INCINERATION OF LOW QUALITY MSW IN THE ROTARY WATER-COOLED O'CONNOR COMBUSTOR

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ABSTRACT

The incineration of low quality municipal solid waste (MSW) was studied in a waste-to-energy plant which uses the rotary Westinghouse O'Connor combustor. The low quality waste was prepared by mixing wet citrus rinds and seeds, with approximately 85% moisture content and higher heating value (HHV) of 1133 Btu/lb (629 kcal/kg), with normal MSW. Data on waste mass throughput, mass reduction rate, and ash burnout were collected during the test. The test results indicate that the rotary combustor is capable of efficient incineration of low quality MSW with HHV's as low as 2620 Btu/lb (1455 kcal/kg).

INTRODUCTION

Environmentally safe methods for disposal of municipal solid waste (MSW) have been explored for decades. The disposal of MSW at conventional or specially designed lined landfills is currently the most wide spread method used by municipalities in the United States and many other countries. Alternative disposal methods that could reduce the volume of the solid waste sent to landfills are becoming more and more popular.

Incineration of MSW in heat recovery boilers is one of the most attractive alternatives to direct landfilling of raw MSW. Mass burn and refuse derived fuel (RDF) incinerators are commonly used in many industrialized countries to reduce the volume of the solid waste sent to landfills and to generate useful thermal energy.

The efficient incineration of MSW is a strong function of the heating value and the moisture content of the MSW. MSW generated in many developing third world countries and industrialized Asian countries, such as Taiwan, has a lower HHV and higher moisture content than U.S. MSW. Excess fuel moisture leads to longer MSW burn times. The low HHV of the wet MSW will require that the feed rate of the wet MSW fuel be increased to maintain a minimum thermal throughput. This increases the size of the fuel handling system and can, to a large degree, determine the type of the incineration technology which will be most successful and efficient.

In the rotary O'Connor combustor it is possible to increase the temperature of the combustion air, passing through the perforated water-cooled grates (combustor walls), to levels much above that can be tolerated by conventional air cooled grate systems. This capability is most useful when dealing with highly wet MSW. Higher combustion air temperatures lead to faster drying of the wet MSW and more efficient incinerator performance. It is also possible to reduce the overall process excess air requirement when using higher temperature combustion air.

BURNING OF LOW QUALITY MSW IN THE O'CONNOR COMBUSTOR

In November 1988, Westinghouse Electric Corporation conducted a series of tests at its Bay County, Florida waste-to-energy plant to explore the possibility of burning very low quality MSW in the rotary O'Connor combustor. The performance data obtained during these tests are summarized in the following sections. An independent testing firm was contracted to perform the gas and solid (ash and citrus rinds and seeds) sampling and analysis.

BAY COUNTY FACILITY PROCESS DESCRIPTION

The main components of the Bay County plant are schematically shown in Fig. 1. Two rotary Westinghouse O'Connor combustors, each coupled to a heat recovery boiler, are used for burning MSW to generate steam and, ultimately, electricity. The rated gross capacity the Bay County plant is to incinerate 510 TPD (463 metric tons) of MSW with a HHV of 4500 Btu/lb (2500 kcal/kg).

The O'Connor combustor is a rotary steel drum combustor made of steel water tubes joined to one another by welded steel membranes referred to as combustor webs. Cooling water is circulated through the water tubes to cool the combustor walls and maintain long term integrity. MSW is first pushed onto a travelling conveyor by a front-end loader at the tipping floor level. The feed material is then conveyed into the feed hopper. Hydraulic rams are used to feed the material into the rotary combustor. Preheated high temperature combustion air is forced into the combustor through the perforations in the combustor webs. The transport of the waste through the combustor is achieved by controlling the rotational speed of the combustor.

The rotary combustor is connected to a water-wall boiler which extracts heat from the combustion flue gases to generate steam. Heat in the combustion flue gases is absorbed by the rotary combustor and the boiler water walls, the superheater, the convection section, and the air heater before the flue gas enters the air pollution control equipment and stack. At the Bay County plant, the fly ash that is carried over by the flue gases is collected in the superheater, convection section, and the electrostatic precipitator. CO and O_2 emission levels are monitored continuously by the plant instruments for combustion control and emission monitoring. The generated steam is used to drive a turbine generator and produce electricity. The combustor bottom ash and the collected fly ash are quenched in a quench tank and later deposited into dumpster trucks by the ash drag conveyor. The combined ash is disposed in a lined landfill operated by Bay County, Florida.

Efficient burning of low quality MSW in the Bay County plant is influenced by a number of operational and design factors. In this facility, there is no active control of the amount of MSW that is incinerated to meet the turbine-generator steam demand. The steam production rate is the primary process parameter monitored and controlled by the control room operators for electricity generation. In order to maintain steady steam conditions, low steam production rates by one combustor/boiler train are, to some operator-allowable limit, compensated by an increase in the steam production and MSW incineration rate by the other unit.

There are, however, practical limits to how much normal or wet MSW can be effectively incinerated in each combustor: the plant's control capability at low steam flow rates; the size and the rating of the combustor, the feed handling system; and the ID/FD (induced and forced draft) fans can all affect the amount of low quality wet MSW that can be efficiently incinerated in the rotary combustors.

EXPERIMENTAL RESULTS

The primary purpose of the tests was to rate the performance of the rotary O'Connor combustor, installed at the Bay County plant, when burning low quality MSW. Optimization of steam production rates was not considered a primary objective of the test.

The test campaign consisted of one baseline test (set point 14) with normal Bay County MSW, and three tests (set points 11, 13, and 15) with simulated low quality MSW. The low quality MSW was prepared by adding wet citrus rinds and seeds to the normal Bay County MSW. Citrus rinds and seeds have high moisture content and low heating value.

Prior to the start of each test the wet citrus peels were thoroughly mixed with the normal MSW on the tipping floor by front-end loaders. The weights of the citrus peels and the normal MSW were measured by the plant's truck scale prior to mixing. The mixed fuel was then stored in designated piles on the tipping floor

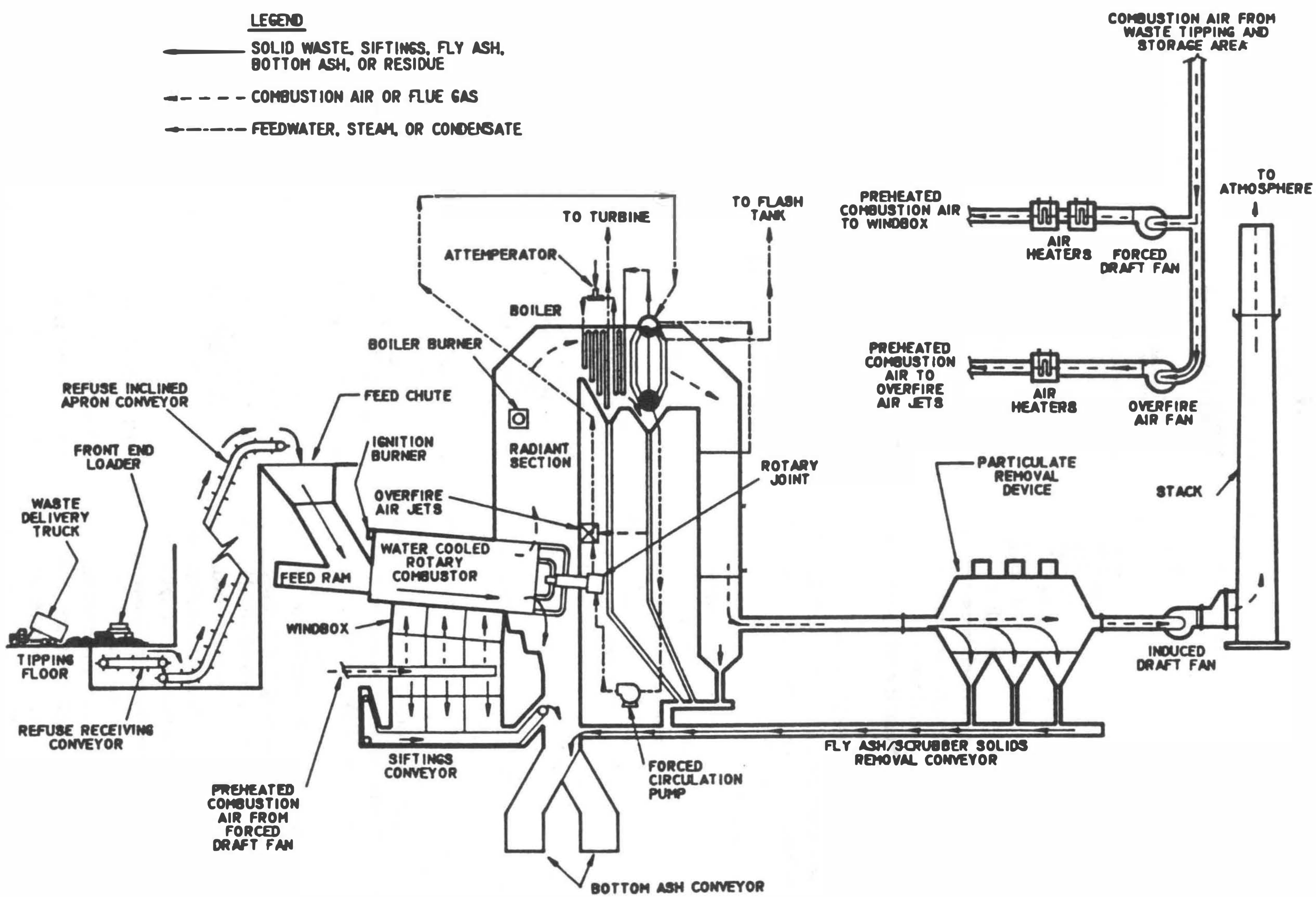

FIG. 1 BAY COUNTY PLANT PROCESS SCHEMATIC DIAGRAM

TABLE 1 TYPICAL ANALYSIS OF US AND TAIWAN MSW (CITY OF TAICHUNG 1983) AND CITRUS RINDS AND SEEDS

ULTIMATE ANALYSIS, wt% (as received)	US	TAIWAN (1983 average for Taichung)	CITRUS RINDS AND SEEDS
Moisture	22	59.77	78.70
Ash	27.58	11.98	0.74
Combustibles			
o Carbon	25.53	13.90	10.21
o Hydrogen	3.35	2.28	1.21
o Oxygen	21.38	11.48	8.88
o Nitrogen	0.0	0.45	0.24
o Sulfur	0.16	0.11	0.02
o Chlorine	------	0.03	------
HHV, BTU/lb	4500	2635	1706
(as received), (kcal/kg)	(2500)	(1464)	(948)

TABLE 2 ACTUAL HIGHER HEATING VALUE AND ULTIMATE/PROXIMATE ANALYSIS OF THE CITRUS PEELS BURNED DURING THE TEST

PARAMETER	SAMPLE 1	2	3	Average
Proximate Analysis (as received), %				
Moisture	84.98	83.68	87.46	85.37
Ash	0.55	0.70	0.57	0.61
Volatile Matter	11.63	12.49	9.83	11.32
Fixed Carbon	2.84	3.13	2.14	2.70
Ultimate Analysis (as received), %				
Hydrogen	10.39	10.30	10.52	10.40
Carbon	6.88	7.57	5.86	6.8
Nitrogen	0.17	0.00	0.18	0.06
Sulfur	0.01	0.11	0.01	0.04
Oxygen	82.00	81.32	82.86	82.1
Ash	0.55	0.70	0.57	0.61
Higher Heating Value, BTU/lb	1149	1266	983	1133
(as received) (kcal/kg)	(638)	(703)	(546)	(629)

and fed, without interruption, to the rotary combustor number two.

During the planning stages of the test, it was assumed that the composition of the Bay County MSW is the same as that of typical U.S. MSW. The composition of the low quality MSW from Taiwan's city of Taichung was also considered in planning the test. The analyses of typical U.S. MSW, low quality MSW from city of Taichung (1983), and reference wet citrus peels (Niessen, 1978) are presented in Table 1. The waste analysis presented in this table were used to come up with the initial estimates of the amount of citrus peels that should be mixed with each ton of MSW in order to simulate the city of Taichung's reference MSW as closely as possible.

During testing, a number of plant instruments were calibrated and continuously recorded. Data on MSW mass throughput, weight reduction, burnout, and steam production rates were also collected. The weight of the ash discharged from the incinerator was also measured. Ash and citrus peels were sampled and sent to an outside laboratory for HHV and ultimate/proximate analysis.

Due to the general difficulty in sampling and analysis of the bulky and highly heterogeneous MSW feed stream by standard calorimetric methods, the HHV of the low quality feed stream was measured indirectly by using the proposed ASME boiler-as-a-calorimeter test procedure. The stack gas molecular weight, temperature, and flow rates were measured manually by U.S. EPA approved methods 1, 2, 3, and 4.

The actual HHV, ultimate and proximate analysis of the citrus peels burned during the test, are presented in Table 2. The actual, as run test operating conditions are summarized in Table 3. The laboratory analyses of the ash sampled during the test appear in Table 4.

TABLE 3 SUMMARY OF AS-RUN OPERATING CONDITIONS

PARAMETERS	SET POINT 11	13	14	15
Feed Streams				
- Total Wet Fuel Feed Rate, TPD	290	329	253	335
- Total Dry Fuel Feed Rate, TPD	153	174	182	160
- HHV (1), BTU/lb	2620	2837	4725	2890
- Moisture (2), wt%	47.14	47.14	28	52.24
Citrus Peels Feed Rate, TPD	97	110	0	141
- Moisture, %	85.4	85.4	----	85.4
- HHV (3), BTU/lb	1132	1132	----	1132
Steam				
- Flow Rate, Klb/hr	36.6	48.6	71.5	49.0
- Temperature, °F	740	741	732	739
- Pressure, psig	573	578	584	570
Ash				
- Discharge Rate, lb/hr (dry)	2,161	4,260	7,033	3,584
- HHV (dry basis), BTU/lb	216	436	358	488
- Moisture, %	26.61	24.96	29.48	31.76
- Loss On Ignition (LOI, dry)	NA	2.95	2.80	4.91
Mass Reduction				
- Wet Basis, (5) %	88	80	56	82
- Dry Basis, (6) %	91	84	67	87
Stack Gas				
- Flow Rate, SCFM (dry)	25070	24752	23241	24624
- Temperature, °F	439	460	475	473
- Oxygen, Vol.%	11.64	10.3	8.2	9.54
Heat Recovery Efficiency (7), %	56.3	61.3	69.2	60.6

Note: All values are in English Units
NA: Not available due to possible oxidation of metallic ash oxides to higher oxidation levels during ash analysis.
(1) Calculated by the Boiler-as-a-Calorimeter method.
(2) The moisture content of the MSW fraction was assumed to be 28 wt%.
(3) As received and fired.
(4) Combined fly ash and incinerator bottom ash.
(5) Wet MSW / Wet Ash basis
(6) Wet MSW / Dry Ash basis
(7) H.R.E. = (Total Heat Output)/(Total Heat Input).

DATA ANALYSIS

The heating value of the MSW decreases as its moisture content increases. Mass burn MSW incinerators have to deal with seasonal, daily, or even hourly variations in the moisture content and the heating value of the MSW. The major draw back to burning low

TABLE 4 ASH HIGH HEATING VALUE AND ULTIMATE/PROXIMATE ANALYSIS

PARAMETER	SET POINT 11	13	14	15
Proximate Analysis, % (as sampled, wet)				
Moisture, wt %	19.35	21.59	23.61	28.35
Ash	79.73	76.10	74.25	68.12
Volatile Matter	1.49	1.78	0.93	2.81
Fixed Carbon	NA	0.53	1.21	0.71
Ultimate Analysis, % (as sampled, wet)				
Hydrogen	2.29	2.55	2.73	3.27
Carbon	1.29	2.14	2.05	2.69
Nitrogen	0.29	0.03	0.01	0.02
Sulfur	0.21	0.37	0.08	0.21
Oxygen	16.19	18.81	20.88	25.69
Ash	79.73	76.10	74.25	68.12
High Heating Value, BTU/lb (dry basis) (kcal/kg)	216 (120)	434 (241)	358 (199)	488 (271)
Loss On Ignition (dry), %	NA	2.95	2.80	4.91

NA: Not available due to possible oxidation of metallic ash oxides to higher oxidation levels during ash analysis.

quality wet MSW is, however, the reduction in the mass throughput of the dry MSW rather than the energy lost in the vaporization of water. The heat of vaporization of water (970 Btu/lb, 539 kcal/kg), although not negligible, is small compared to the HHV of dry reference MSW (5770 Btu/lb, 3205 kcal/kg). High moisture content MSW will also tend to reduce the flame temperature to levels where combustion cannot be sustained without auxiliary fuel firing. For example, in wood burning plants furnace blackout occurs at a moisture content of around 68% (Drucker, 1984).

As mentioned earlier, direct sampling and analysis of the MSW is very difficult. During this test the boiler-as-a-calorimeter test procedure was used to obtain information on the heating value of the low quality fuels burned, and to obtain approximate estimates of their moisture content. This is accomplished by accounting for the process heat outputs, heat losses and credits, and by measuring the waste feed rate. The calculated HHVs of the fired wastes are presented in Table 3.

The moisture content of the normal MSW fired during set point 14 was assumed to be around 28% based on past experience at the Bay County plant. The moisture content of the low quality fuels burned during the other set points (Table 3) are estimated based on this value of the moisture content for the normal MSW, and the moisture content of the citrus peels found by analysis (Table 2). However, the calculated mixed fuel heating values further reveal that the heating values of the MSW portion of the low quality fuels burned during set points 11, 13, and 15, are lower than the 4726 Btu/lb (2625 kcal/kg) value calculated for the normal MSW during the baseline set point 14. It is, therefore, possible that the moisture content of the low quality MSW fired during these set points could actually be higher than the estimated values presented in Table 3.

The analysis of the ash samples indicate that the quality of the ash became poorer, although not significantly, when burning low quality MSW. The loss on ignition (LOI) values of the ash samples are found to be below 5% for all set points. This is well within the range of the values observed in many modern waste-to-energy plants.

In the Bay County plant the incinerator ash is mixed with the fly ash collected in the boiler before being dragged out of the system. The additional higher excess air (see flue gas oxygen levels in Table 3) which was utilized to dry and burn the low quality wet fuel can contribute to higher carryover of unburnt fly ash from the incinerator. This can contribute to the observed higher ash HHV and LOI values.

The MSW mass reduction rate seems to have improved when burning low quality MSW. This is mostly due to the evaporation of the high moisture in the incoming fuel stream.

Two of the major process parameters monitored continuously by the control room operators are the steam production rate and the furnace flue gas temperature at the inlet to the super heater section. The actual time history of the steam production rate and furnace temperature, measured during set point 13, are shown in Figs. 2 and 3. These figures illustrate the response of the incinerator/boiler system to the introduction of low quality fuel. As can be seen in Fig. 2, the amplitude of the observed fluctuations in the steam production rate became greater when the low quality fuel was being incinerated. This is mostly due to the inexperience of the control room operators in burning very low quality MSW. Many of the incinerator's automatic control features and preset control limits had to be disabled and manually controlled during the test. Manual control naturally leads to wider short term fluctuations in both the steam production rate and the furnace temperature. It is expected that with more operator experience with low quality fuel and proper modification of the incinerator's automatic control logic, the degree of furnace temperature and steam fluctuations can be reduced to levels normally observed when burning normal MSW.

The average flue gas temperature profiles measured during set points 11, 13, 14 and 15 are presented in Fig. 4. As expected, both the combustor front-end temperature and the furnace flue gas temperature decreased when low quality MSW was incinerated.

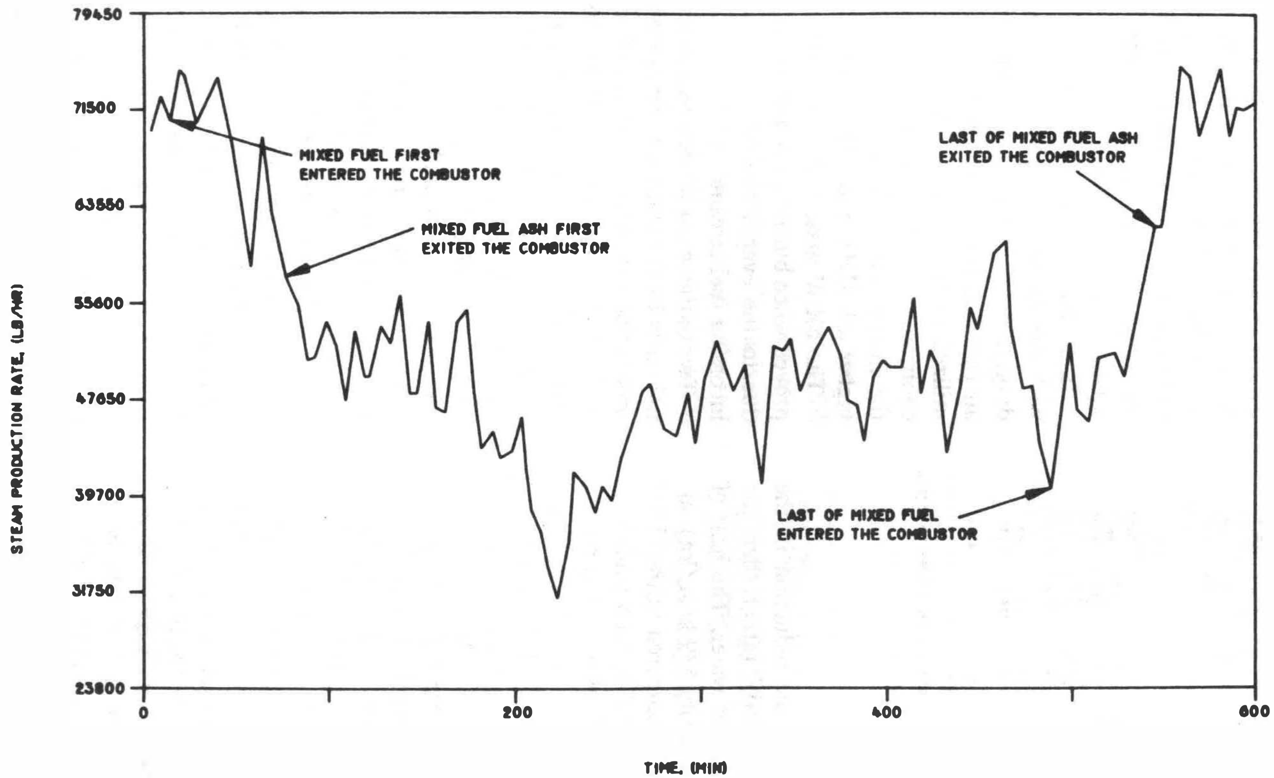

FIG. 2 STEAM PRODUCTION RATE MEASURED BEFORE, DURING AND AFTER INTRODUCTION OF LOW QUALITY FUEL (SET POINT 13)

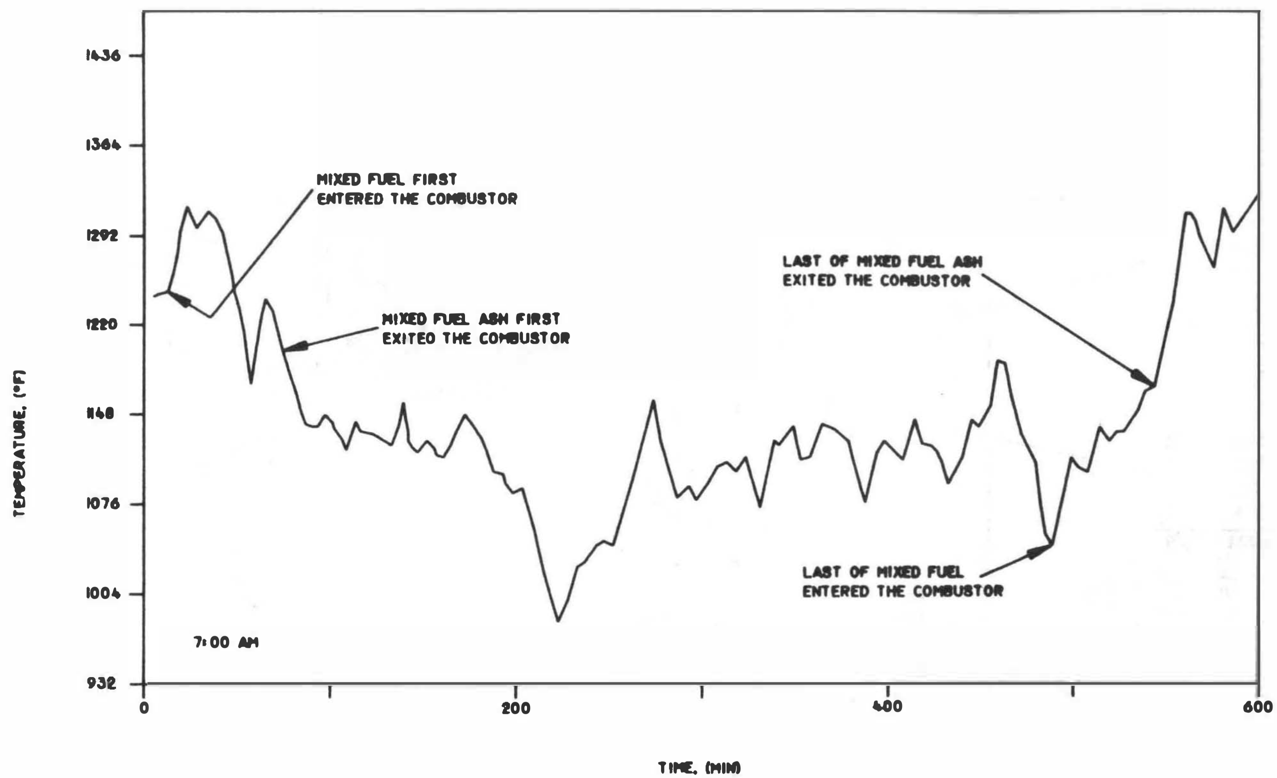

FIG. 3 FURNACE TEMPERATURE MEASURED BEFORE, DURING AND AFTER INTRODUCTION OF LOW QUALITY FUEL (SET POINT 13)

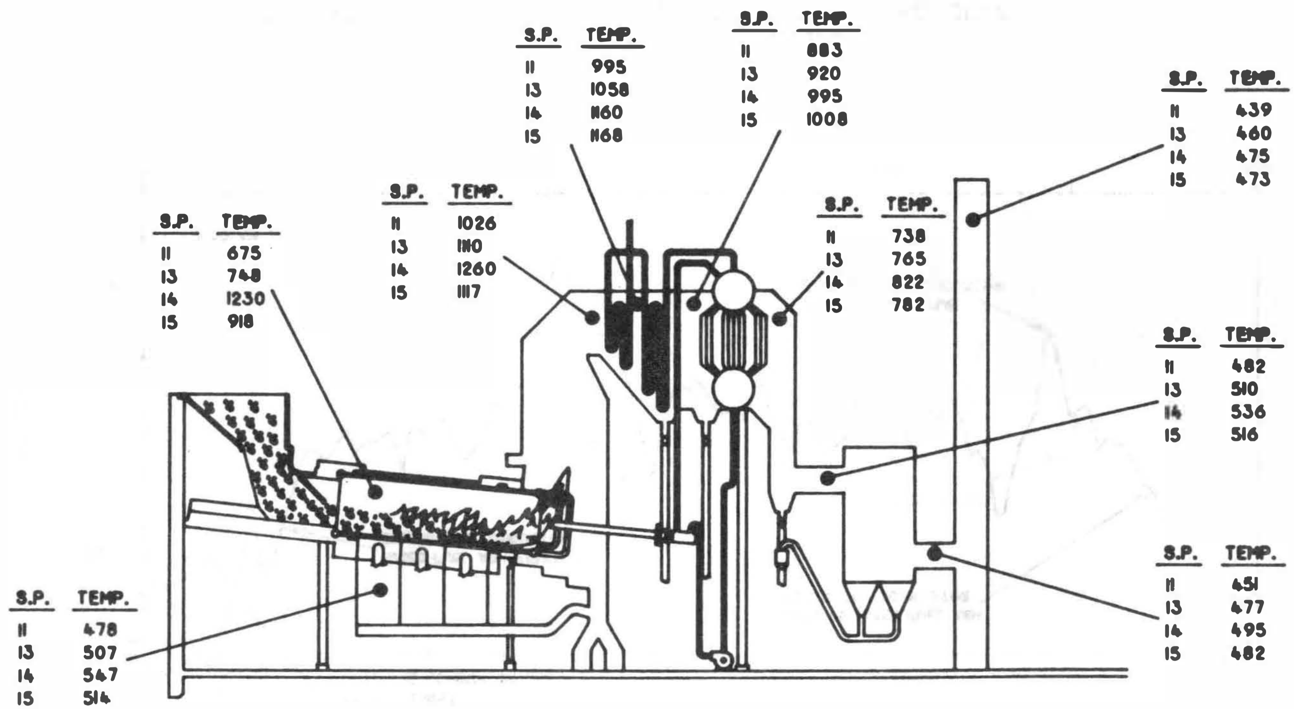

FIG. 4 FLUE GAS TEMPERATURE PROFILE MEASURED DURING SET POINTS 11, 13, 14 AND 15 (DEG. F)

CONCLUSION

The mass-burn rotary O'Connor combustor was found to be capable of incinerating low quality MSW with higher heating values as low as 2620 Btu/lb (1455 kcal/kg). On a dry basis, the fuel feed rate did not appreciably decrease when burning low quality wet MSW. The quality of the combined bottom ash and fly ash discharged when burning low quality MSW was found to be comparable to the quality of the ash discharged during the burning of mostly normal, higher quality MSW.

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