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Naval Construction Battalion Center
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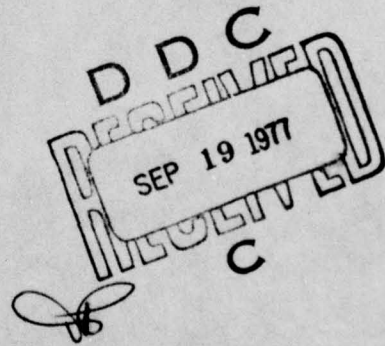
OPERATIONAL TESTING OF A
CONTROLLED AIR INCINERATOR
WITH AUTOMATIC ASH HANDLING

November 1976

An Investigation Conducted by

SYSTEMS TECHNOLOGY CORPORATION
Xenia, Ohio

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This study was performed at a privately owned controlled air incinerator facility in Kingsland, Texas. Without the enthusiastic assistance of the plant owner, Mr. C. E. Whitehead, this program could not have been brought to this successful conclusion.

The cooperation and assistance of all the personnel involved with the operation of the San Services, Inc. plant is sincerely appreciated.

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1.0 INTRODUCTION

This test was conducted to provide quantitative data for evaluating the performance of a package controlled air incinerator with automatic ash handling. The results of this evaluation are presented as an energy balance which can be used when evaluating such units for heat recovery applications.

The tested unit was a nominal 1 ton per hour Consumat controlled air incinerator. This incinerator burns batch fed charges of refuse in a fixed bed, primary combustion chamber with less than stoichiometric air to create the heat needed to pyrolyze the rest of the charge. (Pyrolytic combustion minimizes ash carry-over out of the unit.) Pyrolysis products are burned to completion in an oil fired, modulated after burner.

This unit burned mixed municipal and commercial waste. The paper and cardboard content of this waste exceeded 80%. Sufficient data was collected to provide complete mass and energy balances. With these balances, preliminary engineering estimates of the system's thermodynamic performance could be made.

Incinerator performance was monitored for a period of 4 days covering a total elapsed time of 88 hours. For 68 of the total 88 hours, the incinerator was being charged with refuse at a rate of about 1,800 lbs. per hour. The reported data is representative of the operating period. During the other 20 hours, the incinerator was in burn down.

2.0 SUMMARY OF THE TEST CONDUCTED

2.1 OPERATION OF THE SYSTEM

The incinerator system was built by Consumat Corporation of Richmond, Virginia. This consumat Model C-1200 controlled air incinerator has a semi-automatic ram feeder and ash handling system. The operation of the unit is as follows:

Refuse is deposited by packer trucks on an enclosed tipping floor. A front-end loader is used to move the refuse to the charging bin of the incinerator. A light bulb over the control panel signals the operator when the incinerator is ready to receive refuse. When the light comes on, the operator pushes a starter to begin the automatic feed cycle which closes the door over the charging bin and opens a refractory lined guillotine door between the furnace and the bin. Next, a hydraulic charging ram pushes the solid waste charge into the primary combustion/pyrolyzing chamber. After pushing the charge into the furnace, the ram returns to its starting position, the guillotine door closes, and the bin door reopens to receive more refuse in preparation for the next cycle.

The system has a timer which prevents the operator from reinitiating the automatic charging sequence until approximately 12 minutes have elapsed. This delay timer is used to meter refuse into the incinerator at the proper rate.

Inside the primary chamber, a portion of the charge is combusted with air to release the heat needed to pyrolyze the rest of the waste. Modulated underfired air is supplied by a force draft fan through a manifold system in the bottom of the primary chamber to maintain oxygen deficient conditions. Over temperature conditions in the primary chamber are controlled by air modulation and use of a water spray system.

Partially combusted gases leave the primary chamber and pass into the after burner which is centered above the primary chamber. Additional air is mixed with the pyrolysis gases and the mixture is burned with 13 gallons per hour of No. 2 fuel oil to form a relatively clean, high temperature, flue gas. The flue gas is dispersed to the atmosphere through a 30 foot, refractory lined stack.

Ash is removed through a refractory faced door located opposite the charging door by a hydraulic ram located below the charging ram which cycles just before a charge is called for. The ash is rammed through the ash door into a 5 cubic yard ash cart located at the end of the primary chamber opposite the feeder. The top of the cart houses a continuous water spray system to quench the ash. About three times a day, the ash cart is to be lifted out of the pit and dumped into a special trailer used to take the ash to a landfill.

2.2 TEST PROCEDURE

A mass balance of the disposition of material within the system is a necessary prerequisite to developing an energy balance. In order to prepare a mass balance, all system inputs and outputs must be known.

The incoming refuse stream was measured by weighing every packer truck discharging waste during the study. The gross and tare weights of these trucks were measured with 4 Loadometer highway wheel scales.

Some nonprocessable materials were removed prior to incineration to protect the incinerator. These materials include bulky noncombustibles such as metal furniture, old fencing, and

garbage cans. The nonprocessables were removed from the tipping floor and loaded onto a pickup truck which was weighed as it left the plant to determine the amount of nonprocessable material bypassing the incinerator.

Each packer-truck load of refuse was characterized using the photosort technique described in the Navy's R⁴ Decision Guide.

The weight of ash leaving the primary chamber was determined by using the Loadometer scales to weigh the ash cart. After the first 4 weighings, it was found that the largest deviation in the net weight of ash in the cart was 12% from the average. Since weighing the ash was an exceptionally difficult and time consuming task, the average of these four weights was used as the "weight" of each subsequent load removed from the ash pit.

Control thermocouples in the system were used to determine the temperatures in the primary and afterburner chambers.

Sampling ports were installed by Consumat on the stack. Thermal expansion of the ports, caused by the high temperature of the stack, prohibited removal of the caps. Hence, the temperature of the flue gas near the top of the

stack could not be measured. Instead, the temperature of the stack gas at the afterburner outlet was taken to be the stack temperature. A dilution air inlet just downstream of the afterburner was used to insert a probe for withdrawing gas samples. This probe was inserted at an angle to permit drawing the sample near the afterburner temperature probe. Thus, the temperature and composition of the stack gas were measured at this point; a point which is representative of conditions entering the breeching of an energy recovery, controlled air incinerator.

The quench water used by the unit to control over temperature conditions in the primary chamber represents a significant energy loss as the vaporized water leaves the stack (the latent heat of vaporization of the water). A totalizing timer was attached to the quench water control to determine the amount of water introduced into the primary chamber during the test since the flow rate of the spray nozzles in the primary chamber was known to be 2 gpm.

The amount of No. 2 fuel oil used by the afterburner was measured by "dipsticking" the fuel storage tank.

Moisture and fixed carbon content of the ash were determined at Systech. The amount of unburned material (green ash) was computed by subtracting the moisture, unburned carbon, and theoretical fixed ash content of the residue from the total weight of the ash removed from the system.

The mass flow rate of the flue gas was determined from the stoichiometric air fuel ratio for the oil/refuse blend and the excess air level determined by the Orsat analysis.

3.0 RESULTS OF THE TEST

The data collected during the 68 hour test is recorded in the data ledger supplied to CEL with this report. A data summary is tabulated in the following pages.

3.1 MASS AND ENERGY BALANCES

Figure 1 lists the refuse composition determined by analysis of the photosort data. A moisture content of 25% on an as-received basis was assigned to this refuse. Typical analysis of similar refuse should have a moisture content of 19%. But, it rained 2 of the 4 days. Hence, the moisture content was raised to 25% on an as-received basis. Note that the high paper and cardboard content in this composition is probably due to the many commercial customers of this disposal service.

Figure 2 tabulates the ultimate analysis used in the combustion calculation. The ultimate analysis of the refuse was determined by converting the refuse composition into an ultimate analysis. The reported moisture level of 33% is on a dry weight basis which is 25% on an as-received basis.

The weight of refuse applied to the cumulative ultimate analysis is that total weight of refuse charged into the incinerator minus that amount which came out as green ash.

| <u>CATEGORY</u> | <u>WT. (lb)</u> | <u>%</u> |
|-----------------|-----------------|---------------|
| Paper | 61,991 | 49.0 |
| Cardboard | 36,942 | 29.2 |
| Wood | 2,530 | 2.0 |
| Yard Waste | 5,313 | 4.2 |
| Garbage | 8,223 | 6.5 |
| Cloth | 2,530 | 2.0 |
| Rubber | 253 | 0.2 |
| Plastics | 1,265 | 1.0 |
| Iron & Steel | 1,139 | 0.9 |
| Aluminum | 759 | 0.6 |
| Glass | 506 | 0.4 |
| Inert Material | 2,657 | 2.1 |
| Not Processed | <u>2,404</u> | <u>1.9</u> |
| | TOTAL: | 126,512 100.0 |

Moisture Content - 25% As Received Basis

FIGURE 1 CHARACTERIZATION OF WASTE INPUT
DURING 4-DAY TEST

| WT. (Dry) Fraction | REFUSE | OIL | CUMULATIVE |
|-----------------------|--------|--------|------------|
| Total Weight | 65,997 | 7,325 | 73,322 |
| Mass Fraction | .90 | .10 | 1.00 |
| C | 42.88 | 87.00 | 47.29 |
| H ₂ | 5.69 | 13.00 | 6.42 |
| O ₂ | 41.06 | --- | 36.96 |
| N ₂ | 0.49 | --- | 0.44 |
| S | 0.19 | --- | 0.17 |
| Ash | 9.61 | --- | 8.65 |
| H ₂ O | 33.33 | --- | 30.00 |
| HHV | 7,403 | 20,000 | 8,661 |

FIGURE 2 ULTIMATE ANALYSIS

Excess Air 38%

Flue Gas Temperature = 1720

ORSAT AVERAGE RESULTS

CO₂ = 12.1%
 O₂ = 6.2%
 CO = 0.4%
 N₂ = 81.3%

FIGURE 3 FLUE GAS SUMMARY

In other words, only refuse and fuel oil actually burned were accounted for in the combustion calculation.

Figure 3 is a tabulation of the flue gas analysis from the Orsat analyzer and temperature measurements. Only select readings were used in arriving at the average Orsat result. Readings taken late in the test were suspect because the sample probe had deteriorated because of the high temperature conditions found in the incinerator. The excess air level was calculated for standard hydrocarbons using the Orsat results.

Results of the ash analysis are summarized in Figure 4. 13.25 bins of ash were removed from the ash pit during the period of the test.

The total ash output was estimated to be 59,600 lbs. The ash returned to Systech's Laboratory appeared to contain no green ash and was probably not representative because of the small sample sizes. The amount of dry inert ash was determined from the refuse's ultimate analysis; the weight of unburned carbon was determined from the ratio of unburned carbon to inert ash as determined in the laboratory ash analysis.

Assuming a uniform moisture content of the incinerator residue, the remaining portion of the total ash was attributed to "green" ash. Slides taken of the ash removed from the incinerators seem to support this theory. Almost 27,000 lbs. of the total 59,000 lbs. of ash was green. Further analysis of the ash output of this system is probably warranted.

With a total wet ash output of over 59,000 lbs. the incinerator reduced the weight of the refuse only 53%. But, as Figure 5 illustrates, the incinerator provided a 90% volume reduction.

Figure 6 is the mass balance of the system. Figure 7 illustrates the average steady state energy balance of this system on an hourly basis. This energy balance is representative of the 68 hour period that the incinerator was charged. The 20 hours of burndown time were not accounted for and probably have little bearing on steady state operating conditions. Almost 24% of the input heat was loss in the green ash (unburned refuse).

The high rate of No. 2 fuel oil firing is the result of an effort by the operator to assure a clear plume and comply with local air pollution control regulations.

| | |
|------------------|----------------------|
| TOTAL ASH OUTPUT | lb. <u>59,653</u> |
|------------------|----------------------|

COMPOSITION OF ASH

| | |
|--------------------------|--------|
| Quench Water | 23,265 |
| Dry Inert Ash | 6,756 |
| Unburnt Carbon | 2,567 |
| Green (Unburnt) Material | 27,065 |

FIGURE 4 ASH SUMMARY

| | |
|------------------------------|---------------------|
| Volume Of Refuse Received | 684 yd ³ |
| Volume Ash Removed | 66 yd ³ |
| Incinerator Volume Reduction | 90% |

FIGURE 5 VOLUME SUMMARY

INPUTS

| | |
|-----------------------------------|------------------|
| TOTAL REFUSE RECEIVED AT PLANT | 126,512 lb. |
| NonProcessable | 2430 |
| Moisture | 31020 |
| Burnable Refuse (dry) | 93062 |
| | |
| AIR INTO INCINERATOR | 474,833 lb. |
| | |
| PRIMARY TEMPERATURE CONTROL WATER | 10,886 lb. |
| ASH QUENCH WATER | 23,265 lb. |
| NO. 2 FUEL OIL | <u>7,325 lb.</u> |
| | |
| TOTAL: | 642,821 lb. |

OUTPUTS

| | |
|------------------------------|-------------------|
| NONPROCESSABLES | 2,430 lb. |
| ASH | 59,653 lb. |
| Quench Water | 23265 |
| Dry Inert Ash | 6756 |
| Unburnt Carbon | 2567 |
| Unburnt Material (Green Ash) | 27065 |
| | |
| DRY FLUE GAS | 491,217 lb. |
| Fuel Oil | 7,325 |
| Burned Refuse | 56,674 |
| Air | 474,833 |
| Water | 41,906 |
| | |
| WET FLUE GAS | <u>89,521 lb.</u> |
| | |
| TOTAL: | 642,821 lb. |

FIGURE 6 MASS BALANCE

| | <u>MBtu/hr</u> | <u>%</u> |
|--------------------------|----------------|-------------|
| INPUTS | | |
| Refuse | 10.13 | 82.5 |
| No. 2 Fuel Oil | <u>2.15</u> | <u>17.5</u> |
| TOTAL | 12.28 | 100.0 |
| OUTPUTS | | |
| Dry Flue Gas | 3.09 | 25.2 |
| Humidity .08 | | |
| Bound Moisture .58 | | |
| Combustion Water .93 | | |
| Control Spray .41 | | |
| Wet Flue Gas | 1.87 | 15.2 |
| Unburnt Carbon | .53 | 4.3 |
| Unburnt Refuse | 2.95 | 24.0 |
| Unaccounted & R/C Losses | <u>3.84</u> | <u>31.3</u> |
| | 12.28 | 100.0 |

FIGURE 7 AVERAGE STEADY STATE ENERGY
BALANCE*

*68 hr. Operating in 88 hr.

3.2 RELIABILITY

No major breakdowns were observed during the entire 88 hour test. A continuing problem with the over temperature control water spray was observed. It was later learned from a representative of Consumat that the well water pump at this rural installation was not sufficient for supplying water to both the ash quench and over temperature control spray. As a result of this lack of water pressure, insufficient cooling water passed across the over temperature control nozzles and caused one of these nozzles to disintegrate. Therefore, whenever the water spray was activated, a continuous stream, rather than a spray, emitted from this nozzle location, causing the material in the path of this stream to extinguish. This situation was probably the cause of the high green ash content.

Once a day the operator has to clear the air passages inside the primary chamber. This clearing is done through removable plugs provided on the outside of the incinerator.

4.0 CONCLUSIONS

The evaluation of the Consumat controlled air incinerator showed that the unit could be used as a primary combustion chamber for a heat recovery system. Assuming that 80 percent of the sensible heat in the flue gases can be recovered, a waste heat recovery system could be expected to convert 32 percent of the input heat to steam or hot water. If the burn out of the unit were improved (probably as a result of reducing its rated capacity) recovery rates approaching 50 percent might be achieved.

The unit generally performed in a satisfactory manner. Refuse was being fed at too rapid a rate to achieve good burn out; green ash was being emitted. The ash handling system operated well.

Almost 23% of the released input heat was supplied by clean fuel burned in the afterburner. This rate of fuel consumption may be excessive.

The unit operated with 6.2% oxygen in the flue. Operating at 38 percent excess air is considered proper for these units.