

Figure 14 – Micrograph montage illustrating localized adherence of ash fines along the outer surface of the qualification-test, medium membrane-coated, PRD-66 filter element.

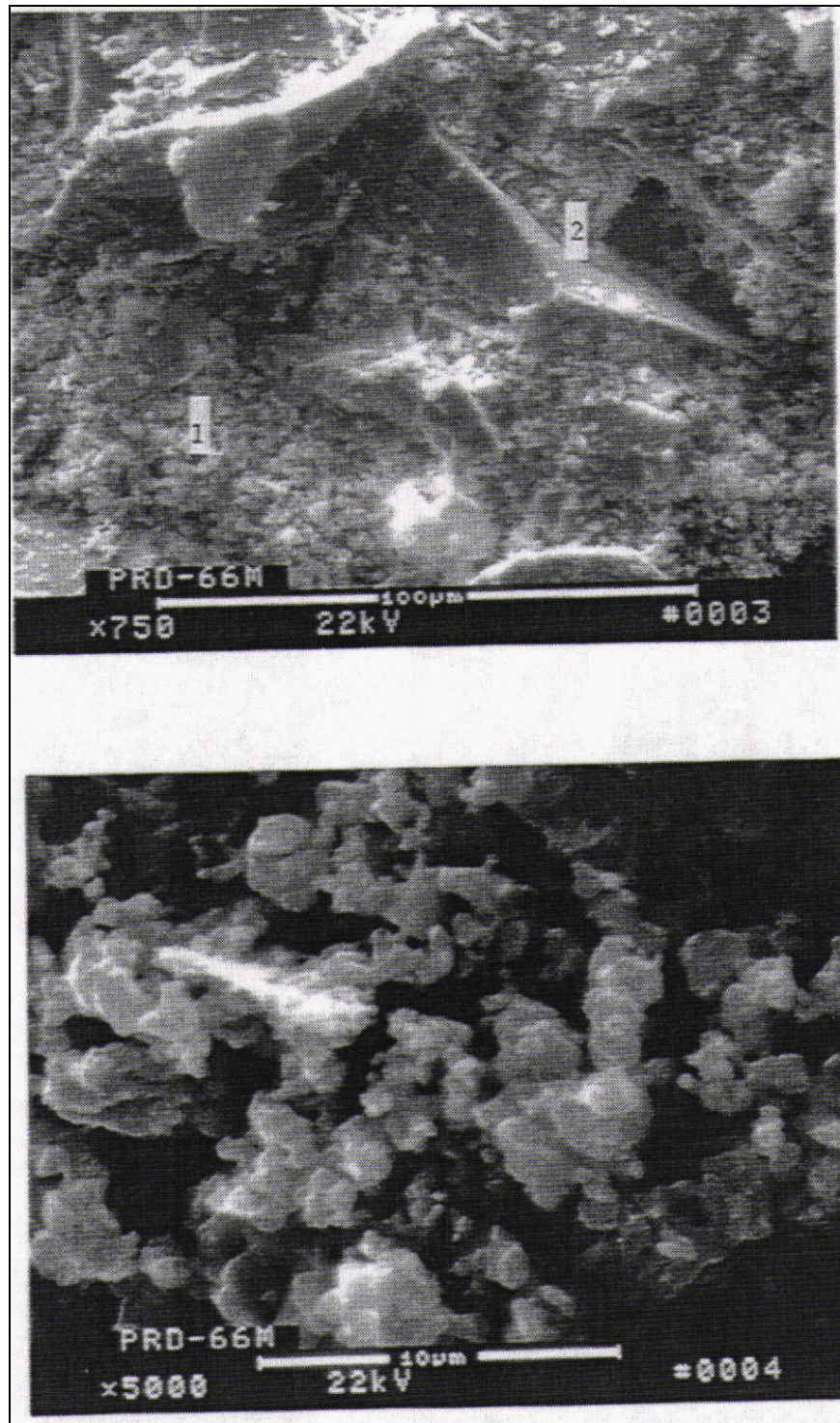


Figure 15 – Higher magnification micrographs illustrating the adherence of ash fines between adjacent alumina-rich grains present along the outer surface of the qualification-test, medium membrane-coated, PRD-66 filter element. The highly porous network of ash fines is shown in the lower micrograph.

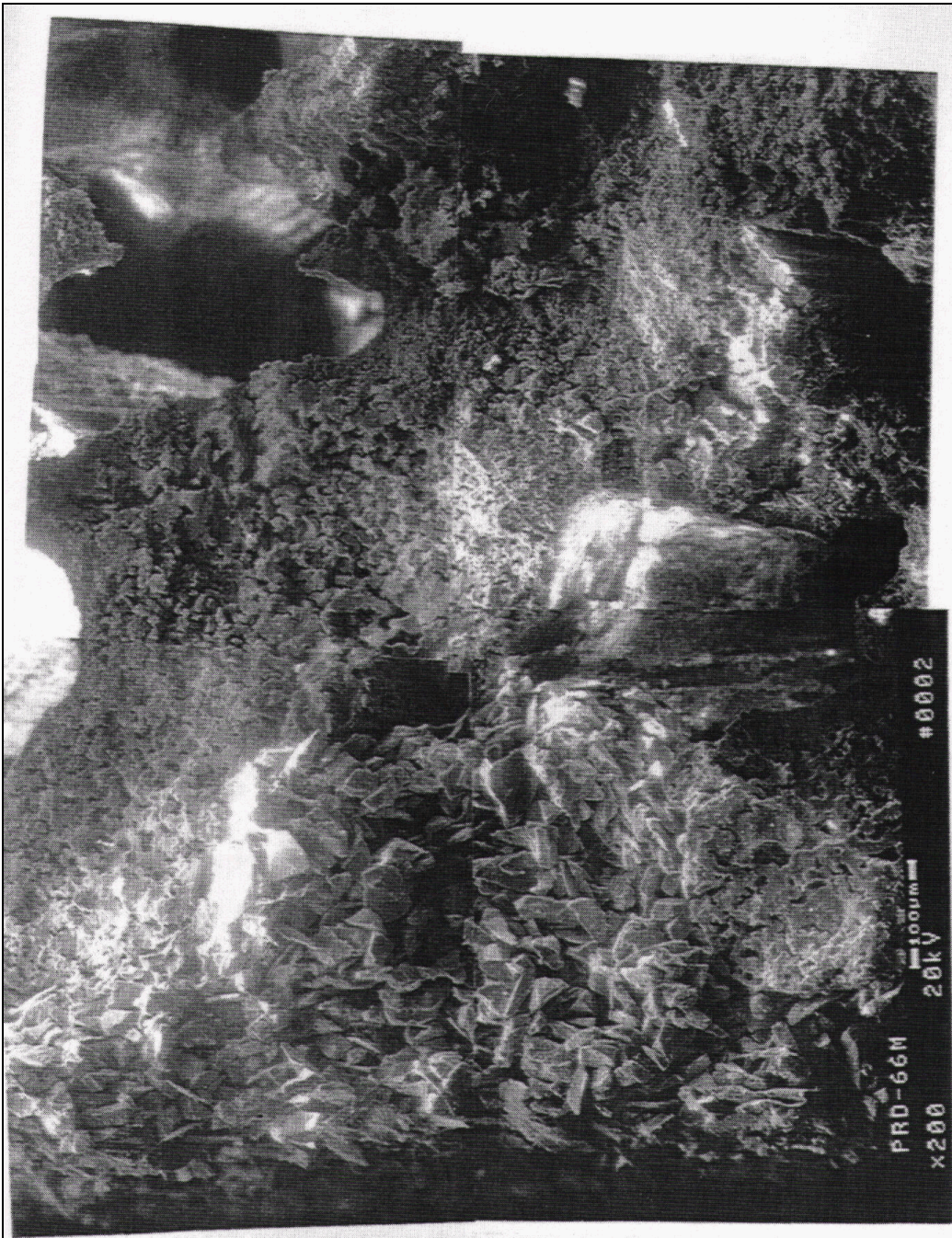


Figure 16 – Micrograph montage illustrating the morphology of the cross-sectioned filter wall of the qualification-test, medium membrane-coated, PRD-66 filter element.

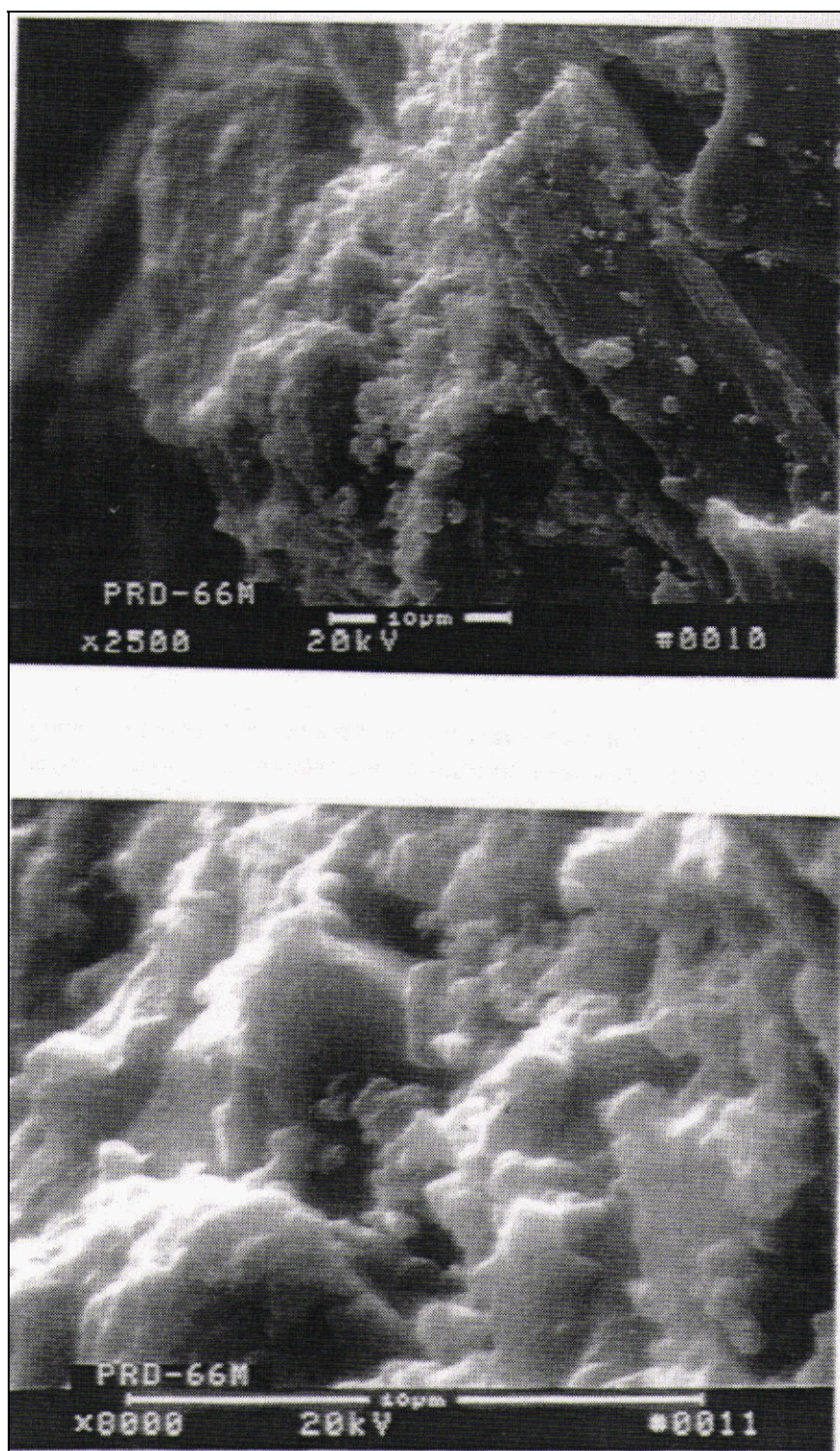


Figure 17 – High magnification micrographs illustrating the adherence of ash fines along the outer surface of the alumina-rich grains that were present within the membrane of the qualification-tested, medium membrane-coated, PRD-66 filter element.

Comment

Limited penetration of ash fines into the membrane-coated filament wound filter matrix was identified for sections of the PRD-66 filter elements examined in this effort. Characterization of additional sections removed from the qualification-tested filter elements, and extended field operation (i.e., >500-1000 hours) are needed to confirm whether the DLC PRD-66 element performs as a barrier vs. bulk filter.

Based on the results of the qualification testing, both coarse and medium membrane-coated filter elements were considered to be acceptable for use in Westinghouse's APF system at the Foster Wheeler PCFBC test facility in Karhula, Finland. In view of the gas flow resistance measurements for the as-manufactured candles, production of the coarse membrane-coated elements was selected as the filter type of choice for use at Karhula.

PCFBC Candle Filter Testing

Twelve, 1.5 m, DuPont PRD-66 candle filters were manufactured with the coarse membrane coating, and shipped to Karhula at the end of July 1997. All twelve filter elements arrived intact, and were initially inspected, prior to consideration for inclusion within the Westinghouse APF. During inspection of the elements, the following comments were made:

- Generally all elements had a smooth outer surface finish
- Questions arose as to whether there would be an acceptable fit of the candle within the metal filter holder due to the extended length of the DLC hemispherical flange
- High intensity light source inserted along the i.d. of each filter element indicated general uniformity along the length of each candle
 - On one or two of the elements, bands of denser areas of matrix were evident near the end caps
 - On several elements, the intensity of the light appeared to be greater than along the body, possibly indicating a thinner area of the matrix
 - If discontinuities existed, they were located at the bottom of the elements, near the end cap
- All end caps were generally uniform
- A section of the matrix (~1-2 mm wide) was removed from the bottom end cap of one element during ultrasonic evaluation. This technique was modified to eliminate material removal during continued testing of the PRD-66 filter elements.
- Only one element had a slightly rougher outer membrane surface.

Seven DLC PRD-66 candles were installed in the bottom array of the Westinghouse APF, and were operated for a period of 342 to 581 hours (i.e., Test Segment 2: September 4, 1997 through November 7, 1997). Table 6 identifies the PCFBC operation conditions during conduct of this test campaign. At the conclusion of the test program, the filter vessel was slow cooled and inspected. All PRD-66 filter elements had remained intact during operation in the PCFBC environment. During removal from the filter array, one element failed at the base of the flange due to binding of the candle with ash in the filter holder mount, and the force required for disassembly. Divoting was not evident along the outer surface of the filter elements, implying that the integrity of the combination membrane had been retained during the first 581 hours of service life. Due to the relatively "soft" and fragile nature of the PRD-66 filter matrix, removal

of the membrane (i.e., "nicks") occurred along several areas of the candles during disassembly of the elements from the filter array, as well as during cleaning and subsequent handling.

Summary and Conclusions

- The as-manufactured, outer membrane-coated DLC PRD-66 filter elements achieved the gas flow resistance specifications identified by Westinghouse.
- Continued production modifications have lead to the development and application of a coarse membrane coating along the hoop wrapped, outer surface of the filter elements. After 581 hours of exposure in the PCFBC environment, the integrity of the coarse membrane was retained.
- Further efforts are needed to address the barrier vs bulk filtration characteristics, of the PRD-66 filter element during long-term operation in PFBC, PCFBC, or gasification applications. This includes extensive microstructural analyses of the elements which have experienced greater than 500-1000 hours of field test exposure.
- Additional efforts remain to be focused on the development and production of the dual membrane, barrier candle filter; further strengthening of the flange; and the incorporation of a chip resistant outer surface.

References

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3. M. A. Alvin, T. E. Lippert, B. S. Diaz, E. B. Smeltzer, and R. E. Tressler, "Durability of Ceramic Filters," *Proceedings of the Coal-Fired Power Systems '94-Advances in IGCC and PFBC Review Meeting*, 545-571, DOE/METC-94/1008.
4. M. A. Alvin, T. B. Lippert, E. S. Diaz, B. B. Smeltzer, and G. J. Bruck, "Filter Component Assessment," *Proceedings of the Advanced Coal Based Power and Environmental Systems 397 Contractor's Review Meeting*, Pittsburgh, PA, July 22-24, 1997.