AUGMENTED INSPECTION TEAM

U.S. NUCLEAR REGULATORY COMMISSION

ABB COMBUSTION ENGINEERING - HEMATITE: CHEMICAL REACTION EVENT

AUGUST 22, 1996

INSPECTION REPORT NO. 070-00036/96003(DNMS)

U.S. NUCLEAR REGULATORY COMMISSION

REGION II

AUGMENTED INSPECTION TEAM

Docket No.:	070-00036
License No.:	SNM-33
Report No.:	070-00036/96003(DNMS)
Licensee:	ABB Combustion Engineering
Location:	3300 State Road P Hematite, MO 63047
Facility:	Hematite Nuclear Fuel Manufacturing Facility
Dates:	August 22 through August 28, 1996
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EXECUTIVE SUMMARY

On August 22, 1996, an unanticipated chemical reaction occurred in the large evaporation tank outside the licensee's maintenance and recovery building (Building 240). The reaction caused the ejection of hot materials and liquids from the tank which landed on the other tanks in the evaporation complex, the surrounding dike and asphalt, and the adjacent sides and roof of Building 240. These materials initiated a fire in the mop water boildown tank which was located next to the large evaporation tank. The reaction also caused a large column of reddish brown vapor and steam to rise from the tank approximately 15-20 feet high. A steady wind took the vapor plume over the oxide and pelletizing plant roofs and out over the restricted area fence. The plume extended in the east-northeasterly direction along the valley which extends from the plant along State Route P.

The licensee's actions during the event were appropriate and in accordance with the Emergency Plan Implementing Procedures. Decisions by the Emergency Director were conservative and interfaces with the offsite emergency responders and agencies were generally smooth. However, the AIT noted weaknesses with the licensee's sampling program for identifying potential offsite consequences during the event including: lack of procedural guidance for performing and assessing radiological and chemical sampling; inappropriate air samples; and, lack of records documenting sample locations or results.

The Augmented Inspection Team (AIT) concluded, that based on limited air sampling during the event and additional sampling after the event that there were no indications of adverse chemical or radiological consequences to plant staff, members of the public, or the environment as a result of the event. One employee strained his back while evacuating and was taken to the hospital for treatment. Results of air samples taken from the licensee's fixed environmental samplers, a lapel air sample taken during the event, and vegetation and soil samples taken after the event were all at normal background. In particular, an independent analysis conducted by the Oak Ridge Institute of Science and Engineering of soil and vegetation samples indicated that there was no uranium activity above normal background. Ammonia samples taken along the public road and nearest residence downwind were also negative.

Although the event initiator could not be definitively identified by the licensee or the AIT, it was likely due to an organic - ammonium nitrate interaction that occurred at an elevated temperature. The ammonium nitrate accumulated in the large evaporator for a period of about six weeks. During this time, an organic was likely introduced into the large evaporator, probably by way of the mop water boildown tank. Samples of residual chemical material were obtained for analysis. The results of these analysis were not available at the conclusion of the inspection.

Notwithstanding the lack of a definitive identification of the initiating reaction, the root cause of the event appeared to be a lack of management control over the process involving both design and operational control issues.

The design of the outside hold and evaporator tank system did not meet standard chemical safety practice for isolating acids and bases, and there were no positive controls over what material was placed in the system. The system was open, unmarked and unposted.

Inadequate operating procedures, out of date Process and Instrument Diagrams (P&IDs), inadequate labeling and component identification, inadequate operator training, inadequate communications and a lack of maintenance were contributing causes. In particular, the system was operated in a manner that was not consistent with the approved operating procedures. Although many of the issues identified by the AIT were known by the operating staff, the licensee operated the system without taking appropriate and timely corrective action for the problems.

The AIT concluded that the licensee had opportunities to identify the problems with the system design and control. Two precursor events occurred over the past eight years, involving unanticipated vigorous reactions in the storage and evaporation tanks. No investigation or corrective action records could be located for either event. No root causes were identified and no corrective actions were taken.

The AIT concluded that the licensee's root cause investigation for the event was thorough and identified the same basic causes and issues as the AIT. After reviewing the licensee's corrective action plan, the AIT concluded that the licensee had appropriately addressed the causes identified to preclude the recurrence of a similar event.

REPORT DETAILS

1.0 Purpose of the Augmented Team Inspection

Following initial notification and review of the August 22, 1996, event involving an unanticipated vigorous chemical reaction and release from the licensee's evaporation tank complex, the NRC formed an Augmented Inspection Team (AIT) to examine the circumstances surrounding the event. The AIT Charter (Enclosure 2) directed the team to evaluate: 1) the potential for a similar event to occur in other areas of the facility; 2) the licensee's response to the event; 3) the adequacy of the licensee's root cause analysis and proposed corrective actions; 4) the radiological and chemical consequences to plant staff and members of the public; and 5) the potential for system interactions with other facility safety systems.

2.0 System Description

The purpose of the outside hold and evaporation tank system is to reduce the volume of liquid wastes generated by the Recycle/Recovery Area processes. The three liquid waste streams processed by the outside evaporation system include the "dry side" potassium hydroxide (KOH) scrubber solution, the "wet side" filtrate (nitrate solutions), and mop water (contaminated cleaning solution). The system consists of a small evaporation tank, a large evaporation tank, a mop water boildown tank, and a hold tank located on a diked concrete pad outside of the Building 240 maintenance shop on the south side of the plant.

The dry side KOH scrubber solution is used to neutralize residual fluorides remaining after the conversion of uranium hexafluoride (UF_6) to uranium dioxide (UO_2). The uranium oxides are heated in a furnace and the offgases are "scrubbed" prior to release. As the KOH scrubber solution becomes depleted (neutralized), it is collected in a KOH hold tank. This material is basic with a pH of about 8 and contains mostly water, KOH, potassium fluoride (KF), and some suspended particulates. The concentration of uranium is generally around 0.01 to 0.1 grams of uranium per liter (gU/l). From the KOH hold tank, the spent scrubber solution is pumped to the small steam heated evaporation tank to boil off the water. The dried residual material is removed from the tank and is packaged for disposal.

The wet side filtrate is generated from the contaminated (chemical) uranium purification process. In this process, uranium compounds are dissolved in nitric acid, and precipitated in the form of UO_4. The remaining liquids (filtrate) are acidic with a pH of about 1.5 and contain water, nitric acid, ammonia, ammonium nitrate, trace hydrogen peroxide, and metals (iron, nickel, copper). The concentration of uranium can vary, but is generally less than 1 gU/l. This waste stream is collected in two filtrate tanks. From these filtrate tanks, inside

the building, the solution is pumped to the large evaporation tank for concentration and disposal or further reprocessing, depending on the uranium concentration.

The mop water boildown system collects contaminated cleaning fluids for similar concentration. However, this tank may contain dirty floor mop water, organic material and metals.

Both the filtrate and inside KOH hold tanks are interconnected by a common 1.5-inch diameter header that travels about 100 feet through Building 240 to the outside tank pad. The header is used to feed the outside hold tank and both evaporation tanks. Each tank has a single manual isolation valve. Due to the interconnection and common header, strong acids and bases are mixed within the line as there is no way to flush or completely blow down the piping after a liquid transfer. Additionally, the large and small evaporation tanks and mop water boildown tank are open vessels with no covers. Each is steam heated and can boil over and/or be overfilled. Tank overflow and any rain water is collected in a common sump and pumped back to the large evaporation tank. Therefore, the contents of the three tanks can be directly intermixed as a result of tank overflows, residual liquid in the 100-foot run of pipe, or a single leaking or mispositioned valve.

3.0 Event Summary and Sequence of Events

(Charter Item No. 1)

A detailed chronology of the events prior to, during, and following the reaction is presented in Enclosure 3.

On August 21, 1996, at 1:30 p.m., an operator made a transfer of approximately 1100-1200 liters (l) of filtrates from one of the filtrate storage tanks to the large evaporation tank at the back (south side) of Building 240. At 8:30 p.m. that night, a second operator blew out the header using plant air and then established the valve line-up for a transfer of potassium hydroxide solution to the small evaporation tank. At 8:45 p.m., the operator transferred the KOH solution to the small evaporation tank. At 11:00 p.m., a third operator entering the area noted more vapor than usual extending from the evaporation tank complex. Similar observations were made by other plant employees as they arrived for the day shift on August 22, 1996.

At 7:00 a.m. on August 22, the large evaporation tank began foaming visibly, and subsequently foamed over the sides about 15 minutes later. At 7:25 a.m., the licensee terminated steam flow to the tanks. At this point, a small reddish brown glow was observed near the top of the tank. At 7:30 a.m., solution overflowed the containment dike and began flowing onto the surrounding asphalt. At 7:35 a.m., a vigorous boil-over of the tank was observed followed by a reduction in the reaction. At this point, the licensee placed an absorbent boom around the material which had spilled out of the tank pad to prevent it from migrating off the asphalt.

At 7:50 a.m., the reaction accelerated rapidly. Workers in the area were directed into the building complex. The health physicist and facility manager observed a large reddish brown column of vapor inside the white steam vapor rising from the large evaporation tank to a height of approximately 20 feet. A steady wind of up to 5 miles per hour carried the vapors in the easterly direction into the valley extending along Route P on which the plant is located.

4.0 Licensee Response to the Event

(Charter Item Nos. 3 and 5)

The inspectors assessed the licensee's actions during and following the event, including their immediate response to the event, implementation of their emergency plan and implementing procedures, event notifications and reporting, interactions with offsite emergency responders, and subsequent management response and followup actions. The assessment was based on the following:

- Interviews with staff and management directly involved with the event and the local fire department.
- Observations by onsite NRC inspectors during the recovery from the event.
- A review of the licensee's emergency plan; implementing procedures for fire and explosion, notifications, recovery, and decontamination; and, licensee records of actions taken and communications made with local, state, and federal agencies, and immediate site neighbors.

The AIT concluded that overall, licensee response to and recovery from the event was adequate. Specifically:

- The licensee made a conservative judgment of the potential consequences of the rapid reaction which occurred in the large evaporation tank, evacuated the plant process buildings, and declared an Alert. Licensee personnel evacuated to the emergency operations center (EOC) and accountability of persons onsite was completed in a timely manner.
- Emergency Plan Implementing Procedures (EPIPs) were implemented in a timely manner. Two emergency response teams, wearing appropriate chemical suits and supplied compressed-air breathing apparatuses (SCBAs), quickly reentered the plant complex to terminate the UF_6 supply and determine the status of the evaporation tank complex. They noted that the column of vapor rising from the large evaporation tank had ceased and a small fire in the mop water evaporation tank was underway.

The licensee's emergency director (ED) made a conservative decision to wait for the fire department before entering the affected area to extinguish the fire because there were no personnel unaccounted for. The ED presented a timely briefing to the fire department's incident commander based on the approved pre-fire plan. After careful consideration of potential consequences, fire fighters accompanied by a licensee emergency response team entered the affected area and quickly extinguished the fire.

- Road blocks were established by the local sheriff and fire department in appropriate locations. In addition, several ambulances and fire trucks were staged to enter the plant if needed as specified in the licensee's pre-fire plan. One employee who had strained his back while evacuating was successfully transported to the hospital after the licensee communicated his condition.

- The licensee made timely notifications of the classification and status of the event to the following agencies:

  - Jefferson County Emergency Management (911)
  - NRC Operations Center
  - Missouri State Emergency Management Agency
  - Missouri Department of Natural Resources
  - Missouri Department of Health

  The licensee established and maintained continuous communications with Jefferson County Emergency Management and the NRC until the event was terminated. In addition, the licensee made numerous phone calls to many of the site's immediate neighbors.

- Licensee management acted quickly at the conclusion of the event to de-energize, lock, and tag the pumps associated with transferring liquids to the evaporation tanks. In addition, all associated valves were tagged out to ensure that the valve line-up for the last transfer to the tank complex would not be changed before the licensee or NRC inspectors began their investigation.

- The licensee expedited a clean-up of the spill which resulted from the boil-over of the tank. The liquid was initially contained on the surrounding asphalt by placing an absorbent boom around the spill. The residue from the spill hardened quickly and thus prevented the spread of contaminated materials off the asphalt. Cleanup of the area was complete before a heavy rain occurred on August 23, 1996, the day after the event.

- The licensee conducted an initial critique of its event response with the offsite responders during the afternoon of August 22. A more detailed critique was held and observed by an NRC inspector

that evening. In particular, the licensee identified radios, ambulance response time, and sounding the evacuation alarm when the liquid spilled over onto the ground, as areas for improvement.

4.1 Weaknesses Identified During Licensee Response to the Event

The AIT identified the following weaknesses in the licensee's response to the event:

4.1.1 Inadequate Procedural Guidance for Sampling

The licensee performed limited sampling during and after the event for potential chemical and radiological consequences offsite. The EPIPs provided no guidance to the safety sector commander or his designees on the number, type, or location of field samples. For example, the licensee took three samples using ammonia tubes (at the nearest downwind residence and further down the public road), but did not have tubes available to sample for nitric acid or nitrous oxide concentrations, chemical species which could have been released from the reaction. In addition, the inspectors noted that a complete supply of the various types of tubes possessed by the licensee was not available in the EOC (carbon monoxide, hydrogen, etc.). Some were available only in the health physics office. In the event that the HP office was not available during an event, certain types of tubes would not be available for sampling.

There was no guidance for performing air sampling or for determining whether the results were acceptable. One complicating factor in quickly analyzing air samples for uranium is that radon is collected during the sampling and the analyst must wait for it to decay (usually at least 72 hours) before an accurate count of the uranium can be made. Nevertheless, some guidance on acceptable results appears necessary in order for the ED to make an informed decision about the likelihood and severity of offsite consequences from an event.

4.1.2 Inappropriate Air Sampler

The licensee used a lapel sampler to measure the concentration of airborne uranium at the nearest downwind residence because it did not possess a readily mobile air sampler. Lapel samplers run at a low volumetric rate (approximately 2 liters per minute), thus collecting a sample for 20 minutes results in a small volume of air collected (approximately 40 liters). Such a small volume may not be representative of actual air concentrations, and significant uncertainties in the calculated concentrations are likely.

4.1.3 Inadequate Record-Keeping

Records of offsite and/or downwind sampling locations and results of the ammonia samples were not available. The licensee had to reconstruct the sampling events for the inspectors during interviews after the event. The individual who performed the sampling stated that the ammonia tubes

indicated no ammonia at the three sampling locations. Although the licensee had maps on clip boards available for personnel performing offsite surveys, they were not used.

4.2 Conclusions

The licensee implemented the EPIPs in a timely and efficient manner. Decisions by the ED were conservative and interfaces with the offsite emergency responders and agencies were generally smooth. However, the NRC concluded that the licensee's sampling program for identifying potential offsite consequences during the event was inadequate.

5.0 Precursor Events and Potential for Similar Event

(Charter Item No. 2)

5.1 Precursor Events

Discussions with the operations staff indicated that the facility experienced a vigorous chemical reaction in one of the outside evaporation tanks about 8 years ago. However, that event was apparently not as severe as the recent one and it did not involve an orange-brown colored gas. In addition, about 3 to 4 years ago, there appeared to have been an event whereby KOH was inadvertently pumped back into one of the filtrate tanks, causing a rumbling sound to be heard coming from the tank. No investigation or corrective action records could be found for either event.

5.2 Potential for Similar Event in Other Areas of the Plant

The inspectors assessed the potential for a similar event to occur in other areas of the facility by interviews with engineers and operators, a selected review of procedures, and tours of the plant.

The inspectors did not identify any other areas of the plant in which strong acids and bases were transferred through a common header or were stored in close proximity. The licensee did have a commercially procured water de-ionization system which utilizes muriatic acid and caustic soda to adjust the pH of the system. The acid and base were fed into the make-up tanks via two separate lines connected to the two 35-gallon drums.

Condensed filtrate sludge containing the residues from the large evaporation tank, including ammonium nitrate, was stored in double-walled barrels in the south yard. The chance for a similar event to occur for the materials stored in these barrels was considered negligible since there was no credible heat source.

5.3 Conclusion

The AIT concluded that the licensee had opportunities to identify the problems with the system design and control. Two precursor events involving unanticipated vigorous reactions in the tank complex were not investigated. No root causes were identified and no appropriate corrective actions were taken. The AIT also determined that other conditions did not appear to exist at the facility which could cause a similar event.

6.0 Root Cause Investigation

(Charter Item No. 4)

The inspectors assessed the licensee's root cause investigation for the event and evaluated the licensee's initial corrective actions. These evaluations were based on the following:

- Independent NRC review of the circumstances surrounding the event through interviews with licensee staff; review of records, drawings, and procedures; and, walk-downs of the wet and dry recovery processes and evaporation tank complex.

- Independent sampling of the liquids in the KOH and filtrates hold tanks and the residues from the evaporation tanks.

- Interviews with the team of engineers and managers assembled by the licensee to investigate the event.

- Review of the report of the licensee's investigation and the letter to the NRC dated August 29, 1996, detailing the licensee's recovery plan.

6.1 Results of NRC Investigation

6.1.1 As-Found Conditions

(Charter Item No. 8)

The inspectors arrived onsite at about 4:00 p.m., on August 22, 1996. Initial and subsequent system walkdowns indicated that a vigorous exothermic chemical reaction had taken place in the large evaporation tank. Most of the material in the large evaporation tank had chemically reacted and a water soluble residue, which hardened upon cooling, had been ejected out of the tank. Some of the material had splattered on the Building 240 wall and sections of the tar-covered roof. The inspectors noted that the portions of the tar roof where the expelled material had been deposited appeared to have melted and re-solidified. In addition, pipe lines containing anhydrous ammonia, natural gas and

hydrogen were located about eight to twelve feet from the tank where the reaction took place. The as found valve line up for the system supported the transfer of KOH to the small evaporation tank.

The material in the mop water boildown tank, including the internal plastic liner, had been ignited by the hot debris emitted from the large evaporation tank. However, no other equipment or safety systems outside of the evaporation tank pad were affected by the event.

The inspectors were informed by operations personnel of a change in system operating practices within approximately the last year. Previously, the licensee would remove the evaporation tank residue after each wet side batch run (typically 7-10 days). However, within the past year or so, the licensee changed the cleanout frequency to about once every 3 to 4 batch runs. No safety analysis was performed for this change. As a consequence, the large evaporation tank accumulated a greater amount of residue from the wet side, including ammonium nitrate and metals. The large evaporation tank had last been cleaned out about 6 weeks prior to the event.

6.1.2 Possible KOH Addition to Large Evaporation Tank

The inspectors considered the possibility that the reaction was caused by the inadvertent addition of KOH to the large evaporation tank which contained a nitric acid solution. However, this possibility was not considered credible for the following reasons:

- The only flow path by which a large amount of KOH could be added to the large evaporation tank was through the tank's inlet manual isolation valve. (Small amounts of KOH could be added to the tank through the evaporation complex pad sump.) Had the isolation valve been left open during the previous KOH transfer, the chemical reaction would have taken place at the time of the transfer, about 10 hours prior to the event.

- Had a subsequent addition to the large evaporation tank been made just before the 7:00 a.m., shift turnover, the isolation valve would likely have been found open instead of closed, because the valve is located directly above the open tank where the reaction occurred. Under this circumstance, the valve would be inaccessible to an operator not in a chemical suit, which was not immediately available in the area.

- KOH was not inadvertently added to the large evaporation tank through a leaking isolation valve. The inspectors observed leak tests performed by the licensee on all of the valves on the outside pad header. The large evaporation tank isolation valve did not leak.

- The inspectors also noted that the as-found chemical conditions did not appear to support a strong acid-base reaction. The pH of the filtrate tank was 1.5 and the KOH tank was about 8. However, the pH of the residue was about 2.5, still strongly acidic.

  The team concluded that there was no indication that the reaction resulted from a valve misalignment or mechanical failure.

6.1.3 <u>Other Potential Chemical Reactions</u>

Based on observations, it appeared that the tank incident was driven by a strong exothermic chemical reaction. It is very likely that the reaction(s) that occurred during the chemical reaction incident involved the thermal decomposition of nitric acid, ammonium nitrate, potassium nitrate and possible nitrite compounds. The presence of unknown materials such as hydrogen peroxide, organic materials, metal nitrates or incompletely oxidized metal in the large evaporation tank could have initiated the reaction(s). The exact cause of the reaction initiation could not be determined due, in part, to the lack of control over what could enter the large evaporation tank, the lack of chemical analyses of the process streams, and the lack of documentation of the process streams that went into the large evaporation tank.

Prior to the incident, there was a large quantity of solid material in the tank. Based on the composition of the main process stream (wet side), this solid material was probably comprised of various nitrate salts along with traces of nitric acid.

As the reaction occurred, the boiling rate increased and the tank boiled over. The temperature of the boiling liquid could not be determined. However, based on a steam jacket temperature of 250-300 degrees fahrenheit and the fact that the solution was probably saturated with salts, the temperature was certainly above that required for boiling of pure water (212 degrees fahrenheit). The tank began ejecting chunks of material that appeared soft and paste-like but which hardened into a rock-like consistency upon cooling. This material was a light green-to-yellowish color and was probably composed of various nitrate salts. Licensee personnel dissolved a piece of this material in water. The pH of the resulting solution was 2.5 indicating the presence of an acid.

The evolution of reddish-brown fumes from the large evaporation tank was indicative of nitrogen oxides (gas) which would be consistent with nitric acid decomposition.

The fire in the mop water boildown tank may have originated when a piece of the material ejected from the large evaporation tank landed in the mop water boildown tank. The contents of this tank had been boiled down and the composition of the mixture was unknown. It was suspected that the contents were organic materials with high boiling points plus unknown salts. The temperature of the contents of the mop water boildown tank would have been over 212 degrees fahrenheit and the

temperature of the material from the large evaporation tank would have been close to the temperature of the boiling solution in the tank. As this material was probably composed of nitrate salts and nitric acid (oxidizing agents), it reacted with the organics resulting in the fire. Licensee personnel sampled the mop water boildown tank after the incident. The material was placed in a beaker with nitric acid and boiled down until part of the bottom of the beaker was dry. At this point the material flashed indicating that nitric acid and heat would ignite the material from the mop water tank.

6.1.4 System Design Deficiencies

The inspectors identified several apparent design deficiencies that either may have contributed to the event or could increase the possibility of a future unplanned chemical reaction in the evaporation pad area. Those design deficiencies included:

- The filtrate and inside KOH hold tanks were cross-connected to each other through a common discharge header. The interconnection of tanks containing acids and bases does not meet standard chemical safety practices.
- The simple discharge line to the outside pad transferred both acids and bases to separate tanks. However, the pipe run is configured such that the line cannot be completely flushed out prior to changeover of the liquid source. Consequently, a significant amount of liquid from the previous transfer operation would remain in the pipe and was often pumped into a tank other than the one intended.
- The outside hold and evaporation tanks were connected by a common header. Each tank was isolated from that header by a single isolation valve. This configuration rendered the system vulnerable to single failures such as a mispositioned or leaking valve which could result in an unplanned chemical reaction.
- Any overflow or boilover from the outside hold and evaporation tanks and the mop water boildown tank collected in a common sump. All liquid collected in the sump, including rain water, was pumped into the large evaporation tank. This design feature could result in the addition of alkaline and organic liquids to the large evaporation tank containing nitric acid and ammonium compounds.

6.1.5 Management Controls

The team identified deficiencies with the implementation of management controls for the process, as discussed below:

- System drawings and P&IDs did not reflect the current "as-built" configuration of the Outside Hold and Evaporator Tank system. Specifically, drawing C-5009-1022 (September 1991) and the figure in OS 853 (Revision 1) did not reflect the actual system piping configuration.

- Most of the system components (valves and pipe lines) were not labeled or otherwise positively identified.

- Operating procedures were unclear and contained a number of deficiencies or inaccuracies as described below:

    1) OS 806, Recycle/Recovery Area Wet Scrubber, dated November 6, 1995, was not clear in that Section 2.0, Nuclear Safety, required that the uranium content of the scrubber solution be measured once per week and the solution drained if greater than 1 gU/liter. However, the next step stated that based on historical data, the scrubber solution may be transferred without analysis. Actual plant practice for sampling the scrubber was not consistent between the operating shifts, and it was not clear whether the sampling frequency was being met. Management's expectations were not clearly disseminated to the operators.

       Step 5.1.7, which described how the scrubber solution level is maintained, referred the operator to Steps C, D and E for further instructions. However, there were no such steps in this procedure.

       Operational instructions were written for ammonia addition to scrubber No. 1 only. The current plant practice was to add ammonia to all scrubbers. Additionally, the disposition of the No. 1 scrubber solution to the utility room hold tank or cylinder wash precipitation tank, as described in Step 5.9.1, was not in accordance with current plant practices. Spent scrubber solution (with ammonia) was sent to the inside KOH hold tank for subsequent transfer to the small evaporation tank.

       Operational instructions for disposition of KOH solution, as described in Step 5.9.2, did not appear to be consistent with current plant practices. After mixing and sampling the solution, instead of completing a tank transfer, additional KOH solution was added to refill the tank without further sampling.

    2) OS 853, Outside Hold and Evaporator Tanks, dated September 6, 1995, was not clear in that Section 1, Nuclear Safety, required that the supervisor approve transfer of any solution upon completion of Steps B and C. The procedure contained no steps labeled B and C.

The procedure was originally written to calculate the amount of uranium to be added to the Continuous Inventory Log by first pumping the filtrate to the outside hold tank to measure the volume, and then transferring it to an evaporator. However, the current plant practice was to pump the filtrate (or KOH tank) directly to a designated evaporation tank. Liquid inventory appeared to be roughly estimated rather than calculated.

The process diagram attached as Figure 1 did not reflect the current system configuration. Tank drainage lines and inlet configurations had been changed since the figure was released.

The instructions in Step 5.0, Concentration Check, were no longer applicable to the way the system is being operated. Material was not recycled back into the system. Final disposition of the sludge remaining in the tank was not specified in a standard operating procedure.

3) OS 808.2, Boildown of Liquid Waste, dated September 21, 1995, did not completely reflect how the system was being operated. Section 2.0, Nuclear Safety Requirements, limited the mop water boildown tank to 1 kg of uranium. However, discussions with the operators indicated that no positive controls had been developed to assure that the mass limit was not exceeded. The system was open, unmarked and unposted. The operators indicated that there may have been past instances of material being added to the mop water boildown tank without the appropriate log entries being made.

The procedure did not specify a limit on the concentration of uranium-contaminated liquid allowed to be processed. The procedure was used as guidance for liquids with less than 1 gU/liter; a separate traveler (a temporary procedure) was used for processing liquids with greater than 1 gU/l. Plant policy was that travelers were to be used for one time operations not covered by an approved operating procedure. However, due to operational problems with the waste water centrifuge, liquids with greater than 1 gU/liter were being processed in the mop water boildown tank as a routine practice under a traveler. The operating procedure had not been revised.

4) OS 850, UO_4 Filtration, dated July 22, 1996, did not accurately reflect how the system was operated in that Section 1.0, Process Description, stated that the filtrate is dispositioned to the outside hold tank, which had not been used for a significant period of time.

Section 7.0, Filtrate Hold Tanks, described vessel level control through the use of two level alarms for each tank. However, the inspectors noted during tours of the filtrate tank area that the alarms were inoperable. The alarms had been inoperable for about one year.

The inspectors also identified several potential weaknesses with the means of implementing the double contingency principal. Although two independent samples were taken to determine the concentration of uranium in the filtrate, the actual calculation was not double-checked for arithmetic errors. Also, there was no double check that the sampled tank was the tank aligned for transfer to the outside evaporator tank. This methodology left the process vulnerable to a single failure.

- Operator training consisted of about 1.5 days of classroom training followed by on-the-job-training (OJT) under an experienced operator. Inspector discussions with several new and several experienced operators indicated that this amount of training may not be sufficient to ensure that the process is operated in accordance with management expectations. This concern was amplified by the generally weak overall quality of the operating procedures, which appeared especially difficult for new operators to understand.

- No preventive maintenance program had been established for the Recycle/Recovery area. In addition, there was a corrective maintenance backlog which included items such as: 1) one of two evaporation tank steam coils had been inoperable since February 1995; 2) the filtrate tank level alarms had been inoperable for about one year; and 3) the process return line from the outside pad had been plugged and the pump was inoperable since December 1995.

  The lack of maintenance support resulted in the operations staff working around problems. A portable "sandpiper" pump was being used to transfer sludge since the permanent pad pump was not suitable for the current process. In addition, the operators were using flashlights to observe tank levels at night since the outside lights were not working.

6.1.6 Process Safety Concerns

During system walkdowns, the inspectors identified the following process safety concerns in the Recycle/Recovery area:

- Level control over the outside hold and evaporation tanks was not adequate. The filtrate and KOH tank pumps were located in a

building about 100 feet from the outside tank pad. There were no vessel level instrumentation or level alarms at the pumps, nor a local pump shutoff switch at the pad.

- Vessel level control at night was potentially hazardous in that outside lighting was inadequate. Operators determined the vessel level by shining a flashlight into the open tanks, which are steam heated and give off vapors that make visual observation difficult.

- The physical location of some process valves made manual operation during normal and offnormal conditions potentially hazardous to the operators. The outside tank isolation valves were located above or adjacent to open steam-heated tanks such that there was the risk of liquid and hot metal burns. Additionally, the steam isolation valves were located behind the tanks making them difficult to physically operate and exposed the operators to hot metal burns.

6.1.7 Plant Communications

The inspectors identified several concerns related to communication between operating shifts and with the flow of information up the management chain, as discussed below:

- The area foreman used electronic mail to forward important process information to the day management and other shift foremen. There did not appear to be any guidance as to what information was to be recorded. Review of recent electronic mail from the area foreman appeared to be limited in scope and depth in regards to daily operating information.

- The operators had no logs in which to record the ongoing activities, offnormal conditions, or system status. Informal (scratch paper) notes were often used to track the status of tank transfers.

- Use of the equipment malfunction logs appeared to be informal and not consistent. The inspectors noted many log entries which had not been acknowledged by supervision. Some of the log entries concerned plant equipment that had been inoperable for a significant period of time (greater than one year).

- Many of the equipment and process concerns identified by the inspectors were known to the plant staff and had been brought to management's attention. Due to the length of time that some of these concerns went unaddressed, the inspectors concluded that management had not adequately evaluated or corrected plant deficiencies in a timely manner.

6.1.8 NRC Investigation Conclusions

Although the event initiator could not be definitively identified, it was likely due to an organic - ammonium nitrate interaction that occurred at an elevated temperature. The ammonium nitrate accumulated in the large evaporation tank for a period of about six weeks. During this time, some type of organic material was likely introduced into the large evaporation tank, probably by way of the mop water boildown tank and pad sump.

Notwithstanding the lack of a definitive identification of the initiating reaction, the root cause of the event appeared to be a lack of management control over the process involving both design and operational control issues. The design of the outside hold and evaporator tank system did not meet standard chemical safety practice for isolating acids and bases. As a result, there were a number of potential pathways for inadvertently mixing incompatible chemical solutions including organic materials. In addition, there were no positive controls over what material was placed in the system. The system was open, unmarked and unposted.

The AIT identified operational control weaknesses including inadequate operating procedures, out of date P&IDs, inadequate labeling and component identification, inadequate operator training, inadequate communications, and a lack of maintenance. Of particular concern was the fact that the system was operated in a manner that was not consistent with the approved operating procedures. Although many of the issues identified by the AIT were known by the operating staff, the licensee operated the system without taking appropriate and timely corrective action for the problems.

6.2 Results of Licensee Investigation

The licensee's root cause investigation was conducted concurrently with the AIT investigation. The licensee identified three root causes for the event:

- Inadequate management practices. This included: 1) limited supervision in the area; 2) insufficient maintenance attention; 3) failure to act on operator suggestions; and 4) failure to remove obsolete piping and equipment in the area.

- Inadequate system engineering and safety features. This included: 1) incompatible chemicals used in the same complex in close proximity; 2) utilization of a common manifold and complex valving for a variety of liquids with no automation or interlocks to ensure proper valving; 3) no dedicated tanks for each type of liquid; 4) the distance between the source and receiving tanks

created communications difficulties; 5) some equipment was not labeled; 6) a common sump for the entire evaporation complex; 7) no level indication for the evaporation tanks or interlocks for the pumps; and 8) insufficient lighting.

- Failure to ensure appropriate human performance. This included: 1) inadequate training for operators and area supervisors; 2) procedures which were not up-to-date or missing important guidance; 3) drawings which were out-of-date; 4) communication problems between shifts, departments, and with management; and 5) lack of ownership for the area by all staff involved.

6.3 Corrective Actions

6.3.1 Immediate Corrective Actions

The AIT concluded that licensee management acted quickly at the conclusion of the event to ensure no further operations were conducted within the tank complex until the event investigation was complete. Immediate actions were taken to de-energize, lock, and tag the pumps associated with transferring liquids to the evaporation tanks. In addition, all associated valves were tagged out to ensure that the valve line-up for the last transfer to the tank complex would not be changed before the licensee or NRC inspectors began their investigation.

6.3.2 Long-Term Corrective Actions for Operation

The licensee's corrective action plan was provided to the NRC in a letter dated August 29, 1996, and is divided into two phases. The first phase involved those steps necessary to return the dry side of the recovery process (spent KOH evaporation) to service including:

- Disconnect and cap-off the wet filtrate piping to isolate filtrates from KOH piping.
- Lock out the filtrate pump.
- Remove the small evaporation tank from the pad and dedicate the large evaporation tank to KOH solution only.
- Remove the mop water boildown tank from the pad to preclude the intrusion of organics.
- Improve the lighting in the area.
- Install communication equipment to allow direct communications between operators during transfers.
- Tag and label all equipment and valves.
- Use a log to improve shift-to-shift communications.
- Revise procedures using inputs from operators and supervisors.
- Retrain operators and supervisors in procedures and management's expectations for operating the process.

The second phase involves preparation for returning the wet recovery and mop water boildown systems to service including:

- Installation of separate piping and tank system for filtrates.
- Relocation of the KOH tank to a separate pad away from the filtrate evaporation area.
- Installation of separate containment for mop water evaporation.
- Installation of secondary containment and sumps for the three evaporation systems to prevent mixing.
- Installation of material transfer stop controls at the evaporation tanks to enable the operator to monitor tank level.
- Providing additional lighting for the evaporation area.
- New log for mop water to control constituents.
- Revise procedures and train personnel.
- Establish a preventive maintenance program for recovery system equipment.

In addition to the above, the licensee is scheduled to complete an integrated safety analysis for the recovery and recycle processes by the spring of 1997.

6.4 Conclusions

The AIT concluded that the licensee's root cause investigation for the event was thorough and identified the same basic causes and issues as the AIT. As with the AIT investigation, the licensee was not able to determine the initiator for the event, primarily because of the lack of control over and insufficient knowledge of the constituents in the large evaporation tank at the time of the event. After reviewing the licensee's corrective action plan, the AIT concluded that the licensee had appropriately addressed the causes identified for the event to preclude its recurrence.

7.0 Radiological and Chemical Protection

[Charter Item Nos. 6 and 7]

The inspectors reviewed the licensee's radiological and chemical protection practices implemented during and following the event. The inspectors also reviewed the radiological and chemical effects on licensee personnel involved and members of the public. The review was based on the following:

- Radiological surveys of the spill area.
- Air sample results from the licensee's fixed environmental air samplers.
- Reports of ammonia tube sample results.
- Interviews with responders, operators, and health physics personnel.
- Lapel air sample results for individuals on shift during the event.
- Direct field observations.
- Independent samples of soil and vegetation downwind of the event.

7.1 Radiological and Chemical Protection Evaluation

The licensee had three fixed continuous air samplers located outside the restricted area fence for the plant. Sampler AS-3 was located near the downwind direction of the vapor plume as it extended from the plant into the valley. Sample results for the filter which was pulled after the event were normal. The other two air samples, taken from samplers which were not located in the downwind direction, were also at normal levels (less than 10 percent of the 10 CFR 20 Appendix B value of 5×10^{-14} microcuries per milliliter for Class Y uranium).

In addition to reviewing the environmental air sample results, the inspectors took independent soil and vegetation samples from the area immediately outside the restricted area fence in the downwind direction of the vapor plume. Results for the soil and vegetation samples (analyzed independently by Oak Ridge Institute of Science and Engineering) were 3 picocuries per gram or less for total uranium which is normal background.

The inspectors were informed that the results of ammonia sampling performed during the event near the closest residences in the downwind direction were negative. Upon arrival at the site on the afternoon following the event, the inspectors did not note any visibly abnormal clouds at the facility, nor did any tours identify any discoloration of vegetation surrounding the facility. Operators who were in the area of the evaporation tanks during the hour immediately preceding the event reported no unusual odor. None of the plant's closest neighbors complained of odor during the event. The inspectors concluded that there were no adverse chemical consequences to members of the public offsite as a result of the event.

The inspectors also reviewed the lapel sample results for workers present during the event and those involved in the decontamination of the area following the event. The licensee uses lapel air samplers, which consist of a pump attached at the waist with a filter head attached at the collar, as its primary means of monitoring for internal intake of radioactive material. The highest dose received for any of the individuals involved with the event was for an operator who was present in the area before the evacuation and who was directly involved in the clean-up of the spill (chipping up the hardened residue from the asphalt around the tanks and washing down the tank sides and dike with water). The operator's dose was 2.16 Derived-Air-Concentration-hours (DAC-hours) which equates to 5.4 millirem. The licensee's action level for a shift is 8 DAC-hours or 20 millirem. Based on these results, the inspectors concluded that the radiological consequences of the event for radiation workers onsite were minimal, and within the routine exposures expected in the contaminated area at the site.

7.2 Conclusions

The AIT concluded that the licensee's radiological and chemical protective measures for the event appeared to be adequate. There were no indications of adverse consequences to plant staff, members of the public, or the environment.

8.0 Exit Meeting

The team met with licensee representatives during a public meeting on August 28, 1996, and summarized the purpose of the AIT, the AIT Charter, and the inspection findings. The team discussed the likely informational content of the report. The results of the analyses for the independent samples taken by the AIT were not available at the time of the exit meeting. The licensee did not identify any information included in this report as being proprietary in nature.

PERSONNEL PARTICIPATING IN THE EXIT MEETIN

ABB Combustion Engineering

B. Kaiser, Vice President, Nuclear Fuel Manufacturing Operations
G. Page, Manager, Ceramic Operations
R. Land, Manager, Facility and Infrastructure
D. Stokes, Quality Assurance Engineer, Investigation Team Leader
E. Saito, Health Physicist

U. S. Nuclear Regulatory Commission

R. Caniano, Deputy Director, Division of Nuclear Materials Safety, Region III
R. Pierson, Chief, Fuel Cycle Licensing Branch, Office of Nuclear Materials Safety and Safeguards (NMSS)
G. Shear, Chief, Fuel Cycle Branch, Region III
W. Troskoski, Senior Chemical Safety Inspector, NMSS
J. House, Senior Radiation Specialist, Region III
J. Jacobson, Resident Inspector, Paducah Gaseous Diffusion Plant
A. Dauginas, Public Affairs Office, Region III

Augmented Inspection Team Charter - ABB Combustion Engineering - Hematite

Examine the circumstances surrounding the chemical reaction event at the ABB Combustion Engineering - Hematite facility on August 22, 1996, including, but not limited, to the following:

1. Develop and validate a chronological sequence of events and activities for the chemical reaction event evolution, detailing events just prior to and immediately after the chemical reaction event and determine what the plant conditions were at the time of the fire.

2. Evaluate the potential for a similar event to occur in other areas of the facility and determine if there were any precursor events and how these were dealt with. Include in this an evaluation of potential OSHA issues such as labeling and proper identification of valves.

3. Evaluate the licensee's actions during and following the event; including their immediate response to the event, implementation of emergency plans and procedures, event reporting, followup actions, and management response.

4. Evaluate the extent of the licensee's analysis and determination of the root cause for the event and the initial evaluation of appropriate corrective actions.

5. Determine if appropriate attention was given identifying the consequences, including dose and contamination, chemical reactions, and plant equipment damage.

6. Evaluate the adequacy and appropriateness of radiation and chemical protection precautions taken by the licensee.

7. Evaluate the radiological and chemical consequences of the event to both the plant staff and the general public.

8. Determine if there were potential systems interactions that may affect other facility safety systems.

ABB Combustion Engineering Event

Chronology of Events

8/21 1330 Last transfer of filtrates to large evaporation tank. Blew out potassium hydroxide system with plant air. Pumped filtrates for 1-1.5 hours (approximately 1100 -1200 liters).

2030 Operator blew out transfer line into large evaporation tank with plant air.

2045 Transfer of potassium hydroxide solution to small evaporation tank.

2300 Operator notes that there is more vapor than normal extending from evaporation tank area.

8/22 0600 Numerous employees noticed heavy layer of vapor/smoke in valley northeast of plant when they arrive onsite.

8/22 0700 Large evaporation tank foaming visibly. No noticeable odor reported.

0715 Solution in large evaporation tank began foaming over the sides. Reaction causing pieces of material to jet out of tanks. Facility manager notifies area supervisor.

0725 Steam flow to tanks terminated. Reaction worsens. More material blown out of large evaporation tank. Red and orange color noted near the top of the tank. Vapor rising from tank over Building 240 roof.

0730 Secondary containment breached when solution overflows containment dike.

0735 Vigorous boil-over of large evaporation tank. Reaction then dies down.

0745 Licensee places absorbent pigs around spill to prevent spread of liquid. Make-up air to building turned off.

0750 Reaction accelerates rapidly. Health Physicist directed everyone in the area to enter the building and proceed to the front, away from the affected area. Announcement made over intercom for employees to evacuate oxide and pellet plants and to go to the front of Building 253.

0750 Reaction continues to accelerate. Health Physicist and Facility Manager note large column (up to 20 feet high) of reddish orange vapor inside white vapor rising from the large evaporation tank.

0752 Emergency alarm sounded. Emergency Director and response team assemble at front of Building 253.

0753 Evacuation alarm sounded. Plant personnel begin exiting to licensee's emergency operations center (EOC).

0755 All plant employees in EOC. Emergency director declares an Alert based on report of fire at the evaporation tanks behind Building 240. Emergency response teams begin to suit up in chemical suits and supplied breathing air (SCBAs) for reentry. Licensee security guard calls 911. 911 initiates emergency response from local fire departments, sheriff, and ambulances.

0800 Emergency response team sent in to shut off the uranium hexafluoride supply to the oxide plant.

0803 Emergency response team sent to observe status of affected area from around the south side of Building 230 (Rod Loading Plant). Initial indications were that the vapor cloud had cleared and there was no fire, but upon advancing further, discovered small fire in the mop water evaporation tank adjacent to the large evaporation tank.

0805 Personnel accountability complete. All personnel onsite accounted for. Emergency Director orders response team to wait for Fire Department since there are no employees unaccounted for and no immediate need to enter affected area. Licensee establishes permanent link with 911 in the emergency communications room in the EOC.

0810 NRC Operations Center notified of an Alert. Continuous phone communications with plant established.

0812 Emergency Director downgrades event classification to Unusual Event based on reports from the response team.

0815 Fire Department onsite. Emergency Director briefs Incident Commander on status.

0820 Downwind samples gathered. No ammonia detected.

0825 Ambulance onsite. One employee taken to hospital for a strained back. Employee was not contaminated.

0833 Downwind lapel air sample initial result of 4×10^{-9} microcuries per milliliter alpha activity reported to Emergency Director. Not abnormally high result.

0840 Fire in mop water evaporation tank extinguished by fire fighters using 2.5-gallon fire extinguisher after ascertaining that there was no further hazardous materials release. No further boiling in large evaporation tank noted. Emergency classification downgraded from Unusual Event and all clear sounded.

0853 Licensee begins decontamination of response teams, fire fighters and equipment. Employees allowed to reenter Building 230.

0903 Licensee adds make-up water to evaporation tanks.

0915 Employees allowed to reenter Buildings 240, 253, 254, and 255 (Oxide and Pelletizing). Licensee locks and tags pumps and valves associated with evaporation system from filtrate and KOH hold tanks to evaporation tanks on pad in back of Building 240.