THE ARGONNE INCINERATOR PROGRAM

by

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The problem of incineration at various AEC sites has been under fire for some time. At most sites operational difficulties have prevented the successful operation of production models of incinerators.

Knolls Atomic Power Laboratory constructed a pilot-plant-sized unit and have done considerable experimental work with it. The original design incorporated a system of "dead ending" the combustion gases; that is, running the gases resulting from combustion through a series of absorption chemicals which would remove the products of combustion. This flowsheet would provide the ideal system in that there would be no gases discharged to the atmosphere and therefore no possible radioactive contamination of the surrounding area. Due to the variations in feed material composition, the combustion rate and consequently the off gas volume fluctuated to such an extent that it was impossible to control the process for "dead ending" the gases. This system was abandoned in favor of a system which used conventional wet scrubbing equipment to remove the radioactive particles from the exhaust gas streams. As in the original flowsheet the combustion was supported by oxygen rather than air. Here again the variety in feed material resulted in excessive "puffing" due to accelerated periods of burning. This problem was partially solved by installing an expansion chamber in the gas train between the combustion chamber and the gas scrubbing equipment and by using a mixture of air and oxygen to support the combustion.

Los Alamos, after many design changes, constructed a production sized incinerator. The main problem encountered with their unit was that it would not continually support combustion. After major modifications in the location of the combustion air entry ports and in the method of introducing the combustion air into the combustion chamber, the unit now appears ready to be tested.

The Argonne incinerator has been burning active wastes on a production basis since July 1951. The most serious problem that has been encountered to date has been in buckling that has occurred in the lower walls of the incinerator body. This was apparently caused by local over heating. The insulation has been removed from this part of the incinerator body and was replaced by an air jacket. It is felt that by reducing the temperature of the wall the buckling will stop, however, measurements are being taken to ascertain this fact.

The criteria for the economic feasibility of the incineration process is the cost of storage of active wastes. If some method of storing wastes is available which costs less than $2.00 per cubic foot, it is cheaper to store the waste than to process it. If the cost of storage is higher, then it is cheaper to reduce the volume of the waste, by incineration or some other process, before storing it.

The nature of work at Argonne dictates the necessity for rigid control of all active wastes. The solid active wastes are segregated into two major subdivisions, combustible and non combustible. All active combustible wastes, with the exception of very active wastes are processed through the incinerator. The cost of collecting, handling, guarding, and transferring the wastes is high. By incinerating the wastes and thereby reducing the volume, a considerable saving is effected.

A great variety of solid materials become contaminated. Included in recent collections were: filters, paper (absorbent, note, news, filter), wood (benches, flooring, tables, desks, chairs), gloves (rubber, canvas), clothing, shoes, laboratory glassware, ring-stands, pipe, fittings, processing equipment of all sizes and shapes, and dead animals (up to goats).

In all areas where activity is present, 7-1/2 gallon cans made of stainless steel and fitting with a foot-operated slide top are provided. Inside each of these dry active waste cans is a cardboard liner.

Two such cans, one for combustible, the other for noncombustible waste, are provided at each location. Any dry active waste may be deposited in these cans if it is small enough and if its activity does not exceed 50 mr/hr. Special containers are provided when requested for bulky or highly active wastes.

A portable stainless steel collection dolly is used to transport the liners when the containers are emptied. Besides scheduled pick-ups, collections are made when requested. Combustible solid waste goes to the effluent control area for incineration. Noncombustible waste is taken directly to the solids storage area.

A storage area is provided for retention of solid, noncombustible radioactive waste. It consists of concrete-lined trenches with removable wooden covers and is regularly monitored to see that active liquids are not building up. The solid wastes are kept in black iron boxes 4 x 5 x 6 ft. in the trenches. These bins are of such a size that eventually they may be covered, loaded on railroad cars, and shipped to a national graveyard if one is eventually set up.

The storage space is expensive. It costs about $7.00 a cubic foot. The collection process costs another $5.00 per cubic foot, making the total cost of solid storage almost $12.00 a cubic foot. This high cost of storage is the reason combustible wastes are segregated. Nearly 80% by volume of the solid wastes are combustible. They are incinerated in the unit shown in Figure 1 and 2. This unit, designed by A. D. Little, Co., Cambridge, Mass., has a burning chamber capable of handling 100 ft.^{3} in an 8-hour day.

The charge is introduced through a chute equipped with interlocked doors to prevent the escape of radioactive gases. The charge builds up on the grates of the furnace and is ignited with gas jets. Combustion air is supplied above and below the grates through tuyeres.

During most of the burning period the combustion is self supporting. The gas jets are again used for final ashing. The ash falls through the grates into water and settles down the collection cone through an 8-inch plug valve into a collection drum fitted with an expendable cloth bag filter (Canton canvas). When the drum is full of ash, the valve is closed, a new container is inserted, and the filter bag is used to dewater the ash to sufficient dryness to allow storage in freezing weather.

Combustion gases must, of course, be freed of their radioactivity before discharge. On leaving the furnace, the gases pass first through a Schreier-Bartolucci vane plate washer where the larger pieces of fly ash are scrubbed out with a water stream that also cools the gases. Water for this scrubbing operation is pumped from the bottom of the ash collection drum to the top of the Schreier-Bartolucci tower and returned from the bottom of the tower to the bottom portion of the incinerator body.

The gases are then passed to a Pease-Anthony Venturi. In this apparatus, the high-velocity gas stream is used to disintegrate a water stream admitted at the throat of the Venturi. The resulting intimate mixture of air and water is admitted tangentially to the bottom of a Peabody scrubber. In this disengaging section, the gas and the droplets of water that now contain a large fraction of the smaller dust particles are separated. The gas flows upward through the Peabody tower, passing through fine holes in the scrubbing plates. There the gas is brought into further intimate contact with water or a suitable alkaline scrubbing solution. In the upper portion of the tower, the gas and water are separated by a mechanical baffle system, and the gases then flow to an electric heater located above the scrubbing tower. Sufficient heat is added in this reheater to vaporize any fine mist particles which are still present in the gas and to raise the gas temperature several degrees above the dew point, thus preventing condensation in the remainder of the system.

Both liquid systems must periodically be drained and recharged. The liquid collected is put into the regular effluent-control-building liquid system.

The preceding treatment may be enough in most cases of operation to reduce the radioactivity to a permissible level. However, as a final safeguard, the gases are passed through a filter of the AEC type. Such a filter is capable of removing radioactive particles to well within tolerance levels under operating conditions. When replacement is necessary, the loaded filter is burned in the furnace. From the filter, the gases are drawn through a positive displacement blower and discharged above the roof.

The incinerator is now on routine operation and is processing the daily accumulation of contaminated combustible wastes. It has been demonstrated capable of a beta decontamination factor of 8×10^7, and this is not the limit. The data from a series of controlled runs made with known quantities of mixed fission product activity are shown in Table 1. The exhaust gas of the unit has always been well below the design specification for the beta air contamination of 2.1×10^5 dpm/m^3 and, indeed, has even been lower than the influent combustion air.

This unit is producing about 6 ft.^{3} of ash per 100 ft.^{3} of charge. Even though the installed cost (including engineering) is about $120,000, an operating saving of about $400 per 100 ft.^{3} processed is expected, and the unit should pay for itself in a little over a year.

TABLE 1

DECONTAMINATION ACHIEVED IN INCINERATOR

	Activity of air in*		Activity of Feed	Activity of Exhaust Air		Beta Decontamination Factor**
Run	(dpm/m^3)	(Total dpm)	(Total dpm)	(dpm/m^3)	(Total dpm)	
1	195	4×10^5	1×10^7	14	2.8×10^4	3.6×10^2
2	116	2.3×10^5	9×10^7	2	4×10^3	2.2×10^4
3	185	3.7×10^5	3.7×10^9	2.5	5×10^5	7.4×10^5
4	166	4.2×10^5	1.6×10^{11}	4	2×10^4	8×10^7

Operating Conditions:

Length of run: 4 hours (2-1/2 hours burning time)
Air flow: 500 m^3/hr.

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*Naturally occurring radioactivity in air due to radon-thoron daughters.
**Decontamination factor is total activity of air in feed divided by the total activity of the exhaust air.

Since the ANL incinerator was one of the first units to be constructed, it was somewhat overdesigned. A rather extensive experimental program has been planned to investigate the operating characteristics, and efficiencies of the various pieces of equipment that comprise the unit. The aim of this program is to obtain the maximum efficiency for each type of gas cleaner and for the incinerator itself. Since this is a prototype unit, in essence, for any future incinerators, we are striving to reduce the number of pieces of gas cleaning equipment and thereby reduce both the initial cost and the operational cost of the incinerator.

The major portion of the investigation to date has centered around the Pease-Anthony Venturi-Peabody Scrubber couple. The effect of the scrub water to gas ratio in the Pease-Anthony Venturi can be seen in Figure 3. The water rate was varied between 0 and 13.0 gallons per minute and the gas flow from the incinerator was varied between 285 and 425 standard cubic feet per minute. This resulted in a water gas ratio varying between zero and 45.6 gpm/1000 SCFM. The left side of the curve, the area between 0 and 15 gpm/1000 SCFM shows the result of increased efficiency due to the increased water to gas ratio, and reaches a maximum at about 15 gpm/1000 SCFM. At the higher water to gas ratio it is thought that the water "jets" across the throat of the venturi, rather than forming a spray, which results in a lower efficiency due to the less intimate contact between the scrub water and the flowing gas stream. Visual observations have shown that at a lower water to gas ratio the scrub water sprays into the throat of the Venturi and forms a wall of water through which the gas must pass. The zero point (46% efficiency) is the amount of clean up contributed by the Peabody scrubber since there was no scrub water used in the Venturi during these runs. During all of these runs the efficiency of gas cleaning was measured around the Venturi-Peabody couple and the scrub water rate to the Peabody scrubber was held at 5.5 gallons per minute.

Efficiency appears to be inversely proportional to scrub water temperature in the Venturi over the range investigated (90°F to 125°F) as evidenced in Figure 4. All other variables, except feed composition were held constant during these investigations. A more extensive investigation of the variable of water temperature is in the process of being carried out, particularly in the lower temperature (60°-90°F) range since this range appears to hold forth the promise of more efficient operation.

The Peabody Scrubber was modified so that the scrub water could be introduced on ary of the four plates rather than just on the top plate. The results of varing the number of wet plates are shown in Figure 5. As can be seen efficiency is directly proportional to the number of wet plates in the range of zero to three wet plates. It appears that since the same result (93% efficiency) is obtained with both three and four wet plates that the fourth plate is unnecessary.

Water rate to the Peabody seems to have very little effect of the efficiency of the tower as long as the plates were kept wet. Seventy-two per cent efficiency was obtained at 2.5 and 7.0 g/m and 70% at 5.5 g/m. In this experiment the efficiency of the Venturi was purposely kept low so as to accentuate any changes that may have occurred in the Peabody.

The water temperature also appears to have very little effect on the efficiency of the Peabody scrubber. Sixty-eight per cent was obtained at 145°F and 70% was obtained at 100°F.

The effect of primary and secondary air on the particulate concentration of the incinerator exhaust gas can be seen in Table 2. This experiment was done in the nature of a scouting experiment and more extensive investigation will be carried out in the future. The secondary air enters above the grates in a tangential manner and imparts a swirling motion to the gases. This results in a more complete combustion and as such seems to reduce the particulate loading in the exhaust gas stream.

TABLE 2

Scrub Water Flow Rate		
gal/min		
Schreier-Bartolucci	9.0	9.0
Pease-Anthony Venturi	5.0	9.3
Peabody Scrubber	5.5	5.5
Combustion Air Flow, S.C.F.M.		
Primary	0	155
Secondary	155	0
Feed Material	Wood	Wood
Particulate Concentration mg/cu.ft.	0.6	1.7

Note: Samples were taken directly after the Schreier-Bartolucci scrub tower.

Sampling of the gas stream to determine the efficiency of each piece of equipment is carried out in two ways. The first method is based on the total amount of activity entering and leaving each unit. The second method is based on the total amount of particulate (based on weight) entering and leaving a unit. Experimental results have shown that these two methods produce nearly equal results.

The gas stream is monitored after it has passed through the final unit of the cleaning train (AEC filter). This monitoring, based on particulate activity insures safe operation of the incinerator with respect to the total amount of radioactivity discharged to the atmosphere.

Sampling of particulate borne in a fluid stream can be accomplished by two means. These methods are isokinetic sampling and instantaneous sampling. Since the particulate loading of the gas in the ducts varies considerably over short periods of time, the results of instantaneous sampling would not be reliable and, therefore, the isokinetic sampling method was employed.

In order to reduce turbulence and to obtain a true representation of the stream being sampled, it is necessary to have a long straight section (10 pipe diameters minimum) prior to the sample point or to use straightening vanes or some other device so as to produce uniform velocity at the sample point. A device known as a Stairmand disc will produce a uniform velocity and a uniform cross section particulate loading. While this device produces high flow resistance in the duct, it is a convenient means of producing a representative gas flow and was used prior to all sample points. These points are two-inch pipe couplings welded into the gas duct through which the sample probe or head is inserted.

Three types of sampling equipment are used, all employing the principal of filtering the gas stream to remove the particulate.

The monitoring sampling device used to determine the amount of radioactivity being discharged to the atmosphere is a modified Filter Queen vacuum cleaner which draws the gas through a filter paper. For efficiency determinations, the gases which are below 220°F are sampled by means of a conical sample head which contains a Whatman #44 paper. This device is placed inside the gas duct facing downstream. When the gas stream is being sampled the head is faced upstream and by means of vacuum the sample is drawn through the filter paper in the sample head. The sample flow rate is measured by a gas rotameter and then the volume calculated from the length of time that the sample was being pulled.

In cases where the gas temperatures are too high to allow use of filter paper a special fiber glass filter is used. This material has an average pore size of 0.6 microns. The only sample point at which this paper is necessary is prior to the Schreier-Bartolucci scrubber. Here, in addition to high temperatures, a heavy particulate loading is encountered. A sample head large enough not to plug up in the time necessary to obtain a sample would be too large to fit in the gas duct, hence a third type of sampler is needed.

In this sampler the gas containing the particulate is removed from the duct and then passed through the filter media. In order to be on a comparable basis, both influent and effluent gas samples to this scrubber are taken in this sample head.

After the sample has been taken, the filter medium is removed and the radioactive count is determined. For weight determinations, the sample medium is dried and weighed prior to and following the sampling. Both weight efficiencies and activity efficiencies can be determined on each sample. Efficiencies are based on the influent and effluent concentrations of the particulate in the gas at each unit of the scrubbing train.

It is felt that the incinerator program has been on the whole quite successful. The incinerator has operated safely and economically in reducing the volume of dry active combustible wastes produced at the Laboratory. As previously stated this is an experimental model and efforts are being made to simplify the flowsheet.

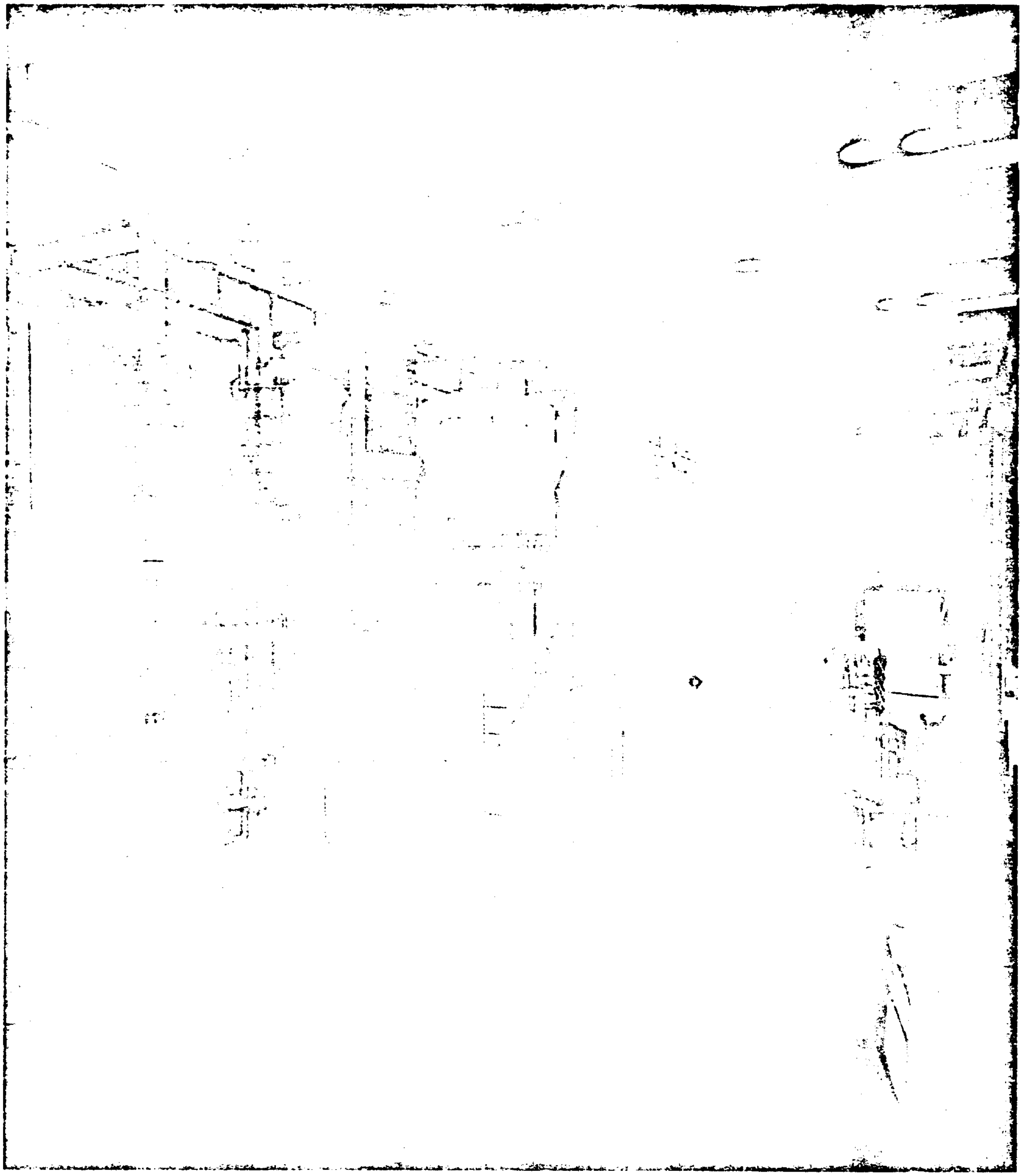

Fig. 1—Contaminated combustible waste incinerator.

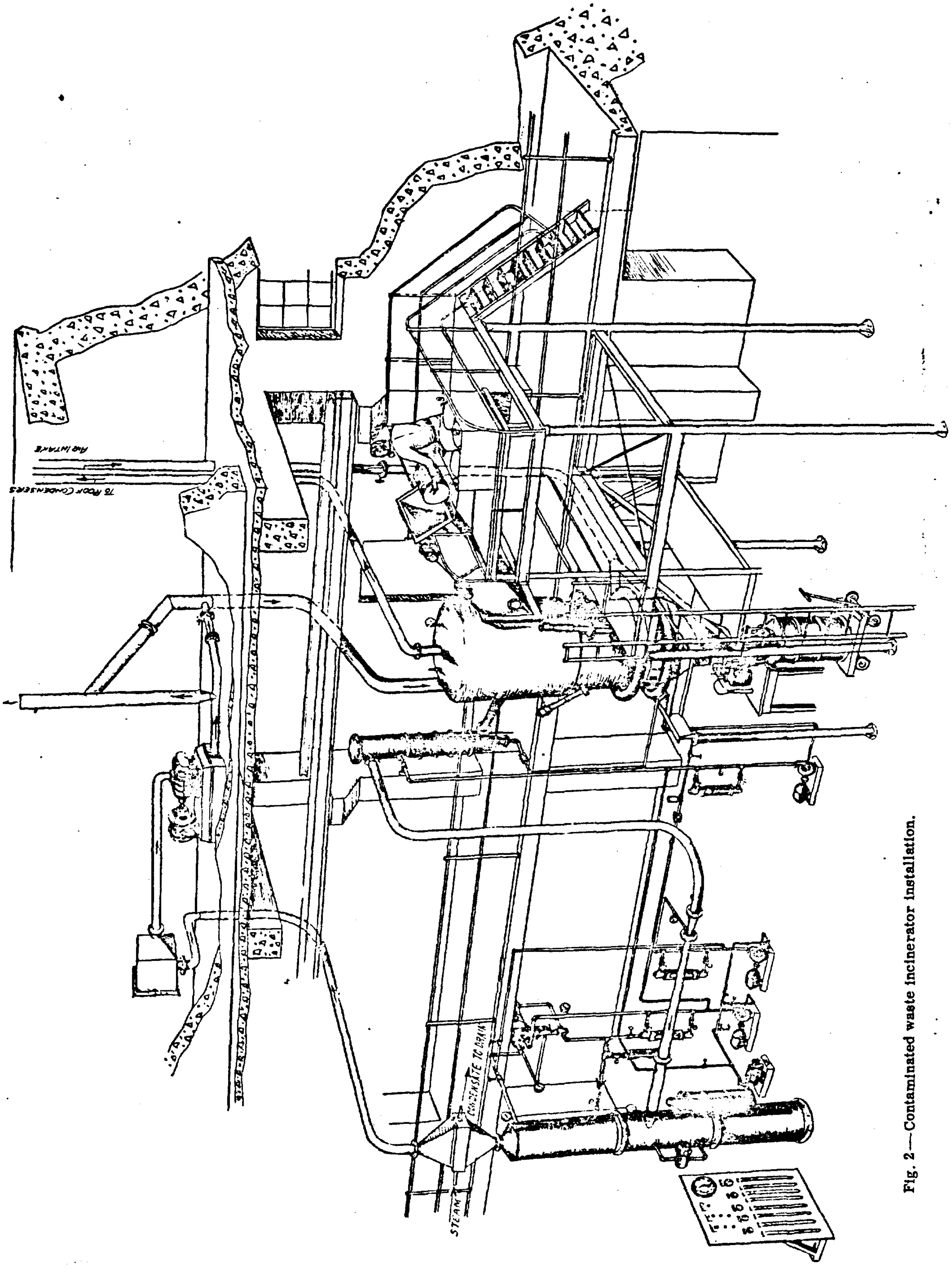

Fig. 2—Contaminated waste incinerator installation.

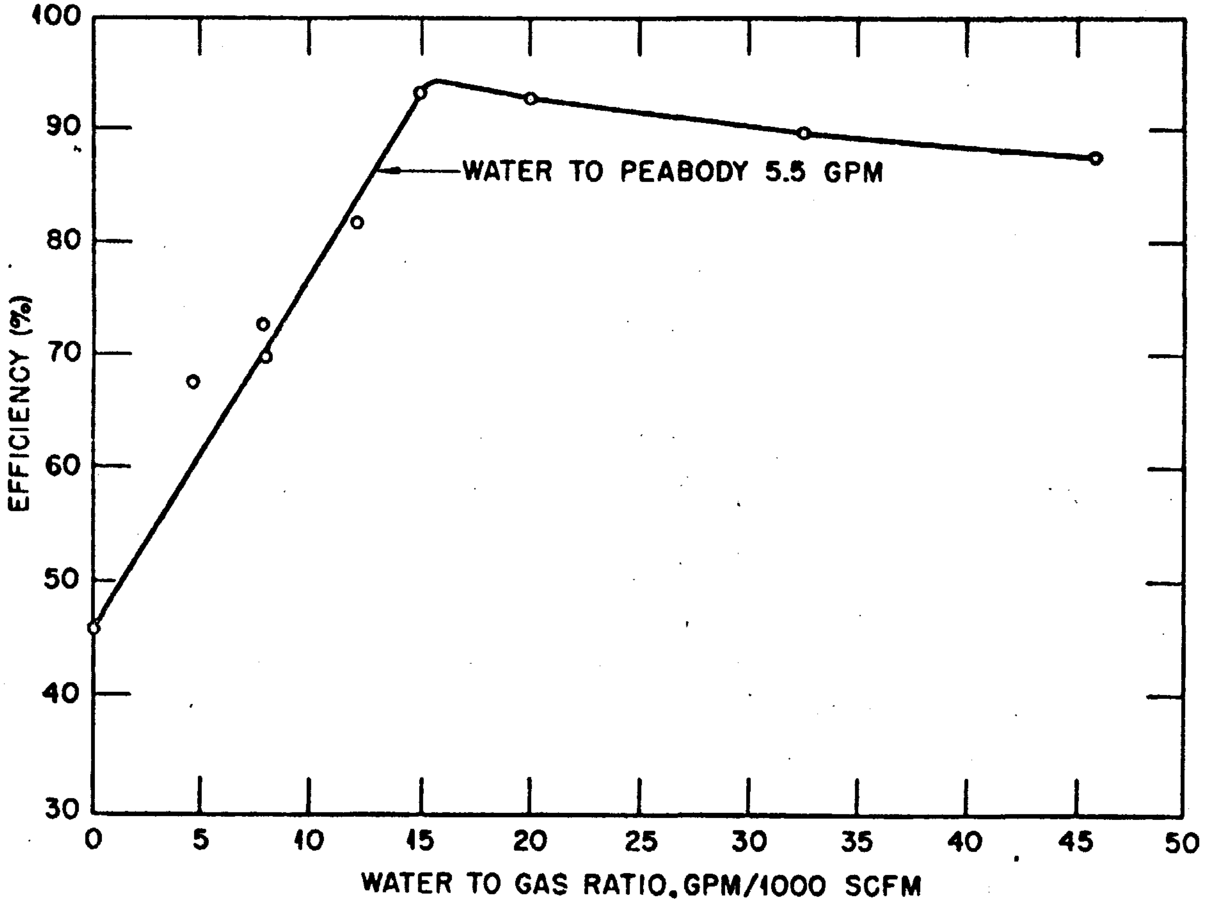

Fig. 3—The effect of the water to gas ratio (venturi) vs. efficiency in the Pease Anthony-Peabody couple.

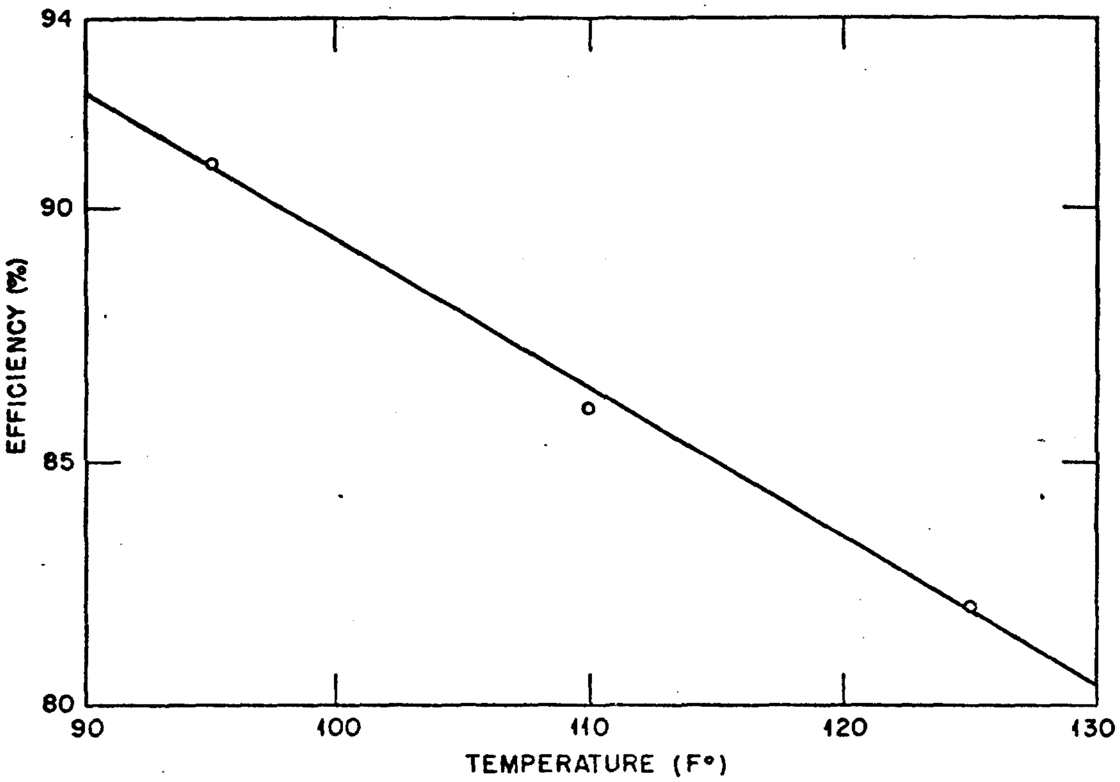

Fig. 4—The effect of scrub water temperature in the venturi on efficiency.

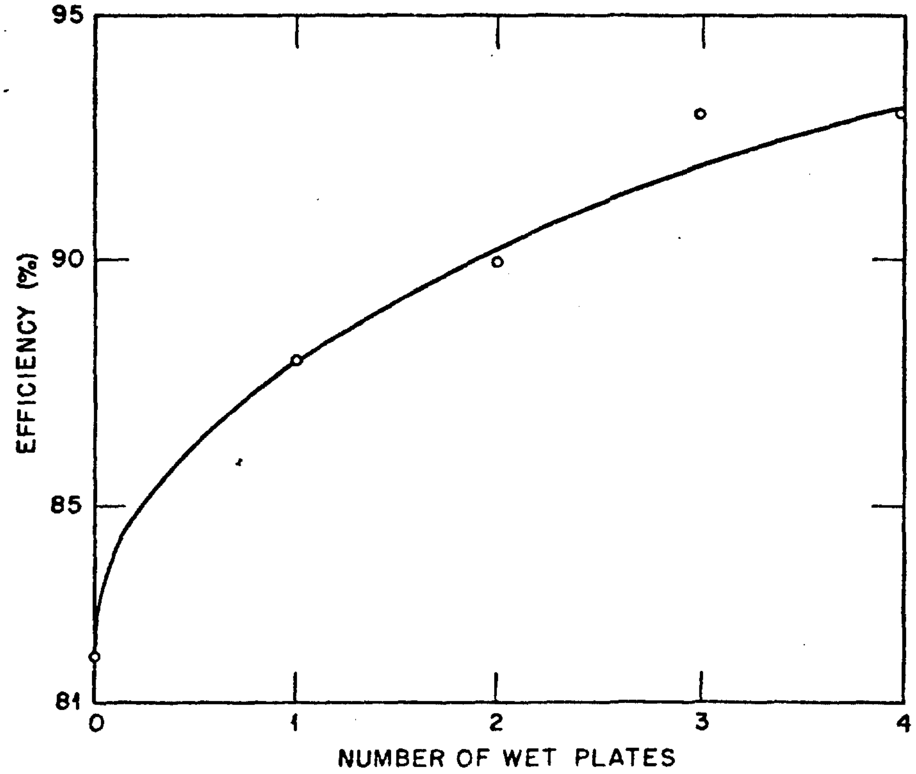

Fig. 5—Effect of number of wet plates in the Peabody on efficiency.