Feasibility of Incineration of Biological Laboratory Wastes

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INTRODUCTION

The sterile disposal of biological laboratory wastes, particularly those in an aqueous solution, has always been of concern to hospitals, research laboratories and public health agencies. The dangers of spread of infection from these materials are compounded when means for (on-site) disposal is not provided. This fact becomes more obvious when we consider the complications arising when disposal of infectious materials is attempted by public or private waste handling and disposal agencies. Some of the possible problems associated with current remote disposal practices are: 1) storage 2) handling 3) transport 4) processing if required 5) exposure by the uninformed and 6) suitability of disposal facilities. In view of these difficulties, on-site disposal, in general, appears to be the most logical solution from the standpoint of total process control.

The only aspect of this disposal problem which will be covered in this discussion will be the investigation of the technical feasibility of incinerating an aqueous slurry of biological laboratory egg wastes contaminated by pathogenic organisms. Due to the infectious nature of the wastes, the incineration system must insure the complete destruction and sterilization of all organisms. It was established that the combustion gases must have been at elevated temperatures for a period of at least three seconds prior to discharge.

The complex problems in safely handling materials of this nature can easily be imagined but will only be mentioned in this discussion.

EGG WASTE CHARACTERISTICS AND QUANTITY

The following table is a summary of the approximate characteristics of the three waste streams to be effectively processed.

Although the investigation was based on the following projected flow rates of waste materials, an ultimate system would be required to be capable of processing approximately five times the normal flow rates indicated or 400 gallons per hour. Translated into egg quantities, depending on their size and weight, this would be equivalent to 32,700 eggs per hour which for this Laboratory would be 34,000,000 eggs per year – a very large quantity indeed!

LABORATORY WASTE PRODUCTION

Depending upon the studies and/or production underway at the biological laboratory, either the embryo or the albumen was used. Therefore, the usual waste streams are those indicated as Waste No. 2 and Waste No. 3. Waste No. 1 (whole egg: embryo, albumen, shell) would only occur under abnormal conditions. However, Waste No. 1 and Waste No. 2 have similar characteristics from the standpoint of this

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TABLE 1. APPROXIMATE CHARACTERISTICS OF CONTAMINATED EGG WASTE STREAMS

	WASTE NO. 1 (whole egg)	WASTE NO. 2 (shell and albumen)	WASTE NO. 3 (shell and water)
DENSITY, lbs/gal	9	9	11.5
ASH CONTENT, percent	5	5	20-40
WATER CONTENT, percent	75	75	49-79
COMBUSTIBLES, percent	20	20	1.0
AVG. PARTICLE SIZE, inches	3/32	3/32	3/32
CONTAMINATION	. . . .	. Lethal	

10 to 14 day-old embryonated chicken eggs weighing approximately 25 oz. per dozen

investigation and therefore whole eggs were used for the pilot test work.

The normal operating procedure at the biological laboratory involved in this study would produce one of the wastes for a period of several weeks or months and then a different waste for a similar time period. During these periods, the flow rate would vary from day to day.

TABLE 2. APPROXIMATE AQUEOUS WASTE MATERIAL FLOW RATES

	Minimum	Normal
WASTE NO. 1, gph (whole egg)	6	75
WASTE NO. 2, gph (albumen and shell)	6	60
WASTE NO. 3, cfh (shells only, no water)	0.1	1.0
WASTE NO. 3 Flush water 30 to 180 gph		

INVESTIGATION PROGRAM

It was agreed that the pilot scale investigations and tests should be based on providing a design flow rate capability of 80 gph of Waste No. 1 or Waste No. 2; a flow rate of 15 gph of shells with a maximum of 1 gpm (60 gph) of flush water resulting in a 75 gph shell/water slurry.

Three different types of combustion systems were investigated; atomized thin burning, fluidized bed burning, and mass burning on a rotating hearth. Manufacturers of each system with pilot testing facilities were selected for the combustion trials.

Table 3 indicates the basic analyses made of the purchased 10 to 14 day embryonated eggs to be used for these pilot combustion tests.

PILOT TEST – ATOMIZATION BURNING

The test was performed on a Thermal Research and Engineering Corporation pilot unit. The system basically involves pumping the aqueous waste through a nozzle into the path of a tangentially fired burner in a refractory envelope. The schematic system is illustrated in Figure 1.

TABLE 3. BASIC CHARACTERISTICS OF EGGS ACTUALLY USED DURING INVESTIGATION

	WASTE NO. 1 (whole egg)	WASTE NO. 2 (shell and albumen)	WASTE NO. 3 (shell and water)
SPECIFIC GRAVITY	1.28	1.39	1.38
ASH CONTENT, percent	5.29	7.56	–
WATER CONTENT, percent	68.2	67.5	58.0
Btu/lb (wet basis)	2,938	2,921	0

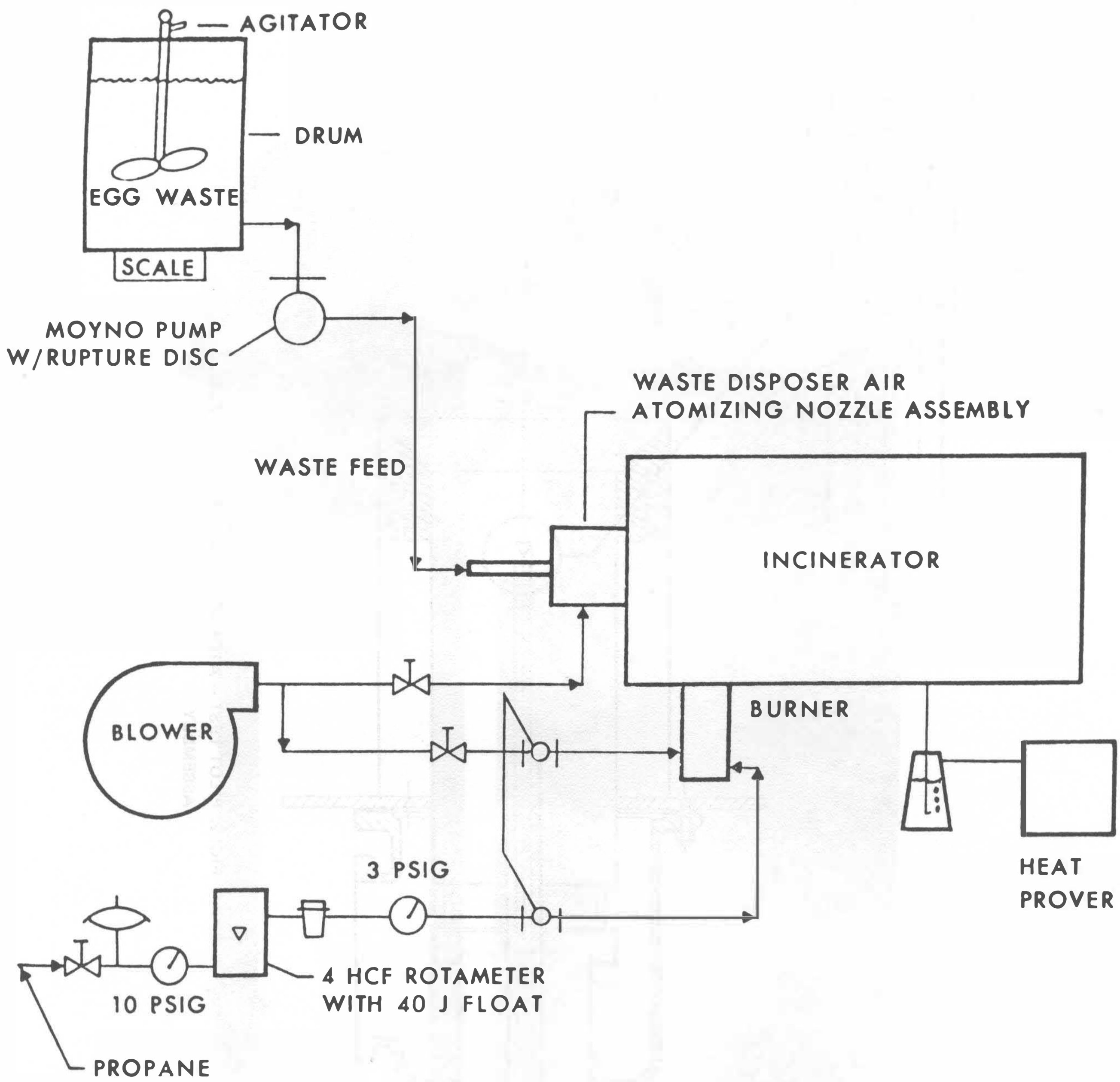

FIG. 1. SCHEMATIC ATOMIZING BURNING SYSTEM

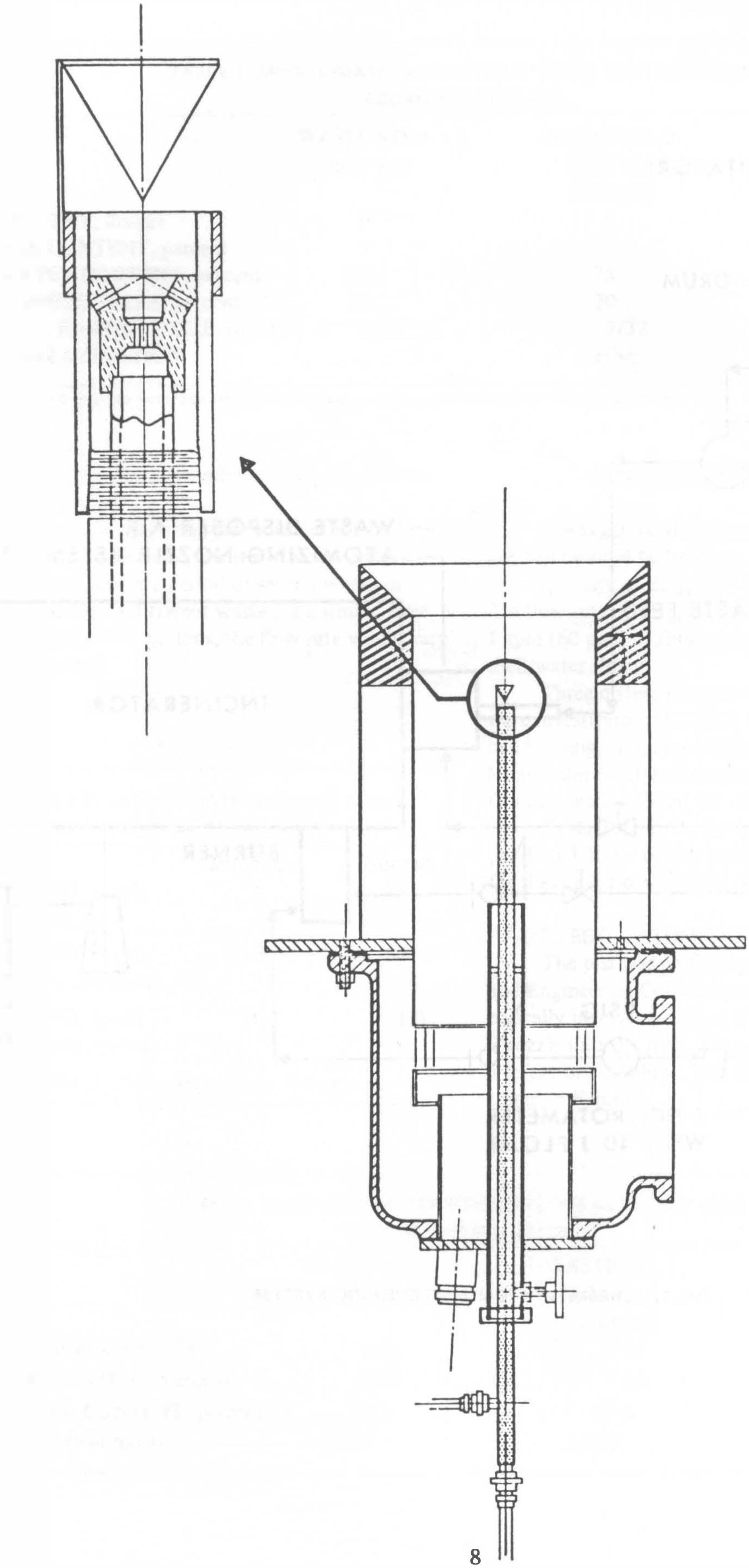

FIG. 2. PILOT TEST – ATOMIZATION BURNER NOZZLE ASSEMBLY

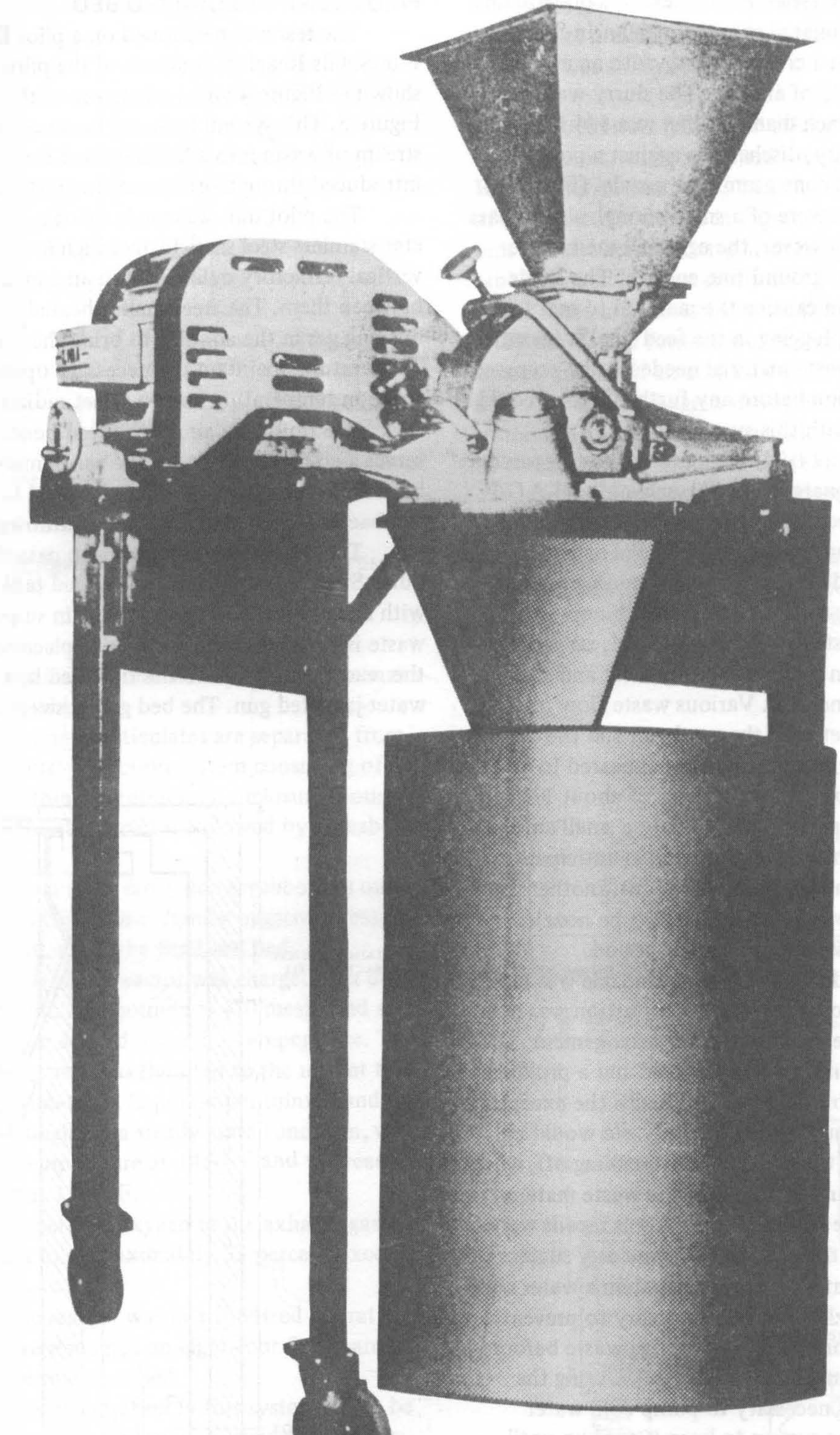

FIG. 3.

The waste material for this test was prepared by passing the embryonated eggs through an In-Sink-Erator, resulting in a crushed slurry with an average particle size of 3/32 of an inch. The slurry was pumped through a 3/8 inch diameter line to a 1/4 inch spud gun at the extremity, discharging against a position adjustable inverted cone atomizing nozzle, (Figure 2).

The particles were of a small enough size to pass through the line; however, the egg shell membrane apparently was not ground fine enough. The shells adhered to this film causing the material to mat together, creating a plugging in the feed line. It became obvious that the waste material needed to be prepared in a different fashion before any further testing could be accomplished with this system.

For the second trial, the material was prepared by passing embryonated eggs through a Model A G-F Pulva-Sizer equipped with stirrup type hammers operating at a rotor speed of 6,000 RPM and utilizing a 0.032 inch round perforated mill retaining screen. Figure 3 illustrates this pulverizing machine.

With the waste more finely ground, no problem was encountered in pumping the material and spraying it into the incinerator. Various waste flow rates as well as distances between the spud gun and the cone were tried. The optimum condition appeared to be a flow rate of 400 lb/hrs. with a space of about 1/4 inch between the gun and cone. Since only a small amount of waste material had been prepared, in anticipation of again running into plugging problems, another trial was scheduled to evaluate a different type nozzle, as well as to run a test for a prolonged period.

For the third trial a sonic type nozzle was installed, but regardless of adjustment combustion was not as good as with the previous burner arrangement. Therefore, the previous nozzle was replaced and a prolonged test was run. The burning was good with the exception that every few minutes some of the waste would collect on the face of the cone, finally breaking off, which resulted in an unburned chunk of the waste material to escape complete combustion. Various means were tried to overcome this problem without any success.

It was evident that with this system a water cooling atomizing nozzle would be necessary to prevent early coagulation or cooking of the egg waste before it is actually discharged into the flame. During the pilot studies it was necessary to pump cold water through the feeding system to keep it cool up until the time of actually starting to feed the waste material. There would also need to be some development work for cooling the cone at the end of the nozzle since this is where the unburned material built up until it finally broke away in chunks.

PILOT TEST – FLUIDIZED BED

The test was performed on a pilot Dorr-Oliver FluoSolids Reactor. A sketch of the pilot unit is shown in Figure 4 and a schematic of the system in Figure 5. This system basically involves forcing the stream of waste into a hot sand bed fluidized by air introduced through orifices at the bottom.

The pilot unit was made up of a 12 inch diameter stainless steel shell 11 feet high located inside a vertical refractory cylinder with an annular space between them. The steel shell is heated externally by burning gas in the annulus to bring the fluid bed up to temperature, maintain the necessary operating – reaction temperature and to offset radiation losses.

The fluidizing air, introduced beneath, also serves a combustion air for the waste material to be burned. The air tuyeres are so designed to prevent run-back of the bed material on shutdown.

The test eggs which had been passed through a Pulva-Sizer unit were put into a head tank equipped with an agitator to keep the solids in suspension. The waste is conveyed by a positive displacement pump to the reactor and fed into the fluidized bed through a water-jacketed gun. The bed gun is swept by atomiza-

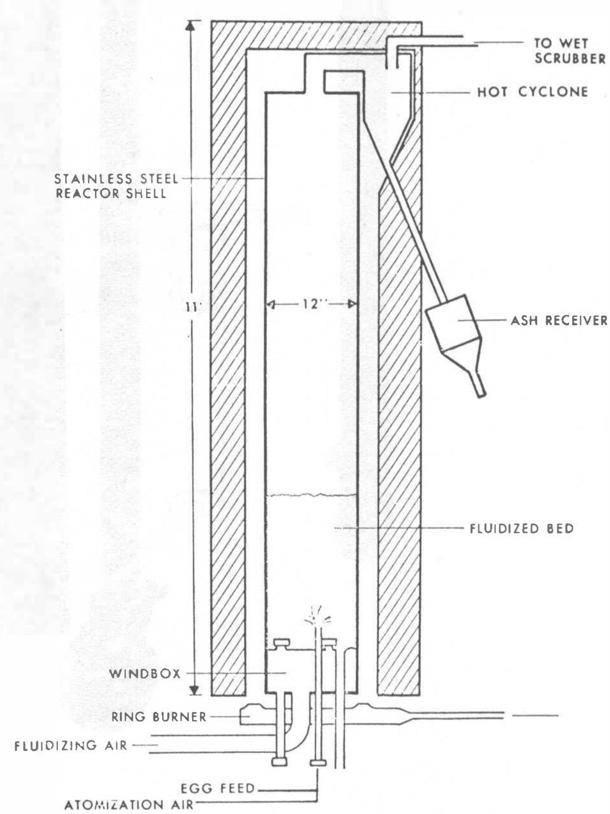

FIG. 4. PILOT TEST – FLUIDIZED BED

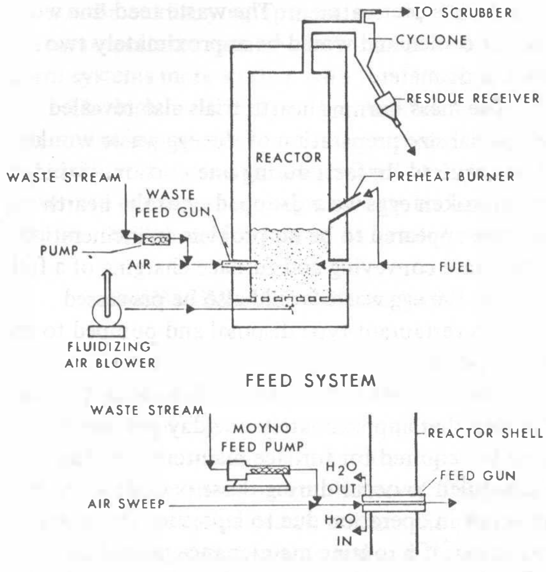

FIG. 5. SCHEMATIC FLUIDIZED BED SYSTEM

tion air to keep it clean and to disperse the waste as it enters the fluid bed.

The entrained particulates are separated from the gases in a dust collection system consisting of a hot cyclone within the refractory enclosure mounted at the top of the steel reactor followed by a Peabody gas scrubber.

An induced draft fan at the scrubber gas outlet is controlled to maintain a slightly negative pressure in the freeboard above the fluidized bed.

For this test the reactor was charged to a depth of three feet with 200 pounds of -10 mesh sand and preheated to the desired operating temperature. The pulverized egg waste was then fed to the unit at the rate of approximately 1/2 pound per minute and the system was brought to a steady state condition, with the sand bed temperature at 1450°F and the reactor exhaust gases at 1250°F.

The five percent oxygen in the exhaust gases was equivalent to approximately 33 percent excess air.

When the reactor was in a fluidized operating condition there remained an eight-foot freeboard above the churning sand bed.

Although incineration in this system might be considered almost instantaneous, previous investigations by Dorr-Oliver indicate that a discrete particle in the churning bed and freeboard has a seven to eight second detention period in this temperature range.

This test was run for six hours at an average waste feed rate of thirty pounds per hour. No problems were encountered in the feeding system and the test results reveal that combustion of the organic material was complete.

MASS BURNING ROTARY HEARTH

The test was performed on a pilot Morse Boulger horizontal rotary hearth. A schematic sketch of the system is shown in Figure 6. The small pilot unit did not actually have a rotating hearth or the rabble arm stoking mechanisms as would an actual commercial installation such as shown schematically in Figure 7. The furnace was brought up to temperature by means of an auxiliary gas burner. The crushed but not pulverized egg wastes were then deposited onto the hearth through several side ports. There appeared to be no problem in burning the eggs.

In a commercial unit with a rotating hearth and rabble arms, the crushed waste material would be pumped through a feed line and would fall through several entrance ports around the periphery of the hearth and would be agitated as it would be gradually

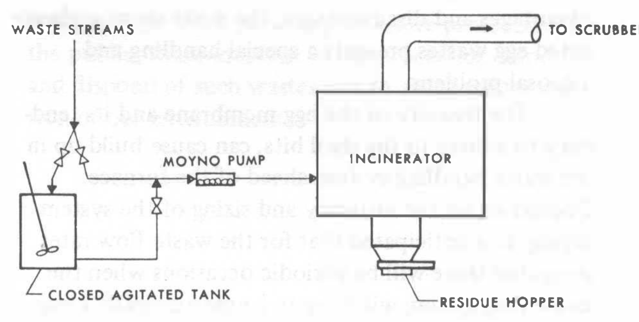

FIG. 6. SCHEMATIC ROTARY HEARTH SYSTEM

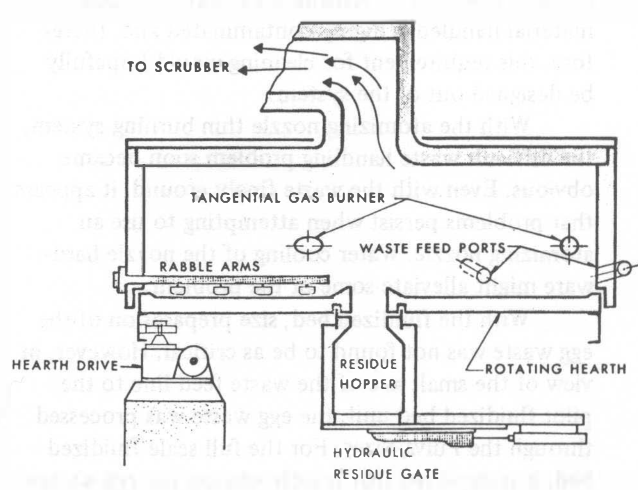

FIG. 7. MASS BURNING ROTARY HEARTH

rabbled to the point of discharge at the center of the hearth. By the time the waste material reaches the discharge point at the center, combustion will have been completed. The normal residence time would be over an hour. The ashes would drop through the discharge port at the center into a receiving hopper. The gases would also leave at the top center of the unit into a suitable air pollution control device.

As shown in Figure 7, auxiliary burners would be installed firing tangentially to supply supplementary heat and to maintain the desired furnace temperature if the heat energy in the waste materials proved to be inadequate. When burning whole egg waste (Waste No. 1) or whole eggs minus the embryo (Waste No. 2) no supplementary fuel requirement was expected once the furnace was brought up to operating temperature. When disposing of shells and water supplementary fuel would be required.

DISCUSSION OF OPERATING AND MAINTENANCE PROBLEMS

Although each incineration system has it own advantages and disadvantages, the make-up of embryonated egg wastes presents a special handling and disposal problem.

The tenacity of the egg membrane and its tendency to adhere to the shell bits, can cause build-up in the waste handling system ahead of the furnace. Depending on the intricacy and sizing of the system piping, it is anticipated that for the waste flow rates projected there will be periodic occasions when the conveying system will have to be mechanically cleaned to remove these accumulations.

Larger conveying pipe size and fewer constrictions or orifices would lessen the tendency for agglomeration. It should be remembered that the waste material handled is highly contaminated and, therefore, this requirement for cleaning would hopefully be designed out of the system.

With the atomizing nozzle thin burning system, the difficult waste handling problem soon became obvious. Even with the waste finely ground, it appears that problems persist when attempting to use an atomizing nozzle. Water cooling of the nozzle hardware might alleviate some of the problem.

With the fluidized bed, size preparation of the egg waste was not found to be as critical. However, in view of the small size of the waste feed line to the pilot fluidized bed unit, the egg waste was processed through the Pulva-Sizer. For the full scale fluidized bed, it is expected that merely passing the egg wastes through a restaurant kitchen-type disposal would be adequate size pretreatment. The waste feed line would be water cooled and would be approximately two inches in diameter.

The mass burning hearth trials also revealed that special size preparation of the egg waste would not be required. In fact, during one portion of this test, unbroken eggs were dropped onto the hearth and there appeared to be no problem in incineration. To facilitate conveying and furnace charging of a full scale unit the egg waste would also be processed through a restaurant-type disposal and pumped to the furnace ports.

For the mass burning rotary hearth unit, it was estimated that approximately one day per month would be required for furnace maintenance. This could be scheduled to occur during those periods when the unit is not in operation due to lapses in laboratory production. If a routine maintenance procedure is followed, no major furnace breakdown is expected.

Due to the substantial sand bed in the fluidized bed reactor, it will heat up and cool down more slowly than the rotary hearth incinerator. This heat reservoir feature has an advantage when there are relatively short interruptions (5 to 12 hours) in waste feeding, but is of no real advantage if the feed interruptions extend to 24 hours or longer. If for some reason access to the reactor interior is required, the sand bed could be drained and, thereby, effectuate more rapid cooling. Since there are no moving parts within a fluidized bed reactor, no major maintenance would be expected.

It is expected that refractory maintenance would be approximately equivalent for both the reactor and rotary hearth furnaces.

In general, for these incineration systems, the areas of concern regarding forced outages, lie principal-

FLOW RATE OF EGGS

10.7	pounds/gallon		1.56	pounds/dozen
80	pounds/cu. ft.		130,000	eggs/day
51	dozen/cu. ft.		10,900	dozen/day
			213	cu. ft./day
		= ±	130,000	eggs/day
400	gallons/hour	=	4,270	pounds/hour
@ 1.56	pounds/dozen	=	2,730	dozen/hour
@ 4	hours/day	=	10,920	dozen/day
@ 260	days/year	=	2,840,000	dozen/year
		=	55,700	cu. ft./year
		=	34,000,000	eggs/year

ly with the auxiliary equipment, i.e., fans, pumps, drives, air pollution control devices, and control and alarm systems more so than with the furnaces.

The high availability of the disposal system is of paramount importance due to the nature of the waste and production quantities anticipated. A stringent preventive maintenance program must be instituted to keep the incidence of failure to an absolute minimum.

SUMMARY AND CONCLUSION

The principal purpose of the pilot burning tests was to determine the technical feasibility of disposing of contaminated egg wastes in each of the three available incineration systems. The pilot units were not all full scale systems in miniature. However, the pilot fluidized bed and pilot hearth systems did prove that effective incineration was practical and feasible. The easily collected residues and the effluents were determined to be sterile.

Based on the burning tests experience and background it was possible to project the furnace-equipment system design required for full scale units.

With the mass burning hearth and fluidized bed systems, the factor controlling the size of the full scale unit would be the quantity of Waste No. 3, i.e., the amount of shells and water to be disposed of. It would seem to be practical to provide a holding tank for this waste stream so that this waste can be fed to the unit at a controlled rate over a longer period of time. From Table 3, it can be noted that the Btu value of Waste No. 3 (shells and water) is essentially zero, and that of Waste No. 1 and No. 2 is approximately 3,000 Btu per pound. When Waste No. 3 (shells and water) is to be incinerated, it will be necessary to provide supplementary heat, at approximately 2,000 Btu for each pound of waste. Once the furnaces are preheated to operating temperature, it is expected that no additional supplementary Btu will be required when burning either Waste No. 1 or Waste No. 2.

With increasing emphasis on medical research and expanding, more sophisticated biological and pathological laboratories, there is a dire need for effective on-site disposal systems for contaminated laboratory wastes.

For this study, only three available incineration systems were investigated. Since then other incineration systems have become available and development of new processes may be underway.

Awareness, research and process development will continue to be necessary to assure protection of the public; those involved in the processing, handling and disposal of such wastes and to avoid contamination of our environment.