United States
Environmental Protection
Agency

Municipal Environmental
Research Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-84-146 Oct. 1984

EPA

Project Summary

Sewage Sludge Incinerator Fuel Reduction, Hartford, Connecticut

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A field demonstration project was conducted to reduce fuel consumption in municipal sludge incinerators by using a more fuel-efficient operating mode. The Hartford Metropolitan District Commission in Hartford, Connecticut, demonstrated a new operating mode at its Hartford Water Pollution Control Plant using three conventional multiple-hearth sludge incinerators.

The more fuel-efficient incinerator operating mode was developed from an extensive program of combustion engineering measurement, testing, and operational analysis. Incinerator operators were then given on-the-job training in the new operating mode during a 14-day demonstration test period. After 12 months of routine operations with the new operating mode, a fuel reduction of 51% was achieved, representing an annual fuel cost savings of approximately $250,000.

The Hartford Plant had just completed a conversion of its sludge dewatering equipment from vacuum filters to continuous-belt filter presses when this project was initiated. Average specific fuel consumption had already been reduced by more than 65%. Together, the annual fuel cost savings from dewatering and improved incinerator operations amounted to $1.3 million.

Comparisons of fuel reductions achieved in four major cities by means of new incinerator operating modes are also reported.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The disposal of municipal sewage sludge by incineration most often requires the use of large amounts of auxiliary fuel. Increasing energy costs in recent years have made incinerator fuel consumption a major problem for many municipal operations. To reduce these costs, the Hartford Metropolitan District Commission instituted two major operational changes at its Hartford Water Pollution Control Plant to drastically reduce incinerator fuel consumption. The first step was a conversion to continuous-belt filter presses; and the second was the adoption of a more fuel-efficient operating mode.

The Hartford Plant was one of the first in the United States to convert to continuous-belt filter presses for sludge cake dewatering.This conversion took place between 1979 and 1982 with the installation of four belt filter presses. The conversion to belt filter presses resulted in dramatic fuel savings of 65% and increased solids production.

In late 1981, the Hartford plant engineering staff and incinerator operators adopted a new, more fuel-efficient operating mode with the technical assistance of the Indianapolis Center for Advanced Research. The new incinerator operating mode has been exclusively used in routine operations

since January 1982. The new operating mode resulted in an additional reduction in the specific fuel consumption of 51%.

The combined result of these two major operational changes was an 83% reduction in the incinerator fuel consumption. These results are reviewed here as an example of how improved dewatering equipment and incinerator operating technology offer new options to those municipal operations that are currently bound to sludge disposal by incineration.

Past Operations

The Hartford Water Pollution Control Plant performs primary and secondary wastewater treatment for more than 45 million gallons of wastewater per day and generates in excess of 200 wet tons of filtered sludge cake per day. The sludge-handling facility was originally designed in 1968 with four dissolved-air flotation thickeners, five drum-type vacuum filters, and three multiple-hearth incinerators.

In 1978, before conversion to belt filter presses, the vacuum filters averaged 13.8% cake solids. Production required continuous operation of three of the five vacuum filters, with two of the three incinerators operating around the clock. The plant operation experienced the typical production and maintenance problems associated with handling an extremely wet sludge cake. In addition, the Hartford plant started to receive sludge from satellite plants in East Hartford and Rocky Hill.

The incinerator operations were also plagued with the common operating problems of handling the very wet cake and were consuming large amounts of fuel. The Hartford incinerators (Figure 1) are equipped for either gas or oil operation and have a maximum capacity of 12.5 wet tons per hour. No common operating procedure was being used by the incinerator operators. Each operator had certain practices and techniques for maintaining temperatures on various hearth levels and for managing incinerator airflow. The operators' preoccupation with just burning the very wet sludge cake resulted in many inefficient operating practices such as high exhaust gas temperatures, combustion occurring too high in the furnace, too much draft and auxiliary airflow, misuse of heated-rabble-arm cooling air, and less than optimum burner use patterns. The degree of remote instrumentation and the controls also handicapped operator performance.

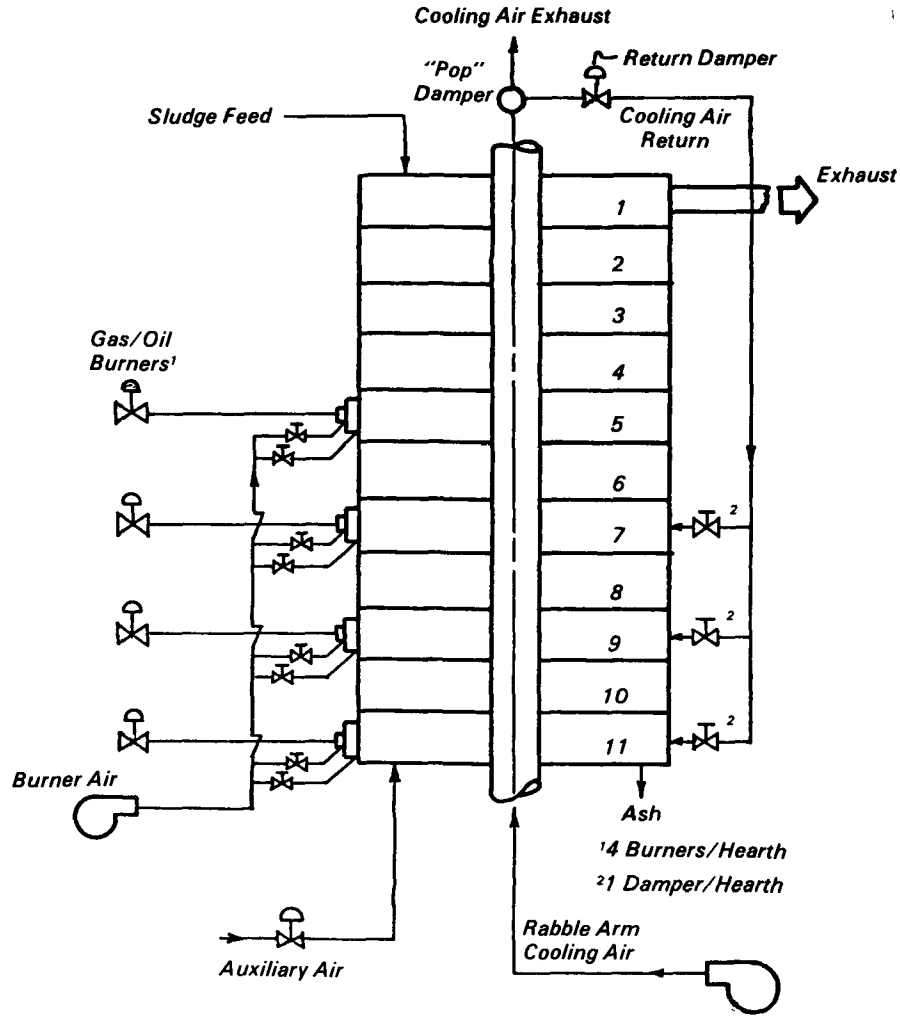

Figure 1. Hartford incinerator system schematic.

In view of these operating problems and the ever-increasing cost of fuel, the Hartford Metropolitan District Commission initiated a major program to find new methods of plant operations and processes to regain control of operating costs. Conversions to the belt filter press and development of the new incinerator operating mode were two of the major projects that were undertaken.

To provide an accurate baseline for comparing the fuel reduction achieved by converting to belt filter presses and in improving the incinerator operating mode, a statistical analysis was made of key operating performance data for past operations during each of the years in which changes were made. In addition, the correlation of specific fuel consumption (measured in gallons of oil per dry ton) with the absolute sludge cake moisture to sludge volatile solids ratio by weight (M/V) was computed to provide a more comprehensive measure of change for comparison.

The average specific fuel consumption for the incinerator operations in 1978 was 125 gallons of oil per dry ton. The sludge cake solids averaged 13.8%, and the volatiles averaged 77.1%. The sludge cake M/V ratio, which is directly related to and principally determines the specific fuel consumption demand, averaged 8.6, which is high.

Belt Filter Press Conversion *Testing and Operational Experience*

Hartford began pilot testing belt filter presses in the spring of 1978. Test results showed that significantly drier sludge cake was produced at higher production rates compared with the performance of

the existing vacuum filters. The plant staff then conducted side-by-side performance tests of the most qualified machines to select the first press for procurement and installation. The first press was installed in 1979 with a carefully monitored start-up and shake-down period. Despite numerous mechanical problems and excessive downtime (25%), the belt filter press quickly proved to be so economically beneficial that the approval for acquiring the second press was granted only 4 months after the first one was installed. The payback period for the first press was only 6 weeks since the savings were $1 million per year.

When the second press was selected, performance tests were again conducted to evaluate overall performance, mechanical design, and maintenance features of the presses to incorporate these requirements in bid specifications. The second press, which was supplied by a different manufacturer from the first, was installed in December 1979, just 8 months after the first one

During the first half of 1980, the Hartford plant operated with two belt presses and one vacuum filter. The mechanical reliability sought with the second press was realized along with continued fuel savings and inprovements in sludge cake production. With this continued operational success, the District purchased a third press from this same supplier and installed it in December 1980. During 1981, the plant was able to operate exclusively with belt presses. A fourth press was placed into operation in June 1982 to increase capacity and operational flexibility by pairing two presses to each operating incinerator.

Since the Hartford plant was one of the first to try the belt filter presses, the early operational experiences were problematic, as expected. The initial press operation suffered from numerous mechanical problems with the bearings, spray water pump, filter screen cleaning, filter screen tracking, and filter screen seam closures. With assistance from the manufacturer, the first press was retrofitted and upgraded for more reliable operation. The second, third, and fourth presses were from a different supplier. They have had few mechanical problems and have been satisfactory in operation.

As more operational experience was gained, improvements were made in several key operating conditions. The filter screen seam closure wearing problem was reduced by using higher-molecular-weight plastic scraper blades, which resulted in an increase in filter screen operating life from an average of 500 hours to an average of 1500 hours. Proper polymer conditioning of the sludge cake on all the presses has been a problem. A two-component liquid polymer mix was developed from experiments with the polymer supplier to reduce the dosage requirements to the same level as that required for the vacuum filters. Changes in the sludge conditioning tank to improve polymer sludge mixing have also helped reduce dosage requirements and increased the flexibility to adjust to varying sludge characteristics. Maintaining a constant blend in the mixing of the raw primary and waste-activated sludges from three plants requires close operator control. Sludge blend variations of only 5% to 10% can cause the press screens to plug and the sludge to squeeze out the ends of the rollers, with a resulting loss in percent solids and production. In spite of these operating problems associated with reducing a new operating technology to routine production line practice, the operational improvements and cost savings achieved with the belt filter presses in Hartford have been dramatic.

Fuel Reduction Results

Figure 2 illustrates the reduction of specific fuel consumption for the Hartford incinerator over the period 1978 through 1981 at the average sludge cake M/V ratio recorded for each year The same information appears in Table 1 along with percent solids and incineration rates.

The savings resulting from the belt filter presses is reflected in the sharp reduction in the sludge cake M/V ratio, particularly in 1980, when the major fuel reduction was achieved. The net reduction of an average of nearly 82 gallons of oil per dry ton would translate into a savings of more than 848,000 gallons of oil at the 1982 dry ton production level of 10,351 dry tons. Coupled with the drastic reduction in fuel consumption, there also occurred a 57% gain in the volatile solids incineration rate per operating equipment hour, which is the key production performance parameter. Furthermore, the average hours of incinerator operation per day also dropped from 46.5 in 1978 to 35.7 in 1981 — a 23% decrease.

New Incinerator Operating Mode

These substantial improvements were accomplished after considerable time and effort were invested by the Hartford plant management, staff, and operating personnel. The experience at Hartford with the belt filter presses serves as an

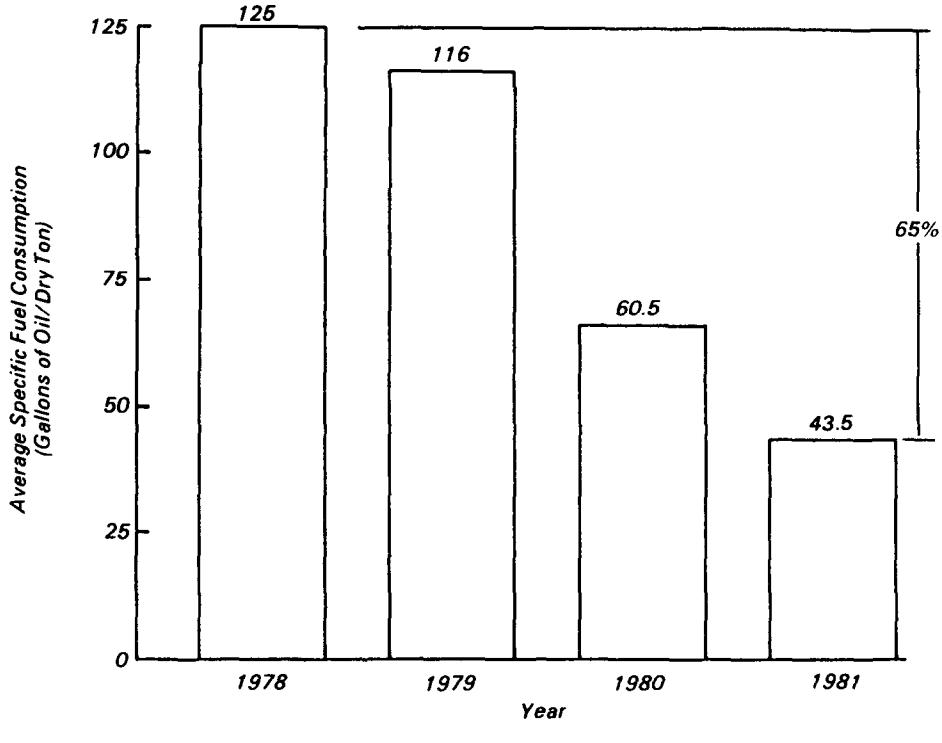

Figure 2. Reduction of specific fuel consumption as a result of conversion to belt filter presses

Table 1. Key Operating Performance Variables for 1978 through 1981

Variable	Year 1978	1979	1980	1981	Percent Change 78-81
Percent solids	13.8	14.5	18.5	19.5	+41
Sludge cake (M/V)	8.6	8.1	5.8	5.4	-37
Fuel consumption (gals/dry ton)	125.2	116.1	60.5	43.5	-65
Incineration rate (volatile tons per incinerator/hr)	0.7	0.7	1.0	1.1	+57

example of the opportunities that exist in many plants throughout the country to achieve internal improvements with the adoption and modification of new operating technologies. At this point, most operations would have been contented with the lower fuel consumption levels that had been achieved. But the dramatic success with the belt filter presses encouraged the Hartford Metropolitan District Commission and staff to pursue other innovative operating technologies to improve their operations further.

One of the technologies adopted was an improved incinerator operating technique that had been developed by the City of Indianapolis Department of Public Works with the Indianapolis Center for Advanced Research (ICFAR) under the sponsorship of the U.S. Environmental Protection Agency (EPA). A more fuel-efficient operating mode was developed for the Hartford incinerator operations from an extensive program of combustion engineering measurement, testing, and operational analysis. The development and testing of the new operating mode was a cooperative effort by the Hartford engineering and operating personnel and combustion engineers from ICFAR. The new operating mode was derived from refined operating technology developed by ICFAR through a major operational research project conducted on the Indianapolis incinerators. On-the-job instruction and training in the use of the new operating mode was also performed to demonstrate the potential fuel reduction and upgrade operator performance.

Operational Testing and Analysis

An operational analysis was made of the Hartford incinerator operations; it included airflow measurements, exhaust gas analysis, assessments of key instrumentation and controls, existing operator-specific practices, load-rate management, incineration and dewatering modes, airflow management, burner use profiles, combustion zone location and control techniques, hearth temperature profiles, etc. A kinetic incinerator analytical model was also used to determine the optimum load rate and plant operating mode that would result in the least possible fuel consumption.

Preliminary analysis of the operator-specific operating modes found several common practices that were contributing to excessive fuel consumption such as: (1) combustion occurring too high in the incinerator, (2) high exhaust gas temperatures, (3) high draft settings and too much auxiliary air, (4) misuse of heated-rabble-arm cooling return air, (5) improper burner use profiles, and (6) improper techniques for controlling the combustion zone location. Also contributing to the high fuel consumption were other problem areas associated with the lack of remote operator controls for airflow dampers and burners.

Results of the airflow measurement were used to help correct problems found in the airflow management approaches being used and to assess the relative impacts of various previously proven techniques on the Hartford incinerator set-up. A preliminary analysis indicated that through optimum airflow management alone, fuel consumption could be reduced 70% with a sludge cake M/V ratio of 5.0 and an incinerator loading rate of 6 wet tons per hour. Furthermore, the kinetic rate analysis for these conditions predicted that the potential fuel consumption for the Hartford operation with such a dry cake was *zero!* This analytical result agreed with the empirically based preliminary estimate drawn from airflow management techniques, since an additional 30% fuel reduction could be reasonably expected from improved combustion zone location control, optimum burner use profiles, improved load rate management, and the synergistic effect of these operating mode techniques on fuel consumption. Based on these results and previous ICFAR experience from similar programs in Indianapolis, Buffalo, and Nashville, periods of autogenous combustion were expected with the new operating mode. Autogenous combustion was achieved several times during the operational trial and demonstration test for as long as 8 hours. During the period when the new operating mode was routinely used, there were many days that no fuel was used for over a 24-hour period.

Based on the operational trial tests and analyses, a new operating mode with specific instructions and operating settings was developed. The new operating mode was then demonstrated in full plant operation for a 2-week performance demonstration. On-the-job operator training in the use of the new mode was also accomplished at the same time. After the successful performance test, the operating mode was further refined for routine operational use.

The new operating mode was characterized by the following general operating guidelines (refer to Figure 1):

- Make maximum use of the heated-rabble-arm cooling air return.
- Use the lowest possible draft to minimize air leakage.
- Maintain combustion on hearth Nos. 7 or 8 to maximize the drying area.
- Replace the cold auxiliary air supply with heated cooling air return.
- Minimize excess air.
- Use lower hearth burners to maximize drying temperature.
- Eliminate airflow to top hearth burners.
- Control combustion location with burner use profile.
- Slow center shaft speed to improve sludge drying.
- Discontinue use of hearth No. 5 burners.

The incinerator operators received specific operating instructions that constituted the new operating mode. These instructions included procedures for sludge load management, operational control of the incinerator, general operating settings, specific settings for normal operations, combustion zone location control, standby and start-up

operations, and techniques to control sludge cake burn-outs. The trial tests indicated that the most effective incineration and dewatering mode was two belt filter presses paired to each operating incinerator. The optimum incinerator loading rate was 6 wet tons per hour per incinerator, based on analysis and trial tests of load rates between 4.5 and 7 wet tons. The 6-ton-per-hour load rate was the lowest rate possible to keep up with the overall plant loading rate and still minimize fuel consumption, considering average sludge cake M/V ratio of 4.5. The improved operating mode also enabled a further reduction in the M/V ratio, because the new mode allowed the presses to be slowed down, resulting in a small increase in cake solids.

Fuel Reduction Results

The new incinerator operating mode was placed into routine operational use directly following the 2-week performance test conducted in January 1982. The new operating mode has now been in routine use by Hartford for more than a year. The 1982 operational data for the Hartford plant were analyzed to measure and compare the fuel reduction achieved. Figure 3 illustrates the computed least squares correlation of the average specific fuel consumption versus the sludge cake M/V ratio for both the baseline period (1978 to 1981) and for 1982, when only the new mode was used.

The improved thermal operating efficiency achieved with the new operating mode is reflected in the change of the slope of the relationship. This result was quite similar to those that occurred in Indianapolis, Nashville, and Buffalo when these operations implemented the ICFAR operating techniques. Figure 4 illustrates the average specific fuel consumption for the Hartford operations from 1978 through 1982. The average specific fuel consumption for 1982 was 21.1 gallons per dry ton compared with 43.5 gallons for 1981 — a 51.1% reduction. With this improvement, the total fuel reduction achieved by Hartford between 1978 and 1982 amount to 104 gallons per dry ton, or 83%. At the 1982 production level, this figure represented a savings of 1.08 million gallons of No. 2 fuel oil compared with 1978.

In addition to reducing direct fuel consumption, the new operating mode provided increased operating flexibility with the equipment, since the incinerators could now be efficiently operated at loading rates of 50 to 60 percent of capacity. Such operation was not possible before without paying a tremendous penalty in excess fuel consumption. For example, compared with past operational averages, the results of the 2-week demonstration test

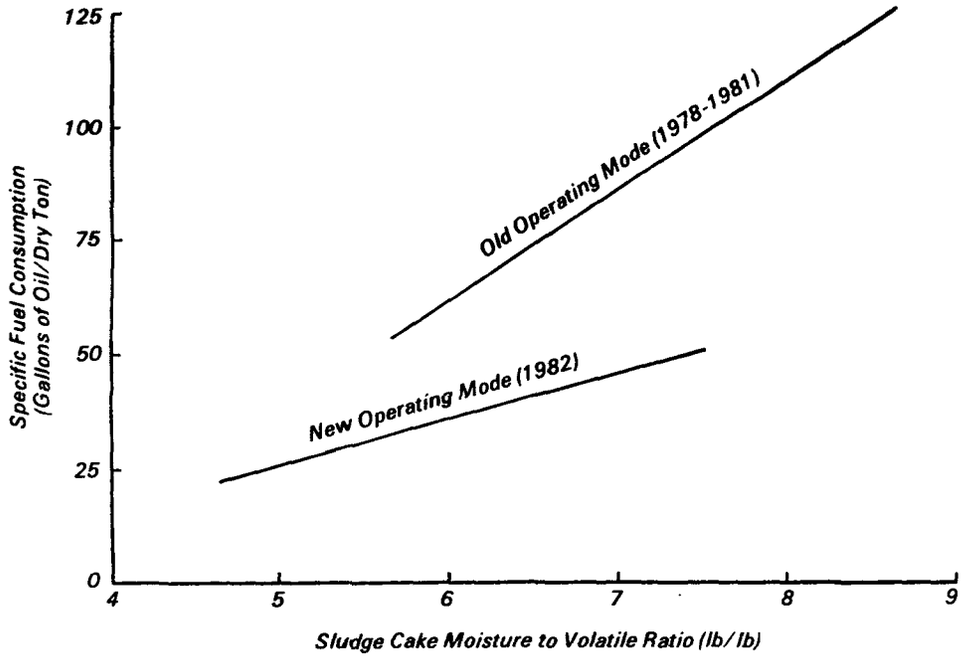

Figure 3. Specific fuel consumption versus sludge cake M/V ratio before and after the change in incinerator operating mode.

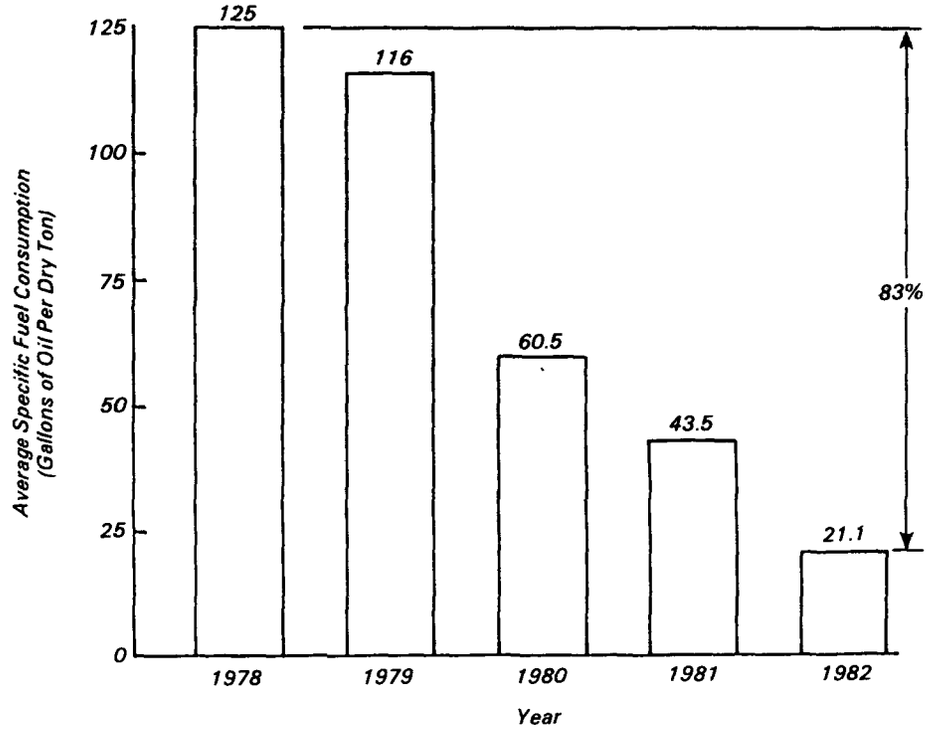

Figure 4. Average specific fuel consumption for 1978 to 1982.

recorded a 76% fuel reduction for the entire test period when the specific fuel consumption was corrected for load rate. Incinerator operation is also now characterized by cooler maximum operating temperature, more steady-state control, fewer particulate emissions, and reduced maintenance on internal incinerator parts.

In spite of the significant fuel reduction achieved with the new operating mode during routine operational use, the Hartford incinerator operation has still further fuel reduction potential to be realized from the new operating mode. Several equipment-related conditions are currently limiting further gains. The most critical of these has to do with the inadequacy of the original rabble-arm raking pattern. The latter was originally set up for a wetter sludge cake (M/V = 8.6) than the current average sludge cake (M/V = 4.5). The drier cake commands a far different number of rabble teeth, depending on the hearth being considered. During the operational tests, an uneven-sludge-distribution problem was encountered several times. A distorted burning pattern resulted, with sludge combustion occurring on three hearths simultaneously and uneven burning taking place on one side of these hearths. This condition also creates an increase in incinerator burn-outs, in which dry sludge cake gets to a point of uncontrollable autogenous combustion and the incinerator steady state thermal equilibrium is lost in the process. Plans are under way to adjust the rabbling pattern for the drier sludge cake. To a smaller extent, some improvement in the instrumentation and remote operating controls would also permit improved operator performance.

Cost Savings

The nominal cost savings from reducing incinerator fuel consumption on an annual basis was estimated from the change in the specific fuel consumption from 125 to 21 gallons of oil per dry ton. Based on the 1982 production of 10,351 dry tons, the savings would be more than $1.08 million per year using an estimated cost of $1.00 per gallon for No. 2 fuel oil.

In addition to the incinerator fuel savings, other energy savings were realized from the belt filter press conversion. Since the plant started up in 1972, the activated sludge mixed liquor suspended solids (MLSS) level to a more desirable 2,000-mg/L range. The resulting decrease in the dissolved oxygen demand reduced the daily air usage to about 55 million ft^3 per day. This reduction in turn reduced the electrical energy requirements of a 3,000-hp air compressor by 20%, which amounted to a $200,000-per-year savings on electricity costs. Also, each vacuum filter had a 71.5-hp requirement, as opposed to 22 hp for each belt press. This reduction in electrical use resulted in an estimated savings of $25,000 per year. Together, these additional savings totaled more than $231,000 per year.

The total operating costs saved by converting to belt filter presses and the new incinerator operating mode is estimated to be more than $1.3 million per year.

Conclusions

1. Fuel consumption in multiple-hearth incinerators can be significantly reduced by improving dewatering equipment and by optimizing existing incinerator operating modes with more fuel-efficient operating techniques.

2. A conversion from vacuum filters to continuous belt filter presses resulted in a 65% fuel reduction.

3. The use of a new incinerator operating mode in routine operations achieved an additional 51% fuel reduction and a reduction in equipment maintenance problems.

4. Reduction in fuel use from dewatering and incinerator operating improvements resulted in annual cost savings of approximately $1.3 million.

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The full report was submitted in fulfillment of Contract No. 68-02-3169 by Battelle Columbus Laboratories under the sponsorship of the U.S. Environmental Protection Agency.

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The complete report, entitled "Sewage Sludge Incinerator Fuel Reduction, Hartford, Connecticut," (Order No. PB 84-243 096; Cost: $10.00, subject to change) will be available only from:
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