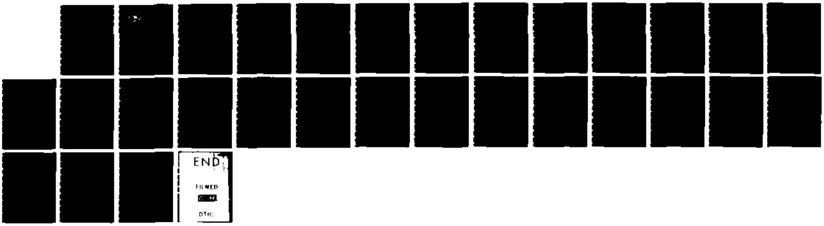
AD-A137 224 LONG-TERM EVALUATION HEAT RECOVERY INCINERATOR SYSTEM - JACKSONVILLE - DECEMBER 1982 - MAY 1983(U) VSE CORP OXNARD CA D LEIPERT ET AL. DEC 83 NCEL-CR-84.005 1/1

UNCLASSIFIED N00123-82-D-0149 F/G 13/2 NL



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CR 84.005

NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

Sponsored by
NAVAL FACILITIES ENGINEERING COMMAND

LONG-TERM EVALUATION HEAT RECOVERY INCINERATOR SYSTEM - JACKSONVILLE - DECEMBER 1982 - MAY 1983

December 1983

An Investigation Conducted by
VSE CORPORATION
3410 South A Street
Oxnard, California

N00123-82-D-0149

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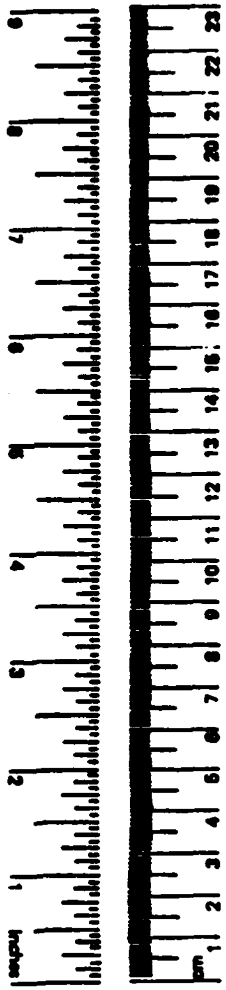
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

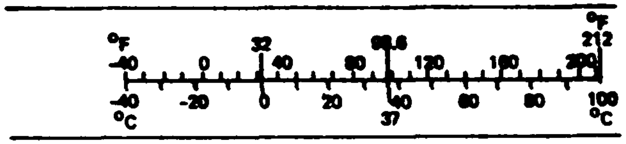
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CR 84.005	2. GOVT ACCESSION NO	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Long-Term Evaluation Heat Recovery Incinerator System - Jacksonville - December 1983 - May 1983		5. TYPE OF REPORT & PERIOD COVERED Final Dec 1982 - May 1983
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) D. Leipert Z. Parker		8. CONTRACT OR GRANT NUMBER(s) N00123-82-D-0149
9. PERFORMING ORGANIZATION NAME AND ADDRESS VSE CORPORATION 3410 South A Street Oxnard, CA 93043		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Y0817-006-01-213
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Civil Engineering Laboratory Port Hueneme, CA 93043		12. REPORT DATE December 1983
		13. NUMBER OF PAGES 24
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Facilities Engineering Command 200 Stovall Street Alexandria, VA 22332		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

HRI, Heat Recovery Incineration, Solid Waste Incineration, maintainability, reliability, availability

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is the second report which addresses the long term evaluation of the NAS Jacksonville Heat Recovery Incinerator. Operational data was collected from December 1982 to May 1983 and then analyzed for reliability, availability, and maintainability.

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FOREWORD

This report is the second of three reports on the operation of the Heat Recovery Incinerator (HRI) at NAS Jacksonville. The report covers data received from the period of December 1982 to May 1983. The data was analyzed to provide results on reliability, availability, and maintainability of the Jacksonville HRI.

The first report covered data from June to November 1983. The final report will compare the first two reports, analyze any changes and make recommendations on the use of the HRI technology at Jacksonville.

Other aspects of the overall solid waste to energy project being conducted by NCEL under the sponsorship of the Naval Facilities Engineering Command include a study of Refuse Derived Fuel (RDF) use in Navy fossil fuel boilers; a survey method for estimating solid waste generation at shore facilities; methodology for predicting the economic feasibility of HRI technology at shore facilities; and a study of the HRI at NS Mayport.

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1.0 INTRODUCTION

The Resource, Conservation, and Recovery Act (RCRA) of 1976 mandates the use of fuel derived from recovered material to the maximum extent practicable in Federally owned fossil fuel-fired energy systems. The Naval Air Station (NAS) Jacksonville Heat Recovery Incinerator (HRI) installation is one of two Naval facilities in Florida designed to recover energy from solid waste generated on base. The other is located at Naval Station Mayport. By the incineration of waste materials, the HRI is intended to reduce landfill problems and generate steam to be used by Naval activities.

The purpose of this task is to evaluate the performance of the HRI in terms of reliability, availability, and maintainability (RAM) parameters, long term cost-effectiveness, and overall thermal efficiency (TE). Results will be used to develop Navy criteria for the optimum plant design in the 50 ton per day (TPD) range.

2.0 SCOPE

This task involved screening, condensing, and analyzing operational data logged by plant operating personnel for a 6-month period (December 1982 through May 1983). This data was used to compute all RAM parameters. Due to administrative reasons and equipment problems, steam was not produced during this evaluation period. Thus cost-effectiveness and TE parameters were not determined. Samples of the data sheets are given in Appendix A.

3.0 SUMMARY

The NAS Jacksonville HRI operations and maintenance data were analyzed for the purpose of comparing observed performance data to HRI performance objectives. The primary objectives at this installation are to incinerate solid waste at a rate of 2-tons per hour (TPH) and produce steam from the recovered thermal energy. Due to conditions that existed since the onset of the evaluation and have continued through the current reporting period, the full operating capacity of the HRI has not been achieved (Discussed in sections 4.3 and 4.5).

Table 1.

HRI Subsystem	Mean Time Between Failures	Reliability	Mean Time To Repair	Mean Time Between Maintenance Action
Processing	43.8	0.40	3.8	43.8
Storage	745.3	0.85	25.0	248.4
Incineration	138.3	0.42	5.0	80.6
Ash Removal	426.5	0.75	8.5	170.6
Steam Generation	-	-	-	-

Performance parameters were determined based upon the HRI operational scenario during the current 6-month evaluation period (See Table 1). The raw data for the determination is listed in Appendix B. All the parameters calculated for the HRI demonstrated a decrease in performance and reliability from the previous reporting period. The number of failures that occurred during the current reporting period remained approximately the same as the previous period. But, this was accompanied by an overall drop in HRI operating time of about 63%, which statistically created a marked decrease in reliability. Without substantially more operating time logged by the HRI equipment the true relationship between failures and equipment run time cannot be reliably established.

The decrease in HRI operating time was due in part to a substantial amount of equipment downtime associated with contractor modifications.

Each HRI subsystem has continued to statistically demonstrate the same performance characteristics as in the previous reporting period. The processing subsystem consists of a diverse system of equipment operation and is subjected to frequent startup cycles. Consequently, it has a high probability of equipment breakdown and has demonstrated the poorest reliability of all four subsystems. The storage subsystem, having uncomplicated design characteristics, proved to be the most reliable as it experienced only one failure in 745 hours of operation. Although the ash removal subsystem demonstrated the second highest MTBF of all four subsystems (426 hours), this figure represents a 64 percent drop from the previous reporting period.

The incineration subsystem required the most maintenance attention during the current reporting period. The incineration subsystem accounted for more than half of the overall HRI failures and maintenance actions. Frequent jamming of the incinerator ash rams and ash conveyor chain assemblies continued to be a problem.

A rather high MTTR of 25 hours demonstrated by the storage subsystem was due to persisting adjustment problems associated with replacement of a feed conveyor belt.

4.0 OPERATIONAL SCENARIO

4.1 Processing Subsystem. The solid waste processing subsystem prepares raw solid waste for incineration by reducing waste particle size to less than 12 inches, removing magnetic and undersized materials (metallic, glass, and ceramic particles), and depositing the remaining waste into a storage bin. The processing equipment (consisting of the flail mill, industrial shredder, magnetic separator, trommel screen, and associated conveyors) was designed for a nominal "throughput" capacity of 5 TPH with a duty cycle of 9 HPD (5 days per week). During the 6-month reporting period (December 1982 through May 1983), an estimated 428 tons were processed during 175 hours of subsystem operating time for a throughput rate of 2.4 TPH. Subsystem operating time was measured by the storage bin feed conveyor run time meter. Specific equipment operating time varied as follows:

o Flail Mill	144.3 hours
o Shredder	7.1 hours
o Trommel Screen	175.0 hours
o Magnetic Separator	175.0 hours
o Conveyor network	175.0 hours

Only the flail mill and shredder are metered. Other equipment is presumed to operate with an identical duty cycle as the storage bin feed conveyor. The industrial shredder was rendered unavailable during much of the reporting period as it experienced a part supply logistic delay.

4.2 Storage Subsystem. The storage subsystem acts as a surge bin to compensate for the difference between the amount of waste brought into the plant and the processing rate, versus the incinerator(s) burn rate. Under normal conditions, the storage bin discharge conveyor should run continuously while the incinerators are in operation. However, the storage bin rated capacity of approximately 29 tons would be inadequate should incineration rate reach its nominal capacity of 2 TPH. This deficiency becomes magnified in the event of unplanned outages from processing equipment failures and long periods of downtime, which occurred frequently during this reporting period. Due to problems with the other subsystems, the actual capacity never equalled the rated capacity and this deficiency did not effect HRI performance.

The nominal discharge capacity of 3 TPH was not achieved during this period. Plant operating personnel reduced the screw auger and carriage drive speed in an attempt to mitigate jamming problems (Discussed in Section 6.2).

In addition, an estimated 215 hours of incineration time was accrued by direct feeding from the tipping floor (bypassing the storage bin) due to "bin empty" conditions; the "bin empty" conditions resulting from breakdown of the processing subsystem.

4.3 Incineration Subsystem. The operating scenario of the incineration subsystem deviated significantly from its intended mission. This subsystem was designed to incinerate 2 TPH using two of three incinerators simultaneously with the other on standby (each incinerator has a nominal capacity of 1 TPH). Only two incinerators were available during this evaluation period. Under no circumstances were they operated in tandem to incinerate solid waste. Furthermore, the subsystem operated at approximately 20 percent of capacity (0.40 versus 2 TPH). It is likely that this departure from the desired capacity had a positive influence on incinerator and ash conveyor reliability and maintainability (R&M) performance. During the 6-month period, the incinerator feed controls were operated manually by plant personnel. Examination of available data indicates that manual operation of the incinerator feed controls was performed in an effort to avoid maintenance problems with the automatic control circuit. Thus very little time was logged by automatic control circuit components (i.e., interlocks, limit switches, pushbutton switches, etc.).

4.4 Ash Removal Subsystem. The ash conveyor required the removal of ash from only one incinerator at a time due to the operating capabilities of the incineration subsystem. This had an effect of reducing the load stresses imposed on conveyor components by wet ash deposits. For this reason, its R&M performance under "intended conditions" could not be determined from available data.

4.5 Steam Generation Subsystem. The steam generation subsystem was designed to produce 6,280 pounds (lb) of steam per hour. Due to boiler water level control problems and administrative decisions, no steam was produced during this period.

5.0 RELIABILITY

This section addresses the reliability of the HRI as demonstrated from December 1982 through May 1983. It is divided into two main subsections. The first subsection provides a summary of the calculated reliability parameters and identifies the most unreliable subsystems. The ensuing subsection (Technical Discussion) focuses attention upon the postulated causes of HRI subsystem unreliability.

5.1 Six-month Reliability Parameters.

The following reliability parameters (See table 1) were determined from HRI Equipment Status Log data for the December 1982 through [illegible] 1983 reporting period.

Table 2.

HRI Subsystem	Operating Time	Observed Failures	MTBF	R
Processing	175.0	4	43.8	0.40
Storage	745.3	1	745.3	0.85
Incineration	968.6	7	138.3	0.42
Ash Removal	853.2	2	426.5	0.75
Steam Generation	-	-	-	-

HRI Function	R
1. Process and incinerate solid waste (1 through 4 above)....	0.11
2. Incinerate solid waste (3 and 4 above)..................	0.32
3. Produce steam using solid waste.............	Insufficient data

The storage subsystem demonstrated the highest reliability with [illegible] failure in 745 hours of operation. Three maintenance actions were required to unjam the storage bin discharge screw angers. As this number relates to the equipment operating time it is roughly consistent with the previous reporting period. Details of this problem are presented in Section 5.2.

The incineration subsystem experienced the poorest reliability as demonstrated by a 52 percent drop in its MTBF. This relates to a reliability value of .42, which means the incineration subsystem can be expected to operate successfully for a full week 42 percent of the time.

Each HRI subsystem has experienced a severe decrease in reliability during the current reporting period. The average decrease in subsystem reliability from the previous reporting period is 23 percent. The current subsystem reliability values, when compounded, equate to an overall HRI system reliability of 0.11. This poor demonstration of reliability and performance is due in part to a very inconsistent schedule of HRI system operation. The schedule of operation was interrupted by contractor modifications of the incinerat[illegible] ment and logistics delays associated obtaining parts to complete mainte[illegible]. These problems led to a reduced level of operate time while at the sam[illegible] ing more problems with equipment operation. The frequent start-up [illegible] amount of operating time associated with equipment installation and [illegible] created an operational profile that exhibi_ed a higher rate of equipment failure than would be found in a normal consistent mode of operation.

5.2 Technical Discussion.

One of the primary purposes of this current long term RAM assessment is to provide input to develop guidelines for small-scale solid waste [illegible] plant design. The initial six-month evaluation period revealed certain "weak links" in the HRI system. In regard to these early observations, certain recommendations were proposed to remedy the problems. The implementation of the resulting design changes are discussed in the following sections.

5.2.1 Processing Subsystem. The processing subsystem demonstrated the poorest reliability over the current six-month reporting period. This is expected since the processing subsystem is more functionally intricate than the other HRI subsystems. However, four failures in 175 hours of operation is unusually high for equipment that is predominantly mechanical in nature. The failure information revealed that all four failures that occurred were experienced by conveyor belt equipment (two broken belts, one broken belt clip, and one worn-out idler roller bearing).

During the previous six-month reporting period, excessive wear of the flail mill shaft bearing was a problem. This problem was believed to be caused by dust and dirt contamination. Such contamination usually results in abrasive wear of the bearing surface and subsequent failure of the flail mill. Plans were made to install a pressurized oil misting system on the shaft bearing assembly. This plan was implemented early in the current reporting period. In theory, the oil misting system should decrease contaminant intrusion while also maintaining a cool operating temperature. Analysis of current reporting period data has revealed that no failures or maintenance actions involving flail mill shaft bearings occurred. Although a sufficient amount of flail mill operate time was not accrued to prove the success of the system, there is a high probability that the oil misting system has fulfilled the intended function. Shutdown of the HRI system (June 1983) prevented any further evaluation of the oil misting system.

Another problem of concern during the previous reporting period was the occurrence of various motor burnouts due to high operating temperatures resulting from the accumulation of dust and dirt. No motor burnouts or overheating problems were encountered during the current reporting period. Improved preventive maintenance (cleaning, lubrication) may have contributed to these circumstances, but it must be considered that such a limited amount of operating time for the reporting period inhibited the formation of any reliable conclusions.

5.2.2 Incineration Subsystem. Incinerator number three was not utilized during the current reporting period. The reliability for the incineration subsystem reflects those failures sustained by incinerators number one and two.

The incineration subsystem experienced seven failures during the current reporting period. With only 967 hours of operation, seven failures is unusually high. This is demonstrated by a 36 percent drop in reliability from the previous reporting period. Four of these failures were related to the hydraulic power system. The other three failures were varied (fire under the deck plates, incinerator feed belt, and door warpage). A considerable amount of maintenance time was required to straighten warped incinerator doors. This, combined with substantial delay time waiting for parts led to excessive amount of downtime for incinerators number one and two. Current data did not permit conclusive interpretation of these symptoms, but possible causes for this problem include the intense heat the doors are subjected to and the manner in which force is applied to operate the doors.

The hydraulic power systems of incinerators number one and two have experienced many hydraulic leaks and associated maintenance actions. This is common for hydraulic systems. The four hydraulic system failures resulted in complete loss of hydraulic power, leading to incinerator shutdown. Three of the four failures were attributed to hoses while one failure was caused by a hydraulic door cylinder. In a few other situations the hydraulic hoses were replaced due to leakage or wearout that indicated failure was imminent.

Analysis of data during the previous reporting period disclosed a problem with the configuration of the hydraulic lines and component parts. Inefficient routing and extended lengths of hosing led to maintenance problems. Many of the hydraulic lines also were difficult to access for maintenance. To ameliorate these problems, hard piping was installed and reconfigured during the current reporting period. It is the view of the HRI maintenance personnel that this action has made access for repairs more convenient while eliminating the problems with rubber hose durability. Sufficient system operate time was not accrued following these design changes to provide for a reliable evaluation.

During the previous reporting period, the breaking off of thin chips of refractory material from the interior walls of the incinerators was a major problem. This material deterioration persisted through the current reporting period. It is believed that this process (spalling) is the result of frequent heating and cooling cycles. The intended mission of the incinerators calls for continuous operation of 120 hours per week. Without the interruptions of waste stream fluctuations and maintenance shutdowns, problems resulting from cyclic temperature variation would be minimized.

6.0 MAINTAINABILITY

Maintainability is defined as a characteristic of equipment design and installation which is expressed in terms of ease and economy of maintenance, availability of equipment, and accuracy in the performance of maintenance actions. This section evaluates the maintainability of the HRI during the 6-month evaluation period.

6.1 Six-month Maintainability Parameters.

The following maintainability parameters (See table 3) were determined from HRI Equipment Status Log data for the December 1982 through May 1983 reporting period. MTTR is the average time (duration) required to restore a failure. Only hands-on corrective maintenance time is included for this parameter. Mean-Time-Between-Maintenance Actions (MTBMA) is the average subsystem operating time accrued before a maintenance action is required. A maintenance action is an event which requires immediate maintenance attention to correct a failure, make adjustments, unjam equipment, or other actions required to maintain a fully operable system.

Table 3.

HRI Subsystem	MTTR (Failures)	MTBMA (Maintenance Actions)
Processing	3.8 (4)	43.8.(4)
Storage	25.0 (1)	248.4 (3)
Incineration	5.0 (7)	80.7 (12)
Ash Removal	8.5 (2)	170.6 (5)
HRI Overall	6.6 (14)	40.4 (24)

The most significant maintenance burden during the current reporting period has been the incineration subsystem, which has experienced seven failures averaging five hours to repair and 12 maintenance actions. The seven failures included a wide range of break downs with no particular problematic trend standing out. Jammed ash rams and warped incinerator doors were the most troublesome maintenance actions, contributing to long equipment downtimes.

The processing subsystem also required considerable maintenance attention. Three of the four failures that occurred were conveyor belt wearouts. Most of the maintenance action required by the processing subsystem also dealt with conveyor belt problems.

An overall observation of the HRI maintenance profile reveals that most equipment downtime was incurred as maintenance actions and not equipment failure. Most of the maintenance actions that have occurred consist of events that involved jamming, premature wearing, and overloading. These circumstances may indicate a deficiency in design of equipment operating tolerances and capacities. The problem may suggest a re-evaluation of equipment and system performance requirements along with improvement of the preventive maintenance program.

A basic observation can be made of the ratio between subsystem operating times and hands on repair times. When considering this ratio for the current reporting period, it is noticeable that the amount of corrective maintenance is excessive. For every four hours of operation, the processing subsystem underwent one hour of corrective maintenance. The incineration subsystem experienced a six to one ratio.

Criteria for establishing satisfactory ratios has not been developed for the HRI system, thus the acceptability of the ratios demonstrated should be carefully considered. The HRI subsystem ratios for the current reporting period along with cummulative figures are provided in Table 4.

Table 4.

HRI Subsystem	Operate Time (Hours)/Repair Time (Hours)	
	Dec. 82 - May 83	June 82 - May 83
Processing	4/1	5/1
Storage	30/1	36/1
Incineration	6/1	10/1
Ash Removal	28/1	16/1

6.2 Technical Discussion.

Jams have been cause of maintenance action for the storage bin screw augers and the ash conveyor chain assembly. The storage bin discharge screw augers operate in tandem to discharge waste at the discharge end of the storage bin. Under normal conditions the two counterrotating screws discharge solid waste onto a conveyor belt. At the same time, the carriage upon which the screws are mounted traverses back and forth throughout the length of the storage bin. As waste builds inside the bin, jams periodically occur between the two screws. This type jam occurs most frequently near the discharge point.

Another type of jam occurs when the screws attempt to traverse through a big pile. The load of a large pile is often too great for the carriage drive unit. To combat these problems, plant operators have reduced the speed of the discharge operation and manually controlled the traversing motion to keep the screws at the edge of the solid waste pile. This requires increased manpower to perform incineration operations. Based upon the various problems experienced at this site, many which have been well-documented before this analysis (i.e. nonuniform waste distribution inside bin, type of wastes and their affect on screws, discharge from bottom only), it is believed that the screw augers discharge method is not suitable for this type of solid waste processing applications.

One other maintenance design problem is the location of the storage bin feed conveyor motor. This drive motor at the top of the 14 foot high storage bin is mounted on the bin (pit) side of the conveyor belt rather than the catwalk side. This renders it inaccessible for preventive and corrective maintenance operations.

Ash conveyor jams are due largely to the deposit of unburned (or not completely burned) objects into the quench tank where they can get between the chain and sprockets. This problem is manifested by the chain jumping off the sprocket and is best controlled by minimizing the introduction of noncombustible solid waste material into the incinerators.

7.0 AVAILABILITY

Availability is the unconditional probability that the system will be capable of operating at its specified level of performance when called upon to do so at any random point in time.

There are two types of availability that can be calculated, inherent and operational use availability. Inherent availability (A_i) is the probability that the system will be capable of operating at its specified level of performance when called upon to do so at any random point in time; excluding logistics delays. It is expressed as:

$$A_i = \frac{\text{Operate Time}}{\text{Operate Time + Repair Time}}$$

Operational use availability (A_u) is calculated by making use of logistics delays. The limitations of the data source utilized for this evaluation precludes the collection of logistics data, therefore operational use availability can not be calculated.

The HRI availability figures for the current reporting period are presented in Table 5.

Table 5.

HRI Subsystem	Operate Time	Repair Time	A_i
Processing	175.0	41	.81
Storage	745.3	25	.97
Incineration	968.6	155	.86
Ash Removal	853.2	31	.96
Steam Generation	-	-	-
HRI Overall	968.6	252	.79

8.0 THERMAL EFFICIENCY

During this reporting period, no steam was produced due to various technical and administrative reasons. Solid waste was incinerated on an "as available" basis providing the appropriate equipment was operable. Since the TE equation compares the energy consumed to "steam produced" it is not possible to provide this parameter. Thus it is only possible to give an index of how much energy was consumed to fulfill solid waste incineration goals. Equations 1 through 6 provide for the computation of heat derived from the various energy sources. Equation 7 is the sum total of the heat from these six sources. All heat values are expressed in British Thermal Units (Btu).

Energy Consumption Equations.

1. Heat derived from solid waste.

$$H_{sw} = (h_{sw})(M_{12}) = (8200\ \text{Btu/lb})(856{,}000\ \text{lb})$$
$$= 7.019 \times 10^9\ \text{Btu}$$

where

H_{sw} = Heat value in Btu derived from solid waste and supplied to HRI (8,200 Btu/lb measured during 1981 short term test at NAS Jacksonville)*

h_{sw} = Heating value of solid waste in Btu/lb

M_{12} = Solid waste supplied to HRI in lb

2. Heat derived from virgin oil.

$$H_{vo} = (h_{vo})(M_{20}) = (19{,}602.6\ \text{Btu/lb})(50{,}225.56\ \text{lb})$$
$$= 9.846 \times 10^8$$

where

H_{vo} = Heat value in Btu derived from virgin oil and supplied to HRI

h_{vo} = Heating value of virgin oil in Btu/lb = 19,602.6 Btu/lb

M_{20} = Virgin oil supplied to HRI in lb

*Naval Civil Engineering Laboratory, Technical Memorandum M54-81-03, "NAS Jacksonville HRI Short-Term Performance, Solid Waste Characterization, and Front End Processing Line Evaluation," by Mary Lingua, Apr 1981.

3. Heat derived from waste oil.

$$H_{wo} = (h_{wo})(M_{21}) = (19{,}673 \text{ Btu/lb})(0 \text{ lb})$$

$$= 0 \text{ Btu (none used)}$$

where

H_{wo} = Heat value in Btu derived from waste oil and supplied to HRI

h_{wo} = Heating value of waste oil in Btu/lb

M_{21} = Waste oil supplied to HRI in lb

4. Heat derived from front-end loader diesel fuel.

$$H_{f1} = (h_{df})(M_{22}) = (19{,}602.6 \text{ Btu/lb})(2445.7 \text{ lb})$$

lb)

$$= 4.794 \times 10^{7} \text{ Btu}$$

where

H_{df} = Heat value in Btu derived from front-end loader diesel fuel

h_{df} = Heating value diesel fuel in Btu/lb = 19,602.6 Btu/lb

M_{22} = Diesel fuel supplied to front-end loader in lb

5. Energy equivalent of electrical power supplied to the HRI.

$$E_t = (e_t)(T_{kwh}) = (11{,}600 \text{ Btu/KwH})(58{,}280 \text{ KwH})$$

$$= 6.760 \times 10^{8} \text{ Btu}$$

where

E_t = Electrical power in Btu supplied to the HRI

e_t = Conversion factor in Btu/KwH = 11,600 Btu/KwH

T_{kwh} = Total KwH supplied to the HRI

6. Thermal energy of the makeup water supplied to the HRI.

$$H_w = (h_w)(M_{17}) = (48 \text{ Btu/lb})(0 \text{ lb})$$

$$= 0 \text{ Btu}$$

where

H_w = Thermal energy in Btu of the makeup water supplied to the HRI

h_w = Heating value of water in Btu/lb

M_{17} = Makeup water supplied to HRI in lb

7. Sum total of heat derived from all sources supplied to the HRI.

$$H_{HRI} = H_{sw} + H_{vo} + H_{wo} + H_{fl} + E_t + H_w$$

$$= 8.685 \times 10^9 \text{ Btu}$$

8. Sum total of heat derived from auxiliary sources of energy.

$$H_{AUX} = H_{vo} + H_{wo} + H_{fl} + E_t + H_w$$

$$= 1.708 \times 10^9 \text{ Btu}$$

9. Percentage of total heat produced derived from auxiliary sources.

$$\frac{H_{AUX}}{H_{HRI}} = \frac{1.708 \times 10^9}{8.685 \times 10^9}$$

$$= 20\%$$

APPENDIX A

DATA SHEETS

DECEMBER 82 - MAY 83

HRI EQUIPMENT STATUS LOG

1. INSTALLATION	2. BEGINNING DATE (YEAR MONTH DAY)	3. PAGE OF PAGES
NAS JAX	8 0 0 9 2 9	

4. DATE	5. TIME	6. CODE	7. HHRS	8. EXPLANATIONS
2 9	0 7 3 0	T1R		HRI start up. Began cleaning trommel screen--Routine Mainte-
				nance. HRI burning waste that was left in storage from last
			2	week in Incinerator #2.
2 9	0 8 3 0	H1		Completed routine maintenance. Began processing waste.
2 9	1 6 3 0	P2		Shut down processing. Continue to burn from storage bin in
				Incinerator #2.
3 0	0 0 0 0	T1		HRI operating without problems.
	0 8 0 0	A7		Begin routine maintenance. During this time we replaced the
				belt on the ash convevor drive motor due to excessive wear.
				Cleaned primary and secondary chambers for incinerators #1 and
			6	#3. #2 still burning on fuel oil.
	1 2 3 0	H1		Routine Maintenance completed. Began processing solid waste.
	1 6 3 0	P2		Secure processing for the day. Continue burning in incinera-
				tor #2 and start burning in #3.
0 1	0 0 0 0	H1		HRI operating trouble free. Began processing waste.
	0 7 0 0	T3		Ash convevor won't work. Troubleshooting. Stopped burning.
	0 8 3 0	T3	3	Seems to be problem in drive motor.
		T5		Called for help at this time. Still processing waste.
	1 3 3 0	T3	1.5	Electrician arrives--begin troubleshooting
	1 5 0 0	T3		Drive motor bearings are shot! Placed order for entire new
		T4		motor.
	1 6 3 0	H4R		Stopped processing waste. Shift change. Still waiting for
				part (motor). Should receive it tomorrow afternoon. At
				present, we are not incinerating due to ash convevor problem.
				Sweeping facility and cleaning incinerator #2 slag buildup.
				Noticed an exceptional amount of slag has accumulated during
				the past few days. Probably due to excess air entering through
			3	feed door, high primary furnace temperature.
0 2	0 0 0 0	H4		Ash convevor still down. All equipment idle.
	1 6 3 0	H4		End of day and still no motor. Base supply office says that
				we will definitely receive one by tomorrow. No regular
				scheduled maintenance performed.

9. FOR ANALYST ONLY	10. SUPERVISOR

Figure A-1. Completed Equipment Status Log

HRI EQUIPMENT STATUS LOG

1. INSTALLATION	2. BEGINNING DATE YEAR MONTH DAY	3. PAGE __ OF PAGES
XAS JAX	8 0 1 0 0 3	2

4. DATE	5. TIME	6. CODE	7. MHRS	8. EXPLANATIONS
03	0000	H4R		Performing maintenance checks described in operation manual,
				page 10. Required changing oil breather. Noticed slight oil
				leak from reducer.
	1100	H4	2	Completed maintenance checks.
	1300	H3		Received drive motor! Installing.
	1420	H3	1.5	Completed installation--testing ash conveyor. All OK.
	1430	H2		Secured all equipment since today is Friday. Will resume
				incineration on Monday.
04	0000	H2		Secured for weekend.
05	0000	H2		Secured
06	0000	H2		Secured
	0800	H1		Began processing and incinerating in #2 and #3.
	0930	H1	3	Hopper ram stuck on #2. Unstuck itself after 3 attempts.
				No cause found.
	1300	T1		Stopped processing. Continued burning using #1 now.
	2100	B3		Boiler feed pump inoperable. Troubleshooting.
	2300	B6		Could not find problem. Shut down steam production until
				morning shift comes in. Continued incineration.
07	0000	B6		Boiler feed still inoperable. Continue incineration.
	0730	B3R		Began working on boiler feed problem while couple guys
				perform routine maintenance on boilers #1, 2 and 3.
	0930	H1	6/2	Completed both PM and CM. Boiler feed problem resolved.
				Cause was inoperable shut off valve. Resumed complete
				operation.

9. FOR ANALYST ONLY	10. SUPERVISOR

Figure A-2. Completed Equipment Status Log (Cont'd)

HRI CONSUMABLES and RUN TIME LOG

1. WEEK ENDING DATE________(Month/Day/Year)   2. SHEET NO.________

3. SOLID WASTE RECEIVED (TONS)	4. SOLID WASTE NOT ACCEPTED (TONS)	5. REJECTED BY HAND (LBS)	6. TROMMEL AND MAGNET REJECTS (LBS)	7. REJECTED BY DUST FILTER (LBS)
8. WET ASH REMOVED (LBS)	9. ELECTRICAL ENERGY (KWH)	10. BOILER FEED WATER (GALLONS)	11. BLOWDOWN (GALLONS)	12. FLAIL MILL FEED CONVEYOR (RUN TIME)
13. SHREDDER FEED CONVEYOR (RUN TIME)	14. STORAGE BIN FEED CONVEYOR (RUN TIME)	15. ASH CONVEYOR (RUN TIME)	16. INCINERATOR BLOWER 1 (RUN TIME)	17. INCINERATOR BLOWER 2 (RUN TIME)
18. INCINERATOR BLOWER 3 (RUN TIME)	19. INDUCED DRAFT FAN 1 (RUN TIME)	20. INDUCED DRAFT FAN 2 (RUN TIME)	21. INDUCED DRAFT FAN 3 (RUN TIME)	22. BOILER 1 STEAM (LBS)
23. BOILER 2 STEAM (LBS)	24. BOILER 3 STEAM (LBS)	Non-Metered Items		
		25. DIESEL FUEL (to front-end loader):________Gallons 26. HYDRAULIC OIL used:________Gallons 27. No. 2 FUEL OIL used:________Gallons 28. WASTE OIL used:________Gallons		

29. REPAIR PARTS (Specify WR No.):

30. COMMENTS:

31. INITIAL ________

Figure A-3. HRI Consumables and Run Time Log

APPENDIX B

MONTHLY SUMMARY OF

NAS JACKSONVILLE HRI DATA

DECEMBER 82 - MAY 83

OPERATION SUMMARY TABLE - JACKSONVILLE HRI

	DEC	JAN	FEB	MAR	APR	MAY	TOTAL
RUN TIME (HOUR)							
FLAIL MILL	0	33	18	0	93	0	144
SHREDDER	0	0	2	0	5	0	7
S.B. FEED CONV.	0	39	20	0	110	6	175
ASH CONV.	0	278	108	26	415	27	853
INCINERATOR #1	0	0	0	0	0	0	0
INCINERATOR #2	0	294	120	57	428	69	968
INCINERATOR #3	0	0	0	0	0	0	0
ID FAN #1	0	0	0	0	0	0	0
ID FAN #2	0	294	120	57	114	0	584
ID FAN #3	0	0	0	0	0	0	0
BOILER #1	0	0	0	0	0	0	0
BOILER #2	0	0	0	0	0	0	0
BOILER #3	0	0	0	0	0	0	0
ENERGY CONSUMED							
KILOWATT HOURS	2520	12240	9840	7320	20320	6040	58280
BOILER FEEDWATER (GAL)	0	0	0	0	0	0	0
DIESEL FUEL (GAL)	0	60	75	30	120	60	345
HYDRAULIC OIL (GAL)	0	41	45	65	25	0	176
NO. 2 FUEL OIL (GAL)	0	1510	693	724	3655	503	7085
WASTE OIL (GAL)	0	0	0	0	0	0	0

OPERATION SUMMARY TABLE - JACKSONVILLE HRI (CONTINUED)

	DEC	JAN	FEB	MAR	APR	MAY	TOTAL
OUTPUT TOTALS							
SOLID WASTE RCVD (TON)	0	166	45	0	281	16	[illegible]
SOLID WASTE INCINERATED (TON)	0	141	71	0	263	7	428
HAND REJECTED (LB)	0	9.07	5.59	0	5.87	0.66	21.19
TROMMEL REJECTED (LB)	0	2.45	4.50	0	4.75	4.14	15.84
DUST REJECTED (LB)	0	0	0	0	0	0	0
WET ASH REJECTED (LB)	0	13.36	18.07	0	7.60	4.42	43.45
BLOWDOWN (GAL)	0	0	0	0	0	0	0

FILMED

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