

The Enigma of Incinerator Design

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ABSTRACT

Until recently municipal refuse incinerators were largely empirically designed. The increasing emphasis on prevention of pollution of the environment, together with rapidly changing refuse constituents and characteristics, is forcing a change in these previously accepted design approaches. However, definitive, correlated, accurate, and analytical information is required to replace the empirical bases of design used in the past. In too many instances this information is not available at present. Those areas in incinerator design that urgently need more definitive design information are outlined herein.

INTRODUCTION

One of the major problems facing urbanized areas throughout the world, today, is how to dispose of the volumes of solid waste being generated by our modern civilization. In the major urban complexes, incineration of these wastes is fast becoming imperative, due to the necessity of achieving maximum volume reduction for this material. Since municipal incinerators have been designed and built in this country for some one hundred years, the layman or uninitiated looks on this phase of engineering design as an established technology. It is not for a number of reasons.

Until recently, municipal incinerator plants were little more than enclosures empirically designed

to contain a fire and, more or less, conveniently charge material to the burning chamber, convey it through this chamber, and discharge the residue from the furnace.

The modern incinerator requires a more technical approach to design. A number of factors contribute to this need. Refuse constituents and characteristics are changing rapidly. New developments in packaging and manufacture of other disposable items result in increasing variability in refuse. Continuing urbanization of our civilization has created increasing pressures for improvement of our environment. Definitive, correlated, accurate, and analytical information is required in many instances, instead of the empirical bases of design as used in the past. In too many instances, this information is not available at present [1]. Outlined on the following pages are those areas in incinerator design that urgently need more specific design information.

FURNACE CONFIGURATION

Early incinerator furnaces were almost invariably designed with two or more chambers. The primary chamber included the volume over the grates. The secondary chambers, downstream from the primary chamber, were required for the completion of combustion, since the arrangement of these furnaces and enclosures did not allow sufficient volume to be included in the primary chamber.

With the recent introduction of continuous feed furnaces and the resulting changes in furnace configuration and location of furnace volumes, it has become possible to provide, in the primary chamber, the entire furnace volume theoretically necessary for completion of combustion. This flexibility in furnace volume arrangement has resulted in a multitude of different configurations and a continuing discussion as to whether or not combustion can be completed in the primary chamber. Furnace arrangements have varied from large box-type enclosures with essentially the entire furnace volume in one chamber, to relatively small flue-type enclosures over the grates intended to convey the gases generated to a secondary chamber for completion of combustion, to box-type enclosures with a reflecting arch, and so forth. These varying furnace enclosures have not been tested to the extent necessary to establish whether one type of design performs better than another. Such testing as has been done, together with observation of furnace operation and results, indicates that none of these furnace configurations give optimum operating results. Each configuration has its own peculiar problems.

It is generally known that three conditions must be satisfied for proper combustion, i.e., sufficient time for completion of combustion; temperatures high enough for the substances being burned; and turbulence for proper mixing of the gases being burned. A large furnace volume may be inadequate if it is improperly utilized. Thus, if the gases are allowed to stratify and are not subjected to adequate turbulence and mixing, they may pass out of the chamber without fully utilizing the entire volume. On the other hand, when the solid wastes are volatilized, which usually occurs rather rapidly, and oxygen is present, they cannot be transported over an appreciable distance without combustion occurring.

An optimum furnace configuration would provide sufficient volume for retention of gases in the high-temperature zone of maximum fuel volatilization so as to complete combustion, and would be arranged so that the entire volume is effectively utilized. Temperatures are generally high enough for proper combustion with present-day refuse. Turbulence should be provided by a properly designed overfire air system. Some development work and testing will have to be performed before proved optimum furnace configuration is determined.

Of course, the foregoing discussion is concerned primarily with present-day practice in the

design of municipal refractory incinerator furnaces in the United States. A number of new shapes and arrangements of incineration facilities have been proposed over the past several years. These include: a cylindrical furnace with combustion air introduced tangentially; a furnace arranged and operated much like a blast furnace; a furnace arranged so that the burning takes place in the mass of refuse; furnaces that gasify the refuse and burn the gases separately; and so forth. Great claims are made for some or all of these new furnace units. However, there is a great deal of development and testing work that must be done to prove these designs, develop realistic operating and maintenance costs, and develop operating requirements and techniques before they will be ready for commercial utilization.

GRATES

There are numerous types of grate designs manufactured in the United States, and still more varieties available from European manufacturers. These types may be broadly classified as those that agitate the burning refuse and the nonagitating type. There seems to be a general consensus in the industry that the agitation is helpful. However, discussion is presently taking place in the industry as to whether the agitation should be a more-or-less rapid tearing motion or a slower gentle stirring or displacement. This discussion can probably only be resolved by intensive observation of operating results with each type of grate in a similar furnace configuration, each burning the full range of refuse types.

Another aspect of grate design, in which there is extreme variation and much discussion, is the percentage of air openings provided. These have varied, depending on the particular type and brand of grate, from 2 percent to over 30 percent. With such a large variation in this rather basic aspect of grate design, it would seem that one approach would be more nearly correct than the other. The proponents of the small air openings cite as the advantages of their approach: small volume of siftings; short flame; relatively low quantity of underfire air, thus reducing particle entrainment; and the ability of the grate to meter the flow of air to the furnace chamber. The manufacturers of grates with a large percentage of air openings state that the removal of siftings ash from the fuel bed, as soon as possible after they are formed, aids burning, and the capability of passing large volumes of air through the fuel bed is desirable to meet varying refuse conditions.

Several observations can be cited at this point. The quantity of siftings to handle from a grate with a large percentage of air openings is significantly greater than that from a grate with a small percentage of air openings. The handling of these siftings has been a problem in that present methods used create increasingly serious water pollution problems. This problem can be solved by a resourceful design effort and development of, as yet untried, handling systems.

Based on visual observations, it appears to be desirable to pass greater volumes of air through a bed of wet refuse than for dry refuse. This would not necessarily result in greater particulate entrainment, if the air openings are large and the velocities low. However, due to the poorer air metering characteristics of the grate with the larger air openings, it may be necessary to divide the underfire air plenums for this type of grate into smaller segments, in order to properly control the location of the greatest volume of air passing through the fuel bed.

It would seem that there would be an optimum range of percentage of grate air openings that was much narrower than the present 2 percent to over 30 percent. The only way this will be determined is by extensive testing and collection of data relating residue burn out and particulate discharged from the combustion chamber for various types and characteristics of refuse, to grates with different percentage of air openings and varying air flows. This is a major undertaking. However, if we are truly interested in obtaining better, more consistent operating results from incinerators in the near future, it is necessary.

AIR SUPPLY

As recently as six years ago, there was little general discussion in the field as to the design of the combustion air system for an incinerator. Today, there seems to be a wide divergence of opinion with respect to two basic aspects of this portion of incinerator design. One of these design considerations is how much of the total combustion air should be introduced through the grate versus over the fire. The other consideration, which has developed only recently, is whether or not all the overfire combustion air, utilized to promote turbulence and mixing of the gases, should be introduced through the sidewall or a portion introduced through the roof. The question of introduction of overfire air through the sidewall versus the roof is, no doubt, largely a matter of furnace configuration. Particular attention should be

given during design to determining the total quantity of overfire air, distributing this quantity to the proper furnace areas, and selecting number of nozzles, nozzle diameters, and system pressures to create turbulence in the burning gases without the throw of the air jet causing the flame to impinge on the grate or the furnace walls.

The question of how much air to introduce into the furnace through the grates versus over the fire has been touched on briefly in the previous discussion on grates. Over the last eight years, the opinion has varied that from 25 to 100 percent of the total combustion air should be introduced through the grates. The reason cited for introducing a relatively small quantity of combustion air through the grates is that a large quantity would aggravate the entrainment by the flue gases of particulates from the fuel bed [2]. This is, no doubt, a relatively more serious problem with those grate designs having small air openings, since when it is attempted to pass larger volumes of air through the small openings, velocities would increase and particulate pickup from the fuel bed would increase. With the type of material we have to burn, it seems to be unrealistic to consider designing the system for introduction of the total combustion air through the grates. The material being burned in modern incinerators is highly variable and can be highly volatile and "flashy." Because of these factors and the need to create turbulence and control furnace burning conditions and temperatures, some of the total combustion air should be introduced over the fire. Thus, the proper proportioning of underfire to overfire air is, at present, a matter of conjecture.

This is another area where testing and correlation of data would be helpful in design. Tests should develop, for each grate type, relationships between quantity of underfire air, particulates entrained, and residue quality [3]. These correlations may also yield procedures for determining the optimum range in air quantities and pressures, and the most desirable location for introducing overfire air.

SLAG CONTROL

The problem of slagging on the side walls over the grates in refuse incinerator furnaces has only been recognized as a major problem within the past five years. Slagging occurred in batch-type plants but, because of the furnace configuration, it generally did not occur over the grates and, therefore, was not as serious a problem as it has been in so-called continuous feed furnaces.

The method generally applied in modern incinerators for the control of this slagging involves the reduction of the lower furnace sidewall temperatures to the point where the slag will not adhere to the wall or run down the face of the wall. Two media, air and steam, have been used successfully to achieve the desired wall cooling. The one plant in which steam was used to achieve wall cooling included waste heat boilers [4]. Thus, steam was available for this use from normal plant operation at this facility. In most present day plants, which do not include waste heat boilers, air may be preferable to steam for cooling, since the air is required in any case for combustion. Thus, the air used for wall cooling, when properly discharged into the furnace after performing its cooling function, can be considered as a portion of the total required combustion air.

While air has been used successfully in a number of plants to control furnace sidewall temperatures, most of the installations using air-cooled cast iron in the side wall construction have been applied to pusher-type grates, while most of the air cooled silicon carbide wall constructions have been applied to traveling grate type of units. The wall cooling is generally accomplished by passing air up along the outside face of the lower furnace wall and discharging the heated air into the furnace at the top of this special wall construction. In approaching the selection and design of this portion of the furnace system, consideration should be given to the particular burning characteristics of the different grate systems, principally the maximum rate of heat release and its location in the furnace. The best system of wall cooling is one in which the maximum wall heat-transfer surface is exposed to the flow of cooling air, and provision is made in the layout of the cooling air-feed system for maximum flexibility with respect to the wall area where the cooling air is applied and the quantity of cooling air utilized in each area or zone.

It would be desirable for future furnace wall designs to obtain information as to required air quantities, proper location of cooling air application, and system pressure requirements for different furnace systems and different wall-cooling systems. Until and unless this type of information is obtained, these systems will have to be laid out empirically and a large ignorance factor included.

REFRACTORY CONSTRUCTION

Another important subject of discussion in the design of a new refractory walled municipal incinerator plant is what quality of refractory firebrick to

use in the different areas of the furnace. High refractory maintenance costs, cited by people responsible for plant operation, underscore the importance of using silicon carbide or some other abrasion and slag-resistant material near the grates, and high-quality refractory, such as super duty firebrick, in much of the remainder of the furnace. Some designers have specified high heat duty firebrick in flue areas where gas temperatures are lower and more stable. Other designers are specifying more expensive high alumina firebrick in hotter furnace areas, and still others have gone to much more extensive use of silicon carbide than has been generally thought to be necessary in the past.

The designers are all trying to develop a better product, although their approaches are entirely different. The designer utilizing high heat duty refractory in the near flue-areas of the furnace system is attempting to control the rapidly increasing cost of incinerators by using less expensive materials where the service conditions are less severe. The designer utilizing more expensive materials throughout the furnace system is attempting to reduce the refractory maintenance costs and increases the availability of these plants at the expense of adding to the already rapidly increasing construction cost of incinerators. In the absence of definitive information on refractory maintenance in existing incinerators, it is difficult, if not impossible, to evaluate these two opposite approaches to this design problem.

In this important area of plant design and operation, information should be developed from existing plants utilizing different refractory materials as to the maintenance experience with each type of material in different furnace environments and during differing periods of continuous and intermittent furnace operation. This experience should be correlated with temperatures, moisture conditions, and other environmental conditions in the different furnace areas. By developing such information, the suitability of materials, presently being used, can be evaluated and other materials tried where service of present materials is not satisfactory or where less expensive materials may be applicable.

AIR POLLUTION CONTROL

The present emphasis on maintenance and improvement of our environment has, in the past ten years, introduced an entirely new set of problems to the field of incineration. One of these problems is how to control the air-borne pollutants generated in an incinerator and prevent them from being dis-

charged to our environment. In order to select the air pollution control equipment best suited to a particular problem, one should have concise information as to the nature, characteristics, and magnitude of the problem.

In general, present day codes limiting emissions to a level of 0.85 lb of particulates per 1000 lb of flue gas, corrected to 50 percent excess air, can be met by properly designed water spray and/or wetted baffle wall systems or by properly selected cyclone dust collectors. This proper design or selection implies that one must have a knowledge of the quantity and size distribution of particulates discharged from the main furnace combustion chamber. This information is practically nonexistent, and what does exist is widely scattered and largely unavailable. Information should also be available as to the flue gas environment, so that materials of construction can be properly selected. There is probably less known about the gaseous constituents of the flue gases than there is of the particulate matter. Ideally, the foregoing information should be correlated with waste type, furnace loading, length of furnace operation per day, amount of excess air and overfire air, grate type, furnace shape, furnace temperature, and so forth.

The more rigid present-day air pollution codes will require the application of more sophisticated abatement equipment than has been used to date in American incinerators. Such equipment includes medium to high-energy wet scrubbers and electrostatic precipitators. In considering the application of this equipment, the same information is required with respect to quantity and size distribution of particulates as with the less sophisticated types of control systems.

With refractory furnaces, the gases must be cooled prior to being discharged to the air pollution control equipment. This cooling is usually accomplished by the addition of spray water to the gas stream. A portion of the gaseous pollutants discharged from the furnace would be removed by this cooling water. In a number of existing plants, the collected spray water has been found to have a pH of 2 to 3. Since much of this more sophisticated equipment is fabricated out of metal, it will be subject to severe corrosion problems during operation. However, since little or nothing is known about the chemistry of this low pH reaction, selecting material for this service is a serious problem.

If an electrostatic precipitator is being considered, it is important that the gases be cooled adequately without carrying moisture over into the precipitator. Only two systems of gas conditioning

have reportedly been used in European incinerators incorporating electrostatic precipitators. These systems are presently being offered in the United States on a guaranteed performance basis but are relatively expensive. If more extensive information were available as to the characteristics and constituents of the gases that were to be treated in an incinerator, I feel that a less expensive system that is easier and less expensive to operate than those presently offered might be developed.

Thus, in attempting to satisfy the increasingly stringent air pollution codes being formulated across the country, more concise correlated information is required as to incinerator flue gas characteristics and constituents before designs can be developed that give assurance of meeting the stipulated air pollution requirements at minimum cost and reasonable operation and maintenance [5].

WATER REQUIREMENTS

Many modern incinerators use large quantities of water in various cooling and materials handling operations. A number of these uses, such as moving of grate siftings, quenching of residue discharged, cooling and washing of flue gases, and sluicing of collected fly ash to a point of collection and disposal, all expose the water to pollutants that are objectionable from the standpoint of public health and make them objectionable for direct process reuse due to excessive suspended solids and, in some cases, low pH. Thus, this water must be treated before discharge to a watercourse or before reuse in the plant.

There are a number of problems associated with treatment of this process water. The water discharged from contact with flue gases, either from gas cooling or gas washing, is low in pH and contains a large quantity of suspended solids [6, 7]. The pH is being corrected in some existing plants by the addition of chemicals. This water is presently treated in settling basins that reportedly remove 50 to 70 percent of the suspended solids. The more successful an incinerator plant is from an air pollution control standpoint, the greater the quantity of fine particulates that will be removed from the gas stream and more difficult will be the suspended solids removal in present conventional settling basins. If it is planned to reuse this process water in the incinerator plant, the fine particulates may accumulate and become troublesome. In a "once through" system, the solids and low pH could create a stream pollution problem.

The overflow water from undergrate siftings, sluices, and ash residue quenching reportedly is of high pH, contains large quantities of suspended solids, and has a high BOD [8]. This water also is a potential pollution problem as presently handled at existing incinerator plants. It has been reported that equal volumes of residue conveyor water overflow and spray chamber water overflow will approach a neutral pH. However, these limited tests cannot be considered to be conclusive, and the high BOD would still be a problem in the process water.

Better process water-treatment systems will be required at incinerator plants in the future. To properly design these improved systems, we need information on the quantity and size distribution of the suspended solids, the chemical constituents and pH of major process water fractions, and the effectiveness of chemical treatment of these waters utilizing the more common coagulants, in addition to polyelectrolytes.

HEAT RECOVERY

The question of recovery of the large quantities of heat generated in the incineration process is continually being raised, particularly within the last five years. Such systems, although rather crude, have been designed and built in this country, in the most part with limited success. More sophisticated systems have been constructed in Europe recently. In most cases, these European plants utilize supplementary heat to a great extent. Many of these plants rival modern power plants in terms of equipment utilized and operation.

Recent inspections and reports on these very advanced plants indicate that many of the previously outlined problems of air and water pollution can be answered by the application of this type of facility in the United States. However, firsthand experience, private communications from others in the refuse disposal field in the United States, and recently reported experience from Europe, especially Germany, indicate that severe and very expensive maintenance problems are often encountered in these installations [9 - 17]. This maintenance, consisting of frequent tube repair and replacement, appears to be due to severe metal wastage on the fire side of the boiler tubes.

Since the mechanism of this tube wastage is, at present, unexplained, no assurance can be given in the design of such a facility that the installation will or will not be subject to such attack. Thus, before the potentials of the extraction of waste heat from

incinerator flue gases can be realized, the unknowns in the present technology, especially as related to flue gas constituents and metal wastage mechanisms, must be rigorously explored and answered.

RATING OR SIZING OF FURNACES

It has been the practice in sizing water pollution control plants or water treatment plants to predict the capacity requirements for these facilities at some future date and design the facilities for those future requirements. Some standby equipment is generally provided for those elements of the treatment system that are critical to maintenance of plant treatment capability.

When sizing an incinerator plant, it has been common practice to make population and per capita refuse generation predictions to determine tons per day of refuse that must be disposed of at the selected future date. The incinerator size selection was then either based on the aforementioned quantity or increased by a factor to allow for some equipment down-time. However, since these units are furnaces, they are vitally affected by the increases in refuse heat content that have occurred in the past. Between 1950 and 1960 alone, the average heat content of refuse in the metropolitan areas of Eastern United States rose from approximately 4000 to 5000 Btu/lb. This rise in heat content has accounted for many of the problems encountered in plants built in the early 1950's insofar as maintaining their capacity is concerned.

There are indications that average heat content of American refuse will continue to rise and, in specific localities receiving large volumes of industrial wastes, the heat content may even today be well above the presently accepted average figure of 5000 Btu/lb. It is unfortunate that the rating of refuse furnaces in tons per 24 hr has become so deeply engrained in incinerator technology, since the truly important factor to consider when sizing furnaces and furnace components, is the quantity of heat released in the furnace. Thus, in predicting future capacity requirements, one should also take into account anticipated increases in refuse heat content and size his facility accordingly.

MISCELLANEOUS

Many other more-or-less secondary problem areas exist in present-day incinerator design technology. Much discussion has taken place over recent years as to how much instrumentation to use in an

incinerator plant. The discussion generally ranges from no instrumentation to automation of a plant much as a modern day power station. I feel, as do most other designers in the field today, that both positions are extreme.

One of the reasons incinerator technology has not advanced as rapidly as it should have in recent years, is that either insufficient instrumentation has been applied in operating plants to allow the accumulation of useful operating results that could be correlated with other plants, or the instrumentation that was applied was not used or was allowed to fall into disrepair. Other instrumentation systems that would be useful in assessing plant operation and results, such as weighing of material as it is charged into the furnaces, has not been developed by the instrumentation or materials handling people because they felt, to date, that there would be no market for this equipment. Taking of such measurements as furnace outlet temperature continues to be a problem, due to uncertainty as to sensor location and use of a sensor that is not ideally suited to this application.

We are not at a point in incinerator design technology where a furnace can or should be instrumented to the extent of attempting automatic operation. However, as a minimum, sufficient instruments and controls should be provided for the operator in a location convenient to a furnace observation point to allow him to rapidly monitor the entire operation of his furnace unit from charging inlet to stack outlet, and to allow him to manually set selected furnace controls from remote stations located in the furnace operating panel. Those conditions, indicative of or vital to proper furnace operation, should be recorded. With enough of the proper kind of information and measurements, furnace malfunctions can be isolated more promptly, and results of furnace operations can be compared on a more realistic basis with results in other plants with similar comprehensive information.

CONCLUSION

It can be seen from the foregoing that a great deal of information is lacking in vital areas of incinerator design technology. Much of the information that is being used today in incinerator design is empirical, is incomplete and uncorrelated, is hearsay, or based on visual incomplete inconclusive "spot" observations. In many instances, it is inconclusive and unreliable.

Good engineering design requires the determination of optimum solutions to problems such as

outlined in the preceding material. An optimum engineered solution is one which meets stipulated performance conditions and combines low cost with long service life, minimum maintenance and manual operation, and creates a minimum of secondary nuisance. Much more data must be collected from presently operating incinerators and properly correlated with furnace type, furnace configuration, operating variables, refuse composition, and so forth. Only then can the optimum processing equipment and system be selected and laid out with complete assurance.

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DISCUSSION by J. W. Stephenson, Havens and Emerson, New York, New York

This paper presents a realistic picture of the present status of municipal incinerator design. Present practices are vastly advanced over those of very few years ago, and the technology is improving rapidly. At the same time, as the author points out, much information is still needed to permit proper application to incineration of established technology from other combustion processes.

Any questions as to designers' uncertainty concerning, and quest for, soundly based design parameters can be dispelled by a review of the report on incinerator design practices presented at the 1966 National Incinerator Conference [1]. This report points up the fact that the only agreement among designers is in disagreement in many if not most aspects of incinerator design.

For a time in recent years, the remark, "We have the technology — all we have to do is apply it," cropped up frequently to plague the incinerator designer. It seemed to be made most often by highly placed officials and scientists on occasions when it would attract the maximum publicity, and suggested to the less knowledgeable and to the public in general that only a willingness to spend the money was necessary to overcome our problems. Happily, a practical understanding of the problems seems to be taking hold, and this remark is heard less frequently today.

At present, we are more often faced with the question of why our incinerators are inferior to those in Europe which, in some eyes, have overcome all problems and are revenue producers as well.

There can be no questioning the fact Europe is well ahead of us in the *number* of *modern* plants incorporating steam and power production and more sophisticated air pollution control equipment; however, the suggestion that the European plants are problem-free is completely contrary to the facts. Boiler maintenance is a serious problem in many plants [2], some plants exclude certain types of refuse which have been found to be trouble-makers,

and the increasing heating value of the refuse is forcing a reduction in capacity of even some of the newest plants.

Assuming that all technical problems could be overcome, the question of whether to include steam and power production facilities in an incinerator would be still primarily one of economics. For example, Chicago, Illinois, and Washington, D.C., will shortly build new, modern large incinerators. Exhaustive economic studies were made in both instances, and as the result of the findings, the Chicago plant will include steam and power production, but the Washington plant will not. In Europe, the fact that power, district heating, and incineration are all municipal utilities in many instances introduces a consideration that would seldom apply here.

Without question, the total cost of acquiring all the information we need will be high, although it would seem that much should be obtainable at relatively modest cost. Increased federal and state grants for practical research in the field is probably part of the answer; it is to be hoped, however, that the results of such research will be released more promptly than has sometimes been the case to date.

An objective, detailed study of European practices, problems, and solutions would yield a wealth of information. Equipment manufacturers should spend the money necessary to acquire dependable design data for equipment for which there is, too often, no factual backup for extravagant claims. But in addition to these, there is a mass of valuable information awaiting only the cooperative effort of those most closely associated with the problem — plant operators, designers and other engineers, health department personnel, and the like — to make it available at modest cost. Test ports and other openings can readily be included in original construction or added to existing plants to permit observation and record of conditions inside an incinerator. Liquid wastes from various points can be sampled and analyzed. Samples of refractories and other materials used in incinerator construction can be placed in strategic locations to permit observation of their action under varying conditions of temperature, moisture, and gas composition. There are many other possibilities.

The author has presented the problems facing us. A cooperative effort on all levels is necessary to find the solutions.

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DISCUSSION by W. M. Harrington, Jr., Whitman, Requardt & Assoc.

The author has effectively detailed the areas of design where additional information must be obtained if incinerator technology is to continue its present accelerated rate of development. The most effective way to gain this information is to have plants designed and constructed so they can be tested and operated to determine the effect of new ideas. Unfortunately, small scale laboratory models have limited value in indicating the results which can be expected with full scale equipment.

I believe it is important when considering a paper such as this to avoid the negative idea that efficient incinerators cannot be designed and constructed. Incinerator technology has made rapid advances in the last three to five years and knowledgeable designers can now provide facilities engineered to allow many years of efficient and nuisance-free operation. Of course, just as with any other mechanical facility, the operating personnel and management must meet their obligation by properly maintaining and operating the facility throughout its life.

Two major points are, in my opinion, stressed in this paper. First, it is necessary for the designer of a modern incinerator to have the knowledge and experience necessary to recognize and handle areas where refined design data will provide flexibility in his design to allow for variations in the consistency of the waste and increases in its heat content. Usually, he will also provide a facility capability to accept some of the new concepts being considered. For example, controlling the quantity and location of the various points of introduction of combustion air can be included in the basic design for very little additional cost, but may assure added years of efficient plant operation. There are many similar considerations which should be made throughout the combustion system design.

The second Major point which we must all recognize is the need to continue developing the technology to the point where a modern incinerator will be accepted as the well-engineered, properly-operated, nuisance-free public service facility necessary to protect all aspects of our environment subject to the deleterious effects of mismanaged solid wastes systems.

DISCUSSION by Frank L. Heaney, Camp, Dresser & McKee, Boston, Mass.

The reasons why incinerator design is such a puzzlement are indicative of deep underlying factors in public works administration. High in the list of such factors should come the extreme difficulty of assuring competent supervision during operation. Power plant operation often has been cited as free of many of the incinerator plant difficulties, mainly because of

licensing, higher wages and hence a much more dependable operating staff. The designing engineer needs not only to include this consideration in his design but to do all he can to make it a requirement.

One of the chief reasons for difficulty, of course, is the widely varying characteristics of the fuel. For example, our present allowances in this office are from 2500 to 7500 Btu lb. Moisture contents, at times, approach practicable limits of combustion. Troublesome chemical compounds further complicate corrosion and slagging problems. It may well be that the designing engineer must pay more attention to the total concept; that is, the drafting and enforcement of ordinances which would assure more control in the handling and collection of the solid wastes. Requirements for covered containers, control, and if necessary, exclusion, of troublesome commercial and industrial wastes, would aid greatly in the overall operation of the incinerator.

It is difficult indeed for a designing engineer to design anything as complex as an incinerator unless he is permitted some voice in attempting to control the conditions under which it must operate. Of the many facets of the solid wastes problem, administration may take top rank as the real enigma.

DISCUSSION by William T. Clark, Day & Zimmerman, Inc., Philadelphia, Pa.

I find that you have carefully covered in a well presented manner the problems involved in the design of large municipal incinerators. It would be very difficult to add to the specific comments regarding the design of incinerators. However, although it is beyond the scope of the title of this paper, I believe that it would be well to stress the need for adequate plant supervision and maintenance by the owners following the construction of new incinerator facilities.

You have indicated that the desing of modern incinerators has advanced far beyond the stage of providing an enclosure designed to contain a fire. Unfortunately, many of the modern incinerator plants have not advanced their plant personnel and management requirements to a degree comparable with the advancement in design of the modern incinerator plant. Incinerator plant owners should be fully advised of the need to obtain highly educated and experienced personnel who are capable of evaluating the combustion conditions, complex instrumentation and need for continuous plant preventative maintenance. The failure of the plant owners to provide adequate operating personnel and adequate maintenance budgets can result in the failure of what would otherwise be an acceptable plant design. Although plant operation is not specifically a phase of incinerator design, it certainly can influence the results of the design engineer's work.