THE
THERMAL DESTRUCTOR

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THE THERMAL DESTRUCTOR

A Facility for Incineration of Chlorinated Hydrocarbons

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DEFENCE RESEARCH ESTABLISHMENT SUFFIELD
RALSTON ALBERTA

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ABSTRACT

Following the Federal Government's decision to ban general use of DDT in Canada, many government agencies were left with stocks of surplus DDT formulations. The largest stock in the Department of National Defence was 107,000 gallons of DDT/kerosene solution; in order to dispose of this, the Defence Research Establishment Suffield had built an incinerator specifically designed to decompose chlorinated hydrocarbons. This paper describes the background history and design of this incinerator facility and outlines its construction and operation. It includes a report on the successful results of the first two months' operating experience, and discusses future plans for destruction of unwanted chemicals.

RÉSUMÉ

En conséquence de la décision du gouvernement fédéral à bannir l'emploi général du D.D.T. au Canada, beaucoup d'agences gouvernementales ont été laissées en possession d'un surplus de stocks à formulaires de D.D.T. Le plus grand dans le Ministère de la Defense Nationale était une solution de 107,000 gallons de D.D.T./kérosène. Pour disposer de celle-ci, Le Centre de Recherches pour la Defense Suffield avait bâti un incinérateur spécifiquement concu pour décomposer les hydrocarbures chlorurés. Ce document décrit les données de base de l'histoire et de la conception de cet incinérateur et esquisse sa construction et son opération. Il comprend un rapport sur les résultats couronnés de succès de l'expèrience exploitante des deux premiers mois, et discute les projets à venir pour la destruction de produits chimiques superflus.

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HISTORICAL BACKGROUND

On January 1, 1970, the Federal Government banned the general use in Canada of the pesticide DDT (p-dichloro-diphenyl trichloroethane) and other chlorinated hydrocarbons. In anticipation of this ban, the Canada Department of Agriculture initiated studies of methods for safely disposing of surplus stocks of DDT. One of the more promising disposal methods appeared to be incineration or thermal destruction. In support of this programme, the Canadian Combustion Research Laboratory (CCRL) of the Department of Energy, Mines and Resources, under Mr. E.R. Mitchell, undertook a study to determine the operating parameters and equipment required for effective thermal decomposition of DDT. Starting from previous studies (1) which showed that DDT is completely decomposed at temperatures at or near 1000°C, burners and firing conditions for DDT/kerosene formulations were investigated, and samples of combustion products were obtained for analysis. The CCRL tests (2) showed that essentially complete degradation of DDT in kerosene could be achieved in a properly designed "blue-flame" burner, with CO_2, H_2O and HCl as the only products of combustion. A complete system also required a scrubbing tower to remove HCl from the effluent gases.

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(1) Chemical and Thermal Methods for Disposal of Pesticides. M.V. Kennedy, B.J. Stojanovic and F.L. Shuman Jr. Residue Reviews (1969) 29, pp. 89-104.

(2) The Thermal Destruction of DDT in an Oil Carrier. H. Whaley, G.K. Lee, R.K. Jeffrey and E.R. Mitchell. Research Report R225, April 1970. Canadian Combustion Research Laboratory, Fuels Research Centre, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Ontario, Canada.

ROLE OF DEFENCE RESEARCH ESTABLISHMENT SUFFIELD

Beginning early in 1970, in response to requests from government departments and industrial firms for assistance in disposing of hazardous chemicals and unwanted pesticides such as DDT, the Defence Research Board (DRB) began to consider the problems involved. Initially the most likely solution appeared to be storage or burial of such materials in a safe location, and the Defence Research Establishment Suffield (DRES) was suggested, because of its large experimental range area, its location in a sparsely settled area with favorable geological terrain, and the availability of scientific and support staff familiar with problems of hazardous chemicals. However, as more and more requests were received, it became apparent that, for some materials such as DDT/kerosene solutions, the large quantities involved made some method of destruction seem preferable. Consequently, DRB began to look for safe and efficient methods for degradation of these chemicals.

In September of 1970 DRES was asked for assistance in destroying the large stocks of unwanted pesticides in the Department of National Defence inventory. The surplus stocks, which included 107,000 gallons of DDT/kerosene solution used for biting fly control, were held at Canadian Forces bases across Canada. Since the Canadian Combustion Research Laboratory had shown that DDT could be completely decomposed by controlled incineration, and since the method could be applied to other hazardous chemicals, DRB decided to investigate commercially available incinerators and the possible construction of a "thermal destructor" facility. DRES was the ideal location for such an installation, since, in addition to the factors previously mentioned, supplies of water and cheap natural gas were readily available. The initial investigation was undertaken by one of us (W.L.M.) to determine all the factors involved.

The basic objective of this study was to investigate the feasibility of developing a full scale facility capable of thermally degrading chlorinated hydrocarbons like DDT to a degree such that the resultant products of combustion could be readily assimilated by nature, and further that these combustion products themselves would not be environmental pollutants. In addition, the facility should have the capability of being adjusted or modified to handle a reasonable range of related combustible waste materials.

Since there was little published information on this subject, contacts were made with other government agencies and industries, in both Canada and U.S.A., where incineration problems had been encountered and where some experience had been obtained. At the same time, technical sources in the literature were searched for names of manufacturers of suitable equipment. The investigations finally lead to Pyrotherm Equipment Limited, of Burlington, Ontario, who were Canadian licensees for combustion equipment developed by Garver-Davis Limited of Cleveland, Ohio. Visits were made to these firms and to some of their installations, and it appeared that these companies were best able to complete the design studies and provide in a short time equipment of the type desired. Consequently, in November 1970, a proposal was prepared for setting up a "thermal destructor" facility at DRES, specifically for DDT disposal, but with a view towards future destruction of other unwanted chemicals. This proposal was approved by DRB Headquarters, and by the Federal Government Treasury Board in early December. Detailed engineering plans were prepared and a contract awarded to Pyrotherm Equipment Limited for the fabrication and erection of the "Thermal Destructor". Plans for site preparation and ancillary structures were completed in February and contracts awarded to local contractors in March. The entire facility was completed and placed in operation in early June, just six months after the feasibility studies were concluded.

DESIGN OF DESTRUCTOR AND SITE DEVELOPMENT

Basically, the Destructor consists of a horizontal cylindrical combustion chamber (see Figs. 1 and 2), with a dual fired (natural gas and oil) burner installed at one end and a vertical cylindrical scrubbing tower attached to the other. The DDT/kerosene solution when injected into the burner is completely burned in the combustion chamber and the gaseous products of combustion pass into the scrubbing tower. This tower has a continuous flow of water down through it to cool and absorb the hydrochloric acid gas produced. CO_2 and H_2O are discharged into the atmosphere, while the liquid effluent is piped into holding ponds, where it is neutralized, before being recirculated through the scrubbing tower.

The Thermal Destructor was designed and built specifically for incineration of chlorinated hydrocarbons, with provision for expansion (by adding a second scrubbing tower) to handle compounds that also contain sulphur. The nominal waste fuel feed rate is 100 U.S. gal/hr; however, to avoid exceeding the heat capacity of the combustion chamber, the maximum feed rate for any given waste fuel is limited by the maximum design heat capacity of the furnace (15 million BTU/hr).

Within this limitation, normal plant control is based entirely on combustion temperature. That is, upper and lower operating temperature limits, as determined by experimental and computer studies before incineration is begun, are chosen to bracket the optimum combustion range of a waste fuel. For example, such studies have shown (1,2) that complete combustion of the DDT/kerosene solution is obtained at 1600°F to 1700°F, provided the proper fuel/air ratio is used and the residence time of DDT in the combustion chamber is sufficiently long. Too low a temperature produces DDT vapour which is expelled to the atmosphere, while too high a temperature leads to dissociation, with the formation of chlorine gas and nitrogen oxides. Since perfect combustion is the goal, the plant is operated at 1650°C, with automatic cut-off of the waste fuel if the combustion chamber temperature varies more than 50°F from this value. When the temperature drops below that required for optimum combustion, the waste fuel flow is cut off and additional heat is provided by natural gas combustion until the optimum temperature is re-established.

To support the Thermal Destructor, facilities were designed and constructed to provide optimum safety and efficiency of operation (see Figs. 3 and 4). Waste material, in 45 Imperial gallon drums, is catalogued on receipt and stored in a storage building. Subsequently, each drum is taken by overhead conveyor to a waste transfer station where its contents are pumped into a 1000 gallon holding tank. The drums, when empty, are rinsed with kerosene, and the washings are also added to the storage tank. Ultimately the waste fuel from this tank is pumped to the destructor building and burnt. Behind the destructor building are the waste water lagoons for the cooling water supply.

Technical details of the Thermal Destructor and its construction and operating parameters are listed in Appendix I.

CHEMICAL AND PHYSICAL MEASUREMENTS

Preliminary information on the properties of the DDT/kerosene solution which was first burned was obtained from the Canada Department of Agriculture Pesticide Unit. Based on the Pesticide Registration Number, CDA reported the following characteristics for the liquid formulation.

DDT Technical Grade - 5.25%

Escomat 45 - 18.95%

(Boiling point 440°F, Flash point 160°F - Tag C.C., Specific gravity 0.953 @ 15°C)

Spray Base Oil - 75.8%

(Flash point 125°F - Pensky-Martens C.C., Specific gravity 0.850 @ 15°C)

Average specific gravity - 0.86 @ 15°C

Confirmatory measurements at DRES on the DDT/kerosene solution yielded the following values:

Specific gravity at 75°F - 0.844 (determined by pyncnometer)

Flash point - 116.5°F (determined by Pensky-Martens Closed Cup)

Heat of combustion - 18,000 BTU/lb (determined by bomb calorimetry)

Fractional amount of DDT - 5% (determined by gas chromatography)

This information was used, along with a computer analysis of the combustion process and resultant products, to determine the optimum parameters for operation of the Thermal Destructor. The equation for complete burning of DDT is $C_{14}H_9Cl_5 + 15\ O_2 \longrightarrow 14CO_2 + 2H_2O + 5HCl$. When optimum combustion occurs, only these three gases remain, and the HCl gas will be scrubbed from the effluent stream by the cooling water flow in the stripping tower. The pure hydrocarbon solvents will produce only carbon dioxide and water if complete combustion occurs.

Checks on the actual efficiency of combustion and scrubbing were made by sampling input, effluent and lagoon waters, analyzing for unburned DDT, and measuring the pH and chloride ion concentrations. The effluent gases were also sampled and analyzed for chloride ion and unburned DDT. A method for the extraction of DDT from water was worked out using n-hexane, an accepted solvent for DDT. The parameters for analysis of DDT in the n-hexane solvent by gas-liquid chromatography were also established; details of both of these methods are listed in Appendix II. The measurement of DDT was found to be accurate to 1 part per billion - equivalent to 1 pound of DDT in 450,000 tons (90 million gallons) of water - and the limit of detectability was about one-half of this amount.

To sample the gaseous effluents from the stack, a 35-foot stainless steel sampling line was connected to the stack one foot from the top. A glass fiber filter was inserted near the top of this line, and a suitable trap, bubbler and pump attached to the line at floor level. Dry ice was used to cool the trap, and n-hexane was used as a solvent in the bubbler.

These procedures are used on a regular basis to monitor operation of the destructor. On one occasion, DDT was measured to be present to less than 3 μg/min in the outlet water, and 30 μg/min in the stack effluent, with no detectable DDT in the inlet or lagoon waters. Previous and subsequent samples detected no DDT in either type of effluent. Based on the one positive result as a limiting case, not more than 0.0002% of the DDT entering the destructor remains unburned.

The effluent water is slightly more acidic than the inlet water, as would be expected when the HCl gas is scrubbed out in the stripping tower. No evidence of chloride ion was found in the condensate from stack sampling, indicating that the scrubbing tower is performing as desired.

At the present time, cooling water is continuously recycled from the storage lagoons into the scrubbing tower, with extra fresh water added from time to time to make up evaporative losses. The combination of addition of slightly basic fresh hard water and the alkaline soil walls of the holding lagoons, serves to neutralize the HCl picked up in the stripping tower, and the pH of the water in the storage ponds is remaining constant. Studies are underway to determine whether salt build-up in the pond water is occurring, and whether additional measures for neutralization will be required in the future.

ENVIRONMENTAL AND SAFETY CONSIDERATIONS

Immediately after Destructor start-up, and at regular intervals since then, both effluent water and stack gases have been sampled and analyzed for possible unburned DDT. Within the limits of detection no DDT has been found in the effluent water. Results of stack gas sampling show efficiencies of burning ranging from 100% (i.e., no unburned DDT found) to 99.9998%. This implies that, even if the latter figure is used, in burning the entire DND stock of 107,000 gallons - 460 tons - of DDT/kerosene solution, less than 1.3 ounces (1/6 of a cup) of DDT will remain unburned.

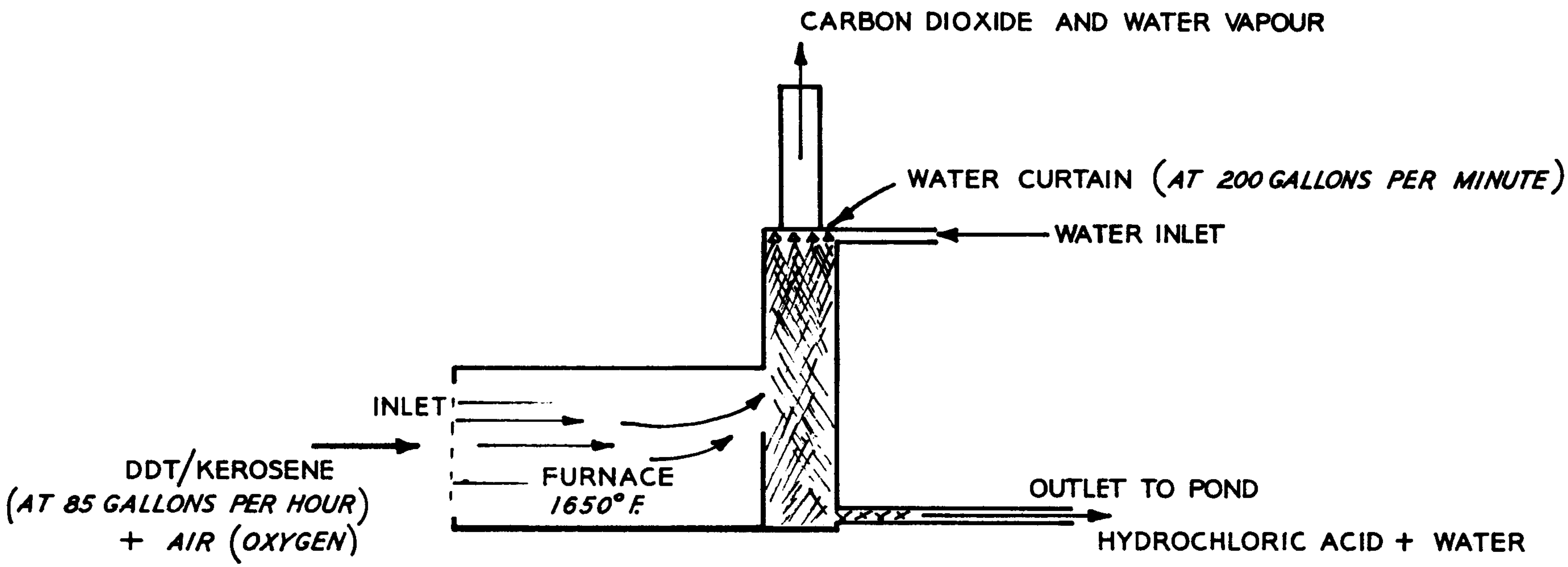
Reduction of the health and environmental hazards from DDT itself and from fire are of prime importance in the operation of the Thermal Destructor. The entire project of DDT disposal has been carried out with advice from the Director of Preventive Medicine of the Department of National Defence, in regard to safety of personnel involved in the shipping and handling of pesticide stocks, and staff handling the liquid material wear the same protective clothing as for any hazardous industrial chemicals. Continuous manual supervision of destructor operation, and regular sampling of outputs, are normal procedures to ensure that no unburned DDT escapes to the environment.

Sophisticated fire safety precautions were considered in designing the site. The entire site is fenced off and designated a No Smoking area. The Destructor facility itself consists of three buildings separated from each other by more than 100 feet. On-site storage is limited to the amount of waste fuel which can be burned in one month's operation, and it should be noted that the DRES continuously manned fire station is only a short distance away from the site.

SCHEDULES AND FUTURE OPERATIONS

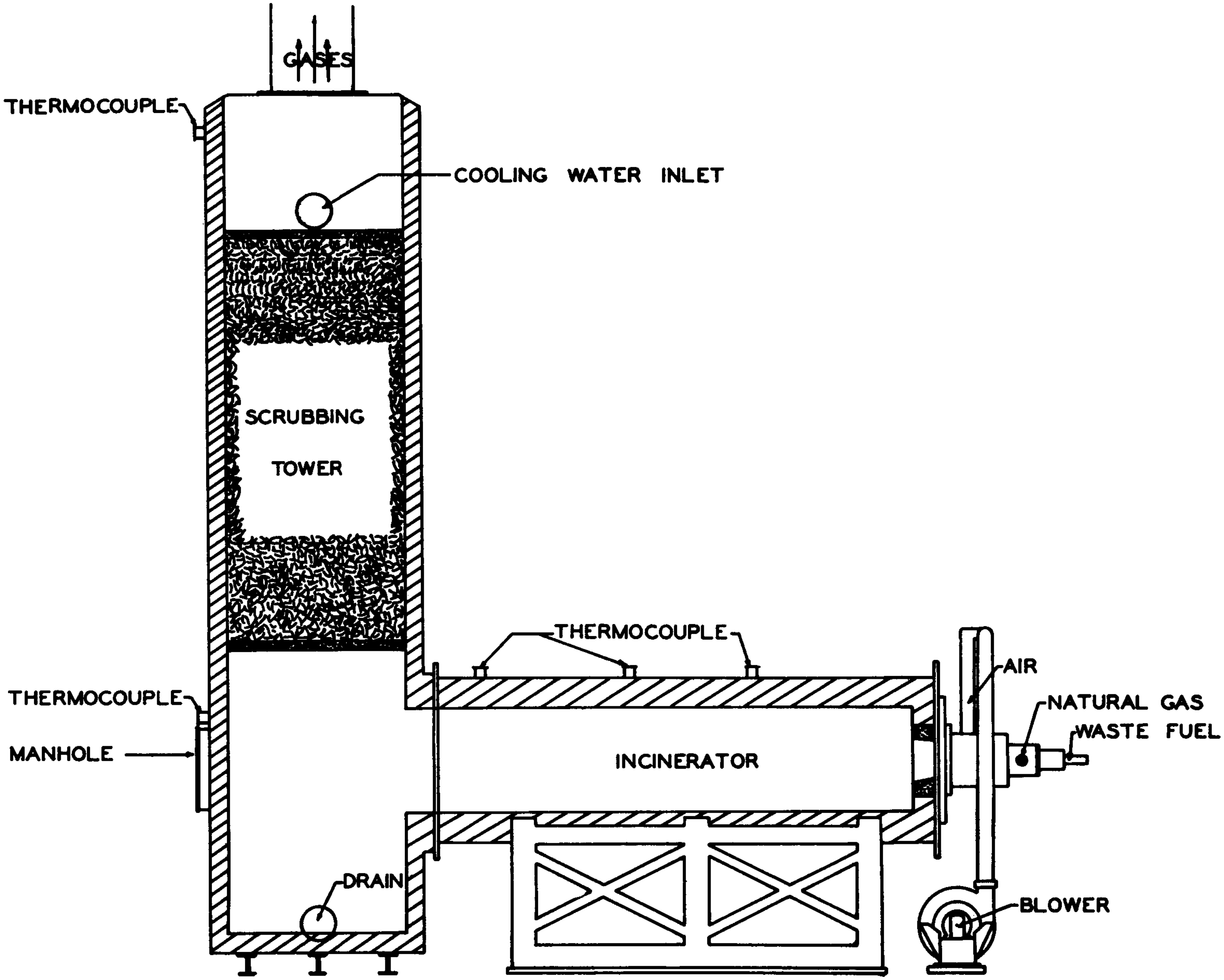
At present, Canadian Forces DDT/kerosene stocks are being shipped from all across Canada to DRES for disposal. Destruction of these DND materials should be completed by late 1971 or early 1972. When DND formulations of DDT are destroyed, surplus stocks from other federal departments, from provincial authorities, and from municipalities will likely be accepted for destruction. Though the Thermal Destructor was designed to destroy chlorinated hydrocarbons, and particularly liquid DDT compositions, research is underway at DRES, in other parts of Canada, and elsewhere, to determine the best way to destroy by incineration other hazardous materials. As stated earlier, the Thermal Destructor at DRES will be capable of handling liquid wastes containing sulphur compounds following the addition of a second scrubbing tower to remove sulphur oxide gases. The original destructor design made provision for adding such a tower when desired.

The problem of disposing of unwanted and possibly hazardous chemicals is rapidly increasing in magnitude. Traditional methods of disposal, such as burial, volatilization, spreading on soil, or burning in open pits or standard incinerators, are becoming increasingly questioned by society. Controlled incineration is one of the cleanest methods for dealing with many unwanted chemicals; however, at present, it is expensive and is not suitable for all compounds. Research is slowly getting under way in several parts of the world into the techniques and economic factors involved in recycling chemicals, and the next few years may see the discovery of better methods of destruction. In the meanwhile, the Thermal Destructor appears to be an excellent solution to complete destruction of a large quantity of one specific unwanted pesticide - DDT in kerosene solution.



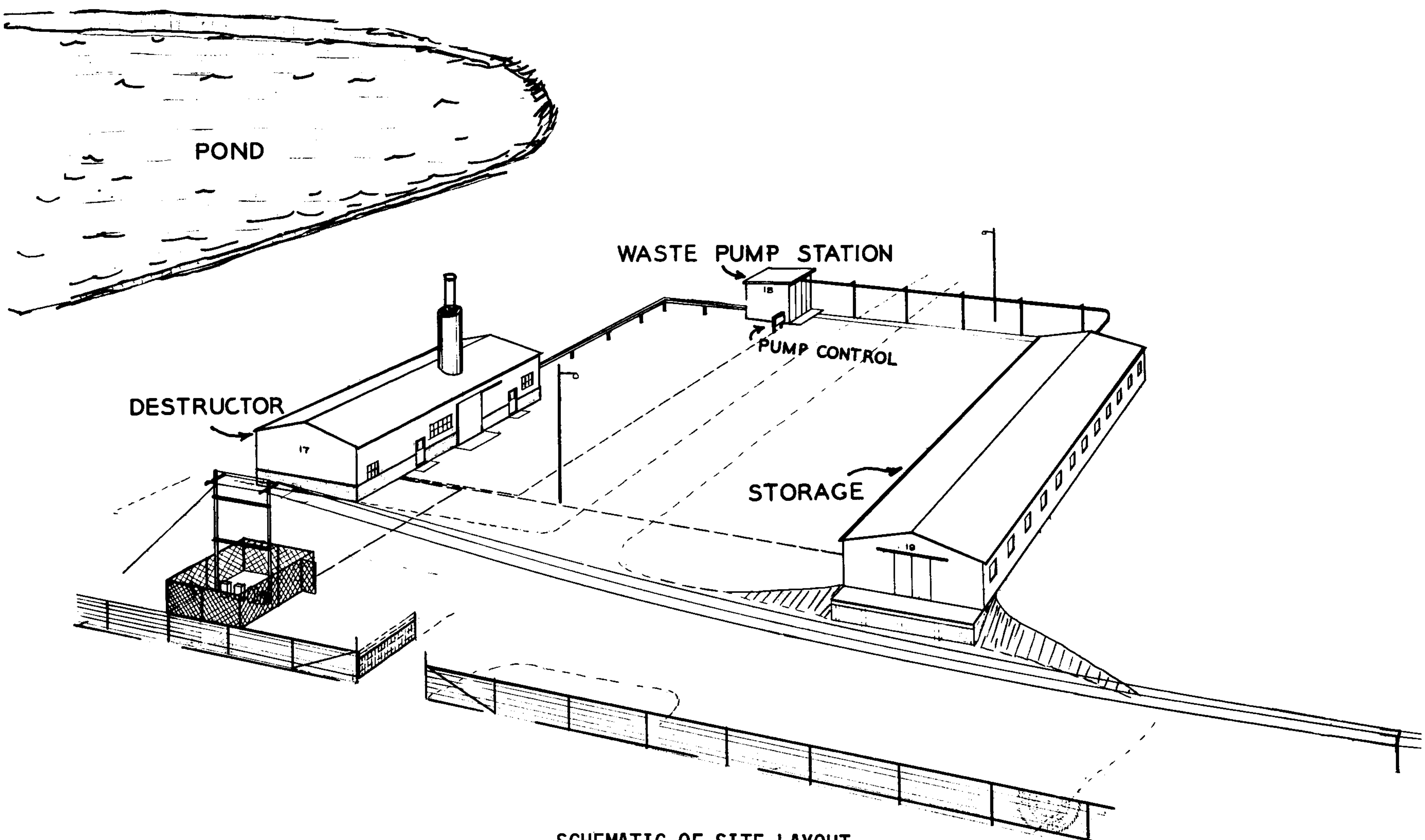
SIMPLIFIED SCHEMATIC FLOW DIAGRAM OF THE THERMAL DESTRUCTOR

FIGURE 1



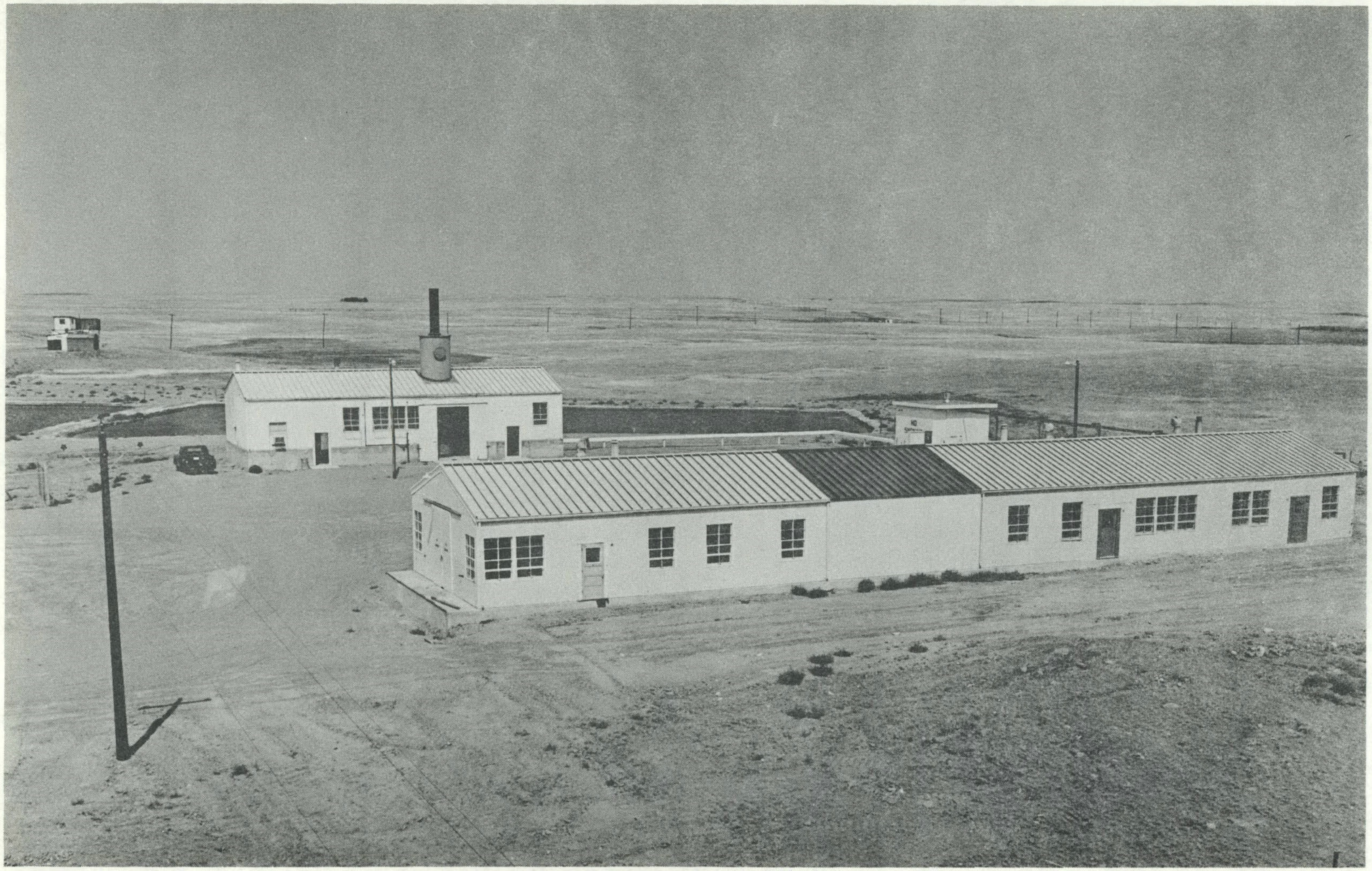
THERMAL DESTRUCTOR

FIGURE 2



SCHEMATIC OF SITE LAYOUT

FIGURE 3



PHOTOGRAPH OF SITE LAYOUT

FIGURE 4

APPENDIX I

SOME FACTS AND FIGURES ON THE DESTRUCTOR

1. Manufacturer - Pyrotherm Equipment Limited
   Burlington, Ontario
   - Canadian licensee

2. Destructor Design - Garver Davis Inc.
   Cleveland, Ohio
   - This company also provided a computer combustion analysis on the waste fuels expected to be burned.

3. Burner - North American Burner
   Cleveland, Ohio
   - Nominal feed rate 100 U.S. gal/hr.

4. Combustion Chamber - Diameter 7 feet, length 15 feet
   - Maximum refractory temperature 3600°F
   - Maximum control system temperature 3200°F
   - Capacity 15,000,000 BTU/hr.

5. Scrubbing Tower - Maurice A. Knight Co.
   Akron, Ohio
   - This company provided all the refractory plus refractory installation.
   - Diameter 7 feet, height 26 feet
   - Cooling water flow 200 Imp. gal/min.
   - Waste water neutralized in waste water lagoon, then recirculated.

6. Water lagoons - two, total capacity 3,000,000 Imp. gallons

7. Temperature for DDT/kerosene destruction - 1650°F

8. Cost of destruction (based only on labour, water, electricity and natural gas costs):
   - During initial operation, $1.00 per gal.
   - After continuous operation begins, (estimated) 25-30 cents per gal.

APPENDIX II

ANALYSIS FOR DDT IN EFFLUENTS FROM THE DRES THERMAL DESTRUCTOR

1. 100 ml samples of the intake, effluent or pond waters are extracted twice with 100 ml portions of redistilled pesticide grade n-hexane (Fisher Scientific Company) by shaking in a 500 ml separatory funnel. The combined solvent layers are evaporated to dryness and the residue is taken up in 5 ml redistilled n-hexane. The efficiency of recovery by this method is 83%.

2. A series of standards covering the range 13 ng/g to 700 ng/g is prepared in n-hexane using analytical standard p,p'-DDT (Polyscience Corporation, Evanston, Illinois).

3. Analysis of the final n-hexane portion from the extraction procedure is accomplished with a Varian Associates Model 1800, dual column gas chromatograph equipped with a Microtek Nickel 63 electron capture detector. The operating parameters are as follows:

a) Column: 6' x 1/8", packed with a 50:50 mixture of 5% QF, and 5% DC-200 on Chromasorb W, AW, DCMS.

b) Temperatures:

(1) Column - 200°C

(2) Injector - 220°C

(3) Detector - 290°C

c) Gas Flows:

(1) Nitrogen - 34 psi

(2) Helium - 60 psi (purge)

d) Attenuation: $10^2 \times 1 \times 1$

e) Injection Volume: 0.3 µl

f) Retention Times: p,p'-DDT - 352 sec.

g) Quantitation Limit: 0.1 γ/ml

h) Detection Limit: 4 pg in 0.3 µl

4. Stack samples are collected in n-hexane in a glass bead bubbler. The solvent is analyzed for DDT directly.

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