**Cyclone Incinerator
Development Program
FY 1976 Annual Report**

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Monsanto

MOUND LABORATORY

Miamisburg, Ohio

operated by

MONSANTO RESEARCH CORPORATION

a subsidiary of Monsanto Company

for the

**UNITED STATES ENERGY RESEARCH
AND DEVELOPMENT ADMINISTRATION**

U. S. Government Contract No. EY-76-C-04-0053

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CYCLONE INCINERATOR DEVELOPMENT PROGRAM

FY-1976 ANNUAL REPORT

A. INTRODUCTION

On July 1, 1975, Monsanto Research Corporation was funded by ERDA/DWMT to continue studies at Mound Laboratory with a cyclone incinerator pilot plant for the consolidation of low level radioactive wastes.

The report summarizes activities associated with the LSA Cyclone Incinerator Program for the period from July 1, 1975, to June 30, 1976. The document includes work performed in June, 1976, which has not been previously reported.

The pilot plant had been installed prior to July 1, 1975, to investigate the feasibility of this method for effectively reducing the volume of LSA wastes. Such a method is badly needed to reduce the costs of transporting such wastes and improving the safety of disposing of them. In addition to using the incinerator to develop parameters for the efficient volume reduction of Mound-generated wastes, the unit is also available for studies to adapt this incinerator concept to the needs of other ERDA sites. The results of such studies then can be used to construct suitable incinerators at these sites.

Operation of the incinerator began in late FY-1975 to accumulate design data. Figure 1 shows a view of the pilot plant as it existed on July 1. Figure 2 shows detail of the original incinerator one-cubic-foot chamber, lid, and deck plate assembly. A schematic of the original pilot plant process is shown in Figure 3.

In the course of performing the burning tests over a period of several months, it was found that the pressure drop in the Brink® Mist Eliminator was greatly affected by condensation of a tar-like material on the surface of the filter

FIGURE 1

MOUND LSA CYCLONE INCINERATOR

FIGURE 3

bed. The Brink[®] Mist Eliminator was finally removed from the system to permit development efforts to be concentrated on improving combustion efficiencies. The original burning chamber was improved and modifications were made to the system which permitted incineration directly in the 55-gallon storage drum (in situ).

To improve the incineration rate, the original air induction system was then replaced with a "periscope" type design air supply system.

For monitoring the system, instrumentation was installed to collect data on temperatures, pressures, combustible gases, carbon dioxide and oxygen, and on particulates in the off-gas stream.

Further improvements were made in the cooling system for the liquid scrubbing system and a vertical leaf filter was incorporated into the scrubber system to improve filtration and reduce waste generation.

Experiments were conducted and data collected to determine pressure drops, electrical consumption, gaseous effluents, and temperature profiles of the system. To further reduce particulates in the off-gas stream prior to HEPA filtration, a high-energy venturi scrubber was installed. A schematic of the present pilot plant process is shown in Figure 4. Currently, the drum enclosure unit illustrated in the figure is not being used.

B. DETERMINATION OF PARTICULATES IN THE OFF-GAS STREAM

Since December, 1975, the incinerator off-gas streams of nearly all the incinerator runs have been sampled for particulates. Sampling has been performed by use of Brink[®] Cascade Impactor Analyzers. These widely accepted Brink[®] analyzers provide particle size distribution, as well as total particulates.

Although particulate sampling is a rather difficult, time-consuming task, and little data from other incinerators are available for comparative analysis, it was considered particularly important to this study for several reasons.

MOUND CYCLONE INCINERATOR

FIGURE 4

- a. Particulate emission data were collected to determine if the cyclone incinerator was particularly effective in keeping the quantity of particulates in the off-gas to a minimum. Also it is beneficial to know if the type of particle formed during incineration could be removed from the gas stream by conventional methods. Many runs with the incinerator conclusively demonstrated the fact that the quantity and size of the particulates were so small in the off-gas that an afterburner was not needed. This small quantity of particulates was attributed to the centrifugal effect of the cyclone air flow and the resulting long retention time in the burning chamber.
- b. The need to characterize the particulates was important because the goal of the incinerator study was to successfully consolidate low level radioactive waste while preventing the escape of radioactive material. Because the radioactive material in general is carried by the particulates, the lower the number of particulates in the off-gas, the lower the quantity of radioactive material. Consequently the particulate information obtained from performing burns with nonradioactive material would serve to indicate the quantity of radioactive material which might be found in the off-gas. Fortunately the cyclone incinerator has been found to be efficient in minimizing the quantity of particulates transferred to the off-gas and so the amount of radioactive material expected to be found in the off-gas should be small.
- c. All radioactive gas streams must be subjected to absolute filtration prior to release to the atmosphere. The absolute filter requires replacement and is not self-cleaning as are the initial stages of the off-gas treatment equipment. Therefore, the quantity of particles in the gas reaching the filter determines the life of the

filter. Particle sampling has supplied information concerning the particle load to be expected at the absolute filter, and has provided a means to evaluate, adjust, and improve the off-gas cleaning equipment prior to the filter. The need for, and the design of, the venturi scrubber installed in June was based on information provided by particle sampling. Only a limited number of runs have been made with the scrubber to date. Data for these runs are summarized in Table I. Although the scrubber is not as yet operating to specifications, the off-gas now emitted from it can be effectively handled by an absolute filter. Changes in operating parameters for the incinerator are expected to further reduce emissions from the scrubber.

The composition of the three types of feed used in the incinerator experiments is given in Table II. The type used for each burn is shown in the second column of Table I.

Table III contains monthly averages of run data collected since December 1, 1975. As can be seen on this chart, there has been a general increase in the rate of combustion, while at the same time particulate emission has decreased.

C. EQUIPMENT IMPROVEMENTS MADE

Early in FY-1976 a larger capacity exhauster was installed to replace the original, marginal exhauster acquired from surplus. Also, an air cooled, closed loop cooling system was installed to reduce water consumption and to minimize the potential for release of plutonium to the environment.

a. Modifications for "In Situ" Burning

To permit burning of waste material directly in a drum or a removable chamber, a new deck plate and a clamping device were designed and installed in October 1975 using the same lid air intake, and baffle assembly (see Figure 5). After a few

TABLE I
SUMMARY OF RESULTS FROM INCINERATION RUNS
FOR JUNE 1976

Run No.	Type Feed	Spray Tank Efficiency (%)			Venturi Efficiency %			Off Gas Loading (MG/CF)			Off Gas Temp. Peak (°F)	Avg. Comb. Air Flow (CFM)	Time Of Burn (Min.)	Feed Wt. (Grams) No Metal	Burning Rate (KG/HR)	Ash (Grams) w/o Metal	Ash %
		Total Part. Removed	Removal of Part. >1μ	Removal of Part. <1μ	Total Part. Removed	Removal of Part. >1μ	Removal of Part. <1μ	Before Deluge Tank	Before Venturi	After Venturi							
306	I	52	78	31	83	100	79	14.2	6.8	1.1	2020	282	12	5264	26.3	237	4.5
307	II	(1)						19.7	-	4.2	1300	260	15	5600	22.4	158	2.8
308	III	55	90	7	63	75	61	11.4	5.1	1.9	1960	352	16.5	5264	19.1	328	6.2
309	I	46	77	18	75	33	85	14.9	8.0	2.0	1980	267	20	5264	15.8	324	6.2
310	II	18	53	3	94	92	95	25.0	20.6	1.2	1200	297	15	5600	22.4	105	1.9
311	III	43	89	0	71	80	70	9.6	5.5	1.6	2000	304	26	5264	12.1	535	10.2
312	I	32	70	9	69	70	68	14.6	10.0	3.1	2160	322	19	5264	16.6	137	2.6
313	II	29	68	18	89	100	88	29.6	21.2	2.4	1440	282	12	5600	28.0	170	3.0

Note: (1) Sampling equipment malfunctioned.

TABLE II
COMPOSITION OF INCINERATOR FEEDS

	<u>Type I</u> ¹	<u>Type II</u> ¹	<u>Type III</u> ¹
Paper	32	2	48
Plastics			
PVC	9	23	1
Polyethylene	29	9	6
Polypropylene	8	2	-
Rubber	13	3	26
Cloth	3	61	6
Leather	-	-	-
Wood	-	-	7
Metal	6	-	6

¹Weight %

TABLE III

SUMMARY OF MONTHLY AVERAGES OF OFF-GAS DATA FROM INCINERATOR RUNS DURING FY-1976

Spray Tank Efficiency (%)				Venturi Efficiency (%)			Loading (MG/CF)									
Month	Total Part. Removed	Removal of Part. $>1\mu$	Removal of Part. $<1\mu$	Total Part. Removed	Removal of Part. $>1\mu$	Removal of Part. $<1\mu$	Before Spray Tank	After Spray Tank	After S.C. Filter	After Venturi	Comb. Air Flow CFM Avg.	Time of Burn (Min)	Feed Wt. Grams (No Metal)	Burn Rate (KG/HR)	Ash Wt. Gm. No Metal	Ash Wt %
Dec.	57%	94%	28%	-	-	-	9.8	4.4	-		330.5	25	5955	14.3	358	6.0
Jan.	60.5%	89%	29.4%	-	-	-	7.0	3.7	-		283	22.6	5492	14.6	263	4.8
Feb.	47.4%	83%	31.5%	-	-	-	12.5	6.7	4.5		279	19	5354	16.9	182	3.4
Mar.	50.3%	79.4%	34%	-	-	-	13.0	6.6	4.4		279	17.5	5390	18.5	205	3.8
Apr.	48.7%	75.6%	33.5%	-	-	-	14.2	6.4	3.2		289	16.5	5370	19.5	211	3.9
May	42.4%	68.2%	34.6%	-	-	-	10.9	6.5	2.8		212	22.5	5376	14.3	156	2.9
June	39.2%	75%	12.3%	77.7	78.6	78.0	17.4	11.0	-	2.2	296	16.9	5390	19.1	249	4.6

Av. 4.2

FIGURE 5

runs were made in October with this arrangement, the air intake to the old assembly was blocked off. Then, a new air intake pipe was installed which could be moved up and down in the drum and rotated to direct the flow of the air and to provide more complete combustion. The modification is shown in Figure 6.

Later, various replaceable discharge nozzles were fabricated to improve combustion air flow patterns. Pointing the nozzle downward at an angle of 18° and inducing air into the chamber at a rate of 260 ft/sec provided good burning characteristics.

The new system permits "in situ" burning and will greatly simplify incinerator chamber maintenance. The new air intake apparatus provides increased flexibility of combustion air handling.

b. Instrumentation Installation

The original incinerator installation had only the minimum instrumentation necessary to run the system. In September, gas analyzers, pressure transmitters, thermocouples, particulate samplers, and recorders were ordered to measure and/or record the following data:

Gas Composition

The oxygen and carbon dioxide content.
The combustibles composition.

Pressure

The pressure change across the incinerator chamber and spray tank.
The pressure change across the venturi scrubber.
The pressure change across the Pitot tube for air flow measurements.
The pressure change across fiber bed filters.

FIGURE 6
ADJUSTABLE AIR SUPPLY SYSTEM

Temperature

The off-gas temperature.

The combustion chamber temperature.

The combustion chamber wall temperature.

Particulates (Size and Quantity)

After the combustion chamber.

After the spray tank.

After the final filter.

c. Modification to Filtration System

Because no data were available for sizing the scrub liquor filter on the original pilot plant, a small 3 sq.ft., bag type filter was installed. Experimental runs in FY-1975 showed that this size filter was rather small and awkward to handle. Accordingly, a 27 sq.ft. vertical leaf filter with a bottom mud discharge was ordered in December, 1975, and installed in March, 1976 (See Figure 7). The residue is removed from the filter by vibration of the leaves. The cake discharged from the leaves accumulates in the bottom of the filter housing and is periodically removed as a sludge through a drain valve.

This unit is currently operated manually. However, it is a type of filter which can readily be modified to operate remotely on an automatic cycle by using two units in parallel. The vertical leaf filter has proved to be more efficient in the removal of particulate matter than the 5 μ filter bag system formerly used. The vertical leaf filter has also eliminated bag changing and disposal required by the filter bag system, thus reducing radioactive material handling and improving overall volume reduction efficiency.

FIGURE 7

d. Off-Gas Handling Modifications

Experiments in FY-1975 demonstrated that the Brink^(R) High Efficiency filter did an excellent job in removing particulate matter (see Table IV). However, it was found that the particulates caught were not readily washed out of the filter element. The gradual build-up of residue increased the pressure drop across the filter element and severely limited the gas flow. A special wash with acetone and ethanol did not restore the filter element to its original usefulness. Some experimentation was performed with the high velocity type fiber element intermediate between the coarse high velocity spray catcher type element and the low velocity high efficiency type. The high velocity element also became plugged.

The deep fiber bed type filter may still be quite useful and further experimentation seems warranted because of the advantages inherent in its design. These advantages include the following:

1. Moderate pressure drops for equivalent cleaning efficiency (assuming particle wash-out rate equals the pick-up rate).
2. Toxic soluble gas removal capabilities.
3. Efficiency is not effected by air flow volume.
4. A virtually passive removal system.
5. Designed for wet operations.

A substantially thinner fiber bed at a slight sacrifice in efficiency, could improve washing of the bed markedly. Flow from the outside of the element to the inside (to increase surface area) would increase the time before any potential loading of particles would cause problems in operation.

TABLE IV
FINAL BRINK FILTER PERFORMANCE
ON PLUTONIUM-238 SPIKED RUNS

<u>Run No.</u>	Influent and Effluent of Final Brink Filter <u>Total Sample Counts - DPM</u>	
	<u>Influent</u>	<u>Effluent</u>
89	4.4	1.6
90	2.1	1.6
92	Quenched	< Blank
94	4760	< Blank
95	202	< Blank
97	38	< Blank
98	55	< Blank

A hybrid system using a deep fiber bed filter with other scrubbing techniques could be of value such as a high efficiency element after a venturi scrubber.

Because of the plugging problem, the possibility of using a wet electrostatic or wet charged particle type scrubber in place of a high energy venturi scrubber for a suitable particulate removal system, was investigated also. The charged particle type scrubber appears promising, but the present cost far outweighs the operating cost for the high energy venturi scrubber.

The wet electrostatic or wet charged particle type scrubber will be worth considering again if a larger off-gas system is used or if its cost decreases.

Based on the review of off-gas handling methods as noted above and knowing the characteristics of the off-gas being generated by the incinerator, it was decided that the installation of a venturi scrubber after the deluge tank would effectively reduce the concentration of particulates and radioactivity in the off-gas to a level where the gas could be directly exhausted to a HEPA filter bank. Consequently, a purchase order for a venturi scrubber system was placed in February, 1976, and installation of the unit was completed in mid-June 1976. Figure 8 shows the scrubber in place. The particulate removal efficiency of the venturi scrubber are given in Table I of this report.

The off-gas being handled by the scrubber typically has the following characteristics:

1. Air flow 225 ACFM (actual cubic feet per minute) to 550 ACFM at 130°F saturated with moisture.

FIGURE 8

2. Inlet gas 0.06 grains of particulates per actual cubic foot.
3. Inlet particle size distribution (actual measured values from spray tank outlet).

100% below 7 micrometers
97% below 2.7 micrometers
92% below 1.6 micrometers
89% below 1.1 micrometers
74% below 0.56 micrometers
56% below 0.35 micrometers

4. Particle density 2.2 g/ml (actual particle data).

D. PRESSURE DROP ACROSS VENTURI SCRUBBER

An updated typical pressure drop profile across the incinerator system at an air flow of about 280 CFM, is as follows:

- a. Incinerator chamber and spray tank - 18 inch wg (water gage).
- b. Spray catchers - no longer in use.
- c. Venturi scrubber - 55 inch wg. (The venturi scrubber replaces the mist eliminator.)
- d. Total pressure drop - ~75 inch wg.

Before installation of the scrubber the total pressure drop across the system was about 22 inch wg. with 18 inch being contributed by the incinerator chamber and spray tank and 4 inch by the spray catchers.

E. FLUE GAS ANALYSIS

A complete analysis of the flue gas was made for possible significant pollutants in the off-gas stream. Determination of the concentrations of SO_x at the outlet of the incinerator chamber and the outlet of the scrubber system were made using the following method. Sampling for SO_x was carried out by continuous extraction of a portion of the flue gas. This filtered gas sample was pulled through

a sample train consisting of a bubbler containing isopropanol and three cooled midget impingers, the first two of which contained hydrogen peroxide. The SO_x was collected in the impingers and separate measurements of both SO_2 and SO_3 concentrations were made by the barium-thorin titration method*.

The SO_x analysis obtained from runs 277 through 285 are given in Table V. The data indicate a larger amount of SO_x available in Type III material which is to be expected due to the high rubber content. In all cases, the data show that the deluge tank is efficiently removing SO_x fumes from the flue gas. The composition of the three types of feed material is given in Table II. After the scrubber, a maximum of 30 ppm of SO_3 and 15 ppm of SO_2 were noted in a few cases. However, for the majority of the analyses, the concentrations were below the limits of detectability.

Concentrations of vinyl chloride and total hydrocarbons present in the scrubber exit stream were determined with a portable gas chromatograph. The unit used was a Model 511, AID Portable Flame Ionization Detector (FID), Gas Chromatograph. By means of a hand pump, stack gas was drawn through a stainless steel probe into an automatic sampling valve. Total hydrocarbons were determined through a direct path to the FID. For the analysis of vinyl chloride (VC), however, chromatographic separation was necessary prior to introducing the sample into the flame ionization detector.

The results for nine different sample runs are given in Table VI. In the table, readings marked "greater than" (>) are for values which exceeded the instrument range setting at the time of sampling.

On-line control instrumentation is used to continuously monitor combustible gas in the offgas. Results obtained with such equipment were consistent with the spot analyses

*See Federal Register, Vol. 36, No. 247, Dec. 23, 1971, pp. 24890-4.

TABLE V
SO₂ AND SO₃ RESULTS

Type I Materials

<u>Run #</u>	<u>Inlet to Scrubber</u> (PPM)		<u>After Scrubber</u> (PPM)	
	<u>SO₂</u>	<u>SO₃</u>	<u>SO₂</u>	<u>SO₃</u>
279	40	29	ND	ND
282	5	58	4	ND
285	9	34	ND	26

Type II Materials

277	4	7	ND	ND
280	27	148	9	9
283	5	47	ND	ND

Type III Materials

278	95	14	15	4
281	111	2	ND	ND
284	25	127	ND	30

TABLE VI

SUMMARY OF TOTAL HYDROCARBON (THC)
AND VINYL CHLORIDE (VC) RESULTS

<u>Run No.</u>	<u>VC (ppm)</u>	<u>THC (ppm)</u>
277	>500	3,714
277	200	4,500
277		4,714
277		5,143
277		5,000
277		4,214
278	1,040	
278	600	
279		65
279		63
279		47
279		48
279		52
279		42
279		62
280	>156	
280	200	
281	40	
281	40	
281	24	
282	> 77	
282	>308	
282	0	
282	0	
282	148	
282	> 19	
283	19,692	48
283	0	51
283	0	>381
283		>762
283		3,429
283		3,429
284	12	> 24
284		> 24
284		4
284		23
284		22
284		24
285	17	4
285	14	3

given in Table VI. The value of 19,692 ppm for run 283, which was obtained by spot analysis, was confirmed by the line control instrumentation. Actually, such high peaks are instantaneous in nature and occur only occasionally during runs. Therefore, the magnitude of such peaks should not be construed as being representative of the vinyl chloride content of the off-gas for a given run because lack of homogeneity of feed material and fluctuation in the incineration process have a significant influence on the size of the peaks.

Although the data are limited, oxidation of the vinyl chloride appears more difficult than oxidation of butyl rubber or the polyolefins.

The HCl off-gas analyses showed anomalous results (Table VII) which could be caused by sampling, analytical or process problems or a combination of the three. At this time, the possible causes of these anomalies have not been fully investigated.

TABLE VII
MEASUREMENT OF REMOVAL OF HCl FROM OFF-GAS

<u>Run No.</u>	<u>Length of Run (Min.)</u>	<u>Type of Feed^a</u>	<u>% PVC</u>	<u>Incinerator Chamber Effluent (ppm HCl)</u>	<u>Scrubber Effluent (ppm HCl)</u>
277	30	II	23	7140	192
278	10	III	1	950	147
279	20	I	9	103	337
280	17	II	23	475	716
281	12.5	III	1	695	634
282	17	I	9	1120	534
283	24	II	23	2430	239
284	13	III	1	817	304
285	21	I	9	379	594
Average				1570	411

^aSee Table II

The levels of HCl found did not agree with the quantity of PVC burned. Also, in three cases, the scrubber effluent had a higher indicated concentration than the incinerator chamber effluent which further obscured the validity of the data. The average value for the HCl removal efficiency appeared to be about 74%. The quantity of Na_2CO_3 used to neutralize the HCl to an acceptable pH level for different runs corroborated this average value. This value was much less than the values obtained earlier using Drager tubes. The earlier values were 10 to 20 ppm for the scrubber effluent. Further work is being done to determine the cause of these discrepancies.

F. NO_x ANALYSIS OF THE OFF-GAS STREAM

The analytical results on NO_x spot sampling of ten incinerator runs are shown in Table VIII. As can be seen, the average value and some of the individual results showed a higher NO_x content from the outlet of the scrubber than from the inlet. Examination of the sample timing as compared to off-gas temperatures indicated that the scrubber outlet NO_x concentration was more dependent on off-gas temperatures than on scrubber efficiency. In some cases the scrubber outlet samples were taken at a later time and a higher temperature. Therefore, higher concentrations of NO_x were present in the outlet sample than in the inlet. If the scrubber inlet and outlet samples were taken simultaneously, the outlet NO_x concentrations would not be higher than the inlet but would fluctuate with the off-gas temperature. In addition the lack of homogeneity of the feed material caused significant process fluctuations which further complicated the making of accurate measurements of NO_x concentrations. Consequently, instrumentation is being reviewed to find equipment which will accurately monitor NO_x levels in the presence of the process variables.

G. WEIGHT REDUCTION EFFICIENCY OF SYSTEM

In determining the real reduction in feed weight brought about by incineration, the weight of solids in process

TABLE VIII
SUMMARY OF NO_x ANALYSES

Run No.	Incinerator Outlet		Scrubber Outlet	
	Sample No.	NO _x Conc. (ppm)	Sample No.	NO _x Conc. (ppm)
276	(3)	17	(1)	120
	(4)	22	(2)	34
277	(7)	24	(5)	25
	(8)	30	(6)	94
278	(11)	12	(9)	46
	(12)	30	(10)	6.6
279	(15)	9.4	(13)	5.9
	(16)	169	(14)	111
280	(19)	68	(17)	29
	(20)	47	(18)	71
281	(23)	49	(21)	17
	(24)	4.7	(22)	30
282	(27)	29	(25)	44
	(28)	22	(26)	51
283	(31)	54	(29)	55
	(32)	57	(30)	160
284	(35)	34	(33)	109
	(36)	8.8	(34)	16
285	(39)	159	(37)	216
	(40)	53	(38)	73
Average		49.4	65.7	

liquids and of residues removed from filters must be added to the weight of ash to get the total net weight.

Solids occur in the process liquids as a result of the use of a sodium carbonate solution for cooling the incinerator off-gas, removing particulates and scrubbing out acid gases. The scrub liquor is recycled through a filter to remove the particulates and is used as long as practical for scrubbing.

Fresh sodium carbonate and water are added as needed to keep the pH of the scrub liquor above seven and to maintain adequate volume. Spent scrub liquor is transferred to the waste disposal plant where it is combined with radioactively contaminated water from other processing areas at Mound Laboratory.

The waste water is treated by the addition of calcium chloride, ferric sulfate and activated carbon, followed by adjustment of the pH to 11.3. The water is passed through a clariflocculator to remove the precipitate as sludge. Then the clarified water is treated with activated carbon and filtered through a sand filter. Periodically, the sludge is removed from the clariflocculators and sand filter and then drummed for burial.

Based on this processing technique, a calculation has been made to predict what extra volume and weight of sludge for burial would be produced per volume and weight of combustible scrap incinerated. The following information and assumptions have been used in this calculation:

1. The average density of the combustible waste is 8.56 lb/CF based on LSA waste currently processed at Mound Laboratory.
2. The historical average sludge for burial produced from waste water is 0.5% of the waste water treated.
3. The PVC content of LSA feed could be on the average as high as 23% (Type II) or considering an average of all types (Type I, II, and III) could be 11%.

Types I and II are based on Mound Laboratory historical data. Type III is based on Rocky Flats reported data.

4. One pound of PVC is equivalent to 0.69 lb of NaCl (or equivalent salt) in the scrub liquor. This figure is based on an estimate of the chlorine content given in the literature for partially plasticized PVC. It assumes that practically all HCl or equivalent acid gases in PVC will be removed by the scrub liquor.
5. The scrub liquor can be recycled with water and Na_2CO_3 additions until the NaCl or salt equivalent reaches a level of 10% by weight.

The calculated figures indicate the following sludge weights per weight of combustible feed and sludge volumes per volume of combustible feed:

- A. At 23% PVC levels
 - a. 3.3% sludge wt/wt of combustible feed or
 - b. 0.40% sludge vol/vol of combustible feed
- B. At 11% PVC levels
 - a. 1.6% sludge wt/wt of combustible feed or
 - b. 0.19% sludge vol/vol of combustible feed

To these weight percentages must be added the percentage of solids removed directly from the off-gas stream to determine the efficiency of the system.

Initially the scrubber solution was recycled through a GAF Bag Filter. The weight of the used filter was about 0.61% of the original feed weight (based on 30 runs).

The weight of the dried filter cake (averaged from 32 runs) removed from the filter amount to approximately 4.1% of the weight of the original incinerator feed.

About 0.04% by weight of the original incinerator feed was accumulated on the spray catcher (roughing filter) based on the average of 16 runs.

In March, 1976, the bag filter was replaced with a vertical leaf filter. Measurement of the filter cake from the vertical leaf filter for 56 runs indicates that solids amount to an average of approximately 3.5 weight percent of the original incinerator feed.

In addition, the installation of the venturi scrubber has eliminated the use of the spray catcher (roughing filter) and the corresponding residue collected by this filter.

Therefore the total weight percent of residue based on the current operating mode is:

From process liquid	3.3 wt %
From off-gas particulates	3.5
From ash (Table III)	<u>4.2</u>
	11.0 wt %

Consequently, the average total weight of the residue is only 11 percent of the total feed weight. The reduction on a volume basis is even greater as indicated by the data under headings A and B on page 31.

To better understand the thermal characteristics of the system a temperature profile was determined as shown below. The values are based on the averages of readings taken from 20 runs.

Inlet Air	70°F
Combustion Chamber Walls	1000
Combustion Chamber Off-Gas	1100 Av.; 1700 peak
Spray Tank Off-Gas	120
Spray Catcher Off-Gas	110
Recycle Tank Liquor	90
Cooled Process Liquor (9 gpm)	80
Cooling Water Inlet (35 gpm)	70
Cooling Water Outlet (35 gpm)	73

A heat balance on the incinerator system indicates that from 30 to 50% of the heat generated in combustion of the waste is

taken up by the cooling water, air stream, and heat capacity of the system. The remaining 50% to 70% of the heat is dissipated by convection and radiation from the drum (combustion chamber) wall.

If the heat of combustion for each type of material is calculated, the loss of heat through the burning chamber walls in comparison to the heat dissipated by the system may also be determined as given in the following table:

	<u>Calculated Heat of Combustion</u>	<u>Loss by Convection Through Chamber Walls</u>	<u>Dissipated in System</u>
Type I	144,000 BTU/Batch	80,000 BTU's	69,000 BTU's
Type II	103,000 BTU/Batch	72,000 BTU's	32,000 BTU's
Type III	106,000 BTU/Batch	72,000 BTU's	32,000 BTU's

These engineering data will prove valuable in the design of future cyclone incinerators. Choice of cooling system, enclosures, and materials of construction will be based on this information. Since up to 70% of the heat is lost by convection and radiation through the chamber walls, future design will consider reuse of this energy.

In addition to understanding the thermal characteristics of the overall system an appreciation of the burning properties of the combustion chamber was also deemed necessary for evaluating its efficiency. As part of this study thermocouples were attached to the outside wall of the chamber with two thermocouples near the bottom, two near the middle and two near the top. The thermocouples are attached to a special strap so that they can be easily removed from the drum after each burn and reused. The arrangement is illustrated in Figure 9.

Temperatures recorded at the drum skin were lower than expected, with peak temperatures generally being less than 1000°F, while at the same time flue gas temperatures had been observed as high as 2300°F. The lower temperatures at the wall are apparently due to the cooling effect of the combustion air flowing into the drum. This air probably does not completely mix with the hot combustion product gases until

FIGURE 9

it reaches the fuel-gas interface. If this is true, the presence of a clean, comparatively cool air film at the skin of the drum may be responsible for the long life of drums used as burning chambers.

Also the data indicate that burning occurs largely at the fuel-gas interface with the solids (unburned fuel) preventing the induced air from penetrating deeper into the drum. For this reason there is a lag between temperature peaks registered by thermocouples located at different depths of the drum. This lag is shown in the time-temperature plot given in Figure 10.

H. ENERGY CONSUMPTION OF THE SYSTEM

The one remaining milestone for the determination of utility requirements for the system was completed in June, 1976 (see Milestone Chart). The electrical energy consumed by the equipment associated with the incinerator was calculated. For the three-phase motors used to operate the pumps and exhausters, the following formula was used:

$$P = \sqrt{3} E I \cos \theta$$

where: P = power in watts

E = voltage in volts

I = current in amperes

$\cos \theta$ = power factor and averages 0.85 during an incinerator burn

The following table is a summary of the power used by the motors.

<u>Description</u>	<u>Volts</u>	<u>Amps</u>	<u>Watts</u>
Buffalo Forge Exhauster	460	9	6095
PIA Exhauster	460	12	8127
Scrub Liquor Pump	460	4.5	3047
Cooling Water Pump	460	6.5	4402
Radiator Fan	460	4.5	<u>3047</u>
		Total	24,718

FIGURE 10

The venturi pump is rated at 0.1 horsepower which corresponds to 75 watts. Total power consumed by the motors is 25 kilowatts.

Other electrical requirements include fumehood ventilation, instrument operation and lighting. The fumehood ventilation was prorated from the building filter bank fan and amounts to 3 kilowatts. Instrumentation requirements vary from 0.5 KW to 4 KW, depending upon the use of heaters and the vacuum pump. Lighting requires a total of 0.85 KW.

Therefore, total electrical consumption is 29 to 33 KW, or a total electrical consumption of approximately 11 KW hours per drum of waste incinerated assuming an average time of 20 minutes (one-third hour) per burn. This energy consumption is equivalent to \$0.04 per kilogram of waste at present MRC electrical rates.

I. MILESTONE STATUS FOR FY-1976

Calculation of the electrical requirements completes the milestones given in the attached schedule. However, as indicated previously, some additional work is necessary on the flue gas analysis due to analytical problems and changes in equipment.

J. PELLETIZATION AND IMMOBILIZATION OF INCINERATOR ASH

The ash that is produced by the cyclone incinerator is a relatively inert, fluffy material which can be difficult to control while being handled or packaged. Conversion of the ash to a more compact form could facilitate its handling and storage and render it more inert to the possibility of leaching.

Preliminary investigations show that the cyclone incinerator ash may be fabricated into pellets, greatly reducing its volume and surface area and, hence, its susceptibility to leaching. To evaluate different forms of compaction, some samples of the ash have been combined with metal powder to make a metal matrix pellet. Some examples are shown in Figure 11.

→ Ash pressed then fired at 1000 C for two hours (no binder).

→ Ash pressed then fired at 1000 C for two hours, water used as a binder.

Ash with iron matrix, pressed then fired at 1000 C for two hours, water used as a binder.

→

Ash with nickel matrix, pressed then fired at 1000 C two hours, water used as a binder.

→

FIGURE 11

Pellets fabricated, using water as a binder, were pressed at 20,000 psi and then fired at 950°C to remove moisture and to partially sinter the pellet. Pelletizing brings about a large reduction in volume and surface area, which could enhance the efficient and safe handling and storage of radioactive ash.

The pellets fabricated, using metal as a matrix, proved to be a very hard and durable product. These pellets were pressed at 20,000 psi again using water as a binding media. The metals used to date have been Ni, Fe, Cu, and Al. All of these pellets have demonstrated characteristics similar to the metals used as their matrix. The internal heat generated by the decay of radioactive material in the ash can be readily dissipated by the metal matrix, thereby avoiding destruction of the pellet through overheating. The matrix also serves as an encapsulation media of the waste particulates.

CYCLONE INCINERATOR PROJECT

FISCAL YEAR 1976

	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE
07-31-75	■ 1A	□ 1B	□ 1C	□ 1D □ 1E □ 1F	□ 1G	□ 1H		□ 2A □ 3A	□ 2B □ 3B □ 4A □ 3C	□ 4B	□ 5A	□ 6A
08-30-75		■	□	□ □ □	□	□		□ □	□ □ □ □ □	□	□	□ □
09-30-75			■	□ □ □	□	□		□ □	□ □ □ □ □	□	□	□ □
10-27-75				■ ■ ■	□	□		□ □	□ □ □ □ □	□	□	□ □
11-27-75					■	■		□ □	□ □ □ □ □	□	□	□ □
01-02-76						●		□ □	□ □ □ □ □	□	□	□ □
01-31-76								□ □	□ □ □ □ □	□	□	□ □
02-29-76								■ ■	□ □	□	□	□ □
03-31-76									■ ■	□	□	□ □
04-30-76										■	●	■ ●
05-31-76												○ ▲
06-30-76												● ▲

Legend: Milestone Target ○ , Revised Target △ , Terminated or Deferred X, Projected Activity Status □ , Actual Completed Activity ■ , Completed Milestone ●

1. Install Instrumentation and Optimize Incineration (12/31/75)
 - A. Installation of impactor (08/01/75)
 - B. Installation of new exhaustor (08/15/75)
 - C. Installation of recycle water, chiller and flow meter (09/15/75)
 - D. Add wetting agent to all spray nozzles (10-10-75)
 - E. Optimize burning for reduction of particulate in offgas (10/15/75)
 - a. Vary air flow and oxygen content
 - b. Install oxygen stream to exhaust at chamber and test for use on after burner
 - c. Final decision on use of cyclone, catalytic oxidizer or other type after burner for particulate reduction in exhaust stream (05/15/76)
 - F. Install and test more efficient roughing filter (10/20/75)
 - G. Determine effectiveness of spray tank and improve if necessary (10/30/75)
 - H. Install instrumentation for determining operating parameters (pressure drops, temperature profiles, O₂ and CO₂ content, etc. (11/15/75)
2. Determine temperature and pressure profiles of system (03/15/75)
 - A. Temperature profile of system (02/01/76)
 - a. Incinerator inlet air
 - b. Combustion chamber walls
 - c. Combustion chamber offgas
 - d. Spray catcher offgas
 - e. Mist eliminator offgas
 - f. Recycle tank liquor
 - g. Scrub liquor after cooling
 - h. Cooling water inlet
 - i. Cooling water outlet
 - j. Process water
 - B. Pressure drops (03/01/76)
 - a. Incinerator chamber
 - b. Spray catcher
 - c. Mist eliminator
 - d. Roughing filter
 - e. Total system
3. Gaseous Effluent Tests (04/01/76)
 - A. Particulate (02/15/76)
 - a. Size
 - b. Amount/distribution
 - B. Condensables (03/10/76)
 - a. Identify (water, organic, hydrocarbon, i.e., aldehydes, acids, alcohol, ketones, etc.)
 - b. Amount
 - C. Noncondensables (03/25/76)
 - a. Identify (CO₂, CO, hydrocarbons, HCN, HCOH, SO₂, NO_x, H₂, O₂, ClO₂, HF, etc.)
 - b. Amount
4. Identify and measure liquid and solid waste generated (05/01/76)
 - A. Identify and measure total solid waste generated per unit volume of feed (03/18/76)
 - a. Liquid filter
 - b. Filter cake from liquid filter
 - c. Roughing filter
 - d. Mist eliminator filter media
 - B. Identify and measure total liquid waste generated per unit volume of feed (04/15/76)
 - a. Recycle water
5. Determine Efficiency of waste volume reduction (06/01/76)
 - A. Determine volume of ash per unit volume of feed (06/01/76)
6. Determine utility requirements (06/15/76)
 - A. Total electric consumption
 - a. Exhauster
 - b. Water mist pump
 - c. Water chiller
7. Final Program Report (07/01/76)