

BAGHOUSE OPTIMIZATION AT A MEDICAL WASTE INCINERATOR

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ABSTRACT

Phoenix Services, Inc., owns and operates the Baltimore Regional Medical Waste Incinerator in Baltimore, Maryland, USA. New regulations for dioxins and furans imposed emission limits considerably below historical emission levels. Therefore, the company had to consider available technologies for dioxin/furan control. After trials with different technologies, Phoenix Services, Inc., decided to replace their woven fiberglass filter bags with expanded polytetrafluoroethylene (ePTFE) membrane catalytic filters. This new membrane/catalytic filter system collects fine particulate matter on the surface and destroys dioxins and furans in the gas stream. This catalytic filter system offered several key advantages to Phoenix Services, Inc.: 1) destruction of dioxins and furans instead of adsorption on a catalyst surface; 2) no dioxin-filled residue to dispose of; 3) a passive system requiring minimal operating and maintenance attention; 4) no new capital equipment; and 5) a minimal learning curve.

Although Phoenix Services was getting superior PCDD/F reduction with the new membrane/catalytic filters, the supplier of the new filters wanted to optimize the system to make it as cost effective as possible. The system economics were based on an expected filter life of five years, so bags were removed for analysis on a periodic basis to assure this goal would be met. It was also expected that by adjusting the cleaning system, the amount of absorbent material used for acid gas scrubbing would be reduced. While the filter replacement cost represented a significant expenditure at some future date, the scrubbing agent was by far the largest variable expense in the operating budget.

After installation of the ePTFE/catalytic filter system in June 1999, and upon recommendation by the supplier, Phoenix Services refurbished the filter bag cleaning system of the baghouse. This was completed in September 1999. It was immediately noted that the membrane filter media operated with different ΔP characteristics than the glass bags. By October there was a dramatic reduction in scrubbing agent consumption. It became apparent that the reduction was due to decreased filter bag cleaning. The results showed a reduction of more than 20% in adsorbent use.

Further analysis was performed to determine the effect of waste composition on these results. Four years of data were investigated to confirm changes in scrubbing agent consumption. Even though the plastic (high chlorine) fraction of waste continued to increase, there was about a 33% reduction in adsorbent cost. The company saved over \$100,000 in the first year of operation and reduced PCDD/F emissions by an order of magnitude, well within the new regulatory limits.

This paper discusses the actual step-by-step optimization process. The procedures could be useful for process/maintenance/production engineers and/or managers for a Municipal Solid Waste, as well as Medical Waste, Incinerator facility. This paper is aimed at providing actual data from the plant, giving a factual view of new products and their benefits to the plant.

INTRODUCTION

Plant Description

The Baltimore Regional Medical Waste Incinerator processes regulated medical waste and general waste from hospitals and clinics in Baltimore, Maryland, and regulated medical waste from health care institutions throughout the mid-Atlantic area of the United States. The plant, which began commercial operation in January of 1991, is the largest dedicated medical waste incinerator in the world, and is now owned and operated by Phoenix Services, Inc.

The process consists of two identical controlled air-type incineration lines, each with a nominal-processing rate of 85 tons of waste per day. The entire facility is permitted to process up to 150 tons per day. Each incineration line comprises primary, secondary, and tertiary combustion chambers, a heat recovery steam generator, and a dry-injection/fabric filter air pollution control system. A hydraulic pusher feeds waste into the primary

chamber of the incinerator. The primary chamber consists of a series of stepped hearths, each equipped with a hydraulic pusher. A sub-stoichiometric amount of combustion air is delivered continuously through pipes in each hearth, maintaining the temperature in the primary chamber at approximately 1650°F. Over a period of about eight hours, the solids are tumbled down the hearths and reduced to a char. Combustible gases driven off from the pyrolyzed solids are burned with excess air in the secondary chamber, which is maintained at a temperature of approximately 1800°F. Combustion gases are then maintained above 1800°F for an additional one second of retention time in the tertiary chamber. After the tertiary chamber, additional tempering air is added to reduce the gas temperature to approximately 1400°F and the combustion gases then pass into the fire-tube boiler. The tempering air is designed to reduce the combustion gases below the fusion temperature of alkali metal salts that are characteristic in solid waste combustion gases, and that can foul

heat transfer surfaces. Energy recovered as steam in the boiler is delivered to turbine drivers on the induced draft fans, and used to heat the building and water for disinfecting reusable waste shipping containers. Flue gases pass out of the boiler at approximately 525°F and flow into a crossover manifold which enables operating either incinerator with either air pollution control system. Figure 1 gives a schematic of the system.

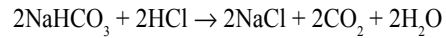
AIR POLLUTION CONTROL SYSTEM

The original air pollution control system consisted of two identical parallel lines. Each line had a conditioning tower, a dry reactor, and a pulse jet fabric filter. The gas leaving the boiler at approximately 500°F was cooled by water quench in the conditioning tower. Dry hydrated lime (Ca(OH)₂) was fed into the reactor. The vessel had a proprietary solids re-circulation system to minimize sorbent usage. The system was designed to meet emission rates for particulate, hydrogen chloride (HCl) and sulfur dioxide (SO₂). Table I gives the system (each of two) summary of the original design parameters.

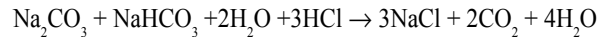
A decision was made to change from hydrated lime to sodium bicarbonate (NaHCO₃) in 1994. The expectation was a reduction in operational problems associated with the lime. Since the reaction of the sodium bicarbonate and the flue gas can occur at a higher temperature, the water quench was also taken out of service. This further helped to simplify the operation. Between the radiant cooling and air in-leakage, the baghouse inlet temperature could still be kept below the 260°C maximum temperature for the filter media.

In 1996 sodium bicarbonate was replaced with trona, a natural sodium sesquicarbonate (Na₂CO₃ • NaHCO₃ • 2H₂O). The reaction of trona with the HCl in the flue gas stream is similar to the reaction of sodium bicarbonate.

Sodium Bicarbonate Reaction:



Trona Reaction:



This switch was based on a lower reagent cost. After more than four years of operation, this decision has proven to be economical and without the complications experienced with the lime.

EMISSIONS STANDARDS

From the beginning Phoenix Services was under stringent emissions standards imposed by the State of Maryland for both criteria and hazardous air pollutants (HAPs). In September 1997, under requirements of Sections 111 and 129 of the Clean Air Act as amended in 1990, the US EPA promulgated new source performance standards and emission guidelines, for new and existing Hospital/Medical/Infectious Waste Incinerators. The most stringent requirements were for those units capable of processing more than 5.5 metric tons of waste per day.

The new emissions limits for particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), and acid gases (HCl and SO₂) were essentially the same as those imposed on the facility by the original operating permit. However, for certain HAPs (lead [Pb], cadmium [Cd], mercury [Hg], and dioxins/furans [PCDD/F]), the new regulations impose concentration-based limits. The previous HAP emissions were based on risk assessment using dispersion modeling to demonstrate an acceptable ambient impact from emissions. The new concentration-based limits were significantly more stringent than the risk-based limits. The results from previous compliance testing indicated that the new metals limits could be met with the existing system. However, the new PCDD/F limit of 2.3 ng TEQ/dscm @ 7% O₂ (1.76 ng TEQ/Nm³ @ 11% O₂) could not be met on a consistent basis.

Baltimore Regional Medical Waste Disposal Facility

PROCESS FLOW DIAGRAM

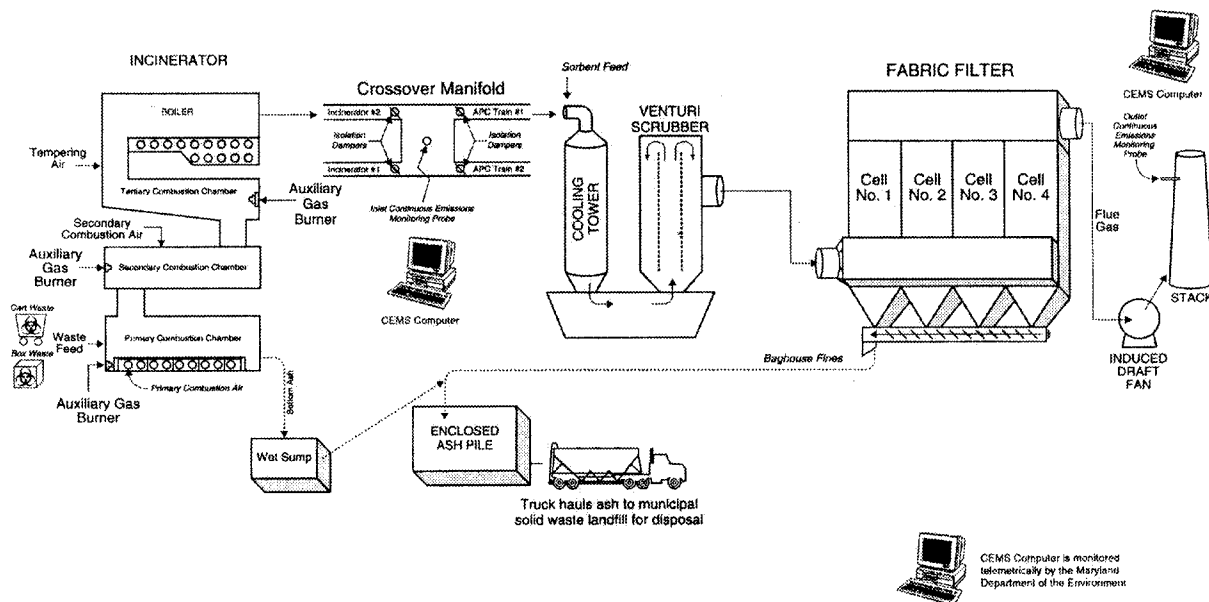


Fig. 1. Plant Configuration for Phoenix Services Medical Waste Incinerator Facility (auxiliary gas inputs are used only for startup and shutdown).

TABLE I
Air Pollution Control System Summary of the Original Design Parameters

Gas Flow – Boiler outlet	43,200 acfm
Gas Temperature – Boiler outlet	500°F
Gas Flow – Baghouse inlet	36,920 acfm @ 285°F
Baghouse Size	
- Bags per module	144
- Total bags	576
- Bag size	6" diameter x 168" long
- Total cloth area	12,667 ft ²
- Gas to cloth ratio (gross)	2.91 ft/min
- Gas to cloth ratio (net)	3.89 ft/min
Emission Rate	
- Particulate	0.015 gr/dscf (corrected to 12% CO ₂)
- HCl	90% reduction or 50 ppmv @ 12%CO ₂
- SO ₂	(3 hour average)
	70% reduction or 40 ppmv @ 12% CO ₂
	(3 hour average)

ALTERNATIVES CONSIDERED

Anticipating the eventual requirement to reduce PCDD/F emissions from the plant, Phoenix had performed trials in late 1995, with both standard powdered activated carbon (PAC) and a proprietary activated carbon product, injected into the flue gas. The results were acceptable for both materials and enabled a target injection rate to be established for future reference.

In late 1996 experiments were conducted with trona injection immediately downstream of the boiler. Along with fly ash, ferric chloride (FeCl₃) is also believed to catalyze *de novo* synthesis of PCDD/F. Ferric chloride is present on mild steel surfaces that have been corroded by hydrogen chloride. Such surfaces were present in the boiler tubes, the inactive water quench vessels, and the interconnecting ducts. There was a possibility that injecting the alkaline sorbent further upstream could reduce the ferric chloride available to catalyze PCDD/F synthesis. While these results did show a significant decrease in PCDD/F emissions, this change alone would not be enough to meet the pending regulations.

In 1997, Phoenix Services, Inc., was introduced to a new filtration media alternative. The concept combined an ePTFE membrane and catalytic felt substrate. The substrate was needle-punched felt made from ePTFE fibers filled with a dioxin/furan destroying catalyst. The catalyst was proven to destroy gaseous PCDD/F at low temperature (356° F – 500° F). PCDD/F molecules diffuse on the catalyst surface and react to form insignificant amounts of CO₂, H₂O and HCl (See Fig. 2). When compared to conventional PAC injection, the new technology offered the following advantages to Phoenix:

- 1) Gas phase PCDD/Fs are destroyed, rather than simply being adsorbed on a solid.
- 2) The system is a passive solution, without the need for a new chemical feed system.
- 3) Conversion to the new technology is simply a matter of rebagging the baghouses.
- 4) Potential future liabilities associated with PCDD/F contaminated solid residues are reduced.

- 5) The system provides the particulate capture, filter pressure drop, and mechanical life advantages of an ePTFE filter media.

Based on a thorough analysis of capital and operating costs, Phoenix Services decided to install the membrane catalytic filter media.

BAGHOUSE OPERATIONS

The catalytic filters were installed in the first and second baghouses in May and June 1999, respectively. From the beginning, the catalytic filter media system gave emission levels of PCDD/F well below the required limits. The baghouse performance, however, did not initially meet the expectations of the supplier. The flange-to-flange pressure drop across the baghouse was higher than expected, often over 12 inches water gauge (inches H₂O w.g.).

The cleaning frequency was also higher than anticipated (approximately 30 minutes at full boiler load). While this pressure drop was considered normal with the previous filter media and had little effect on the plant operations, there was concern over the potential impact this would have on the life of the catalytic filter media.

The supplier made a thorough inspection of the cleaning system and documented all problems. As a result of this survey, suggestions were made on repairs. Over the next several months, Phoenix Services incorporated the suggestions made by the supplier. With these changes, it was possible to adjust the cleaning parameters. The result was a significant reduction in the average differential pressure across the system and less frequent cleaning. It was possible to reduce the pressure drop to below 6 inches w.g. across the fabric or increase the cleaning cycle to about 3 hours. This increased flexibility in the baghouse cleaning cycle made it possible to make other adjustments in the system while maintaining compliance with all emission regulations.

In October 1999, there was a significant drop in the trona used per ton of waste processed compared to the previous month. Phoenix continued to fine-tune the operation over the next several months. The result was a dramatic decrease in trona consumption. Figure 3 Acid Gas Sorbent Usage shows the monthly average ratio from January 1996 until December 2000.

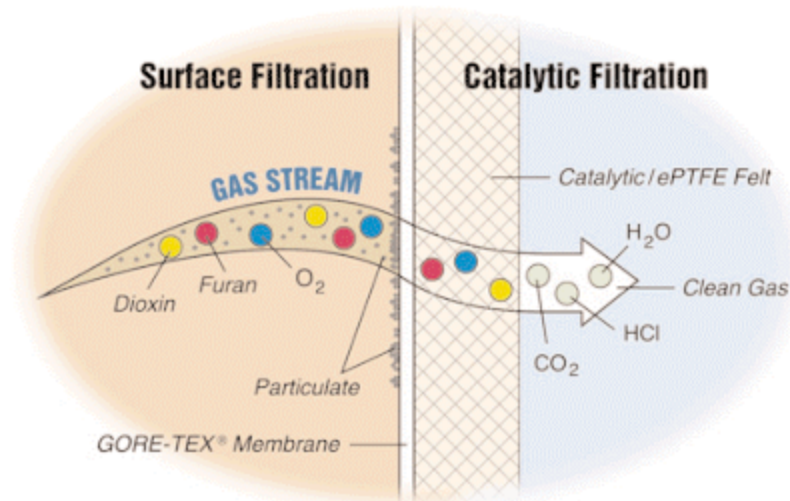


Fig. 2. Cross section of the catalytic filter.

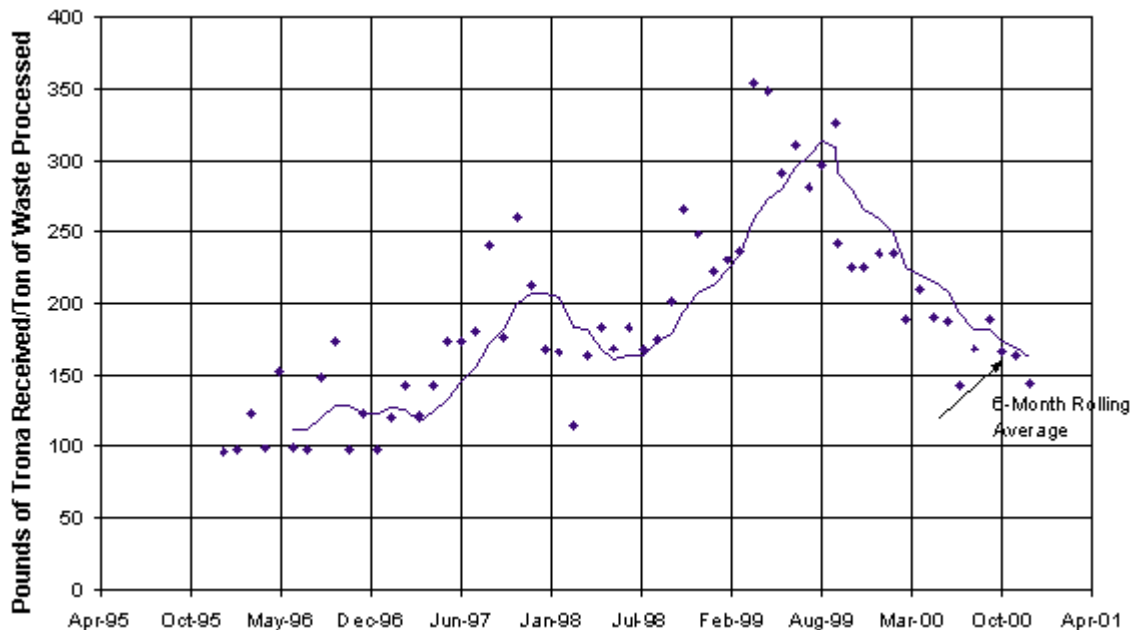


Fig. 3. Acid gas sorbent usage.

Phoenix also compared the amount of “spot” waste treated as a fraction of total waste processed. Typically the plastic content is higher in the spot waste than in the hospital waste and results in elevated HCl in the flue gas. An increase in spot waste would require more reagent to meet emission levels (or removal percentage). Figure 4 shows Trona Consumption Vs Spot Waste Fraction for the period January 1996 through August 2000. Using a linear regression, the trona consumption increased by 440 pounds for each increase of 0.1 in ratio of spot waste to total waste during this time. In a closer examination of the raw data, Phoenix noticed that the spot waste fraction was high during the fall of 1999, while the trona consumption had decreased from historic values.

A separate comparison of trona consumption vs. spot waste for the period January 1996 through September 1999 (Fig. 5) and the period November 1999 through December 2000 (Fig. 6), was made. This clarified the impact the installation and optimization of the membrane/catalytic filters had on trona con-

sumption since it was normalized for the changes in spot waste ratio. Since November 1999 (after tuning the cleaning system), the slope of the regression line decreased significantly. At a spot waste ratio of 0.3, the trona usage dropped from 196 pounds/ton of waste to 154 pounds/ton, or a decrease of 27%. At 0.4 spot waste ratio, the trona usage had decreased by about 47% (from 239 lb/ton to 163 lb/ton). This unexpected result highlighted that the reagent consumption decrease seen since August 1999 (Fig. 3) was more dramatic than previously expected.

It is believed the decrease in trona usage was related to the improved cleaning of the membrane bags. The adjustments to the cleaning cycle enabled sorbent to remain on the bags longer before the cleaning set point was reached. With each cleaning cycle, the spent sorbent would be removed. Less residual cake of alkali salts on the bag surface would result in a lower pressure drop after cleaning than experienced with the fiberglass bags. The membrane filter bags, which cleaned less often consequently required less adsorbent per unit time to provide the same HCL

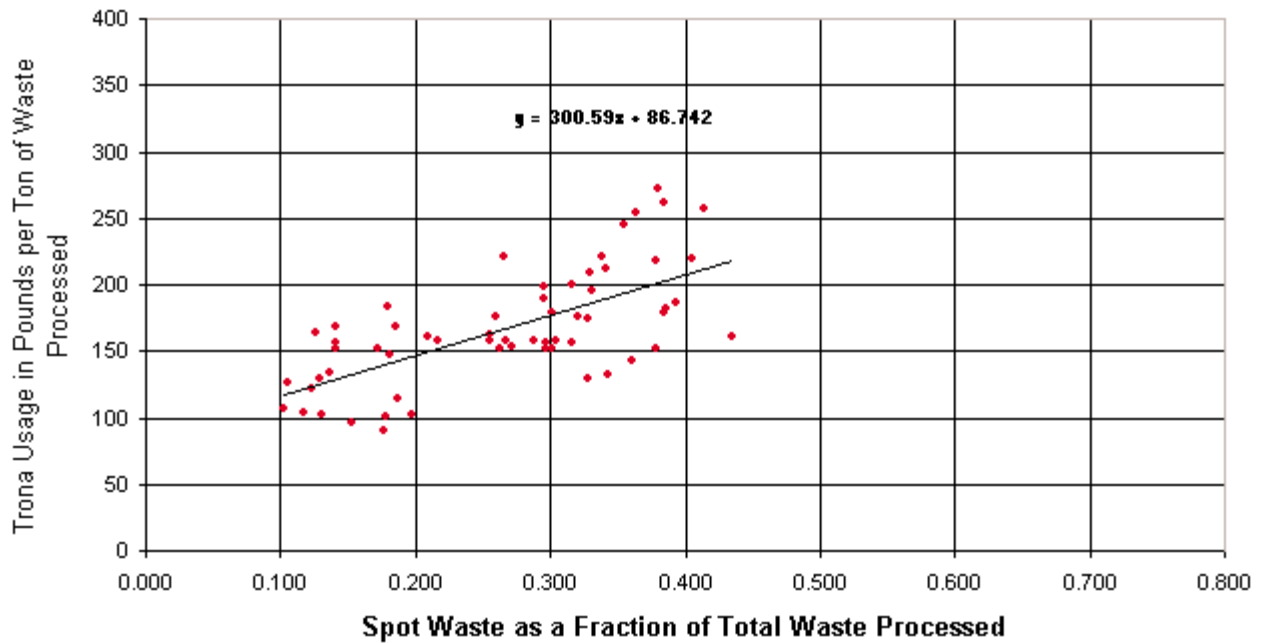


Fig. 4. Trona Consumption vs. Spot Waste Fraction (January 1996 through August 2000).

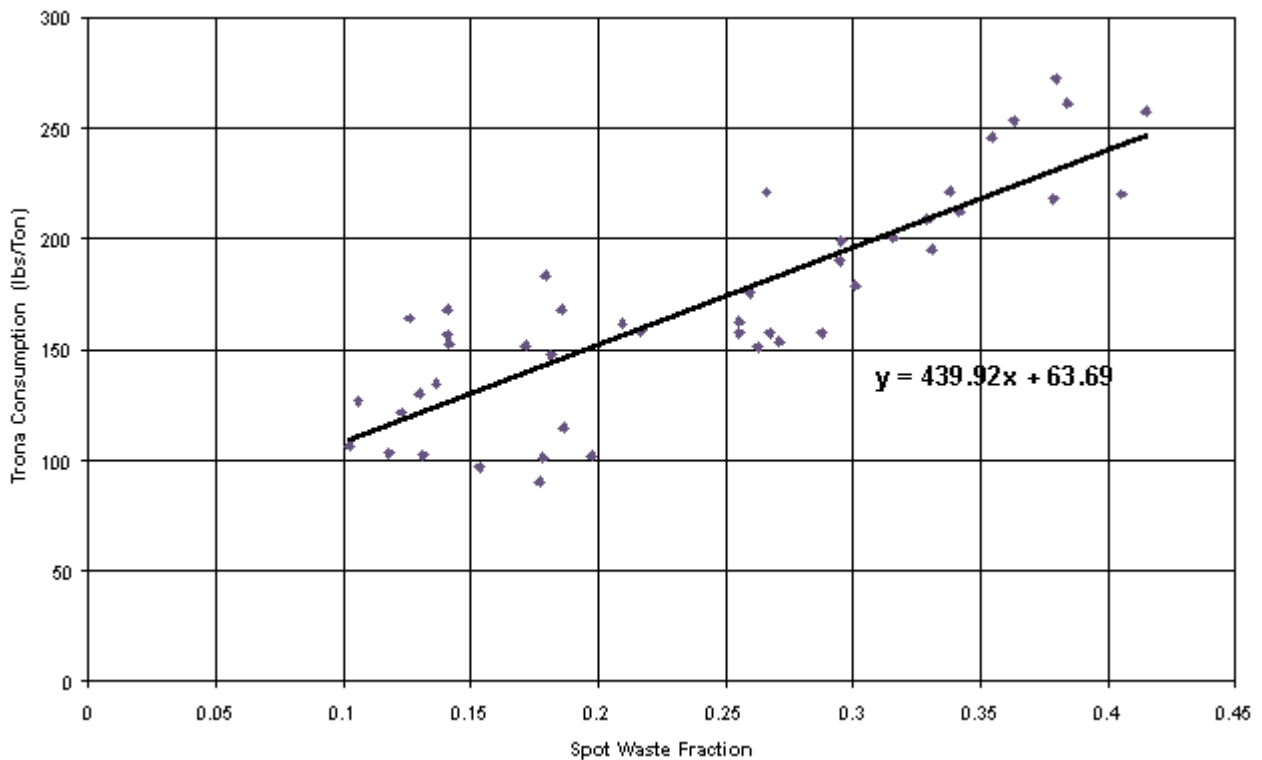


Fig. 5. Trona Consumption vs. Spot Waste Fraction (January 1996 through September 1999).

adsorption. More important, the destruction of PCDD/F and particulate removal would be unaffected since the membrane and catalysts are not dependent on a dust cake for efficiency.

BAGHOUSE OPERATING COSTS

According to the US Environmental Protection Agency cost model, the components of the annual operating cost of a fabric filter include the following:

- Operating and supervisory labor
- Operating materials (i.e., absorbents for acid gas removal)

- Maintenance labor (excluding labor for bag changes)
- Maintenance parts (including filter bags and labor to change bags)
- Power consumption (fan energy and compressed air)
- Dust disposal

With two years of operating data with the ePTFE membrane/catalytic filter media, the major operating cost reduction has been the absorbent usage. In comparing the average cost of trona for the three-year period of 1997 through 1999 with January through August 2000, Phoenix noticed more than a 20%

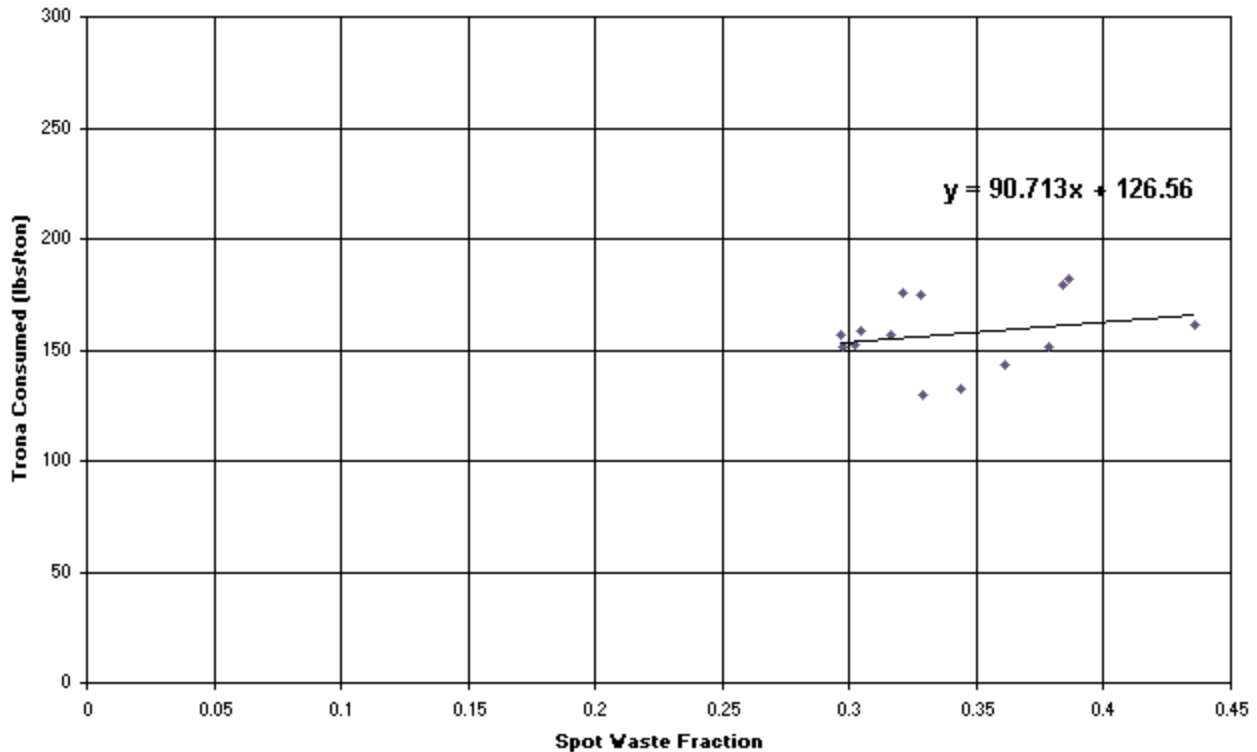


Fig. 6. Trona Consumption vs. Spot Waste Fraction (November 1999 through December 2000).

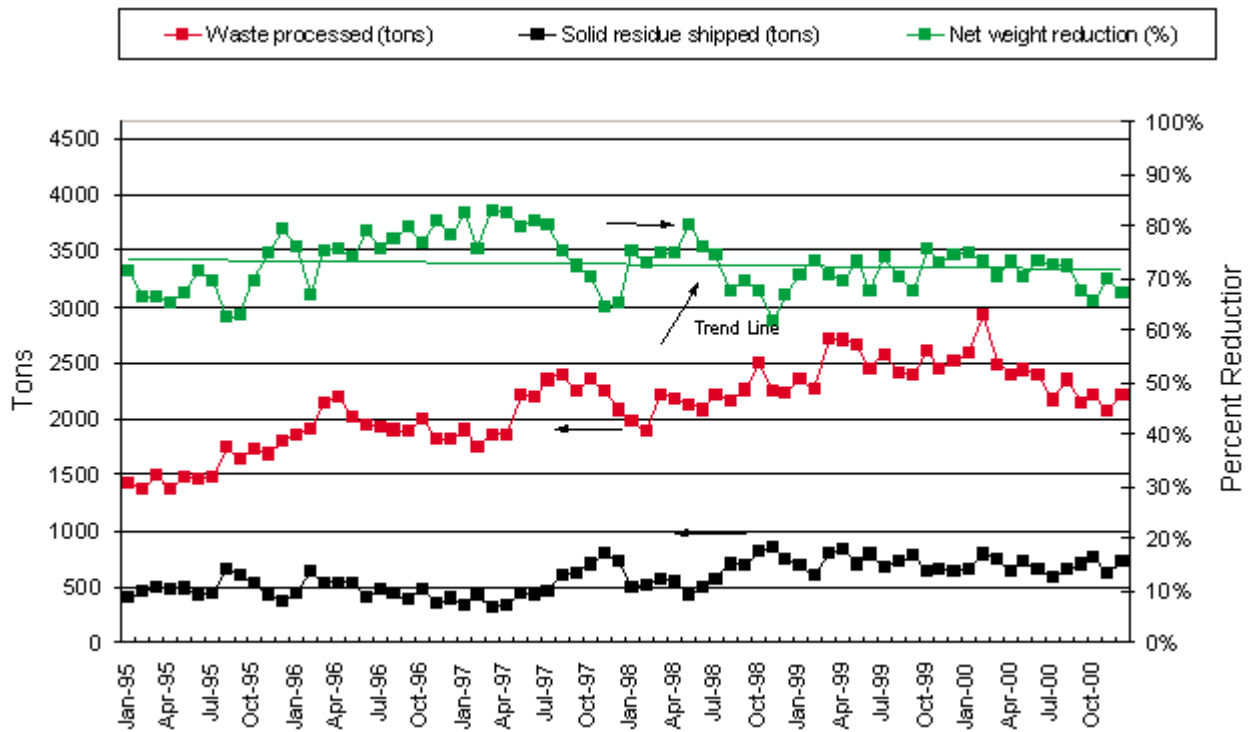


Fig. 7. Solid waste reduction.

decrease in cost. (Note: The average spot waste ratio for 1997 through 1999 was 0.259. It had increased to an average of 0.383 for January to August 2000). The total savings for the year 2000 compared to 1999 was over \$180,000.

In looking at the monthly data, the decrease in trona consumption began about the same time the cleaning system was being optimized. While this work was initially begun to prolong bag life, the saving in trona cost has been a real benefit. Prior to

the adjustments to the cleaning system, the baghouse was cleaned on-line about every 30 minutes (when operating near full boiler load) with an off-line cleaning cycle one to three times per day. The data suggests the reagent was being removed from the bag before it had a chance to completely react with the acid gases. Currently the baghouse is cleaned on-line about every 2 to 3 hours with off-line cleaning once every 18 to 36 hours (depending on plant operation). With a longer cleaning

cycle it is possible to more accurately adjust the reagent feed rate to meet the HCl removal requirements. This results in less overfeeding of reagent to maintain the 3 hour averages for acid gas emissions.

While there may have been other operating savings expected as a result of the improvements to the cleaning system, they are minor in comparison. Even with a seven-fold reduction in pulse cleaning frequency, the savings for any reduction in compressed air consumption would be minimal compared to the reagent cost reduction. Less frequent cleaning should result in longer life for the catalytic filters.

Because the ePTFE membrane catalytic filter system is for PCDD/F control, a direct comparison of bag replacement cost is not appropriate. (Note: The operating cost comparison of a baghouse with a carbon injection system is beyond the scope of this paper). Periodic laboratory analysis of used filters is conducted to check their performance and to predict expected bag life. By identifying potential problems early, the media replacement cost will be in line with expectations.

The amounts of waste processed and the tons of solid residue were similar for 1999 and 2000 (See Fig. 7). Intuitively, with lower reagent usage, there would have been a reduction in the total ash for disposal. The data does not show any trend in ash disposal costs at this time. Most of the residue generated is bottom ash and the moisture content of that can vary significantly. In the case of Phoenix Services, any savings have not been documented and are believed to be minor compared to the reagent cost savings.

CONCLUSIONS

To date the performance of the ePTFE/catalytic filter media system has met all the regulations for PCDD/F emissions. The decision to purchase this technology over other alternative systems was made on the basis of a thorough investigation of capital and expected operating costs. In that evaluation a five-year catalytic filter life was assumed. Based on the laboratory results, the catalytic activity and bag strength are at 100%. With an expected life of five years, the true cost effectiveness will be realized over the next few years.

Aside from the media replacement cost, there were no other tangible differences in the operating cost associated with the baghouse portion of the membrane catalytic system compared to the other alternatives. Even though the reagent consumption was not considered in the initial evaluation of the PCDD/F control technologies, Phoenix Services has realized substantial savings.

The effort to optimize the baghouse operation can lead to significant cost savings while assuring compliance with emission regulations.

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