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SUMMATION OF CONDITIONS AND INVESTIGATIONS FOR THE COMPLETE COMBUSTION OF ORGANIC PESTICIDES

Municipal Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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by

Boyd T. Riley, Jr.

Independent Management Consultant on
Environmental Affairs
Cincinnati, Ohio 45229

Project Officer

Richard A. Carnes
Solid and Hazardous Waste Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF AIR, LAND, AND WATER USE
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The Municipal Environmental Research Laboratory contributes to this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on the biosphere, and

- a search for ways to prevent contamination and to recycle valuable resources.

A summation of the conditions necessary for the satisfactory disposal of pesticides by incineration is a necessary step in achieving these objectives.

CONTENTS

I. CONCLUSIONS AND RECOMMENDATIONS

1. The overwhelming majority of the experimental data in pilot scale incinerators or larger, which is reported in this document, concerns the combustion of Class IV Halogen-containing pesticides. Little information is available on the combustion characteristics of inorganic or metallo-organic pesticides, as well as phosphorus-containing pesticides, and nitrogen-containing pesticides.

2. The conditions necessary to thermally oxidize or burn certain combustion products formed from some pesticides may preempt the combustion conditions necessary to disassemble or partially combust the pesticides themselves. For example, nitrogen-containing pesticides have been shown to produce cyanide on combustion. Obviously, both the environmental and human toxicity impact is great if cyanide is released into the environment. Cyanide can be destroyed thermally into CO_2 and nitrogen or nitrogen oxides, but the conditions for this combustion reaction are much more rigorous than those reported for many pesticides. Thus nitrogen-containing pesticides should be burned in a facility which is capable of totally destroying cyanide. One such field scale facility operated at 2600 F; one-half second retention time; and a cyanide effluent of one part per million. (Dow Chemical Co. Inc., Midland, Michigan)

The metallo-organic pesticides may be destroyed by combustion; however, the metal element components will pass through the system, changed, at most, only to metal oxides. These oxides may be of significance as toxic agents in many eco-systems. Consequently, air pollution and/or water pollution control systems must be emphasized in such a combustion facility. Such metallic compounds must be extracted and contained prior to combustion of the organic portion of the pesticide, or must be encased in a solid matrix which renders them biologically inert during combustion. One system which holds promise is the use of a high temperature or slagging incinerator with recycle of scrubbed or filtered metallics back into the slag.

3. Since small quantities of pesticides and other toxic materials will inevitably escape any type of combustion and air pollution control system, environmental consideration must be emphasized when pesticide incinerators are sited and sized. The mass flow or dilution capability of the relatively immediate environment of the proposed location must be carefully assessed to assure that no significant ecological damage will occur. There will be a small change in the eco-systems in any area where pesticides are destroyed, just as small changes are caused by almost any other industrial activity. It is important, however, that these changes be of minimal consequence in terms of the ecological balance of the area. To take advantage of dilution capacity of the environment, pesticide incinerators should be of limited capacity, and should be located in such a way that dilution by natural forces is maximized.

4. Combustion data reported on various pilot plant experiments cannot be extrapolated to include other incinerator designs because turbulence measurements were not reported. Consequently, one may only assume that for the particular design investigated, pesticides may be expected to

be combusted to the efficiencies reported by the researchers. A deviation from the experimental device, such as a change in blower or burner design, may produce results which do not correlate well with those reported by the various researchers. The data reported by the researchers is somewhat suspect because of the very small quantities which necessarily had to be measured. Some of the reported results could be changed drastically by small differences between the amount of pesticide actually fed into the incinerator and the quantities reported. (To determine efficiency of combustion to three or more places in accuracy, one must also measure the input of materials to be burned to three or more places in accuracy.)

5. This program has not attempted to evaluate the various emission control systems used by researchers. Extrapolation of the results from these emission control systems is required in order to design a pesticide combustion system. These emission control systems may contribute one or two places in accuracy for determining the overall system destruction efficiency.

6. This program did not report on any experiments for the combustion of pesticides in containers. Where large quantities of pesticides are stored in small containers, e.g., aerosol one pound bombs, it would be pointless to attempt to remove the pesticide from the container, since this operation would be much less efficient and would release more pesticide into the atmosphere than would actual incineration of the pesticide.

7. In the absence of any other type of evaluation, a simplistic example was derived in order to produce an overall combustion system efficiency required for pesticides. The number suggested by this example is 99.99999 percent. Admittedly, this number represents a probable worst-case system, and one may argue that somewhat lower efficiencies are adequate. Lower efficiencies would place greater stress on the environmental forces which are required to dilute those pesticides and pesticide derivatives which are released into the environment. Additional work needs to be conducted in order to verify the percentage efficiencies required for the combustion of pesticides.

8. Additional work is required to develop a coding system which will relate the toxicity of a pesticide with its longevity in the environment and with the production of toxic combustion products. There appears to be a range of difficulties associated with combustion of various pesticides. Certain types are readily combusted, produce virtually no undesirable combustion products, and have very short lives when released into the environment. Hence, a much less rigorous combustion system is required for the treatment of these pesticides than, for example, of a mercury-containing metallo-organic pesticide.

9. All types of incinerators are not compatible with pesticides disposal. While the requirements for the combustion of certain classes of pesticides are readily achieved by many types of incinerators, the requirements for other classes are extreme and will probably require custom designs and extremely sophisticated operation and monitoring programs.

II. INTRODUCTION

Data presented to the Solid & Hazardous Waste Research Laboratory of the U.S. Environmental Protection Agency from several sources has indicated that pesticides are produced in the United States at an annual rate of 1.3 billion pounds per year. Commercial production of certain types of pesticides was started as much as 50 years prior to the date of this report. Certain pesticides have been stockpiled by both governmental and commercial organizations, and, in some instances, use of these materials has been legally terminated. Thus, an adequate technique for disposal of these stockpiles of materials, as well as lesser quantities of many types of pesticides currently in use, must be discovered. In lieu of an improved estimate, and after review of many documents pertinent to the subject, the author suggests that as much as 10 percent of the annual production of pesticides in the United States might require disposal in some manner, as opposed to productive use. Hence, from the national viewpoint, the technologies and financing required to dispose of comparatively large quantities of these materials with minimal insult to the environment is a problem of considerably importance.

Pesticides, by their very nature, are formulated to be extremely toxic in order to allow them to accomplish their genocidal mission against selected species. Very often, many other species are also affected by the application of these materials. In addition, undesirable effects from pesticides have been noted in remote areas of the world where man has not intentionally applied pesticides for any purpose. These undesirable side effects result because of a bio-refractory property of some types of pesticides. As a result, certain pesticides deteriorate very slowly (tens of years) after release to the environment, and migrate in unexpected ways through the biosphere. The compensating factor favoring the use of pesticides and acceptance of their adverse effects is significantly increased yields in food crops for the human population of the world, as well as supplementary foods to much of the animal population of the United States. A termination of the production and use of all types of pesticides will result in large scale famine throughout the world and would have a significant effect on food supplies in the United States. To minimize unwanted environmental insult from pesticides, safe use standards must be developed, and adequate means of disposal of unwanted or overly hazardous pesticides must be developed.

Prior to this time, no standard or scientifically proven methods for the complete and safe disposal of all types of pesticides have been recognized by the U.S. Environmental Protection Agency. A small industry has been established to dispose of hazardous materials including pesticides; however, little fully researched technology has been documented at the present time. Many methods of disposal have been attempted, including open dumping of pesticides and pesticide containers and injection into sub-surface strata. Pesticides have also been incorporated, intentionally and unintentionally, in sanitary landfill areas. Many examples of undesirable effects from these practices can be cited. In its June 30, 1973 Report to Congress on Hazardous Waste Disposal, the U.S. Environmental Protection Agency reported that in mid-1970, a pesticide applicator rinsed and cleaned a truck, and thus dumped unused Endrin into the Cuivre River at Moscow Mills, Missouri. This act resulted in the killing of an estimated 100,000 fish and necessitated the closing of the river for one year to all sport fishing activities. In another incident, a local firm near Waynesboro, Tennessee dumped polychlorinated biphenyls (PCB's) into the local landfill dump. These PCB's were washed into Beech Creek and caused several cattle deaths and created a potential for hazards to humans residing on the creek further downstream. These brief examples indicate the significance of improper disposal of pesticides.

The Report to Congress on Hazardous Waste Disposal, dated June 30, 1973, by the U.S. Environmental Protection Agency, lists 14 federal statutes which are applicable to the control of pesticides. In particular, the Federal Insecticide, Fungicide, and Rodenticide Act, as amended by the Federal Environmental Pesticide Control Act of 1972 (Public Law 92-516) has bearing on the problem of pesticide disposal. Section 19 authorizes the Administrator of the Environmental Protection Agency to determine safe methods for the disposal of excess amounts of pesticides or pesticides whose registration has been cancelled under the auspices of this act. The purpose of this report is to assist in the compliance with Section 19 of FIFRA as amended.

To approach a discussion and summary of activities for the combustion of pesticides, some type of system for classifying pesticides must be utilized. For purpose of this report, the pesticide classification system suggested by the Midwest Research Institute in their report entitled Guidelines for the Disposal of Small Quantities of Unused Pesticides, submitted to the Industrial Waste Treatment Research Laboratory, Edison, New Jersey, part of the National Environmental Research Center, Cincinnati, Ohio, will be followed. The classification system offered by Midwest Research Institute is reproduced as follows.

PESTICIDE CLASSIFICATION SYSTEM

Pesticide Classification	Number of Pesticides
I. Inorganic and Metallo-organic pesticides	
Mercury compounds	28
Arsenic compounds	17
Copper compounds	11
Other heavy metal compounds	6
Cyanides, phosphides, and related compounds	6
Other inorganic compounds	11
	79
II. Phosphorus-containing pesticides	
Phosphates and phosphonates	19
Phosphorothioates and phosphonothioates	34
Phosphorodithioates and phosphonodithioates	27
Phosphorus-nitrogen compounds	8
Other phosphorus compounds	5
	93

III.	Nitrogen-containing pesticides	
	N-alkyl carbamates, aryl esters	22
	Other N-alkyl carbamates and related compounds	7
	N-aryl carbamates	6
	Thiocarbamates	10
	Dithiocarbamates	13
	Anilides	13
	Imides and hydrazides	9
	Amides	6
	Ureas and uracils	20
	Triazines	14
	Amines, heterocyclic (without sulfur)	18
	Amines, heterocyclic (sulfur-containing)	12
	Nitro compounds	26
	Quaternary ammonium compounds	6
	Other nitrogen-containing compounds	19
		201
IV.	Halogen-containing pesticides	
	DDT	1
	DDT-relatives	8
	Chlorophenoxy compounds	12
	Aldrin-toxaphene group	16
	Aliphatic and alicyclic chlorinated hydrocarbons	15
	Aliphatic brominated hydrocarbons	5
	Dihaloaromatic compounds	10
	Highly halogenated aromatic compounds	19
	Other chlorinated compounds	4
		90
V.	Sulfur-containing pesticides	
	Sulfides, sulfoxides and sulfones	6
	Sulfites and xanthates	4
	Sulfonic acids and derivatives	5
	Thiocyanates	4
	Other sulfur-containing pesticides	4
		23
VI.	Botanical and Microbiological pesticides	19
VII.	Organic pesticides, not elsewhere classified	
	Carbon compounds (9 carbon atoms)	18
	Carbon compounds (9 carbon atoms)	23
	Anticoagulants	4
		45
	TOTAL	550

The classification system organizes all types of pesticides into seven general classes, based on chemical structure and ranked primarily by toxicity. The most toxic is Class I Inorganic and Metallo-organic pesticides, followed by phosphorus-containing pesticides, nitrogen-containing pesticides, halogen-containing pesticides, sulfur-containing pesticides, botanical and microbiological pesticides, organic pesticides not elsewhere classified or miscellaneous. A second aspect of classification of importance, when one considers disposal of pesticides, is the environmental stability or persistence of the various types of pesticides. The preceding classification system was not developed to incorporate this information. In general, however, the Class I Inorganic and Metallo-organic pesticides are both highly toxic and highly persistent.

Other types of persistent compounds include most of the chlorinated hydrocarbon type pesticides and some of the sulfur-containing types of pesticides. A "persistence" analysis is of considerable importance to the operation of a combustion type disposal system, since small quantities of unburned materials will necessarily escape from the system. It becomes exceedingly important in analyzing the environmental impact of such a system to know the quantity which may be successfully diluted into surrounding environment. In the case of persistent pesticides, this number is necessarily much lower than for those pesticides which do not persist for long periods. For persistent pesticides, some type of environmental in-put, out-put model is needed for each site which might be considered as a possible location for the combustion of pesticides, so that the introduction of the pesticide as a trace in the combustion system effluent does not exceed the ability of the site to absorb the burden successfully and to disperse it into a wider region via natural means at levels which are not toxic to any eco-system.

A third area of importance with respect to both classification of pesticides and their disposal via combustion is the possibility of generating toxic degradation products via partial or complete combustion. For example, the combustion of metallo-organic pesticides may completely destroy or reduce to carbon dioxide the organic portion, while introducing relatively large quantities of toxic metal oxides into the environment. The toxicity of these metal oxides may approach that of the original pesticide if released quantities are of significance to the dilution capabilities of the impacted eco-system. Similarly, certain phosphorus-containing pesticides will readily produce, as a combustion by-product, highly toxic gases, among which pyro-phosphates are a typical example. These by-products are intermediate steps in the complete combustion of phosphorus-containing pesticides. When completely reacted, phosphorus-containing pesticides should produce some type of phosphate compound which is quite innocuous and compatible with most eco-systems. If released in large quantities, phosphates can lead to significant deterioration of surface waters by enhancing the eutrofication phenomena. Nitrate compounds may be expected to behave similarly to phosphorus compounds. Finally, combustion of certain types of pesticides, particularly the halogen-containing pesticides, may produce combustion products which require additional treatment. A classic example would be the combustion of DDT to produce a hydrogen chloride gas. This gas is an acid and will react in an acid-base manner with any compound susceptible to its activity. Hence, it would require a relatively exacting scrubber system in order to first, capture the gas, and second, neutralize it by the addition of some basic material, so that a salt, for example, calcium chloride, could be formed for disposal purposes.

The reader should carefully note that this report addresses itself only to the disposal of Class II Phosphorus-containing pesticides, and lower classifications. The Class I Inorganic and Metallo-organic pesticides are not addressed in the data summation portion of this document. These pesticides contain heavy metal elements which are toxic to many eco-systems. Examples are mercury, arsenic, and copper. Hence, combustion of Class I pesticides without additional treatment would release them in slightly different form, perhaps with only slightly lower toxicity than the original pesticides. Data from all the sources provided for this report have offered little information in this problem area. Hence, it has been largely omitted from this report. A combustion system could be used to treat Class I Inorganic and Metallo-organic pesticides provided these metallic compounds were retained in a slag type of material with extensive controls on gaseous and/or liquid emissions from the system. The high temperature slagging furnace or incinerator could be used to stabilize these compounds by enclosing them in a glass-like matrix. This matrix could then be used as an aggregate or placed in a landfill. The rate of leaching and deterioration of the matrix would be on the order of thousands of years; hence, for ecological purposes, rendering the metallic compounds harmless. The operation of such a system would be extremely expensive if its only purpose was to destroy pesticides. Such high temperature unit processes are in operation throughout the United States, and the metallo-organic pesticides might be destroyed by these unit operations if additional monitoring programs could be utilized to assure that leakage to the environment was minimal. Such furnaces are typified by: electric arc furnaces, oxygen utilizing furnaces for high temperature combustion of coal or other types of fuel, and slagging type incinerators which operate at very high temperatures and produce a molten slag rather than an ash residue. Typical processes which include slagging operations are: The Torrax Process of the Carborundum Co., The Melt-Zit Process of American Thermogen, The Purox Process by Union Carbide Corp., some SWRS research programs, and most aluminum and steel producing electric furnaces.

III. DEFINITION OF COMPLETE COMBUSTION

Combustion, or the chemical reaction of organic and inorganic materials with oxygen at elevated temperatures, may be considered as a unit process, and, as such, is quite similar in characteristics to many unit processes used in chemical engineering technology. Combustion reactions, as other chemical reactions, reach only a certain degree of completeness. Completion of the reaction, or the amount of unreacted materials leaving the reaction container, may range from one in two, to one in a hundred thousand. The results of the reaction may be forced towards either extreme by adjustment of reaction conditions. Ordinarily a system of optimization is utilized in chemical engineering in order to reach the lowest possible cost for the unit process. For our purposes, cost of pesticide combustion has to be secondary, while completeness of reaction must be our paramount interest.

To assess the degree of completeness of reaction which is acceptable for the combustion of pesticides, factors other than the operation of the combustion unit process must be considered. Perhaps the single most important factor is the nature of the pesticide to be combusted. A second factor is a consideration of the intended use of the pesticide and its acceptable environmental impact when used in the prescribed manner. Another factor which must be considered is the persistence of the pesticide which will be released in small quantities to the environment via the combustion process, and which is subjected to additional physical processes and chemical reactions that are naturally found in the environment. Such processes include the absorption of infrared and UV energy from sunlight, interaction with mild organic acids and mild bases which are normally found in the environment, reaction with oxygen and ozone found in the atmosphere, and reaction with biochemical systems present in plant life, microbiological life, and animal life. Finally, the in-put, out-put capacity, i.e., the relationship between the quantity of pesticide expected to reside in a defined area and that which will probably be dispersed beyond the boundaries of the defined area by natural forces, of the area which is most directly impacted by the location of a pesticide combustion process must be considered.

A related technical problem of considerable significance in establishing levels for emission of pesticides into the environment is the difficulty of measuring very small quantities of pesticides and their combustion by-products. For example, if a combustion process operates at 99.999 percent efficiency based on pesticide in-put and out-put, the amount of pesticide released in the effluent combustion gas stream is under one part per hundred thousand. This quantity may be further diluted by other reactants, e.g., carbon dioxide, nitrogen, excess air, and combustion products from auxiliary fuel, and thus will escape detection by most sampling and measuring techniques. This small amount of pesticide emitted on a continuous basis into the environment, which does trap the material, may have environmental consequences of great significance.

In order to begin to assess these environmental consequences, a hypothetical worst-case analysis can be conducted for each pesticide to be disposed of by combustion in a certain location. If one wishes to incinerate a pesticide of toxic properties, similar to Endrin, one may assume an incineration efficiency of 99.999 percent, or one part in 100,000, escapes from the incinerator, either as material absorbed on ash residue or as a gaseous combustion product. If the capacity of the incinerator is 1,000 pounds per hour of pure pesticide, then 1/100 of a pound per hour of pure pesticide escapes the incinerator and is transferred to the local environment. In order to simplify the environmental impact analysis, one could assume that the incinerator impacted directly on the local drinking water supply. The suggested level of Endrin, as a maximum in drinking water, is 0.001 milligrams per liter. Thus, our incinerator could require approximately 4.54 million liters of dilution water per hour of operation. This water supply would be the equivalent of the water supply required for a city of 150,000 persons. If our hypothetical incineration operation on Endrin discharged into a surface water course in which fish life was protected, we would be forced to consider the impact on selected species of fish. The mean toxic limit of Endrin on Blue Gill is 0.0002 parts per million. This level reportedly causes death of 50 percent of the fish contacted in a 48 hour period. Hence, an acceptable level of discharge would necessarily be at least one order of magnitude greater, or 0.00002 milligrams per liter. Thus, a diluting flow of 225 million liters of water per hour would be required. Such a flow would be equivalent to approximately one percent of the average flow rate of the Ohio River. If our incinerator operated 24 hours a day for 300 days every year, it would incinerate approximately one half of one percent of the total production of all pesticides in the United States. It has been suggested that perhaps 10 percent of the total annual production requires adequate disposal. Hence, 20 incinerators of the type used in our example would be required, and a diluting flow of roughly 20 percent that of the average flow of the Ohio River would be required in order to safely disperse trace quantities escaping from the incinerator into the environment under the conditions suggested by our worst-case example.

In the author's opinion, this worst-case example suggests that a combustion system which is to be used for the most toxic types of organic pesticides must achieve an efficiency at least two orders of magnitude greater than the efficiency cited in the example computations; or an overall efficiency of pesticide destruction of 99.99999 percent from the combustion complex would be a reasonable requirement from the environmental viewpoint. It would appear that any incinerator complex attaining this efficiency overall would provide adequate safeguards for all environmental impact purposes.

Data presented later in this report suggests that the attainment of 99.999 percent combustion efficiency is achievable in several types of incinerators under optimum operating conditions, and that even greater efficiencies might conceivably be achieved, but the monitoring of the effluent gases was beyond the sensitivity of the techniques utilized in the testing programs.

A second approach for attaining higher overall efficiencies would be the use of a second unit operation to further process effluents from an incinerator. Such unit processes might include after burners, or high efficiency scrubbers, followed by a carbon absorption and recombustion of the carbon in the pesticide incinerator.

Logical arguments for the reduction of the required incinerator efficiency for systems which are utilized to destroy less toxic pesticides or which incorporate dilution capabilities that are less hazardous to the environment than the example offered can be presented. However, if one wishes to make a preliminary determination for a safe overall number, a pesticide reduction via combustion and auxiliary processes approximately seven orders of magnitude represents our best judgment.

Since combustion is to be used as a destructive process for at least certain classes of pesticides, other environmental protection restrictions must also be considered. Most obviously, the pesticide destruction process must comply with all stationary source air emission requirements. Principal among these concerns are carbon monoxide, halogens, hydrocarbons, and particulate material. Each of these out-put variables must comply with existing statutory requirements. In addition, they can be used as a good indication of the overall efficacy of the combustion operation. For example, if carbon monoxide is detectable in the effluent gas stream, one or more of the following may require rectification: (1) insufficient oxygen is present for complete combustion, (2) mixing is poor, (3) retention time is insufficient for proper combustion, (4) premature quenching of combustion reactions by cold surfaces is occurring. Also, when carbon monoxide is detectable, hydrocarbons are likely to be present, hence unburned or partially burned pesticide.

Since many pesticides are sorbed on inert dusts, particulate emissions may be noticeably affected by the inclusion of such a pesticide on otherwise satisfactory stationary combustion processes.

All of these constraints must be weighed when researching, planning, designing, and operating a combustion system for the destruction of pesticides.

IV. INTRODUCTION TO COMBUSTION ON A MOLECULAR BASIS

Many technical problems may be encountered in an attempt to achieve the levels of combustion efficiency suggested in the preceding section. In order to better understand the phenomena which take place in the combustion chamber and which pertain directly to the achievement of the combustion efficiency goal, one must visualize the steps through which a molecule of pesticide must pass in order to be degraded via oxidation at increased temperatures. First, the pesticide molecule must be physically introduced into the combustion chamber. It must then absorb sufficient energy to raise its temperature or level of molecular activity to sufficient state to allow it to become unstable and to react with similarly excited oxygen molecules. The sources of energy which might impact on the pesticide molecule may be radiation from the combustion of other molecules of either pesticide or auxiliary fuel or radiation from the wall of the combustion chamber. When the molecule has reached a stage at which bonds are unstable and broken simply because of its increase in internal energy, it may react with molecular oxygen provided it comes in contact with this oxygen. A certain amount of time is required for the temperature of the molecule of pesticide to reach a reactive level. Next, an atom of molecular oxygen must be available to the pesticide molecule in order for a reaction to take place. Hence, adequate mixing of these two different chemical species is required. At the time of reaction between the molecule of pesticide and the molecular oxygen, energy will be released which will further increase the energy content of the molecule, thus making other reactive sites available to additional oxygen molecules, and ultimately resulting in a destruction or deterioration of the original pesticide molecule. This change in the molecule will continue under ideal oxidizing conditions until the ultimate product of carbon dioxide and water is formed, along with the most oxidized species of inorganic molecules. The reactions may be terminated at any intermediate point if temperature decreases so that stability is once again achieved by the chemical species present, or if one or more of the reactants is decreased in availability to such a level that the probability of collisions and reactions occurring within the combustion chamber is reduced to an insignificant level.

To affect the probability of reactions occurring, one may control the external parameters of the combustion process. These parameters have often been described as time, temperature, and turbulence in classic combustion terminology. As pointed out earlier, time is required for the pesticide molecule to reach an adequate temperature for reaction to take place. Additional time is required to allow for the random collision of excited pesticide molecules with excited oxygen molecules, and finally additional time is required for the degradation products of the pesticide molecule to further degrade to their highest oxidation states. The total time for all reactions to take place under proper operation is a function of the design and resulting turbulence of the combustion chamber, as well as the rate of mass flow through the combustion chamber. Once constructed, the physical bounds of a combustion chamber usually cannot be changed during operation. Hence, time of combustion is a direct function of total mass flow through the combustion chamber, which in turn is an operating variable and directly in the hands of the operator of the device.

The temperature in the combustion chamber is a function of the rate of heat release by the reactants, the rate of mass flow through the combustion chamber, and the rate of heat loss through the walls of the combustion chamber. Turbulence, or physical mixing, within the combustion chamber serves to increase the probability of collision or association between various reactant molecules, and is a function of design and mass flow.

In order to achieve the combustion efficiencies which are proposed, attention must be given to the design and the operation of the combustion chamber. Since our goal is to achieve very high combustion efficiencies, the operating parameters of the combustion unit operation must be adjusted so as to favor complete reactions. This may be done by designing the combustion chamber in such a way as to maximize turbulence, or mixing, by incorporating baffles and gratings within the combustion chamber, so that the flow of gases through the combustion chamber is diverted several times. Such a design increases operating costs because a greater pressure drop is required in order to achieve passage of the combustion gases through the combustion chamber than is found in many combustion systems. Since temperature is a constraining factor on reaction rate and reaction completeness, additional reactants must be added so that the average temperature throughout the combustion chamber significantly exceeds the temperature actually required for reactions of the pesticide molecule to take place. Since the availability of reactant molecules and, in particular, oxygen, are also critical, excess oxygen must be supplied to the combustion chamber. Increasing the average temperature of operation will increase both the construction cost of the combustion chamber and the operating costs, since auxiliary fuels other than pesticides may be required in order to assure that the desired temperature levels are achieved and maintained during operations. The use of excess oxygen or excess air, if air is the source of the oxygen supply, also increases operating costs since the combustion chamber must be increased in size in order to produce effective retention times or reaction times, and to contain the increased massed flow of materials through the chamber. To achieve high combustion efficiencies, for any given design, temperature throughout the combustion chamber must be in excess of those required for reactions to occur; oxygen must be available in quantities 25 to 50 percent greater than stoichiometric reaction conditions would require, and retention time must be considerably in excess of that actually required for molecular reactions to take place.

For any given design, an optimum region of operation may be determined via experimentation. Once this region is determined, little can be done to improve the operation of a specific design without redesigning and reconstructing the combustion chamber. The reader should note that simply increasing flow rates of the various reactants does not necessarily result in improvements in combustion efficiencies. For example, if excess air is increased from approximately 25 percent to 300 percent, efficiency of combustion will be decreased. This decrease occurs because, while additional oxygen molecules are available for reaction and the probability of reaction is increased, additional heat is also required in order to raise the average temperature to the reaction level. Thus additional fuel would be required. If additional fuel is added, the construction materials may fail. In addition, because the mass flow rate has been significantly increased, retention time in the combustion chamber has been significantly decreased, resulting in a net decrease in combustion efficiency.

For a given installation, mass flow of gases, resulting from both air as an oxidizer and fuel, have peaked combustion efficiency curves which represent an optimum operating condition. The effect of turbulence on combustion efficacy via design increases in direct proportion to energy expended on turbulence until a completely mixed condition is achieved within the desired retention time, after which additional energy expenditure on turbulence produces no further benefits. The lower end of the turbulence phenomena is an area where laminar flow is achieved and little or no physical mixing takes place; hence, little or no reaction takes place between oxygen and pesticide molecules.

More could be written describing the complex variable interactions occurring in a combustion phenomena. The purpose of this section is to give the reader a superficial introduction to combustion phenomena only to assist him in understanding and interpreting the techniques used to generate the data reported in succeeding sections of this report.

V. SUMMATION OF CONDITIONS AND INVESTIGATIONS

After a preliminary review of all the sources of data supplied by the Solid & Hazardous Waste Research Laboratory, it was decided that the best approach was to develop a standard data reporting sheet which could be applied to data from various sources, and to attempt to report these data on a comparable basis. A list of the sources of information supplied by the Solid & Hazardous Waste Research Laboratory is displayed in Appendix D.

The purpose of this report is to summarize data from pilot plant or larger installations on the incineration of pesticides. Hence, data of a laboratory nature was excluded because this data is not comparable to field or pilot plant operations and often may not be extrapolated to represent those conditions. Within these limitations, the bulk of the data was supplied by three organizations: Midwest Research Institute, under contract to the Solid & Hazardous Waste Research Laboratory; T.R.W. Inc., under contract to the U.S. Army Research and Medical Development Command; and Versar Inc. Lesser quantities of data were available from the Marquardt Corporation. Information available from Mississippi State University was reviewed extremely carefully. However, the only data furnished was on laboratory combustion devices, where only very small quantities--a few grams--of samples were combusted under idealized laboratory conditions. These data simply are not comparable to pilot plant or field scale data; therefore, no data from Mississippi State University has been included in this report.

The author feels additional data is available from other sources than those included in the report. For example, a trip report by Midwest Research Institute, which is included in Appendix A, indicates the combustion of pesticides by the U.S. Army at Edgewood Arsenal. Numbers are reported which imply an extremely sensitive monitoring and measuring system, and this would imply that data is available at the Edgewood Arsenal on combustion of pesticides which would be of value to this report. The author feels other organizations, both governmental and private, may have data they might be willing to have included in this report if they were contacted. Such contacts are currently beyond the scope of this contract effort.

The standard data reporting sheet was designed essentially so that each page may be used singularly by any reader. Therefore, it is composed essentially of two portions: an identification section, and a section devoted to reporting of experimental measurements. The identification section consists of a citing of the origin or source of the data, a brief description of the type of incinerator that was used to generate the data, the type of pesticide studied, classification of the pesticide according to the M.R.I. Classification System, and any obviously hazardous products of combustion that could be derived from the pesticide. The data reporting portion of the sheet consists of a column entitled "Experiment No." in which the experiment number of the originator of the data is utilized so that correlation with the original report can readily be made. Three columns are devoted to the feed rate of various types of fuels. Pesticides are usually in two forms; pure pesticide mixed or sorbed on an inert powder base which could be emulsifiable or may be used as a dry dust; and pure pesticide dissolved into a liquid carrier, such as a light fuel oil, e.g., kerosene. The pesticide is initially tabulated, as grams per hour of actual pure pesticide compound fired at a specified rate. "Pesticide As Fired" is reported if the pesticide is carried in oil, as this will affect combustion calculations and any auxiliary fuel required. When the pesticide is fired as a dust, the dust does not enter into the combustion calculations, although it does affect the amount of ash and particulate emissions produced in the combustion chamber and thus affects the design. The next column is "Excess Air" and this is reported in percent excess air, which is a common reporting technique for most incinerators and combustion devices. These measurements usually are calculated from Orsat analyses which are accurate, at best, to only 1 percent. Relatively large errors of a few percent, for example, have relatively little significance to the actual operation of the combustion device. The next column is "Combustion Temperature", again reported in degrees Fahrenheit, since most American instrumentation and most combustion devices are instrumentated for degrees Fahrenheit. Two temperatures are reported; an average through the combustion chamber, and a maximum, if available, e.g., flame temperature. The next column is entitled "Retention Time" in seconds. Again, this is the most common reporting form in the United States, and applies to the actual time the pesticide would remain in the combustion chamber in volatile form and thus is capable of reacting with oxygen and being degraded. The next column is "Pressure Drop Inches of Water". Little data for this column was found in the sources reviewed. However, these data are a minimal measurement from which turbulence or mixing efficiency inside the incinerator may be computed, e.g., Reynold's number is a unitless comparative measure of the degree of frictional energy loss or turbulence in fluid flow. These data would require a measurement of pressure at the entrance and exit of the incinerator with corrections for temperature. With knowledge of fuel feed rate, pesticide feed rate, combustion temperatures, and pressure drop across the combustion chamber, one would be able to predict, within rather broad limits, the combustion efficiency one might expect from other types or designs of incinerators.

The next column is entitled "Pesticide in Gas Effluents Parts per Million", or "Cyanide in Gas Effluents Grams per Hour", or "Pesticide in Gas Effluents Mg/M^3", or "Pesticide in Gas Effluents Grams per Hour", or "Pesticide in Gas Effluents Milligrams per Hour". This column was added to the form to enable one to begin to assess the actual quantities of pesticide which would be released from a particular incinerator installation. Certain data sheets were modified so that this column might read "Hydrocarbons in Gas Effluents Grams per Hour, or Parts per Million". Again, these data are incorporated in order to indicate the magnitude of the quantities of pesticides derivatives potentially being released into the environment during the operation of the combustion device.

The final column is "Incinerator Efficiency". This number is critical for the determination of the overall efficacy of combustion as a process for completely oxidizing waste pesticides. These data are quite sensitive to the accuracy of other measurements. Incinerator efficiencies were computed in different ways by different investigators, but generally are comparable and indicate efficiency prior to other unit operations, such as scrubbing. For example, some sources of data reported efficiency in terms of pesticide destroyed; others reported efficiency in terms of total hydrocarbons released, including pesticides, degradation products, and auxiliary fuel. In most cases, however, reported efficiencies were so high that the difference between pesticide being released and hydrocarbon in other forms being released was a very small number.

At the bottom of the data sheet is a small space utilized for special notations concerning the experiments, or missing data, or the way certain data were reported on that page. Again, the purpose of these notes is to enable each data sheet to be utilized singly, rather than making it dependent on reference to other reports or pages. The majority of the data included in this report have been transcribed from other reports exactly as reported. Some minor modifications to the data, particularly in the column of pesticides reported in grams per hour as fired, were necessary in order to produce comparable numbers.

This report has not attempted either to reduce field data to finished calculations, since information was not ordinarily available to enable this to be done with ease, or to extensively modify the data as reported. The principal calculations by the author were: to report pesticide in-put on the basis of pure compound, and to supply only total retention time in the combustion chamber, where several retention times were reported. When reporting pesticide in-put, the author always computed data to two decimal places accuracy, though the investigations seldom reported sufficient significant digits to justify such accuracy by the author. Subsequently the reader may assume that pesticide in-put is the author's computation when reported to two decimal places. When these data are reported to fewer significant digits, they represent calculations or measurements by the original investigators.

Where data was available that could have been modified by extensive calculations, this was noted in the note section of the data page pertaining to that particular set of experiments. Finally, the data sheets have been organized in such a way as to class pesticides by type and class rather than incinerators by type and class. This will give the reader a cross reference to several types of incinerators used on the same type of pesticides.

INDEX TO PAGE LOCATIONS OF DATA BY PESTICIDE AND INVESTIGATOR

NOTE: Numbers in this table refer to page numbers of this document.

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	Malathion - 5 Lbs/Gal or 60% $C_9 H_{16} O_5 P_1 S_2$
	CLASS OF PESTICIDE II Phosphorus-Containing
TYPE OF INCINERATOR Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION** Pyrophosphates

EXPERIMENT NO.	FEED RATE			EXCESS AIR	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR.	AUXILIARY FUEL GAL./HR.	%	AVG.	MAX				
1	1058.70	0.95	1.71	130	1980	--	4.4			>99.996
3	881.79	0.79	1.40	44	1840	--	9.8			>99.999
5	702.17	0.63	0.25	176	1140	2010	13.0			>99.998
7	1192.06	1.14	0	114	1270	1945	12.4			>99.999
9	2177.28	1.78	0.14	95	1755	2105	7.8			>99.999
11	378.30	0.33	1.06	311	1105	--	8.8			>99.999

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	Malathion - 25% Dust $C_9 H_{16} O_5 P_1 S_2$
	CLASS OF PESTICIDE
	II Phosphorus-Containing
TYPE OF INCINERATOR	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION
Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	Pyrophosphates

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS GM./HR.	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX.				
A	3330	--	1.07	43	1490		8.7			> 99.999
B	4570	--	2.25	37	1900		7.7		1.2×10^{-3}	> 99.999
C	3130	--	1.08	113	1340		11.3			> 99.998
D	3290	--	2.77	156	1710		3.7			> 99.999
E	1500	--	0.96	157	1170		8.2			> 99.995

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	Atrazine 4 Lb/Gal Liquid $C_8 H_{14} N_5$
	CLASS OF PESTICIDE III Nitrogen-Containing
TYPE OF INCINERATOR Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION** CN

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	CYANIDE IN GAS EFFLUENTS GM/HR.	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
1	1631.37	1.89	2.60	79	1860	1960	5.1		--	
2	1586.06	1.99	2.60	123	1860	2060	4.1		< 0.1	
3	1540.74	1.69	1.14	138	1340	2020	7.6		36.7	
4	1586.06	1.89	0.88	90	1290	1980	9.6		39.1	
5	3579.96	4.37	2.40	76	1730	1990	3.8		< 0.1	
6	3262.75	4.25	0.72	93	1030	1760	6.0		1358	
7	3534.64	4.28	1.15	143	1300	1900	6.9		128	
8	3579.96	4.20	3.01	140	1720	1920	2.9		< 0.1	
9	1495.42	1.73	2.37	52	1900	1980	6.4		13.8	

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	Atrazine - 80% Wettable Powder $C_8 H_{14} N_5$
	CLASS OF PESTICIDE
	III Nitrogen-Containing
TYPE OF INCINERATOR	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION
Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	CN

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	CYANIDE IN GAS EFFLUENTS GM/HR.	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL/HR.		AVG.	MAX				
A	2900.22		2.20	43	1960	1920	5.5		9.6	
B	3579.96		2.25	125	1770	1970	6.1		< 0.1	
C	2718.96		0.71	146	1120	1720	10.8		174.8	
D	3398.70		1.82	71	1780	1950	6.5		0.3	
E	3715.91		0.67	111	1200	1800	13.2		46.2	

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	50% Captan - Wettable Powder (In Water) $C_9 H_8 O_2 Cl_3 N S$
	CLASS OF PESTICIDE
	III Nitrogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	Cyanide, HCl, SO_x

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	CYANIDE IN GAS EFFLUENTS GM/HR.	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL/HR.		AVG	MAX				
1	2857.68	1.70	2.30	137	1820	2120	3.6		32.6	
2	2857.68	1.71	1.52	94	1680	2040	6.4		33.9	
3	1632.96	0.94	2.33	76	1850	2160	5.0		12.9	
4	1134.00	0.93	2.44	135	1790	2170	3.9		20.6	
5	1270.08	0.93	0.94	192	1220	2040	8.1			
6	1406.16	0.92	1.01	130	1230	2010	10.4		5.4	
7	2222.64	1.68	0.72	252	1200	1900	13.2		17.3	
8	2041.20	1.63	0.98	99	1280	1980	13.2		20.9	

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	Picloram - 10% Pellets $C_6 H_3 O_2 N_2 Cl_3$
	CLASS OF PESTICIDE
TYPE OF INCINERATOR	III Nitrogen-Containing
Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION HCl and CN

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS GM./HR.	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR		AVG.	MAX.				
A	1260	--	2.38	93	1890	2075	3.7		1.07×10^{-5}	> 99.999
B	1250	--	2.50	170	1720	2320	5.6		7.06×10^{-5}	> 99.998
C	1200	--	0.95	226	1200	1860	20.90		$< 1 \times 10^{-5}$	> 99.979
D	2380	--	0.91	227	1310	1800	20.80		3.99×10^{-5}	> 99.981
E	2340	--	2.41	72	1700	1585	13.00		8.88×10^{-3}	> 99.976

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	Picloram - 10% in H_2O $C_6 H_3 O_2 N_2 Cl_3$
TYPE OF INCINERATOR	CLASS OF PESTICIDE III Nitrogen-Containing
Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION HCl and CN

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS MG./M.^{3}	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX.				
1	1870	2.32	0.68	298	1000		15.31		0.03	>99.837
3	1510	1.93	1.51	187	1160		13.06		< 0.01	>99.637
4	1285	1.51	2.40	62	1715		7.68		0.02	>99.979
5	1110	1.47	3.30	130	1870		2.57		0.06	>99.997
6	3465	3.59	3.25	116	1890		2.36		0.02	>99.999

Note: All experiments except #5 and #6 produced high CN content in the effluent gases. Runs #5 and #6 achieve <0.1 gm/hr emission.

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	Aldrin - 19% Granules $C_{12}H_8Cl_6$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS GM./HR.	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX.				
A	1866	3.21	--	48	2150		5.49		3.87×10^{-4}	> 99.999
B	1705	2.43	--	155	1860		5.10		2.71×10^{-2}	> 99.998
D	3758	2.49	--	120	1945		4.61		2.71×10^{-4}	> 99.999
F	1841	1.54	--	113	1635		6.61		3.54×10^{-5}	> 99.999

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	Aldrin - 41.2% Emulsifiable Concentrate $C_{12} H_8 Cl_6$ **CLASS OF PESTICIDE** IV Halogen-Containing
TYPE OF INCINERATOR Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION** HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
2	3479.11	2.02	2.92	128	1930		3.38			> 99.999
4	1614.81	0.94	0.44	230	1745		9.61			> 99.999
6	657.72	0.38	0.96	158	1620		8.35			> 99.999
8	1351.72	0.78	2.33	70	2125		4.34			> 99.999
10	616.89	0.71	0	380	1155	2020	14.29			> 99.998

ORIGIN OF DATA	PESTICIDE
T.R.W. Systems Group - 7/73 to 8/74 Contract No. D.A.D.A. 17-73-C-3132 "Thermal Degradation of Military Standard Pesticide Formulations"	Chlordane - 5% Dust $C_{10}H_6Cl_8$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Custom Design Tube-Furnace consisting of Burner, Refractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDRO-CARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL/HR		AVG.	MAX				
A11-6-6	22.65	--	1.0	18.7	2135		0.162		27	
18					1840		0.510		1	
30					1725		0.886		< 1	
A11-11-6	33.97		1.0	14.8	2180		0.163		10	
18					1925		0.528		< 1	
30					1650		0.936		< 1	
A11-1-6	22.65		1.0	45.0	1850		0.148		< 1	
18					1685		0.474		< 1	
A11-8-6	33.97		1.0	47.7	1955		0.138		< 1	
A11-12-6	22.65		1.0	71.0	1745		0.130		< 1	
A11-9-6	33.97		1.0	71.9	1690		0.134		< 1	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.

2. Data sheets reported only measure of hydrocarbons as out-put measure.

3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
T.R.W. Systems Group - 7/73 to 8/74 Contract No. D.A.D.A. 17-73-C-3132 "Thermal Degradation of Military Standard Pesticide Formulations"	Chlordane - 72% Emulsifiable Mixed 1:3 with #2 Oil $C_{10}H_6Cl_8$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Custom Design Tube-Furnace consisting of Burner, Refractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDRO-CARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL/HR		AVG	MAX				
A5-3-6		1.0	0	45	1960		0.153		2	
A5-4-6		1.0	0	12	2125		0.174		4	
18					2080		0.538		-	
30					1880		0.950		-	
A5-5-6		0.75	0	77	1665		0.186		15	
18					1510		0.591		2	
30					1330		1.038		1	
A5-8-6		0.75	0	46	1850		0.205		< 1	
A5-10-6		0.75	0	98	1580		0.173		77	
18					1540		0.531		15	
30					1435		0.914		< 1	
A5-13-6		1.0	0	47	2045		0.143		< 1	
A5-14-6		1.0	0	72	1815		0.134		< 1	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.

2. Data sheets reported only measure of hydrocarbons as out-put measure.

3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
T.R.W. Systems Group - 7/73 to 8/74 Contract No. D.A.D.A. 17-73-C-3132 "Thermal Degradation of Military Standard Pesticide Formulations"	DDT - 5% Solution in Oil $C_{14}H_9Cl_5$
	CLASS OF PESTICIDE IV Halogen-Containing
TYPE OF INCINERATOR Custom Design Tube-Furnace consisting of Burner, Refractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION** HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDRO-CARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
A1-2-6		1.0	0	30	2300		0.146		2	
18					2200		0.449		1	
A1-3-6		0.75	0	30	2120		0.210		< 1	
18					1990		0.653		< 1	
A1-5-6		0.5	0	76	1700		0.288		336	
18					1580		0.882		5	
30					1475		1.523		2	
A1-7-6		1.0	0	12	2220		0.174		1	
18					2170		0.528		2	
30					1990		0.908		3	
A1-9-6		1.0	0	-7	1775		0.239		3450	
18					1525		0.774		5900	
30					1225		1.405		4260	
A1-11-6		1.0	0	53	1825		0.152		< 1	
A1-13-6		0.5	0	26	1540		0.407		< 1	
18					1400		1.295		< 1	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.

2. Data sheets reported only measure of hydrocarbons as out-put measure.

3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	DDT - 10% Dust $C_{14}H_9Cl_5$
	CLASS OF PESTICIDE
TYPE OF INCINERATOR	IV Halogen-Containing
Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION** HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
2	997.92			58	2125		3.76			>99.994
3	997.92			164	1765		2.46			>99.999
5	1723.68		3.50	128	1905		2.46			>99.999
6	2222.64		2.61	111	2095		3.68			>99.999
8	997.92		2.77	124	1930		4.22			>99.995

ORIGIN OF DATA	PESTICIDE
Versar Inc., October 18, 1974 - Report to U.S.E.P.A. entitled "A Study of Pesticide Disposal in a Sewage Sludge Incinerator" Contract No. 68-01-1587	DDT - 20% Solution $C_{14}H_9Cl_5$
	CLASS OF PESTICIDE
TYPE OF INCINERATOR	IV Halogen-Containing
Multiple Hearth Furnace by Envirotech Inc. 30" Inside Diameter - 6 Hearths and Afterburner	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION
	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
9	181.6				1546	1720			1.710	99.79
10	181.6				1515	1680			0.43	--
11	181.6				1536	1680			1.65	99.986
12	181.6				1546	1680			0.55	99.993
13	454				1538	1660			--	--
14	454				1545	1640			2.15	99.993
15	454				1488	1650			2.84	99.982
16	454				1475	1640			0.45	99.994

Notes: 1. Data on excess air rates was not computed by Versar; however, Orsat analysis data reported indicates air was supplied at two to three times stoichiometric requirements.

2. Sludge feed at rate of 45 Kg/hr. DDT Solution feed at rate of 0.91 Kg/hr on third hearth for Experiments 9 - 12.

3. DDT Solution feed at rate 2.25 Kr/hr for Experiments 13 - 16.

ORIGIN OF DATA

T.R.W. Systems Group - 7/73 to 8/74
Contract No. D.A.D.A. 17-73-C-3132
"Thermal Degradation of Military Standard Pesticide Formulations"

PESTICIDE

DDT - 20% Oil Solution
Mixed 1:3 with #2 Fuel Oil
$C_{14}H_9Cl_5$

CLASS OF PESTICIDE

IV Halogen-Containing

TYPE OF INCINERATOR

Custom Design Tube-Furnace consisting of Burner, Refractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.

POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION

HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDRO-CARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL./HR		AVG.	MAX				
A2-5-6		1.0	0	26	2100		0.151		< 1	
18					1990		0.470		< 1	
30					1810		0.819		< 1	
A2-7-6		1.0	0	75	1900		0.122		< 1	
A2-9-6		1.0	0	-3	2000		0.212		2430	
18					1795		0.686		4210	
30					1495		1.242		4040	
A2-11-6		0.75	0	12	1940		0.238		< 1	
18					1880		0.738		8	
30					1680		1.314		< 1	
A2-12-6		0.75	0	28	2005		0.207		< 1	
18					1905		0.649		< 1	
30					1675		1.156		< 1	
A2-13-6		0.75	0	70	1720		0.178		< 1	
18					1640		0.553		< 1	
A2-14-6		0.75	0	90	1385		0.189		265	
18					1370		0.573		89	
30					1340		0.965		5	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.

2. Data sheets reported only measure of hydrocarbons as out-put measure.

3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
T.R.W. Systems Group - 7/73 to 8/74 Contract No. D.A.D.A. 17-73-C-3132 "Thermal Degradation of Military Standard Pesticide Formulations"	DDT - 20% Oil Solution (Continued) $C_{14} H_9 Cl_5$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION
Custom Design Tube-Furnace consisting of Burner, Refractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDRO-CARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL./HR		AVG.	MAX				
A2-17-6		1.0	0	92	600		0.204		874	
18					980		0.530		640	
30					1220		0.832		185	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.

2. Data sheets reported only measure of hydrocarbons as out-put measure.

3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	DDT - 25% Emulsifiable Concentrate $C_{14}H_9Cl_5$
	CLASS OF PESTICIDE IV Halogen-Containing
TYPE OF INCINERATOR Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION** HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
A	1097.71	1.18	1.30	92	1955		5.10			>99.996
B	1918.72	2.09	2.03	162	1785		2.41			>99.995
D	1628.42	1.77	4.59	120	1955		1.58			>99.974
F	4649.40	5.38	--	143	1760		1.80			>99.992
H	2422.22	2.63	3.68	135	1975		1.54			>99.992
J	1242.86	1.35	1.27	138	1870		6.17			>99.980
N	1796.25	2.57	--	166	1790		5.81			>99.976
P	3338.49	3.73	--	164	1935		2.44			>99.996

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	DDT - 25% Emulsifiable Concentrate $C_{14} H_9 Cl_5$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
A	3157.05	5.00	0	130	1901		1.36			> 99.99
B	3411.07	5.00		217	1712		1.44			> 99.99
C	3633.33	5.00		150	1770		1.28			> 99.99
D	1909.65	3.50		49	1985		2.36			> 99.99
E	1755.43	3.50			1677		1.25			> 99.99
H	3828.38	3.50		77	2150		1.11			> 99.99

Note: 1. Midwest Research Institute initially started experimentation with an actual loading rate of their incinerator of 10 pounds of DDT per hour as a 25 percent emulsifiable concentrate. Due to the occurrence of a black smoke plume from the stack, alleged to be the fault of an undersized scrubbing system, the loading rate was reduced to approximately 5 pounds per hour of the DDT.

ORIGIN OF DATA	PESTICIDE
T.R.W. Systems Group - 7/73 to 8/74 Contract No. D.A.D.A. 17-73-C-3132 "Thermal Degradation of Military Standard Pesticide Formulations"	DDT - 25% Emulsifiable Concentrate $C_{14}H_9Cl_5$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Custom Design Tube-Furance consisting of Burner, Refractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDRO-CARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR	AUXILIARY FUEL GAL./HR		AVG.	MAX				
A4-2-6		1.0	0	31	2000		0.164		5	
18					1890		0.504		4	
30					1710		0.089		5	
A4-4-6		1.0	0	65	1900		0.137		< 1	
A4-5-6		0.75	0	46	1725		0.219		< 1	
A4-6-6		0.75	0	94	1750		0.166		33	
18					1530		0.537		23	
30					1270		0.964		17	
A4-7-6		1.0	0	87	1250		0.168		438	
18					1415		0.477		8	
30					1450		0.782		36	
A4-9-6		0.5	0	29	1775		0.368		2	
18					1640		1.153		1	
A4-10-6		0.5	0	103	1510		0.272		22	
18					1430		0.842		34	
30					1220		1.455		29	
A4-11-6		0.5	0	16	1900		0.392		1420	
18					1490		1.313		150	
30					1210		2.398		24	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.

2. Data sheets reported only measure of hydrocarbons as out-put measure.

3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
T.R.W. Systems Group - 7/73 to 8/74 Contract No. D.A.D.A. 17-73-C-3132 "Thermal Degradation of Military Standard Pesticide Formulations"	DDT - 25% Emulsifiable Concentrate (Continued) $C_{14} H_9 Cl_5$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Custom Design Tube-Furnace consisting of Burner, Refractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDRO-CARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
A4-12-6		0.75	0	14	1775		0.284		552	
18					1640		0.876		410	
30					1480		1.509		48	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.

2. Data sheets reported only measure of hydrocarbons as out-put measure.

3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
Versar Inc., October 18, 1974 - Report to U.S.E.P.A. entitled "A Study of Pesticide Disposal in a Sewage Sludge Incinerator" Contract No. 68-01-1587	DDT - 75% Dust $C_{14} H_9 Cl_5$
	CLASS OF PESTICIDE
TYPE OF INCINERATOR	IV Halogen-Containing
Full Scale Multiple Hearth Sewage Sludge Incinerator located in Palo Alto, California.	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION
	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS GM./HR.	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR		AVG.	MAX.				
1	6920				1162	1450			0.015	99.970
2	6920				1172	1460			0.015	99.975
3	16350				1160	1480			0.116	99.977
4	16350				1218	1475			0.022	99.983

Notes: 1. Data on excess air rates was not computed by Versar; however, Orsat analysis data reported indicates air was supplied at two to three times stoichiometric requirements.

2. DDT Dust feed 2 grs/100 gms sewage sludge for Experiments 1 and 2, and 5 grs/100 gms sewage sludge for Experiments 3 and 4.

ORIGIN OF DATA	PESTICIDE
Versar Inc., October 18, 1974 - Report to U.S.E.P.A. entitled "A Study of Pesticide Disposal in a Sewage Sludge Incinerator" Contract No. 68-01-1587	DDT - 75% Dust $C_{14} H_9 Cl_5$
	CLASS OF PESTICIDE IV Halogen-Containing
TYPE OF INCINERATOR Multiple Hearth Furnace by Envirotech Inc. 30" Inside Diameter - 6 Hearths and Afterburner	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
5	2270				1396	1660			1.31	99.995
6	2270				1441	1700			1.93	99.997
7	2270				1435	1650			1.60	99.998
8	2270				1438	1660			55.75	99.66

Notes: 1. Data on excess air rates was not computed by Versar; however, Orsat analysis data reported indicates air was supplied at two to three times stoichiometric requirements.

2. DDT formulation feed at rate of 5 gms per 100 gms Sewage Sludge.

ORIGIN OF DATA	PESTICIDE
Versar Inc., October 18, 1974 - Report to U.S.E.P.A. entitled "A Study of Pesticide Disposal in a Sewage Sludge Incinerator" Contract No. 68-01-1587	DDT - 75% Dust $C_{14} H_9 Cl_5$ **CLASS OF PESTICIDE** IV Halogen-Containing
TYPE OF INCINERATOR Multiple Hearth Furnace by Envirotech Inc. 30" Inside Diameter - 6 Hearths and Afterburner.	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION** HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
1	908				1406	1640			3.42	99.981
2	908				1388	1600			0.74	99.983
3	908				1318	1620			3.29	99.980
4	908				1360	1640			1.31	99.96

Note: 1. Data on excess air rates was not computed by Versar; however, Orsat analysis data reported indicates air was supplied at two to three times stoichiometric requirements.

2. Sewage sludge was used as auxiliary fuel. DDT Dust formulation was fed at rate of 2 gms per 100 gms of sewage sludge.

ORIGIN OF DATA	PESTICIDE
T.R.W. Systems Group - 7/73 to 8/74 Contract No. D:A.D.A. 17-73-C-3132 "Thermal Degradation of Military Standard Pesticide Formulations"	Dieldrin - 15% Emulsifiable $C_{12} H_8 O_1 Cl_6$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Custom Design Tube-Furnace consisting of Burner, Refractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDROCARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR.	AUXILIARY FUEL GAL/HR		AVG.	MAX				
A9-8-6		1.0	0	13	2235		0.177		150	
18					2000		0.567		3	
30					1765		0.999		2	
A9-6-6		0.75	0	15	2060		0.244		3	
18					1900		0.770		2	
30					1690		1.366		2	
A9-1-6		1.0	0	29	1915		0.174		< 1	
18					1820		0.543		< 1	
A9-7-6		0.75	0	49	1910		0.212		< 1	
A9-4-6		1.0	0	71	1975		0.131		1	
A9-5-6		1.0	0	111	900		0.166		451	
18					1150		0.461		248	
30					1275		0.749		67	
A9-11-6		0.75	0	91	1710		0.182		46	
18					1515		0.571		25	
30					1415		0.980		22	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.

2. Data sheets reported only measure of hydrocarbons as out-put measure.

3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
T.R.W. Systems Group - 7/73 to 8/74 Contract No. D.A.D.A. 17-73-C-3132 "Thermal Degradation of Military Standard Pesticide Formulations"	Dieldrin - 15% Emul. Mix with 3:1 Chlordane 72%
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Custom Design Tube-Furnace consisting of Burner, Réfractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDRO-CARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR	AUXILIARY FUEL GAL./HR		AVG.	MAX				
A6-11-6		1.0	0	13	1835		0.209		90	
18					1760		0.654		380	
30					1550		1.166		285	
A6-10-6		0.75	0	15	1985		0.268		30	
18					1760		0.867		1	
30					1460		1.588		1	
A6-3-6		1.0	0	46	1960		0.162		1	
18					1850		0.510		1	
A6-2-6		0.75	0	50	1820		0.225		1	
18					1750		0.693		1	
A6-6-6		1.0	0	73	1680		0.153		3	
18					1620		0.471		2	
A6-1-6		0.75	0	70	1840		0.197		3	
18					1755		0.616		3	
30					1585		1.072		3	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.

2. Data sheets reported only measure of hydrocarbons as out-put measure.

3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
T.R.W. Systems Group - 7/73 to 8/74 Contract No. D.A.D.A. 17-73-C-3132 "Thermal Degradation of Military Standard Pesticide Formulations"	Lindane - 1% Dust $C_6 H_6 Cl_6$
	CLASS OF PESTICIDE
TYPE OF INCINERATOR	IV Halogen-Containing
Custom Design Tube-Furnace consisting of Burner, Refractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDRO-CARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL/HR		AVG.	MAX				
A10-8-6	6.7x9	--	1.0	18.6	1940		0.165		< 1	
18					1900		0.507		1	
A10-9-6	4.5x3		1.0	40.9	1885		0.143		1	
A10-1-6	4.5x3		1.0	44.8	1690		0.145		< 1	
A10-7-6	6.7x9		1.0	49.3	1885		0.140		< 1	
A10-10-6	6.7x9		1.0	89.1	1684		0.124		3	
18					1490		0.395		< 1	
30					1350		0.583		< 1	
A10-4-6	4.5x3		1.0	106.0	1140		0.140		705	
18					1230		0.413		133	
30					1225		0.594		< 1	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.
2. Data sheets reported only measure of hydrocarbons as out-put measure.
3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
T.R.W. Systems Group - 7/73 to 8/74 Contract No. D.A.D.A. 17-73-C-3132 "Thermal Degradation of Military Standard Pesticide Formulations"	Lindane - 12% Emulsifiable Concentrate $C_6 H_6 Cl_6$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Custom Design Tube-Furnace consisting of Burner, Refractory Lined Section, Water Cooled Section, Afterburner Section, Quench Section, and Scrubber.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDROCARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL/HR		AVG	MAX				
A7-3-6		1.0	0	14	2135		0.173		487	
18					2000		0.545		14	
30					1790		0.954		13	
A7-7-6		0.75	0	14	2030		0.243		3	
18					1950		0.755		3	
30					1735		1.346		2	
A7-9-6		1.0	0	31	2410		0.146		3	
18					2005		0.480		2	
A7-6-6		0.75	0	28	2000		0.222		3	
18					1850		0.700		3	
30					1635		1.239		3	
A7-11-6		1.0	0	50	2145		0.136		1	
18					1910		0.435		1	
A7-5-6		0.75	0	47	1830		0.210		9	
A7-2-6		1.0	0	73	1475		0.146		810	
18					1630		0.424		2	
A7-4-6		0.75	0	77	1220		0.215		1050	
18					1450		0.613		39	
30					1480		1.028		14	

Notes: 1. Summary of data suggested efficiencies of greater than 99.99% were achieved, but these calculations were not shown.

2. Data sheets reported only measure of hydrocarbons as out-put measure.

3. Samples were collected at 6", 18", and 30" from point of injection. These are summarized by modifying the T.R.W. experimental numbering system to read A1-2-6, 18, 30, etc.

ORIGIN OF DATA	PESTICIDE
The Marquardt Corp., February 1974 "Report on the Destruction of 'Orange' Herbicide by Incineration" Contract No. F41608-74-C-1482	"Orange" Herbicide $C_{10} H_{10} O_3 Cl_2$
	CLASS OF PESTICIDE
TYPE OF INCINERATOR	IV Halogen-Containing
S.U.E. Burner manufactured and sold by The Marquardt Corp. Includes Scrubber.	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F.		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS MG/HR.	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX.				
I	2.11×10^5			89	1820		0.16	6.25	2.4	
II	2.20×10^5			89	1759		0.15	6.0	1.8	
III	2.60×10^5			52	1900		0.16	3.4	2.4	
IV	2.60×10^5			53	1786		0.14	7.7	1.8	
V	2.93×10^5			34	2049		0.14	5.7	2.4	
VI	2.60×10^5			52	2100		0.16	5.2	6.6	
VII	2.94×10^5			34	2053		0.15	5.6	3.0	
VIII	1.95×10^5			37	2210		0.18	4.9	1.8	

Note: 1. Marquardt did not report incineration efficiencies; however, worst conditions show efficiency of 99.99999757 percent. Reported hydrocarbon data does not correlate with this efficiency since hydrocarbon contents of 50 to 100 PPM were measured.

ORIGIN OF DATA

Midwest Research Institute - 6/73 to 9/74
E.P.A. Contract No. 68-03-0286
"Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"

PESTICIDE

Toxaphene - 20% Dust
$C_{10} H_{10} Cl_8$

CLASS OF PESTICIDE

IV Halogen-Containing

TYPE OF INCINERATOR

Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb. per Hour Class Incinerators. Multiple Chamber Type.

POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION

HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS GM./HR.	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX.				
A	3520	--	1.02	94	1240	1645	16.0		1.1×10^{-2}	> 99.999
B	2750	--	1.07	166	1240	1765	11.0		5.4×10^{-3}	> 99.999
C	3060	--	2.30	53	1845	--	6.1		1.1×10^{-1}	> 99.996
D	3850	--	2.32	44	1875	1645	7.5		6.8×10^{-3}	> 99.999
E	3430	--	2.56	122	1765	1920	5.3		5.4×10^{-3}	> 99.999
F	3310	--	2.35	121	1850	1900	5.2		1.0×10^{-1}	> 99.997

ORIGIN OF DATA	PESTICIDE
Midwest Research Institute - 6/73 to 9/74 E.P.A. Contract No. 68-03-0286 "Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides"	Toxaphene - 60% Liquid Emulsifiable $C_{10} H_{10} Cl_8$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION
Constructed by M.R.I. at M.R.I. according to design standards published by the Incinerator Institute of America for 100 Lb per Hour Class Incinerators. Multiple Chamber Type.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
1	753.88	0.63	0.27	349	1150	--	10.2			> 99.999
4	906.29	0.75	1.67	47	1895	1910	7.3			> 99.999
6	1940.50	1.61	0.70	71	1895	2090	7.7			> 99.999
8	1339.02	1.11	0	212	1245	--	9.5			> 99.999
10	1262.82	1.06	0	228	1255	2080	12.9			> 99.999
11	642.29	0.53	0.44	150	1205	--	13.2			> 99.999

ORIGIN OF DATA	PESTICIDE
Versar Inc., October 18, 1974 - Report to U.S.E.P.A. entitled "A Study of Pesticide Disposal in a Sewage Sludge Incinerator" Contract No. 68-01-1587	2, 4, 5 - T - 20% in Polyalcohol Solution $C_{10} H_9 O_3 Cl_3$
	CLASS OF PESTICIDE
	IV Halogen-Containing
TYPE OF INCINERATOR	**POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION**
Full Scale Multiple Hearth Sewage Sludge Incinerator located in Palo Alto, California.	HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS GM./HR.	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR		AVG.	MAX.				
9	1108				1290	1660			0.102	99.991
10	1108				1249	1640			0.111	99.990
11	3450				1274	1675			0.126	99.996
12	3450				1294	1725			0.366	99.990

Notes: 1. Data on excess air rates was not computed by Versar; however, Orsat analysis data reported indicates air was supplied at two to three times stoichiometric requirements.

2. 2, 4, 5 - T Solution fed 2 grs/100 gms sewage sludge for Experiments 9 and 10, and 5 grs/100 gms for Experiments 11 and 12.

ORIGIN OF DATA	PESTICIDE
Versar Inc., October 18, 1974 - Report to U.S.E.P.A. entitled "A Study of Pesticide Disposal in a Sewage Sludge Incinerator" Contract No. 68-01-1587	2, 4, 5 - T - 20% in Polyalcohol Solution $C_{10}H_9O_3Cl_3$
	CLASS OF PESTICIDE: IV Halogen-Containing
TYPE OF INCINERATOR: Multiple Hearth Furnace by Envirotech Inc. 30" Inside Diameter - 6 Hearths and Afterburner.	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION: HCl

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	PESTICIDE IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL./HR.	AUXILIARY FUEL GAL./HR.		AVG.	MAX				
17					1456	1670			1.0	99.98
18					1460	1640			0.16	99.99
19					1436	1640			0.67	99.99
20					1380	1640			0.29	99.98
21					1429	1600			0.05	99.99
22					1458	1600			0.01	99.99
23					1435	1600			0.48	99.99
24					1441	1600			--	--

Notes: 1. Data on excess air rates was not computed by Versar; however, Orsat analysis data reported indicates air was supplied at two to three times stoichiometric requirements.
2. Sewage sludge feed rate 45 Kg/hr.
Experiments 17 - 20 2,4, 5 - T Solution rate - 0.91 Kg/hr
Experiments 20 - 25 2, 4, 5 - T Solution rate - 2.25 Kg/hr

ORIGIN OF DATA	PESTICIDE
The Marquardt Corp. 7/72 to 7/73 Report entitled "Toxic Waste Burner Evaluation" Contract No. F04611-73-C-0007	Hydrazine $N_2 H_4$
	CLASS OF PESTICIDE
TYPE OF INCINERATOR	
S.U.E. Burner and Venturi Scrubber manufactured by Marquardt.	POTENTIALLY HAZARDOUS PRODUCTS OF COMBUSTION

EXPERIMENT NO.	FEED RATE			EXCESS AIR %	COMBUSTION TEMP. °F		RETENTION TIME SEC.	PRESSURE DROP IN. H_2O	HYDRO-CARBONS IN GAS EFFLUENTS PPM	INCINERATOR EFFICIENCY %
	PESTICIDE GMS./HR.	PESTICIDE AS FIRED GAL/HR	AUXILIARY FUEL GAL/HR.		AVG.	MAX				
4	3750				1270		20.1		< 10	
17	2513				2060		20.1		< 10	

Note: 1. The Marquardt Corp. performed extensive combustion experiments on Hydrazine and two other liquid rocket propellants. Data was reported in "raw" or unreduced form. Hence, this sheet is included to inform the reader that such data is available and could be used if properly reduced by Marquardt or others.

AUTHOR'S INTERPRETATION AND ANALYSIS OF THE DATA

1. In general the data suggest that combustion may be used as a technique for the safe destruction of certain classes of pesticides. To date the data have been collected mostly on Class III and Class IV pesticides; hence, additional research is needed to explore the efficacy of incineration on other classes of pesticides.

General conclusions which determine minimum operating conditions for incinerators to destroy pesticides may not be drawn specifically from these data because of the absence of information on mixing. Thus, while one may conclude that the types of incinerators tested were generally satisfactory under certain test conditions, the interaction between retention time, combustion temperature, and mixing precludes direct extrapolation of the operating conditions of the test incinerators to other designs.

2. Little data is available on Class II Phosphorus-containing pesticides; however, the data summarized indicate that these pesticides were successfully destroyed via combustion at a temperature range from 1150 F to 1900 F and retention times ranging from approximately 4 seconds to approximately 12 seconds, depending on mass flow conditions. In the absence of turbulence data and without exhaustive numeric analysis, the data suggests that malathion, the only Class II pesticide tested, could be destroyed safely in most incinerators that achieved an operating temperature of greater than 1400 F and a retention time of approximately 8 or more seconds. An incinerator whose operating temperatures were higher, or whose mixing was improved, and whose retention time was somewhat decreased from the 8 second figure might also be acceptable as a disposal process.

3. The data suggests that Class III Nitrogen-containing pesticides require temperatures in excess of 1750 F and retention times of greater than 4 seconds in order to achieve satisfactory cyanide destruction. Again, this data is presented without adequate turbulence data; hence, my conclusion can only be interpreted as a general guideline.

4. Class IV Halogen-containing pesticides were successfully combusted in different types of equipment under conditions ranging from two-tenths of a second retention time and approximately 2000 F combustion temperature to 1200 F or 1300 F and 8 to 10 seconds retention time in a different type of combustion equipment, both of which gave 99.999 percent or better combustion efficiency. Again, in the absence of turbulence data, it is difficult to extrapolate these data to other equipment because of the tremendous differences in the operating characteristics of the two types of combustion devices.

5. Some data was reported by Versar Inc. on the combustion of DDT in a full scale multiple hearth sludge incinerator. The feed rate of DDT, however, was 2 gr per 100 gr of sludge, and auxiliary fuel was used in addition to both these fuels. Hence, the efficiency of pesticide destruction might be as much a function of monitoring error, because of the high dilution of combustion gas components, as a function of combustion efficiency. The author believes these data should be verified in several

other carefully monitored situations before one concludes that multiple hearth sludge incinerators can be used for any type of pesticide destruction. The author does not feel the data reported are invalid, but rather that the difficulties in monitoring under the conditions of a full scale operation are extremely taxing on equipment and personnel, and very small errors in monitoring technique or operating conditions may result in the release of significant quantities of pesticide to the environment, if multiple hearth incinerators are generally used as a technique for the destruction of Class IV pesticides.

APPENDIX A - DESCRIPTION OF TEST INCINERATORS

The information displayed in Appendix A has been excepted from original sources of data. This information pertains to the incinerator system utilized to collect data on the combustion of pesticides. The purpose is to give the reader ready access to additional information on the particular designs utilized in the experiments producing the combustion data. When available from the original materials, line drawings illustrating the incinerators have been photocopied and included.

1. Description of Test Incinerator Used by Midwest Research Institute

The M.R.I. incinerator was constructed according to the Incinerator Institute of America specifications for small multiple chamber incinerators. It consists essentially of: a burner, a 300 standard cu ft per minute induced draft blower, a primary chamber of 26.3 cu ft, a secondary chamber of 20.6 cu ft, and an overall heat release design rate of 650,000 BTU's per hour. Figure A-1, photocopied from M.R.I.'s report, entitled "Incinerator Scrubbing System," illustrates the layout for the incinerator and an elaborate scrubbing system designed to recover pesticides downstream from the incinerator. Nominal dimensions and design flow rates are given on the figure. A second figure, A-2, entitled "Incinerator Configuration," shows design dimensions of the incinerator as constructed by M.R.I. The design was modified somewhat to allow the addition of powdered pesticides, along with auxiliary fuel, into the primary chamber of the incinerator.

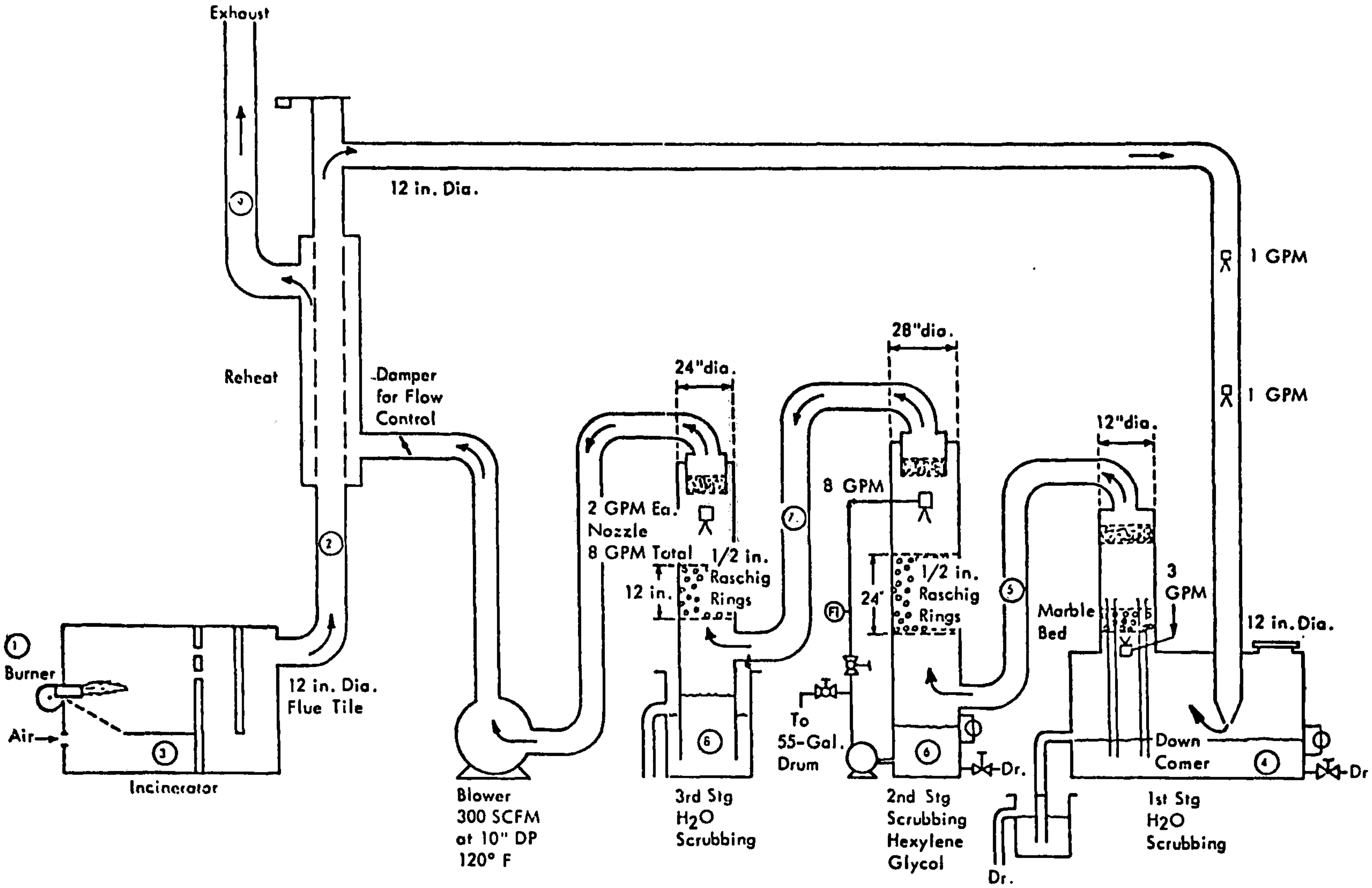

Figure A-1. Incinerator Scrubbing System

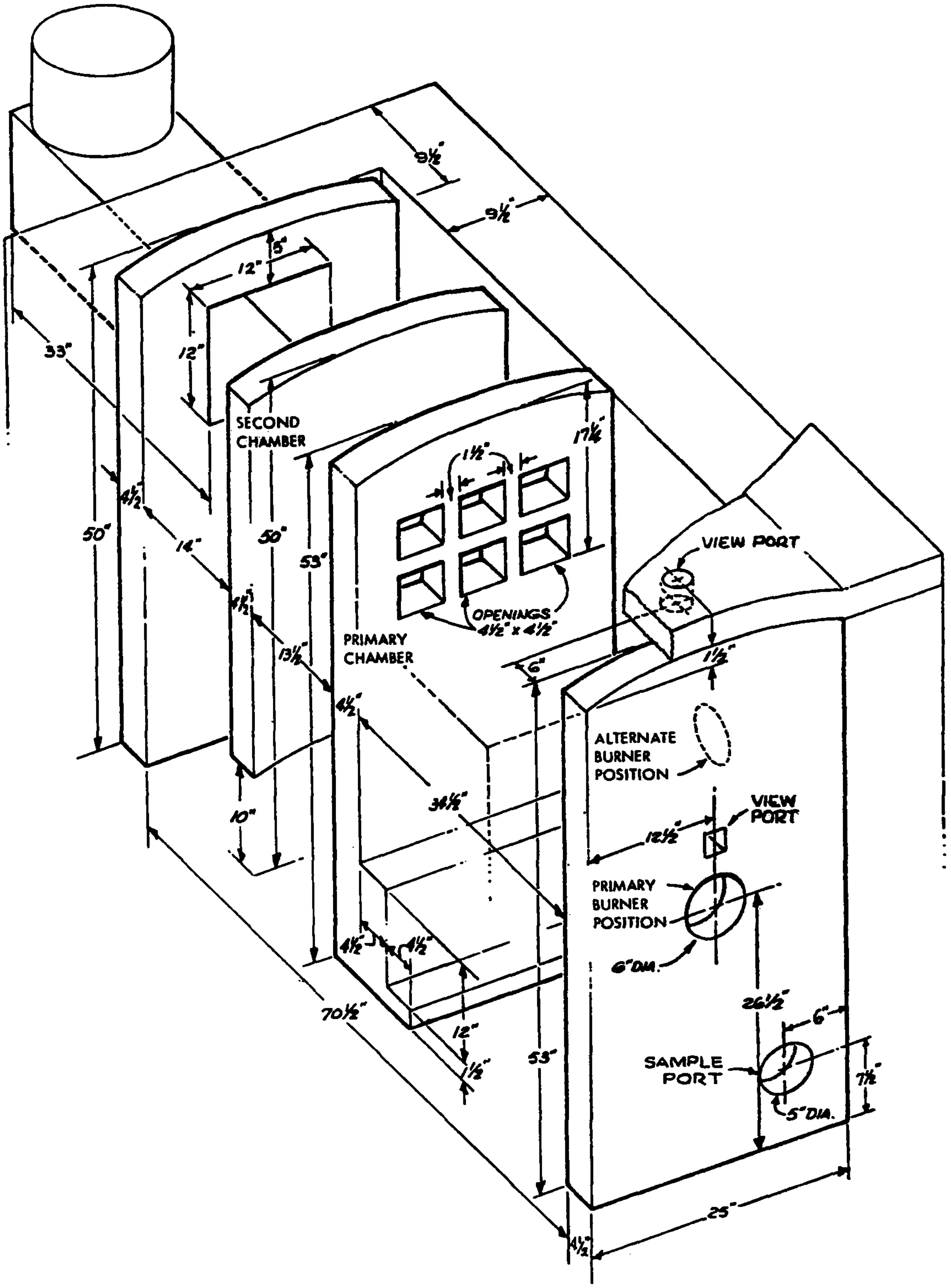

Figure A-2. Incinerator Configuration

2. Description of the Incinerator System Utilized by T.R.W. Inc.

The process consists of: the burner, refractory lined sections, water cooled sections, quench chamber, and scrubber, as shown in Figure A-3, entitled "Schematic Pesticide Incinerator." The first refractory lined section contains the ports for inserting the water cooled dust injector. Ports for inserting the sample probe are shown along the axis of the furnace, both in the refractory and the water cooled sections. Thermometers for measuring the coolant water temperature are shown installed in the coolant sections. The quench chamber has two rows of three spray nozzles to reduce combustion gas temperature prior to entering the scrubber. The entire burner-incinerator-scrubber assembly is a sealed system.

A clear blue flame at a nominal 1 gallon per hour distillate No. 2 oil flow rate was attained. The combustion gas temperature was measured with a platinum 10 percent rhodium thermocouple. Chromel-alumel thermocouples were attached to the outer shell of the refractory lined section at 6, 18, and 30 in. from the back plate. Temperature of the back plate was also recorded.

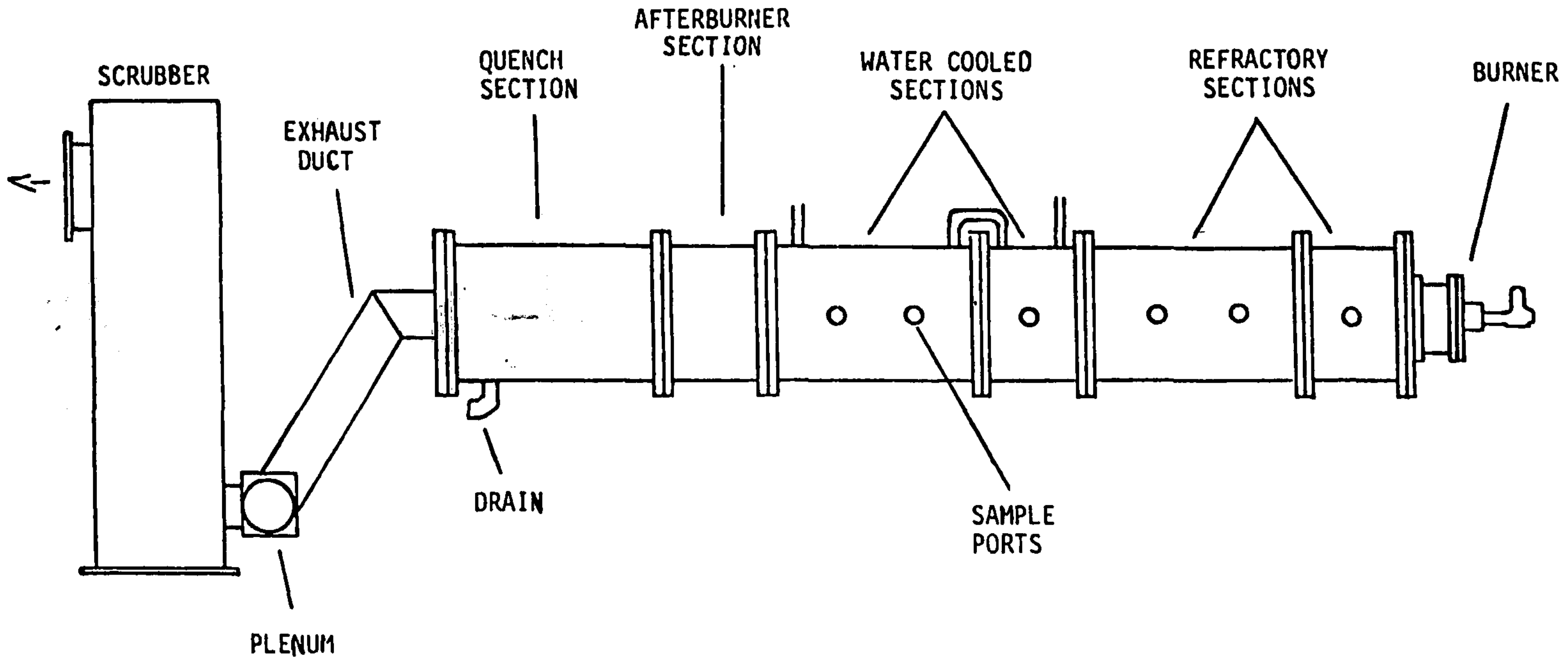

Figure A-3. Schematic of Pesticide Incinerator

3. Description of the Incinerator Test Facilities of The Marquardt Corp.

The following information has been excerpted verbatim from a report supplied by the Marquardt Corporation.

"3.0 Test Facilities. The major components of the system consisted of a SUE Burner incinerator and reaction tailpipe, venturi scrubber, scrubber collection tank, natural gas and "Orange" Herbicide fuel supply systems, air supply system, caustic solution supply system, scrubber water collection system, and scrubbed effluent stack and sampling platform. Operating personnel, controls, and instrumentation were housed in a concrete block control room which was adjacent to the test set up and provided visibility of the test cell. A detailed description of the test set up and control system is described in Appendix B. The following paragraphs present a brief description of the system components and facilities utilized.

3.1 Incinerator and Reaction Tailpipe. The basic air-cooled SUE incinerator and uncooled reaction tailpipe are shown in Figure 2*. Natural gas was used for system ignition and temperature stabilization. "Orange" Herbicide was injected either via slot nozzles (configuration shown) or with a single central poppet type nozzle. The incinerator/reaction tailpipe was 12 inches in diameter with a combined length of 19 feet.

3.2 Venturi Scrubber and Scrubber Tank. Combustion gas leaving the reaction tailpipe passed through the venturi scrubber and into the scrubber tank. Scrubbing water or a caustic solution (NaOH/water) was injected at the venturi inlet and mixed with the combustion gas at velocities up to 400 ft/sec. in the venturi throat. Spent scrubber water was pumped from the scrubber tank to holding tanks for disposal. The water saturated, scrubbed effluent gases were discharged through the scrubber stack. See Figures 6 and 16.

3.3 Air Supply System. Combustion air was supplied from the facility air storage system via a remotely operated control valve and a choked venturi meter. See Figure 3.

3.4 Natural Gas System. Natural gas was used to preheat the incinerator system to an equilibrium temperature (approximately 800° F) prior to introduction of the herbicide. Upon ignition of the herbicide, the natural gas was turned off and a small air flow was supplied through the natural gas system to cool the gas injection nozzles during sustained herbicide combustion.

*Only Figure 2 is reproduced here, as Figure A-4 "Basic Test Arrangement of N_2O_4 SUE Incinerator."

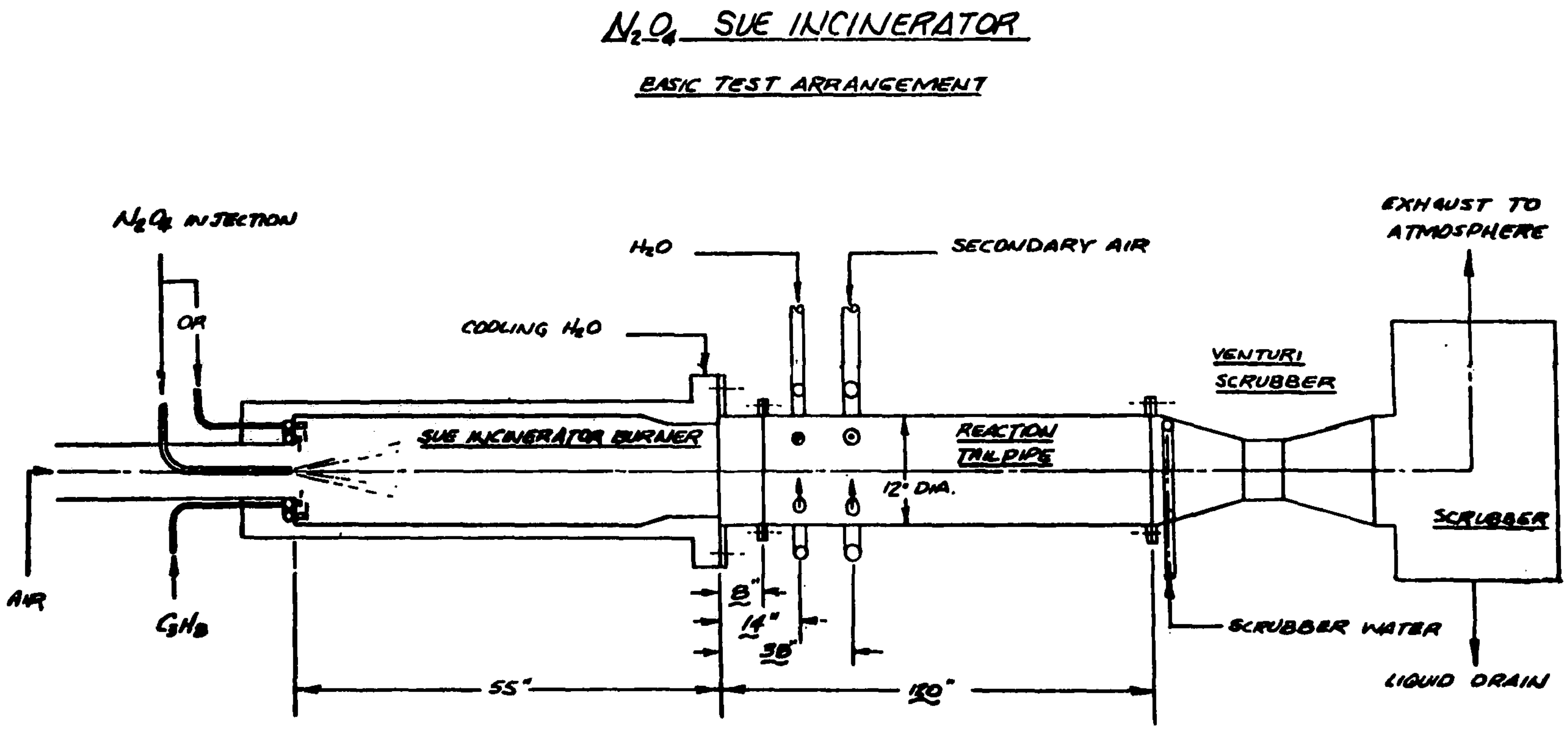

Figure 2

Figure A-4. Basic Test Arrangement of N_2O_4 SUE Incinerator

Both natural gas and cooling air mass flow were measured with a choked venturi meter. Cooling air flow was added to primary air flow in calculating total incinerator mass flow and fuel/air ratio. Flow was regulated by a remotely operated control regulator. A gaseous nitrogen (GN_2) purge system was included to clean the system during shutdowns.

3.5 Primary Fuel ("Orange" Herbicide or JP-4) System. Fuel was supplied from a 300 gallon, 500 psig feed tank through either of two parallel 5 micron filter pots, a remotely operated control valve, and a turbine type flowmeter. This system is shown in Figure 4. The feed tank was pressurized with nitrogen which was vented to atmosphere through a charcoal bed. A herbicide fuel tank preheater was used to permit heating of the "Orange" Herbicide to 90 to 180° F prior to incineration. The fuel line to the incinerator was purged with a GN_2 system. Fuel injection in the incinerator was either by a single central poppet type nozzle or a series of radial injection slot nozzles as discussed in Appendix B. A shop air bubbler was used to mix the fuel tank contents prior to test.

3.6 Caustic Solution and Water Supply Systems. A solution of NaOH and water was injected into the system at the venturi scrubber inlet to neutralize the HCl and Cl_2 resulting from combustion of "Orange" Herbicide. The solution was approximately 12% by weight of NaOH and was injected at a rate to provide 1.1 to 3.1 times the amount required to neutralize the theoretically expected amounts of HCl. Fresh water was also injected at the same location to cool the combustion gases to saturation temperature, and to provide a total liquid flow of approximately 5 gpm per 1000 cubic feet of gas flow. The caustic solution was stored in a 4500 gallon tank and supplied to the control valve by a pump. See Figure 5. Caustic solution (50% by weight of NaOH) was loaded from drums into the caustic supply tank and tap water added to obtain the desired strength solution. Provisions were included to bubble shop air through the solution to ensure thorough mixing. Fresh water was supplied from the 140 psig facility system. Both flows were controlled by remotely operated control valves and metered with turbine type flowmeters. See Figure 14 foreground.

3.7 Scrubber Liquid Collection System. Spent scrubber water was collected in the scrubber tank and periodically pumped, by a float actuated switch, from the scrubber tank to one of three 5500 gallon holding tanks. See Figure 6. All spent scrubber water from an entire burn was thus collected and held until the results of the Air Force bioassay testing for that burn indicated that the water could be safely drained into the facility's 1.4 million gallon concrete waste water tank (also referred to as a holding pond). The system included a sample tap for the collection of spent scrubber water samples for chemical analyses and bioassay testing. Scrubber water samples were also drawn from the bottoms and sides of the holding tanks."

4. Description of Proto-type Furnace Used by Versar Inc. for the Investigation of Pesticide Incineration

The following information has been excerpted directly from a report prepared by Versar Inc.

"4.2 Proto-type Furnace Operations. A schematic diagram of the Envirotech Corporation proto-type 76.2 cm. (30 in.) multiple hearth furnace shown in Figure 1* represents the normal configuration of the system. For the purposes of this series of experiments, the cyclone was by-passed and the scrubber was arranged for closed circuit operation by the addition of a reservoir approximately 1.22 m x 0.91 m x 0.91 m (4 ft x 3 ft x 3 ft) fitted with a surface closure and an access port to allow periodic sampling. The major purpose of recycling the scrubber water was to minimize escape of unburned pesticide to the environment; however, it also provided samples for a chloride production analysis.

Provisions were made to allow a continuous measurement of the individual hearth temperatures, the afterburners and exhaust temperatures and the oxygen and carbon dioxide content of the emergent gas stream. Provisions were also made to collect the product (ash) and to impound the scrubber water pending the outcome of the analyses."

The equipment used in full scale tests was very similar in schematic plan and layout to that used in the pilot scale examination.

*Reproduced here as Figure A-5.

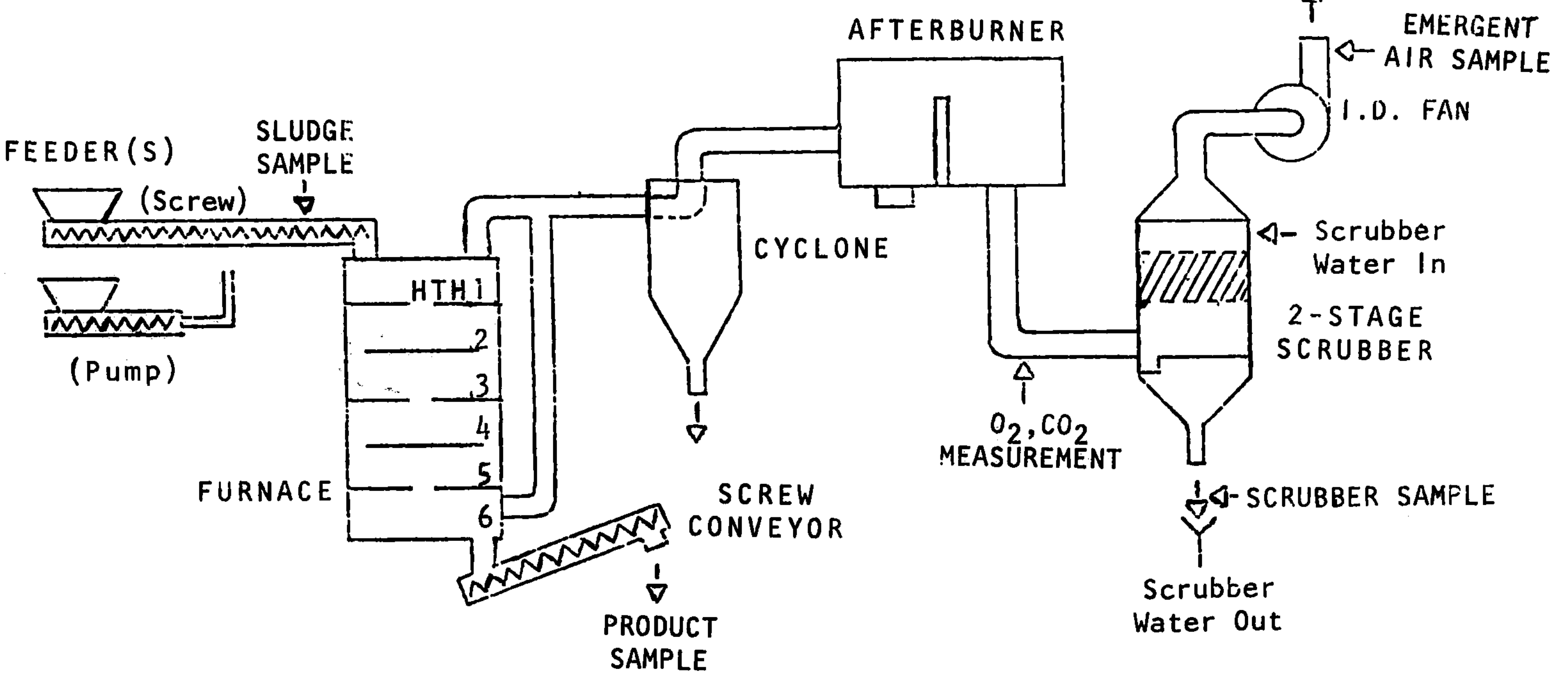

Figure A-5. Schematic of 30-inch I.D. X 6 HTH Pilot Furnace System

APPENDIX B - OTHER SIGNIFICANT TEST FACILITIES OR PROGRAMS

This appendix is included to provide the reader with brief information concerning those facilities which might be used for the combustion of pesticides, or those facilities which were used for pesticide combustion tests but whose data were not deemed comparable to the data reported.

1. John Zink & Company Incinerator Owned and Operated by the General Electric Company, Pittsfield, Massachusetts

This facility consists principally of a cylindrical combustion chamber. On one end of the cylinder are two oil burners which may be utilized to fire liquid pesticides or hazardous materials. At the opposite end of the cylindrical container is a quenching and scrubbing system for removing particulates and other airborne pollutants. Tests were run during the period September 10 through 12, 1974, and were observed by Mr. Ira Leighton of the Region One office of the Environmental Protection Agency. A distillate oil containing 20 percent by weight DDT emulsion was burned, and effluents from the incinerator were monitored for the detection of DDT. Essentially no DDT was detected, and very high combustion efficiencies for DDT were reported. The feed rate of the DDT, as well as the actual amount of pure DDT fired, was not available. Hence, these data were not included in the data sheets in the main body of this report.

2. Edgewood Arsenal, Aberdeen Proving Grounds, Maryland

This facility is owned and operated by the Department of Defense, and more specifically by the U.S. Army. The officer in charge is Lt. Col. William O. Lamb of the U.S. Army Environmental Hygiene Agency. Data offered by Midwest Research Institute in the form of a trip report indicated that Edgewood possessed a standard multiple chamber type incinerator quite similar to the M.R.I. incinerator, and that a considerable amount of testing of pesticides and their destruction was on-going. Efficiencies of destruction of greater than 99.9998 percent were reported, with excess air in the range of 50 to 83 percent, and a retention time of 1.73 seconds at 2500 F. The author believes that additional data could be obtained at the Edgewood Arsenal Facility that would be an excellent supplement to the data provided in this report. The Figure B-1, "Modified Agent Incinerator" is included to illustrate the Edgewood Arsenal installation.

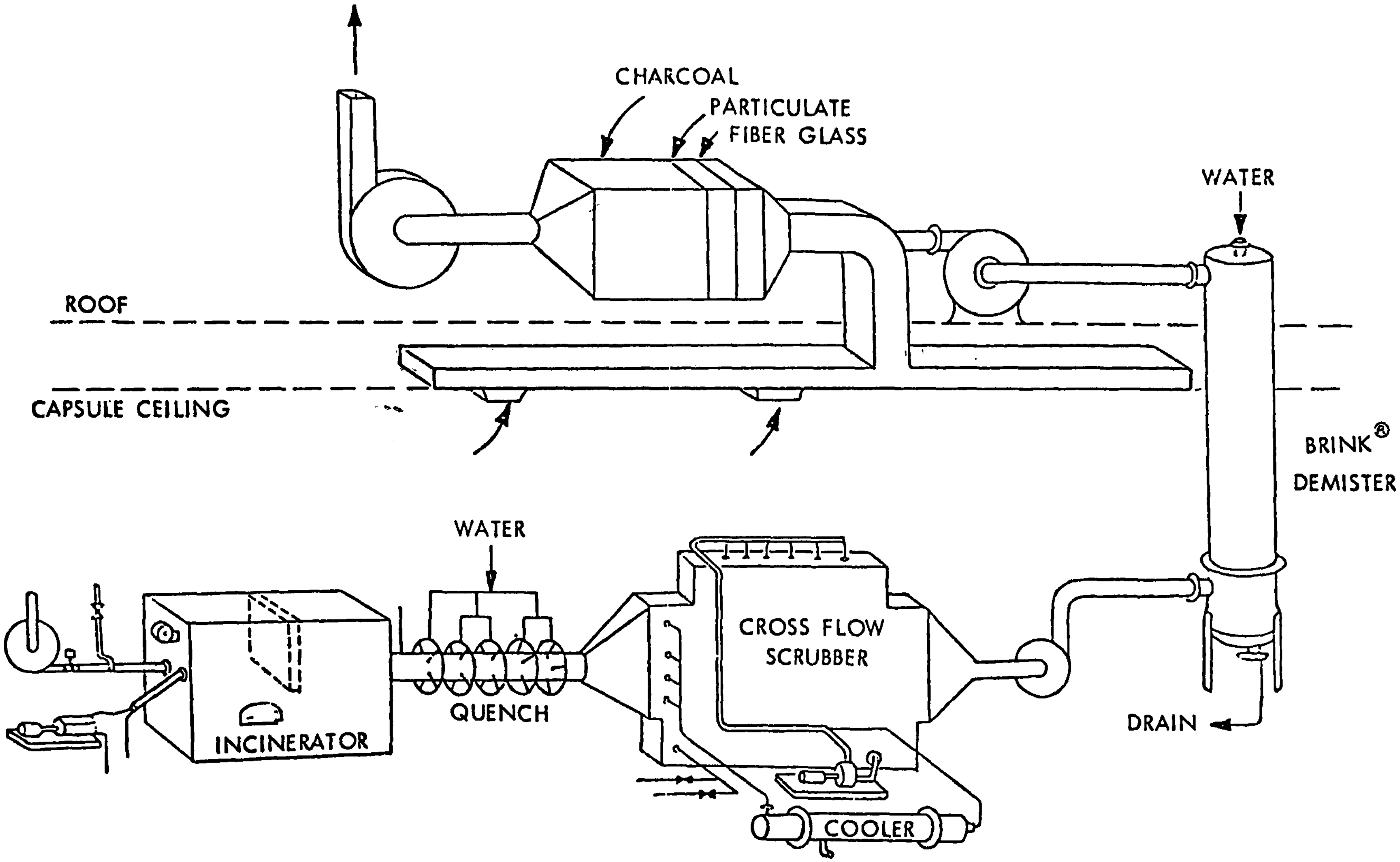

Figure B-1. Modified Agent Incinerator

3. Molten Salt Process of Atomics International Division of Rockwell International Corporation

This process consists of pyrolyzing and combusting pesticides in a eutectic mixture of molten salt at about 1800 F. Information on the system has not been included in the report because of a proprietary information claimed by the Rockwell International Corporation. A request was presented to the Rockwell International Corporation for release of the information to be included in this report, but no answer, either positive or negative, was received. Hence, the information is not included.

4. MT Volcanus Incineration Vessel

The MT Volcanus Incineration Vessel offers a unique approach to the destruction of pesticides and other toxic or hazardous materials. Two high temperature incinerators have been mounted on a tanker vessel of modest proportions. The tanker loads combustible non-corrosive liquid wastes; puts out to sea; and burns these wastes. The air pollutants are injected into the atmosphere, but may be diluted satisfactorily for some wastes by the larger space available for this purpose at sea. Little data on this vessel and its combustion system is currently available; however, since the incinerators make use of auxiliary fuel, one could anticipate that for Class III and lower classes of pesticides the vessel might be satisfactory as a disposal technique. A major demonstration and test program has recently been completed on the MT Volcanus; however, these data are not available for inclusion in this report.

5. Mines Branch Program on Environmental Improvement, Canadian Government

This organization conducted tests on the combustion of liquid formulations of DDT in 1970 and reported these. The tests appear to have indicated satisfactory combustion of DDT in the incinerator design used by the Mines Branch Program. The design essentially consisted of a combustion chamber oriented in a vertical fashion with a burner at the top, quench tank, and gas bypass at the base of the chamber. Information on efficiency and method of computation was sparse in the reports available to the author. Hence, these data were not included in the data summation presented in the body of this document.

6. Mississippi State University, State College, Mississippi

Under grant from the U.S. Department of Agriculture, lengthy investigations were carried out on the thermal destruction of many pesticides. According to the data submitted to the author, the overwhelming majority of the work reported was of laboratory scale under very idealized conditions. Hence, these data were not included in the main body of this document. There is some indication that a pilot scale incinerator exists as a part of this study, and that it has been used for testing of the destruction of various pesticides. However, these data were not available during the compilation of this report and are, therefore, not included.

7. The Combustion Power Company, Menlo Park, California

The Combustion Power Company has designed and has offered as a commercial facility a fluidized bed type incinerator for the destruction of liquid and solid wastes. A portion of these liquid wastes might well be construed to be pesticides. Some tests have been conducted on the destruction of pesticides with the system by the company, but these data were not available during the compilation of this report; hence, are not presented. The facility might offer an additional option for the destruction of certain classes of pesticides.

8. Additional facilities which might be investigated for the combustion of pesticides include the Pinebluff Arsenal, in Arkansas; and the Rocky Mountain Arsenal, near Denver, Colorado. The Dow Chemical Company has been active in thermal destruction of certain types of industrial wastes and may have systems and information which may be of benefit to the E.P.A. program on pesticides destruction by thermal means.

APPENDIX C - TECHNIQUES FOR CONVERTING THE TABULATED DATA INTO METRIC UNITS

The tabulated data sheets are expressed partially in metric units and partially in English units, according to the most common usage and most common technique of reporting for the several documents from which the reported data were extracted. All of the data may be converted to metric units if there is a need.

Under the general heading of feed rate, three columns are included. The first, "Pesticide, Grams per Hour", describes the pure pesticide formulation fired. Grams per hour is a metric designation. The second column "Pesticide As Fired, Gallons per Hour" is utilized because most pesticide formulations were liquid. Gallons per hour may be converted to liters per hour, a metric designation, by multiplying the data displayed by 3.785. The third column "Auxiliary Fuel, Gallons per Hour" represents fuel oil utilized to maintain desired temperatures. Again, gallons per hour may be converted to liters per hour by multiplying by 3.785.

The column entitled "Excess Air, Percent" can be considered either as a metric or English designation, since the percentage is a representation of the relative measure of two numbers.

The general heading "Combustion Temperature, Degrees Fahrenheit" shows two temperatures, average and maximum. The temperature may be represented as degrees centigrade by subtracting 32 from the Fahrenheit degrees reported and then multiplying that number by five-ninths. "Retention Time, Seconds" is considered a metric designation, as well as an English designation. The column entitled "Pressure Drop, Inches of Water" does not include any data at the present time. It would be possible to convert this to centimeters of water by multiplying the data, if it were shown, by 2.54. The succeeding column entitled "Pesticide in Gas Effluents or Hydrocarbons . . ." is expressed in parts per million or in metric units. Parts per million is generally considered to be equivalent to milligrams per cubic meter. Hence, the data is, for the most part, represented in metric units.

The last column "Incinerator Efficiency" again is a numeric representation and is the same in either the English or metric system.

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Richard A. Carnes (Project Officer) 513/684-4487

16. ABSTRACT

The disposal of various types of pesticides by incineration without significant insult to the environment is a major problem. This project summarizes the findings of several investigators, who tested the combustion efficiency of several pilot plant scale incinerators on several classes of pesticides. A brief discussion of a classification technique for pesticides is included, as well as a brief discussion of theoretical combustion requirements.

17. KEY WORDS AND DOCUMENT ANALYSIS

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*Pesticides *Incinerators Combustion efficiency	Retention time Excess air	13B

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