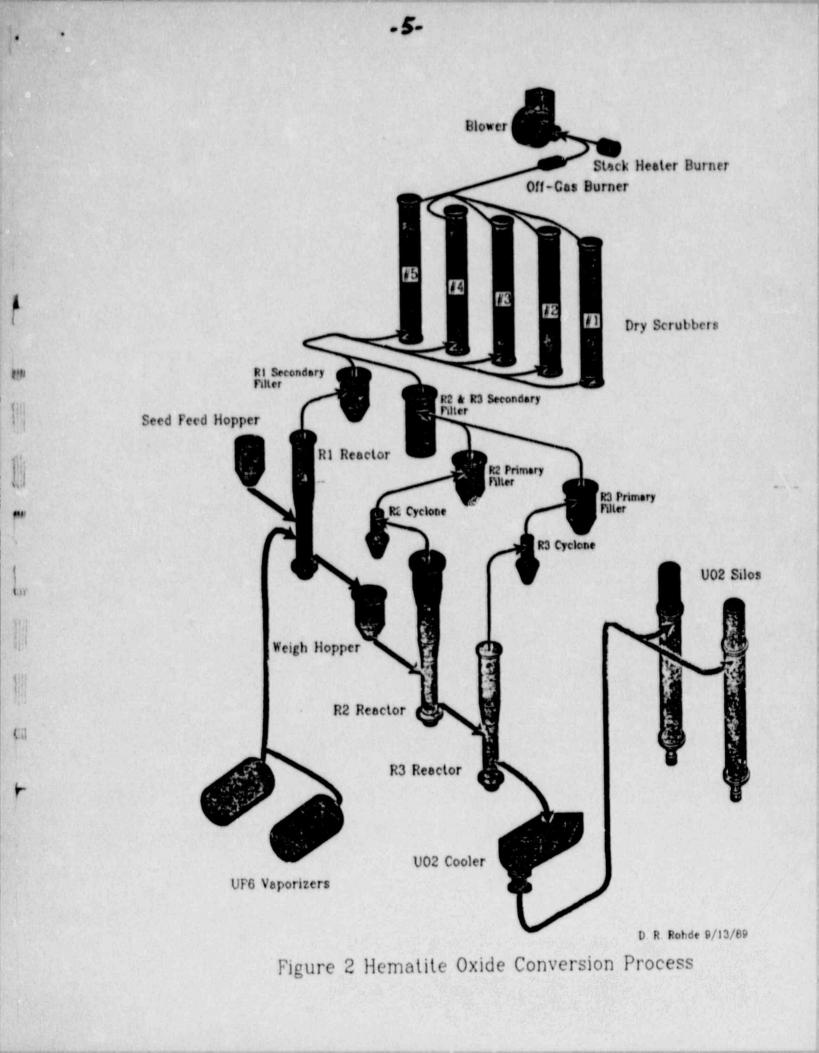
Seed, small particles of UO_2F_2 , are pulsed into the reactor as required to prevent the particle growth from causing loss of fluidization.

The fine UO_2F_2 is filtered out of the reaction gases on porous inconel filters (R-1 internal filter) and blown back into the bed by timed pulses of nitrogen. These gases are passed through a second porous metal filter (the R-1 secondary filter) which is not pulsed operating at lower temperature.

The lower temperatures and the absence of a blowback system increases the life of these filters and assures, via pressure drop measurements across these filters, that a primary filter failure will not go unnoticed.

The R-2 and R-3 reactors employ a mixture of cracked ammonia (hydrogen) and steam, fed in as fluidizing gases, to reduce the UO_2F_2 to UO_2 . Approximately 90% of the UO_2F_2 is converted in R-2 and the last of the fluoride is removed in R-3 at higher temperatures and higher hydrogen concentrations.

The automatic dump cycle from the weigh hopper to R-2 is interrupted every two hours and the excess bed in R-3 is unloaded to a UO_2 cooler and pneumatically transferred to storage silos.



When R-3 unloading is complete, R-2 is unloaded to R-3 and the weigh hopper unloading cycle is resumed.

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The offgas products from R-2 and R-3 pass through cyclone separators. The R-2 cyclone is unloaded to the weigh-hopper and the R-3 cyclone dust is unloaded into transport hoppers.

The gases then pass from the cyclones to the primary filters above each reactor. These filters are cleaned by pulsing with nitrogen and the dust is unloaded from the housings as required. The gases from the two reactors are combined and passed through the R-2/R-3 secondary filter which, like the R-1 secondary filter, is operated at reduced temperatures and is not equipped with a blowback system.

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After double filtration through porous metal filters, the reaction products pass through steam heated lines to five 20' tall, 12" diameter monel scrubbers filled with 5/8" limestone chips. These scrubbers serve a dual purpose. They effectively scrub out 90 to 95% of the HF from the off-gas system and trap UF₆ released to the off-gas system.

One of these scrubbers is unloaded and refilled each shift. Every other day on day shift, two scrubbers are unloaded and refilled.

After cooling, the limestone is scanned for activity, the reading recorded and the limestone is dispositioned.

The scrubbed gases are burned and exhausted through a heated 30' stack to the atmosphere.

IV. ANALYSIS OF EVENTS

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On the morning of August 29, 1989, the production superintendent asked Health Physics to check the limestone.

The surface contamination of six drums of limestone unloaded from scrubbers #1, 2 and 3 ranged from 30,000 to 75,000 dpm (roughly 200 times the normal level and 100 times the level occasionally observed in 3% of the limestone).

The more contaminated limestone was dark green to black with only an occasional tinge of yellow. Since the reaction of UF_6 with limestone produces a strong yellow CaU_2O_7 (the color characteristic of the Uranyl ion), it seemed apparent that no substantial quantity of UF_6 had entered the scrubber system. This resulted in the obvious, though erroneous, conclusion that, in spite of the indication that some UF_6 might have passed through R-1 unreacted, the contamination more likely resulted from broken filters.

The scrubber off-gas sample was removed and checked by alpha count techniques for uranium. This showed 8mg of Uranium which was calculated to be a 274 gram release.

Environmental samples of soil, vegetation and standing water, including water from a puddle just beyond the fence, were collected downwind and north and east (the primary wind direction) of the plant. No significant radiation was detected in any of the samples.

The R-1 secondary filter was opened overnight to inspect for damage. Approximately 1kg of green powder was found on the filters, apparently UF_4 . No leaks were detected initially, but one filter showed significantly less resistance to flow and was found by water immersion to have a 3/4" long crack in one of the six tubes. The downstream side of the filter was heavily coated with green powder.

Scrubber #5 was later unloaded and found to have surface contamination levels of $300,000 \text{ dpm}/100 \text{ cm}^2$. The rock also contained substantial quantities of light brown dust.

Cleanup continued with the cleanup water being collected and dispositioned for recovery.

A grab sample of the limestone from scrubber #5 was analyzed and found to contain substantial quantities of Uranium (2.5%). This indicated that as much as 10kg of Uranium might have been captured in this scrubber alone.

Meanwhile, both the R-2/R-3 secondary filters and the R-1 primary filters were removed and found to be intact.

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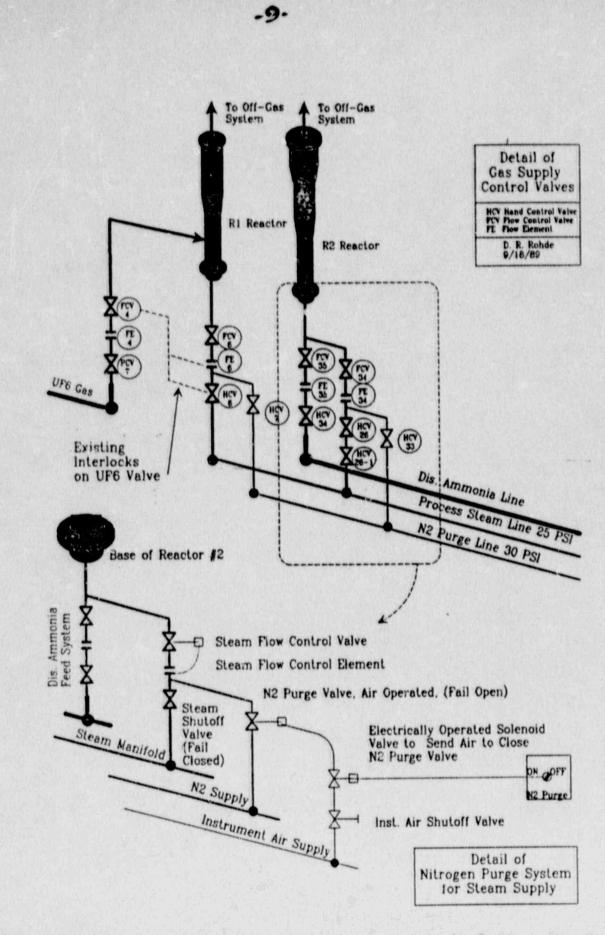
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Dry scrubber #1 - loaded on midnight shift 08/28/89 - was unloaded and found to be clean. i.e. < 150 dpm/100cm² of contamination.

There was no Uranium in the R-2/R-3 off-gas lines. The following conclusions were reached based on this information.

- 1. The Uranium passed through the R-1 filters as a gas, i.e. as UF_6 . Small amounts of Uranium solids might have penetrated through the R-1 secondary filter, but not through the R-1 primary filter, and no Uranium had passed through the R-2/R-3 off-gas line or into the R-2/R-3 secondary filter.
- The incident occurred prior to reloading scrubber #1 on the midnight shift.
- 3. The probable cause was the previously identified problem with the R-2 Nitrogen valve actuator solenoid which flushed Nitrogen through the steam header to R-1. (See Figure 3.)

Subsequent interviews with the operators responsible for startup August 28, 1989, indicated no irregularities in the startup other than setting off the CAM on the fourth floor and a slower than normal overflow from R-1 to the weigh hopper of $UO_2^{r_2}$.



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Figure 3 Conversion Reactor Gas Supply System

However, on examination of the weigh hopper recorder, it appeared that only 2-3kg of UO_2F_2 was transferred to the weigh hopper. Part, or all of, this transfer may have resulted from splashing of the fluidized bed rather than from the conversion of UF₆ to UO_2F_2 .

In any case, it is clear in retrospect that little, if any, conversion occurred in the R-1 reactor and that this occurred because there was little or no steam fed to R-1.

The question then is, what happened outside the R-1 reactor in the off-gas lines and scrubbers?

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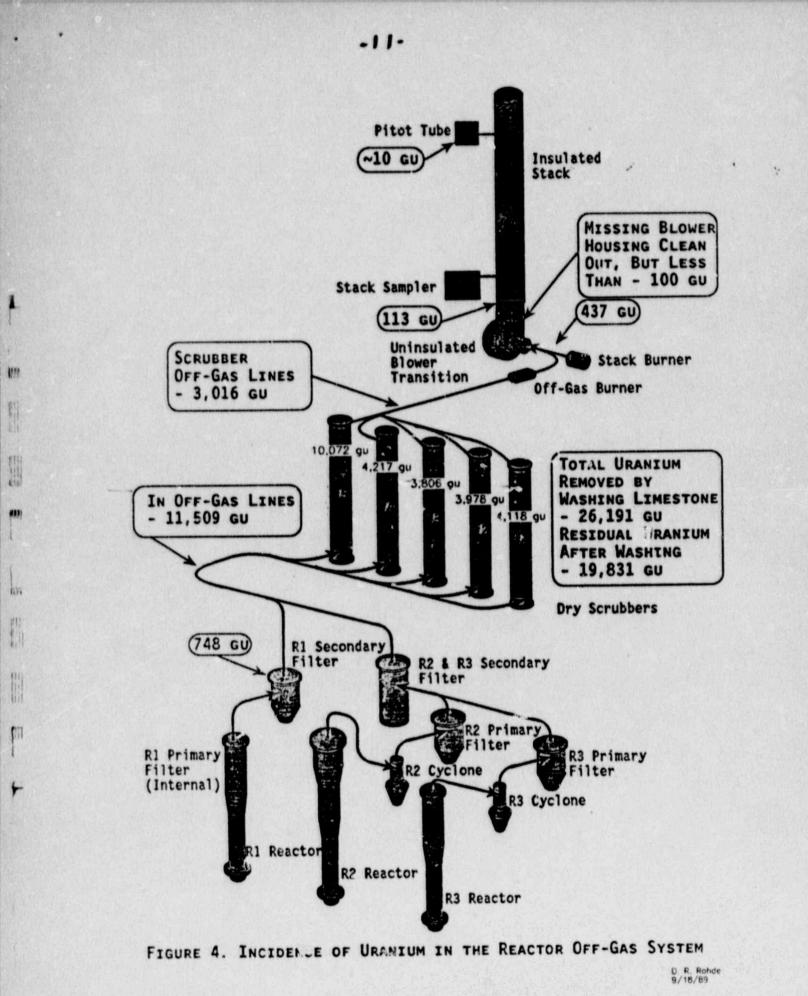
The condition which prevented steam from entering R-1 would also prevent steam from entering R-2 and R-3. However, the flow of cracked ammonia (hydrogen) through a separate flow control valve would not be affected. Consequently, R-2 and R-3 supplied 12 lbs/hour of cracked ammonia to the system - 1.059 lb. moles of hydrogen/hour. Theoretically, this would provide sufficient hydrogen to the off-gas system to reduce 372 lbs/hour of UF₆ to UF₄ --- a 238% excess.

It seems probable that the greensalt (UF_4) observed in the off-gas lines resulted from the reaction of this hydrogen with UF_5 . The UF_4 found on the R-1 secondary filter probably resulted from back diffusion of Hydrogen into the filter as well.

The dry scrubbers appear to have had substantially unequal distribution of gas based on the contamination observed in the limestone. As much as 40% of the reaction products may have passed through the #5 dry scrubber and 15% through each of the other scrubbers.

The four scrubbers receiving less gas contained discolored limestone and limited amounts of dust. The rock was generally stained green though spotty with some areas of black. Both stains probably resulted from greensalt.

The rock in scrubber #5 clearly contained more light brown dust with 8 - 9% uranium - probably a mixture of UO_2 , UO_3 , CaU_2O_7 , CaO and $CaCo_3$. This may have resulted from the heat of reaction which caused decomposition of the limestone and pyrohydrolysis of the UF₄ later in the process (after 20:40) when the steam feed was reinstituted.



Subsequent leaching of the rock with dilute nitric acid and water to remove the surface contamination removed only 57% of the uranium in the limestone. This strongly suggests that significant quantities of uranium penetrated the rock, presumably as UF_6 , in addition to that which was filtered out of the gas stream as UF_6 .

Additional uranium removed from the scrubber of gas lines 3.016 kgU may have resulted from dust carryover.

The limited quantity removed from the blower intake and unheated stack transition (0.69kgU) was yellow and low in assay 58-65% U, suggesting some mixture of UO_3 and/or UO_2F_2 with limestone dust and/or calcium oxide, limestone dust or calcium diuranate. No UF₄ was found.

Any residual UF_6 , CaU_2O_7 , or UF_4 entering the off-gas burner probably decomposed in passing through the moisture laden flame of the off-gas burner.

The 30' heated stack wall was clean except for a small (approximately 10g) deposit of yellow on the pitot tube which assayed 67-77%U. This probably contained some UO_2F_2 or UO_3 , and mixed with a dilutent other than calcium.

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V. MATERIAL BALANCE

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Two types of material balances were conducted. The first, to determine the apparent loss during the critical 1:55 hours without steam and the second, around the complete 4.05% campaign.

The mass error around the critical time interval would be expected to be much smaller since it covers only about 1% of the material involved in the larger campaign balance. The campaign balance, however, would be expected to have a smaller error as a percent of the materials measured, for the most part, with considerable accuracy.

Both material balances are heavily dependent on the assay of the spent limestone which is singularly difficult to sample since it is a mixture of dust and rock of varying sizes and substantially different assays, ranging from 8 -9% in the dust to 0.5% in the rock. The sampling technique probably results in biased low assays since the samples were of necessity removed from the top of the drums and some of the dust slid to the bottom when the drums were righted for sampling. The error involved due to the presence of dust is probably less than 3kg however, since some of the dust adheres to the limestone and the total dust content seems to be about 1.5%. There are also noticeable variations in the uranium concentration within the limestone drums.

The UF₆ flowmetor was assumed to accurately reflect the flow rate.

In any case, the results of the two material balances indicate during the critical 1:55 hour period that the release to the environment was 3kg or less and the "sanity check" balance over the entire 4.05% (21.8kg or <0.3%) campaign does not invalidate this conclusion.

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MATERIAL BALANCE I

FOR THE CRITICAL 1:55 MINUTES

Input	64.80 kgU	
Output		
R-1 Secondary Filter	solids 0.748	
ADU from Line Cleanou	it 14.001	
Cleanup Liquor Solids	0.112	
Miscellaneous Liquors	0.412	
Limestone Leach Solut	tion 26.191	
Limestone After Leach	19.831	
Scrubber Blower Intal	e Solids .325	
Scrubber Stack Cleand	.113	

CRITICAL LOSS

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61.733kgU

MATERIAL BALANCE II

FOR THE 4.05% CAMPAIGN

UF ₆ Seed	7214.885kgU 62.141kgU		
2660	02.141890		7,277.026kgU
Output			
Conversion System		7193.476kgU	
Offgas System		61.733	
			7,255.209kgU

CAMPAIGN LOSS

21.817KGU

MATERIAL BALANCE DATA FOR 4.05% CAMPAIGN

INPUT		٦			
LOT/RESIDUE NO.	UF6 lbs	UF6 HEEL	NET UF6 KG	96 U	KGSU
A-728-S 0204	4982	1.0	2259.332	67.611	1527.557
A-729-S 0132	4985	6.0	2258.425	67.611	1526.943
A-730-S 0194	4980	3.0	2257.517	67.614	1526.398
A-731-S 0168	4984	2.0	2259.785	67.627	1528.225
A-732-5 0109	4966	1360.0	1635.646	67.604	1105.762
STARTING BED			NET WT KGS	% U	
52294-CF-687-M			18.665	78.32	14.618
52295-CF-687-M			22.645	78.44	17.763
52296-CF-687-M			21.145	80.29	16.977
SEED					
52402-CG-687-M			15.690	81.47	12.783
			[TOTAL	7277.026
OUTPUT					
LOT/RESIDUE NO.	LOT WT	RCY WT	NET WT KGS	% U	KGS U
B-156-S	2078.215	126.085	1952.130	87.80	1713.970
B-157-S	2078.005	122.460		87.80	1716.969
B-1583	2060.630	130.025		87.80	1695.071
B-159-S	1833.545	304.135	1529.410	87.80	1342.822
R-2 BUFF					
53248-CA-728-S			20.930	83.08	17.389
53249-CA-728-S			15.275	83.08	12.691
53255-CA-728-S			11.435	83.08	9.501
53256-CA-728-S			19.750	83.08	16.409
53258-CA-729-S			14.225	83.08	11.819
53269-CA-729-S			13.060	83.08	10.851
53270-CA-729-S			18.355	83.08	15.250
53271-CA-729-S			9.575	83.08	7.955
53273-CA-730-S			10.920	83.08	9.073
53278-CA-730-S			8.805	81.23	7.153
53280-CA-730-S			19.540	81.23	15.873
53284-CA-731-S			16.920	81.23	13.745
53285-CA-731-S			13.360	81.23	10.853
53307-CA-731-S			26.410	81.23	21.454
53317-CA-732-S			13.140	81.23	10.674
53325-CA-732-S			19.505	81.23	15.844
53328-CA-732-S			9.945	81.23	8.079
53332-CA-732-S			13.135	77.11	10.128

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R-3 CYCLONE FINES		NET WT KGS	% U	KGSU
53274-CC-729-S		13.870	87.23	12.099
53276-CC-730-S		12.690	87.23	11.069
53290-CC-731-S		19.290	87.45	16.869
53365-CC-732-S		1.900	87.45	1.662
R-3 BUFF				
53286-CA-730-S		14.770	87.230	12.884
R-3 BUFF C/O				
53318-BD-731-S		23.700	87.230	20.674
53364-CA-732-S		5.035	87.230	4.392
R-3 CYC C/O				
53363-CC-732-S		20.060	87.230	17.498
R-2 BED				
53366-BD-732-S-1		28.600	85.600	24.482
53366-BD-732-S-2		23.630	85.600	20.227
53366-BD-732-S-3		21.115	85.600	18.074
53366-BD-732-S-4		19.230	85.600	16.461
53366-BD-732-S-5	and the second	14.580	85.600	12.480
C/O FROM R-2 BOTTOM		4.010	85.600	3.433
R-3 BED			14 4 10	
53383-CB-732-S-1		22.430	87.703	19.672
53383-CB-732-S-2		17.375	87.703	15.238
53383-CB-732-S-3		18.400	87.703	16.137 .
53383-CB-732-S-4		20.410	87.703	17.900
53383-CB-732-S-5		22.420	87.703	19.663
53383-CB-732-S-6		17.735	87.703	15.554
53383-CB-732-S-7		17.150	87.703	15.041
53383-CB-732-S-8		9.345	87.703	8.196
C/O FROM R-3 BOTTOM		3.915	\$7.703	3.434
R-1 BED				
53382-CF-732-S-1		22.750	79.310	18.043
53382-CF-732-S-2		24.000	79.310	19.034
53382-CF-732-S-3		24.000	79.310	19.034
C/O FROM R-1 BOTTOM		14.400	79.310	11.421
RETURN SAMPLES				
A-732-5		11.100	77.860	8.642
53385-CF-730-S		19.500	77.860	15.183
R-1 SEED				
A-732-S		19.700	81.950	16.144

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MISCELANEOUS		NET WT KGS	%U	KGSU
53372-DE-000-S	UTILITY HOOD & DS BLOWER C/O	14.120	70.690	9.981
53373-BD-000-S	SILO C/O			
	BLENDER 1,2,3,4 C/O			
	BLENDER KO	18.665	87.394	16.312
	SILO K/O			
	DIVERTER VALVE C/O			
53374-DJ-000-S	SPLASH TANK C/O	5.160	74.410	3.840
53375-DD-000-S	VACUUM SWEEPS			
	PREFILTER K/O	10.665	72.000	7.679
	UTILITY HOOD PREFILTER KIO			
53377-DD-000-S	E.B. C/O VAC SWEEPS			
	W.B PREFILTER K/O			
	MICRONIZER FILTER K/O	23.780	67.650	16.087
	OXIDE PLANT VAC SWEEPS			
53378-DB-000-S	E.B. FILTER K/O	11.850	51.510	6.104
53379-BD-000-S	BLENDER HOOD C/O	2.075	85.010	1.764
UTILITY HOOD C/O		11.900		0.236
UTILITY HOOD C/O		3.490	GAMMA	0.030
EAST BANK FILTER			GAMMA	1.188
WEST BANK FILTER			GAMMA	5.284
MISCELANEOUS GA			GAMMA	0.758

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TOTAL PRODUCT CONVERSION SYSTEM 7193.476

URANIUM IN PRE-LEACHING	ROCK	19.831KG
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WEIGHT BEFORE LEACHING	4.776KG
WEIGHT AFTER LEACHING	4.093KG
WEIGHT LOSS IN LEACHING	0.693KG
PRE-LEACHING ROCK	0.927%U

DRUM NO.	SCRUBBER NO.	KG LIMESTONE	%U	KGU
7	1T	89	1.178	1.048
8	11	99	0.766	0.758
9	11	63	0.776	0.489
13	1B	96	0.473	0.454
14	18	100	0.605	0.605
15	iB	105	0.728	0.764
	A Constanting and the faith	The second second second	CHARLES & COMPANY	4.118
16	2T	108	1.076	1.162
17	2T	56	0.920	0.515
18	2T	94	0.479	0.450
19	2B	111	0.351	0.390
20	2B	53	9.726	0.385
21	2B	73	1.474	1.076
C. LA CARACTERIZATION			a the second	3.978
22	3T	79	0.681	0.538
23	3T	87	0.986	0.858
10	3T	96	- 0.552	0.530
11	38	82	1.375	1.128
12	3B	55	1.368	0.752
The second second	Contraction of the second s		and the second	3.806
27	4T	113	0.697	0.788
28	4T	105	1.021	1.072
29	4T	29	1.440	0.418
24	4B	90	0.522	0.470
25	4B	99	0.712	0.705
26	4B	66	1.157	0.764
ANT AND THE REAL PROPERTY OF	and the second sec			4.217
1	5B	35	1.632	0.571
2	5B	116	1.445	1.676
3	5B	93	2.232	2.076
4	5T	95	2.139	2.032
5	5T	105	1.791	1.88
6	5T	99	1.855	1.83
	No. of Concession, Name	A State State State State		10.07
		2491 KGS		
		5493 LBS		26.19

URANIUM RECOVERY FROM DRY SCRUBBER LIMESTONE BY ACID LEACH

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		NET WT KGS	% U	KGSU
R-1 BUF C/O		1.010	74.070	0.748
DRY SCRUBBER STACK C/O		0.195	58.160	0.113
DRY SCRUBBER BLOWER INTAKE C/C	1916년 1111년 11일(영화) 1917년 - 1917년 11일(영화)	0.495	65.580	0.325
CLEAN UP LIQUOR SOLIDS		4.395	2.540	0.112
INPURE ADU FROM R-1 OG LINES		8.165	43.950	3.589
		1.740	45.080	0.784
		6.950	49.340	3.429
		6.520	53.080	3.461
		4.795	57.100	2.738
DRY SCRUBBER LIMESTONE LEACH S	OLUTION	2491.000		26.191
DRY SCRUBBER LIMESTONE AFTER L	EACH (COMPOSITE)	2139.250	0.927	19.831
ADU FILTRATE	900 LTS			0.023
	925 LTS			0.009
ADU PRESS/FILTER CLEANUP		15.020		0.156
		5.225		0.040
		17.050		0.115
ADU PRESS CLOTHS		1.310		0.027
		4.420		0.042

DRY SCRUBBER & OFF-GAS CLEANUP PRODUCT 61.733

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VI. ENVIRONMENTAL IMPACT

The immediate action taken to assess environmental impact caused by the event was to survey the area most likely to have received deposition of released uranium. Samples for urinalysis from all employees who potentially could have been affected were requested. Expanded surveys were conducted on a more systematic basis in the days following discovery of the event. The following sections discuss specific areas of investigation.

Meteorological Data

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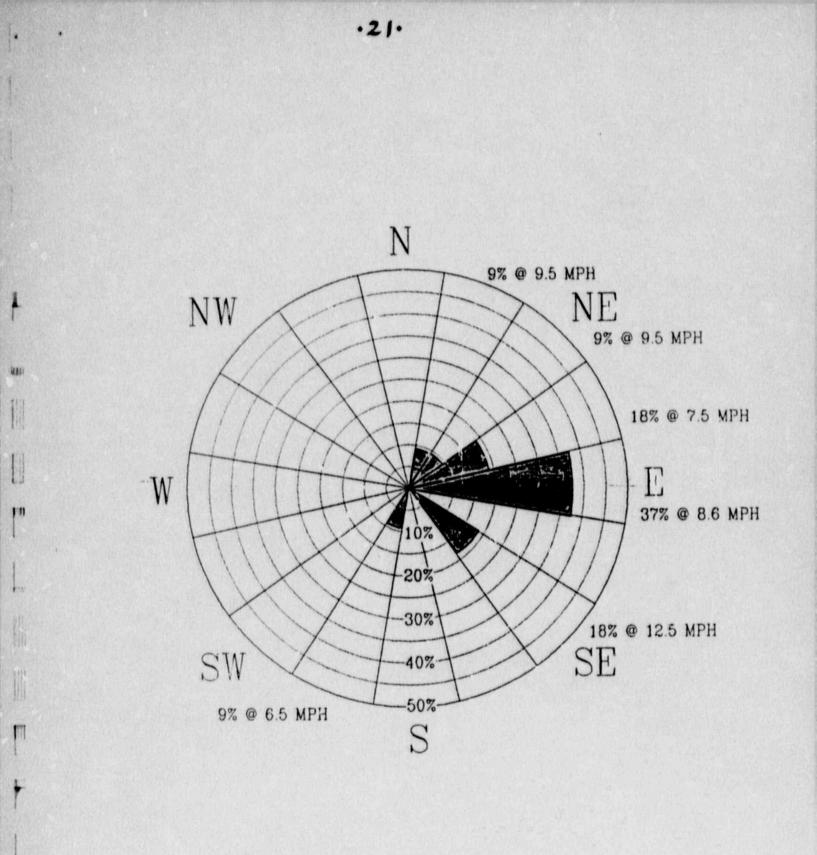
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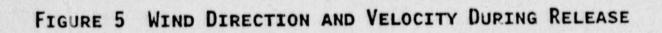
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The Hematite plant has wind direction and velocity indicators on the roof top and continuous recording of this information on a strip chart recorder. An evaluation of this information shows that the wind direction during the release was predominantly to the east an average velocity of approximately S mph. Figure 5 depicts the wind character during the release periods. Additionally, a strong rainstorm started near the end of the second release period. An estimated 3/4" of rain fell during the storm, which lasted about two hours. Prior to the storm, a white discharge from the scrubber emission stack was observed by several employees to curl downward and impinge on the trees and ground to the northeast of the plant and about 50' outside the perimeter fence.

Neighboring Residences

The closest residence is approximately 300 meters to the west, and an additional residence is about 400 meters to the northeast. One residence to the southwest is about 600 meters from the plant. An aerial photograph (Figure 6) depicts the plant and surrounding environment and residences.





Wind Direction And Velocity From the August 28, 1989, Uranium Release

Time	KEH	Direction	
10:50	5.0	NE	
11:00	11.5	ENE	
11:10	9.5	ESE	
11:20	5.0	NE	
11:30	10.0	ESE	
11:40	7.5	NE	
11:50	13.0	E	First part of release begins, 11:50
12:00	6.5	ENE	
12:10	10.0	E	
12:20	12.0	E	
12:30	9.5	NE	
12:40	6.0	E	
12:50	8.5	ENE	성화 전에서 가지 않는 것은 것이 없는 것이 없다.
13:00	9.0	SE	First part of release ends, 13:05
Average	e 9.3		
13:10	8.0	ENL	
13:20	8.0	ESE	
13:30	5.5	NE	
13:40	8.0	E	Second part of release begins, 13:40
13:50	6.5	E	
14:00	16.0	SE	
14:10	9.5	NNE	
14:20	6.5	SSW	Second part of release ends, 14:20
Averag	e 9.3		
14:30	3.5	SSE	
14:40	7.0	SW	
14:50	13.0	NE	
15:00	3.5	S	
15:10	6.5	W	
15:20	3.5	NW	
15:30	5.0	WSW	
15:40	7.0	W	

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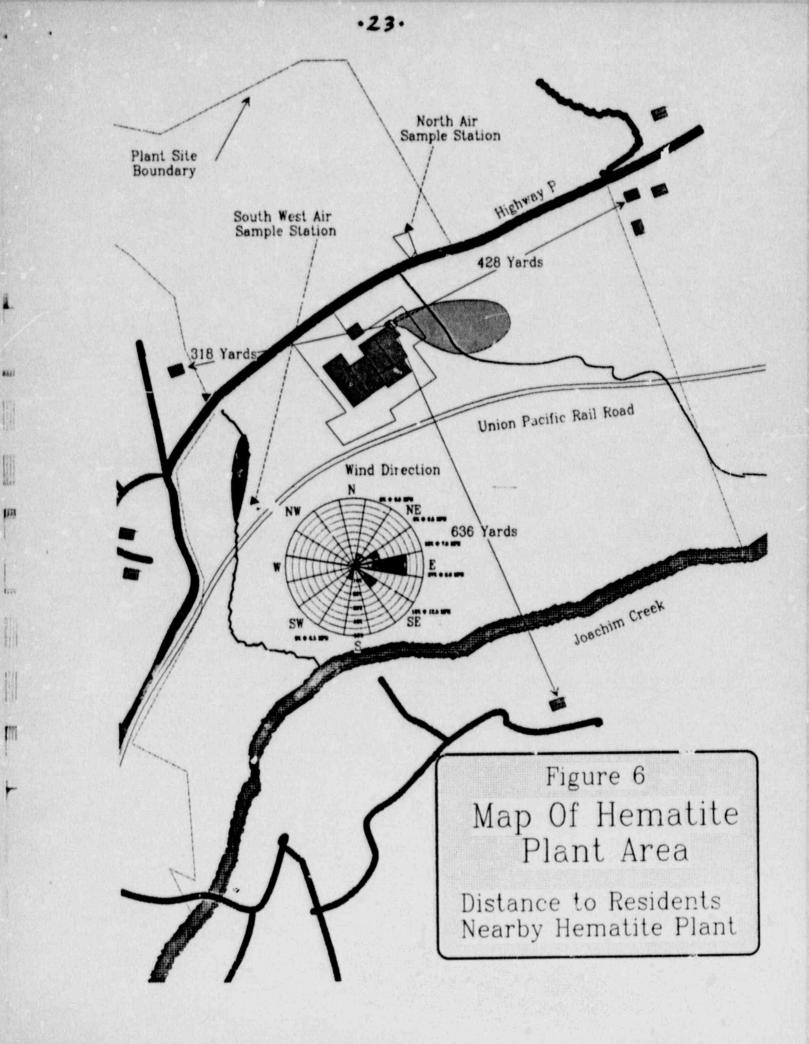
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Notes: There release was probably in two parts. The first occurred from 11:50 to 13:05. The second occurred from 13:40 to 14:20. The weather data recorded here brackets both releases.

The velocity measurements are in units of miles per hour (MPH). The direction is the direction toward which the wind is blowing.



Nearest Residence Calculation

The nearest residence in the general wind pattern during the release periods is 428 yards from the plant. The calculation performed assumed that the maximum quantity of 3kg of insoluble uranium compound was released and that an individual was at the nearest residence was initially and remained outdoors and inhaled it for the total duration of the release. Assuming that 12% of the intake was retained in the lungs, and taking credit for known wind direction during the event, this dose is below 0.2 mR. (Considering virtual source - concentration at the stack, plume meandering within sector, wake effect of wooded area between stack and residence, and particle deposition from the plume, the dose would be further reduced by more that a factor of 10.)

NEAREST RESIDENT DOSE:

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			% Wind	- 1 C - 1	
		Building	in NE	Lung Do	se (mR)
Distance (m)	×/0	Wake Effect	Grid	3kgU	300gU
400	×/Q 2.6E-5	1.5	0.36	0.12	0.01

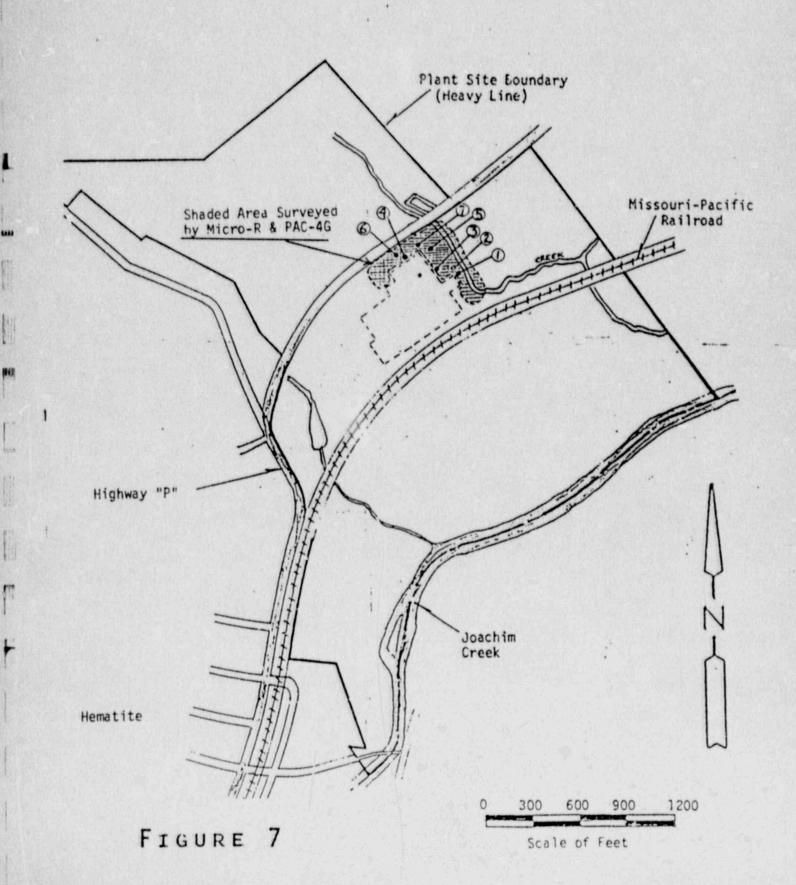
REMOTE AIR SAMPLING:

(uCi/ml)
1.3 E-14
2.0 E-15

Survey Data

1. Initial Sampling and Surveys - Tuesday, August 29, 1989 Shortly after discovery of the contaminated limestone scrubber beds, surveys were made and samples were taken in the area where a release would most likely have deposited uranium compounds. All sampling and surveys at this time were outside the outer perimeter fence, and locations are shown in Figure 7. Surveys for gamma radiation were made with a Ludlum Model 19 micro R meter in order to detect areas of radioactivity greater than background. Surveys for alpha contamination were taken with a portable PAC-4G survey meter. These surveys, as can be seen in Figure 7, covered an area in the predominant wind direction which subtended over 220° of arc around the release point. Standing water, soil and vegetation samples were taken from an area which ranged about 130° of arc around the release point and included the predominant wind direction.

AREA SURVEY AND SAMPLES TAKEN 8-29-89



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The results of these early samples and surveys showed no indication of measurable release of uranium from the scrubber stack; results were generally indistinguishable from background. The specific results are:

Samp1 Numbe		Values .	
1.	Water pool east of trailer	Background	
2.	Soil bank near SW corner of limestone pile	13 pico Ci/g	
3.	Soil along fence line due E of Oxide scrubbers	16 pico Ci/g	
3a.	Vegetation along fence line due E of Oxide scrubbers	4 pico Ci/g*	
4.	Water pool in roadway to limestone pile	Background	
5.	Water puddle 50' E of fence, in NE corner	Background	
6.	Soil middle of field, N of Oxide Building	Background	
6a.	Vegetation middle of field, N of Oxide Building	1.2 pico Ci/g*	
7.	Vegetation leaves from tree 20' from NW corner	10 pico Ci/g*	

*wet basis

2. Subsequent Sampling and Surveys

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Additional samples and surveys were taken on Friday (September 1), Saturday (September 2), Wednesday (September 6) and Thursday (September 7, 1985).

- a. The samples taken on September 1 and 7, 1987, were shared by CE and the NRC AIT for later comparison of results. Figure 8 depicts the location of samples taken and are seen to encircle the plant site restricted are as well as more distant locations (#7 and #8) along Joachim Creek. These samples were sent out to Teledyne for evaluation and results are shown in Table A.
- b. On Saturday, September 2, 1989, a radiation survey was performed that centered on the scrubber stack from which the release emanated, and went in three concentric circles of radii 100, 200, and 300 yards, respectively. There were twelve survey points per circle, beginning with the north and going clockwise. Figure 9 shows the General Area Survey Map at the plant location just described. Two instruments were used in the survey, the Ludlum micro R meter (gamma) and a portable PAC-46 alpha survey meter. Background for the PAC-46 meter is between 56 and 150 cpm.

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TABLE A

TELEDYNE	PCI/G	DRY BASIS
SOIL	ALPHA	BETA
ST-1	14 + 6	28 <u>+</u> 3
- 2	14 ± 6	43 <u>+</u> 3
- 3	16 + 6	47 <u>+</u> 3
- 4	17 + 6	45 <u>+</u> 3
- 5	20 <u>+</u> 7	48 🛧 3
- 6	20 + 7	40 <u>+</u> 3
-7	9.1 + 5.2	17 + 2
- 8	< 5	8.7 ± 1.7

VEGETATION

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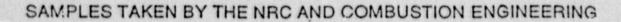
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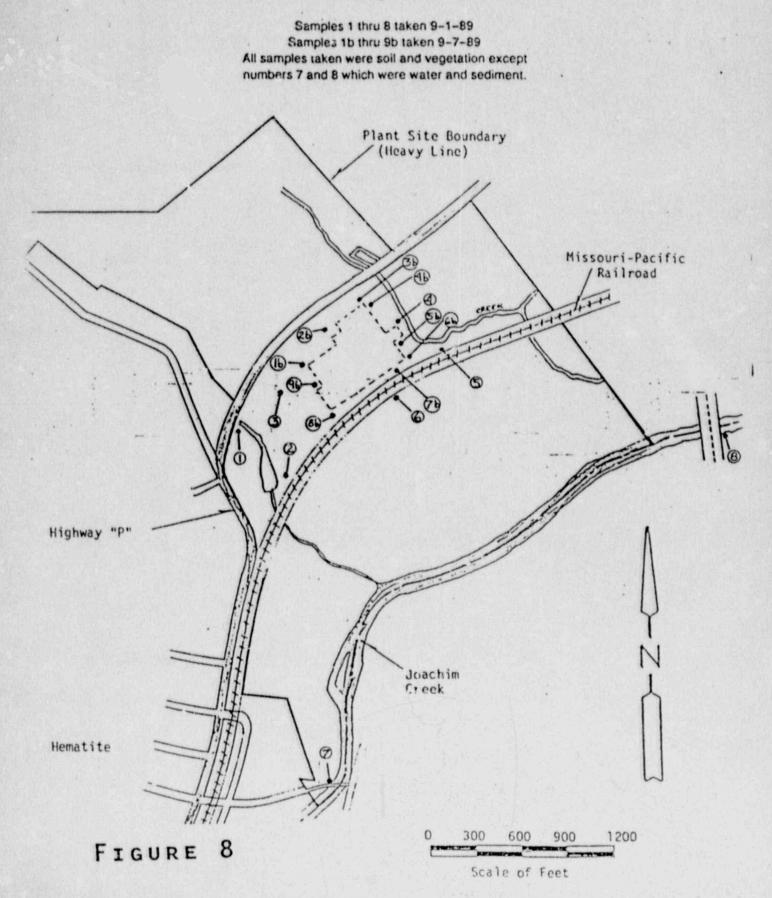
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	PCI/G	WET BASIS		
	ALPHA	BETA		
SP-1	1.0 ± 0.4	9.9 <u>+</u> 0.4		
- 2	1.5 ± 0.6	19.0 ± 1.0		
- 3	1.4 ± 0.4	10.0 ± 1.0		
- 4	4.1 ± 1.0	64.0 <u>+</u> 1.0		
- 5	1.0 ± 0.3	15.0 ± 1.0		
- 6	1.7 ± 0.7	15.0 ± 1.0		
H20	PCI/L			
1120	ALPHA	BETA		
SP-7	<4	6.4 ± 1.9		
SP-8	<4	6.8 ± 2.0		

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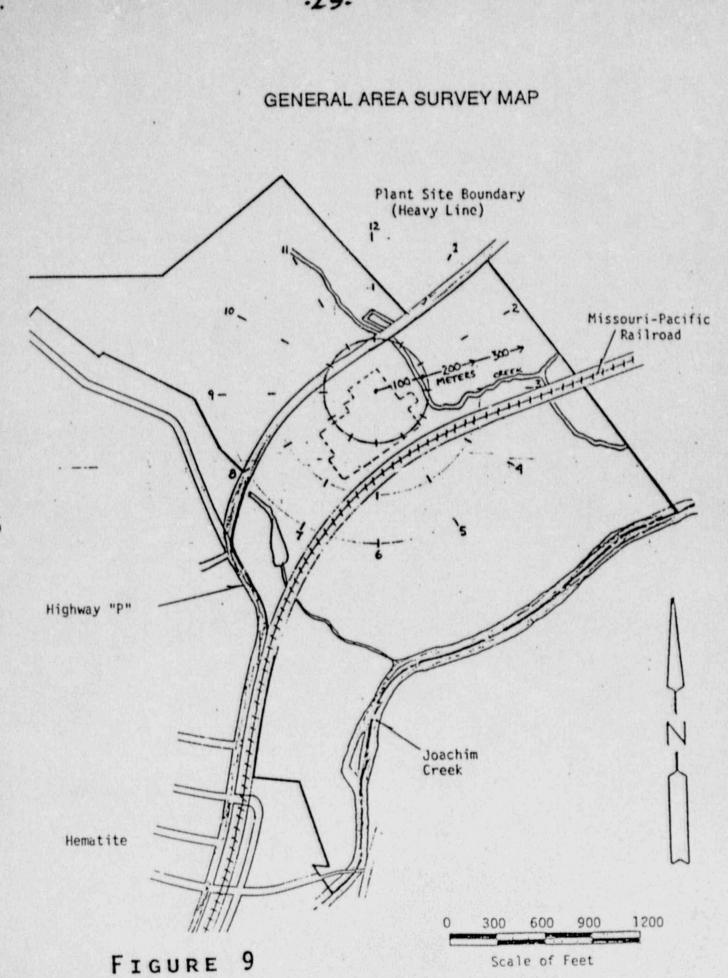




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Table B presents the readings taken at each survey point. Examination of the readings shows no discernible trends for either gamma or alpha, regardless of distance or direction from the stack. All readings are within anticipated background ranges.

c. In addition to soil and vegetation samples, six smear samples were taken on the plant rooftop. Two were taken on the Oxide Building roof and four were taken on the new Pellet Plant roof (Building 254). The results are as follows:

Sample Number	Location	Alpha CPM	DPM/100cm ²
1.	Stack in center of Oxide roof	25	89
2.	Near door in Oxide roof	109	388
3.	NE corner, new Pellet Plant	4	14
4.	Center E edge, new Pellet Plant	5	18
5.	SE corner, new Pellet Plant	4	14
6.	NE corner, Warehouse	3	11

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d. On September 6, the roadway area just inside the perimeter fence around the UF₆ conversion area was surveyed and smeared for contamination. Figure 10 shows the locations sampled and Table C indicates the results obtained. All readings are within the normal range expected for the area.

LOCATION	MICRO-R 1 READINGS	PAC-4-G ² ALPHA READINGS	LOCATION	MICRO-R ¹ READINGS	PAC-4-G ² ALPHA READINGS	LOCATION	MICRO-R ¹ READINGS	PAC-4-G ² ALPHA READINGS
100-1	5	75	200-1	4	50	300-1	6	75
100-2	4	50	200-2	7	100	300-2	7	75
100-3	6	50	200-3	6	75	300-3	7	75
100-4	7	100	200-4	9	75	300-4	7	75
100-5	7	100	200-5	7	100	300-5	7	100
100-6	7	75	200-6	6	75	300-6	6	50
100-7	N/A	N/A	200-7	9	100	300-7	7	100
100-8	4	100	200-8	6	75	300-8	6	75
100-9	7	75	200-9	1 4	125	300-9	5	50
100-10	5	75	200-10	6	100	300-10	6	75
100-11	7	100	200-11	7	50	300-11	6	75
100-12	6	125	200-12	5	75	300-12	5	50

GENERAL AREA SURVEY

ALL METER READINGS ARE PEAK READINGS.

(1) Microroentgens per hour.

TABLE [

(2) Counts per minute.

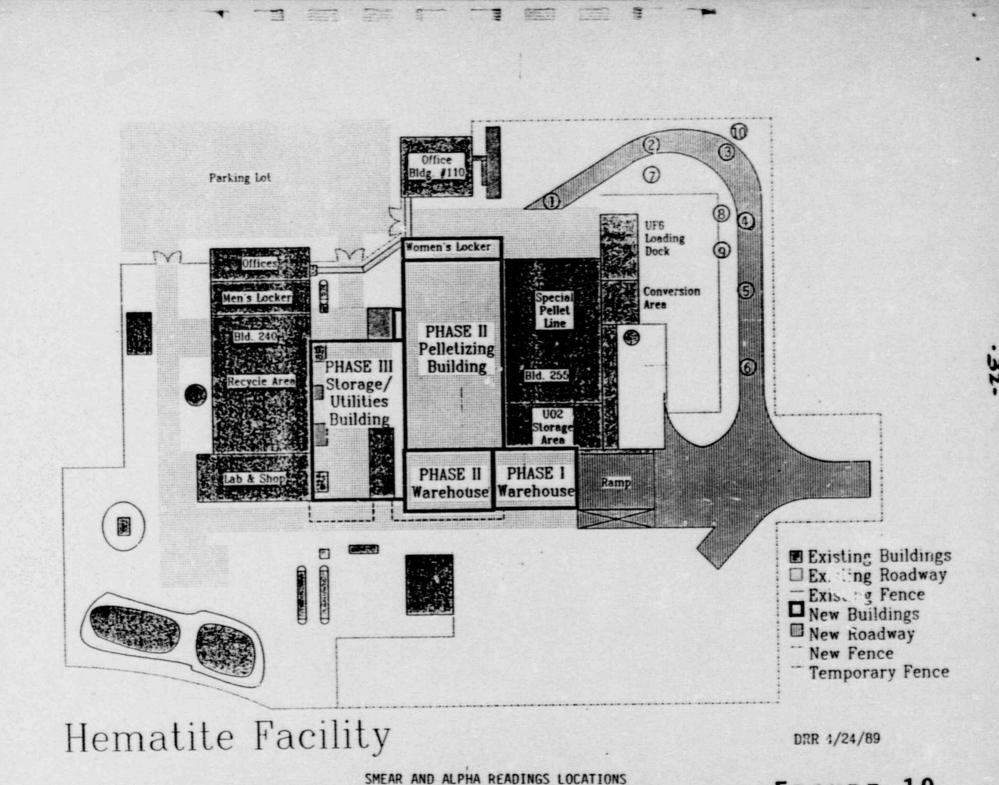


FIGURE 10

CLEAR AREA ROADWAY (FENCED) CONTAMINATION CHECK

SAMPLE NUMBER	FIXED READING CPM (NO BKGD SUBTRACTED)	SMEARS
1	100	11
2	75	0
3	100	4
4	100	0
5	175	4
6	100	0
7	50	GRASS
8	75	GRASS
9	100	GRASS
10	50	GRASS

THE FIXED READINGS ARE PEAK READINGS. SEE MAP FOR SAMPLE LOCATIONS.

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TABLE C

VII. PERSONNEL EXPOSURE

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During the Incident

Six employees had potential radiological health involvement in the August 28, 1989, release. Their radiological exposure was minimal, with the majority of internal depositions being below detectable levels. The radiological exposure for these six people was determined by two different methods. Inhalation exposure in MPC hours was calculated from fixed air samplers located in the area of the scrubber. Urine samples were taken several times after the release discovery for radiological bioassay. These results are shown below.

Employee	MPC-hrs	Micrograms U/liter in Urine
Employee A		
08/29/89		<1.0
08/30/89		<1.0
08/31/89		<1.0
Employee B		
08/29/89		<1.0
08/30/89	1 10 · · · · · · · · · · · · · · · · · ·	<1.0
08/31/89		<1.0
08/31/89	•	<1.0
Employee C		
08/28/89	3.39	
08/29/89	1.67	<1.0
08/30/89	2.20	<1.0
08/31/89	2.42	<1.0
Employee D		
08/31/89		<1.0
09/01/89	•	<1.0
Employee E		
08/29/89	1.31	<1.0
08/30/89	2.91	<1.0
08/31/89	2.35	<1.0
Employee F		
		.1.0
08/30/89		<1.0
08/31/89		<1.0

Employee	MPC-hrs	Micrograms U/liter in Urine
Employee G		
08/28/89 08/29/89	3.19 (1) 21.89 (1)	
08/30/89		1.4 (2)
08/31/89		<1.0
09/01/89		<1.0

Administrative action level is 32 MPC-hrs in any week.
 Administrative action level is 25 micrograms U/liter.

During the Limestone Unloading

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Three employees were involved in the scrubber limestone unloading on August 29, 1989. Subsequent urine and fecal samples were taken for radiological bioassay. Their radiological exposure was minimal, with the majority of internal depositions being below detectable levels. The results are set forth below:

Employee	MPC-hrs	Micrograms U/ liter in Urine	Micrograms U/ gram in Fecal
Employee G			
08/28/89 08/29/89 08/30/89	3.19 (1) 21.89 (1)	1.4 (2) <1.0	
08/31/89 09/01/89 09/06/89	÷	<1.0 <1.0	0.47
Employee H			
08/30/89 08/31/89 09/01/89 09/06/89	2.91 2.35 2.25	<1.0 <1.0 <1.0	0.10
Employee I			
08/29/89 08/30/89 08/31/89 09/01/89 09/07/89	13.09 (1) 4.85 0.58 1.74	<1.0 3.1 (2)	0.02

(1) Administrative action level is 32 MPC-hrs in any week.

(2) Administrative action level is 25 micrograms U/liter.

VIII. ROOT CAUSE ANALYSIS

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Three fundamental problems are responsible for the August 18, 1989, release incident:

- * Lack of recognition of a potential system failure mode.
- Inadequacies in the system for communicating and documenting the needs for maintenance.
- * Failure in training the operating staff of the need to assure that conversion of the UF_6 was actually occurring.

Lack of recognition of a potential system failure mode.

Until the August 28 incident, the potential for feeding nitrogen into the process steam header was not identified or analyzed.

This problem is clearly the most fundamental cause of the release.

Inadequacies in the system for communicating and documenting the needs for maintenance.

None of the supervisors saw the note that maintenance work was required and the note was not available to the operators in the control room. It is clear that the conversion system would never have been operated with a disabled nitrogen valve.

Failure in training the operating staff of the need to assure that conversion of the UF, was actually occurring.

The startup crew recognized that the overflow to the weigh hopper was unusually slow. They were primarily concerned that the overflow line was plugged and assumed incorrectly that when they collected a sample and saw material collecting in the weigh hopper that the system was operational. While there were some indicators available that conversion was <u>not</u> occurring, the operators failed to properly interpret that information since they had no experience or training that would suggest that a total lack of conversion was possible.

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1X. CONSEQUENTIAL ITEMS

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Two additional potential improvements were also identified:

First, the sampling system was not designed to handle particulates.

Second, the environmental sampling rate should be expanded - both in terms of ability to sample to provide remote air sampling in the normal downwind direction (which would have allowed more definitive statements on the environmental impact) and in terms of collecting prompt data after the fact to more accurately assess potential environmental impact (and help reassure the public).

X. CORRECTIVE ACTIONS

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An extensive review of the conversion line system was conducted. As a result of these reviews, interlocks connected to the R-1, R-2 and R-3 nitrogen value positions have been installed which will shut off the UF_6 flow automatically if the nitrogen value is not in the closed position.

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A main enance requirements log has been prepared for posting in the conversion plant control room. All maintenance requirements will be posted on this log and the entries will be signed. A decision and the authorized individual who made the decision will be included on the log if the maintenance is not considered critical to operation. When restarting, the UF₆ control valve switch will not be unlocked from the closed position until all critical maintenance requirements have been released.

All conversion operators are now aware of the necessity of watching closely for any indication that conversion is not occurring and this information will be included in all oxide training programs in the future to assure that every oxide operator is aware of the potential problems.

A new dual purpose scrubber off-gas sampling system is being installed prior to startup and will be tested in place (see Figure 11). This system will operate on a more dilute stream to minimize condensation and will include both an isokinetic sampler for particulates and a low volume sampler for fluoride.

A third remote sampling site will be installed east of the plant to provide emergency sampling capability by March, 1990.

Additional technicians for emergency environmental sampling will be trained from the Quality Control staff to free Health Physics technicians for other emergency work and another Micro-R survey meter will be purchased to expedite future environmental survey efforts if future emergencies arise. This t- ining will begin this year and be completed by March, 1990.

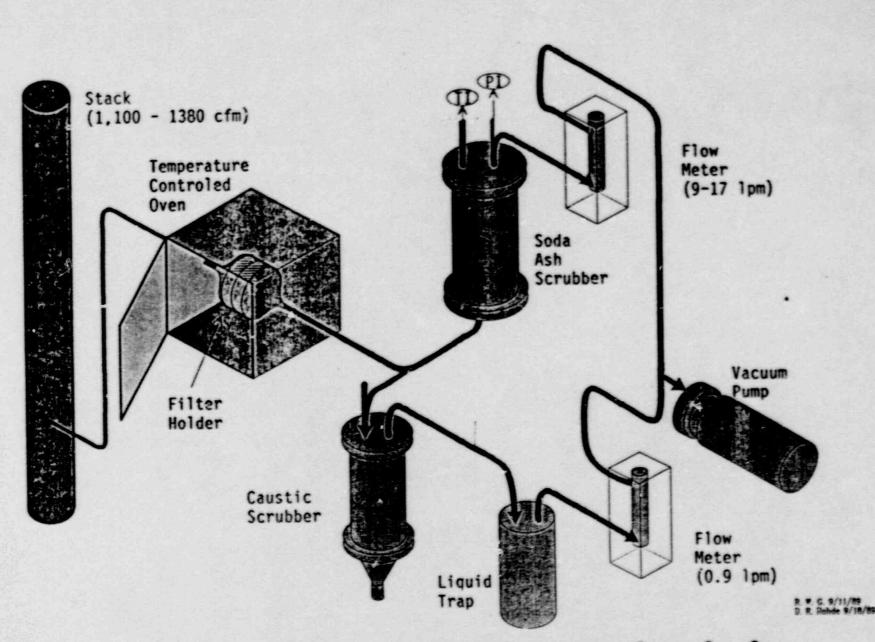
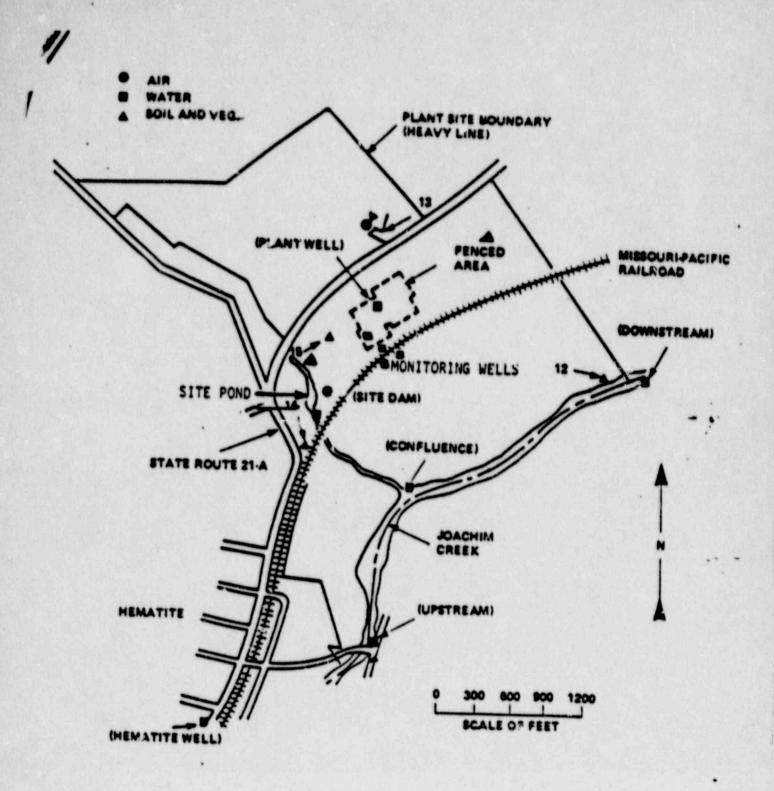


FIGURE 11 REVISED HEALTH PHYSICS STACK SAMPLER FOR OXIDE OFF-GAS



Location of Monitoring Sites Around Hematite Facility

License No. SNM-33, Docket 70-36

Revision:

1

Date: 1/24/83 Page: 1.5-6



CONFIRMATORY ACTION LETTER

ATTACHMENT F

CAL-R111-89-020

UNITED STATES NUCLEAR REGULATORY COMMISSION REGION III 700 ROOSEVELT ROAD GLEN ELLYN, ILLINOIS 60137

SEP 0 1 1989

Docket No. 70-36

Combustion Engineering, Inc. (CE) ATTN: Mr. James A. Rode Plant Manager Hematite Fuel Manufacturing Post Office Box 107 Hematite, MO 63047

Gentlemen:

This refers to the conversation between Mr. James A. Rode and Dr. Bruce Mallett of my staff on August 30, 1989, concerning the recent inadvertent release of uranium from the conversion process system at the Hematite facility. As discussed, the NRC is concerned about causes of the release, damage to equipment, potential exposure to workers onsite and potential for offsite deposition. Consequently, we have dispatched an Augmented Inspection Team (AIT) on August 30, 1989 to begin review of the event and your actions. Mr. Donald Sreniawski of my staff is the team leader.

Based upon the conversation with Dr. Mallett, it is our understanding that you have ceased operations involving the affected conversion process line as of August 30, 1989, other than investigating causes and damage to components, and will take the following actions:

- Prohibit restart of the portions of the UF₆ to UO₂ process line in the oxide plant that were involved with the refease event until (a) the root cause of the release has been determined, (b) any damaged portions of the process line have been repaired, and (c) your conclusions regarding the cause, adequacy of repairs, and basis for restarting the process line have been provided to the AIT Team Leader and the NRC Region III Administrator.
- Maintain records of all activities associated with the release and followup investigation by CE for review by the NRC.

CONFIRMATORY ACTION LETTER

Combustion Engineering, Inc. 2 SEP 01 1989

Issuance of this Confirmatory Action Letter does not preclude the NRC from taking other actions regarding this matter including issuance of an Order requiring implementation of the above commitments. If your understanding differs from that set forth above, please call me immediately.

Sincerely,

a Bert Dame

A. Bert Davis Regional Administrator

cc: Dr. P. L. McGill, Combustion Engineering, Inc. DCD/DCB (RIDS)