WASTE TIRE CO-FIRING FOR INCREASED WINTER STEAM PRODUCTION IN HARFORD COUNTY RESOURCE RECOVERY FACILITY

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ABSTRACT

The HCRRF is a cogeneration facility. It features four modular two-stage combustors, three boilers and one turbine generator set. The installed capacities are 360 STPD₇ for MSW incineration, 165,000 lb/hr of steam recovery and 1.2 MW of power generation. The latter allows the use of excess steam mostly during the summer for electrical generation. In accordance with permit limitations, the HCRRF can co-fire waste tires at rates up to about 10% by weight in order to boost its unit steam output.

The HCRRF is connected to the U.S. Army's Edgewood Arsenal by means of a 15,000-ft long pipeline. Up to 125,000 lb/hr of saturated steam (at 360 psia) can be delivered to the U.S. Army for district heating and cooling purposes. Since the Army needs about twice as much steam during the winter as in the summer, waste tires are exclusively co-fired during the winter season.

Besides furnishing descriptions of the facility and their operations, a multi-year consecutive data base was analyzed. Major performance parameters were established in order to compare the results of winter and summer operations. These results were then assessed in terms of the guarantees stipulated in the Service Agreement.

The stability of the performance parameters was checked with regard to forecasting. Curve fit procedures were the method of choice. Most importantly, measurable effects were investigated which could be ascribed to waste tire burning.

INTRODUCTION

How to dispose of waste tires is a problem which is faced by many municipalities. Harford County in Northeastern Maryland tackled this problem in a unique way. Its landfill had an inventory of millions of tires. When a fire broke out, it was difficult to subdue and it created a public nuisance.

In late 1986, plans were being made for the Harford County Resource Recovery Facility (HCRRF). The idea was to build a "medium-tech" facility which could burn the County's trash and recover steam for sale to the U.S. Army. The logical site was the Edgewood Arsenal, where the Army operated a district heating network.

As the Army's steam records were being examined, it was determined that winter demand was about twice that of summer demand. The reason was that not enough air conditioning was done with absorption chillers. Because of this lopsidedness, there was interest in finding a low-cost supplemental fuel which could spike steam generation during the winter. By considering waste tires for this purpose, the opportunity pre-

sented itself to solve a waste disposal and an energy management problem simultaneously.

The facility's owner and operator, Consumat Systems, Inc. (CSI), had prior experience with co-firing waste tires (WT) with regular municipal solid waste (MSW). This experience helped to convince the Northeast Maryland Waste Disposal Authority (the project sponsor) to agree with such a concept.

In fact, it was decided to actually "mine" all waste tires from the landfill and transport them to HCRRF. This approach offered two advantages:

(a) The landfill would act as a buffer between the collection, storage and burning of tires.

(b) The inventory of old tires would gradually be reduced.

The first advantage would facilitate the seasonal burning of tires while the second would reclaim valuable landfill space.

Now that three winter seasons of tire co-firing have successfully been completed, it is appropriate to evaluate major performance parameters. It is the scope of this paper to compare winter performance with summer performance. What are the effects of the tires on steam recovery, electrical power demand and ash generation? Were emissions maintained within legal limits? Did the tires adversely affect equipment availability and utilization? The fact that old and dirty tires are removed from a landfill has led to some special observations which will also be discussed in the paper.

DISCUSSION

Project History

The Harford County Resource Recovery Facility (HCRRF) is situated on the west side of the U.S. Army's Edgewood Arsenal at Joppa, Maryland. Figure 1 shows a reference map. This location is far away from the County's waste centroid, a choice which was dictated by the fact that the U.S. Army was the only suitable energy user.

The project was developed by the Northeast Maryland Waste Disposal Authority (NEM) through a competitive procurement process. Issued in July 1983, the final procurement document called for a 20-year full service proposal which included ownership and operation. Two companies, i.e., Consumat Systems, Inc. (CSI) and Vicon Recovery Systems, Inc. (VRS) had previously been qualified to respond.

During subsequent competitive negotiations, CSI emerged as the winner. Although the original technical specification did not call for the co-firing of MSW and WT, this requirement was incorporated into the Service

Agreement. The latter was concluded on April 15, 1986.

Accordingly, the term "Acceptable Waste", or AW, was broadened to ". . . include bulk loads of tires delivered to the Facility . . . provided that the maximum diameter of any tire so delivered should not exceed forty (40) inches . . ."

The intent was to provide the County with a method by which its waste tire stock pile cold be removed from the landfill. But rather than simply disposing of these in some way, they were to be used as a premium fuel to kick up steam production during periods of the year when the Army needed it most. Thus, the plant operator was to have combustion equipment which would tolerate the co-firing of MSW and WT without preprocessing.

In Schedule 2 of the Service Agreement, a "Monthly Tire Obligation and Stabilization Fund" was stipulated. The terms of this obligation called for CSI to process 600 ST of tires per month during the period from November to January. Thus, a total of 1800 ST of tires were to be processed during this three month period. The same terms specified that these tires were ". . . not to be mounted on metal rims and be reasonably free from foreign materials . . ."

Furthermore, a portion of the steam revenues earned from the burning of tires was to be put into a Stabilization Fund to be owned by the County. The remainder was to be retained by CSI. A "Tire Steam Conversion Factor" of 12,000 lb of steam generated per ST of tires burned was to be used for determining the "Monthly Tire Steam Obligation."

The two-stage combustion technology developed by Consumat Systems, Inc. (CSI) was the technology of choice. CSI built the Facility during the July 1986/ December 1987 period. Commercial operation started on January 20th, 1988.

During the ensuing years, waste generation in Harford County grew more than expected. As a result, some of the waste stream is bypassing the HCRRF today. In order to conserve valuable landfill space, NEM is planning to expand the Facility by adding a materials recovery facility as well as a new furnace and a new boiler. Efforts are now under way to increase steam sales to the Army.

Facility Description

In the HCRRF, four identical furnaces are installed, each with a unit waste burning capacity of 90 $STPD_7$ (short tons per day on a 7 day a week basis) (at 100% MCR). The waste input consists typically of 340 $STPD_7$ of so-called "inspected waste" (IW) and 20 $STPD_7$ of
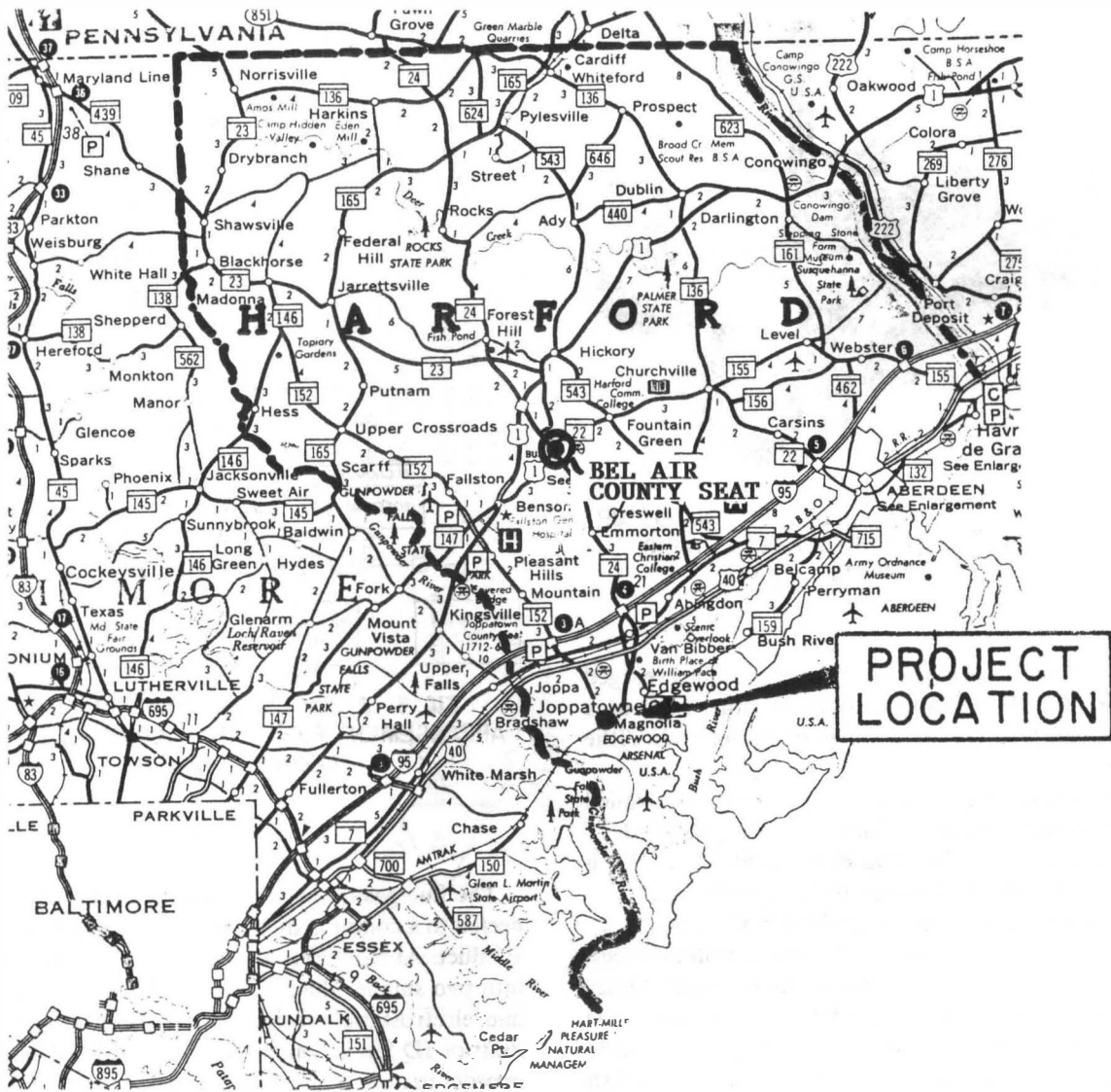
FIG. 1   REFERENCE MAP FOR LOCATION OF HARFORD COUNTY RESOURCE RECOVERY FACILITY

tire waste (TW) mixed in. Inspected waste means trash which is dumped on the tipping floor by packer or container trucks and from which inspectors remove objectionable materials such as oversized tree logs and wood products, large automobile and machinery parts, liquid wastes, etc.

Since most—if not all—the waste tires originate in the landfill, they are delivered to the HCRRF. In addition, some of them are still mounted on their wheel rims. Thus, waste tires are simply dumped on the tipping floor in their "as-received" condition. In this connection, it must be emphasized that there is no preprocessing of these tires at all. Consequently, they are burned as whole tires no matter what condition they are in.

Front loaders are used for building separate stockpiles of IW and TW. Since there are no provisions for weighing individual loads, the front loader operators work along volumetric principles. Accordingly, they pick a given number of scoops from the inspected waste pile, followed by a single scoop from the tire pile. Illuminated displays next to the furnace charge boxes alert the front loader operator when another load is needed.

While experienced operators manage this procedure rather well, the only accurate weight information comes from the scale house. The latter cannot readily be equated with the "number of scoops." Therefore, this type of information is only accurate insofar as it concerns inventory on the tipping floor. It does not directly relate to individual loads charged.

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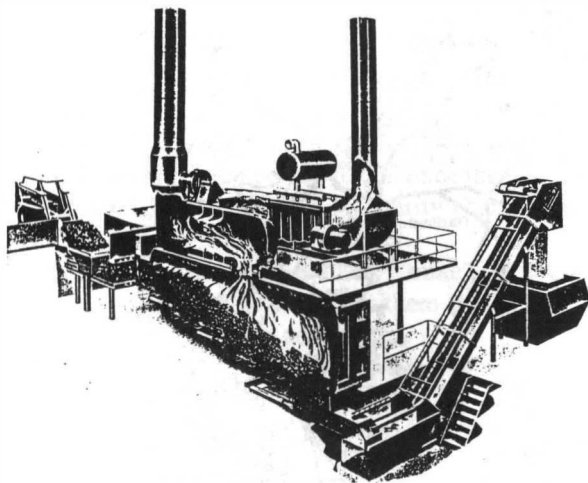
FIG. 2 TWO-STAGE CONTROLLED AIR COMBUSTOR
IN HARFORD COUNTY RESOURCE RECOVERY
FACILITY

FIG. 3 BLOCK DIAGRAM FOR EQUIPMENT
ARRANGEMENT FOR HARFORD COUNTY RESOURCE
RECOVERY FACILITY

As a result, operating and test data must be averaged and/or totaled over long periods of time, such as a month, before it can be depended on for analysis in the data base.
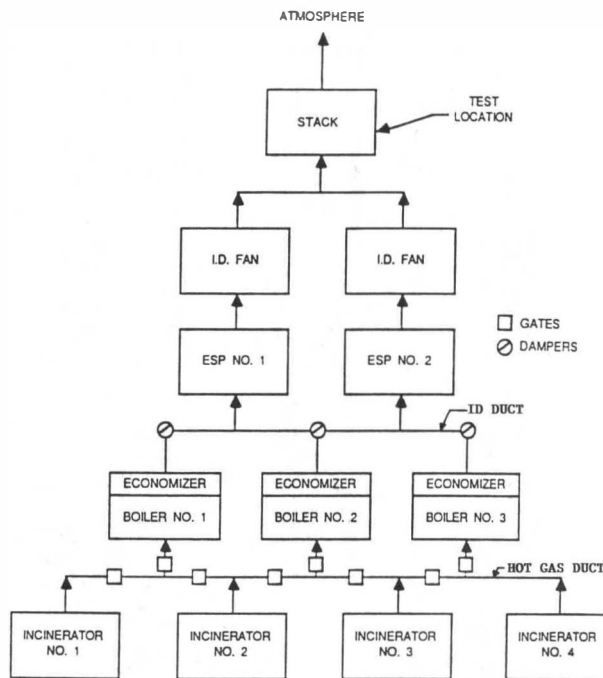
The furnaces are based on the two-stage controlled air combustion process which has been installed by Consumat in more than two dozen facilities in North America. Figure 2 illustrates this principle.

In the first stage, waste is gasified with only a minimum of air present. Compared to water wall furnaces, the waste retention time is considerably longer. Other than being dropped gradually from one hearth to the next, the waste particles remain stationary. This feature results in low particulate loads leaving the furnace. Ash is pushed off the last hearth into a quench tank which also acts as a liquid seal.

The gas/vapor stream from the first stage rises into the second stage, which is called the upper chamber (UC). Here, excess air is admitted in order to complete the combustion process.

All flue gas outlets from all furnace UCs are manifolded into a single "hot gas duct." Each furnace can be taken off the manifold by means of isolation gates without affecting any of the others. For details, refer to Fig. 3.

Three identical boilers are installed for the production of saturated steam at 365 psia. Each boiler has a nameplate capacity for 55,000 lb/hr for a facility total of 165,000 lb/hr. The flue gas inlets and outlets to the boilers are controlled by isolation gates. Thus, any one boiler can be taken down for service without interfering with the operation of the others.

The flue gas outlets from the three boilers are connected to a common duct called the "induced draft" or ID duct. At the end of the building, the ID duct splits into two smaller ducts, each of which is connected to one electrostatic precipitator, or ESP. One induced draft or ID fan is connected to the outlet of each ESP in order to push cleaned flue gas into a common exhaust stack. The ESPs are of four-field construction, however, initially only three fields are installed. The fourth field is reserved for facility expansion. The ID fans have two-speed motors, the higher speed of which is intended mostly for periods of waste tire co-firing.

The energy management system in the HCRRF is described by the simplified flow schematic in Fig. 4. After satisfying the steam demand of the pipeline leading to the Army's district heating network (DHN), the remainder can be directed to either one or all of three potential uses: (a) the boiler feed pump turbine, (b) the turbine generator set, and/or (c) the deaerator feedwater heater. Since both turbines are of the back-pressure type, their exhaust steam can also be dumped into the deaerator. Various steam vents are provided for safety purposes. Since no two-way switch gear was furnished, the turbine generator output must always be kept well below the facility's in-plant needs. Therefore, de-
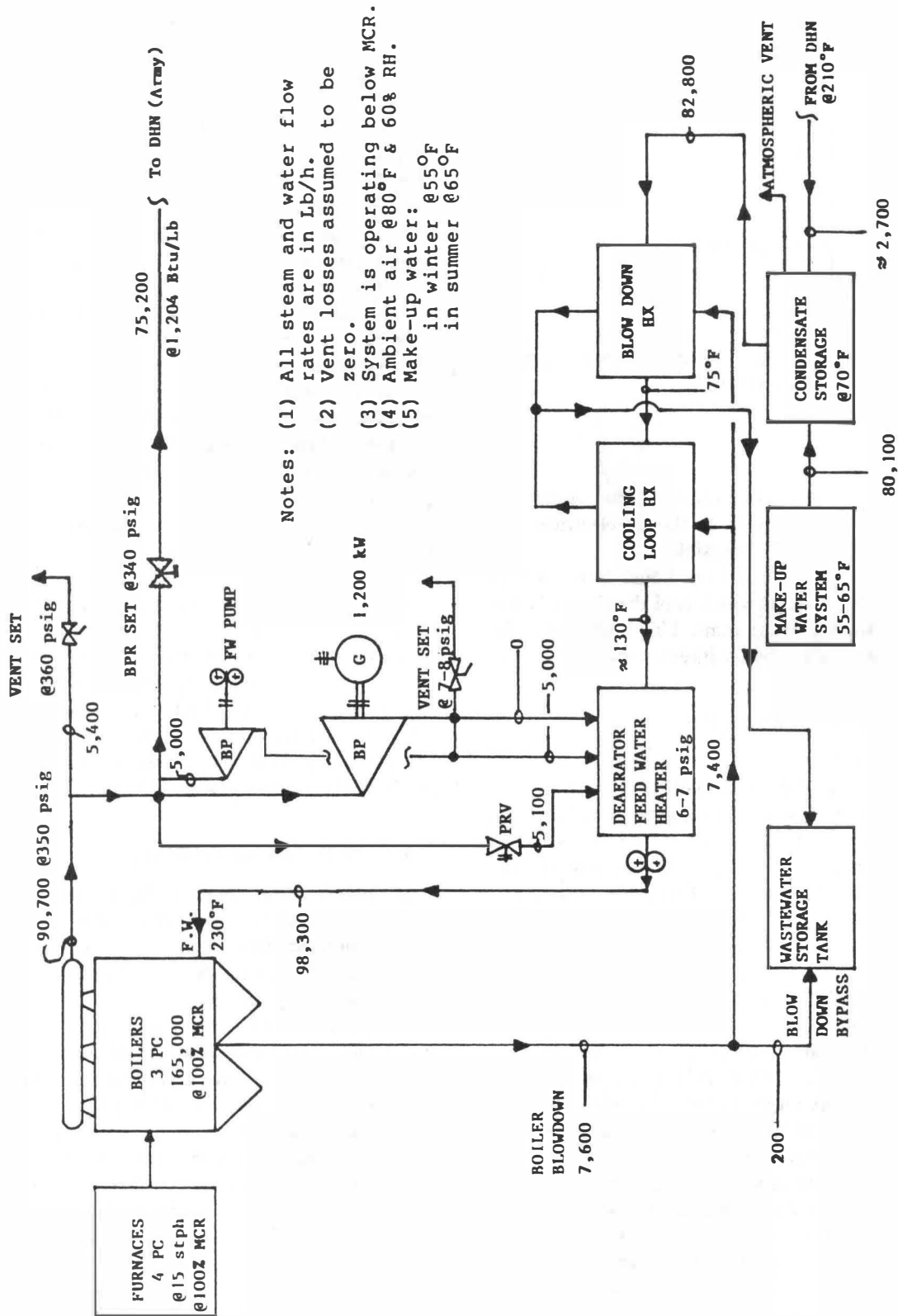
FIG. 4 SIMPLIFIED FLOW SCHEMATIC FOR HARFORD COUNTY RESOURCE RECOVERY FACILITY
(Installed Capacity @HHV = 5400 Btu/lb for 340 STPD₇ + 20 STPD Tires = 360 STPD₇)
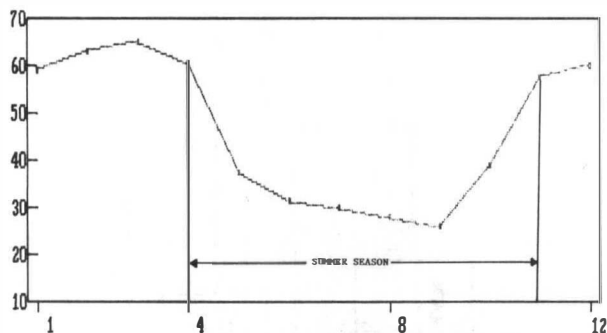
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FIG. 5 AVERAGE ARMY STEAM PURCHASE PROFILE
FROM HARFORD COUNTY RESOURCE RECOVERY
FACILITY

pending on operating conditions, excess steam may need to be blown off as well. In theory, electrical production up to 1000 kW is possible.

Waste heat is recovered from boiler blowdown as well as from the systems which cool the charge boxes, the furnace walls and the rams. This heat is used for heating make-up water before its entry to the deaerator.

Data Base and Performance Parameters

The plant operator furnishes a monthly report which contains—among other things—the following: *(a)* acceptable waste burned, *(b)* steam generated, *(c)* steam sold, *(d)* ash produced, *(e)* electricity generated and *(f)* equipment downtime. The reporting period used is the calendar month. The amount of electricity purchased from the utility is obtained separately from monthly invoices. However, since these invoices are not composed on a calendar month basis, a procedure was developed for converting all pertinent utility data to the same consistent monthly format.

The average steam purchase profile of the Army is shown in Fig. 5. The difference in winter and summer purchases is rather large. In fact, the winter average typically is 1.9 times larger than the summer average.

All data was entered into a Lotus type spread sheet in order to calculate monthly balances for steam and electricity. The spread sheet was organized in a manner which permitted the creation of clones, i.e., one for the summer seasons and one for the winter seasons. This was done to facilitate the comparison of performance during tire co-firing periods with performance during periods when only inspected waste was fired.

For the analysis of facility performance, several performance parameters were found to be useful. These included availability factors, utilization factors, load factors and plant capacity factors. The descriptive terminology was borrowed from the North American Electric Reliability Council and adapted to the HCRRF [1]. Previous applications of the adapted terminology were already discussed in other papers [2, 3]. Detailed definitions may be found in Table 1. Since there are different unit numbers of furnaces and boilers and each unit can be isolated from the others, it was appropriate to calculate these performance factors separately for the furnaces and boilers.

Other performance parameters which were calculated involved the upper chamber temperature, the specific ash rate, the specific steaming rate, the specific electric rate and the specific reject rate. After all computations were completed for 42 consecutive months, i.e., the lifetime of the facility, the computer was directed to calculate lifetime totals. The results are shown in Table 2.

Afterwards, the computer was directed to disregard the first six operating months and calculate the performance parameters for the next 36 months. This was done in order to exclude any bias by having more entries during one season than the other. Also, it appeared that plant operations stabilized at the end of the initial period. Thus, 18 winter months and 18 summer months remained in the analysis. In Table 3, the seasonal results are compared for each observation year. In addition, the winter and summer parameters are presented for all three observation years combined.

Results of Performance Analysis

In Table 2, totals are presented for major operating parameters such as waste burned, ash produced and steam generated. From these totals, compliance can be determined by CSI with the respective guarantees made in the Service Agreement.

The guarantee for processing acceptable waste during any given year was set at a minimum of 81,045 ST. During actual operations, CSI exceeded this guarantee by about 43%. Since tires were included as part of acceptable waste, it is safe to conclude that their presence did not adversely affect attainment of the tonnage guarantee. The guaranteed conversion factor for steam from the burning of acceptable waste was 4400 lb steam/ST-AW. However, in actuality CSI delivered 21% more steam. The Tire Steam Conversion was guaranteed by CSI at 12,000 lb steam/St-TW. With 12% more steam, CSI surpassed this guarantee as well.

In addition to the above, CSI had made a Residue Generation Guarantee which limited ash output to 0.450 ST Ash/ST-AW. In practice, CSI came to within 97.4% of this limit. There is evidence that the burning

TABLE 1 DEFINITION OF AVERAGE PERFORMANCE PARAMETERS FOR HARFORD COUNTY RESOURCE RECOVERY FACILITY

Parameter	Abbreviation	Formula	Explanation
Tire Ratio [ST/ST]	TR	$\dfrac{AWB}{RWB}$	with AWB=acceptable waste burnt during reporting period (Note: AWB includes MSW and waste tires) RWB=rubber waste burnt during reporting period (Note: RWB includes regular rubber component in MSW as well as waste tire deliveries)
Availability Factor for Grates or Furnaces [h/h]	AFg	$\dfrac{ha1 + ha2 + ha3 + ha4}{n \times hc}$	with ha1,2,3,4=hours of available time per unit during reporting period hc=hours of calendar time during reporting period n=number of grates or furnaces installed=4
Utilization Factor for Grates or Furnaces [h/h]	UFg	$\dfrac{ho1 + ho2 + ho3 + ho4}{n \times hc}$	with ho1,2,3,4=hours of operating time per unit during reporting period
Load Factor for Grates or Furnaces [ST/ST]	LFg	$\dfrac{W1 + W2 + W3 + W4}{n \times ho \times Cgh}$	with W1,2,3,4=waste tonnage burnt per unit during reporting period Cgh=unit waste burning capacity=3.75[stph] and ho=ho1 + ho2 + ho3 + ho4
Plant Capacity Factor for Grates or Furnaces [dimensionless]	PCFg	$\dfrac{W1 + W2 + W3 + W4}{n \times hc \times Cgh}$ and PCFg=UFg x LFg	
Availability Factor for Boilers [h/h]	AFb	$\dfrac{ha1 + ha2 + ha3}{n \times hc}$	with n=number of boilers installed=3
Utilization Factor for Boilers [h/h]	UFb	$\dfrac{ho1 + ho2 + ho3}{n \times hc}$	
Load Factor for Boilers [Lb/Lb]	LFb	$\dfrac{S1 + S2 + S3}{n \times ho \times Sgh}$	with S1,2,3=steam generated per unit during reporting period in [Lb] Sgh=unit steaming rate=55,000 [Lb/h] and ho=ho1 + ho2 + ho3
Plant Capacity Factor for Boilers [dimensionless]	PCFb	$\dfrac{S1 + S2 + S3}{n \times hc \times Sgh}$ = UFb x LFb	
Specific Ash Rate [ST/ST]	SAR	$\dfrac{A}{W}$	with A=ash tonnage removed during reporting period W=waste tonnage burnt during reporting period
Gross Specific Steaming Rate [Lb/Lb]	G-SSR	$\dfrac{S}{W \times 2,000}$	with S=total steam produced during reporting period
Army Specific Steaming Rate [Lb steam/ST waste]	A-SSR	$\dfrac{SP}{W}$	with SP=total steam purchased by Army during observation period
Specific Electric Rate [kWh/ST]	SER	$\dfrac{E}{W}$	with E=total electricity consumed during observation period
Specific Rejects Rate [ST/ST]	SRR	$\dfrac{R}{W}$	with R=rejects tonnage during observation period

Parameter	Units	Totals
Trash Received	ST	389,300
Rejects Removed to Landfill	ST	1,678
Total Waste Accepted	ST	387,622
Tires Received	ST	17,717
Total Waste Burnt	ST	405,339
Ash Removed to Landfill	ST	177,697
Ash from Tire Burning	ST	17,712
Steam Produced from All Waste	x10^6 Lb	2,126
Steam Produced from Tire Waste	x10^6 Lb	241
Steam Sold to Army	x10^6 Lb	1,989
Steam Used in Turbines (1)	x10^6 Lb	505
Electricity Purchased	MWh	13,197
Electricity Generated (2)	MWh	6,147
Electricity Consumed (2)	MWh	19,344
Equivalent Fuel Savings (6)(3)	bbl	473,176
Facility Operating Time (4)	hrs	30,168
Furnace Operating Time (5)	hrs	116,112
Boiler Operating Time (6)	hrs	85,133

Notes: (1) Includes estimates of steam used by feedwater pump
turbine drive
(2) Includes electrical energy equivalent of steam
consumption by feedwater pump turbine drive
(3) Primary energy required for incinerating waste and
generating steam for district heating, expressed in
equivelant barrels of #2 oil
(4) Jan 1988 was start-up month with only 10 operating days
(5) Aggregate for 4 units
(6) Aggregate for 3 units

of tires tends to boost the rate at which ash is generated. In fact, in Table 2 the totals for tires received and ash generated from tires are equal, i.e., one ST of tires burned also results in one ST of ash to be disposed of. This apparent paradox is discussed further under specific ash rate below. (Note: The differential ash rates for MSW and tires are calculated and not measured values.) However, since ash disposal in the County's landfill is an expense item, it is obviously desirable to make improvements in this area in any case.

The comparison of seasonal performance factors in Table 3 shows that co-firing tires with inspected waste did not interfere with the efficiency of operations. On the contrary, all parameters improved during the winter season. For example, the availability of the furnaces increased by about 2.2%. Likewise, the availability of the boilers increased by about 2.2%.

With regard to equipment utilization, there were improvements during the winter as well, with increases of about 3.0% for the furnaces and about 2.7% for the boilers. In terms of the plant capacity factors, the picture is even brighter. During the winter, waste throughout was up by about 6.3%. Boiler output grew by about 8.8% during the same period.

At first sight, one might conclude that waste tire burning is good for plant performance. However, during interviews with operating personnel, it was determined that heavy maintenance work was deferred as much as possible from the winter to the summer months. The motive for doing so was simply an economic one, i.e., the Army needs more steam during the winter and pays for it at a better rate.

Comparison of the specific steaming rate (SSR) with the specific ash rate (SAR) and specific electric rate (SER) indicates that unit steam production goes up by about 14.8% during the winter. However, on the downside, the consumption of electrical energy rises by some 11.7% and about 13.5% more ash is made. Thus, increased energy revenues may be offset—at least in part—by increased expenses.

To date, the higher heating value (HHV) of the fuel has not been experimentally determined. However, the SSR is directly related to the HHV and from Table 3, the seasonal ratio of the SSRs can be calculated:

$$\frac{\text{SSR Winter}}{\text{SSR Summer}} = \frac{2.792}{2.433} = 1.148$$

During design of the HCRRF, an HHV = 4500 Btu/lb was assumed as an average for MSW only. Thus, for the mix of MSW and tires, an HHV = 4500 × 1.148 = 5166 Btu/lb can be projected. Furthermore, an HHV = 12,000 Btu/lb was assumed as the design value for waste tires.

By using actual total tonnages for the three observation years, i.e., 165,103 ST for MSW, or 91.2% of total fuel and 15,922 ST for tires, or 8.8% of total fuel, HHV can then be projected directly:

$$(165,103 \times 4,500) + \frac{(15,922 \times 12,000)}{165,103 + 15,922} = 5160 \text{ Btu/lb}$$

This is the same value which was previously obtained by application of the SSR ratio. The surprising closeness of this fit suggests that waste tires burn well. No experimental determinations were made for unburnt combustibles in the ash, neither for MSW nor for the MSW/tire mix. However, during occasional visual inspections, no unburnt tires were observed in the ash pile.

With regard to the tire ash paradox, there are at least five potential reasons for its appearance:

(a) Unusual amounts of inerts such as rims and sand are attached to the tires.

(b) Tires do not burn, i.e., their exit condition is the same as the entry condition.

(c) MSW during the winter is exceptionally high in inerts.

(d) Other residue (which is added to the ash), such as solids from wastewater settling tank, is substantially more during the winter.

(e) Tires produce unique ash particles which are capable of absorbing and/or adsorbing large amounts of water during quenching.

TABLE 3 SEASONAL PERFORMANCE PARAMETERS FOR HARFORD COUNTY RESOURCE RECOVERY FACILITY

Parameters	Year 1 Observation		Year 2 Observation		Year 3 Observation		All Years Combined	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Tire Ratio	2,000	14.66	2,000	12.15	2,000	13.43	2,000	13.26
AFg	.9719	.9880	.9603	.9782	.9351	.9674	.9557	.9779
UFg	.9499	.9871	.9578	.9782	.9340	.9664	.9473	.9772
LFg	.8790	.9519	.9388	.9115	.9166	.9799	.9115	.9476
PCFg	.8349	.9396	.8993	.8916	.8561	.9470	.8635	.9261
AFb	.9533	.9763	.9445	.9612	.9453	.9724	.9477	.9700
UFb	.9365	.9734	.9432	.9612	.9446	.9717	.9414	.9688
LFb	.3963	.4843	.4114	.4852	.4093	.4862	.4057	.4852
PCFb	.3712	.4714	.3881	.4664	.3866	.4725	.3820	.4701
UC Temp	1,993	2,091	2,003	2,078	1,969	2,064	1,987	2,076
SAR	.4087	.4778	.4130	.4662	.4085	.4527	.4101	.4655
Gross-SSR	2.445	2.759	2.374	2.877	2.484	2.744	2.433	2.792
Army-SSR	1.103	2.059	1.352	2.346	1.292	2.244	1.252	2.214
SER	48.62	50.97	44.33	50.17	39.91	48.81	44.74	49.98
SRR	.0034	.0033	.0045	.0034	.0061	.0037	.0047	.0035

It would be be beyond the scope of this paper to further research the tire ash paradox. However, in view of the discussions furnished above, it seems that reasons *(a)*, *(b)* and *(c)* can be eliminated. However, reasons *(d)* and *(e)* remain open to further discussion.

The upper chamber or UC temperature is a thermal control parameter which is set by the operator according to what type of waste is charged. In case of the addition of tire waste, this parameter is set about 90°F higher on the average. This is largely to accommodate the improved heating value for such a waste mix. Beyond increasing the set point, the induced draft fans are switched onto high speed. While this facilitates cooling during tire burning, it also leads to increased electrical energy consumption and a higher excess air rate.

Environmental Compliance

Environmental performance of the HCRRF is governed by the conditions specified in the permit. The most important one of these specifies that flue gases in the exhaust stack must not exceed a certain concentration limit for particulate matter. The Maryland Department of the Environment (MDE) has set this limit at 0.03 grain/dscf @ 12% CO_2.

The results of testing indicate that this limit has not been exceeded. This statement holds true for both the winter and summer tests. Compared to waterwall furnaces, two-stage controlled air combustors are known to produce significantly lower raw gas loadings. How-ever, two-stage combustion also results in a substantial shift of the particle size distribution towards the low micron end.

During facility design, there was uncertainty as to how tire burning would affect particle size distribution and, with it, the capture ratio of the electrostatic precipitators. Based on the test results, it can now be stated that the design margins were satisfactory even for burning a mix of MSW and tires.

However, in anticipation of new requirements expected from the MDE and the U.S. EPA for "municipal waste combustors" with a capacity of less than 250 STPD per unit, additional testing has been conducted. The goal was to determine the emissions of carbon monoxide, hydrochloric acid, nitrogen oxides and sulfuric acid.

While not all data was received, the preliminary results are displayed in Table 4. Average emission rates and emission factors are listed separately for the winter and summer season.
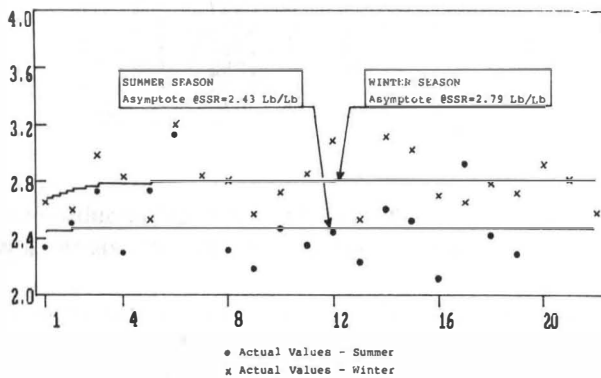
PERFORMANCE TRENDS

Several curve fit methods were used for analyzing the data base in order to search for trend lines. Of these, the inverse *t* and/or *v* functions were found to be most useful. They have a tendency to disregard the more erratic values during the early operating months. On the other hand, with more stability expected in later operating months, these functions tend to approach

TABLE 4 SEASONAL EMISSIONS FOR HARFORD COUNTY RESOURCE RECOVERY FACILITY

Test Date	Emission Rates [Lb/h]		Emission Factors (2) [Lb/ST]	
	Winter 1-6/9-88	Summer 9-26/28-90	Winter (3) 1-6/9-88	Summer (4) 9-26/28-90
Particulate Matter (Front Half)(PM)	1.803	2.285	0.1433	0.1237
Lead (Pb)	0.0691	0.0861	0.0054	0.0047
Carbon Monoxide (CO)	2.106	NA	0.2101	NA
Sulfur Dioxide (SO$_2$)	22.18	NA	2.7663	NA
Nitrogen Oxides (NO$_x$)	63.50	NA	4.9422	NA
Hydrochloric Acid (HCl)	NA	99.40	NA	6.0400

Notes: (1) Arithmetic averages of 3 test runs.
(2) Determination of simultaneous waste burning rate was not accurately measured.
(3) Average specific flue gas rate during winter was 235,000 DSCF/ST.
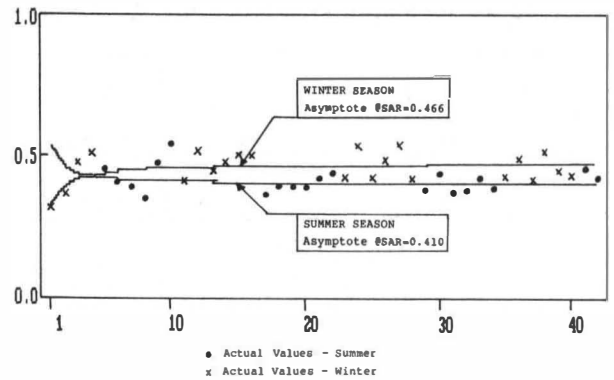(4) Average specific flue gas rate during summer was 167,000 DSCF/ST.

Actual Values – Summer
Actual Values – Winter

FIG. 7 CURVE FIT FOR SEASONAL ASH RATES FOR HARFORD COUNTY RESOURCE RECOVERY FACILITY

Actual Values – Summer
Actual Values – Winter

FIG. 6 CURVE FIT FOR SEASONAL STEAMING RATES FOR HARFORD COUNTY RESOURCE RECOVERY FACILITY

Actual Values – Summer
Actual Values – Winter

FIG. 8 CURVE FIT FOR SEASONAL ELECTRICITY CONSUMPTION FOR HARFORD COUNTY RESOURCE RECOVERY FACILITY
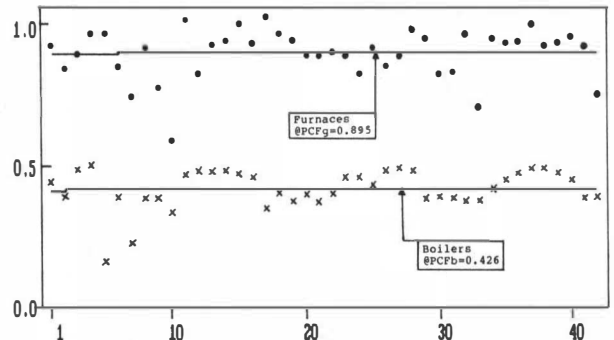
FIG. 9 CURVE FIT FOR FURNACE AND BOILER CAPACITY FACTORS FOR HARFORD COUNTY RESOURCE RECOVERY FACILITY
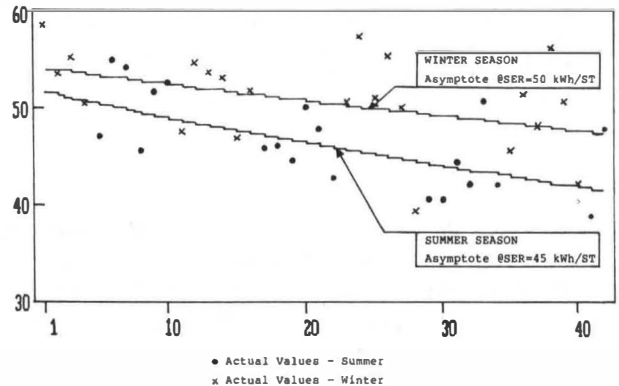
straight lines. In case of horizontal lines, their vertical intersects would correspond to the arithmetic averages previously calculated.

In Fig. 6, such curve fits are shown for the specific steaming rates, i.e., one for the winter season and one for the summer season. The resultant straight lines have intersects of 2.79 lb/lb for the winter and 2.43 lb/lb for the summer, respectively. Excursions of actual values from the calculated lines diminish in recent times, especially during the winter season.

A similar pattern is presented in Fig. 7 for the seasonal ash rates during the winter and summer. However, the seasonal curve fits for electricity consumption forecast lines with a negative slope. These are shown in Fig. 8. This seems to suggest that less electricity is being consumed in recent months. At this point, the underlying causes have not yet been determined. However, a good guess is that the excess air rates have

been reduced, which translates into less fan horsepower during the summer.

In Fig. 9, the plant capacity factors for the furnaces and boilers are portrayed as a function of operating life.

The wide fluctuation seen in the first year have largely disappeared in subsequent years, except for some seasonal variations. Essentially, stable behavior is forecast.

CONCLUSION AND RECOMMENDATIONS

The data analyzed thus far supports the contention that adding waste tires to regular MSW is an effective method for boosting steam output when needed. None of the performance parameters were degraded because of the tires. The sole exceptions were ash production and electricity consumption. Although neither has reached critical proportions, both should be the target of improvements. Along these lines, the turbine generator switch gear should be upgraded so that more of the excess steam presently vented would go towards increased in-plant production.

The HCRRF has met and/or exceeded all of the performance guarantees demanded in the Service Agreement. Clearly, the burning of waste tires has not interfered with equipment availability and utilization. Operating personnel have learned how to use waste tires reliably and safely within the requirements of the Service Agreement and the Permits.

The prospects of continuing efficient operations within the same parameters are judged to be excellent.

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