Heat Recovery from Incineration of Solid Waste from Hospitals

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OUR NATIONAL ECONOMY, faced with the burdensome realities of double-digit rates of inflation, unemployment, and increasing costs of labor and materials, is further beset by an increasing national dependence upon imported oil and gas supplies in the face of dwindling domestic production. The upward spiral of the cost of imported energy supplies is a prime contributory factor to the runaway inflation we are now experiencing.

The foregoing facts are of paramount concern to managers charged with maintaining an operating budget in health care institutions. Hospital administrators must be constantly alert for opportunities to seize and use new processes or modes of operation that offer the promise of cost containment. If administrative, technical, and cost evaluation studies yield evidence that an innovation or a new process or operation offers a definite cost advantage and the costs can be recovered within an acceptable period, adoption of the innovation should be seriously considered by the institutions' managers.

The practice of heat recovery from the incineration of solid wastes is being employed successfully to replace a portion of health facilities' basic fuel with an energy source derived from their normal day-to-day operation. This practice presents a cost-saving solution to an ever-expanding waste disposal problem, in addition to reducing energy costs.

The modern hospital generates solid waste in volumes which, in certain instances, have reached 25-30 pounds per bed per day (*1*). Before the early 1960s the average solid waste generation rate of hospitals remained stable for a number of years—approximately 7 pounds per bed per day. Admittedly, 25 to 30 pounds is a high average and it applies to a particular hospital or unusual circumstances (*2*). A recommended working average, however, is 15 pounds per bed per day for hospitals with less than 400 beds and 20 pounds per bed per day for

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Categories of waste, by principal components, approximate composition, moisture content, incombustible solids, and heating value of wastes as fired

Categories of waste and principal components	*Approximate composition (percent by weight)*	*Moisture content (percent)*	*Incombustible solids*	*BTU value per pound of refuse as fired*
Type 0—trash: [1] highly combustible waste, paper, wood, cardboard cartons, including up to 10 percent treated papers, plastic or rubber scrap; commercial and industrial	Trash 100	10	5	8,500
Type 1—rubbish: [1] combustible waste, paper, cartons, rags, wood scraps, and floor sweepings; domestic, commercial, and industrial	Rubbish: 80 Garbage: 20	25	10	6,500
Type 2—refuse: [1] rubbish and garbage; residential	Rubbish: 50 Garbage: 50	50	7	4,300
Type 3—garbage: [1] animal and vegetable wastes, restaurants, hotels, markets; institutional, commercial, and club	Garbage: 65 Rubbish: 35	70	5	2,500
Type 4—animal solids and organic wastes: carcasses, organs, solid organic wastes; hospital, laboratory, abattoir, animal pounds, and similar sources	Animal and human tissue: 100	85	5	1,000
Type 5—gaseous liquid or semisolid wastes: industrial process wastes	Variable	(2)	(3)	(3)
Type 6—semisolid and solid: combustibles requiring hearth, retort, or grate burning equipment	Variable	(2)	(3)	(3)

[1] Percentages of moisture content, ash, and BTUs as fired were determined by analysis of many samples; they are recommended for use in computing heat release, burning rate, velocity, and other details of incinerator design. Any design based on these calculations can accommodate minor variations.

[2] Dependent on predominant components.

[3] Variable according to wastes survey.

SOURCE: Incinerator Institute of America, IIA Incinerator/Standards.

hospitals with 400 beds or more (*1*). The increased volume of solid waste generated by hospitals since the late 1960s parallels and coincides with the increased use of single-use disposable and plastic items.

Classification of Hospital Waste

Hospital solid wastes are composed of a mixture of materials with widely varying heating values when incinerated. The heating value is a resultant of variable factors such as the amount of single-use disposable items and plastic items included, whether prepared foods are used, and the amount of teaching and research activity conducted at the facility (*3*).

The Incinerator Institute of America (IIA) has developed a generally accepted scheme for classifying wastes into seven categories ranging from type 0 to type 6. The principal components, approximate composition, moisture content, incombustible solids, and heating value of wastes as fired—as specified by the IIA—are shown in the table.

An analysis must be conducted at each facility to determine accurately the quantity and type of its solid waste volume. A typical profile of hospital solid waste is considered to be composed of the following:

Trash—similar to the IIA type 0 waste and has a heating value of 8,500 BTUs per pound as fired.

Garbage—corresponds to the IIA type 3 waste with a heating value of 2,500 BTUs per pound as fired.

Food service waste—corresponds generally to the IIA type 2 waste, but the heating value is widely variable according to the ratio of garbage to plastics, paper, and wax containers.

Pathological waste—similar to the IIA type 4 waste and has a low heating value of 1,000 BTUs per pound.

Contaminated waste—all waste that has been in contact with a patient or patient area and therefore may be infectious; heating values depend on the type of waste.

Other wastes—street refuse such as sweepings, leaves, contents of litter baskets, and scrap construction materials such as wood and sheetrock masonry are common. Special or hazardous types of waste include discarded, sharp operating-room instruments, needles, radioactive wastes, and possibly explosives. Recent years have seen the increased use of plastics and single-use disposable items. In addition, the newest type of waste material appearing in hospital waste is flame-retardant paper that is used for bedding and gowns (*3*).

As indicated, these types of wastes have heating values ranging from 1,000 BTUs to 8,500 BTUs per pound. The average heat content of the matrix of wastes must be known so that an incinerator-heat recovery system can be properly designed and specified. Ample reserve capacity should be designed into the incinerator-heat recovery system at the initial planning stage to provide for all foreseeable future expansion.

Hospital Waste Disposal Methods

Historically, hospital wastes have been disposed of by the predominant methods of dumping, landfilling, and incineration. Where ample marginal land was readily available, hospital wastes were frequently hauled to open burning dumps or sanitary landfills (*3*).

In urban areas, the existence of large municipal incinerators offered hospitals the attractive incentives of containment of costs and ease of refuse disposal (*4*). The costs of hauling the wastes from hospital to incinerator, in addition to municipal incineration fees, were important considerations in a hospital's decision to use this waste disposal option if available.

Concern for environmental quality resulted in the passage of the Clean Air Act of 1970 (HR 17255, Public Law 91–604). The inability to comply with the gaseous and particulate emissions standards of this act has caused widespread closing of noncomplying municipal incinerators and upgrading and consolidation among the remainder.

In instances where dumping or landfill or municipal incineration has been used for hospital waste disposal, the pathological materials were isolated and retained at the hospital for disposal in an onsite incinerator for pathological waste exclusively. Onsite incineration of the total volume of solid waste has been practiced to some extent by hospitals in the past, but it has actually declined in recent years. This decline can be attributed to the age of the disposal equipment, the low state of technology being employed, and the equipment's inability to comply with the gaseous and particulate emissions standards of the Clean Air Act of 1970. These older incinerators seldom were equipped with waste heat-recovery devices and were subject to the usual criticisms (in many instances deservedly so) of high levels of emissions, large amounts of auxiliary fuel required, and high operating cost.

The disadvantages of each of these briefly described options available to hospitals for the disposal of solid waste highlight the desirability of a universally available system that will eliminate or negate most of the disadvantages and undesirabilities of the customary options.

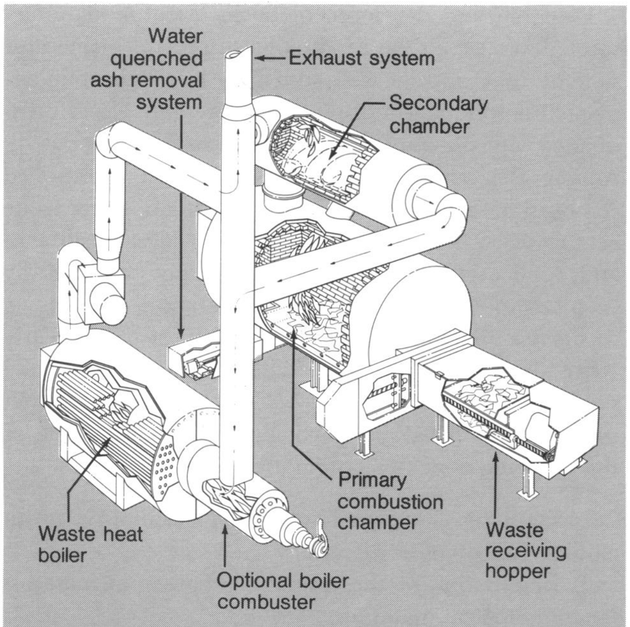
Incineration may be defined as an enclosed combustion process designed to reduce the volume and weight of solid waste that contains a wide range of combustibles. Generally, the weight reduction of solid waste processed by an incinerator ranges from 50 to 80 percent and the volume reduction from 80 to 95 percent, depending on the noncombustible fraction of the waste (*5*).

Research and development by incinerator manufacturers have led to the production of several incinerator systems that appear well suited to hospitals' requirements for solid waste disposal and are capable of compliance with the standards of the Clean Air Act of 1970. Among the newer designs, the small-scale controlled combustion incinerator—coupled with an appropriate heat recovery boiler—has received the widest acceptance and application and is being successfully employed by hospitals today. Controlled air incineration, also known as starved air incineration, was introduced in the early 1960s, but it did not gain wide acceptance until the standards of the Clean Air Act of 1970 required strict control of gaseous and particulate emissions. Some of the advantages of this system are:

1. Disposal of the total volume of hospital waste including pathological materials.
2. Elimination of the need for separate incinerators for pathological materials.
3. Capability of compliance with the existing and projected antipollution standards without the use of stack scrubbers, precipitators, or filters.
4. Heat recovered from the incineration process can be used for the generation of steam, hot water, or hot air and consequently can save basic fuel.
5. The residue remaining after the incineration of wastes is a completely sterile ash.
6. The hauling of unincinerated solid wastes through city streets and public highways to sanitary landfills or municipal incinerators is eliminated, a potential health hazard is avoided, and the cost of waste hauling is saved.
7. The nuisance problems of rodents, insects, odors, and so forth associated with solid waste storage are eliminated.
8. The land required for final disposal of the incinerator residue is vastly smaller than that required for unincinerated wastes. The associated hauling costs are also proportionately reduced.

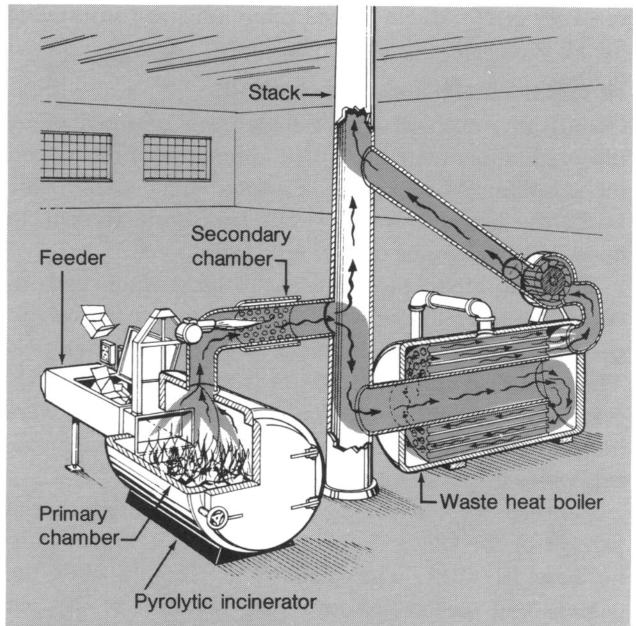
Controlled air incinerators usually have two chambers consisting of a primary combustion or pyrolysis chamber and a secondary or thermal reactor chamber (fig. 1). In some designs the secondary chamber is an integral part of the lower portion of the exhaust stack (fig. 2). In controlled air incinerators the waste is either manually or mechanically fed onto the floor of the primary chamber which may consist of either cast iron grates or a refractory hearth. Waste may be charged into a controlled air incinerator in either a batch process or by intermittent feeding.

Figure 1. Dual chamber incinerator waste heat system



SOURCE: Equipment reference *A*.

Figure 2. Incinerator waste heat recovery system with secondary chamber integral with exhaust stack



SOURCE: Equipment reference *B*.

Batch-loaded systems are loaded with the entire waste charge, which is subsequently incinerated in an automatic burning cycle without further attendance or addition of wastes. The cycle time to burn the waste and cool the incinerator for ash removal and subsequent recharging ranges from 4 to 6 hours for incinerators in the less than 0.5 ton per day range, 12 to 16 hours in the size range up to 3 tons per day, and approximately 16 hours for incinerators of more than 3 tons per day (*6*).

Intermittently fed incinerators are started with a relatively small charge of waste and then fed at some reasonably constant rate throughout the burning cycle. Instruments generally regulate the rate at which waste is charged into intermittently fed incinerators (*5*). The charge of waste is incinerated in the primary chamber with a closely controlled volume of air flowing through the firebed. This process produces temperatures in the range of 1,200° to 1,800° F.

These elevated temperatures produced in an oxygen-starved atmosphere cause a thermal degradation of the waste, releasing combustible gases and producing a minimum overfire turbulence. The combustible gases flow into the excess air-charged secondary chamber where they are ignited by an afterburner at temperatures ranging from 1,800° to 2,000° F. The resulting hot flue-gas emissions are clean, consisting mainly of carbon dioxide and water with little if any particulate emissions. This heat contained in the flue-gas emissions, if not recovered and used at this stage, will rise through the exhaust stack and be lost in the atmosphere.

For recovery, the hot gases are passed through a heat-recovery device—usually a waste heat boiler—to produce steam, although hot water or hot air may be just as easily produced. In passing through the tubes of the waste heat boiler, the hot gases are reduced in temperature from 1,800° to 400° F, the differential being heat donated to the production of steam. The spent gases may now be discharged through a secondary stack into the atmosphere.

Waste heat boilers can use up to 70 percent of the energy normally released and wasted during incineration. The energy recovered from the incineration of solid wastes will not be sufficient to meet a hospital's total energy demands. All of the heat of combustion will not be available for recovery. A number of factors limit the usable energy that may be extracted from each charge. These factors include (*a*) the amount of water in the waste material and the amount of heat energy required to evaporate it, (*b*) heat transfer losses from the incinerator to the surroundings, (*c*) minimum flue gas exhaust temperatures from the waste heat boiler required to eliminate corrosion and condensation problems, and (*d*) the overall efficiency of the incinerator-waste heat boiler system.

Hospitals having capacities between 100 and 700 beds have been found to generate solid waste loads ranging from 2,000 to 17,000 pounds per day (*3*). These estimates are based on general waste and food service waste for patients' meals only. Inclusion of restaurant, cafeteria, and coffeeshop wastes would produce greater waste loads. In addition, extensive research and teaching activities could further increase these estimates substantially. Daily waste loads of these volumes are well within the 50 to 4,000 pounds per hour capacity of small-scale onsite incinerators.

If an incinerator waste-to-energy system is to be economically attractive, one incinerator manufacturer recommends that, as a general guideline, an institution's solid waste load should total at least 3,000 pounds per day (7). Furthermore, the incinerator should be operated for at least 8 hours to further enhance cost efficiency. Regardless of length of burning time, a startup time of approximately 1 hour must be allowed before heat recovery can begin. Similarly, a cool-down period of approximately 1½ hours must be allowed before incinerator residue is removed manually.

Examples of Cost Savings

Many hospitals currently recover heat energy from onsite incineration of solid wastes. Among them is Lancaster General Hospital, Lancaster, Pa., which has 555 beds. This hospital has had a dual chamber incinerator of 2,500 pounds per hour capacity in operation since 1972. In January 1978, a 150-horsepower fire-tube waste heat boiler of 3,000 pounds per hour steam capacity was connected to the incinerator. A hydraulic ram compactor was installed to insure a full charge of waste and thus extend the load time cycle. The cost of the complete heat recovery equipment addition was approximately $50,000 installed. At the time of installation, the payback period on this capital expenditure was projected at 4 years. In the initial 6 months of operation, the heat recovery system showed a $7,629 saving. This sum represented a 6 percent reduction in the fuel oil consumption or 25,430 gallons saved. When the system was placed into operation in 1978, the price of heavy No. 6 fuel oil was 27 cents a gallon in the Lancaster area; by March 1980, the price had escalated to 59 cents a gallon. Because of constantly increased fuel costs, the capital expenditures for the heat recovery system have been amortized much more rapidly than originally projected. Thus, the payback period for the heat recovery system was reduced by 2 years. Over a 6-month period, from October 1979 to April 1980, Lancaster General Hospital realized savings of $15,000 from heat energy extracted from the incineration of its solid wastes.

The Veterans Administration Hospital in Marion, Ind., has a 500-bed capacity. The solid waste profile at Marion is 6,000 pounds per day of predominately type 1 waste with a heating value of approximately 6,500 BTUs per pound. Since the early 1970s this waste load has been disposed of by a controlled air incinerator in operation at the hospital's site. However, no attempt had been made to recover and use the heat generated by the incineration of these wastes.

In February 1980 a horizontal freestanding waste heat boiler was installed with the goals of recapturing 50 to 55 percent of the BTU value in the trash, generating 3,900 pounds of steam per hour, and saving 69,000 gallons of oil per year. The lowest acceptable bid price for the installation of the waste heat boiler was $22,000. The simple payback period on this contract price was calculated to be 10 years.

Maryland General Hospital in Baltimore has a 486-bed capacity. On May 25, 1979, Maryland General began operating an incinerator-heat recovery system. This system consists of a dual chamber controlled air incinerator of 1,500 pounds per hour capacity connected to a 150-horsepower fire-tube waste heat recovery boiler of 4,500 pounds per hour steam capacity.

The system's 1½ cubic yard waste-receiving hopper is intermittently hand fed throughout the 8-hour burning cycle with bagged wastes from all departments of the hospital. The waste is then automatically charged into the incinerator by hydraulic ram. After incineration, the remaining residue is ejected from the lower incinerator chamber by an automatic ash removal system. The residue is deposited in a water-filled quench chamber from which it is removed by an automatic residue ash removal conveyor system and deposited in dumpster receptacles.

The cost of the complete heat recovery system was $225,000 installed, including necessary site preparation. At present, the projected payback period on the heat recovery system investment is 2.2 years. However, Maryland General is planning to form a consortium with five other local hospitals and one nursing home to receive and incinerate their solid wastes. These institutions will be charged for this waste disposal service, but at rates that will be advantageous in each instance. If this affiliation can be effected, Maryland General plans to operate its heat recovery system on a 24-hour basis, and the estimated payback period for the system will be less than 1 year. In this initial period the system has been the key factor in saving 10,000 gallons of No. 2 fuel oil, and $60,000 has been realized through the reductions in costs of fuel and waste hauling.

Columbia Hospital, a 400-bed general hospital serving the greater Milwaukee, Wis., area, is an example of a large urban health facility that was already committed to onsite incineration of its solid waste. Incineration, however, was accomplished with outmoded and unsophisticated equipment that released smoke and pollutants into the atmosphere and created a public nusiance. No attempt was made to recapture the heat energy created by incineration, and an estimated 4,300 BTUs per hour were dissipated into the atmosphere.

Columbia Hospital was being pressured by the Wisconsin State Department of Natural Resources to abandon its incinerator and adopt contract waste hauling as a means of disposal. The hospital elected instead to install a refuse-to-energy system consisting of a pyrolytic controlled-air incinerator coupled to a low-pressure, steam waste heat recovery boiler. The incinerator's capacity is 725 pounds per hour of type 0 refuse, and the boiler output is 4,312 pounds of steam per hour.

The approximate cost of the incinerator-heat recovery system was $82,500 (excluding the stack utilities hookup and field wiring). A year after installation and testing, the hospital expects tremendous savings in energy costs and potential hauling costs. The hospital will save $13,000 annually with the system, if the 1979 natural gas costs in the Milwaukee area are used as a baseline. At present, the incinerator-heat recovery system is supplying low-pressure steam only to the Medical Arts Annex of the hospital. The system was designed with ample capacity to serve the main hospital building as well. Investigations of extending mains to carry waste heat-derived steam into the main hospital building are currently underway. If this connection is made, additional savings of $12,000 per year could be realized.

At the 1980 trash hauling rates in the Milwaukee area of $40 per 20-cubic yard dumpster, the cost of removal of the hospital's solid waste volume would have been $100,000 annually had the hospital chosen the contract hauling option. This sum is saved by using the incinerator-heat recovery system. The estimated payback period is slightly less than 1 year. If natural gas and waste hauling costs continue their expected 10 percent annual growth rate, the payback period will be even shorter.

Another successful incinerator-heat recovery system is in operation at Wadley Hospital in Texarkana, Tex. This institution of 358 beds has had a dual-chamber, controlled-air incinerator and stainless-steel heat recovery boiler combination on line for 4 years. The initial cost of the system was $73,000. The planned amortization period is 5 years. In its first year of operation, the incinerator-heat recovery system was responsible for a saving of $25,217.

A 40-cubic yard volume of solid waste is generated daily at Wadley Hospital. Before the installation of the incinerator-heat recovery system, the waste had been trucked to a landfill at a monthly cost of $1,350. The cost of hauling the minimal amount of residue ash remaining after incineration of wastes to a landfill has now been reduced to $100 monthly.

The basic fuel at Wadley Hospital is natural gas. The natural gas supply was metered to monitor costs, and it was determined that the first-year saving in basic fuel was $10,200. This reduction in fuel costs realized through the production of steam from heat recovered from incineration of the hospital's solid waste and the substantial reductions in hauling costs for the minimal amounts of incinerator residue ash together created an impressive first-year saving.

Conclusions

The actual and projected savings described for the five hospitals are typical of economies that hospitals can realize by adopting the practice of heat recovery from the incineration of solid wastes. The potential for savings from this alternate energy source has been found to vary in response to fluctuations in an institution's basic fuel cost and the available solid waste volume.

After carefully evaluating the savings to be realized through reduced basic fuel consumption, massive reductions in the tonnage of waste hauled to landfills, and the attendant savings of hauling and labor costs, hospital administrators may conclude that heat recovery from waste products presents a reliable alternate energy source and constitutes a viable cost-containment mechanism.

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