

EXPERIENCE WITH BURNING INDUSTRIAL WASTES IN  
STEAM-GENERATING AND HIGH-TEMPERATURE HEAT RECOVERY SYSTEMS

by

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Introduction

Prior to the enactment of the Clean Air Act of 1970 and the dramatic changes in fuel economics of 1974, there was little, if any, impetus for the installation of waste fuel and thermal oxidizer energy systems utilizing heat recovery. Beginning with the above facts, Industry has finally come to realize that fuel costs are a significant part of their cost of goods, which will continue to increase, and that efforts to improve energy utilization are imperative. Most of the early thermal oxidizer systems were installed to meet Federal and State air pollution emission regulations with relatively little heat recovery. Now, these fuel cost escalations make Industry consider heat recovery a required option. In addition, as more attention was paid to the possibilities of effective heat recovery, it became evident that, in addition, there were many waste materials that could be used as substitute and acceptable fuel sources. However, we also learned that these substitute fuel sources had inherent combustion problems which must be considered prior to system design. Since there was, and still is, a sparsity of historical data on these inherent combustion problems, we have had to develop our own experience base in order to properly combust these potentially valuable waste streams. We have also had to assume that the combustion of these materials and their resultant emissions, such as from chlorinated hydrocarbons, rubber tires, salt-based materials, lead battery cases, etc., would not exceed the State and Federal emission regulations. This paper relates the experiences from two specific installations, one of which has been in operation for a few years and examines the research needs that can lead to greater utilization of our nation's waste materials as a replacement or supplement for our scarce and expensive fossil fuel sources.

Steam-Generation from Waste Materials

A. General System Design

CEA designed, built, and operates a plant for the Spaulding Fibre Corporation in Tonawanda, New York. The plant previously used seven, coal-fired boilers to generate process and heating steam. These units did not meet emission regulations and were a constant source of maintenance and repair. Spaulding Management decided that a replacement was necessary

and entered into a contract with CEA to design, build, and operate a system that both utilized and destroyed phenolic fume and could utilize other waste materials as a major fuel source.

The CEA/Spaulding installation consists of five burner-thermal oxidizer units, which take the phenolic-laden exhaust gases as a combustion air source. Figure 1 presents a flow diagram of the system at Tonawanda, N.Y. Three units are capable of handling liquid/gaseous wastes and conventional fuels to generate steam. One unit is capable of handling solid wastes as well as liquid/gaseous wastes and conventional fuels to generate steam. The fifth unit can burn liquid/gaseous wastes and conventional fuels. The installed capacity of this facility is 72,640 kgs/hr (160,000 lbs/hr) of steam.

Figure 2 is a schematic sketch of the solid-waste incinerator. The solid waste storage bin has a live bottom which delivers the shredded refuse to the double-vortex<sup>(TM)</sup> burner. The double-vortex burner<sup>TM</sup>, a proprietary CEA product, is designed to accept the shredded solid materials and burn them, much like a fluidized-bed unit, but increases retention time for complete combustion by the double-vortex principle. Figure 3 is a schematic sketch of the incinerator/waste heat boiler system.

#### B. Types of Waste Used in this Unit

When this installation was made operational in September, 1972, little was known about the advantages and disadvantages of burning waste materials other than wood, bark, and clean solvents such as toluene and methanol. Thus, we had a unique opportunity, with the cooperation of our client, to utilize this operational plant as an in-situ laboratory of full-scale size and problems.

The plant began by burning conventional fuels while the facility completed its start-up and shake-down period. This pollution-control/steam generating facility takes phenolic fume @ 405° K (270° F) from the plant's treaters and uses it as combustion air.

A year was spent in experimenting with the most satisfactory solid-waste handling equipment, since it was our intent to base-load the solid-waste unit. There was a wide range of waste materials that we believed should be investigated, and we therefore decided that the solid-waste stream must be shredded, stored in a bin, and moved by a live-bottom bin to the screw feeder. Solids burned have included soft and hard woods such as pine, oak, and maple; phenolic scraps from Spaulding Fibre; battery cases; tires; residue from dynamite manufacture; dried cow manure; rubber buffings; low grade coal; paper; cardboard; plastics; corn cobs and shredded garbage. Having this wide range of wastes, CEA has experimented with many types of temporary rigs, conveyors, shredders, blowers, classifiers, and densifiers. It is fairly clear that, in a plant of this relatively small size, no single system is the best solution to all. In

all instances, the waste material must be shredded to a size that the combustion system can properly burn.

In regard to liquid wastes, various mixtures of liquid wastes have been burned. The most fascinating liquids are those of the chlorinated-hydrocarbon family. There are enormous amounts of these materials that must be disposed by environmentally sound methods, since they are considered a serious environmental hazard and difficult for disposal. These materials generally have a high BTU value and, if combined with other materials of lower chlorine content, can be incinerated without exceeding air emission regulations. Other liquid wastes that were combusted included tank bottoms, oils contaminated with water, resins, and similar materials. A major problem with this contaminated liquid stream was their high solids content especially as to suspended solids. These materials had to be filtered before entering the double-vortex burners or excessive particulate emissions would result, as well as erosion of the tubes in the waste-heat boilers.

The chlorinated materials had content from 0.17% to as much as 5%. We have conducted a number of experiments in neutralizing the chlorine content by pretreatment. Our latest experiments have shown pretreatment to be a successful method of safely preparing chlorinated-hydrocarbons for use as an alternate fuel source.

One factor that must be faced when using liquid wastes as a fuel source is that their availability is subject to local conditions. Thus, the liquid waste material to be combusted will always be of: varying energy content, solids composition, water contamination, chlorine, and other contaminant content. Thus, a user must be assured that he has the required system to safely handle, store, and combust the material. The hazardous substances list published by EPA should be consulted prior to combusting any contaminated liquid wastes.

### C. Operational Success & Problems

Since placing this Plant "on line" in September, 1972, plant reliability has been 100% primarily due to redundant critical equipment plus a properly-managed PM system for the rest of the Facility. As an example, the thermal oxidizer unit capable of handling solids has never been off the line except for scheduled inspections. All PM has been done during Sunday production shutdowns.

Thermal efficiencies have been consistently 90% or above due to boiler design, economizers, and incoming gaseous wastes at 405° K (270° F).

To provide an idea of the successful operating experience at this Plant, I present the following facts:

1. Total steam generated from September 1972 through May 31, has been 935,217,900 kilograms (2,061,804,300 pounds).

2. Liquid chemical wastes, combustible and relatively clean, from one source successfully combusted has been 4,970,076 liters (1,313,098 gallons) which represents 141,370,000 Mega-Joules (134,000,000,000 BTUs).
3. Liquid wastes accumulated from another source obtained in early 1975 amounted to over 2,649,500 liters (700,000 gallons) and represented 88,620,000 Mega-Joules (84,000,000,000 BTUs).
4. Wood wastes contracted with a pallet manufacturer in March 1974 contributed 15,033,750 Mega-Joules (14,250,000,000 BTUs).
5. Other wood wastes from various sources contributed to over 1,055,000 MJ (1,000,000,000 BTUs).
6. Solid phenolic wastes from the Spaulding manufacturing processes themselves contributed 16,247,000 MJ (15,400,000,000 BTUs).
7. Rubber from tires and buffings since February 1975 have contributed over 4,483,750 MJ (4,250,000,000 BTUs).
8. Resins, alcohols, and other solvents have contributed over 1,055,000 MJ (1,000,000,000 BTUs).
9. Various other wastes such as garbage, trash, battery cases, "corn-cobs", residues, etc. have contributed over 1,055,000 MJ (1,000,000,000 BTUs).
10. In addition, gaseous fumes have contributed 3,281,472 MJ (3,110,400,000 BTUs) while also providing 405° K (270° F) combustion air inlet from process fume which has aided in maintaining the plant up in the 90% plus efficiency ranges.

An initial operating problem that occurred in the fume supply duct was due to the build-up of phenolic material around the dampers preventing them from closing completely. This problem was solved by the use of teflon coating on the metal surface which kept them operational.

When we first began to burn wood wastes it was found that, although in many instances the material "appeared" to be dry, they were in fact quite wet. This resulted in some quenching of the flame and was solved by short-term inside storage and drying prior to their use as a fuel.

The utilization of some solids had some humorous aspects, such as the time we burned supposedly "bone dry" corn cobs for a potential client. Inside these "bone dry" corn cobs was a significant amount of cellular moisture and, not only did we end up with a pulpy mash when it was shredded, but what did get into the furnace gave us the largest pop corn maker in the world. It required several days of work to clean the boiler passes of this pop corn, but we were able to serve free snacks to personnel for a few days -- without beer.

As previously mentioned, various mixtures of liquid wastes were burned in this facility. Most of the solvents were chlorinated hydrocarbons with chlorine content ranging between .1% and 5% by weight. Concentrations as measured in the flue gas were as low as 5 ppm to in excess of 2000 ppm. During this experimental program, damage was caused to the refractories of the boiler by the hydrochloric acid formed within the flue gas. This attack was directed to the binders that make up the refractory. The resultant salt formed would crumble away the refractory and undermine areas of the boiler plate and further serve as collective pockets of corrosion. The greatest problems seem to occur when combusting chlorinated hydrocarbons concentrations in excess of 1%. After much experimentation, the mixed feed rates were set to keep the concentrations of HCl at levels similar to sulfur such as 100 ppm.

Another problem related to the burning of this type of chlorinated material is the high amount of suspended solids which will pass through most standard filters. These particles do not burn and serve to impinge on boiler tube surfaces. Additionally, the low vapor pressure of these chlorinated solvents causes them to activate in the pump sets not to mention corrosion and erosion in the pumps. We also were faced with problems related to the evaporation of these materials when kept outdoors in the prevailing ambient temperature conditions of the summer.

Another problem related to this material was that it stratified into discreet layers in storage thus creating the need for constant agitation and multi-stage filtering so as to minimize back pressure while allowing some degree of filtration. This material could be burned in reasonable fashion if it was low in suspended solids and low in chlorine.

Some work had been done pre-mixing various material into combustible fuels. This applied research is going on currently on a formal scale where various phenol-resin wastes are mixed with appropriate solvents and burned or pre-mixed with fuel oil formed out of the solvents so as to bring them to an acceptable fuel level.

Our operating experience of almost four years has taught us that each waste stream that is proposed as a fuel source should be thoroughly analyzed for its thermal and chemical characteristics. A program should be established to blend these various waste streams into the most suitable fuel. It is possible to offset the disadvantage of one material with the advantage of another.

#### D. Research Needs

The problems associated with solid and liquid wastes derive mainly from the unknown nature of the waste stream materials and are mainly alleviated by basic materials processing which eliminates the major contradictory properties and converts the hazardous materials into acceptable products.

Classification and preparation methods only try to achieve an acceptable level of combustible properties determined by economic considerations.

Large amounts of in-situ, continuous analysis equipment is needed to measure harmful materials and monitor the processing effectiveness. The present impossibility of detecting off-spec materials on more than a statistical basis must be recognized. Constant monitoring is necessary in many instances to detect harmful ingredients or to control properties. It should be remembered that mixtures of materials can produce beneficial as well as deleterious results.

In a few real situations, some waste materials are available on a steady basis making it possible to define the material; the equipment needed to process it; the nature of combustion; effect on heat recovery equipment and emissions; the costs of equipment, power, labor, maintenance and management; and risk factors. In such cases, evaluations can be made of the economic value of the enterprise. More often the materials cannot be defined as to nature, availability, cost, transportation, etc. - well enough to build a plant committed to them.

In general, burning solid wastes requires knowledge of:

1. Preparation: diminution  
drying  
cleaning  
classification  
storage  
transportation:  
    Mechanical feeders  
    Pneumatic feeders
2. Combustion: primary air  
secondary air  
suitable burner  
suitable controls  
refractories  
relationship of particle size,  
    shape, chemistry, etc. to  
    time of combustion, rate  
    of heat release, etc.
3. Ash size: fly ash - combustible, non-combustible  
slag  
bottom ash  
distribution & chemistry
4. Emissions: collected in furnace  
deposited on furnace  
carried over to boiler

deposited in boiler tubes  
 collected by boiler tubes  
 emitted by boiler  
     collected by cyclones  
     collected by scrubbers  
     collected by ESP  
 emitted

5. Corrosion and Erosion: mechanical action  
 chemical action  
 layering  
 diffusion, absorption  
 moisture  
 soot blowing and cleaning

In general, burning liquid wastes requires knowledge of:

- Preparation of liquid wastes: collection methods  
 storage  
 transport  
 sampling  
 testing: all properties; focus on chlorides, lead, mercury, etc.  
 sedimentation  
 viscosity  
 heating value  
 volatility  
 immiscibility  
 filtering  
 dissolved metals  
 harmful materials  
 forbidden emissions  
 disposal of recovered materials  
 moisture and water  
 corrosion  
 flammability  
 safety  
 human hazards  
 water solubles in mixture  
 abrasives
- Storage problems: sediment  
 settling  
 separation  
 sludge
- Piping problems: corrosion  
 erosion  
 leakage

**Pumping  
problems**

**Burning:**

- filtering
- straining
- pressure control
- viscosity
- atomization
- scaling
- sediment
- combustion
  - air required
    - for ignition
    - for combustion
  - flame speed
  - heat release rate
  - ignition temperature
  - flame temperature
  - mixtures
    - combustion combinations:
      - other fuels
      - other burners
    - burner configurations
  - excess air:
    - required
    - excessive
  - furnace temperature:
    - minimum
    - maximum
  - incomplete combustion
  - non-combustibles
  - metal oxides:
    - condensible on surfaces
    - non-condensible
    - eutectics
  - reactions with refractories
  - abrasion
  - deposits:
    - slag
    - non-slag
  - chemical
  - oxidation and reduction

**Heat transfer  
equipment:**

- configuration and design:
  - surface and enclosures
- resistance to:
  - corrosion
  - deposits
  - erosion



thermal stress  
stress corrosion

economical design:  
efficient use of material  
minimum cost  
long life  
cleanable  
repairable  
accessible  
low cost materials

design for power production  
superheater metallurgy  
corrosion, erosion, stress  
tube metallurgy  
cleanability in service  
soot blowing

furnace volume and gas temperature

## High-Temperature Heat Recovery

### A. General System Design

Thermal oxidizers are in prevalent use by Industry to eliminate combustible gaseous, liquid, and solid wastes, while meeting pollution-control requirements.

Operation of these oxidizers, without heat recovery and utilization, is expensive. Soaring fuel costs have in many instances cut into company profit margins to the extent that production methods have had to be changed and price structures of end products altered.

A high-temperature heat recovery installation in this category with heat recovery is located in Duren, Germany. A novel feature of this installation is the use of a rotary heat exchanger or "heat wheel" (Figure 4). The segmented wheel supports a matrix of closely packaged metal plates. As the wheel revolves, thermal-oxidizer exhaust gases flow through one portion, heating the thin metal plates, while fumes to be oxidized pass through the other portion, picking up heat from the previously heated plates. The heat wheel is less expensive and more efficient than tubular exchangers. By varying its speed, fume pre-heat temperatures can, within limits, be maintained at pre-determined value.

CEA's proprietary Double-Vortex™ combustor (Figure 5), which burns gaseous, liquid and solid material singly or in combination, enables the three forms of waste to be burned in a single unit. The D-V combustor is

in the general form of two cones joined end-to-end at the major diameters. Hot combustion gases spiral around the periphery of one cone toward the apex. They reverse direction at the apex and travel up through the center of the combustor and exit through the truncated end of the second cone.

Combustion air and fumes are ducted to a plenum surrounding the combustor and enter through louvers in one of the cones. Combustible material is consumed as the gases spiral through the burner. Gases discharged into an oxidizer chamber where they are retained for one second to assure complete consumption of all combustibles in the gas stream.

## B. Operating Experience

The most difficult problem encountered when preheating gaseous fumes to high temperatures is to precisely know the grain loading of the incoming fume. Since this unit preheats the combustion air to over 922°K (1200°F), the fume is close to its auto-ignition temperature and a fire can occur. In order to assure the design grain loading values, the minimum requirement is to perform a material balance of the material being processed through the treaters.

These material balances should be conducted over a wide range of production loadings to make sure that the system can handle the high-loading end of the process.

The high-temperature heat wheel is a relatively new device, since most heat wheels were designed to operate below 533°K (500°F). The major problem encountered with the heat wheel was the seals between the compartments. A number of modifications have been made to the seals and they now are able to withstand the high temperatures. If the seals begin to fail, then unheated exhaust gases will by-pass the thermal oxidizer and escape to the atmosphere. The resultant odor will not meet air pollution regulations.

## C. Research Needs

1. An in-situ, continuous monitor to measure the incoming exhaust gas grain loading in order to make system air circulation adjustments to prevent auto-ignition.
2. Improved seal techniques for high-temperature heat wheels.

Conclusions

1. The utilization of waste streams as an alternate fuel source is commercially successful.
2. Factual knowledge on the problems associated with combusting solid and liquid waste streams in heat-transfer systems is lacking.
3. The material-handling, storage, and mixing systems must be tailored to handle a wide range of materials.
4. The major problem encountered in heat transfer systems is due to corrosion and must be properly considered in design.
5. When the chemical characteristics of liquid waste streams are known, a composite fuel can be prepared which takes advantage of the disadvantages of one versus the advantages of another.
6. A complete and rigorous preventive-maintenance schedule must be followed when burning solid or liquid waste streams.
7. Ideally, the waste-stream input should be constantly monitored to achieve environmentally-safe combustion.
8. In most cases, tail-end pollution control systems are not required to meet emission regulations.
9. Significant research needs exist if additional waste streams are to be used as alternate fuel sources.

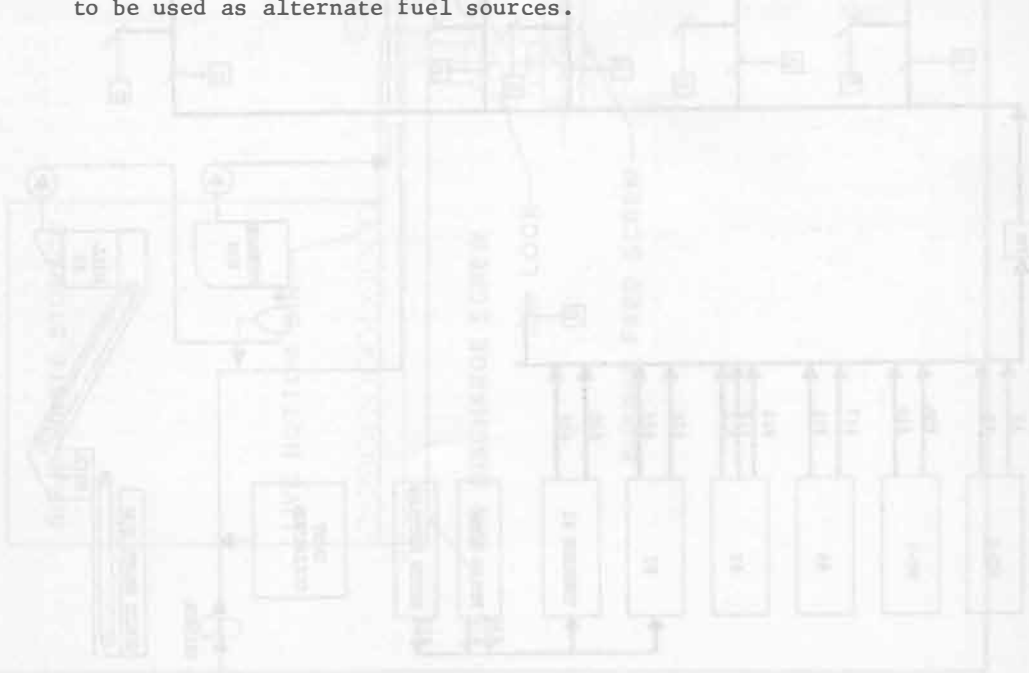
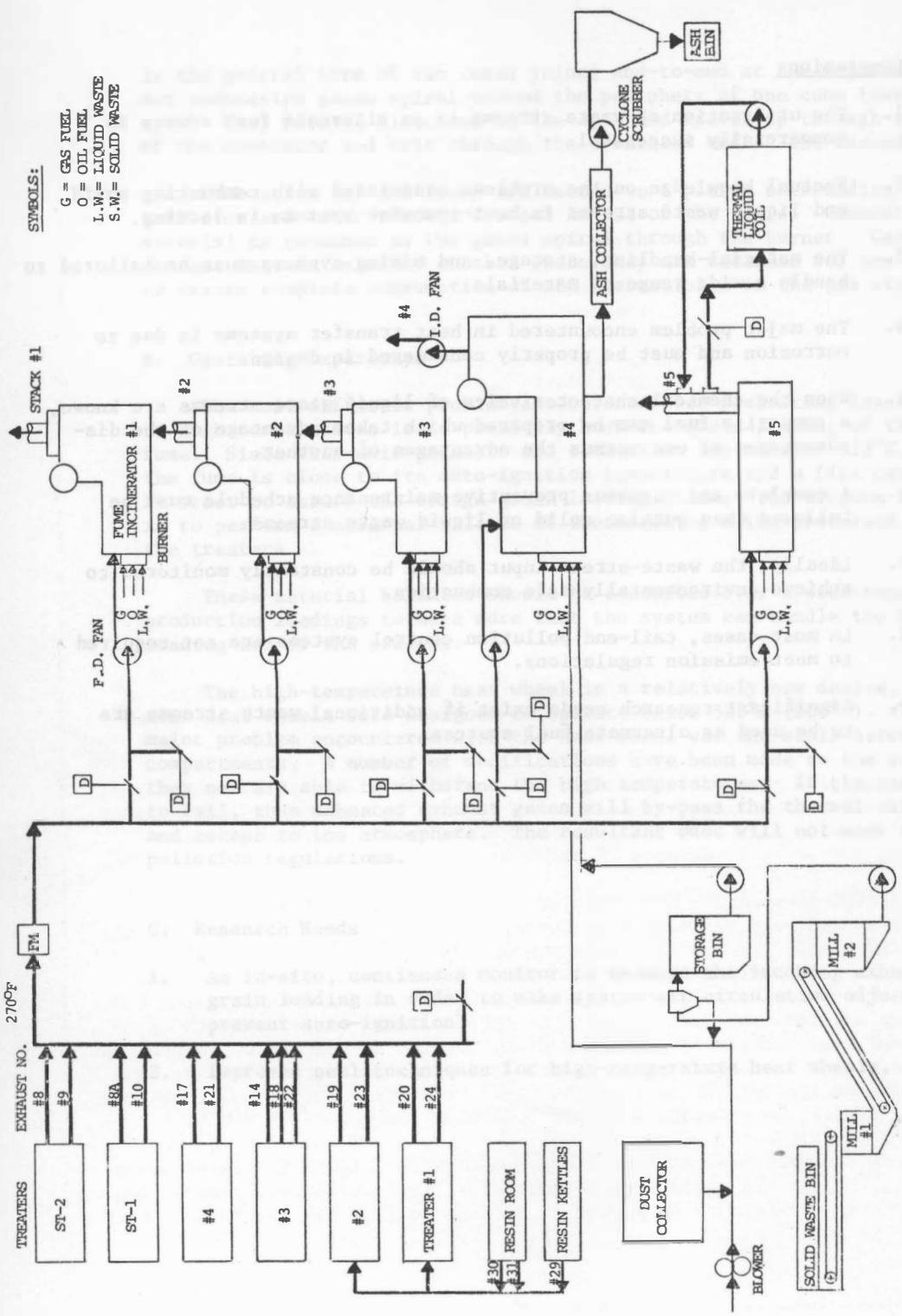


FIGURE 2



FIGURE

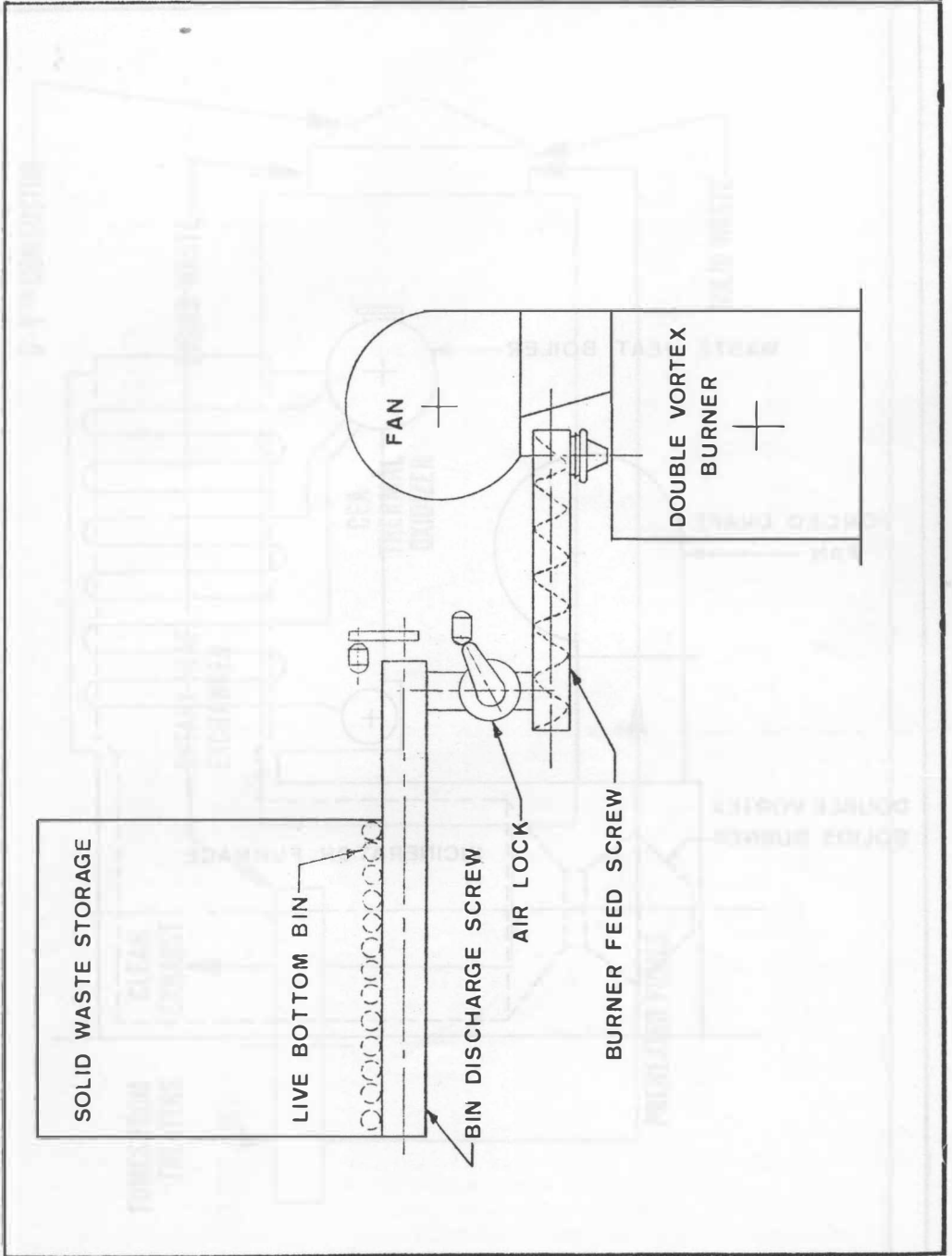


FIGURE 2

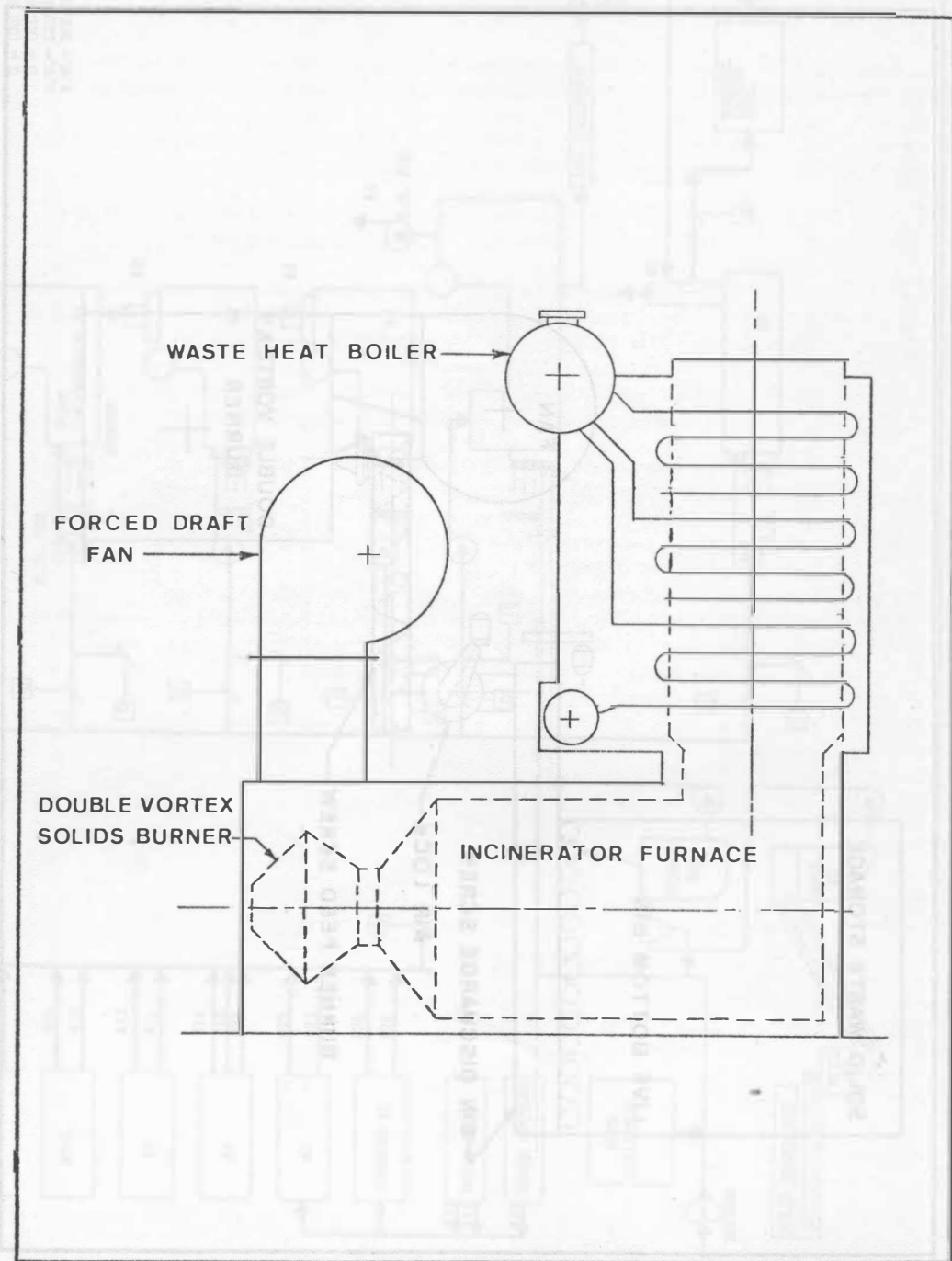


FIGURE 3

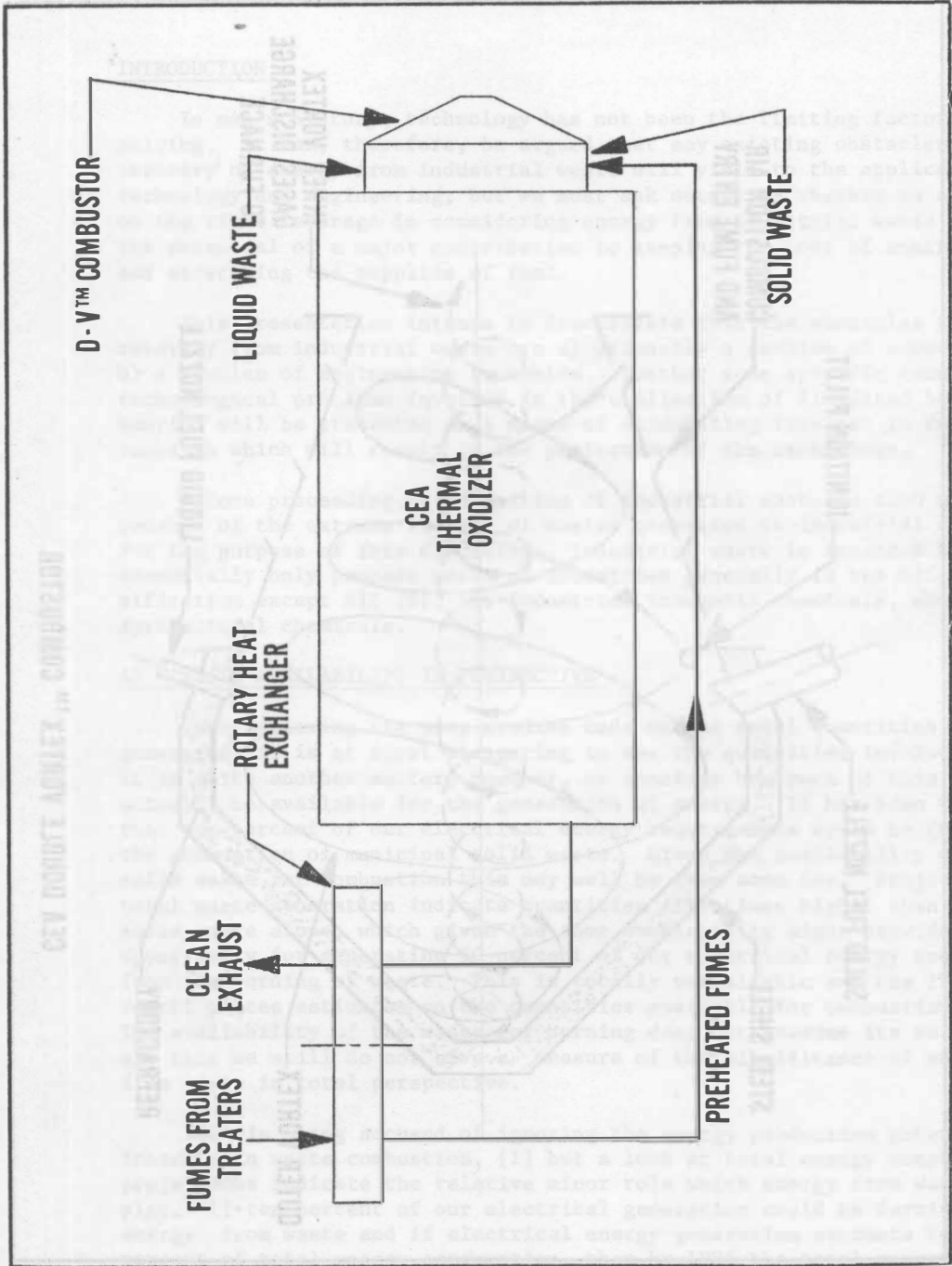
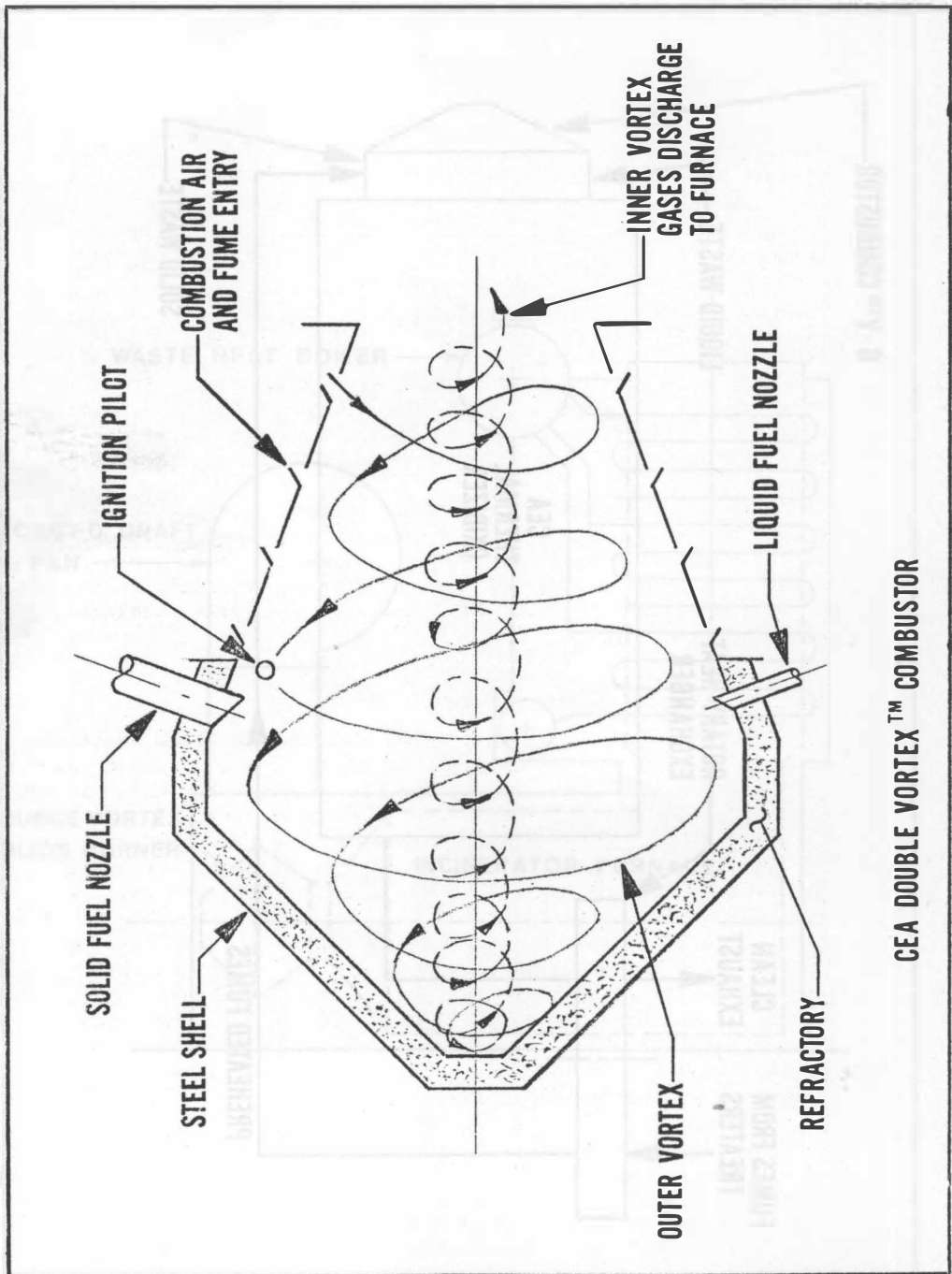


FIGURE 2

FIGURE 4



CEA DOUBLE VORTEX™ COMBUSTOR