FUEL CONDITIONING FACILITY ELECTROREFINER CADMIUM VAPOR TRAP OPERATION

by

D. E. Vaden

Technology Development Division
Argonne National Laboratory-West
P. O. Box 2528
Idaho Falls, ID 83403-2528

To be Presented to
at
DOE Spent Nuclear Fuel and Fissile Materials Management

September 1998

*Work supported by the U.S. Department of Energy, Reactor Systems, Development and Technology, under Contract W-31-109-Eng-38.

DISCLAIMER

ί!L

FUEL CONDITIONING FACILITY ELECTROREFINER CADMIUM VAPOR TRAP OPERATION

DeeEarl Vaden
Argonne National Laboratory
P.O. Box 2528
Idaho Falls, Idaho 83403-2528

ABSTRACT
Processing sodium-bonded spent nuclear fuel at the Fuel Conditioning Facility at Argonne National Laboratory-West involves an electrometallurgical process employing a molten LiCl-KCl salt covering a pool of molten cadmium. Previous research has shown that the cadmium dissolves in the salt as a gas, diffuses through the salt layer and vaporizes at the salt surface. This cadmium vapor condenses on cool surfaces, causing equipment operation and handling problems. Using a cadmium vapor trap to condense the cadmium vapors and reflux them back to the electrorefiner has mitigated equipment problems and improved electrorefiner operations.

1. INTRODUCTION

The Fuel Conditioning Facility (FCF) at Argonne National Laboratory in Idaho processes spent nuclear fuel by electrochemical transport (Ref. 1). This process uses an electrorefiner to separate the uranium from the fission products and structural materials (cesium, sodium, cladding, etc.). The MkIV electrorefiner in FCF consists of a molten LiCl-KCl salt covering a molten cadmium phase. A cover gas of argon sits above the salt phase. Previous research (Ref. 1) has shown that the cadmium dissolves in the salt as a gas, diffuses through the salt layer and vaporizes at the salt surface. Cadmium vapor condensing and solidifying on the cooler areas of mechanical hardware in the FCF MkIV electrorefiner makes it difficult to disassemble components. Also cadmium bridging across the electrical insulators in the electrode assemblies causes electrical shorts, which impedes the electrometallurgical process. A reflux vapor trap (RVT) was designed and built to mitigate the problem of cadmium vapor deposition on cool surfaces in the electrorefiner.

2. EQUIPMENT

The vapor trap, originally built for the electrorefiner cover gas system as a cadmium vapor trap with no reflux capability (Ref. 2), is a 51 cm long rectangular array of 18 thin steel tubes of rectangular cross section, spaced apart to permit cooling of individual tubes via convection. Within each tube are steel inserts that provide additional surface area for heat and mass transfer. The RVT fits vertically into any of the four electrorefiner ports with the lower tube header open to the electrorefiner cover gas space and the upper tube header open to the FCF argon cell. The upper 28 cm of the RVT is exposed to the FCF argon atmosphere for external cooling. Figure 1 is a schematic of the upper section of the vapor trap showing the purge gas flow and the location of the thermocouples.

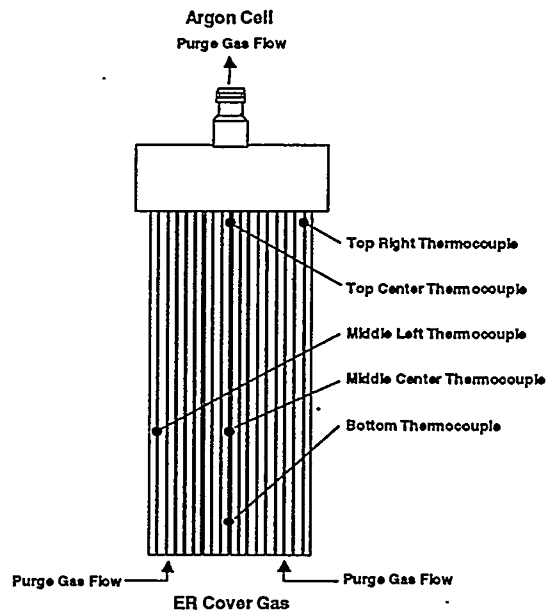

Fig. 1. Reflux Vapor Trap Schematic

The FCF electrorefiner has a cover gas control system that "feeds and bleeds" argon through the cover gas to maintain positive pressure in the electrorefiner. As fresh argon enters the electrorefiner, cover gas saturated with cadmium flows through the vapor trap and condenses in the cooler regions of the trap. Without the trap, cover gas would flow past seals and bearings in the electrodes assemblies, condensing cadmium on equipment surfaces and hindering electrorefiner operations. When the vapor trap channels fill and plug, the cover gas pressure rises, indicating the need to regenerate the vapor trap. Regeneration involves securing cover gas flow and heating the vapor trap to allow cadmium in the trap to melt and flow back into the ER. The molten cadmium flows into a funnel and tube attached in the lower portion of the RVT, with the tube immersed in the molten LiCl-KCl salt.

Publication disclaimer

3. VAPOR TRAP OPERATION

After installing and qualifying the RVT in electrorefiner port B, purge gas flow was started on April 4, 1997. The initial cover gas flow was 0.016 m^3 per minute (0.57 scfm) with a 1.05 mmHg (0.57 inches H_2O) pressure drop across the cover gas system. Figure 2 is a plot of purge gas flow, cover gas system pressure drop, and RVT temperatures from the top center, middle center, and bottom thermocouples (see Fig. 1). On April 9, 1997, the purge gas flow rate was increased from 0.016 m^3 per minute (0.57 scfm) to 0.037 m^3 per minute (1.3 scfm) to increase the argon gas flow through the RVT. The cover gas pressure drop and RVT temperatures increased with the increase in cover gas flow. The heat source is the argon gas leaving the electrorefiner via the vapor trap. The top center temperature stayed below 150 C, which allows cadmium to condense in the vapor trap. Large changes in cover gas flow affected the vapor trap temperatures, as seen in Fig. 2 just before April 13, 1997.

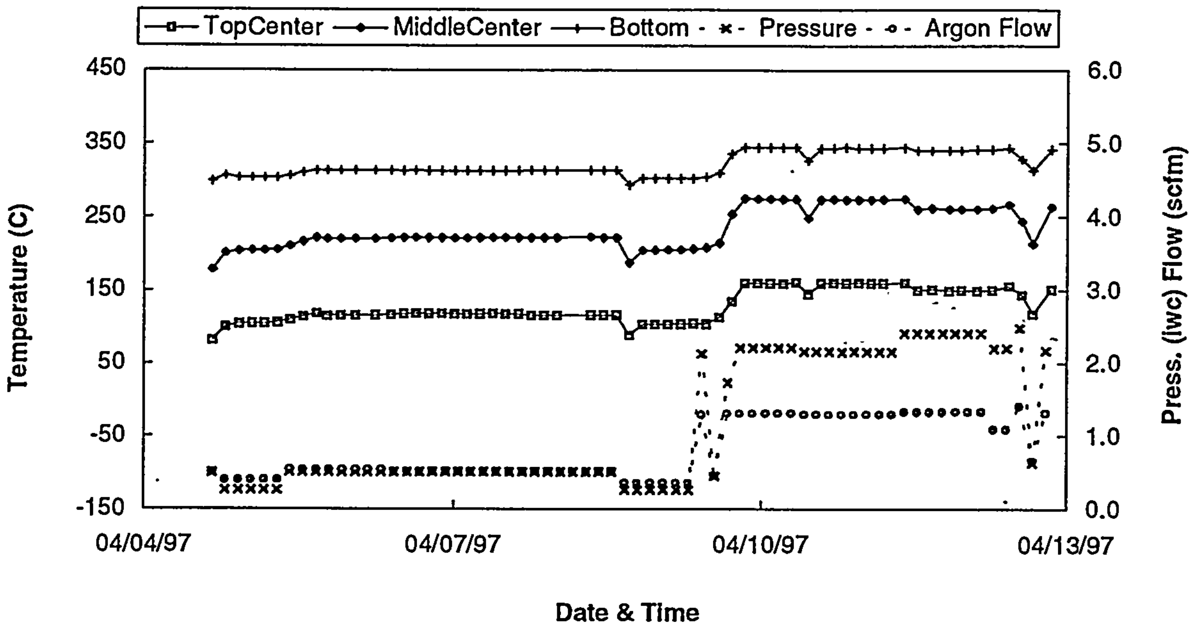

Fig. 2. Reflux Vapor Trap Temperatures, Cover Gas Flow and Pressure

From April 13, 1997 to April 18, 1997, the cover gas pressure started increasing. To keep the pressure below 4.8 mmHg (2.6 inches H_2O), the cover gas control system will reduce the argon flow into the electrorefiner. Figure 3 shows the increase in cover gas pressure and the change in argon flow on April 18, 1997. This is an indication that the vapor trap is starting to accumulate sufficient amounts of cadmium to increase the pressure drop across the trap.

On April 18, 1997, the RVT heaters were energized to heat the vapor trap to melt the cadmium in the trap (reflux the cadmium). Figure 4 shows that prior to regeneration, the RVT temperatures and gas flow were decreasing and the cover gas pressure was increasing. This indicates the vapor trap accumulated enough cadmium to cause a change in pressure, flow and vapor trap temperatures. The regeneration operation took 4 hours, including the time for the monitored temperatures to stabilize upon cooling. After regeneration, the gas flow, pressure and temperatures returned to levels similar to those prior to April 15, 1997. This indicates that regenerating the vapor trap removed the cadmium and restored the vapor trap to normal operation.

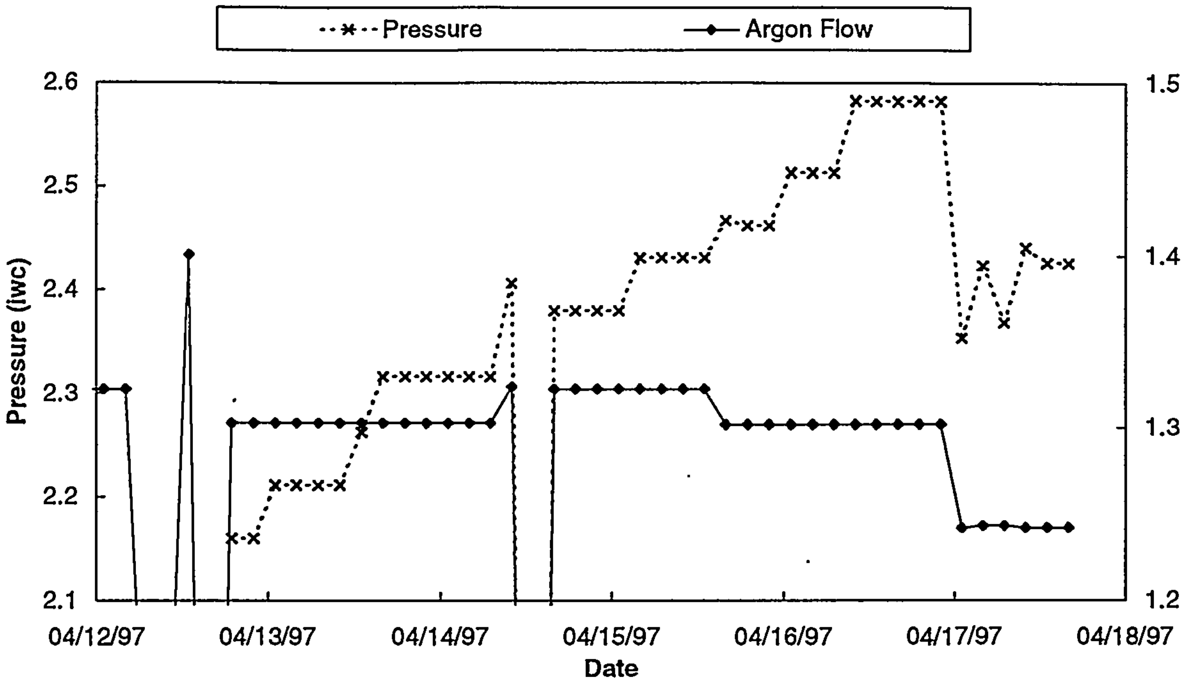

Fig. 3. Cadmium Vapor Trap Plugging

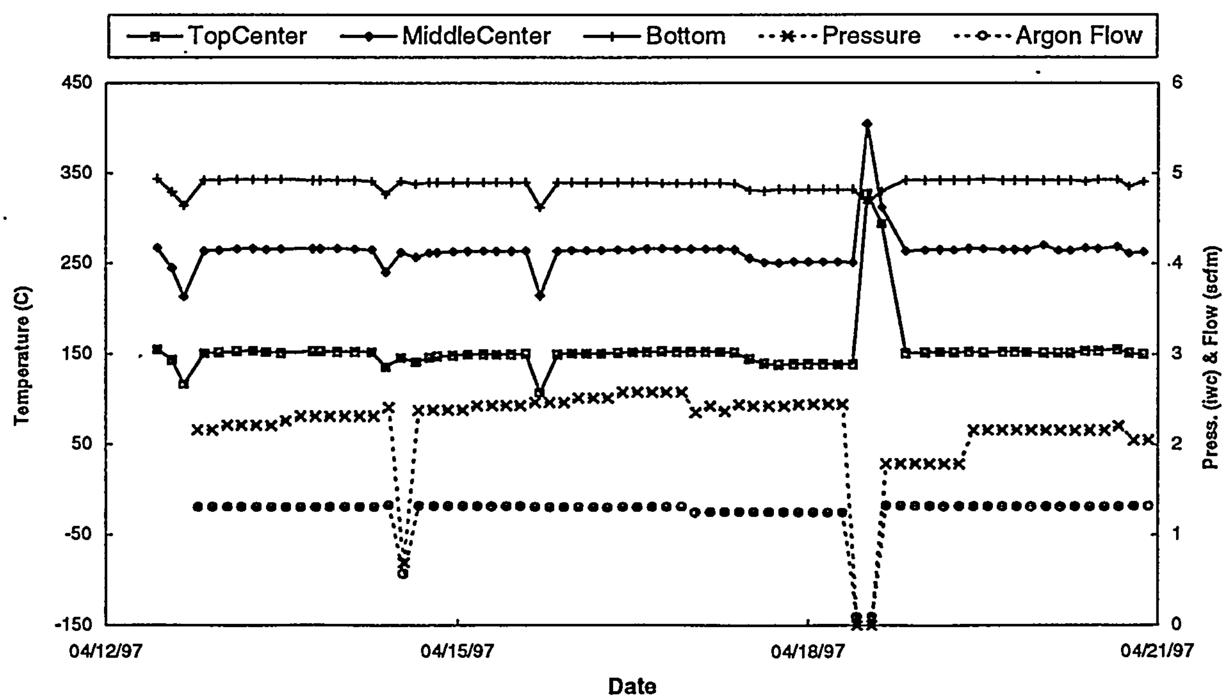

Fig. 4. Reflux Vapor Trap Regeneration on April 18, 1997

From April 18, 1997, to June 19, 1997, the RVT was regenerated four times. The regeneration dates are April 18, May 19, May 30, and June 19. Figure 5 is a photo of the port D electrode assembly on May 13, 1997.

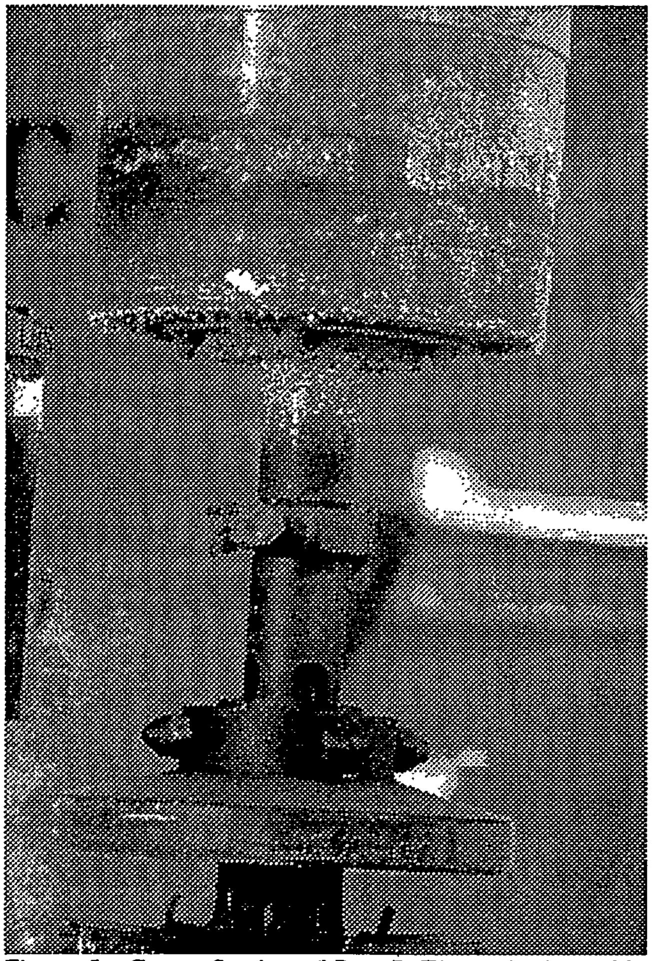

Figure 5. Center Section of Port D Electrode Assembly on May 13, 1997

This is the region exposed to the cover gas when the electrode assembly is installed in the electrorefiner. The bottom of the heat shield and the electrode shaft has cadmium droplets. The ceramic seal at the bottom of the heat shield was replaced after May 13, 1997, which required cleaning the electrode shaft. Cadmium droplets were also removed from the heat shield during the ceramic seal replacement. Figure 6 is a photo of the port D electrode assembly on June 19, 1997, after approximately one month of vapor trap operation with the electrorefiner maintained at 450 °C.

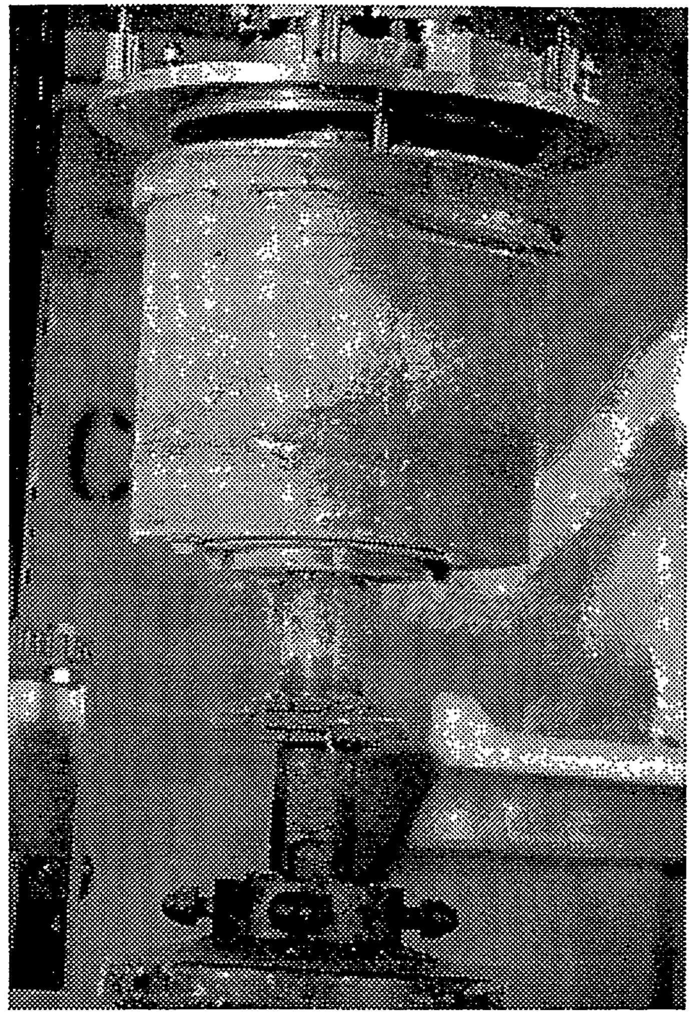

Figure 6. Center Section of Port D Electrode Assembly on June 19, 1997

Cadmium droplets are not present on the bottom of the heat shield or on the shaft. The ceramic seal is devoid of cadmium droplets. What cadmium is present has the appearance of steel wool and not silver droplets. Both figures show cadmium frost in the middle section of the heat shields, but Fig. 6 appears to have less cadmium frost than Fig. 5.

4. CONCLUSIONS

The primary function of the cadmium vapor trap was to mitigate cadmium formation on mechanical equipment. Results are qualitative, but using the cadmium vapor trap has reduced the amount of cadmium related equipment problems in the FCF MkIV electrorefiner. Recently the RVT has been regenerated on a weekly bases to preclude the need to regenerate when an electrorefining experiment is in progress.

5. ACKNOWLEDGEMENTS

This work is sponsored by the United States Department of Energy under Contract W-31-109-Eng-38.

6. REFERENCES

1. K. Michael Goff, Alfred Schneider, and James E. Battles, "Cadmium Transport through Molten Salts in the Reprocessing of Spent Fuel in the Integral Fast Reactor Fuel Cycle," *Nuclear Technology*, Volume 102, pp. 331-340 (June 1993).

2. R. K. Ahluwalia, K. H. Im, E. L. Carls, G. A. Flecher, H. A. Myers, R. C. Frank, and R. F. Malecha, "Unpublished Information," February 1993.