

IMPROVEMENT IN OPERATING AND MAINTENANCE COST WITH A FABRIC FILTER CONVERSION USING POLYTETRAFLUOROETHYLENE (PTFE) MEMBRANE FILTER MEDIA

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ABSTRACT:

Wheelabrator Technologies is owner and operator of the 2250 ton per day North Broward County, Florida, facility. The plant consists of three lines rated at 750 tons/day. Each line is equipped with a spray dryer absorber/fabric filter. The original fabric filter design was a shake-deflate baghouse with ten compartments of 180 bags each.

The typical bag life was one year with the shake-deflate baghouse using standard woven fiberglass bags. Frequent bag failures led to high operating and maintenance cost for the system. The initial upgrade was a conversion from a shake-deflate baghouse to a reverse-air baghouse with sonic horns. The resultant bag life was improved to two years, which represented a significant reduction in maintenance cost.

The latest upgrade for the baghouse system was the installation of PTFE membrane/fiberglass filter bags. The change in the filter media resulted in a dramatic improvement in performance. The baghouse cleaning frequency dropped from 360 cycles per day to approximately 50 cycles per day. The average differential pressure across the baghouse system also dropped by 6 in. w. g. The membrane filter bags have achieved over two years life to date and have significantly reduced operating and maintenance costs associated with the baghouse.

This paper will detail the steps taken in the conversion from the original shake-deflate design using standard filter bags to the reverse-air with sonic horns using membrane bags. An analysis of the cost

of the upgrades and subsequent savings for each step will be included.

INTRODUCTION:

Wheelabrator Technologies is a wholly owned subsidiary of Waste Management, Inc. They currently operate 17 waste-to-energy facilities in the United States ranging in size from 200 tons per day (TPD) to 3000 TPD. Their first plant was a 1500 TPD facility in Saugus, MA, which has been operating since 1975. Since then, Wheelabrator Technologies has safely processed more than 100,000,000 tons of solid waste and generated over 50 billion megawatt-hours of electricity.

Started in 1991, the North Broward County facility is located in Pompano Beach, FL. This facility serves Broward County and receives waste from Dade and Palm Beach Counties. The plant has a rated capacity of 2250 TPD and generates 67.5 megawatts (MW) of electric power.

The plant consists of three combustion trains rated at 750 TPD each. Two overhead cranes deliver the refuse to three Von Roll reciprocating grates. The combustion temperature is above 2500°F and the heat is recovered in waterwall boilers that generate a total of 576,000 pounds per hour of steam at 900 pound per square inch (psig) at 830°F. The steam generates 67.5 MW of electric power that is sold to Florida Power and Light Company. The combustion gas is treated by a spray dryer absorber/fabric filter and

exits a 200-foot stack . (See Fig. 1. - Diagram of Wheelabrator Waste to Energy Plant).

AIR POLLUTION CONTROL SYSTEM:

Each line has its own spray dryer absorber/fabric filter (SDA/FF). The flue gas leaves the boiler at approximately 500°F and enters the top of the spray dryer (approximately 25 feet in diameter by 100 feet tall). Lime slurry is fed in at a nominal rate of 450 pounds per hour. The gases are cooled to below 325°F before entering the fabric filter.

A 10-compartment fabric filter follows each spray dryer. The original fabric filters had a shake and deflate cleaning system. Each compartment contained 180 bags, 8 inches in diameter by 22.5 feet long. The initial bag material was 10 ounce per square yard (oz/yd²) woven fiberglass with a 10% TEFLON B[®] finish. The fabric filter was designed with an air-to-cloth ratio of approximately 2:1 (feet per minute) with all compartments on line.

From the initial startup, the facility has been in compliance with all federal, state and local air pollution control regulations.

EARLY OPERATION:

During the first year of operation, there were no problems with the fabric filter. The fabric filter would operate at a pressure drop of approximately 6 inches water column (in. w.c.) with a reasonable cleaning cycle. After approximately 12 months the pressure drop began to climb and the number of cleaning cycles increased. Eventually, the pressure drop reached 12-13 in. w.c. with continuous cleaning. The high cleaning frequency led to bag failures. While the induced draft fan had sufficient capacity to operate the incinerator at full load under these conditions, the fan was near its limits. Whenever a compartment had to be isolated to replace bags, the boiler load would have to be reduced.

Because of frequent bag failures, it took two men an average of 4 man-hours per day on an intermittent basis to keep up with the fabric filter maintenance. This level of attention was far beyond what could be accomplished as part of the normal operations and maintenance rounds. As a result, overtime was needed to keep up with the routine maintenance needs of the baghouse. The frequent isolation of the compartments and subsequent cooling created a severe corrosion problem. The corrosion around the doors and on the cold walls created holes, which increased the air inleakage and accelerated the corrosion. After a few years, it reached the point

where the fabric filter compartments were patched and all bags were replaced during the annual outage.

The first attempt to lower the pressure drop was to try reversing the filtration face of the fabric. The initial bags were made with the filling face (textured side) inside the bag to ensure high filtration efficiency. Since emissions were not a problem, it was decided to install a set of bags with the warp face (smooth side) on the inside. This would improve the dust release characteristics and hopefully reduce the pressure drop across the fabric. This change did not effect particulate emissions but, unfortunately, did not reduce the pressure drop.

Different bag designs and bag materials (an acid-resistant fiberglass) were tried over several years. There was no noticeable change in performance. Since the bag failures are mainly flex-failures along the vertical crease lines, it was decided to experiment with a different cleaning method.

INITIAL TRIALS:

In 2000 and 2001, trials were conducted with ringed bags, reverse air cleaning and sonic horns. With the shakers disabled, the typical failures along crease lines diminished. The preliminary results looked promising, additional compartments were converted from shaker to deflation only with sonic assist. By the outage in February 2001, one whole fabric filter line had been converted.

The conversion from shake-deflate to reverse-air/sonic did reduce the bag failures. The pressure drop, however, still climbed to 12-13 in. w.c. The high-pressure drop was the result of a thick ash layer on the bag. It was decided to test a few bags with a PTFE membrane surface to improve the release characteristics of the fabric. The result of these tests indicated that it was worth considering the installation of a complete set of membrane bags in one line.

BAGHOUSE IMPROVEMENT PROJECT:

In February 2002 a major baghouse improvement project was initiated on Line #2. The objective was to correct the corrosion problem and the pressure drop problem in a cost-effective manner.

The scope of work included:

- Replacement of the old cell plate and thimbles with a new flat tube sheet
- Installing stainless steel liners on all the cold walls of the baghouse
- Disconnecting the shakers and sealing all housing penetrations

- Installing sonic horns
- Relocating the deflation air duct
- Installing PTFE membrane filter bags with rings

In each compartment the new tube sheets had three sections, two outside and a center. The outside sections were 304 stainless steel and the center was COR-TEN® steel. The tube sheet was flat (with no thimbles) to facilitate clean up after a bag replacement.

The mild steel cold walls (all walls not shared between compartments) were lined with 3/16-inch thick 304 stainless steel plate. The liner extended down into the hopper and up about 4 feet above the tube sheet.

Two sonic horns (230 hertz) were installed in each compartment. Initially they were installed below the upper catwalk. Later they were moved above the catwalk to reduce bag wear.

The deflation air duct came off the inlet side of the induced draft fan in original design. In order to increase the cleaning energy without changing the fan and motor, the duct was relocated to the discharge side of the ID fan.

The new bags had an expanded PTFE membrane laminated to a 10oz/yd² fiberglass fabric. The bags had 5 anti-collapse rings, a plain band at the top and a double-bead snap band at the bottom.

The total cost of the conversion was approximately \$500,000. A rough breakdown would be 50% for the metalwork (material and labor) and 50% for the membrane bags and sonic horns (material and labor).

RESULTS:

After the conversion, the operation of the fabric filter improved dramatically. The baghouse operated at a differential pressure of 5.5–6.5 in. w.c. with a reduced cleaning frequency of 50 cycles per day (compared to over 300 cycles per day, previously).

After one year of operation, the results were so encouraging that it was decided to upgrade the other lines in the same manner. In February 2003, Lines #1 and #3 were renovated and PTFE membrane bags were installed.

Currently all three lines have PTFE membrane bags installed. The first set has been in service for over two years. The pressure drop is still approximately 6 in. w.c. and the system is cleaning about 60 times per

day. The bag failures have been extremely low and as a result, overtime is no longer required to keep up with routine plant maintenance.

BREAKEVEN COST ANALYSIS:

The following is an estimate of the breakeven cost based on the cost of the baghouse conversion and the estimated reduction in operating costs.

Part 1 – Cost of Metalwork (per line)

Total conversion cost (per line) = \$500,000
 Metalwork = 50% of total conversion cost = \$250,000

Maintenance savings:

Estimated maintenance on fabric filter = 2 men
 x 4 hrs/day (every other day)
 2 men x 4 hr/day x 180 days/year x
 \$25/manhour = \$36,000/year

Bag consumption savings:

Bag replacement cost = \$40/bag (shaker design)
 Bags failures per day = 1–3 (every other day)
 \$40/bag x 2 bags/day x 180 days/years = \$14,400

$\$250,000 / (\$36,000/\text{yr} + \$14,400/\text{yr}) =$
 $250,000/50,400 = 4.96$ years to breakeven.

Another way to look at the cost saving of the metalwork is a net present value (NPV) analysis. Assuming a metal life of 10 years (minimum) and using a 10% interest rate (cost of capital), the net present value of the maintenance and bag consumption would be \$309,700. This is higher than the cost of the metalwork alone. The saving on a net present value basis is \$309,700 - \$250,000 = \$59,700. See Fig. 2. - Net Present Value Metal in Appendix 1.

Part 2 – Cost of Bags (Shaker vs Reverse Air/Sonic)

The shaker bags cost approximately \$40 each and achieved one year life. The reverse air (ring bags) cost about \$50 each and achieved two years bag life. With twice the bag life and a cost premium of 25%, it was clearly cost effective to convert from shaker bags to reverse air/sonic bags. Since there was no difference in performance other than bag life (including replacements), the analysis only considered bag cost, install cost and replacement cost.

With the same assumptions as above (10% cost of capital, 10 year life cycle), the shaker bag NPV cost would be \$607,100 and the reverse air/sonic bag

NPV cost would be \$377,300. The savings on a net present value basis would be \$607,100 - \$377,300 = \$229,800. See Fig. 3. - Net Present Value - Bags in Appendix 1.

Looking over a 10-year period, the \$500,000 cost to make the conversion would have resulted in a savings of \$39,500 (\$500,000 - \$309,700 for maintenance - \$229,800 for bags) on a net present value basis. Therefore, the investment to convert from the original shaker-deflate design to reverse air/sonic and to upgrade the baghouse material of construction was advantageous.

THE MEMBRANE DIFFERENCE:

The cost of the membrane bags (with rings) was significantly higher than the conventional fiberglass ringed bags. To date the membrane bags have achieved a longer life than the conventional fiberglass reverse air bags. The membrane bags have also reduced the differential pressure across the baghouse. Since the membrane bags are still in service, the actual service life has not been established at this plant.

A net present value analysis was done for two scenarios. The first assumes a three-year life for the membrane bags. The second assumes a four-year bag life, which is the minimum expected life for the membrane bags. Based on the price of bags only, the membrane bags would have to achieve the 4 year expected life to breakeven.

Material	Life	NPV
Conventional Fiberglass	2 Yr.	\$418,400
Membrane Fiberglass	3 Yr.	\$520,500
Membrane Fiberglass	4 Yr.	\$408,000

However, there was value associated with the decrease in the differential pressure across the baghouse with the membrane bags. Using a 3 in. w.c. decrease in differential pressure (Note: The actual pressure drop has been 6 in. w.c. lower), it is possible to estimate a savings in fan energy consumption.

The actual operating costs of the incinerator system (including the baghouse portion) are considered

proprietary by Wheelabrator Technologies. The following is an estimate of the cost savings for a lower differential pressure using standard fan power calculations:

$$\text{Fan Power Cost (A)} = (0.7457 \times P \times H \times K \times S) / (6356 \times E), \text{ where:}$$

- A = \$ per year
 - P = pressure drop reduction (3 in. w.c.)
 - H = annual operating hours (8400 hours)
 - K = electricity cost \$ per kilowatt-hour (\$0.05)
 - S = gas flow rate in actual cubic feet per minute (173,300 acfm)
 - E = fan/motor/drive efficiency (0.7)
- $$A = 0.7457 \times 3 \times 8400 \times 0.05 \times 173,300 / (6356 \times 0.7) = \$36,600 \text{ per year (estimated)}$$

Applying this estimated fan energy savings to the bag cost NPV analysis and using a 12-year life cycle (the least common denominator for 2-, 3-, and 4-year bag lives), the results are as follows:

Material	Net NPV
Conventional Fiberglass - 2 Yr.	\$418,400
Membrane Fiberglass - 3 Yr.	\$271,100
Membrane Fiberglass - 4 Yr.	\$158,600

Therefore, the additional savings of using membrane bags is expected to be \$147,000 to \$260,000 on an NPV basis. See Fig. 4. - Net Present Value - Bags 2 in Appendix 1.

CONCLUSIONS:

The Wheelabrator North Broward County facility was very interested in reducing the operating costs of the air pollution control system. The relatively short bag life created a situation where corrosion became a serious problem. In order to improve the situation, they modified the fabric filter cleaning system and upgraded the materials of construction. These steps proved to be cost-effective on their own.

The conversion to membrane filter media, although at a significant premium to the conventional fiberglass bags, looks like it will yield a significant cost savings in coming years.

APPENDIX 1

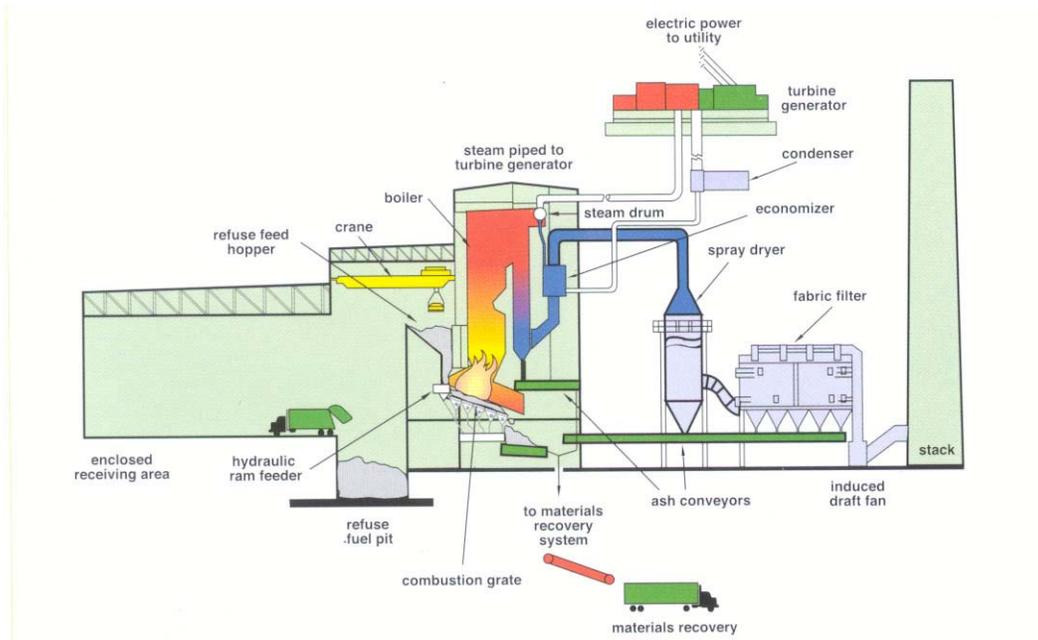


Fig 1.: Diagram of Wheelabrator Waste to Energy Plant

**Net Present Value Analysis
Metalwork Modifications to the Baghouse**

Year	0	1	2	3	4	5	6	7	8	9
Cost Modifications	(\$250,000)									
Maintenance Savings	\$50,400	\$50,400	\$50,400	\$50,400	\$50,400	\$50,400	\$50,400	\$50,400	\$50,400	\$50,400
NPV of Savings	\$309,686									
Net Savings	\$59,686									

Notes:

1. Interest rate of 10%
2. Ten year life for the metalwork
3. Savings based on 8 man hours per day @ \$25/man hours and 2 bags per day @ \$40 per bag; 180 days per year
4. No inflation included in maintenance of bag cost

Fig. 2.: Net Present Value - Metal

**Net Present Value Analysis
Shaker vs. Reverse Air Bags**

Year	0	1	2	3	4	5	6	7	8	9
Shaker Bags	\$72,000	\$72,000	\$72,000	\$72,000	\$72,000	\$72,000	\$72,000	\$72,000	\$72,000	\$72,000
Installation	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000
Bag Failures	\$1,800	\$1,800	\$1,800	\$1,800	\$1,800	\$1,800	\$1,800	\$1,800	\$1,800	\$1,800
Total Installed	\$98,800	\$98,800	\$98,800	\$98,800	\$98,800	\$98,800	\$98,800	\$98,800	\$98,800	\$98,800

NPV Shaker \$607,083

Year	0	1	2	3	4	5	6	7	8	9
Reverse Air Bags	\$90,000	\$0								
Installation	\$25,000	\$0	\$25,000	\$0	\$25,000	\$0	\$25,000	\$0	\$25,000	\$0
Bag Failures	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170
Total Installed	\$116,170	\$1,170	\$116,170	\$1,170	\$116,170	\$1,170	\$116,170	\$1,170	\$116,170	\$1,170

NPV Rev Air \$377,326

Note:

1. Interest rate of 10% (cost of capital)
2. Shaker bag cost = \$40; 1 year life; 2% bag failure/year; \$10/bag labor to change
3. Reverse air bag cost = \$50, 2 year bag life; 1% bag failure/year; \$15/bag labor to change
4. No inflation included in bag, installation or labor costs

Fig. 3. - Net Present Value - Bags

**Net Present Value Analysis
Case 1 - 3 Year Membrane Bag Life**

Year	0	1	2	3	4	5	6	7	8	9	10	11
Reverse Air Bags	\$90,000	\$0	\$90,000	\$0	\$90,000	\$0	\$90,000	\$0	\$90,000	\$0	\$90,000	\$0
Installation	\$25,000	\$0	\$25,000	\$0	\$25,000	\$0	\$25,000	\$0	\$25,000	\$0	\$25,000	\$0
Bag Failures	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170	\$1,170
Total Installed	\$116,170	\$1,170	\$116,170	\$1,170	\$116,170	\$1,170	\$116,170	\$1,170	\$116,170	\$1,170	\$116,170	\$1,170

NPV Rev Air \$418,416

Year	0	1	2	3	4	5	6	7	8	9	10	11
Membrane Bags	\$180,000	\$0	\$0	\$180,000	\$0	\$0	\$180,000	\$0	\$0	\$180,000	\$0	\$0
Installation	\$25,000	\$0	\$0	\$25,000	\$0	\$0	\$25,000	\$0	\$0	\$25,000	\$0	\$0
Bag Failures	\$1,447	\$1,447	\$1,447	\$1,447	\$1,447	\$1,447	\$1,447	\$1,447	\$1,447	\$1,447	\$1,447	\$1,447
Total Installed	\$206,447	\$1,447	\$1,447	\$206,447	\$1,447	\$1,447	\$206,447	\$1,447	\$1,447	\$206,447	\$1,447	\$1,447
NPV Membrane	\$520,476											
Fan Power Savings	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000

NPV Power Savings \$245,293

Net NPV Membrane \$275,183

Case 2 - 4 Year Membrane Bag Life

Year	0	1	2	3	4	5	6	7	8	9	10	11
Membrane Bags	\$180,000	\$0	\$0	\$0	\$180,000	\$0	\$0	\$0	\$180,000	\$0	\$0	\$0
Installation	\$25,000	\$0	\$0	\$0	\$25,000	\$0	\$0	\$0	\$25,000	\$0	\$0	\$0
Bag Failures	\$1,080	\$1,080	\$1,080	\$1,080	\$1,080	\$1,080	\$1,080	\$1,080	\$1,080	\$1,080	\$1,080	\$1,080
Total Installed	\$206,080	\$1,080	\$1,080	\$1,080	\$206,080	\$1,080	\$1,080	\$1,080	\$206,080	\$1,080	\$1,080	\$1,080
NPV Membrane	\$407,951											
Fan Power Savings	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000	\$36,000

NPV Power Savings \$245,293

Net NPV Membrane \$162,658

NOTES:

1. Interest rate of 10% (cost of capital)
2. Fan power savings = \$36,000 per year (based on 3" DP reduction)
3. Reverse air bag cost = \$50; 2 year life; 1% bag failure/year; \$15/bag for labor to change
4. Membrane bag cost = \$100; 3 year minimum life; 0.67% bag failure/year; \$20/bag labor to change (Case 1A)
5. Membrane bag cost = \$100; 4 year minimum life; 0.5%/year bag failure; \$20/bag labor to change (Case 1B)
6. No inflation included in bag, installation or labor costs

Fig. 4. - Net Present Value - Bags 2