Mallett DSIR

OCT 19 1989

Docket No. 70-36

Combustion Engineering, Inc.
Nuclear Power Systems
ATTN: Dr. P. L. McGill
Vice President,
Nuclear Fuel
Manufacturing
Windsor, CT 06095

License No. SNM-33

Gentlemen:

This refers to the augmented team inspection conducted by Messrs. D. J. Sreniawski, G. M. France, III, and F. C. Sturz of the Nuclear Regulatory Commission on August 30, 31, and September 1, 7, 8, 22, and 23, 1989, of events related to an unplanned uranium release at your Hematite facility on August 28, 1989, and to the discussion of our findings with Mr. J. A. Rode and others at the conclusion of the inspection.

The enclosed copy of our inspection report identified areas examined during the inspection. Within these areas, the inspection consisted of a selective examination of procedures and representative records, observations, independent measurements, and interviews with personnel.

The team's efforts were directed towards determining what had occurred, why it happened, the safety significance of the release to workers and to offsite residents and the corrective actions to protect the public health and safety. The regulatory aspects of the incident are not addressed in this report. Should any enforcement action be warranted, it will be covered in future correspondence.

The report also documents the meeting in Region III on September 19, 1989, between Combustion Engineering and the NRC to address Combustion Engineering's evaluation of the release, its causes, and the corrective actions which were being implemented prior to restart of the plant.

On September 1, 1989, I issued a Confirmatory Action Letter (CAL) which documented our understanding of actions your staff planned to take in evaluating the unplanned release and its causes, correcting the problems identified, and informing the NRC of your evaluations and planned actions. Based on the September 19, 1989, meeting, receipt of your written report on September 28, 1989, and our onsite review of your corrective actions and observations of plant restart, we consider the matters identified in the CAL to be closed.

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In accordance with 10 CFR 2.790 of the Commission's regulations, a copy of this letter and the enclosed inspection report will be placed in the NRC Public Document Room.

We will gladly discuss any questions you have concerning this inspection.

Sincerely,

A. Bert Davis
Regional Administrator

Enclosure: Inspection Report
No. 70-36/89003(DRSS)

cc w/enclosure:
J. A. Rode, Plant Manager,
Hematite Fuel Manufacturing
A. E. Scherer, Director,
Nuclear Licensing
C. R. Waterman, Vice President and
General Manager,
Nuclear Fuel Manufacturing
DCD/DCB (RIDS)

RIII	NMSS	RIII	RIII	RIII	NMSS	RIII
France/gd	Stuiz	Sreniawski	Mallett	Norelius	Rouse	Davis
10/18/89	via telecon. btwn. France and Stuiz. 10/19/89	10/18/89	10/18/89	10/18/89	via telecon. on 10/17/89	Paperiello 10/19/89

EXECUTIVE SUMMARY

On August 29, 1989, the NRC Region III office was notified of an apparent unplanned release of enriched uranium from the licensee's Hematite facility on August 28, 1989. In response to this notification and because the licensee at the time did not know the cause of the release and was uncertain of the quantity and chemical form of uranium released, the NRC formed an Augmented Inspection Team (AIT). The AIT was dispatched to the site to review the event, to determine the cause of the event, to evaluate the licensee's corrective actions, and to determine corrective actions needed prior to restart. The team consisted of a section chief and a project inspector from the Region III office and a health physicist from the NRC's Office of Nuclear Material Safety and Safeguards. Also, a Confirmatory Action Letter (CAL) (see Attachment F) was written to the licensee on September 1, 1989. This letter confirmed the licensee's plans to evaluate the event, and to take corrective actions and inform the NRC management of causes and corrective actions prior to restart of the plant.

The Combustion Engineering plant at Hematite receives uranium in the form of solid uranium hexafluoride and converts the vaporized uranium hexafluoride into uranium oxide in a series of fluidized bed conversion reactors (i.e., chemical, not nuclear reactor). The uranium oxide in powdered form is normally shipped to another CE facility for conversion into pellets for fuel for nuclear power reactors. On occasion, the pellets are manufactured at the Hematite plant.

On August 25, 1989, while the conversion process plant was shut down, a production supervisor discovered an air leak in a solenoid which controlled the air flow to a nitrogen valve on one of the conversion reactors. The production supervisor turned off the air to the solenoid which in turn caused the nitrogen valve to fail open. Nitrogen is used to purge the reactors when the process is shut down. He entered his actions into the foreman's log and documented the need for the repair of the valve prior to restart of the process. The following Monday morning, August 28, the new shift supervisor read the log but failed to identify the entry indicating the need to fix the solenoid valve. As a result, the plant was started up with the nitrogen admission valve open. Because of the relative pressures, nitrogen rather than steam flowed into the conversion reactor. Steam is essential to the conversion process. As a result, the conversion process did not occur as planned and uranium hexafluoride gas was released through particulate filters in the reactor. Most of the uranium hexafluoride gas reacted with moisture and hydrogen in the exhaust lines and calcium carbonate in the scrubber system and was retained in these systems, Therefore, only a small amount remained in gaseous form and was released outside the facility. According to operator logs, the process was only operated for about one hour and 55 minutes during the day shift.

Upon return to the site on August 28, and after hearing of startup difficulties, the production supervisor on the afternoon shift inquired as to whether or not the valve had been repaired. He learned it had not been and took action to get it repaired. After downtime for repairs, the conversion system was reconditioned with steam for a later start up. Operations continued in a normal mode. Early on August 29, the production superintendent requested radiation surveys of the limestone being removed from the scrubber. The readings were over a

thousand times higher than normal, which indicated that there had been an unplanned release from the reactors into the scrubbers and possibly into the environment. These high readings caused the plant manager to shut down the conversion process. The licensee performed radiological surveys and collected bioassay samples to determine if workers had received any unnecessary exposure. Preliminary surveys were also made outside of the plant within the owner controlled area. Based on stack sampling analysis, the licensee later estimated a release of 274 grams (less than 10 ounces) of uranium. Although the sampler is primarily intended to provide data to quantify the amount of flouride released, it appears to have provided a reasonable estimate of uranium released.

The AIT reviewed the licensee's handling of this event in the areas of the uranium hexafluoride conversion process, inplant radiation protection and environmental monitoring. The AIT concluded that radiation exposure to the plant workers involved in this event was well within the regulatory limits.

The team observed the licensee perform direct reading radiological surveys both onsite and at one residence offsite. These surveys showed no readings above the expected normal background levels. The AIT concluded that direct reading surveys confirmed that the licensee's estimation of 274 grams released is reasonable. Detailed analysis of environmental samples are still being conducted. Based upon calculations using conservative assumptions, the maximum theoretical whole body dose to the nearest resident would be less than one millirem, well within the EPA annual whole body dose limit of 25 millirem. For comparison purposes, background radiation in the area will give an annual whole body dose of about 200 millirem.

The licensee performed a material balance for the conversion process and accounted for all but 3.1 kilograms of uranium. This value is within the normal range of process losses (due to plateout on process component surfaces) for the total amount of material processed.

The team's evaluation of the licensee's activities before and after the event identified the following weaknesses: (1) failed equipment was not properly identified and shift changeover communication did not assure that all equipment was in proper working order prior to startup of the operation. (2) the sampling system in the stack requires improvement to assure that it can properly collect uranium in particulate form, and (3) the environmental monitoring program needs to be improved. This includes the training of additional people to conduct confirmatory surveys, and the need to enhance the offsite environmental sampling to assure prompt and accurate determination of airborne releases for all wind directions.

Subsequent to the completion of the AIT's onsite inspection, the Combustion Engineering management met with the NRC in the Region III Office on September 19, 1989, and described the lessons learned and corrective actions which were being implemented prior to plant startup. The licensee also described the lessons learned and corrective actions taken in an incident report that was submitted to the Region III office on September 28, 1989 (Attachment D). These actions resolve the concerns identified above. An onsite inspection was conducted on September 22 and 23, 1989, by a Region III project inspector. The inspection confirmed that corrective actions relative to weaknesses in the conversion process were completed.

U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 70-36/89003(DRSS)

Docket No. 70-36 License No. SNM-33

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
Nuclear Materials Safety
Section 1
Bruce S. Mallett for — Date: 10/18/89

Inspection Team Members: G. M. France, III
Region III
G. M. France, III — Date: 10/18/1989

for F. C. Sturz, NMSS
G. M. France, III — Date: 10/18/1989

Approved By: Bruce S. Mallett, Ph.D., Chief
Nuclear Materials Safety Branch
Bruce S. Mallett — Date: 10/18/89

Inspection Summary

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

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.

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. Sreniawski, 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 (UF_6) in 2½ 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 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 UF_6 is heated within a steam chamber until the vapor pressure allows the vaporized UF_6 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 UF_6 reacts with process steam to form uranyl fluoride (UO_2F_2), 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, $CaCo_3$). HF is removed by the reaction of F with Ca to form CaF_2. Excess H_2 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 cm^2. 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 UF_6 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.

4. 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 UF_6 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 UF_6 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 (UF_6 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 cm^2 (normal is 150 dpm/100 cm^2) 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 µg/liter (urine) and 0.47 µg U/g (fecal). (See Pages 34, 35, Attachment D, Incident Report) The licensee has an action level of 25 µg 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 amount 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 plume. In retrospect, this assumption proved valid. However, more samples 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 offsite 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 split with the licensee. The NRC samples have been submitted to a DOE 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 ± 7 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^{235}). 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 Plants.) 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/m^3 (or 2E-12 µCi/ml). This concentration is about 13 percent of the NRC's annual average permissible concentration for uranium (0.007 mg/m^3) 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 UF_6 at the Sequoyah Fuels Corporation Facility at Gore, Oklahoma) that an absorbed dose of 25 µg 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. External 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 anticipation 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 UF_6 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 UF_6 flow automatically if the nitrogen valve is not in the closed position. The lockout mechanism for UF_6 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 UF_6 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 valve to allow UF_6 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 management. 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 been caused by greater air flow due to the upgraded blower. On September 23, 1989, the second cylinder of UF_6 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 UF_6 and N_2 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:

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

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

$$\frac{8.4 \times 10^{-6} \text{ mCi/ml} \times 2 \times 10^{3} \text{ ml}}{2 \text{ mCi/g-U}} = 8.4 \times 10^{-3} \text{ g-U}$$

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

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

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

URANIUM ISOTOPIC RELEASE RATES

Nuclide	Percent Activity (%)	Release Rate (Bq/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

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. $$X/Q = \frac{1}{U(fs_y s_z + A/2)}$$

Equation 2. $$X/Q = \frac{1}{U(3fs_y s_z)}$$

Where

X/Q is relative concentration, in sec/m^3,

f 3.14159,

U is windspeed, 3 m/sec,

s_y is lateral plume spread, in m, as a function of atmospheric stability and distance,

s_z 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 m^2,

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 UF_6 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

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

ESTIMATED DISPERSION DURING CE HEMATITE ACCIDENT RELEASE
STABILITY CLASS B

Distance (m)	Sigma y (m)	Sigma z (m)	X/Q Equation 1 (sec/m^3)	X/Q Equation 2 (sec/m^3)
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

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^3)	X/Q Equation 2 (sec/m^3)
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

Distance (m)	Average of B and C X/Q (sec/m^3)
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

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 uranium 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.

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 breathing 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" (1.52×10^{-2} m^3/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 UF^6 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

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

Distance (m)	U-234 (uCi/ml)	U-235 (uCi/ml)	U-236 (uCi/ml)	U-238 (uCi/ml)	Total Uranium (mg/m3)
1.00E+02	1.25E-11	6.71E-13	1.34E-13	2.72E-12	7.99E-03
2.00E+02	3.57E-12	1.92E-13	3.85E-14	7.79E-13	2.29E-03
3.00E+02	1.59E-12	8.55E-14	1.71E-14	3.46E-13	1.02E-03
4.00E+02	9.10E-13	4.90E-14	9.80E-15	1.98E-13	5.84E-04
5.00E+02	5.92E-13	3.19E-14	6.37E-15	1.29E-13	3.79E-04
8.00E+02	2.27E-13	1.22E-14	2.45E-15	4.95E-14	1.46E-04
1.00E+03	1.44E-13	7.74E-15	1.55E-15	3.13E-14	9.21E-05
MPC	2.00E-11	2.00E-11	2.00E-11	3.00E-12	7.00E-03

TABLE C-2

CONCENTRATIONS FOR STABILITY CLASS C

Distance (m)	U-234 (uCi/ml)	U-235 (uCi/ml)	U-236 (uCi/ml)	U-238 (uCi/ml)	Total 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/ml)	U-235 (uCi/ml)	U-236 (uCi/ml)	U-238 (uCi/ml)	Total Uranium (mg/m3)
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
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

	RECEPTORS			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
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
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 AT RECEPTORS FOR ALL SIMULATION PERIODS

NO.	RECEPTORS X (KM)	Y (KM)	Z (M)	CONCENTRATION (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	2.24E-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
1.00E+03	5.84E-07	2.92E-08	5.96E-09	1.14E-07	7.33E-07

ATTACHMENT D

COMBUSTION ENGINEERING, INC.

HEMATITE NUCLEAR FUEL MANUFACTURING FACILITY

SPECIAL NUCLEAR MATERIAL RELEASE

INCIDENT REPORT

September, 1989

Attachment D

SEP 2 8 1989

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II. CHRONOLOGY

August 25, 1989 Friday
Midnight Shift — 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. — 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.

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 R-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 UF_6 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 UF_6 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_6 flow is restarted. Steam flow was not changed during the shutdown interval.

August 28, 1989		Monday (continued)
	14:20	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		Tuesday
	1:30	First unloading of UO_2 this week to silo, 105kg, after 6:45 hours running time.
	3:30	Second unloading of UO_2 to the silo: 100kg.
	5:30	Third unloading of UO_2 to the silo: 105kg.
	7:30	Fourth unloading of UO_2 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_6 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	NRC [redacted] 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		Wednesday
	9:30	Release confirmed to NRC Region III based on analysis.

III. PROCESS DESCRIPTION

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 $\quad UF_6(g) + 2H_2O(g) \longrightarrow UO_2F_2(s) + 4HF(g)$

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 (H_2).

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

A competing reaction can convert a portion of the UO_2 to Uranium Tetrafluoride (UF_4 or greensalt).

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

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 UF_6 to contact the hydrogen used to reduce the UO_2F_2. However, hydrogen will react with UF_6 to produce UF_4 and hydrofluoric acid

Potential Reaction $\quad UF_6(g) + H_2(g) \longrightarrow UF_4(s) + 2HF(g)$

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 $\quad 2HF(g) + CaCO_3(s) \longrightarrow CaF_2(s) + H_2O(g) + CO_2(g)$

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:

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

Equipment

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 UF_6 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.

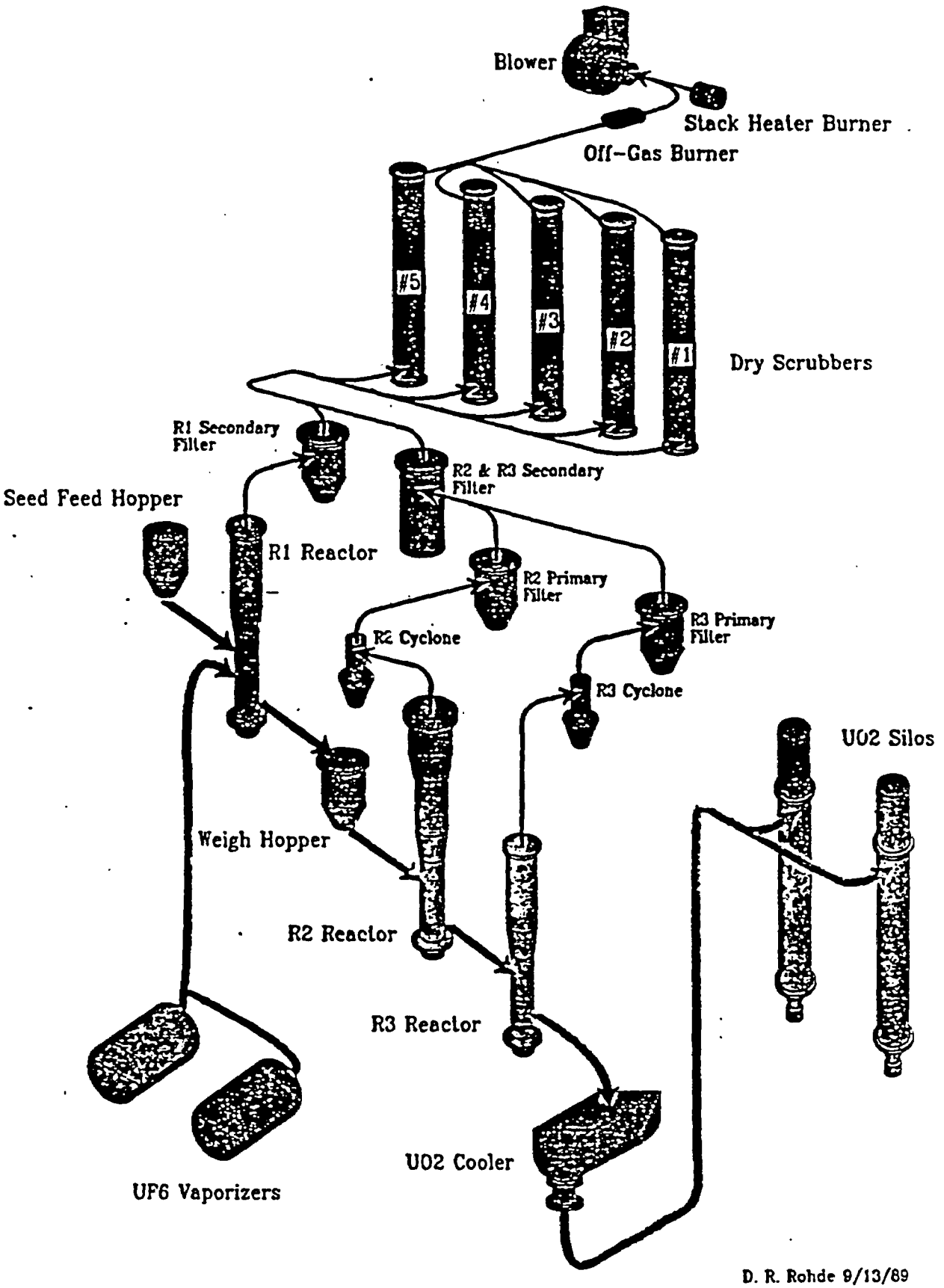

Figure 2 Hematite Oxide Conversion Process

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

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.

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 UF_6 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

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 dpm/100cm^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.

Dry scrubber #1 - loaded on midnight shift 08/28/89 - was unloaded and found to be clean, i.e. < 150 dpm/100cm^2 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.

2. 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_2F_2.

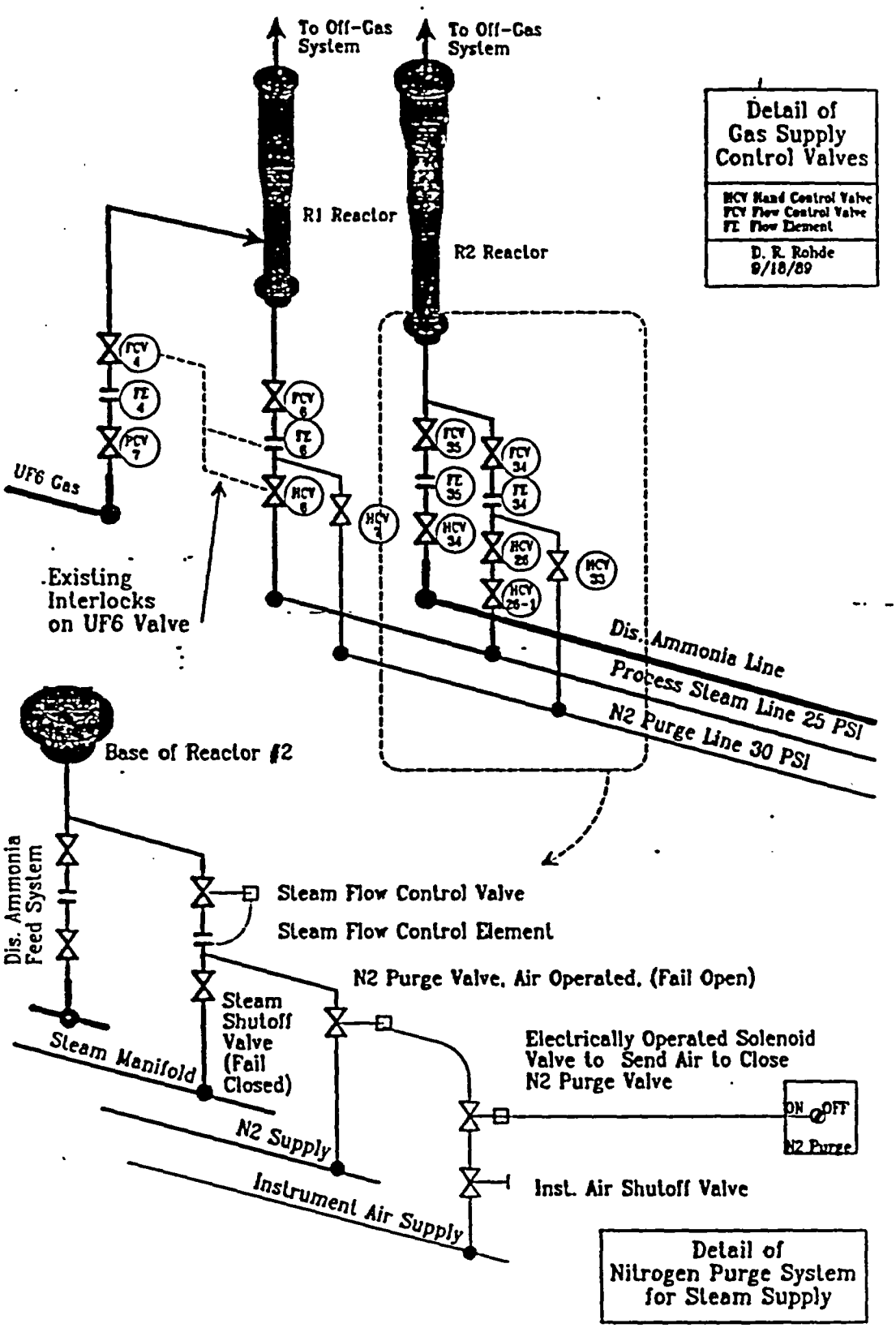

Figure 3 Conversion Reactor Gas Supply System

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 UF_6 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?

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 UF_6 to UF_4 --- 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_6. 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 UF_4 later in the process (after 20:40) when the steam feed was reinstituted.

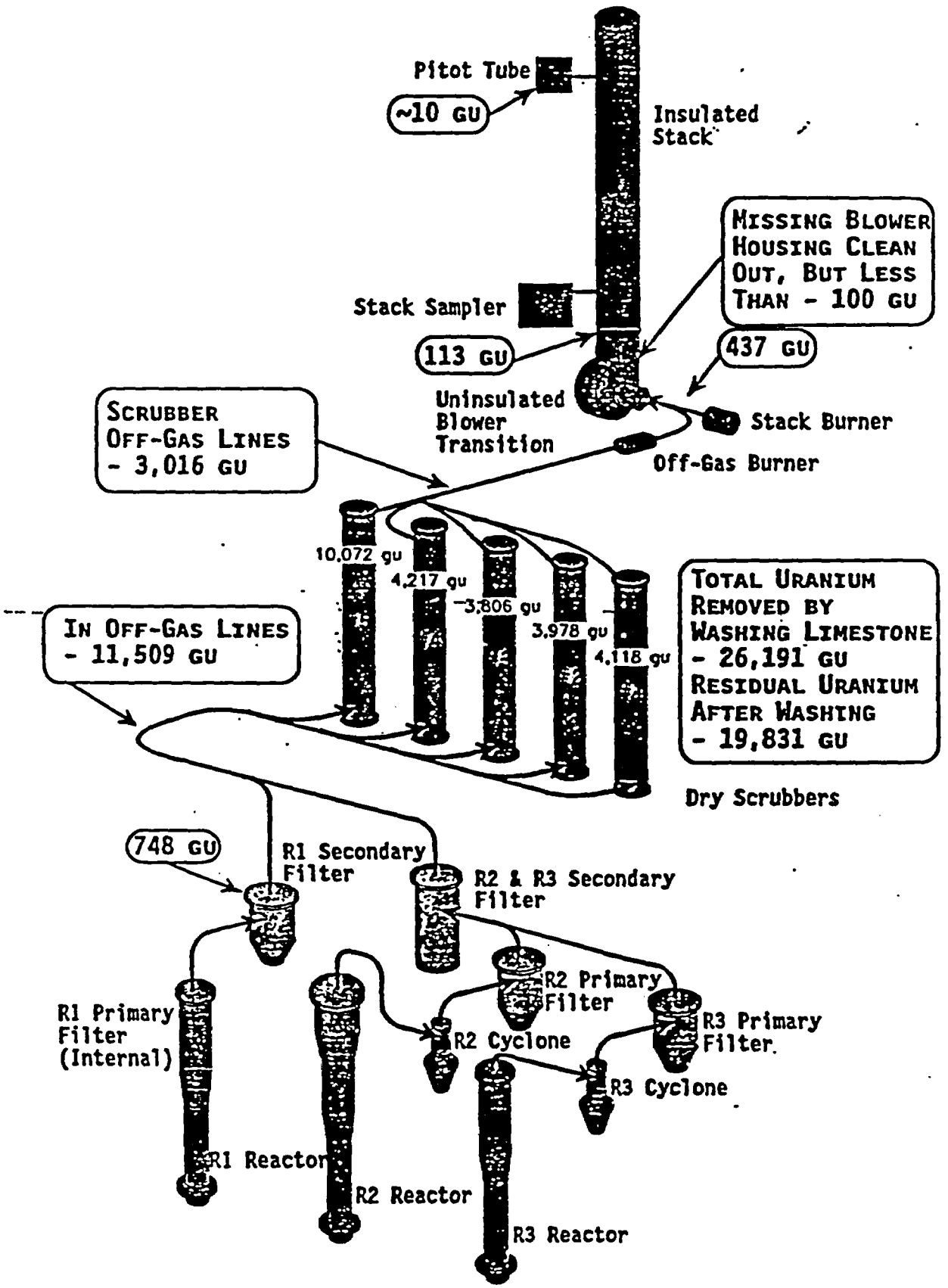

FIGURE 4. INCIDENCE OF URANIUM IN THE REACTOR OFF-GAS SYSTEM

D. R. Rohde
9/18/89

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_4.

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 UF_4 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.

V. MATERIAL BALANCE

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 UF_6 flowmeter 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.

JAR/ear/16111

MATERIAL BALANCE I

For the Critical 1:55 Minutes

Input	64.80 kgU	64.80 kgU
Output		
R-1 Secondary Filter solids	0.748	
ADU from Line Cleanout	14.001	
Cleanup Liquor Solids	0.112	
Miscellaneous Liquors	0.412	
Limestone Leach Solution	26.191	
Limestone After Leach	19.831	
Scrubber Blower Intake Solids	.325	
Scrubber Stack Cleanout	.113	
		61.733kgU
Critical Loss		3.067kgU

MATERIAL BALANCE II

For the 4.05% Campaign

Input		
UF_6	7214.885kgU	
Seed	62.141kgU	
		7,277.026kgU
Output		
Conversion System	7193.476kgU	
Offgas System	61.733	
		7,255.209kgU
Campaign Loss		21.817kgU

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MATERIAL BALANCE DATA FOR 4.05% CAMPAIGN

INPUT LOT/RESIDUE NO.	UF6 lbs	UF6 HEEL	NET UF6 KG	% U	KGS U
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-S 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	1955.545	87.80	1716.969
B-158-S	2060.630	130.025	1930.605	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

	NET WT KGS	% U	KGS U
R-3 CYCLONE FINES			
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	14.580	85.600	12.480
C/O FROM R-2 BOTTOM	4.010	85.600	3.433
R-3 BED			
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	87.703	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-S	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

MISCELANEOUS			NET WT KGS	% U	KGS U
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 K/O		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 K/O				
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 OVS (LIQUID)		19.8 GM/KG	11.900		0.236
UTILITY HOOD C/O OVS (SOLIDS)			3.490	GAMMA	0.030
EAST BANK FILTER				GAMMA	1.188
WEST BANK FILTER				GAMMA	5.284
MISCELANEOUS GAMMA COUNT		---		GAMMA	0.758
			TOTAL PRODUCT CONVERSION SYSTEM		7193.476

URANIUM RECOVERY FROM DRY SCRUBBER LIMESTONE BY ACID LEACH

DRUM NO.	SCRUBBER NO.	KG LIMESTONE	%U	KG U
7	1T	89	1.178	1.048
8	1T	99	0.766	0.758
9	1T	63	0.776	0.489
13	1B	96	0.473	0.454
14	1B	100	0.605	0.605
15	1B	105	0.728	0.764
				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	0.726	0.385
21	2B	73	1.474	1.076
				3.978
22	3T	79	0.681	0.538
23	3T	87	0.986	0.858
10	3T	96	0.552	0.530
11	3B	82	1.375	1.128
12	3B	55	1.368	0.752
				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
				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	1.881
6	5T	99	1.855	1.836
				10.072
		2491 KGS		
		5493 LBS		26.191

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

DRY SCRUBBER/OFF GAS STACK RECOVERY DATA

	NET WT KGS	% U	KGS U
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/O	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 SOLUTION	2491.000		26.191
DRY SCRUBBER LIMESTONE AFTER LEACH (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

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

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 9 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.

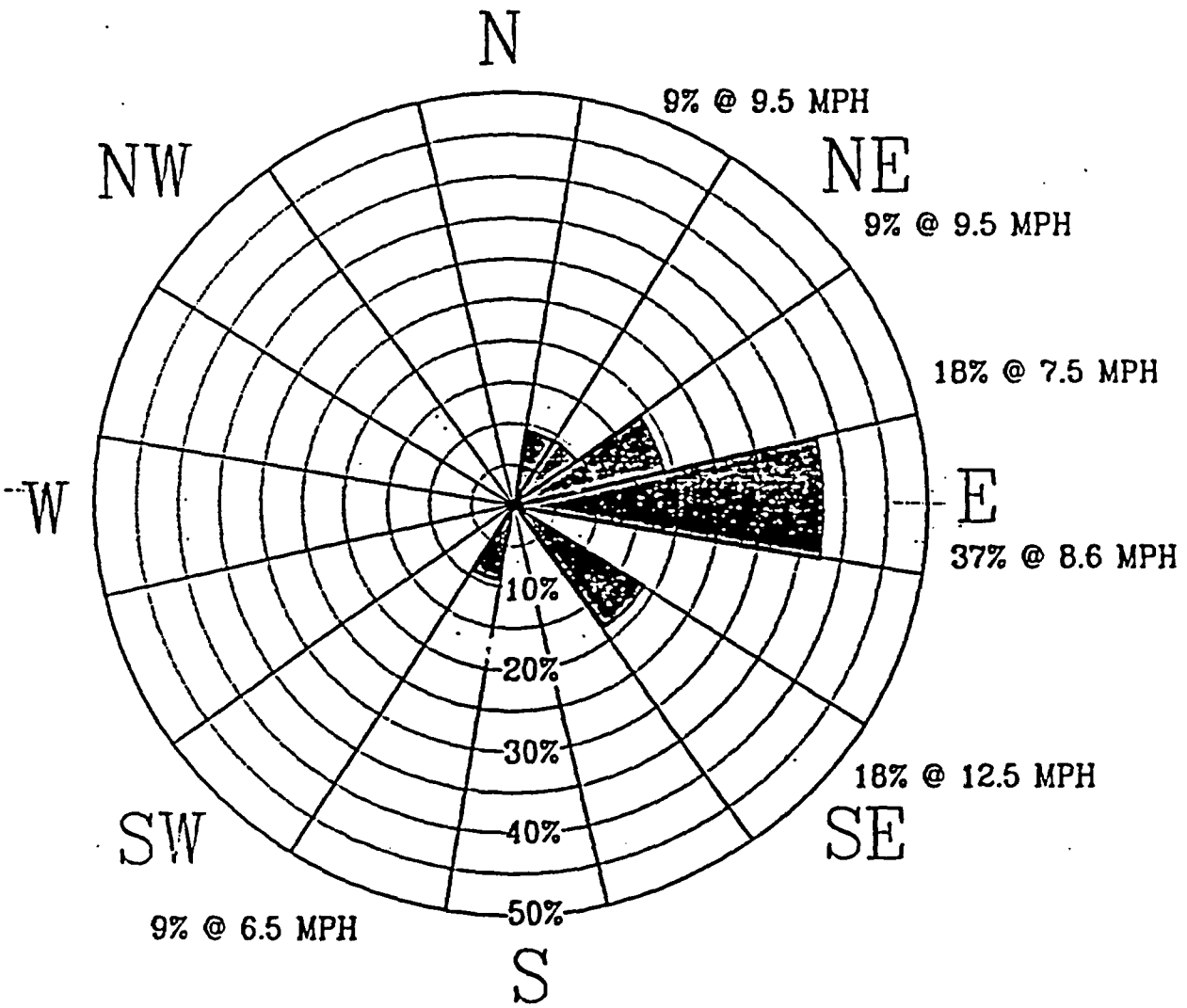


FIGURE 5 WIND DIRECTION AND VELOCITY DURING RELEASE

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

Time	MPH	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	
13:00	9.0	SE	First part of release ends, 13:05
Average	9.3		
13:10	8.0	ENE	---
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
Average	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	

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.

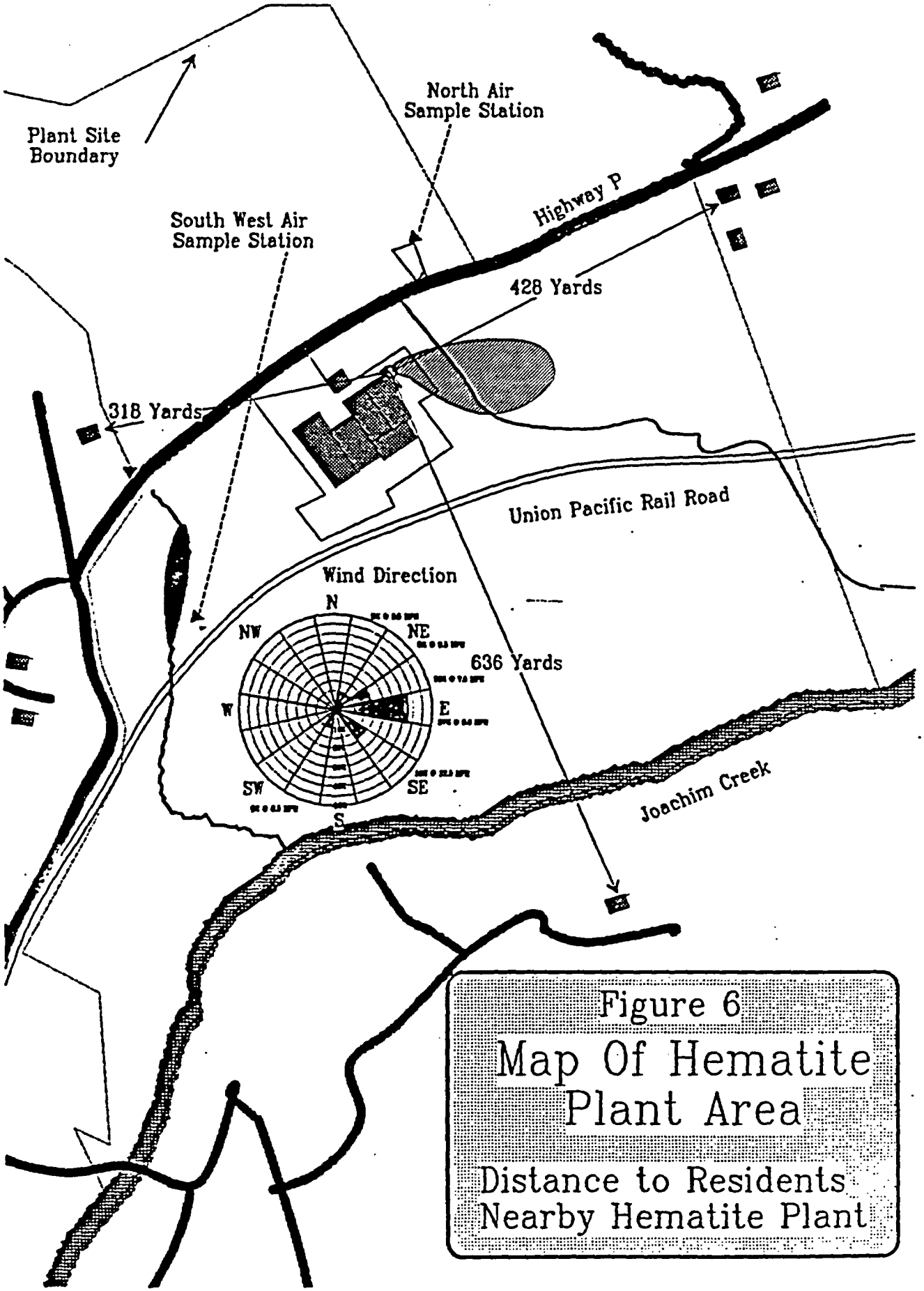


Figure 6

Map Of Hematite Plant Area

Distance to Residents Nearby Hematite Plant

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:

Distance (m)	χ/Q	Building Wake Effect	% Wind in NE Grid	Lung Dose (mR) 3kgU	Lung Dose (mR) 300gU
400	2.6E-5	1.5	0.36	0.12	0.01

REMOTE AIR SAMPLING:

	Concentration (µCi/ml)
NNE Station	1.3 E-14
SSW Station	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

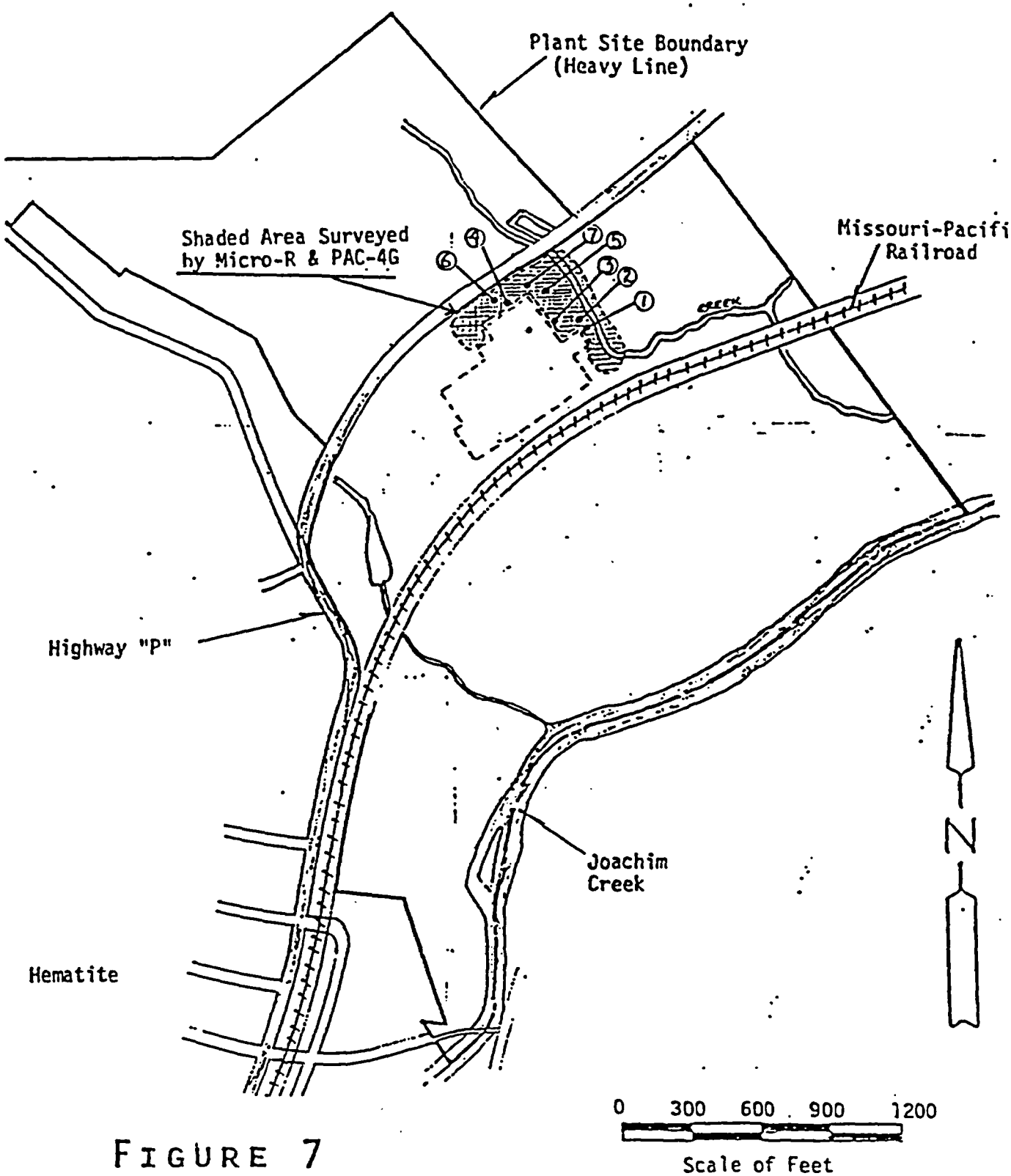


FIGURE 7

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:

Sample Number	Sample Location	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

Additional samples and surveys were taken on Friday (September 1), Saturday (September 2), Wednesday (September 6) and Thursday (September 7, 1989).

a. The samples taken on September 1 and 7, 1989, 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 area 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-4G alpha survey meter. Background for the PAC-4G meter is between 50 and 150 cpm.

TABLE A

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

VEGETATION	pCi/g WET BASIS ALPHA	BETA
SP-1	1.0 ± 0.4	9.9 ± 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 ± 1.0
-5	1.0 ± 0.3	15.0 ± 1.0
-6	1.7 ± 0.7	15.0 ± 1.0

H_2O	pCi/L ALPHA	BETA
SP-7	<4	6.4 ± 1.9
SP-8	<4	6.8 ± 2.0

JAR/ear/16115

SAMPLES TAKEN BY THE NRC AND COMBUSTION ENGINEERING

Samples 1 thru 8 taken 9-1-89
Samples 1b thru 9b taken 9-7-89
All samples taken were soil and vegetation except numbers 7 and 8 which were water and sediment.

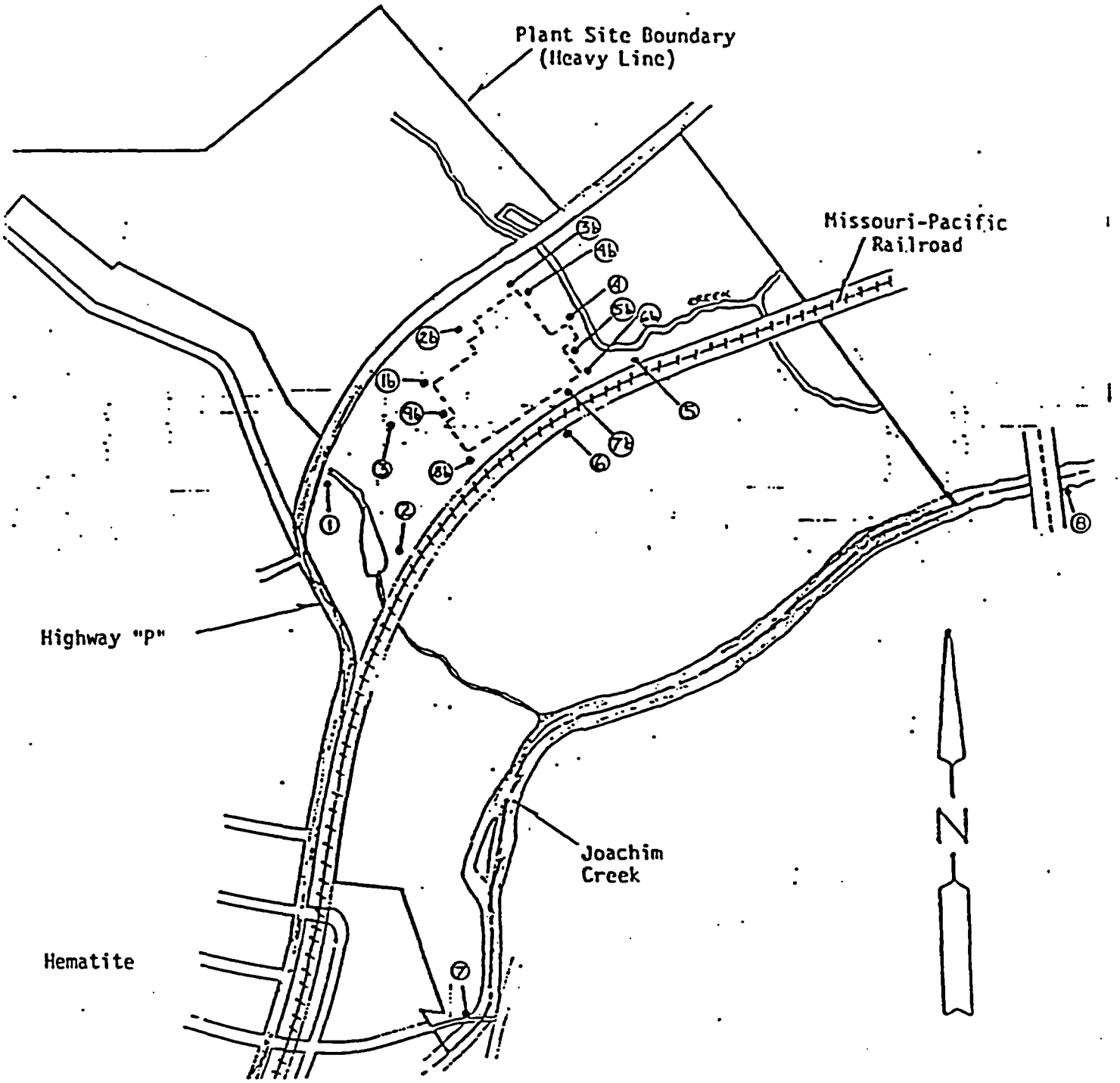


FIGURE 8

GENERAL AREA SURVEY MAP

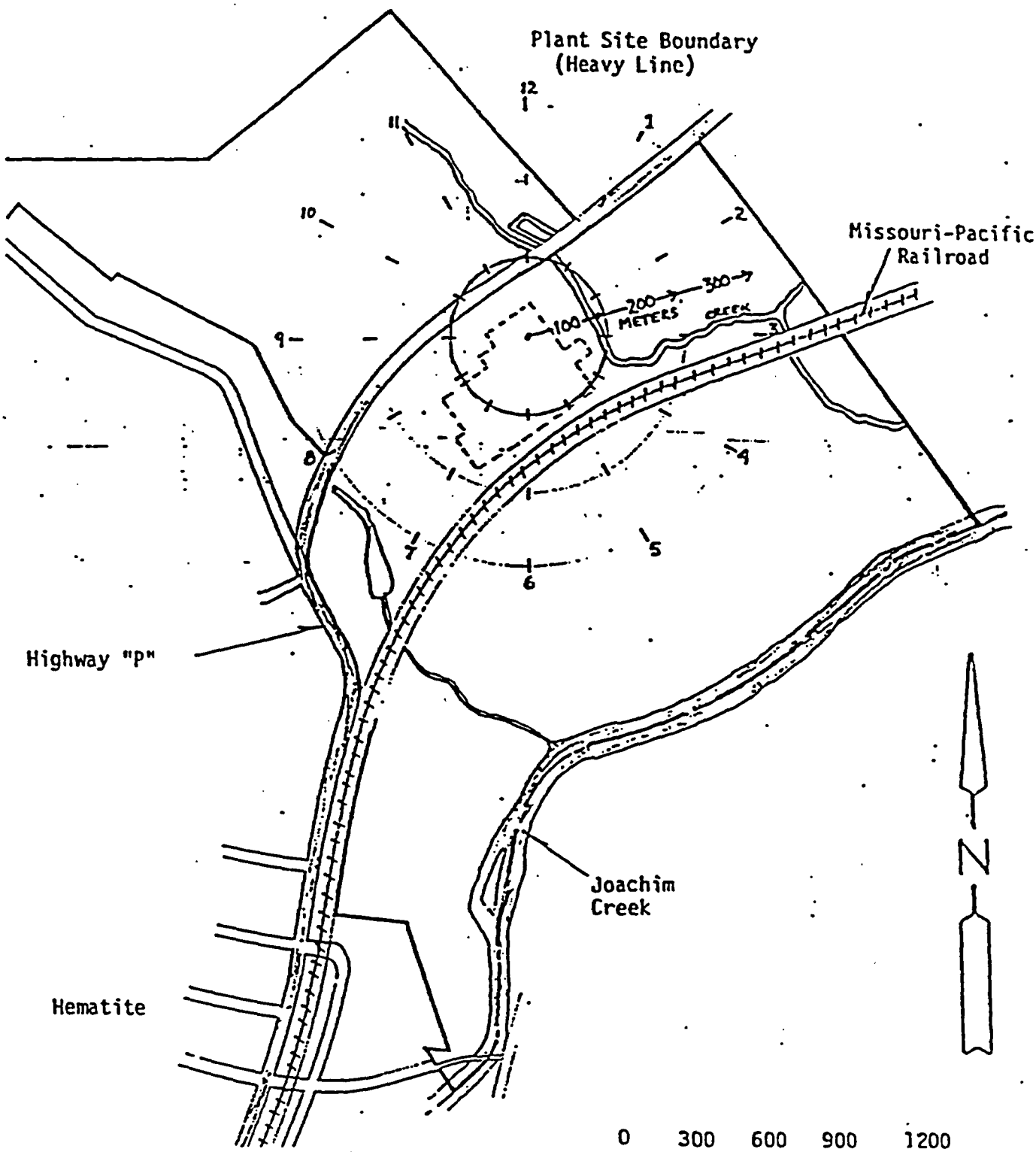


FIGURE 9

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

d. On September 6, the roadway area just inside the perimeter fence around the UF_6 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.

GENERAL AREA SURVEY

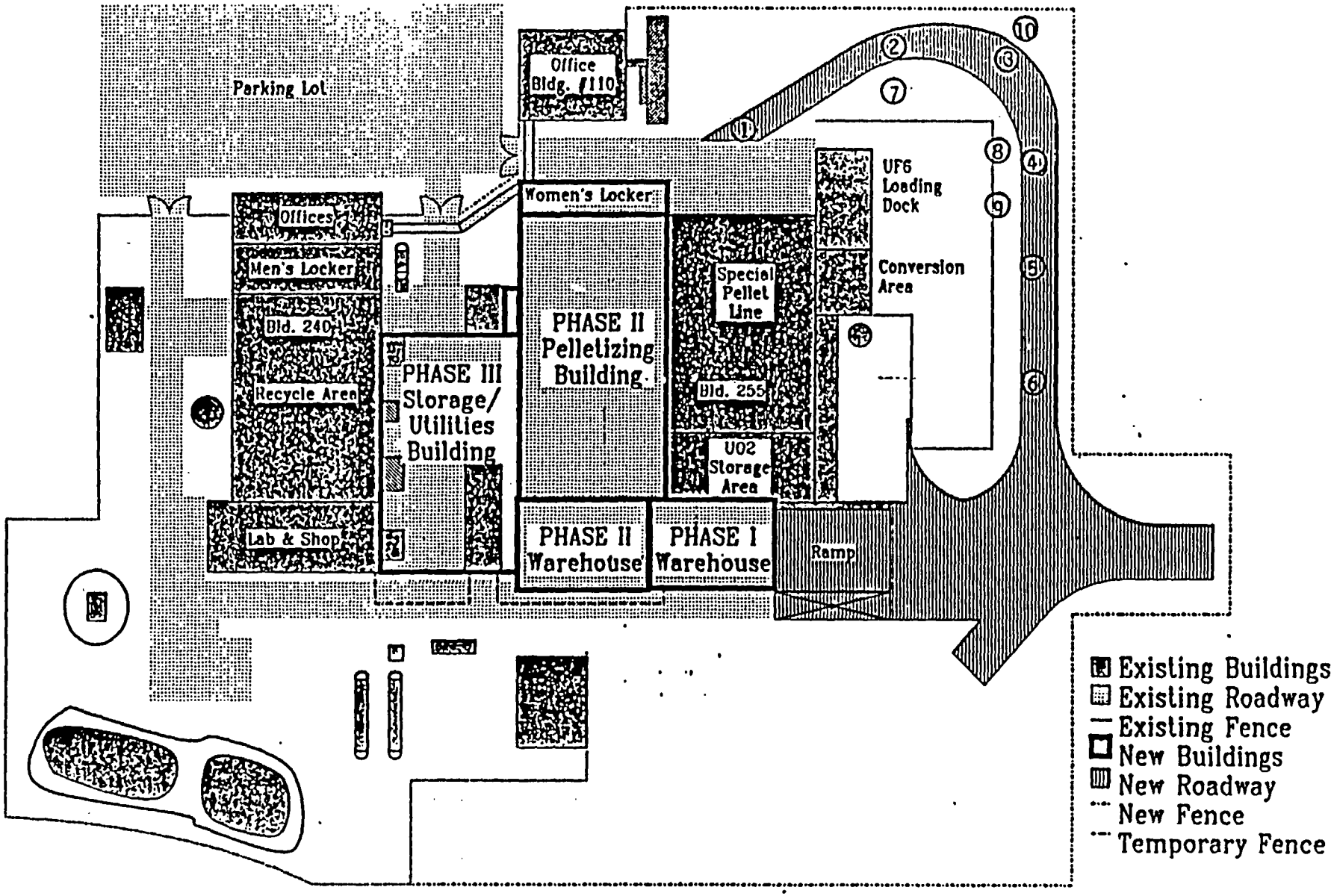
LOCATION	MICRO-R [1] READINGS	PAC-4-G [2] ALPHA READINGS	LOCATION	MICRO-R[1] READINGS	PAC-4-G [2] ALPHA READINGS	LOCATION	MICRO-R[1] READINGS	PAC-4-G [2] ALPHA READINGS
100-1	5	75	200-1	4	50	300-1	6	75
100-2	4	50	200-2	7	100	300-2	7	75
100-3	6	50	200-3	6	75	300-3	7	75
100-4	7	100	200-4	9	75	300-4	7	75
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	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

ALL METER READINGS ARE PEAK READINGS.

(1) Microroentgens per hour.

(2) Counts per minute.

TABLE B



Hematite Facility

DRR 4/24/89

SMEAR AND ALPHA READINGS LOCATIONS

FIGURE 10

CLEAR AREA ROADWAY (FENCED)
CONTAMINATION CHECK

SAMPLE NUMBER	FIXED READING CPM (NO BKGD SUBTRACTED)	SMEARS DPM
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.

TABLE C

VII. PERSONNEL EXPOSURE

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	-	<1.0
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		
08/30/89	-	<1.0
08/31/89	-	<1.0

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

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

During the Limestone Unloading

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	3.19 (1)		
08/29/89	21.89 (1)		
08/30/89	-	1.4 (2)	
08/31/89	-	<1.0	
09/01/89	-	<1.0	
09/06/89			0.47
Employee H			
08/30/89	2.91	<1.0	
08/31/89	2.35	<1.0	
09/01/89	2.25	<1.0	
09/06/89			0.10
Employee I			
08/29/89	13.09 (1)		
08/30/89	4.85	<1.0	
08/31/89	0.58	3.1 (2)	
09/01/89	1.74	<1.0	
09/07/89			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

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_6 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 not 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.

IX. CONSEQUENTIAL ITEMS

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

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 valve positions have been installed which will shut off the UF_6 flow automatically if the nitrogen valve is not in the closed position.

A maintenance 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 UF_6 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 training will begin this year and be completed by March, 1990.

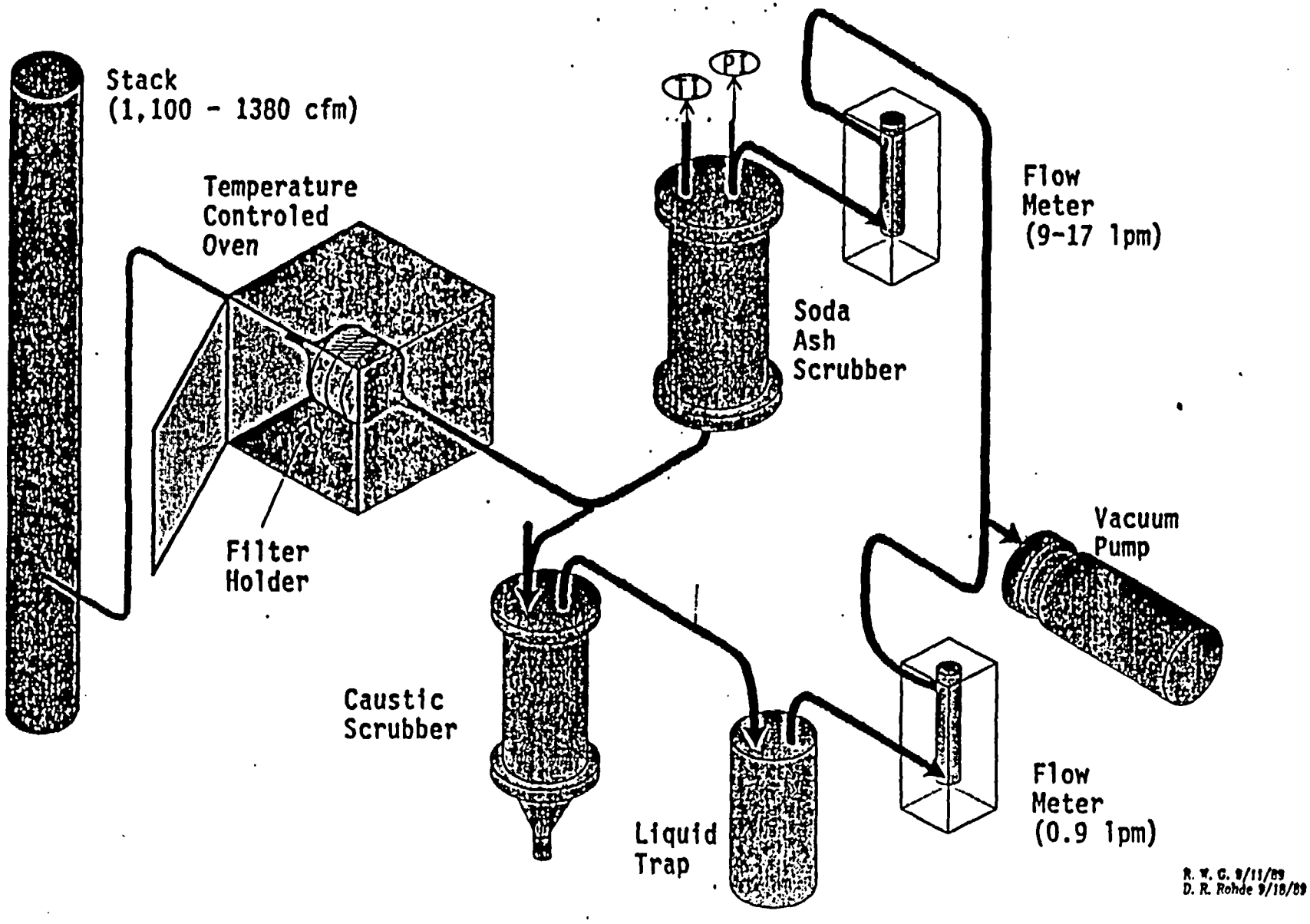
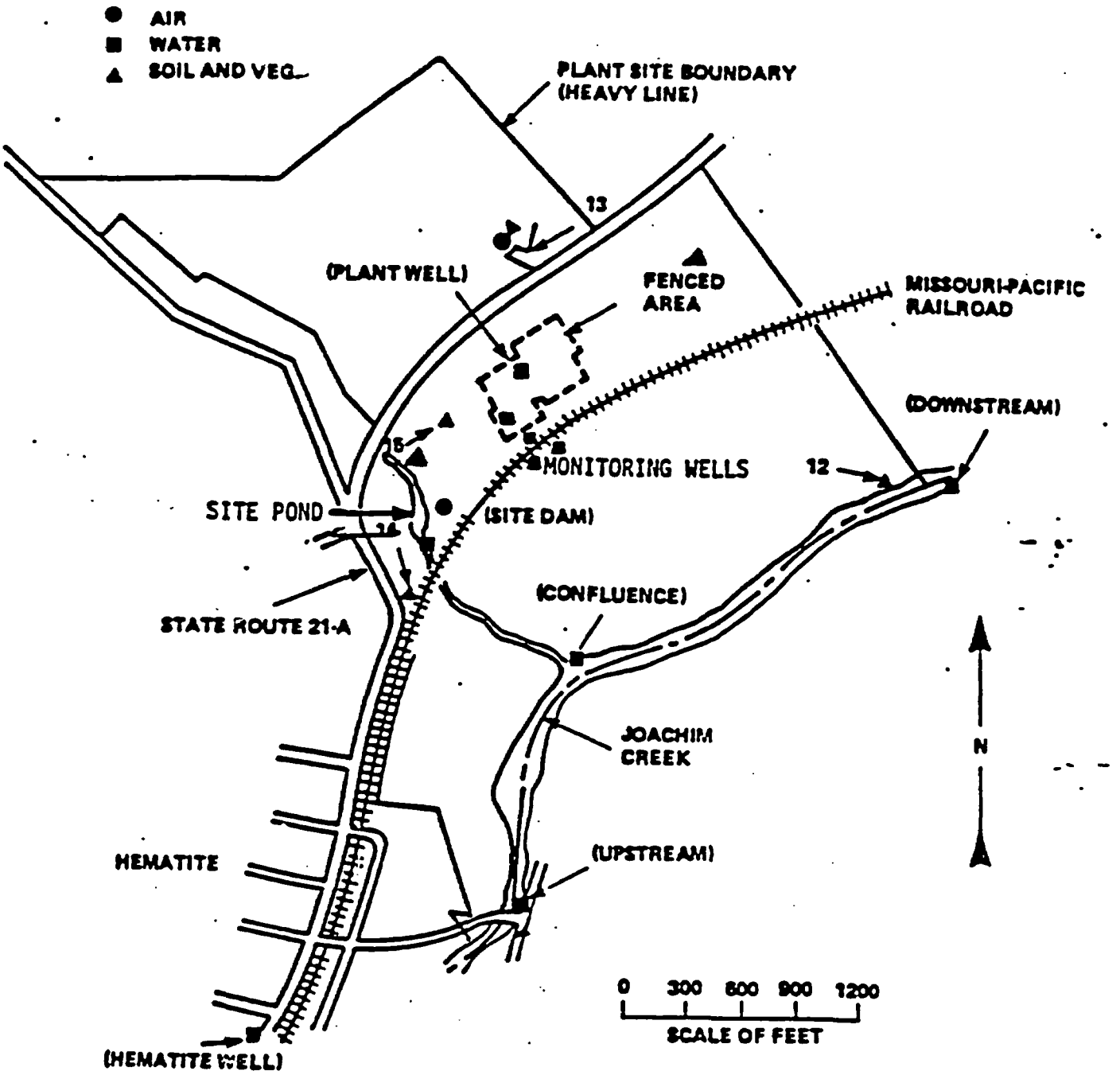


FIGURE 11 REVISED HEALTH PHYSICS STACK SAMPLER FOR OXIDE OFF-GAS



Location of Monitoring Sites Around Hematite Facility

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

SEP 01 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:

1. Prohibit restart of the portions of the UF_6 to UO_2 process line in the oxide plant that were involved with the release 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.

2. Maintain records of all activities associated with the release and followup investigation by CE for review by the NRC.

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 Davis
Regional Administrator

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