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Proceedings of the International Conference on European Waste-to-Energy Technology

October 29-31, 1980

Reston, Virginia

ARGONNE NATIONAL LABORATORY
Energy and Environmental Systems Division

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PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON EUROPEAN WASTE-TO-ENERGY TECHNOLOGY

October 29-31, 1980
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U.S. Department of Energy
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FOREWORD

These proceedings document presentations given at the International Conference on European Waste-to-Energy Technology held October 29-31, 1980, in Reston, Virginia. The conference, sponsored by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA), provided major European designers of waste-to-energy systems with the opportunity to share their technology with an interested American audience.

Managers of European community waste-to-energy plants described their plants and discussed their planning and implementation problems, including site selection, construction, and other operating experiences. In addition, the results of extensive studies made by the DOE and EPA on European waste-to-energy efforts were presented.

The conference concluded with a panel discussion that included representatives from the European systems, the DOE, and the EPA. As well as providing a summary of the information presented, the panel discussion facilitated an informative interchange between those attending and the speakers.

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SESSION I: POLICY OVERVIEW

Moderator: Charlotte Rines (DOE)

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"EUROPEAN AND AMERICAN EXPERIENCES - A POINT OF VIEW."*

Henri-Claude Bailly

Hagler, Bailly & Company
Washington, D.C. 20006, U.S.A.

I hope to convince you today that international cooperation and exchanges dealing with rubbish are worthwhile! Much has been written, and much more has been said, about the fact that Europeans are far ahead of their American counterparts in the recovery of energy through the combustion of municipal solid waste. While there were 23 waste-to-energy-systems operating in the United States in 1979** (Exhibit 1), more than 180 plants

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[*] The author, President of Hagler, Bailly & Company, wishes to express appreciation to the numerous individuals and organizations who provided helpful information, advice, and comment. The following are owed special thanks: Donald K. Walter and Charlotte Rines of the U.S. Department of Energy who, over the past 3 years, have sponsored the study of the European experience; Phillippe Delmas of the French Ecole Nationale d'Administration; Francoise Paublant of RPA SA (Paris); Phillippe Mondan, formerly with RPA SA; and Jean-Louis Poirier and Gerald Schwinn of Hagler, Bailly & Company.

[**] According to a national survey by EPA[1] there were 23 operating waste-to-energy systems in the United States in 1979 with the capacity to process nearly 15,000 tons of municipal solid waste (MSW) per day. By adding the number of current operating units and those under construction, and assuming the completion of all planned units with a project starting date, we can project the operation by 1983 of a total of 51 systems processing 46,500 tons of MSW/day. An additional four planned units that have no firm starting date will be able to process an additional 5,600 tons of MSW/day.

1979	23 units	14,413 tons MSW/day
1983	51 units	46,524 tons MSW/day
1984+	55 units	52,225 tons MSW/day

[1] U.S. Environmental Protection Agency, <u>Resource Recovery and Waste Reduction Activities: a Nationwide Survey</u> (SW-432 November, 1979.

are currently recovering energy from municipal solid waste in Western Europe (Exhibit 2). Some European countries recover energy from more than 50 percent of their municipal waste stream, compared with slightly more than 2 percent in the United States (Exhibit 3).

When one compares the European and American experiences, two interesting questions come immediately to mind. First, what forces were present in Europe during the post World War II era that can explain the rapid development of waste-to-energy systems? Second, what conclusion can be drawn for the development of waste-to-energy systems in the United States? In the rest of my presentation, I will attempt to answer these two questions by drawing a parallel between the market forces active in the United States and Europe in the postwar era and the forces that have emerged since the mid-1970s.

Over the past 10 years I have read -- and heard -- many statements that attempted to explain why waste-to-energy systems developed at different rates in Europe and the United States. One reason forwarded in the early days was that U.S. concerns -- corrosion problems, pollution control, the heating value of waste -- required a different technology from that used in Europe. Hence, the delay. I would like to remind you that similar problems existed in the early 1960s in Europe, and yet did not stop the growth of waste-to-energy systems there. We are likely to hear much more on some of these issues from European manufacturers of such systems and their American licensees over the next 2 days. Another reason for the different development rates was the absence of a U.S. waste-to-energy industry and therefore the need to import technology. As it happens, the countries that manufacture 85 percent of the grates installed in Europe -- West Germany with Martin and VKW, Switzerland with Von Roll, Denmark with Brunn & Sorenson and Volund -- are also among the leading countries in terms of total installed capacity or relative capacity per capita (Exhibit 4). All the same, several countries -- France, Sweden, and the Netherlands -- have not hesitated to use imported technology. Although I concede that the transfer of technology might be easier to effect among European countries than between Western Europe and this country, the absence of a major U.S. grate manufacturer does not explain the lack of penetration of waste-to-energy systems in the U.S. market.

As people ran out of technological and industrial organization arguments, they started to advance institutional ones -- European business patterns are different from U.S. patterns; the decisionmaking time frame in Europe is much shorter; U.S. financial instruments are inadequate. In my mind, none of these specific institutional factors is a key determinant, although I am sure that examples can be found in support of each.

If none of the above arguments contain the key to understanding the U.S.-European differences, where does the answer lie?

In the course of the last decade, I have distilled my experience into a explanation. To put my point of view in perspective, let me share with you my overall conclusions. I should emphasize that these conclusions are not the result of some scientific (by scientific, I mean precise and systematic) comparative analysis. Rather, they are the product of nearly 10 years of consulting to public- and private- sector clients both here and in Europe.

In several European countries in the 1960s and early 1970s, three primary forces were at work with respect to waste management:

> First, landfilling was not perceived as a viable waste management alternative by most municipal government decisionmakers
>
> Second, cost and other financial considerations were seldom an issue when making decisions on waste management
>
> Third, once the municipality made the decision to incinerate, energy recovery was the logical next step.

Today, however these forces are no longer converging in Europe to stimulate the market. The market for large systems, in general the most economical, is saturated. Fiscal austerity is becoming as important to European governments as it is to U.S. governments. The boom era has subsided. The United States represents the only remaining large potential market for waste-to-energy recovery systems. Nonetheless, it remains to be seen whether the emerging U.S. economic and institutional forces will stimulate the full development of such systems.

Returning to my first conclusion -- that landfilling was not perceived as a viable waste management alternative by European decisionmakers -- I believe that three factors converged to shape this attitude:

> First a general lack of landfill space in the vicinity of the municipality

Second, a lack of active government support for this technique, and

Finally, a lack of engineering and political appeal.

I have reviewed the 8 case studies that I directed for the Department of Energy in 1978 and 1979 (then Energy Research and Development Administration (ERDA)), as well as the 16 case studies prepared by Battelle for the Environmental Protection Agency (EPA) (Exhibit 5). The lack of landfill space within the municipality's jurisdiction was cited most often by the municipal government officials interviewed as the primary reason for selecting incineration. The need to go beyond town limits to acquire landfill space created political problems that they preferred to avoid.

The second factor pertains to the government's attitude toward landfilling. European central governments generally adopted a neutral position toward landfilling while "underwriting" incineration and composting. For example, the French government subsidized incineration (which is not synonymous with waste-to-energy) in the early 1960s, whereas no subsidies for sanitary landfills were available before 1975. Government guidelines, regulations, and research generally emphasized incineration with and without heat recovery and composting, thus legitimizing these techniques in the eyes of the decisionmakers. For example, the French government published extensive guidelines (Cahiers des Charges) in the Journal Officiel (the Federal Register equivalent) on incineration and compost nearly 12 months before simple guidelines were issued for landfilling. The first design and operating guidelines for landfills were only published by the French government earlier this year.

In addition to the previous two factors, it is clear that incineration provided unique engineering and political appeal that no other waste disposal method could parallel. Incineration was considered modern, effective, and efficient as opposed to the old-fashioned, unsophisticated, unhygienic land disposal technique. Indeed, incineration was seen as the ultimate engineering solution to the eradication of pestilence, which was the ultimate objective of waste management. Some plants (e.g., Ivry, France and Munich, West Germany), became engineering showcases if not tourist attractions. Several of them even publish brochures in foreign languages for their visitors. The volume of articles on resource recovery published in technical journals in Europe far exceeded those on landfilling techniques. Furthermore, for political reasons (and we will see later, for financial reasons too) municipal councils often preferred subsidized investments to non-subsidized investments, even if this demanded a larger financial contribution from the municipality. Getting something "free" was -- and is -- considered a good test of a mayor's performance in Europe. And, to quote one high European government official, "one does not dedicate a landfill!"

Landfill might have been a "dirty" word in Europe in the 1960s, but people got pretty fired up about incineration in the United States. As the country embarked on a large-scale environmental clean-up that focused, at first, on air pollution, incineration became a burning issue. The Clean Air Act, for instance, was passed in 1963, 2 years before the passage of the Solid Waste Disposal Act. During this period, the Public Health Service and EPA actively promoted sanitary landfilling as an innovative approach to incineration and open dumps, emphasizing the cost-effectiveness -- and reliability -- of this technique. Sanitary landfill design and operation guidelines were published in the United States in the same year as the French issued their guidelines for incineration. Without a doubt, this country did not face a shortage of land for waste disposal nearly as acute as most industrialized European countries.

At the same time as landfill was being promoted, a large-scale experimental effort focused on high technology solutions was launched in the United States to recover material and/or energy from the municipal waste stream. Cities like Franklin, Ohio and Baltimore, Maryland became as well known in Europe as Ivry and Munich were known here. European city engineers looked with envy at these high technology experiments. Unfortunately for the United States, this new generation of technologies did not meet its planners' expectations. What it did do was prove that sanitary landfilling was substantially less expensive and more reliable, in other words less risky, and that the European waste-to-energy recovery technology was superior.

This difference in perception between the Europeans and their American counterparts is accentuated by another very important point -- that cost and other financial considerations were seldom an issue for the Europeans. I believe that two factors go far toward explaining this attitude.

First, plenty of cheap money was available for waste treatment facilities; and second, municipal financing practices favored capital-intensive investment decisions. Let me expand now on these two factors, using France and West Germany as examples.

France is said to be one of the most "centralized" countries of the nonsocialist developed world. Although I believe that such a statement oversimplifies intergovernmental relationships, it is true that the central government plays a key role in manipulating the "demand" as well as the "supply" of public expenditures for waste disposal. In France, there is a complete dichotomy between public investment expenditures and public operating expenditures. This separation applies both to the sources of finance and to the decisionmaking processes. It is one thing to have a waste-to-energy system built, but quite another to get the budget to run it. Let us focus on the capital expenditure side of this problem.

It is the responsibility of local governments to undertake capital expenditures in waste management. But because local governments are generally too poor to finance these investments, they seek assistance from the central government. Two points are important in this respect. First, central government decisions on subsidies and loans are made on an investment-by-investment basis; and, second, loans are usually automatically granted once a central government subsidy is obtained.

The loan is usually granted by the Caisse des Dépôts et Consignations, which serves as banker and -- through its many subsidiaries -- as technical advisor to local governments. Although local governments are no longer prevented from borrowing on financial markets, interest rates are higher and central government authorization is necessary for important bond issues. The fact that subsidy means loan, which means investment, also explains the municipal councils' preference for a capital-intensive, but subsidized investment, even if it entails a large financial contribution from the municipality.*

To my knowledge, every system that has been built in France received large subsidies from the central government. These subsidies ranged from 10 percent to as much as 80 percent of the total investment (Exhibit 6). During the mid-1960s and 1970s, I estimate that the central government disbursed between $75 and $100 million (in today's dollars) in subsidies for waste treatment facilities. These expenditures were part of the public hygiene budget (Crédits à l' Assainissement) which grew more quickly than any other central government assistance program between 1965 and 1975. Thus, by allocating a large budget for subsidies, the central government controlled the supply of public investments in waste disposal facilities, and by manipulating the rate of subsidy, it controlled the demand.

In addition to the availability of cheap money, the budgeting process was also an important factor in the European attitude toward financing waste management. Each November in France, municipalities must submit their budgets for approval to the Prefect who heads a regional jurisdictional entity called a Département**. As a result of this process, municipalities

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* Refer to Rémy Prud'homme "France: Central-Government Control over Public Investment Expenditures" in Political Economy of Fiscal Federation, edited by Wallace E. Oates, Lexington Books, 1977; and A Study of the Financial Practices of Governments in Metropolitan Areas, Office of International Affairs, U.S. Department of Housing and Urban Development, 1973.

**The prefect is appointed by the Prime Minister, on the advice of the Ministry of the Interior. There are 95 Départements in France, including 5 for the Paris metropolitan area.

have been required to undertake specific public investments that were deemed by the higher auhtorities to be in the public good. Once a project and its financing plan have been approved by the Prefect and other relevant authorities, the municipality is absolved from any cost overruns or difficulties in loan repayments. Although many local government officials complain bitterly about central government controls (especially the municipalities that are run by political parties not belonging to the ruling party), my conclusion is that, in general, they happily accept them. For instance, local officials recently opposed government initiatives to decentralize financial procedures. Clearly, local government officials prefer to share the political and financial risks of the investments with higher authorities, who can serve as a scapegoat if the project does not meet expectations. To sum up, in the case of waste management projects in France, the central government proposes, and the local government disposes!

In West Germany, on the other hand, the government is much more decentralized than in France. For one thing, West Germany has a federal structure like that of the United States. Controls over local government expenditures are generally excercised through the State (The "Lander") rather than by the central government (the "Bund").* How, then, did financial practices affect investments in waste-to-energy systems?

---

* The Federal Republic of Germany is divided into eight states that have varied structures of local governments; some have elected mayors, and some have appointed mayors, a collegiate executive, or a chief executive officer. There is a clear distinction made between the professional politician and the professional administrator.

As in France, local governments in West Germany are responsible for waste management. In the 1960s (especially in the latter part of the decade) several municipalities financed waste-to-energy systems out of their revenues. As a result of the German economic boom, municipalities were growing richer and were thus more able to make investments in public projects. In addition, local governments in West Germany enjoy several revenue-raising advantages. As well as having broad powers of taxation (as compared, for example, with French municipalities), they can impose charges on users of their services (e.g., for waste management) to help offset municipality costs.* In the 1970s, the Landers provided extensive financial support to local governments in the form of grants and low-interest loans. Generally, the municipality financed less than one-third of the waste-to-energy systems on its own. For example, the city of Landshut received subsidies from the Lande of Bavaria equal to 21 percent of the total capital cost; nearly 61 percent of its third furnace (yet to be built) will be subsidized by the Lande.**

The French and West German examples indicate that European municipalities generally had easy access to money for waste-to-energy facility investments.† Their direct and non-subsidized financial contribution to such

---

* The regional reform (Gebietsreform) that took place between 1969 and 1972 also led to the administrative integration of small municipal units into larger and more efficient ones, thereby facilitating municipal financing.

**The Lande of Bavaria will also make a 15-year loan at 3.5 percent interest for 15 percent of the capital cost.

† The post-World War II period was one of extensive reconstruction, when many of the original incinerators that were destroyed during the war, for example, were rebuilt.

projects was usually low, and they used outright grants to finance much of the facility (Exhibit 7). It is interesting that in the United Kingdom, one industrialized European country that did not subsidize waste-to-energy systems, the penetration of such systems has been very low. Landfilling represents 87 percent of U.K. waste disposal and no incinerator has been built in the past 10 years.*

During the same period in the United States, the situation was quite different. For one thing, the U.S. government did not attempt to control the supply of waste-to-energy systems; for another, local governments in the United States enjoy more independence and thus expose local taxpayers and local politicians to more risk than their European counterparts.

The relatively low level of investment in waste-to-energy systems in the late 1960s and early 1970s cannot be attributed to the inadequacy of the financing instruments. On the contrary, I believe that traditional U.S. municipal finance sources were adequate for obtaining solid waste investment capital. In fact, solid waste projects have generally enjoyed a greater number of financing options, e.g., revenue bonds and private financing, than other municipal programs for which such instruments cannot be used.

The availability of financing mechanisms did not, however, influence the existing municipal priorities and capital allocation processes. Without a doubt, solid waste disposal in general, and waste-to-energy in particular,

---

* Waste Disposal Authorities in England estimate that in 1977/1978 only 12 percent of the municipal waste was incinerated, at an average cost of £12.23 per ton versus £2.70 for landfilling.

occupied a low position in the list of municipal investment priorities. Financially speaking, the attitude might be described as embracing the principle of "waste not, want not." The federal government did not attempt to change these priorities. By 1975, it had spent only $15 million (in today's dollars) on grants for waste-to-energy systems, a level substantially below that of Western Europe for the same period.

Moreover, because U.S. municipalities operate much more independently than their European counterparts, they are also more conservative; a U.S. community, for instance, can technically be bankrupt. In addition, citizens are often directly involved in financing decisions, e.g., through voter approval of any sizeable bond offerings, which seldom occurs in Europe. Finally, this conservatism is reinforced by a limited ability to evaluate technically complex projects. In Europe, municipalities generally have access to a central development bank, which caters not only to their credit needs but to their technical assistance needs as well.

I am convinced that these two factors -- attitudes toward landfilling, and financing practices -- played a major role in promoting incineration in Europe. Once the decision to incinerate was made, the next logical step was to recover the energy. The reason for this decision was twofold. First, it had always been the appropriate decision from an engineering and planning point of view. Second, it tended to lower the cost of incineration.

From an engineering point of view, utilizing combustion energy was more satisfying than getting rid of it, as energy recovery was synonymous with sound energy management and also helped to control air pollution. From a planning point of view, the production of energy through energy recovery was in line with the type of activities that European municipalities have traditionally supported. Most European municipalities that considered waste-to-energy were either in the energy business already or had good reason to get involved. For instance, in 20 out of 23 cases, municipalities were attracted by the opportunity to use recovered energy to produce steam and electricity to serve the energy needs of their communities. In several cases, this can be explained by the fact that district heating in Europe has traditionally been largely a municipal business, especially in growing and/or new towns. That is to say, European municipal governments consider the delivery of energy services to be part of the overall service that they must provide to their constituency. This is why, in Denmark, the Netherlands, and West Germany combined, more than 90 percent of the waste-to-energy systems were installed in municipalities involved in the energy business (Exhibit 8). Of course, these countries have a long history of municipality involvement in waste-to-energy: in the case of Hamburg, (West Germany), for example, more than 85 years; Copenhagen, (Denmark), more than 45 years; Toulouse, (France), more than 55 years.

In addition to its appropriateness in terms of engineering and planning, waste-to-energy was a logical step from an economic point of view. The investment of capital to finance a waste-heat recovery system was at worst, self-sustaining, and at best, profitable. For example, our analysis of several French cases has indicated that return on investment on the incremental capital cost associated with the waste-heat recovery system ranged between 14 and 24 percent in most instances. In contrast, the average cost of capital for a French municipality was less than 6 percent! With such financial performance, it was logical for the waste-to-energy route to be viewed by European communities as an attractive way to reduce the cost of incineration. Or to put it another way, energy recovery from incineration was one way of preventing the taxpayers' money from going up in smoke. We found, for example, that in 1975 most French waste-to-energy systems were offsetting between 40 and 60 percent of the cost of incineration (Exhibit 9); in 1970, it was only 20 percent (Exhibit 10).* We observed similar cost evolution patterns in West Germany, Denmark, and the Netherlands during the same period.

Thus, we have seen three primary forces at work in Europe in the 1960s and early 1970s -- forces that did not exist in the United States:

- the perception that landfills were not the proper way to dispose of waste
- the fact that cost and other financial considerations were seldom an issue
- and the fact that waste-to-energy was logical for the municipality.

During the same period, on this side of the Atlantic, a number of factors acted to retard the use of waste-to-energy systems: the availability of land,

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* In Paris, for example, waste disposal costs have gradually decreased as energy costs have risen. Disposal costs were 65 francs last year, will be 60 francs this year, and are projected at 58 francs next year.

conservative financial management, and general reluctance on the part of municipalities to enter (or reenter) the energy business. The Americans, as it were, chose to bury the issue of waste-to-energy recovery.

However, the European and American situations are beginning to change. In Europe, while the market is not wasting away, the number of systems entering service has declined drastically in the last few years. This is because many municipalities that would be required to support large plants already have a system in place. The small end of the market, outside Denmark and the Netherlands, is developing slowly, with several countries now promoting sanitary landfill options for this segment of the market.

The French and West German governments, for example, recommend landfills for municipalities of less than 30,000. And in 1975, the French government adopted a policy to support systems only for municipalities with an established district heating potential, thus excluding municipalities of less than 150,000.

In Sweden, the government no longer favors the construction of waste-to-energy systems because of acid rain fallout. In Italy, the Ministry of Environment publicly acknowledges that the development of waste-to-energy systems is being blocked by pollution-related problems. There, at least, incineration has become a soot point. Across the continent, Europeans are reassessing their waste management options, especially for the lower end of the market.*

---

* There seems to be a renewed interest in Europe in material recovery from waste as well as methane recovery from landfills.

Moreover, the overall state of the European economy has tended to make cost and other financial considerations more important.* Decentralized budgeting procedures and "revenue sharing programs" increasingly require trade-offs at the local and regional levels.** At the same time, waste-to-energy systems are becoming increasingly costly to build and operate, given the dramatic rise in labor costs in many countries over the past 5 years.

In the United States, however, several factors are kindling enthusiasm for incineration waste-to-energy systems.

- Sanitary landfill is becoming increasingly expensive as regulations become increasingly stringent

- energy prices are making the systems more attractive, especially at the upper end of the market (it is just a matter of time before energy prices equalize between the United States and Europe)

- waste-to-energy compares increasingly favorably with other alternatives (Exhibit 11)

---

* For example the French budget for Public Hygiene in 1980 was 80 percent of its 1970 level (in constant francs).

**For example, starting this year, each French municipality will receive an overall subsidy and will be responsible for assigning priority uses. A marked structural change in local-authority budgets has also occurred in West Germany since the early 1960s. In 1961, the current and capital budgets roughly balanced each other, but now the current budget accounts for two-thirds of the budget total. All in all, experts agree that investment strength has fallen considerably. (Refer to "Structural Change in Local Authority Budgets in the Federal Republic of Germany: a Comparison Between 1961 and 1977." In Local Finance, International Journal, April 1979, Volume 8, Number 2.)

- The shakedown of the first systems has taken place, and U.S. industry has thus been able to upgrade the new systems' reliability

- finally, the financial conservatism of U.S. municipalities is becoming less of an obstacle with the passage of new legislation such as the "Energy Security Act," which will provide loan and price support guarantees for waste-to-energy projects.

Hagler, Bailly & Company estimates that between 1980 and 1995, the economically feasible market for waste-to-energy systems in the United States will increase from a total installed capacity of 15,000 tons per day to approximately 190,000 tons. In other words, energy could be economically recovered in 1995 from approximately one-quarter of the total municipal waste stream.*

The nation's watchword for the 1980s -- and beyond -- might well be:

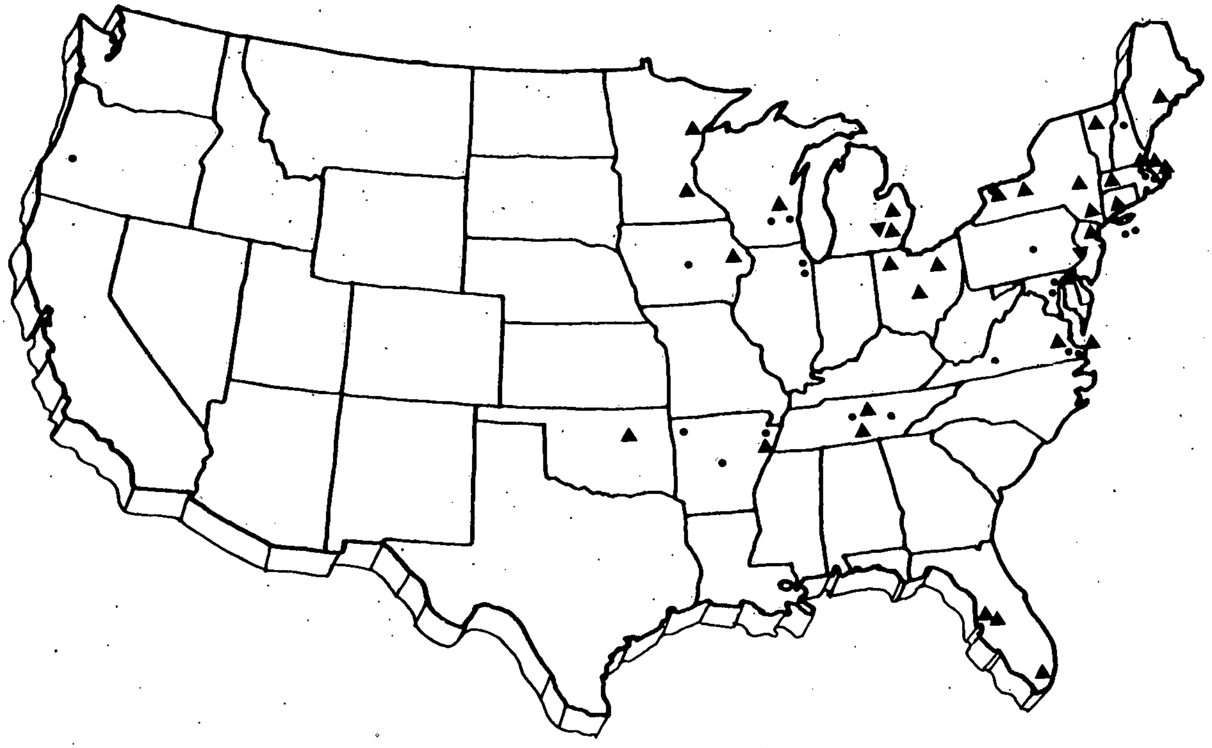
> **There is no reason to assume that we will stop using energy to produce rubbish; but let's start using rubbish to produce energy.**

---

* These estimates are based on a comprehensive market analysis using market segmentation by region and by type of equipment. The technically feasible market was evaluated at 56 percent of the total potential waste stream in 1995 (approximately 200 million tons). Institutional factors or the latest provisions of the federal regulations were not taken into account in the calculation of the economically feasible market.

Exhibit 1

U.S. Waste-to-Energy Systems (in operation, under construction, or planned [1979])



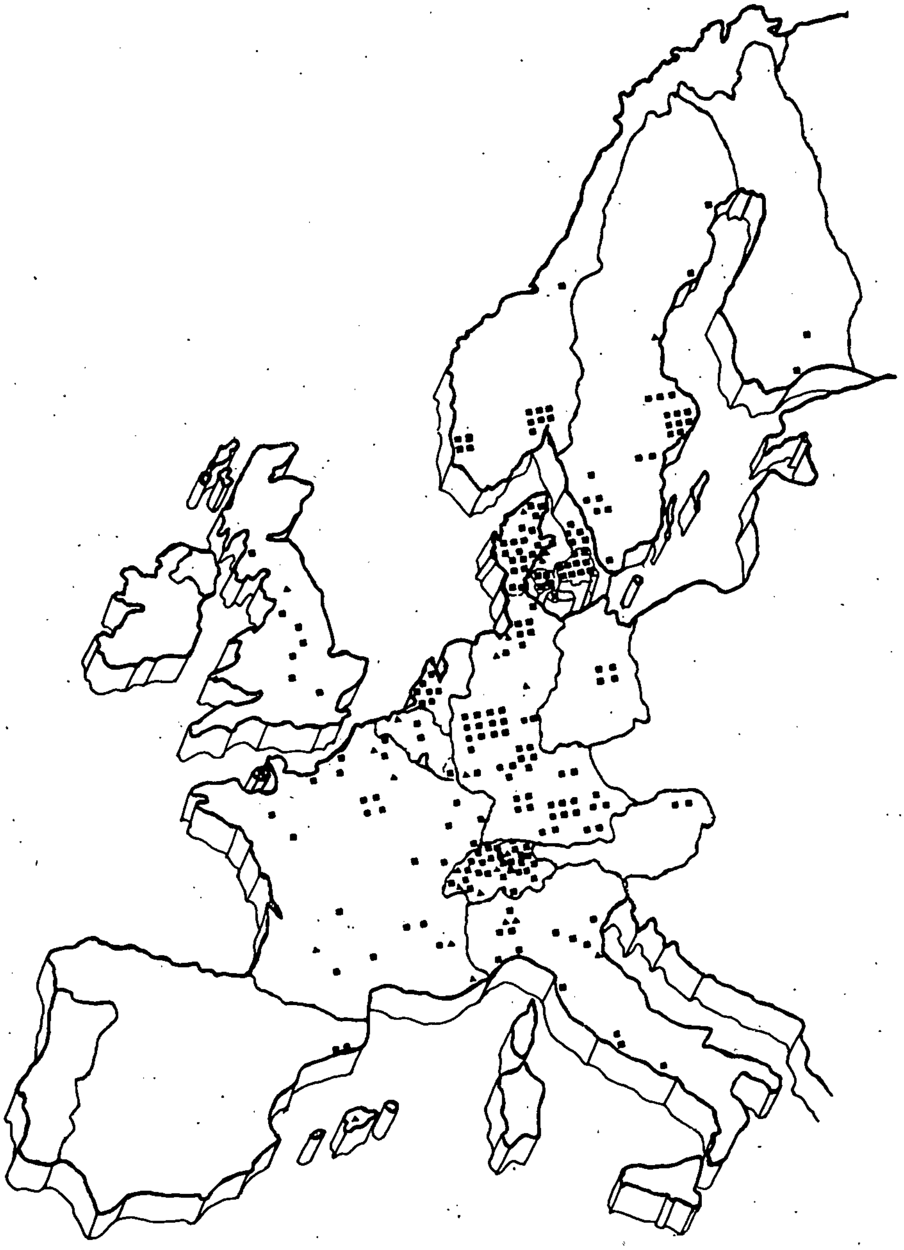
▲ under construction or planned (32)

• in operation (23)

Source: Resource Recovery and Waste Reduction Activities, A Nation Wide Survey, U. S. Environmental Protection Agency, November 1979

Exhibit 2

European Waste-to-Energy Systems (in operation, planned, or under construction [1977])



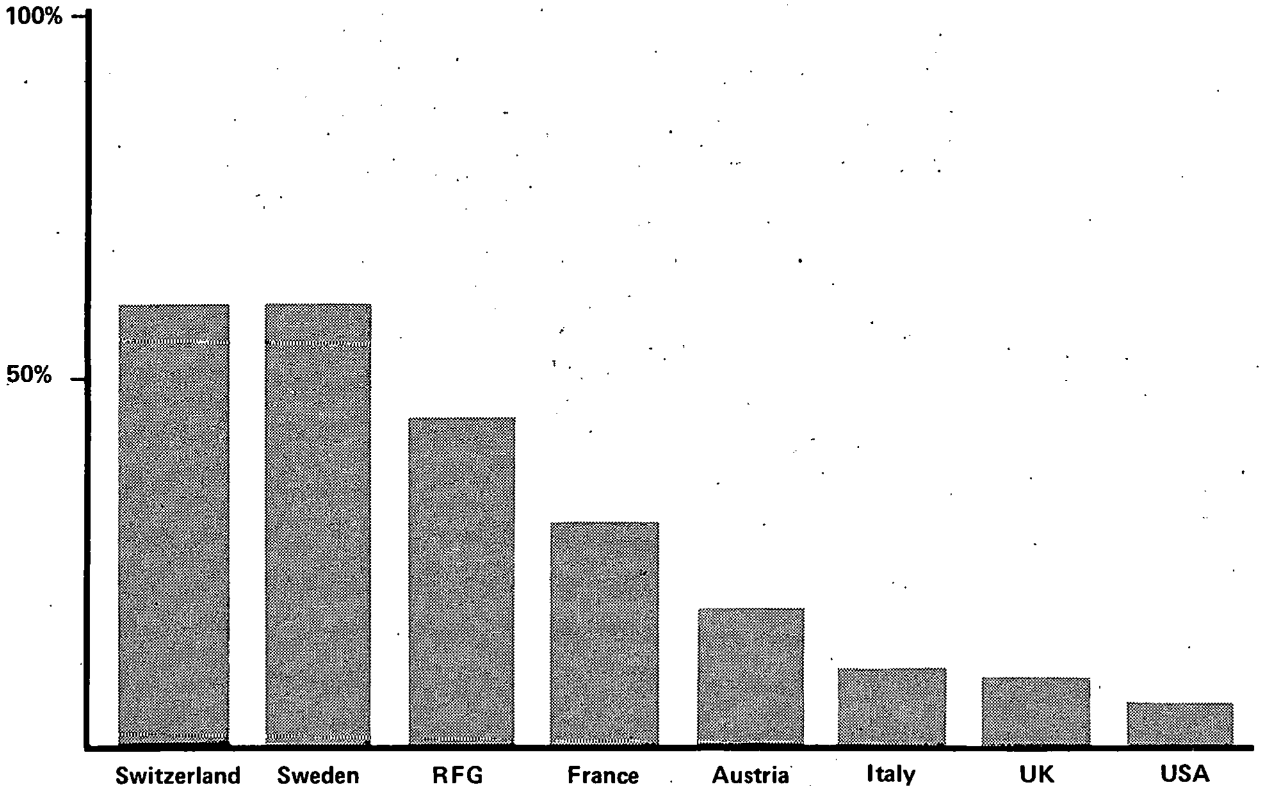
■ In Operation

▲ Under Construction or Planned

Source: European Waste-to-Energy Systems: An Overview,
U.S. Energy Research and Development Administration, June 1977

Exhibit 3

Municipal Waste-to-Energy Recovery as a Percentage of Total Waste Stream (1979)

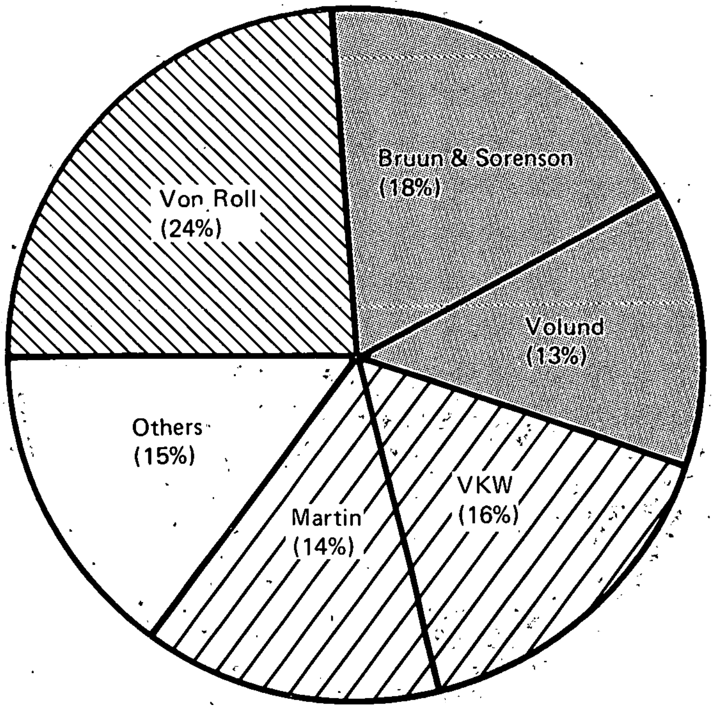


Sources:

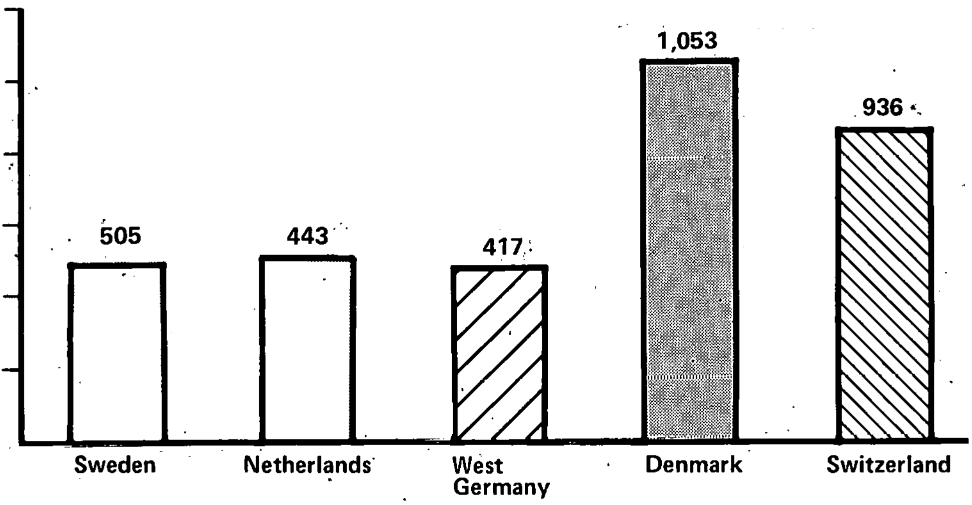
- European Waste-to-Energy Systems: An Overview. U.S. Energy Research and Development Administration, June 1977
- Resource Recovery and Waste Reduction Activities, A Nationwide Survey, U.S. Environmental Protection Agency, November 1979
- Hagler, Bailly & Company

Exhibit 4

Market Shares of Grate Manufacturers (as a percentage of total grates installed)



Installed Capacity per Capita (Pounds per year)



Source: European Waste-to-Energy Systems: An Overview.
U.S. Energy Research and Development Administration, June 1977

Exhibit 5

List of Case Studies

DOE	EPA
1. Kørsor, Denmark	1. Amager, Copenhagen, Denmark
2. Manchester, England	2. Korsens, Denmark
3. Brive, France	3. West Copenhagen, Denmark
4. Irvy-sur Seine, France	4. Deauville, France
5. Rennes, France	5. Dieppe, France
6. Geneva-Cheneviers, Switzerland	6. Issy-Les Moulineaux, Paris, France
7. Landshut, West Germany	7. The Hague, Netherlands
8. Munich, West Germany	8. Savanås, Gothenburg, Sweden
North 1a, 1b	9. Uppsala, Sweden
North II	10. Baden-Brugg, Turgi, Switzerland
South IV, V	11. Hagenholz, Zurich, Switzerland
	12. Werdenberg, Buchs, Switzerland
	13. Dusseldorf, West Germany
	14. Krefeld, West Germany
	15. Stellinger-Moor, Hamburg, West Germany
	16. Wuppertal, West Germany

Exhibit 6

Financing Structure of French Waste to Energy Systems (as percentage of total costs)

	Total Capital Cost (x 1,000 1980 dollars)	Sources of Funds (%)**		
		Central Government Subsidy	Caisse des Dépôts et Consignations	Banks
Toulouse-Le-Mirail 650/tpd				
Phase I (1969)*	$12,400	14	66 (5.25%-6.5%)	20 (8.75%)
Phase II (1975)*	6,100	9	91 (10.2%)	0
Brive (1975) 165/tpd	9,000	50	44 (7.8%)	6 (8.05%)
Rennes (1968) 265/tpd	8,600	30	70 (5.25%-7.0%)	0
Irvy-sur Seine (1969) 2,100/tpd	83,000	16	0	84 (5.25%-6.5%)

*Date put into operation

**Interest rates in parentheses

SOURCE: European Waste-to-Energy Case Studies, U.S. Energy Research and Development Administration and Department of Energy, 1977-1978.

Exhibit 7

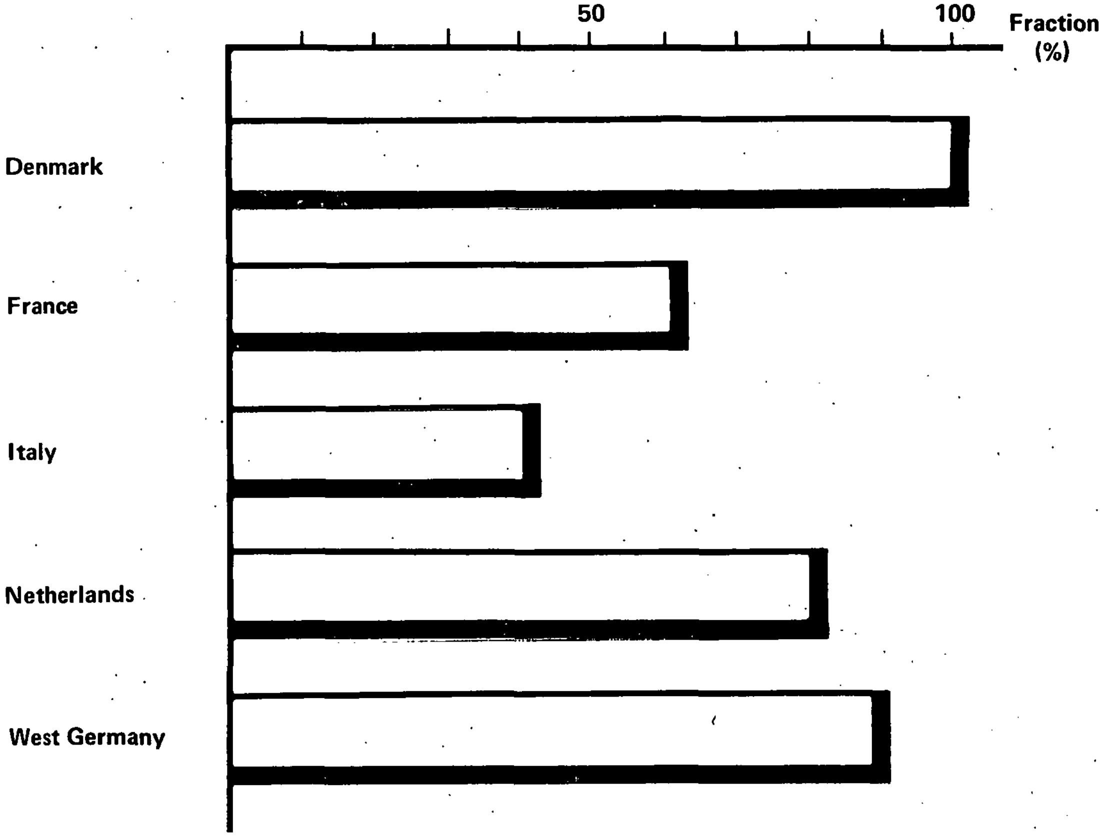
Typical Financing Structure of Waste-to-Energy Systems

Sources of Funds	France	West Germany
Government grants	20 percent	40 percent
Low-interest loans	60 percent	30 percent
Local government	20 percent	30 percent

SOURCE: Hagler, Bailly & Company

Exhibit 8

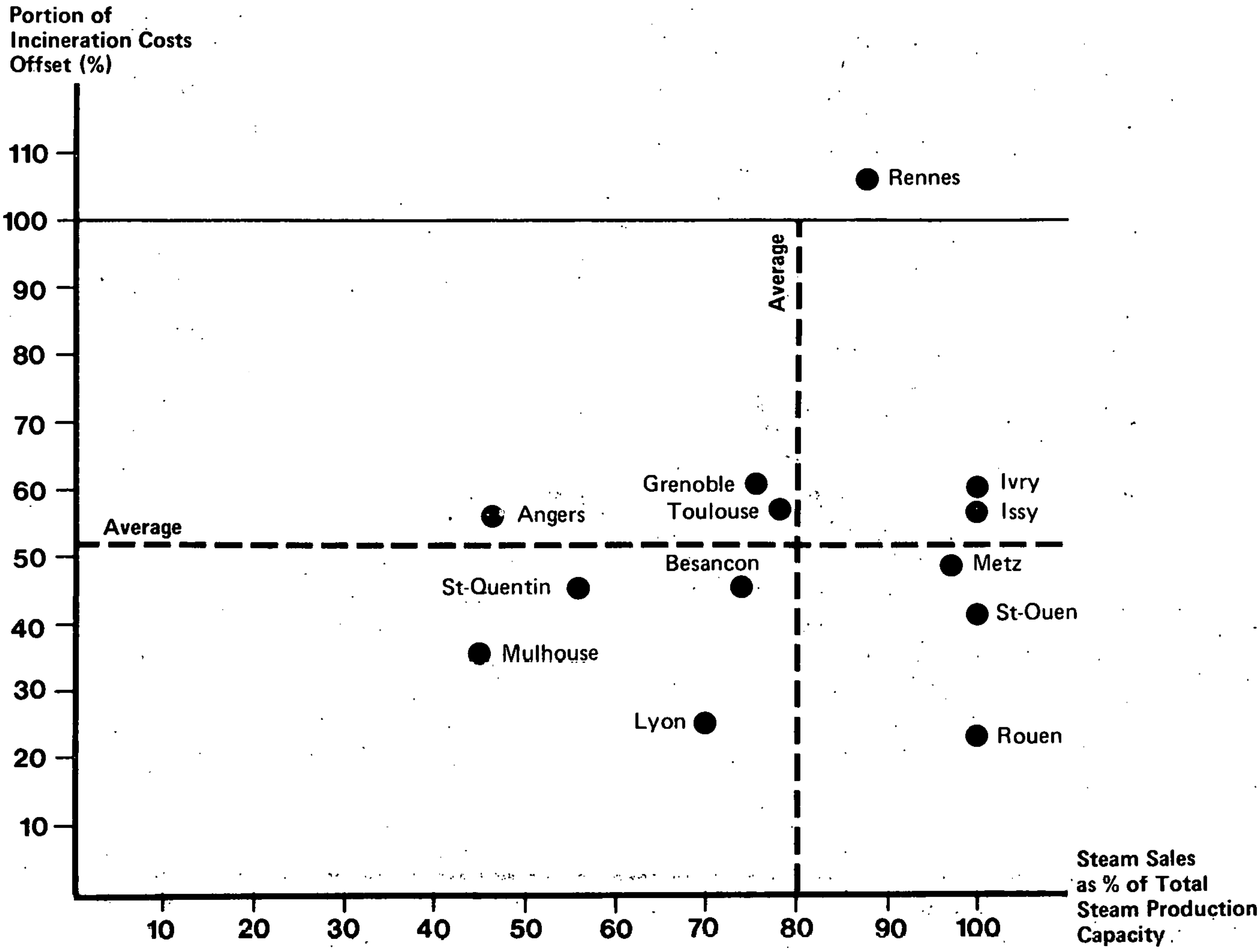
Fraction of Waste-to-Energy Systems Installed in Communities Already Involved in the Energy Business



Source: Hagler, Bailly & Company

Exhibit 9

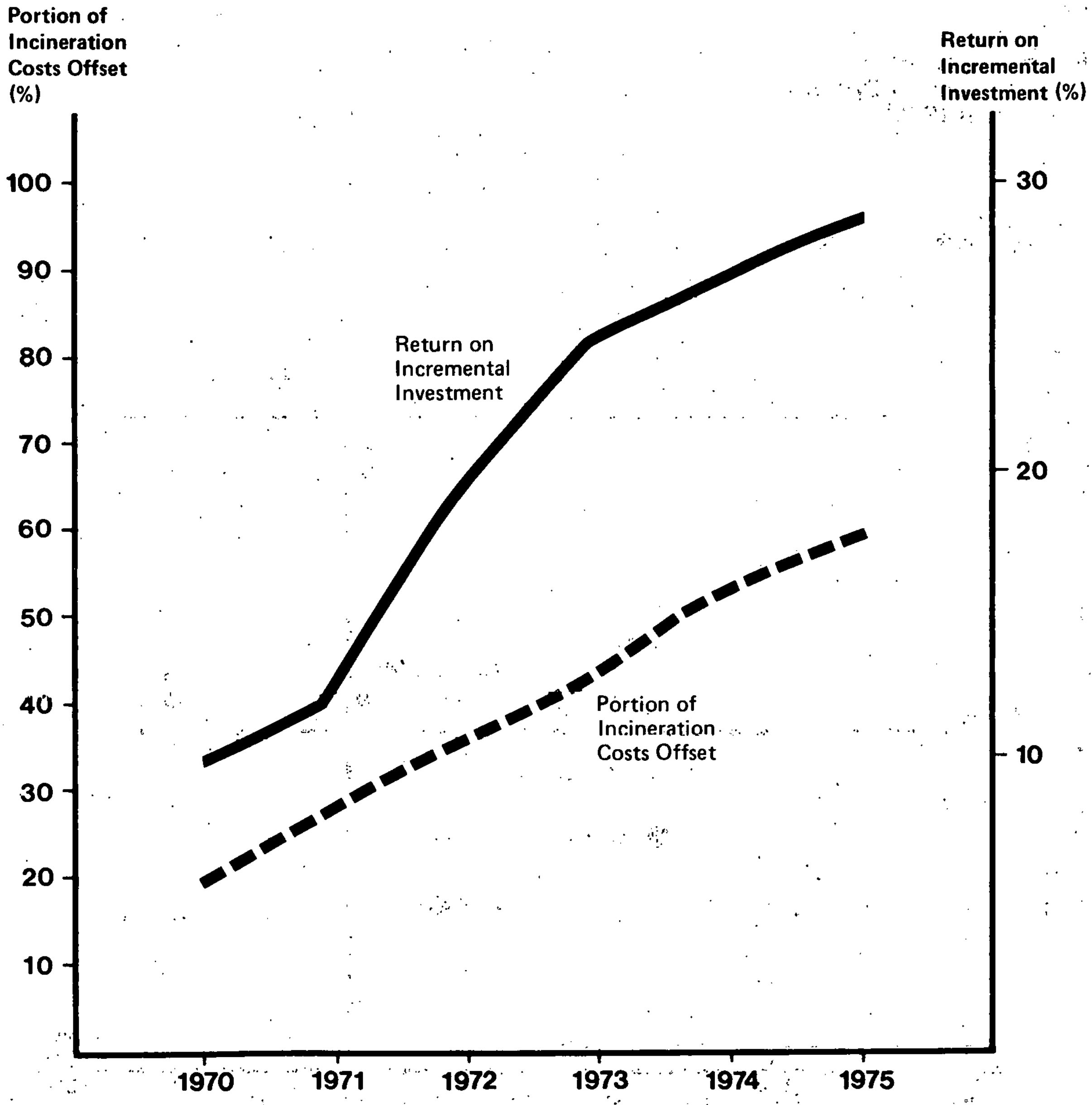
Financial Performance of Waste-to-Energy Systems in France (in 1975)



Source: Hagler, Bailly & Company

Exhibit 10

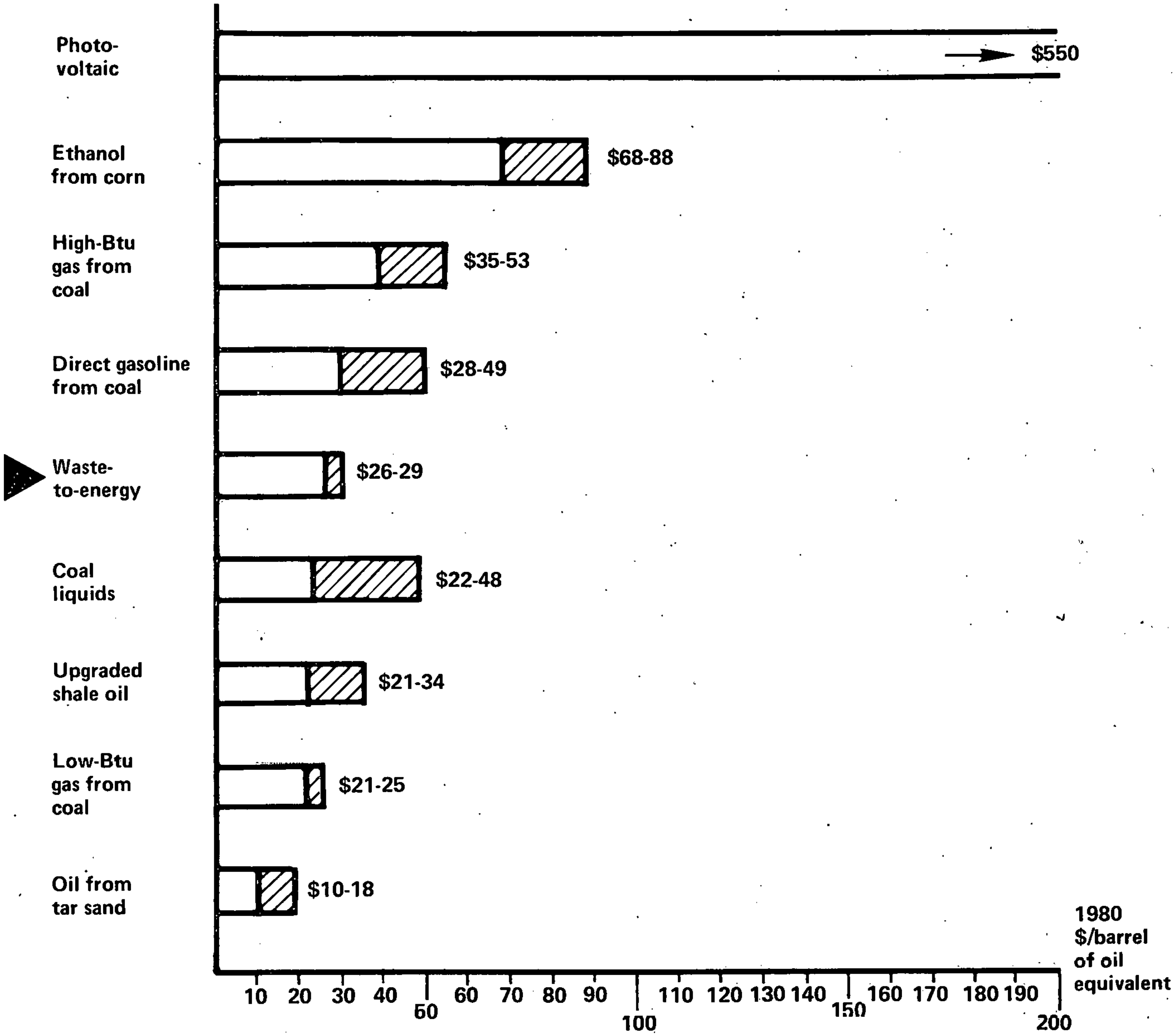
Performance of Waste-to-Energy Systems in France (between 1970 and 1975)



SOURCE: Hagler, Bailly & Company

Exhibit 11

Waste-to-Energy System Costs Versus Costs of Other Technologies



SOURCE: Hagler, Bailly & Company.

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EUROPEAN WASTE-TO-ENERGY KNOW-HOW

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ABSTRACT

This paper summarizes a two-volume evaluation of European refuse-fired energy systems design practices observed in visits in 1977 to fifteen (15) European refuse-fired steam- and hot-water generators.

A major impetus for the development of European waste-to-energy systems was the finding that it is possible to control air pollution from the burning of wastes if the dirty exhaust gases are partially cooled in a boiler. Concurrent with this influence was the disenchantment with old leaching landfills as a long-range solution to the solid waste problem in very crowded countries.

The major conclusion is that the mass-burning of unprepared municipal solid waste in heat recovery boilers is well established, and can be a technically reliable, environmentally acceptable and economic solution to the problem of disposal of solid wastes. When the cost is considered of upgrading current landfills and established new landfills, these mass burning waste-to-energy systems are expected to compare more economically with true sanitary landfills.

Many European areas are moving steadily in the direction of Energy and Environmental Parks that often include refuse burning, electricity production, sewage disposal, industrial waste processing and steam generation and hot-water district heating.

Many conditions in the U.S. have favored landfilling, hence waste-to-energy has not advanced as rapidly as in Europe, but we are moving rapidly toward minimal landfill site availability in most of our metropolitan areas. Hence the lessons that have been learned in 80 years of refuse-fired energy plant (RFEP) experience in Europe can be effectively utilized by many U.S. communities.

INTRODUCTION

For many reasons U.S. development of waste-to-energy systems has lagged behind that of Europe. This project was undertaken to assist American decision-makers and system designers in applying the European know-how to U.S. conditions.

This paper is presented to highlight the principal results from 15 trip reports and 4 evaluation volumes that we submitted to EPA in 1979 covering extensive visits during 1977 to 15 of the most advanced waste-to-energy plants in Europe.

It is a privilege to here summarize the combined know-how of hundreds of diligent developers in this field, many of whom were untiringly generous in answering the countless questions we had to pose in the course of this investigation. In many cases we were handed extensive internal reports containing extremely helpful data on important problems that had been encountered along with data on their solutions. Without all of that generous sharing of know-how our task would have been greatly impaired.

OBJECTIVE

The objective of this research was to define the current best practice in European waste-to-energy technology and to illuminate those design details and operating practices that deserve special attention in transferring that technology to U.S. conditions.

America has entered a new phase of its history in which energy values must be conserved. This study was undertaken to help utilize European know-how in applying waste-to-energy systems in the U.S.

GENERAL CONCLUSION

The best of the European systems are clean, reliable, good neighbors. They are not cheap, but they serve their primary purpose of environmentally acceptably disposing of municipal solid wastes at an average net cost of $16 per ton.

DEVELOPMENT OF THE SYSTEMS

In many cities of Europe the primary motivation for building waste-to-energy systems has been the need to minimize two problems of landfills:

1. Growing scarcity of available land space in crowded metropolitan areas, and

2. Leaching from expanding landfills into surface waters and groundwaters.

A logical choice to minimize the weight and volume of wastes was the combustion method. However, energy recovery from that combustion process was a secondary result of environmental demands on the refuse combustion systems. In order to achieve highly effective removal of flyash from the combustion exhaust gases it was necessary to cool them. In a few small plants it has seemed justifiable to cool the high-temperature gases by means of water sprays or by dilution with air. However, these wasteful methods are less and less defensible as all energy costs continue to rise. Accordingly, the principal cooling method adopted in Europe was to pass the hot gases through a boiler, so that the heat from the gases could be conserved to generate hot water or steam. This could be a low-pressure, firetube boiler, or a high-pressure boiler. Where the steam needs to be generated at high pressure and high temperature, which is required for efficient production of electricity, a water-tube boiler must be used to contain the high pressure safely. This basic fact then led to adaptation to refuse burning of the water-tube-wall, boiler-furnace which had already been developed for fossil-fuel applications in the U.S., and in Europe. However, refuse is not coal, and the adaptation to refuse burning called for skilled innovation and development.

In some respects, municipal solid waste (MSW) is very similar to high-ash, high-moisture, noncaking, low-heat-value coal. However, it is bulkier and much more variable. The alkalis in the ash promote slagging. Also MSW contains more chlorides which are corrosive in high temperature boilers and in wet flue-gas scrubbers. Most of the European manufacturers of waste-to-energy equipment have evolved impressive systems to cope reliably with most of these difficult features of municipal solid wastes.

Increasing Heat Values

Another unanticipated difficulty, which now is history, was the distinct increase in heat value of European refuse over the years.

Figure 1 shows the trend of heat value of refuse from various cities from 1955 to 1975. Thus, while the equipment for reliable clean mass burning was being evolved, the rising heat value of the fuel caused many difficulties from overheating of furnaces, boilers and precipitators. Now the trend appears to have leveled off at a heat value in the same range as that for US-MSW, and many of the systems to be described later are demonstrating highly reliable performance.

Figure 2 shows a typical design of a modern European plant.

The plants we observed and reported on were the vendor's selection of their typical best state-of-the-art.

In order to highlight the main points learned, Tables I, II, and III, and the following description summarizes some of the unique features of the plants visited.

Werdenberg-Leichtenstein

This plant has already been shown in Figure 2. It is very small--132-ton-per-day capacity, only 26,000 tons/year. It supplies process steam, district heat, and has 0.85 mw generating capacity; a jewel of a plant serving 76,000 people in a gorgeous alpine valley. It is the highest cost plant visited, with a net disposal cost of $48.25 per ton. Being very clean, it preserves the environment of that lovely valley.

Baden-Brugg, Switzerland

This is also small, though about twice the capacity at Werdenberg, but burns only 41,000 tons per year. Net disposal cost slightly above average, $18.63 per ton. The principal use of steam is for generation of electricity, capacity 5.2 mw. It is contiguous with, but operated separately from, a hazardous waste processing plant which serves a broad area of Switzerland. Some steam goes to that plant and to the adjacent wastewater treatment plant.

Dusseldorf, West Germany

Relatively old, this is the site of development of the roller grate from 1960 to 1965. From this development have come about 50 roller grate units around the world, including a new one at Singapore, 1200 tons per day.

High pressure, high temperature steam, 932 F (500 C) is required by the steam user, which is the existing municipal coal-fired power plant at Flingern, one-half mile away. The five boilers at this plant are vulnerable to superheater and wall-tube corrosion. Much has been learned about corrosion prevention at this plant, and that knowledge has been generously shared with visitors, in many international meetings, and in numerous publications. A sixth boiler has been added since our visit.

Baled scrap iron is produced from the residue as shown in Figure 3.

Wuppertal, West Germany

This is a new roller-grate plant, operated below full capacity owing to the need to restrict emissions while flue gas scrubbers were being installed and developed. It had a very high capital cost--$89,582 per ton (1971 dollars).

Krefeld, West Germany

This is another new roller-grate plant, with two units, and provision for a third. This plant is pioneering a unique method of co-disposal (sludge and MSW) suspension drying of centrifugally dewatered sludge in hot flue gas, followed immediately by suspension burning of the 10 percent moisture ludge fired into the water-tube-walled furnace above the burning refuse, having the pains of development of any innovative system. Performance data were not available during our 1977 tour.

Paris: Issy-les-Moulineaux

This plant is 18 years old (in 1977), the oldest plant visited and the biggest, a 3-unit total capacity of 1635 tons per day, and burns 589,000 tons per year. It supplies electricity and district heat in Paris. The reverse-acting reciprocating grate has been so satisfactory that the newer Paris plant, Ivry (1969), uses the same grate, only larger. Each of the two units at the Ivry plant has a capacity of 1200 tons per day.

In Paris the maintenance of a clean stack is so important that the precipitator emissions are measured once a month.

Hamburg: Stellinger-Moor

This is another reverse-acting reciprocating grate. Hamburg has had experience with waste-to-energy plants since 1896. A major early problem was lack of heat content in the refuse, therefore the Stellinger-Moor plant was designed in 1970 for very low heat value, 3240 Btu/lb (7535 J/kg). Now with steadily rising heat value (more paper, plastics, less non-combustible) the boiler and precipitator become overheated. Such high flame and gas temperatures also cause boiler corrosion. To protect the precipitator, water sprays had to be added to further cool the boiler exhaust gases.

Zurich-Hagenholz, Switzerland

The newest unit at Hagenholz has also a reverse-acting reciprocating grate. Zurich has had long experience with waste-to-energy, beginning in 1904. Since our visit in June, 1977, the accumulated success and experience at Zurich has culminated in the construction of the first line of a new plant at Josefstrasse, capacity of 511 tons per day, in an industrial area near the city center. It began operation December, 1978.

The manager of these plants, Mr. Max Baltensperger, takes an unusually active part in the planning, design and operation of these plants. Much has been learned there and successfully applied regarding design for minimal tube corrosion.

The Hague, Netherlands

Built in 1968, this plant has also suffered from the steady rise in heat value of European refuse. Installation of a fourth unit in 1974 allowed reduction of the load on the three older units. This has greatly reduced orrosion and maintenance costs. In the new unit, superheater corrosion has een reduced by not placing it in the radiation section of the furnace but by locating it instead in a third pass as shown in Figure 4. Also, Kunstler, air-cooled, sidewall blocks add tertiary air.

This plant sells electricity to the adjacent oil-burning municipal power plant which imposes an unusual reliability requirement; if the waste-burning plant fails to supply a steady output of at least 5.5 mw for the month, it forfeits a 6 percent monthly bonus. Accordingly, the management of this plant impresses on its operating staff the importance of reliable operation.

Dieppe, France

The plant is very small, 120 tons per day, and serves a casino-resort town on the English Channel. Sanitary park: wastewater treatment and incineration plants together; considered essential to upgrading the resort environment. All of the low-pressure steam generated in a fire-tube boiler following a refractory furnace goes to dry sewage sludge to 40 percent moisture. The sludge is then fed with the residue into the furnace.

Nearby, at Deauville, is a similar, newer, very attractive sanitary park with a co-disposal plant located in a residential area. Figure 5 shows a view of the neighborhood from the tipping hall. This entire waste treatment park must be clean. As at Dieppe, most of the waste-derived energy goes to the sludge dryer.

Gothenburg, Sweden

This plant, near the west coast of Sweden, is a part of the largest high-temperature hot-water heating system in Europe. The total heating system depends mainly on imported oil, but the 242,000 tons per year of refuse burned supplies 4 percent of that system's total energy. As oil costs escalate, this plant is becoming an increasingly valued part of the energy system.

Uppsala, Sweden

This, too, is a part of an impressive, oil-fired district heating complex north of Stockholm. Water-tube, waste heat boilers are used for generating saturated steam at moderate pressure to produce hot water for district heating; some of the steam goes to industrial plants nearby manufacturing pharmaceuticals, processed meat, and baked goods. About 5 to 10 percent of the total energy generated in the complex comes from the burning of refuse.

Horsens, Denmark

This is another small plant, 120 tons per day, which uses most of the waste-generated hot gases for drying sludge in a rotary kiln to the point where it can be landfilled nearby. Hot water for district heating is generated in a fire-tube boiler following a refractory furnace.

Copenhagen, Denmark

Two large and impressive modern plants at Copenhagen, built in 1970, Amager and West, together burn 500,000 tons per year to generate not steam, but high-temperature hot water, 250 to 340 F (120 to 170 C), for use in district heating based on the fossil-fuel burning municipal power plant adjacent to the Amager resource recovery plant. These plants utilize a rotary kiln following the reciprocating grates to complete the burnout of the residue.

GENERAL CONSIDERATIONS

Grates

There is a wide range of grate-design concepts for achieving motion of the heterogeneous mass of burning refuse. Almost all furnaces have a ram-type refuse feeder to achieve positive entry of refuse onto the grate. The grate motion then ensures movement of the refuse along the grate surface. Virtually all grates are steeply sloped, up to 30 degrees to aid the movement of the burning refuse from front to back of the furnace.

All grates observed provide agitation of the burning mass. This is in recognition of the need to do two things:

- Continually expose fresh surfaces to ignition and to air flow
- Keep filling in voids that form rapidly when zones of lightweight, highly-combustible material burns. Through these voids primary air may bypass the burning bed unless such holes are promptly filled by rearrangement of the heterogeneous mass.

Even the older traveling grate, which provides no fuel bed agitation, was installed as a multiple series of stepped traveling grates so that as the burning refuse tumbled from one grate to the next, there was momentary agitation and rearrangement of the bed.

Tube Corrosion

Low temperature heating boilers usually operate well below the tube temperature range where corrosion may begin to become a problem, 600 F (315 C).

High temperature, power-generating plants usually generating steam over 750 F (400 C), have encountered corrosion by chlorides from the wastes. Many techniques have been evolved to prevent corrosion, most prominent of which are:

1. Silicon carbide coating on furnace wall tubes directly exposed to flames.

2. Remote location of the superheater in the second or third boiler pass to limit its exposure to flames or excessive temperatures
3. Tube shielding on particularly vulnerable superheater tubes
4. Minimal use of steam jet soot blowers for tube cleaning so as to maintain a protective ash coating.

Secondary Air Jets

Again borrowed from coal-burning practice, well established since the first crude jets were applied to coal furnaces in England in 1858, overfire jets have been found essential to completing combustion in waste burning. This is still an art, with differing experiences and opinions about jet characteristics, size, number, air velocity, and location. But there is general agreement that the intense mixing of burning furnace gases is essential, and best provided by overfire air jets. Further research is needed to help refine the art.

Pollution Control

As was stated before, the main point in incorporating boilers with these waste burners was to thereby cool the hot, dusty gases to below 500 F (260 C), so that high efficiency electrostatic precipitators would survive.

The dust collection efficiencies at these plants ranged up to 99+ percent. In most, but not all, countries of Western Europe, the allowable particulate emission limit is moderate, about 0.07 grain scf (170 mg/Nm^3) corrected to 12 percent CO_2.

Although the limits are not that stringent in France, the plants in Paris demonstrate an unusual concern for clean air; their precipitator emissions are checked every month by a stack test team and average 0.026 to 0.04 gr/scf (60 to 100 mg/Nm^3).

As was mentioned earlier, some of the other, earlier designed plants, have suffered from excessive flue-gas temperatures because of the steady rise in heat value of the refuse. As a result, the temperature entering some precipitators has exceeded 500 F (260 C). This has caused severe corrosion and costly maintenance at those plants. Plants designed for the higher heat values have had no precipitator corrosion problems.

Acid Gases

Although on this survey all environmental agencies visited were found to be alert to the pollutant potential of hydrogen chloride, hydrogen fluoride and, to a minor extent, sulfur dioxide from refuse burning, only West Germany has, as part of its TA Luft regulation announced in 1974, required that new or expanded plants must remove 90 percent or more of these gases from exhaust. To meet this requirement, all new plants in Germany have nstalled wet scrubbers. While HCl and HF are easy to scrub, corrosion of the scrubbers has developed as a major obstacle. Incidentally, these European installers of scrubbers apparently paid little attention to the uniformly unsatisfactory experience with wet scrubbers in American incinerators as described repeatedly by Velzy over the past 5 years.

Now in Europe, as in the U.S., some plants are trying dry "scrubbers". This is an attractive concept which depends on the spray of an alkaline liquid into the hot gas stream, which evaporates and reacts to create a chloride and fluoride powder that can be cleaned from the gases. It is too early to tell how this will work out in actual practice.

Meanwhile, we learned of no agency which is monitoring chlorides or fluorides in the ambient air, probably because the levels are too low to detect with commercially available air-monitoring instruments. The German restriction was apparently imposed simply because it seemed better not to have HCl and HF in the air, regardless of their generally innocuous levels.

Costs

We were surprised to discover little evidence of economies of scale. We did observe widespread evidence of consummate pride in these clean facilities, often located very near to residential areas. This pride was first very obviously manifest in the design stage, resulting in more elaborate and expensive facilities at the larger plants. For example:

1. Closed circuit TV for the operator of the scale for observing incoming traffic
2. Furnace surveillance by TV
3. Luxurious, carpeted conference rooms
4. Mechanical street sweeper at one plant to keep the tipping hall clean
5. Elaborate magnetic separation and baling of steel scrap from the burned residue at some plants
6. Extensive and very attractive landscaping at some larger plants.

Figure 6 shows the relatively uniform net cost per ton of waste processed regardless of size.

WHAT HAVE THE EUROPEANS LEARNED?

1. Waste is a difficult fuel, but it can be utilized for energy recovery in an environmentally acceptable manner, often even when located in the midst of residential areas.

2. These plants are too small to generate electricity economically, hence where there is year-round demand for hot water or steam for process or district heating, the expense of steam-turbopower generation is questionable. However, as energy costs continue to rise, the gain in annual efficiency made possible by co-generation, will favor the more complex plants.

3. Processing of the burned grate residue is often economically feasible to recover useful steel scrap and coarse aggregate suitable for road building, particularly where landfill costs for the final residue are high.

ALTERNATE METHODS

Composting

Many of the cities visited had long experience with composting but uses for the product did not grow as the volume of refuse grew, hence mass burning was the only established alternative available.

Pyrolysis

There is much interest in this subject but none of the plants being tried in the U.S. and in Europe have demonstrated satisfactory operation.

RDF

There is, as yet, little interest in RDF in Europe because of the widespread success of mass burning. Some industrial plants in England are using RDF for steam production and one cement plant there uses RDF.

CONCLUSIONS

1. Europe was forced to precede the U.S. in developing these waste-to-energy systems because they wanted no more:

    a. Leachable landfills

    b. Old brick incinerators spewing flyash.

    As a tertiary influence they had to conserve energy, which has long been much more costly there than in the U.S.

2. A variety of systems have been demonstrated as feasible. Each has its place for:

a. Electric power generation and district heating, or

b. Steam heating only, or

c. Water heating only, or

d. Thermal sludge drying and burning.

There are sound, workable variations of these methods suitable for most applications.

ACKNOWLEDGMENT

In addition to the many equipment vendors and users who helped us, we would, in particular, like to thank Jacques Dartoy of Battelle-Geneva whose experience in this field was especially helpful to us. Also, the help of Steven Levy and the support and counsel of David Sussman of EPA are gratefully acknowledged.

REFERENCES

The information in this paper has been extracted from two volumes which comprise a report to EPA on Contract No. 68-01-4376. The report numbers for the two volumes are PB-80-115-314 and PB-80-115-322. The results have also been summarized in EPA Publication SW-771 entitled: "Refuse-Fired Energy Systems in Europe: An Evaluation of Design Practices".

The two-volume report is supplemented by 15 trip reports on visits to the individual plants.

TABLE I. SUMMARY DATA ON THE 15 SURVEYED PLANTS VISITED (1977)

Plant Name	Mfr.	Start Up Date	Number of Units and Design Cap. Mt/h	Capacity: Daily Design Mt.	Capacity: Actual 1976 Mt/Year	Design Steam Cap. Mt/h: Nom.	Design Steam Cap. Mt/h: Max.	Steam Press: atm.	Steam Press: psig	Steam Temp.: C	Steam Temp.: F	Max. Elec. Gen. Capac. MW
Werdenberg, Switzerland	W&E	1974	1x5	120	26,018	12	16	39	570	395	740	0.85
Baden-Brugg, Switzerland	W&E	1970	2x4	200	41,693	11.4	--	40	590	400	752	5.2
Dusseldorf, Germany	VKW	1965	4x10.1x12.5	1260	297,359	89	94	80	1160	500	932	50
Krefeld, Germany	VKW	1976	2x12	560	114,000	42	--	23	--	376	700	2.8
Wuppertal, Germany	VKW	1/76	4x15	1440	178,000	202	--	29	425	340	644	40
Issy-le-Moulneaux, France	Martin	1965	4x17	1635	588,904	160	168	53	780	410	770	25
Zurich-Hagenholz, Sweden	Martin	7/73	1x21	380	223,595	38	--	45	660	420	788	12
Hamburg-Stellinger-M.,Gmy.	Martin	11/73	2x24	1180	420,680	80	--	52	764	410	770	16.5
The Hague, Netherlands	V-R	1968	4x15	1440	229,000	150	--	40	566	425	797	23
Dieppe, France	V-R	1974	2x2.8	134	14,892	15	--	16	217	180	356	0
Deauville, France	V-R	1976	2x2.8	134	--	15	--	16	217	180	356	0
Gothenberg, Sweden	B&S	1970	3x12.5	900	242,536	157.5	--	22	309	214	417	0
Uppsala, Sweden	B&S	1970	1x5	120	52,040	40	--	15	200	138	280	0
Horsens, Denmark	B&S	1974	1x5	120	18,909	HW	--	--	--	--	--	0
Cophgn. - Amager, Denmark	Volund	1970	3x12	864	255,000	HW	--	--	--	--	--	0
Cophgn. - West, Denmark	Volund	1970	3x12	864	234,230	HW	--	--	--	--	--	0

TABLE II. SUMMARY OF CAPITAL INVESTMENT

Plant	Weighted Average Year of Investment Used to Select Exchange Rate	Exchange Rate, U.S. $	Cost in U.S. Dollars in Weighted Ave. Year U.S. $	Actual 1976 Mt Per Year	Short Tons Per Year	Short Tons Per Day at 365 Days/Yr.	Capital Cost Per Daily Ton Capacity US $
Werdenberg	1973	3.244	4,007,000	26,018	28,620	78	51,103
Baden-Brugg	1970	4.316	3,800,000	41,693	45,862	126	30,243
Dusseldorf	1967	3.999	11,578,000	297,359	327,095	896	12,920
Wuppertal	1975	2.622	48,055,000	178,000	195,800	536	89,582
Krefeld	1976	2.363	25,391,000	114,000	125,400	344	73,905
Paris:Issy	1962	4.900	22,449,000	588,904	647,794	1,775	12,649
Hamburg	1971	2.622	18,307,000	420,680	462,748	1,268	14,440
Zurich	1970	4.316	13,831,000	223,595	245,955	674	20,525
The Hague	1970	3.598	17,237,000	229,000	251,900	690	24,976
Dieppe	1969	5.558	1,562,000	14,892	16,381	45	34,804
Gothenburg	1971	4.858	20,173,000	242,536	266,790	731	27,599
Uppsala	1967	5.165	2,139,000	52,040	57,244	157	13,639
Horsens	1975	6.178	2,946,000	18,909	20,800	57	51,697
Coph. Amager	1971	6.290	25,056,000	255,000	280,500	768	32,604
Coph. West	1971	6.843	29,954,000	234,230	257,653	706	42,434
TOTAL			246,485,000	2,936,856	3,230,542	8,851	
AVERAGE				195,790	215,369	590	35,541

TABLE III. SUMMARY OF REVENUES FROM 15 EUROPEAN REFUSE TO ENERGY PLANTS (U.S. 1976 $ PER TON)

	Sale of Scrap Iron and Road Ash	Sale of Energy(b)		Net Disposal Cost or Tipping Fees	Interest on Reserves	Sludge Destruction Credit	Other Revenues	Total Revenues
Werdenberg-Liechtenstein	0.14	5.80	W,S,E(a)	48.25	--	--	0.45	54.64
Baden-Brugg	--	6.17	E	18.63	0.02	--	0.43	25.25
Duesseldorf	1.21	9.47	S,E	8.84	--	--	--	19.52
Wuppertal	0.58	7.56	E	35.66	--	--	--	43.80
Krefeld	--	--	--	--	--	?	--	--
Paris:Issy	0.26	6.25	S,E	6.27	--	--	--	--
Hamburg:Stellinger-Moor	--	5.92	E	22.55	--	--	--	--
Zurich:Hagenholz	0.02	10.11	S,E	12.66	--	--	1.12	23.91
The Hague	--	5.59	E	15.84	--	--	--	21.43
Dieppe	--	--	--	--	--	?	--	--
Gothenburg	--	8.17	W	19.34	--	--	--	27.51
Uppsala	--	11.70	S	6.83	--		--	18.53
Horsens	--	9.37	W	15.21	--	3.12	--	27.70
Copenhagen:Amager	--	3.00	W	16.57	0.63	--	2.16	22.36
Copenhagen:West	0.15	6.78	W	18.15	2.58	--	0.38	28.04
AVERAGE	0.39	7.38	W,S,E	18.83	1.07	3.12	0.91	28.43

(a) W: Hot Water; S: Steam, E: Electricity.

(b) Data for 1975.

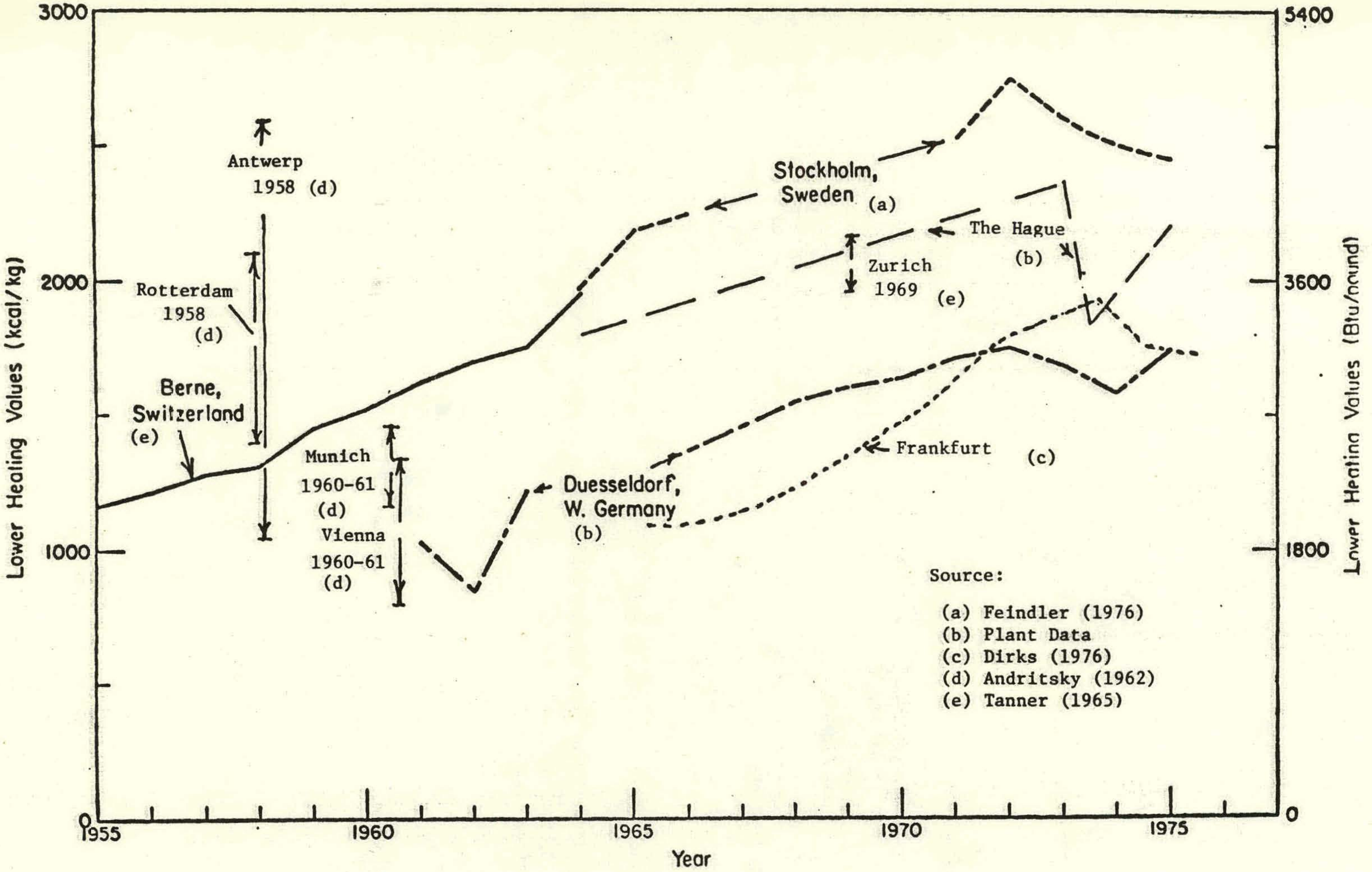
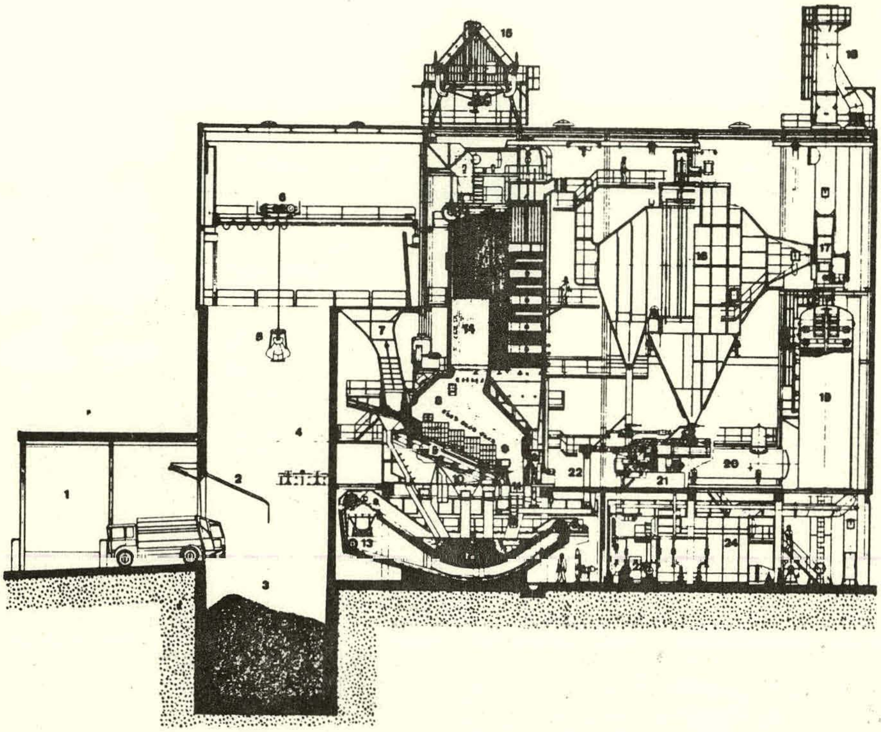


Figure 1. Trend of Heat Value in Refuse at European Cities.



1 Delivery Area
2 Bunker Door
3 Refuse Bunker
4 Crane Pulpit
5 Crane
6 Refuse Grab Bucket
7 Charging Hopper
8 Incinerator Furnace
9 Step Grate
10 Ash Hopper
11 Residue Chute
12 Residue Basin
13 Residue Conveyor Belt
14 Steam Boiler
15 Air Cooled Condenser
16 Electrostatic Precipitator
17 Exhaust Gas Fan
18 Steel Chimney
19 Hot Water Heater
20 Feed Water Tank
21 Turbogenerator
22 Collected Flyash Conveyor
23 Feedwater and Heating Water Pumps
24 Oil-Fired Stand-by Boiler

Figure 2. Section Through a Typical Waste-To-Energy Plant, Courtesy Widmer + Ernst.

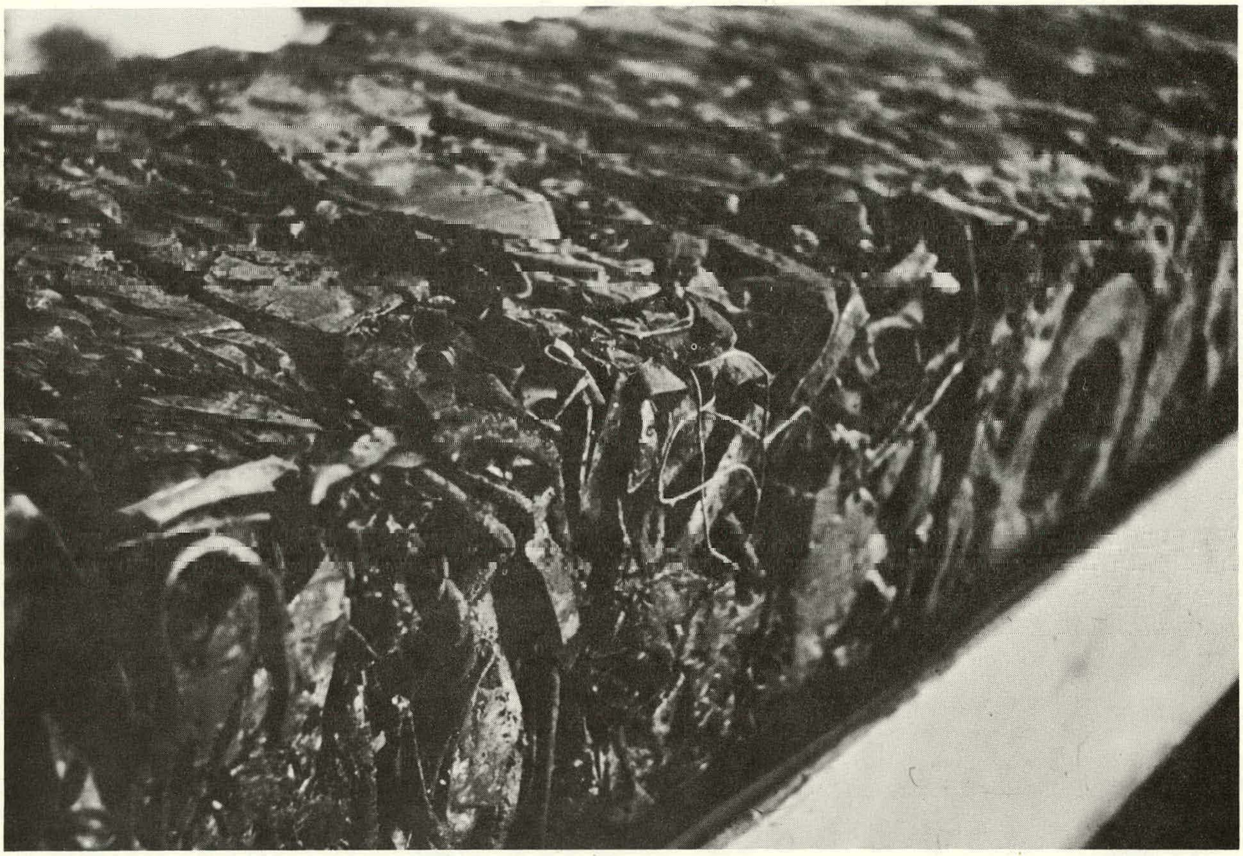
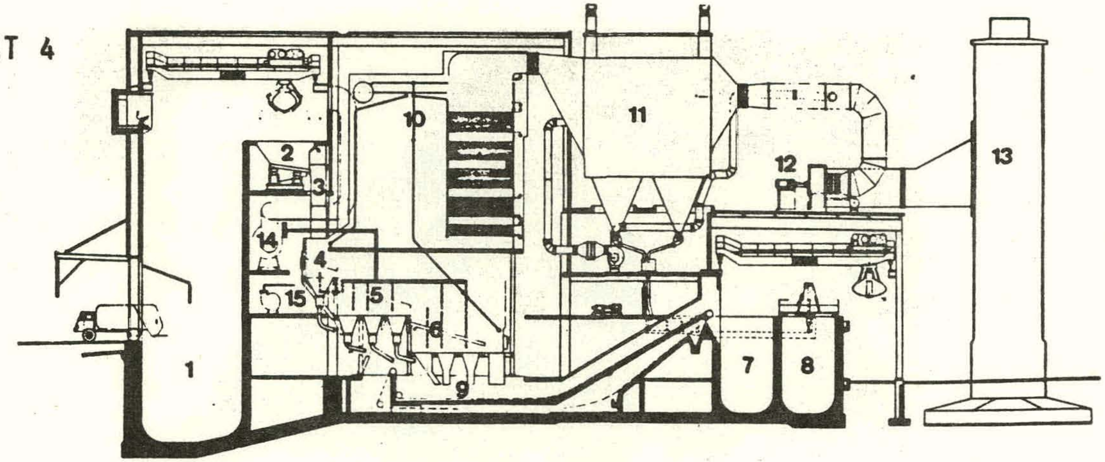


Figure 3. Baled Steel Scrap Produced in the Residue Processing Plant at the Dusseldorf Waste-To-Energy Plant.

THE HAGUE UNIT 4



1 Refuse pit
2 Vibrating hopper
3 Feed chute
4 Feed grate
5 Main grate
6 Burnout grate
7 Clinker pit
8 Settling tank
9 Clinker channel
10 Boiler
11 Electrostatic precipitator
12 Induced draft fan
13 Stack
14 Forced draft fan
15 Overfire air fan

Figure 4. Section of Number 4 Boiler and Auxiliaries at The Hague, Showing the Superheater in the Third Pass.

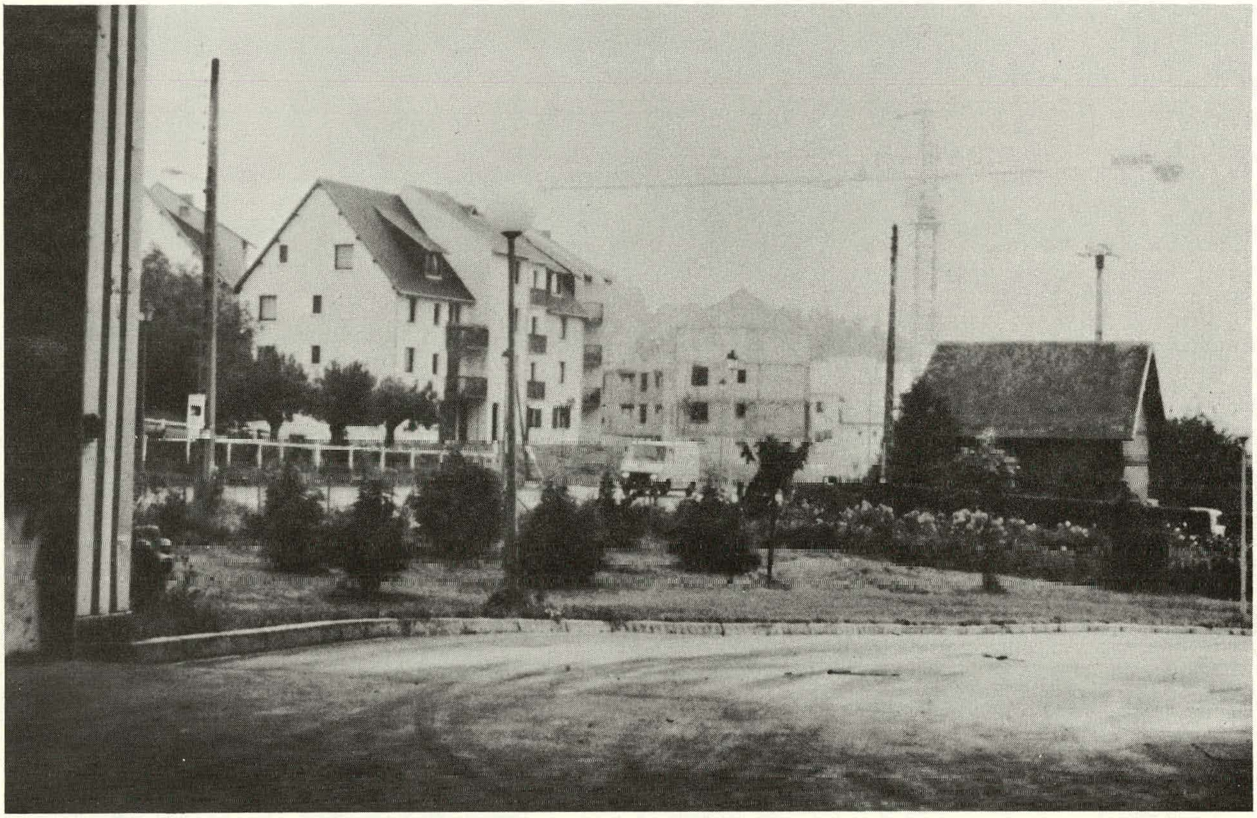


Figure 5. View of Neighborhood from Tipping Hall at Deauville.

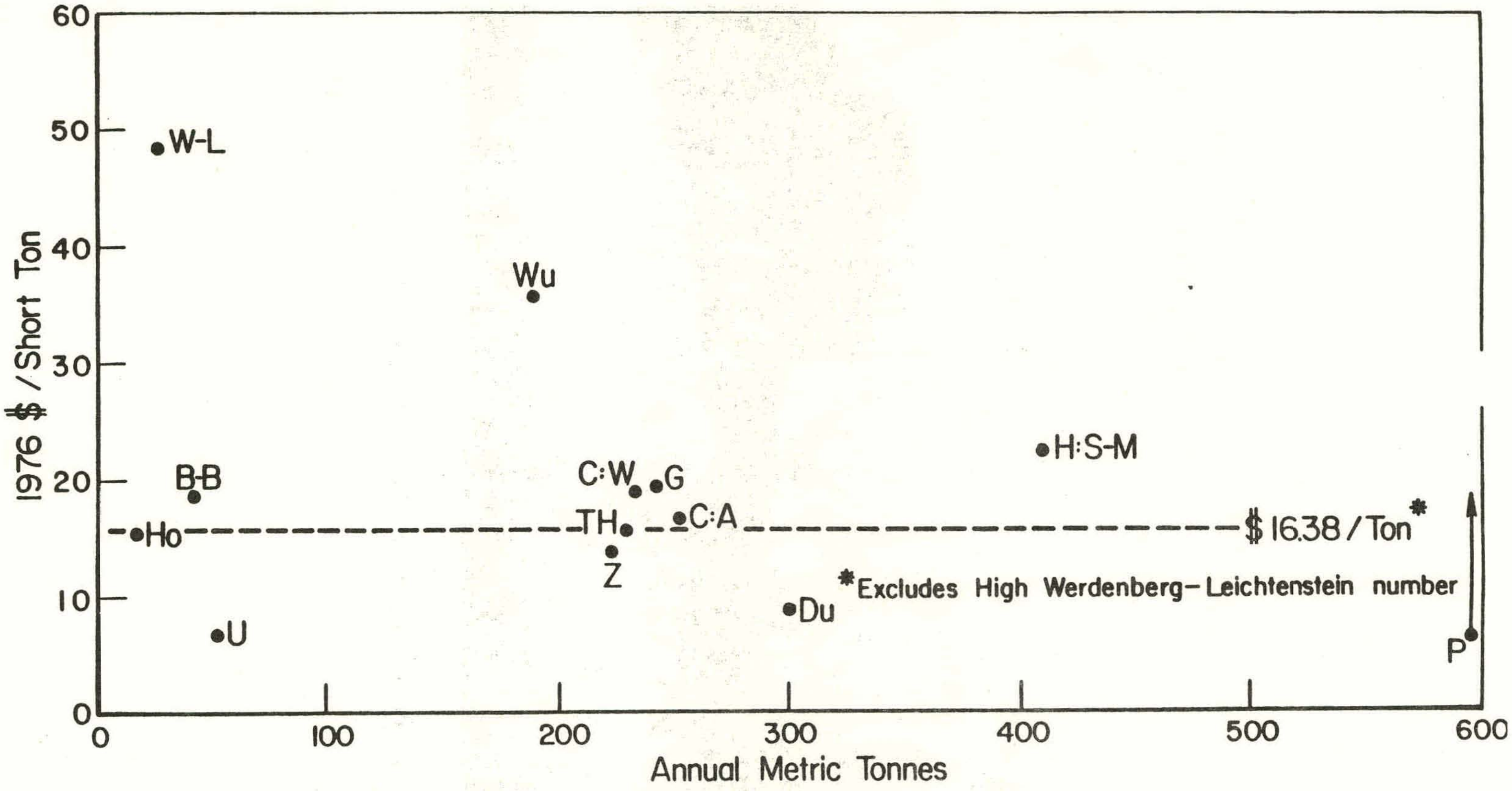


Figure 6. Net Cost of Operation Versus Capacity.

SESSION II: EUROPEAN WASTE-TO-ENERGY SYSTEMS PART I

Moderator: Steve Levy (EPA)

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RESOURCE RECOVERY BY UOP IN THE 1980s

Richard J. Schoenenberger
UOP, Inc.
Des Plaines, Illinois

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THE MARTIN SYSTEM

by W. J. Martin and H. Weiand

Modern, carefully designed and carefully operated refuse combustion plants have proved to be good neighbors even in central, urban locations.

For many years European refuse incineration plants, particularly those with energy recovery, have been visited by engineers, governmental representatives and private citizens from all over the world. Today, we are pleased to have the opportunity here in the United States to report to a larger audience on one of the most frequently visited mass burning systems: the Martin System.

Josef Martin Feuerungsbau GmbH

The firm Josef Martin Feuerungsbau GmbH was founded in Munich in 1925. Its business is the construction of incineration plants, particularly refuse incineration plants, and the manufacture of Martin Reverse Acting Stoker Grates and Martin Ash Dischargers according to our patents. Up to 1980, more than 500 Martin Reverse Acting Stoker Grates and about 6,000 Martin Ash Dischargers have been constructed.

The Martin firm is structured as an engineering office for the planning, design, erection, commissioning and acceptance of plants using the Martin System. Through long-standing agreements with well-established and highly respected foreign firms, the Martin System is used worldwide. Martin has concluded such an agreement with UOP Inc. of Des Plaines, Illinois for the United States of America and other countries.

In the 20 years before the founding of the Martin firm a very comprehensive experience was gained by its founder, the late Josef Martin, during design, construction and operation of approximately 20 refuse incineration plants in different European countries. For instance, the so-called Cascade Stoker Grate for refuse burning was one of his (patented) inventions.

In the years following the founding of the firm, the Martin Reverse Acting Stoker Grate was used in industrial power plants. Much experience was gained with the combustion of low grade, high ash and high moisture content fuels, such as middlings and slurry from coal washing, coke fines, raw lignite, lignite, tannin bark, wood waste, tropical fruit waste and similar low grade fuels (Figure 1).

Since 1960, the Martin Reverse Acting Stoker Grate has been used mainly for the incineration of municipal and trade refuse. As seen in Figure 2, the Martin system is in use around the world. As of July, 1980 there were 169 Martin units in operation or under construction, with an accumulated burning capacity of 47,600 Mg (52,500 US tons) per day. Of the total, 116, or 68.6 percent include energy recovery. Individual unit sizes range from 50 Mg (55 US tons) of refuse per day up to the largest units in the world, such as at the Ivry plant in Paris, where the units are designed for 1200 Mg (1,320 US tons) of refuse per day.

THE MARTIN STOKER

HAS BEEN USED SINCE 1925
FOR THE COMBUSTION OF

LOW - GRADE FUELS

- HIGH - ASH
- HIGH - MOISTURE

SUCH AS

MIDDLINGS } FROM COAL WASHING
SLURRY }
COKE FINES
RAW LIGNITE
LIGNITE
TANNIN BARK
WOOD WASTE
TROPICAL FRUIT WASTE

AND

MUNICIPAL WASTE
TRADE AND INDUSTRIAL WASTE
SEWAGE SLUDGE (COFIRING)

Figure 1. Use of the Martin Reverse Acting Stoker Grate.

COUNTRY	Number of Units	Total burning capacity Mg/day	Units with energy recovery	
			Number of Units	Total burning capacity %
Austria	2	720	2	100.0
Belgium	6	2,313	6	100.0
Brazil	4	600	0	0.0
France	34	8,661	13	63.7
Germany, FRG	16	8,160	15	99.4
Great Britain	10	2,493	7	69.0
Japan	50	11,290	37	85.1
Luxemburg	2	480	2	100.0
Monaco	3	417	3	100.0
Netherlands	16	4,836	8	75.7
Sweden	4	648	2	63.0
Switzerland	12	2,558	11	98.4
USA	8	4,011	8	100.0
USSR	2	400	2	100.0
Total:	169	47,587	116	83.8

Figure 2. The Martin System All Over the World (Update August 1980).

The European Market

In Europe, requests for proposals for refuse incineration plants are usually done on a turn-key basis. The client, which is generally a public body, assigns either the whole project or at least the complete electromechanical portion of the project (from the crane installation to the stack and from the feedwater treatment to the turbine generator) to a general contractor experienced in this special field of activity. In contracts for the supply of refuse incineration plants using its system, the Martin firm may act as the general contractor, as a partner to a general contractor in a joint venture or as a subcontractor for its specific know-how and firing equipment to a general contractor associated with Martin.

The award of turn-key contracts for refuse incineration plants has proved successful in Europe because (1) the overall responsibility and coordination for the electromechanical portion and the civil engineering work are in the hands of a specialized general contractor, (2) the general contractor guarantees the performance of all plant equipment parts and the efficiency and energy yield of the overall plant and (3) the general contractor follows up the schedule of work for the overall plant.

Typical Martin Plants

To introduce our technology let us look at five Martin plants of different design and with different applications of the energy recovered.

(1) Bazenheid, Switzerland (Figure 3)

This relatively small plant comprises two units, each with a burning capacity of 84 Mg (93 US tons) of refuse per day. It is in operation since 1976. The saturated steam (21 bars, or 300 psig) is supplied via steam lines to a large meat processing and sausage factory and to a rendering plant.

(2) Vienna-Spittelau, Austria (Figure 4)

This plant with two units, each having a burning capacity of 360 Mg (400 US tons) of refuse per day, is in operation since 1971. The saturated steam produced is first used to drive a back pressure turbine generator of 2.5 MW capacity for in-plant power requirements and then is used in heat exchangers to provide 170°C (338°F) hot water for the district heating system.

(3) Hamburg-Stellinger Moor, German Federal Republic (Figure 5)

This refuse-fired power plant with a condensing turbine generator contains two units, each with a burning capacity of 450 Mg (500 US tons) of refuse per day. It went into operation in 1972. Steam is produced at 41 bars (580 psig), 410°C (770°F) and drives the 16 MW turbine. The plant is capable of being expanded by another two combustion units, and a second turbine generator has already been installed in 1972.

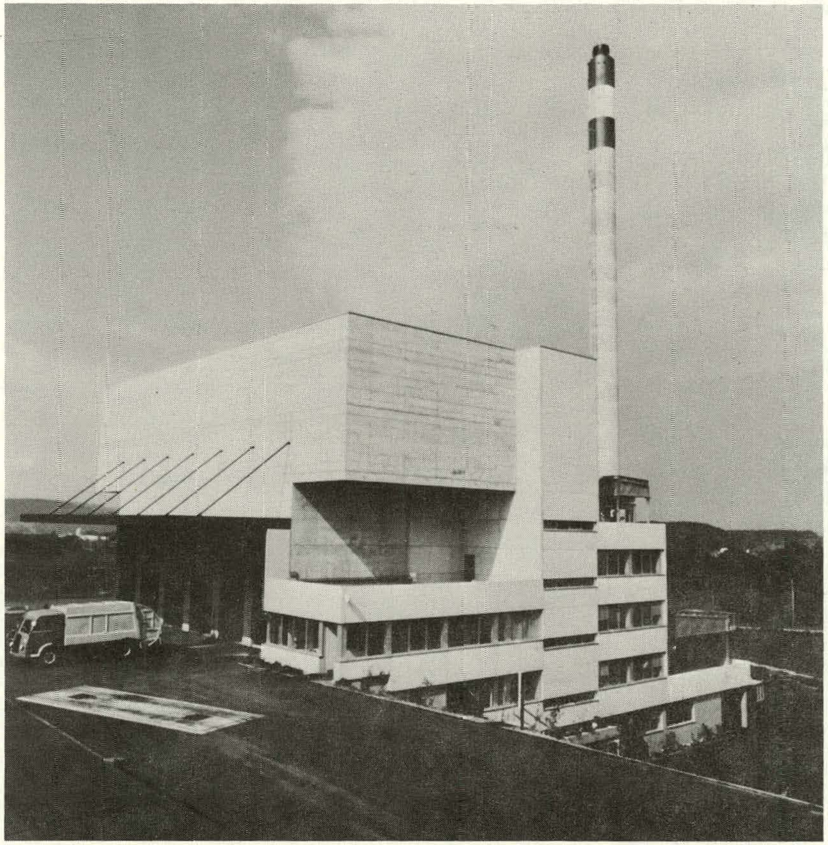


Figure 3. Bazenheid, Switzerland.

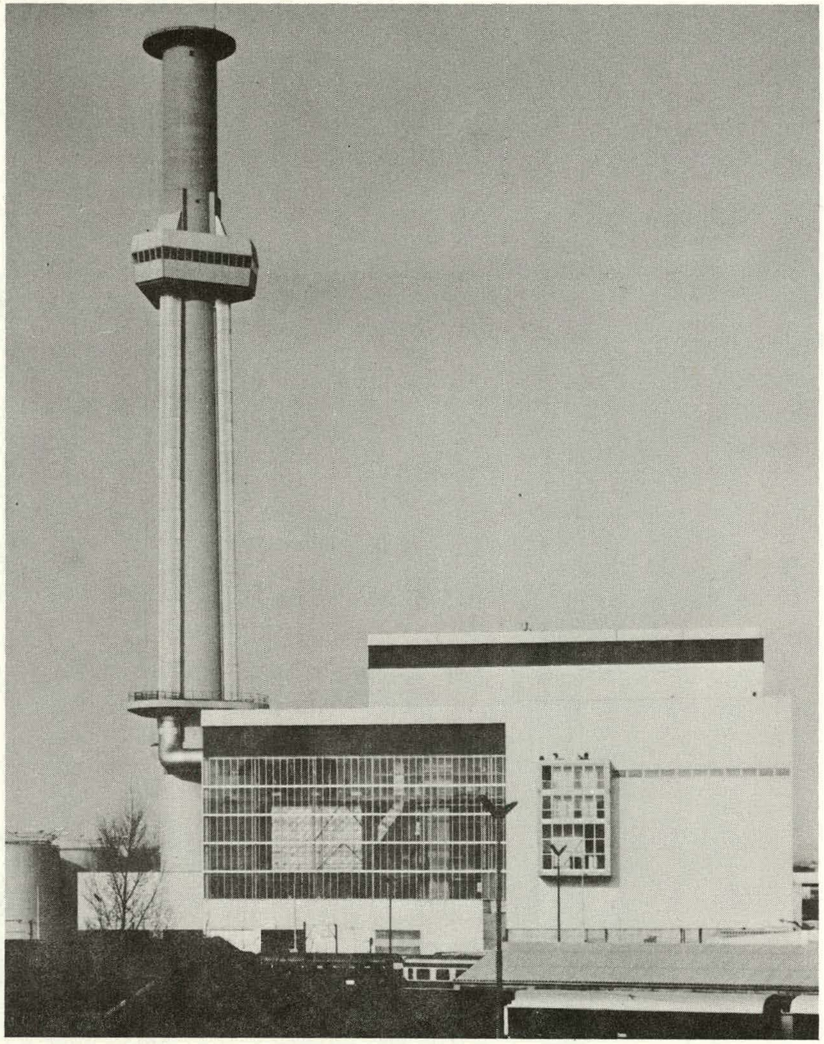


Figure 4. Vienna-Spittelau, Austria.

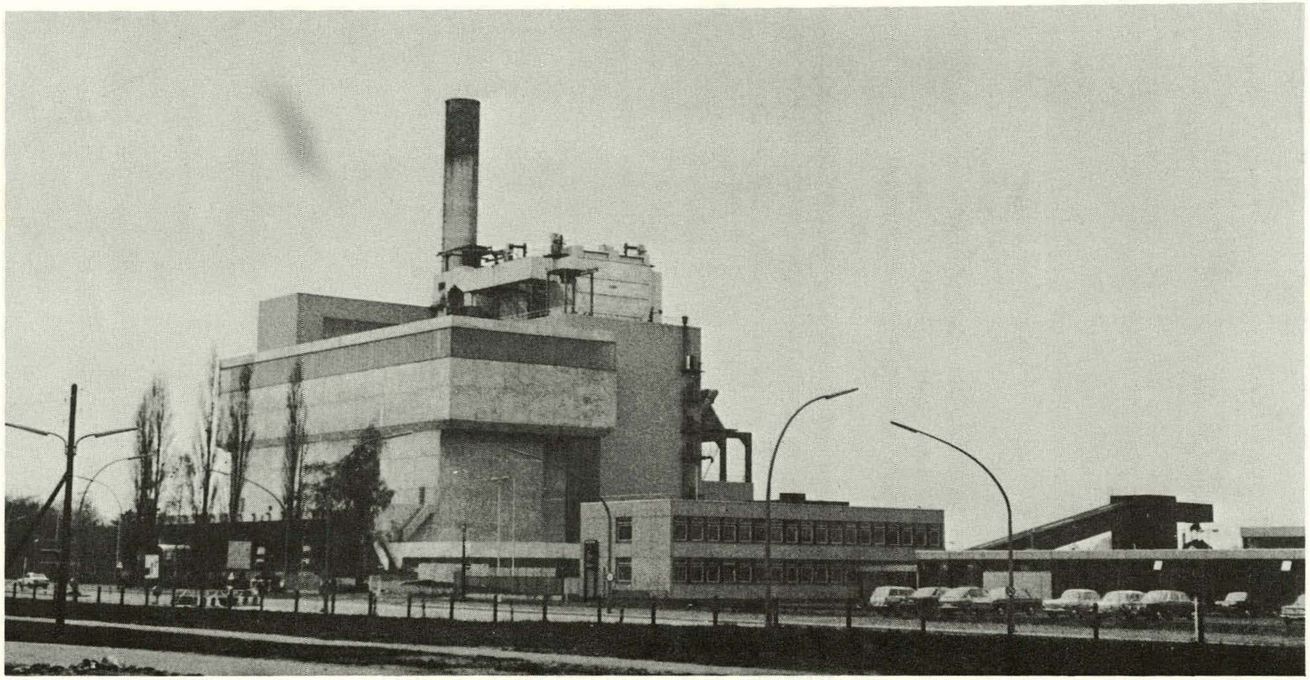


Figure 5. Hamburg-Stellinger Moor, Germany.

(4) Zurich-Josefstrasse, Switzerland (Figure 6)

In this plant, designed to contain two units, one unit of 450 Mg (500 US tons) of refuse per day burning capacity has been installed. It is in operation since 1978. Steam produced at 37 bars (525 psig), 420°C (788°F) is delivered to a tap-off condensing turbine, the capacity of which has been designed for the ultimate plant capacity of two combustion units. From this turbine, steam is taken off for an extensive hot water district heating system and for various direct steam users such as milk processing and food factories.

(5) Munich-North, German Federal Republic (Figure 7)

In the two high pressure blocks of this power station (one block of 68 MW and one block of 112 MW) refuse is burned on large Martin Stoker Grates in addition to pulverized coal. Block I, with two refuse combustion units each having a capacity of 600 Mg (660 US tons) per day, is in operation since 1964. Block II with a single refuse combustion unit of 960 Mg (1,060 US tons) per day capacity, went into operation in 1966. The heat from refuse in block I represents approximately 40 percent of the total heat delivered, while in block II heat from refuse represents approximately 20 percent of the total heat release of the boiler. In addition to electrical energy, this power plant delivers hot water into an extensive district heating system. It may be of interest to note that about 10 to 12 percent of the electric power requirement of the City of Munich is provided by refuse incineration.

Mass Burning (Figure 8)

All of these plants have been designed as "mass burning" plants and equipped with Martin Reverse Acting Stoker Grates. In mass burning plants, the refuse is burned without pre-separation, without shredding and without treatment, just as it is collected by refuse vehicles and discharged into the refuse bunker. It is burned on stoker grate firing equipment, without auxiliary fuel. This straight-forward burning technology has proved superior, not only with regard to reliability and availability in operation, but also when compared economically with other disposal processes available in the market.

The Martin Philosophy (Figure 9)

Just as the heart of every power plant is its combustion equipment, the heart of the Martin System is the Martin Reverse Acting Stoker Grate.

Ten to twenty years ago, the primary goal in refuse plants was the hygienic disposal of municipal and trade wastes. Today, the maximum utilization of the available heat energy is of equal importance. Therefore, economy, availability and continuous load have become essential requirements for and are fulfilled by the Martin System. The state of development attained today by Martin plants is comparable with that of modern thermal power plant technology.

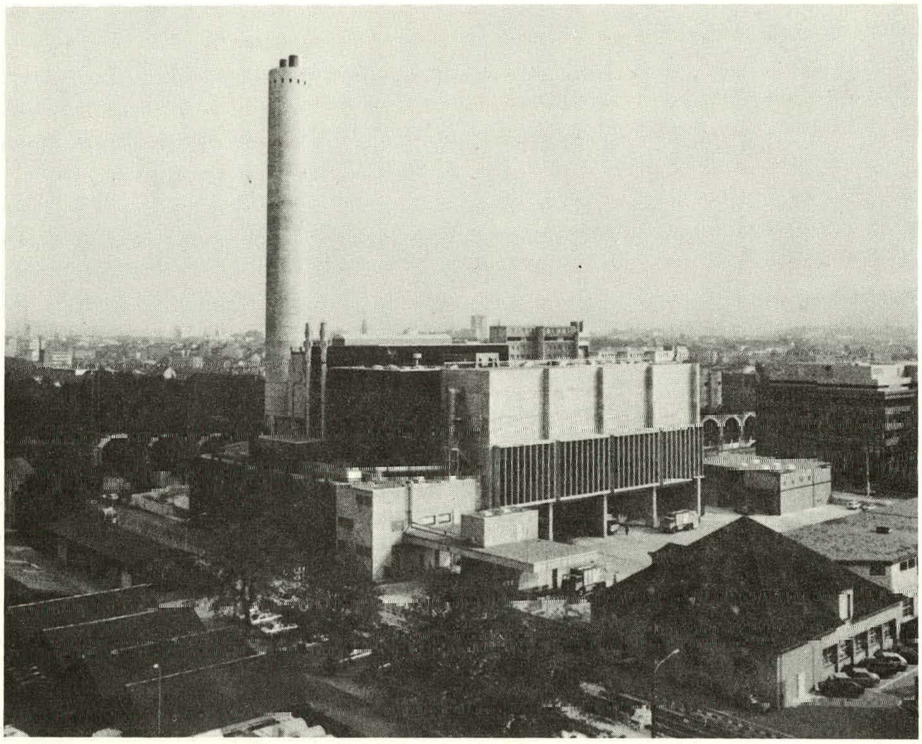


Figure 6. Zurich Josefstrasse.

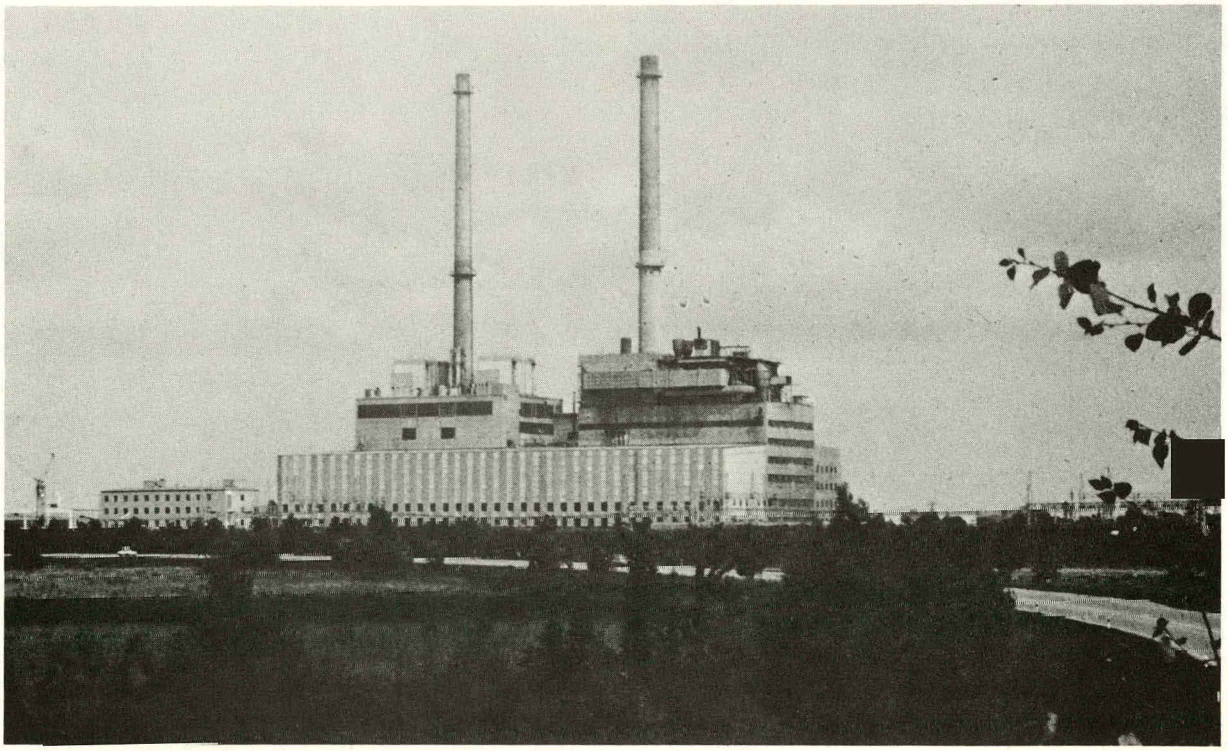


Figure 7. Munich North I and II.

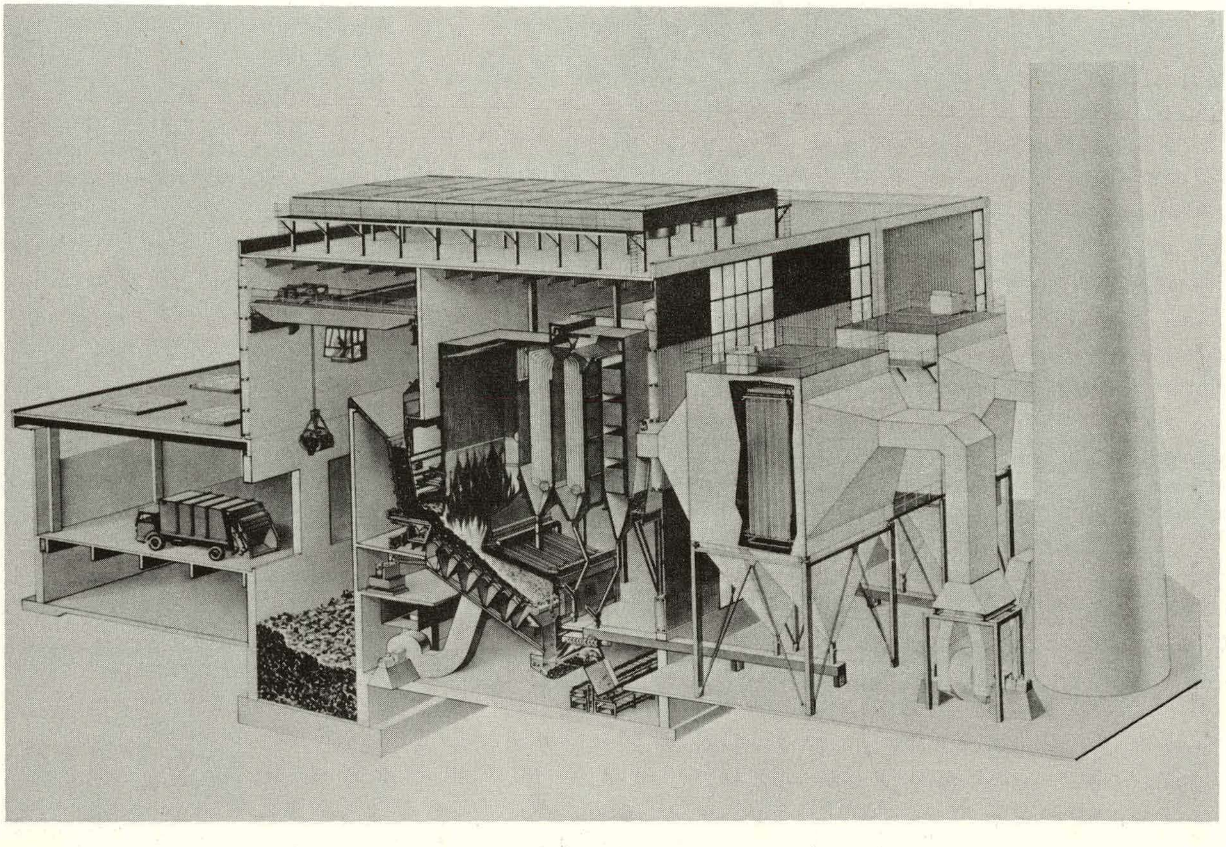


Figure 8.

- CONTROL OF COMBUSTION PROCESS BY
  - LOAD-CONTROLLED REFUSE FEEDING
  - LOAD-CONTROLLED GRATE AGITATION
- CONTROLLED ADMISSION OF UNDERGRATE AND OVERFIRE AIR
- COMPLETE BURN-OUT OF GAS AND RESIDUE
- HIGHEST THERMODYNAMIC EFFICIENCY
- SIMPLICITY OF OPERATION
- GRATE DESIGN ALLOWS LARGEST UNITS (FOR EXAMPLE PARIS - IVRY = 1,200 Mg per DAY AND PER UNIT)

Figure 9. Basic Aspects of Martin Stoker Technology.

From the physical point of view, the Martin design permits concentrated control of fire conditions and flame formation. Thus complete gas burn-out and complete residue burn-out are achieved. With regard to process engineering, control of the combustion process is accomplished by load-controlled refuse feeding, by grate agitation and by controlled admission of both underfire and overfire air. From a technological aspect, the modular design of the Martin stoker grate permits the construction of units over the widest range of capacity sizes. The thermodynamic efficiency of the system is higher due to the fact that the best possible residue and gas burn-outs are achieved.

The Martin Reverse Acting Stoker Grate (Figure 10)

The Martin Reverse Acting Stoker Grate is inclined from the refuse feeding end of the combustion chamber down toward the residue discharge end. Along its length are alternate rows of moving and fixed grate bars. The moving rows slowly push upward in opposition to the gravitational, downward-moving tendency of the layer of refuse. This brings about constant stirring, rotation and leveling out of the refuse bed. Glowing mass from the zone of intense combustion is continuously transported back underneath the freshly fed refuse at the front of the grate. In this manner the different combustion phases, such as drying, volatilization, ignition and burn-out, take place simultaneously.

The essential features of the Martin Stoker Grate technology are (Figure 11):

1. Constant stirring and mixing of the refuse;
2. Uphill transport of part of the glowing mass from the zone of intense combustion back under the freshly fed refuse;
3. Subdivision of the grate surface into several zones with controlled supply of combustion air to these zones according to combustion needs;
4. Grate bar air gaps only 2 millimeters wide with relatively high resistance to combustion air, thus permitting uniform penetration of combustion air into the burning refuse regardless of the thickness or evenness of the refuse;
5. Automatic clearing of the air gaps of the stoker grate during operation;
6. Intense secondary combustion air admission two to four meters above the surface of the grate for good mixing of the combustion gases.
7. Any reasonable stoker width can be built.

The practical results of the Martin technology are:

1. Complete burn-out of the combustible substances in the refuse bed and conversion of the ash into a sintered residue;
2. Concentrated combustion of both the solid and gaseous products in the furnace;
3. Ability to burn even particularly troublesome wastes with high water and ash contents;
4. Excellent control of the combustion process expressed by the steam load curve of a Martin plant with fluctuations of only ± 5 percent;

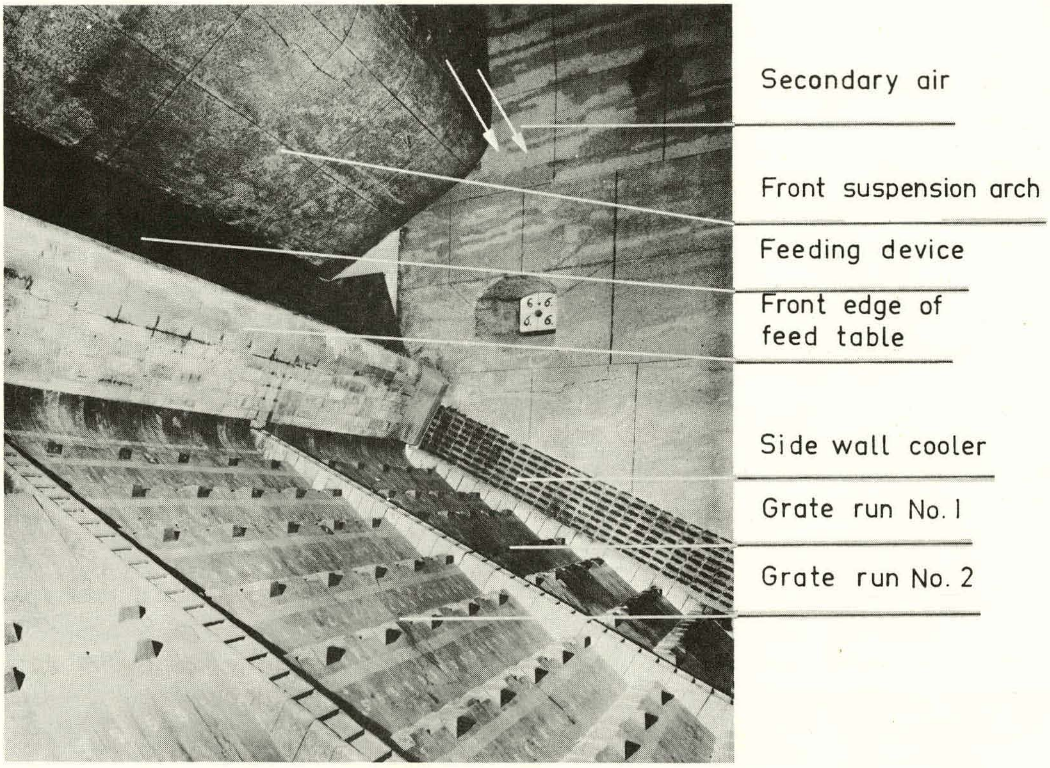


Figure 10. Martin Reverse Acting Grate.

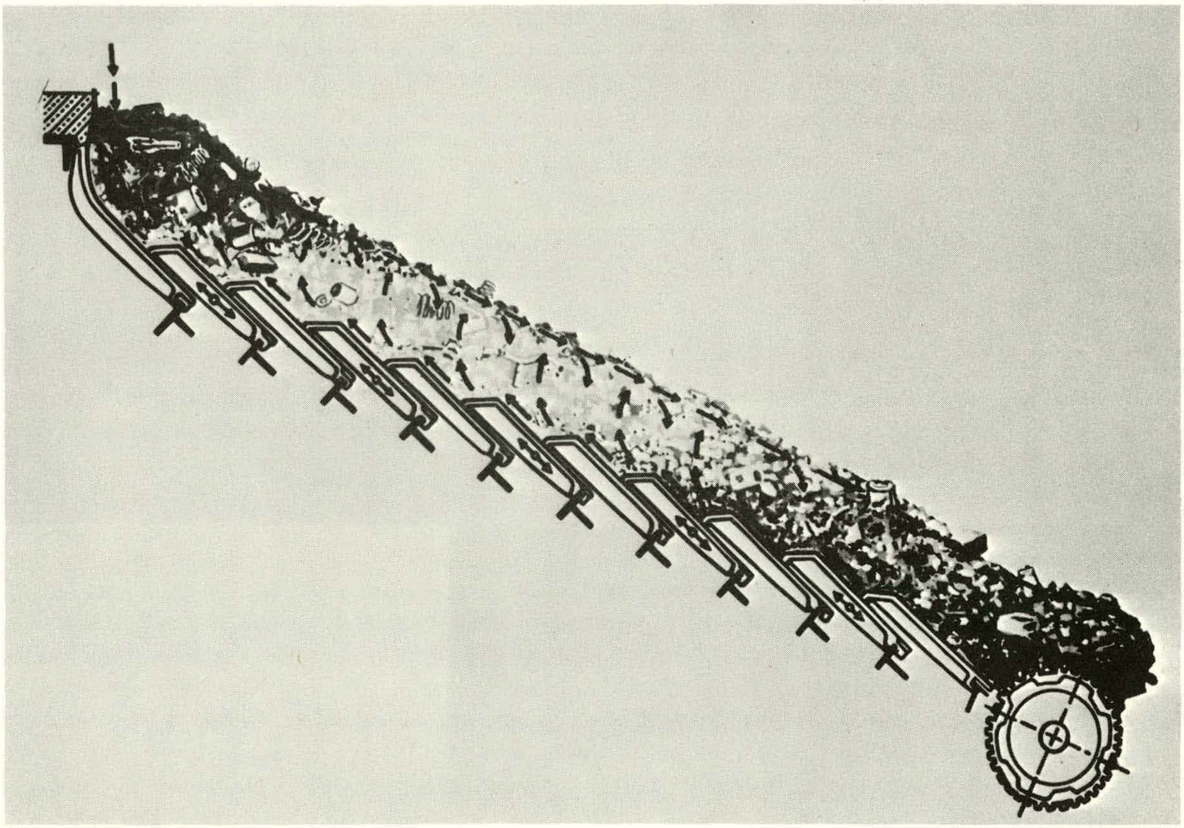


Figure 11.

5. High plant availability and reliability due to the long life of the grate bars, which generally last between five and ten years.

Another essential feature of the Martin Stoker Grate is its design. In theory, the Martin Stoker Grate may be of any width desired. The basic element is the individual grate run which includes all the elements required for drive and air zones. The largest Martin Stoker built to date consists of six parallel grate runs and is installed in the previously mentioned Paris-Ivry plant. Each of these units is 12.8 meters (42 feet) wide between the furnace side walls and has 140 m^2 (1,500 sq. ft.) of active grate surface, but even wider stoker units can be built. Because refuse is a heterogeneous fuel, it requires quick ignition and volatilization in order to obtain optimum residue and gas burn-out. Lengthwise extension of the stoker grate to achieve a higher burning capacity would thus be incorrect. From the process engineering viewpoint, it is only important to determine the proper width of the stoker grate as a function of the needed unit capacity, the water and ash content of the refuse and some other parameters.

Because the Martin Stoker Grate is modular in principle, it is suitable for any size unit and is used for both small and large plants. This is one of the reasons why, for large plants, preference is clearly given to the Martin Stoker Grate.

Boiler Designs

Another important link in the use of the energy content of refuse is the boiler plant, which, in the case of the Martin System, forms an integral block with the stoker grate.

Looking back, it can be seen that the development of boiler design has been influenced by new manufacturing methods and construction materials, by the considerable increase in refuse energy content during the past 20 years, by actual experience with regard to erosion, corrosion, and fouling problems and by new methods of cleaning the boiler heating surfaces.

It may be of interest to you to learn that in the early 1960's it was general state-of-the-art practice to arrange refuse firing equipment separately from the boiler proper so that the refuse would be burned in an uncooled furnace, that is, without being exposed to "cold" boiler sections which might absorb too much heat and thus hamper initial ignition and combustion of the refuse. Because of its long experience in the application of Reverse Acting Stokers to difficult, low grade fuels, Martin felt sure that it could put its grate right between water-cooled furnace walls and underneath the boiler and still obtain safe and quick ignition and good burn-out even with household refuse. Thus Martin became the pioneers of this new layout, and, starting with the large-scale plant for Rotterdam in 1964, it quickly became a complete success. It not only proved the practicality of this new line of incinerator design, but also showed its superiority as to burning capacity per unit, increased overall thermal efficiency, higher plant availability, more compact design of plant, and so forth.

In this context it may be helpful to briefly review the different steps of design which originated with this pioneering deed and which, only later and with hesitation, was adopted by most of the other firms in the field.

Rotterdam Design (Figure 12)

In this type of design, the side walls of the furnace in the immediate vicinity of the stoker grate as well as in the entire radiation portion of the furnace are cooled by boiler tubes. There are two open radiant passes followed by pendant superheater coils or boiler tube banks in the third pass. The fourth, fifth and possibly sixth passes consist of boiler tube banks and the economizer. This boiler design has proved very successful in operation, but its capital cost is relatively high.

Paris-Ivry Design (Figure 13)

In this plant type, downstream of the first furnace pass, the combustion gases flow through pendant superheater coils followed by boiler tube and economizer banks. This boiler design is particularly suitable for large-scale plants and for high steam temperatures. However, the heating surfaces of the superheater are liable to more rapid fouling because the gas temperature is higher as compared to a boiler with two radiant passes ahead of the superheater.

Zurich Design (Figure 14)

The Zurich design evolved from the Rotterdam design and applied advanced engineering techniques in the manufacture of boilers. The superheater is located in the third pass and is formed by horizontal coils. A panel-type heating surface is used as an evaporator surface upstream of the economizer in the fourth pass. This Zurich design is less expensive than the Rotterdam design. But the horizontal superheater coils are more liable to fouling than pendant superheater coils. This, however, can be compensated for by an increased size of the superheater.

Further Developments (Figure 15)

Based on experience with the Ivry and Zurich designs, it has been found that the fouling tendancy of the superheater at continuous full operating load conditions can be reduced by additionally cooling the combustion gases upstream of the superheater. This can be accomplished by an evaporator section, either as a platen heating surface or as a boiler tube bank. Cleaning of these upstream evaporators can be accomplished during operation by any of various rapping devices.

Still another new boiler design shows three open radiant passes and, again, has pendant superheater coils cleaned with rapping devices (Figure 16). This boiler design, which considers all the experience of the previous generations of design, will permit the achievement of very long periods of continuous operation between scheduled shutdowns for maintenance and cleaning.

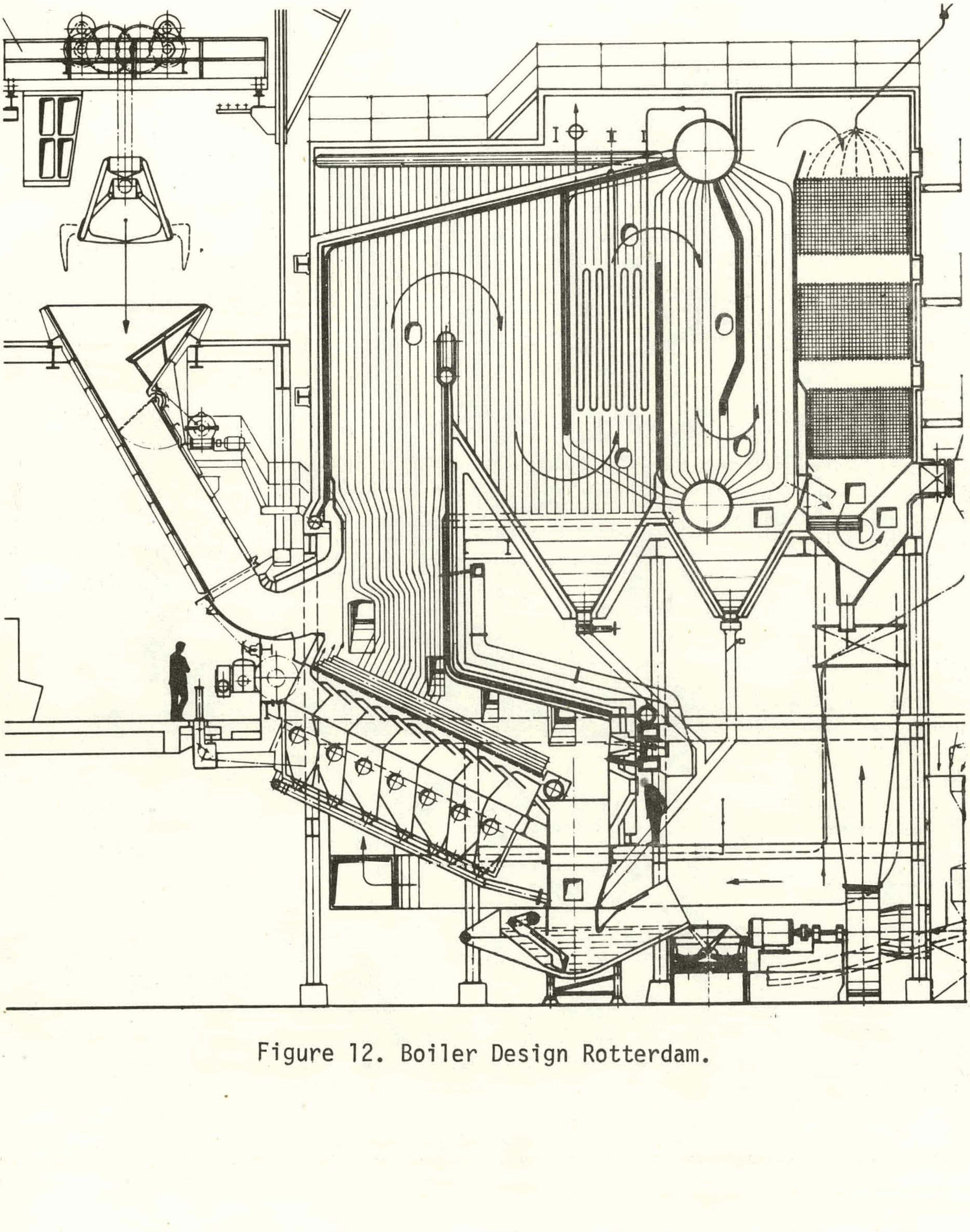


Figure 12. Boiler Design Rotterdam.

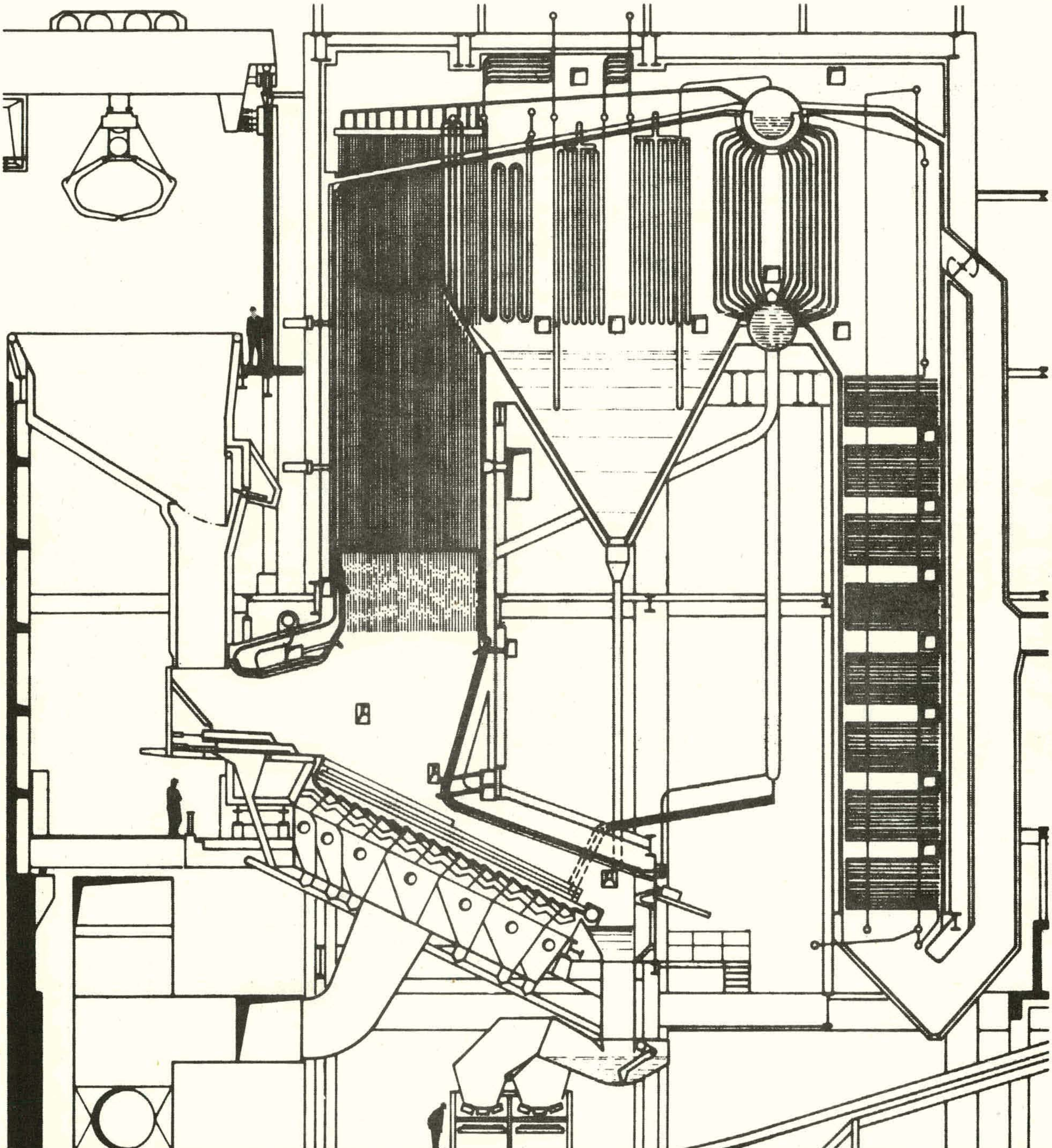


Figure 13. Boiler Design, Paris-Ivry.

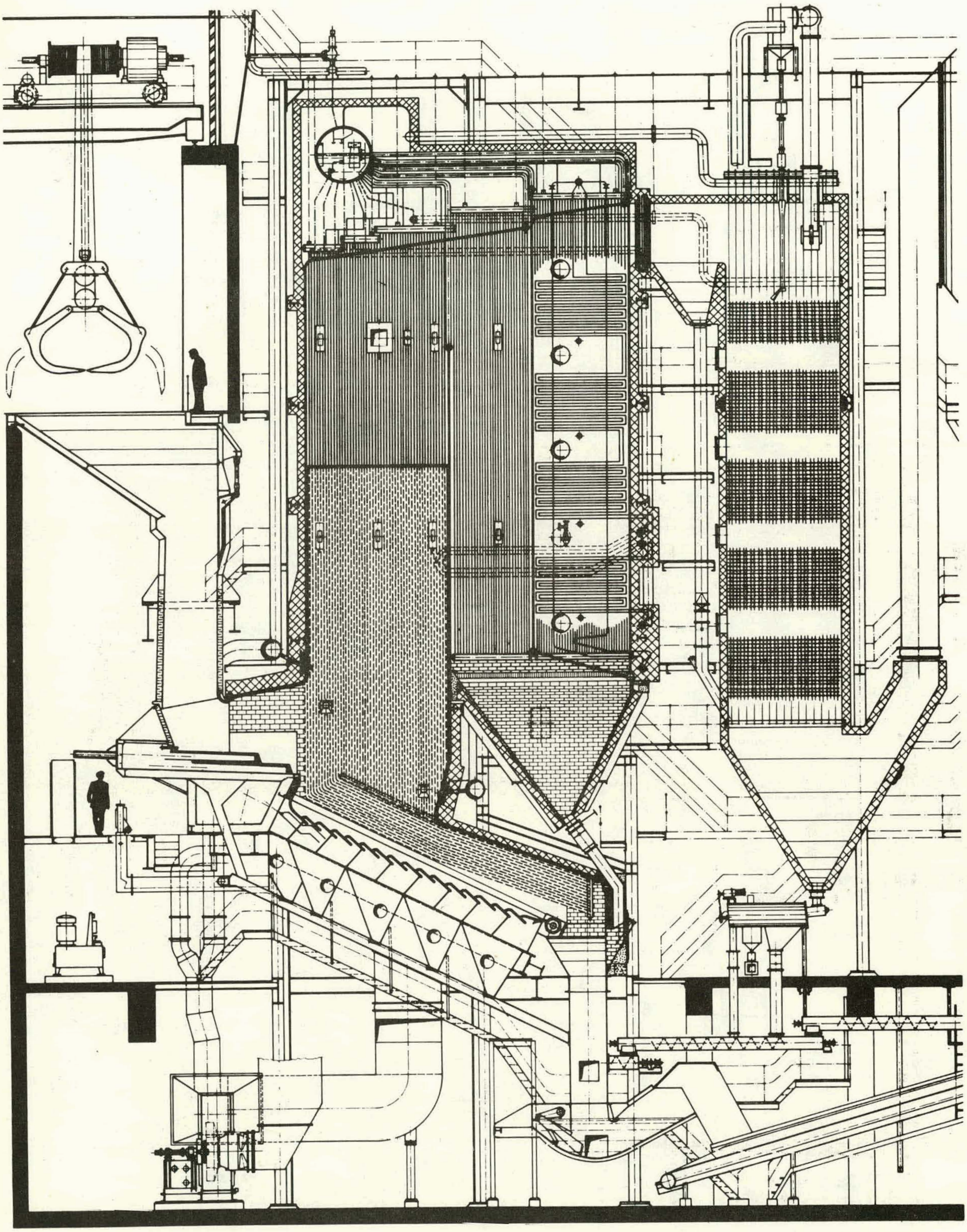


Figure 14. Boiler Design Zurich.

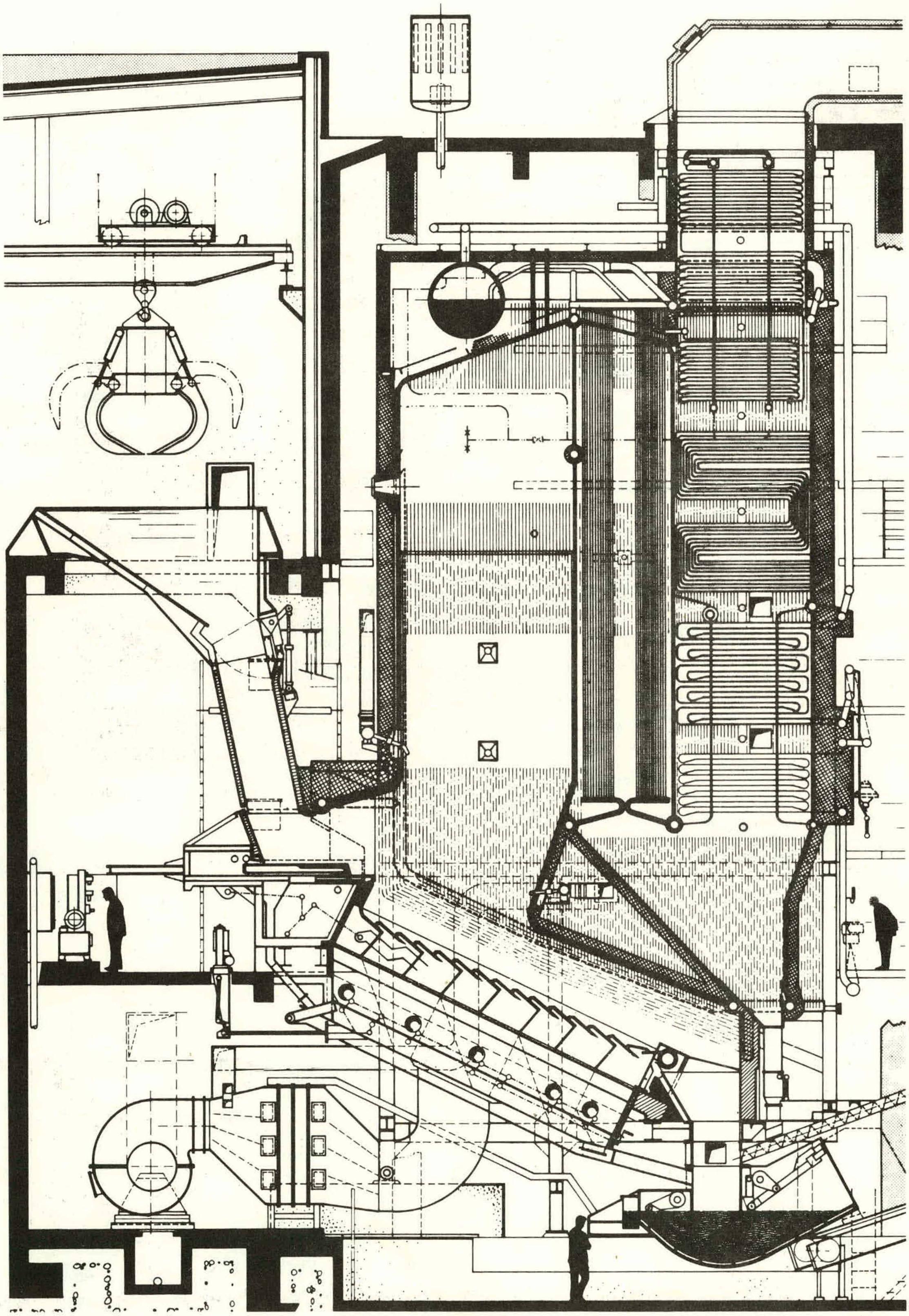


Figure 15. Boiler Design with Rapped Platen Heating Surfaces.

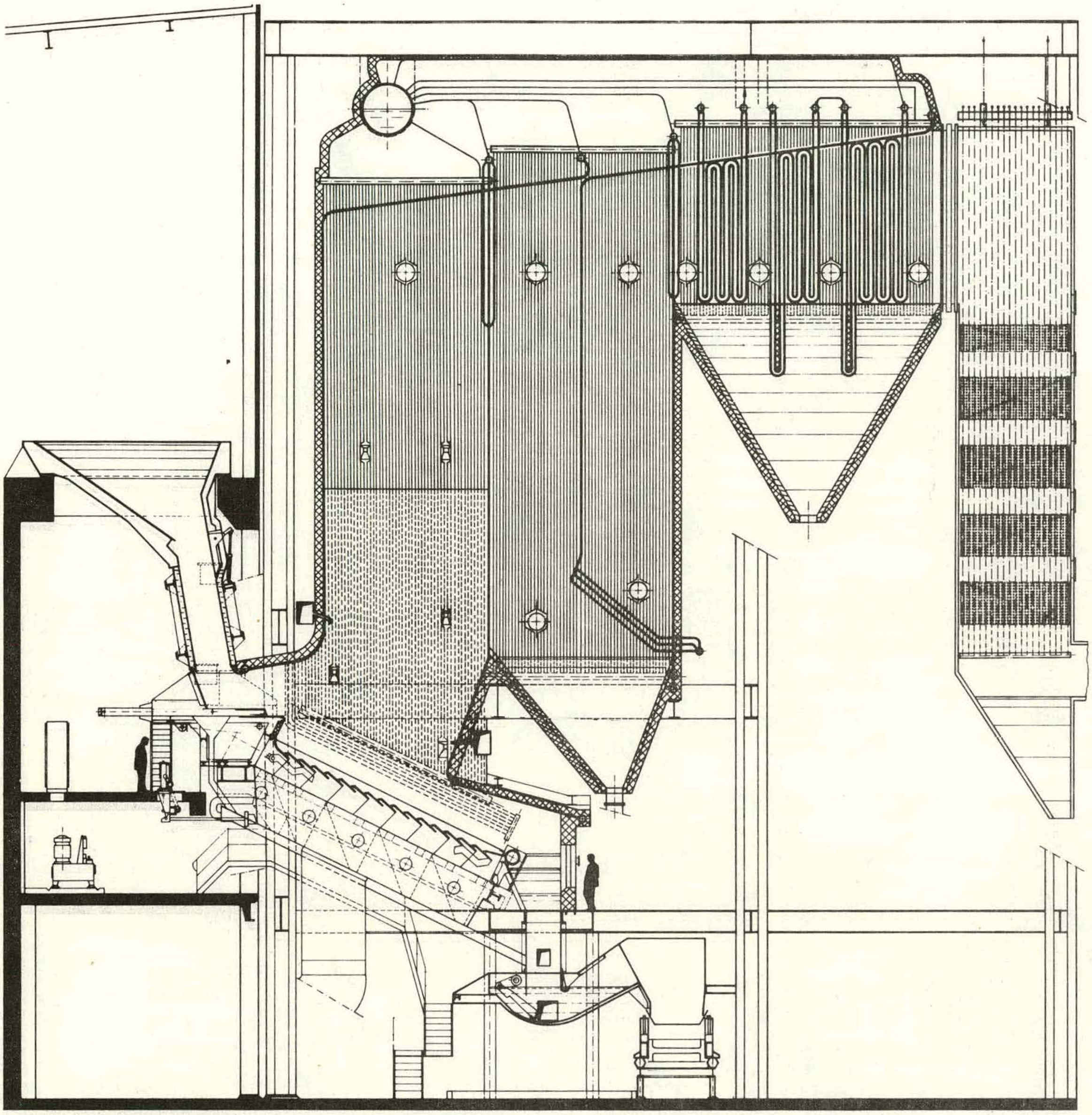


Figure 16. Boiler Design with Three Open Radiation Passes.

When comparing boiler development and periods of continuous boiler operation attained in Martin plants with systems of other designs, one must consider the fact that the Martin Stoker Grate can operate at its full design capacity for many months thanks to the automatic clearing of the combustion air gaps. Because of this, the boilers used in Martin plants can also be continuously operated at higher loads than boilers of other systems which are generally not run under high load conditions.

Over the course of the last fifteen years, it has been found that with a steam condition of up to 43 bars (615 psig) and 400°C (750°F) the corrosion rate of the furnace and superheater tubes is no higher than with boilers fired with fossil fuels. The Martin plants in Paris-Ivry and Nuremberg, however, demonstrate that refuse incineration plants with higher steam conditions, for example 75 bars (1065 psig) and 470°C (880°F), can be built if additional protective measures are applied.

Because of the increasing trend toward use of the heat energy in solid waste for district heat and electric power, further developments are being pursued to improve plant energy output. These developments include reduction of in-plant power requirements (for example, by the use of speed control on induced draft and forced draft fans), reduction of heat losses, increase of thermal efficiency by improved controls and use of electronic process calculations, etc. Figure 17 refers to the five previously mentioned typical Martin plants and shows the quantity of heat produced and the fuel oil equivalent saved by the use of energy from refuse.

Environmental Performance

In West Germany in 1974, the "Technische Anweisung Luft" (Technical Instruction Air) stipulated the following emission limits, corrected to 11 percent oxygen in the exit gases:

maximum dust content: 100 mg/Nm^3 (= 0.041 grains per scf)
maximum HCl content: 100 mg/Nm^3 (= 0.041 grains per scf)
maximum HF content: 5 mg/Nm^3 (= 0.0021 grains per scf)

Electrostatic precipitators are proven and very reliable devices for the removal of fly ash from combustion gases. Optimum values of less than 20 mg/Nm^3 (= 0.0083 grains per scf) are achieved. Specific design details which have proven most successful include low gas velocities of less than 1.0 m/sec. (40 in./sec.), uniform gas distribution, long residence time of the gases in the precipitator and profiling of the collecting surfaces to form collecting pockets.

Emissions of hydrogen chloride (HCl)and hydrogen flouride (HF) have been reduced by washing or scrubbing devices of different designs using alkaline wash water. The known disadvantages of these devices, including the concentration of pollutants in waste water effluents, have increasingly brought about the use of dry separation devices. In these devices a dry absorbing substance such as lime dust ($CaCO_3$) or dolomite dust ($CaCO_3$, $MgCO_3$), both of which are alkalline-reacting, is injected into the furnace or into the flue gas. The injection of sodium hydroxide (NaOH) into the

MARTIN PLANT Use of recovered energy	Refuse burnt Mg/Year	Electricity exported kWh/Mg Refuse	Heat exported GJ/Mg Refuse	Fuel oil equiv. referred to 1Mg of refuse barrels
Bazenheid / Switzerland Export of steam	in 1979: 20,200	0	3.26	0.65
Vienna - Spittelau / Austria Export of hot water and electricity to district heating plant	in 1977: 216,500	32.3	4.60	0.96
Hamburg - Stellingen / Germany Export of electricity	in 1979: 185,780	311.5	0	1.00
Zurich - Josefstrasse/Switzerland Export of hot water, steam and electricity	Jan.- June 1980 52,515	236.0	2.15	1.24
Munich - North - II / Germany Combined refuse and coal fired power plant. Export of hot water and electricity	in 1976: 164,960	570.8	0.90	1.11

Figure 17. Refuse Energy Recovered in Five Typical Martin Plants.

exit gases has also been successful (Figure 18). In all of these instances, a highly effective electrostatic precipitator is also required for separation of the dry or crystalline-bound pollutants.

Martin has made extensive tests for the development of dry means of noxious gas separation by injection of dolomite dust into the furnace. Although the desired goal of HCl emissions less than 100 mg/Nm^3 has not yet been attained, this dry method does seem to be promising for the future.

The development of our combustion load controller represents another important step in the reduction of noxious gas emissions. The uniform, load-controlled feeding of refuse onto the stoker grate, the excellent controllability of the Martin Stoker Grate itself and the carefully controlled admission of air to the individual combustion zones in a Martin plant already help to avoid the formation of noxious gases and their emission. The combustion load controller is under continuing development, and further positive results may be expected as soon as less costly and quicker-reacting measuring devices for the specific noxious gases are available on the market.

Residue, Fly Ash and Waste Water

For the safe disposal or further processing of refuse combustion residue, the standard which has proved to be applicable is the content of putrescible substances in the combustion residue. In this residue the presence of no more than 3 to 5 percent (by weight) unburned carbon and no more than 0.1 to 0.3 (by weight) percent putrescible material is generally stipulated. The Martin Stoker Grate achieves values well below these values.

In many plants the residue is screened, classified and then recovered as an aggregate for road construction. Scrap iron is usually removed magnetically and then sold. Pellets formed by mixing fly ash with cement are solid and insoluble in water and can therefore be disposed of without concern.

The Martin Ash Discharger does not emit any waste water. Just enough water to condition the residue is used, and most of it evaporates in the ash discharger. In some plants, even the boiler blowdown water is directed to the ash discharger, and these plants produce no waste water effluents.

Cofiring of Refuse and Sewage Sludge (Figure 19)

For some years now, Martin has been testing several options for the cofiring of refuse and sewage sludge. For most of the projects, one of the two following proven systems have been used: (1) spreading sludge with a water content of up to 70 percent directly onto the burning refuse bed by means of a rotary-type spreader or (2) for sewage sludges of high water content or for large quantities of sludge, the sludge is first processed in a steam-heated thermal dryer, and the dried sludge is then fed onto the stoker grate together with the refuse.

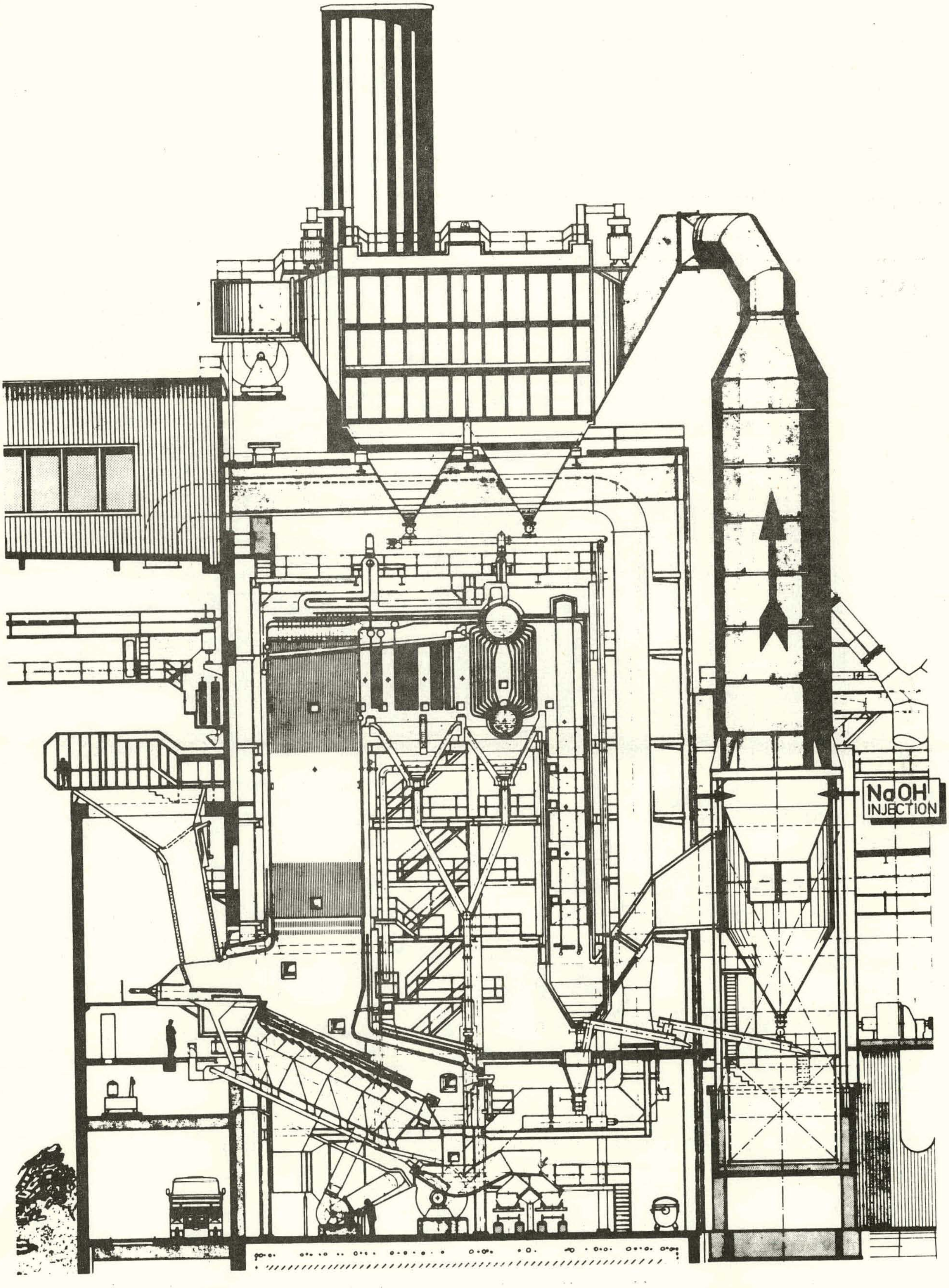


Figure 18. Hamburg Stellinger Plant: Neutralization of Noxious Gases by Injection of NaOH.

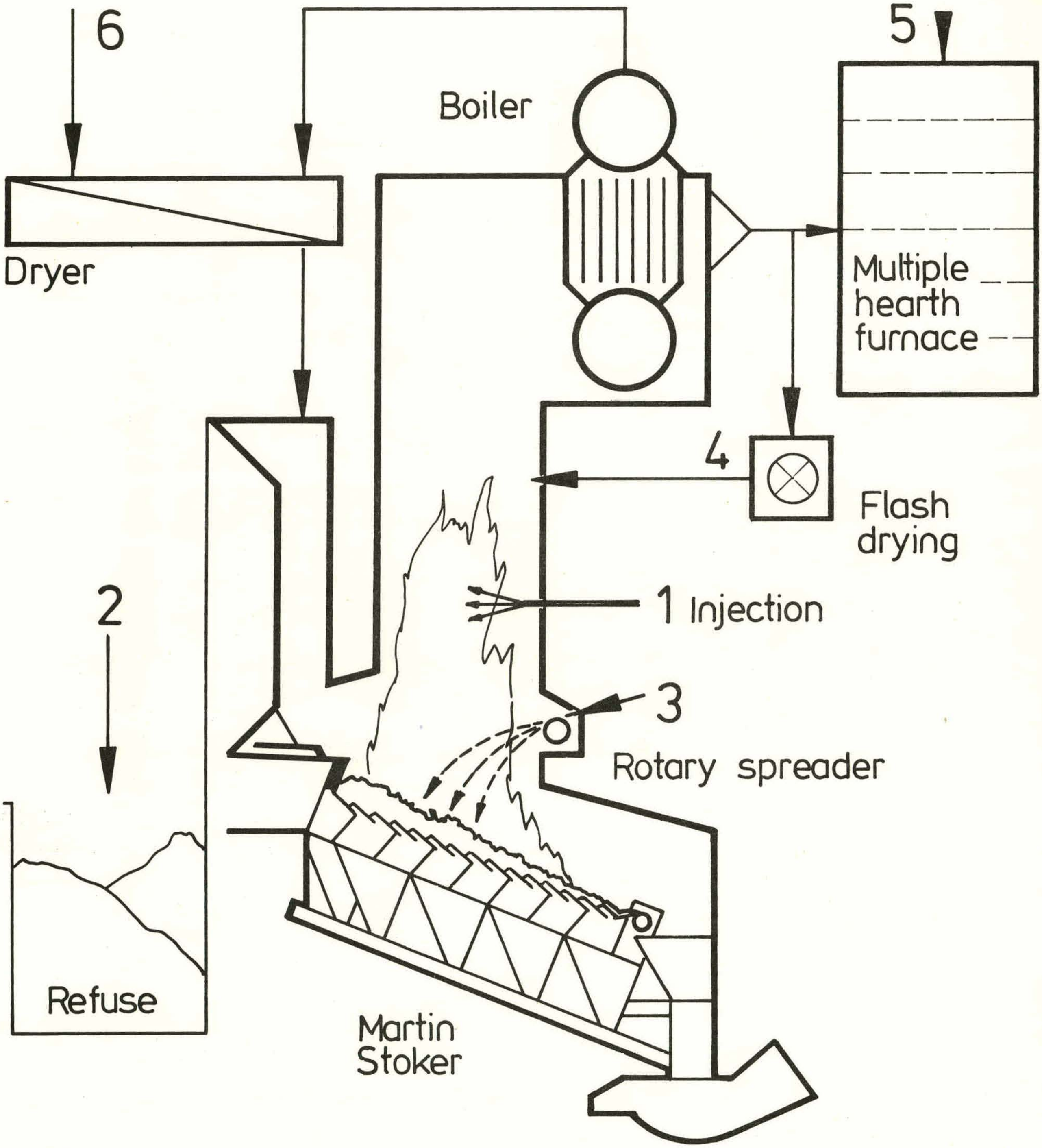
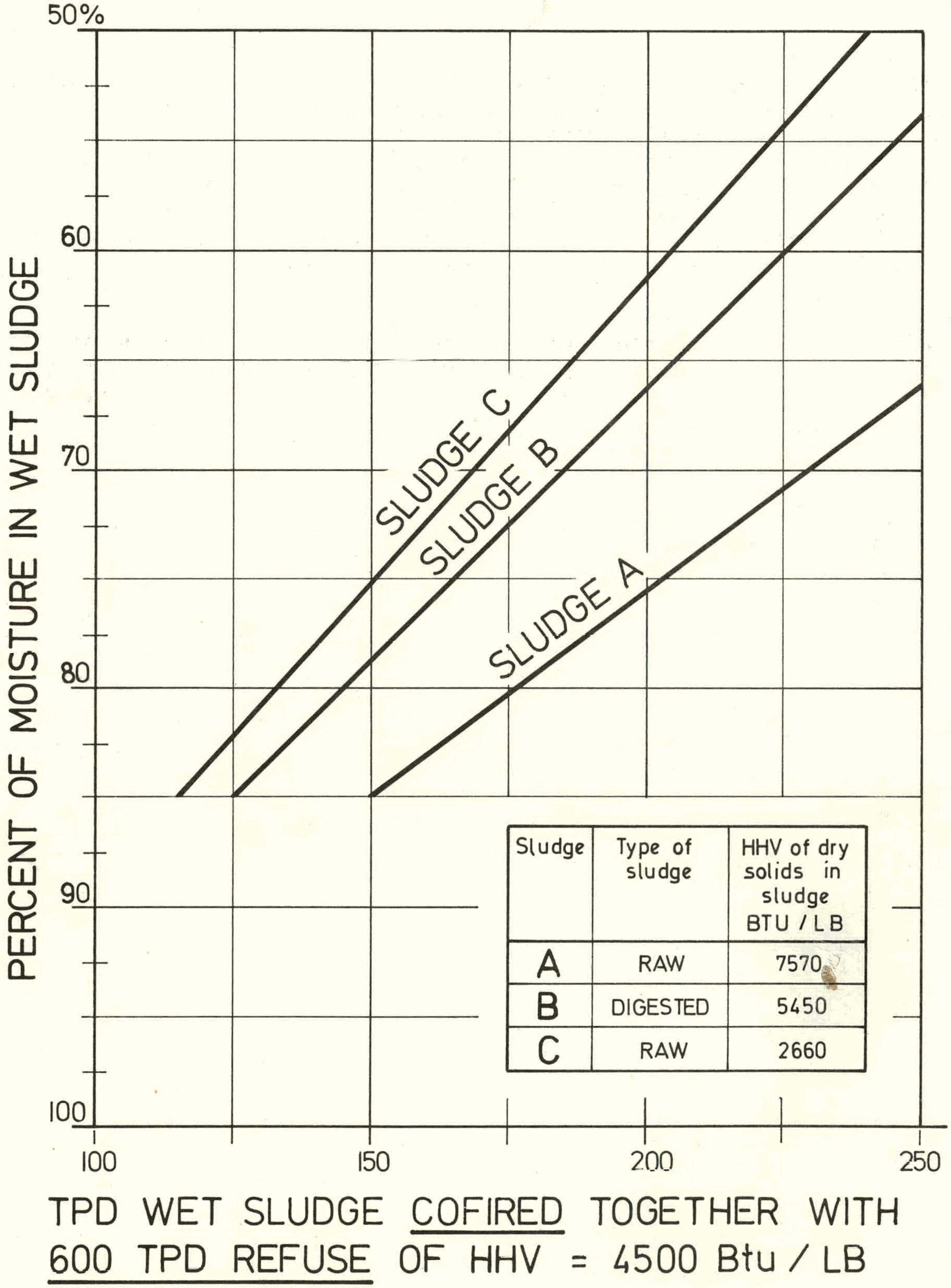


Figure 19. Processes for Codisposal of Refuse and Sewage Sludge.

When cofiring refuse and sewage sludge, the flame end temperature must be at least 1472°F in order to destroy the odors in the gases. Therefore, the quantity of sewage sludge which can be processed with refuse depends on the calorific values or heat contents of both fuels. Figure 20 shows the quantities of sewage sludge which can be combusted together with refuse having a higher heating value (HHV) of 4500 Btu per pound. We are working in close cooperation with our U.S. partner, UOP Inc., to apply these technologies as well as other approaches developed by UOP to the unique requirements set for in U.S. codisposal projects.

This working relationship involves a constant flow and exchange of technical information and on-site assistance extending through all aspects of project design, engineering, construction and operations and maintenance.



Sludge	Type of sludge	HHV of dry solids in sludge BTU / LB
A	RAW	7570
B	DIGESTED	5450
C	RAW	2660

Figure 20. Cofiring of Refuse and Sewage Sludge on a Martin Stoker Grate.

ENERGY GENERATION AND REFUSE DISPOSAL AT ISSY-LES-MOULINEAUX PLANT, PARIS

Fifteen Years of Operating Experience

by Jean Defeche

Refuse Disposal in Paris

Refuse collected in the City of Paris and 54 of its suburbs is transported to four disposal plants: three refuse incineration plants with energy recovery and one transfer station as shown in Figure 1.

The City of Paris is the owner of these plants, but they are operated by T.I.R.U. (Traitement Industriel des Residus Urbains), a special service of Electricite de France, which is a state owned company responsible for the generation and distribution of electricity in France.

To fulfill its duties, T.I.R.U. is comprised of an operations branch, an administration and accounting branch and an engineering office. Due to its many years of experience in the field of engineering and operation, the engineering office of T.I.R.U. is capable of assisting other municipalities in France and abroad in the solution of refuse disposal problems and the construction of processing plants.

In 1979 a total of 1,693,660 megagrams (Mg) (1,866,410 U.S. tons) of refuse were collected as follows:

From the City of Paris (approximately 2.3 million inhabitants)	1,028,465 Mg	1,133,370 U.S. tons
From the Suburbs (approximately 2.2 million inhabitants)	592,130 Mg	652,530 U.S. tons
Deliveries from trade and industry	73,065 Mg	80,520 U.S. tons
	1,693,660 Mg	1,866,410 U.S. tons

This quantity was processed as follows:

- Incineration with energy recovery in the plants of Saint-Ouen (350,650 Mg [386,420 U.S. tons] or 20.7% of the total), Issy-les-Moulineaux (568,000 Mg [625,940 U.S. tons] or 33.5% of the total) and Ivry (648,010 Mg [714,100 U.S. tons] or 38.3%)
- Dumping, especially from the transfer station of Romainville (127,000 Mg [139,950 U.S. tons] or 7.5%).

Figure 1. Municipal Refuse Processing Plants of TIRU and Catchment Areas.

Of the three refuse incineration plants mentioned above, Saint-Ouen using the Volund system has been in operation since 1954, Issy-les-Moulineaux using the Martin System has been in operation since 1965 and Ivry using the Martin System has been in operation since 1969.

The City of Paris began refuse incineration with heat recovery for the disposal of municipal refuse at the beginning of this century. The steam produced in the three plants of Saint-Ouen, Issy-les-Moulineaux and Ivry is used today both for driving turbine generators and for supply into the extensive district heating system of the City (Figure 2). The use of the heat energy contained in refuse, in the form of electrical energy and district heating steam, permitted the recovery of 7.6 million gigajoules (GJ) (7.2×10^{12} Btu) gross heat in 1979. This corresponds to a fuel oil equivalent of approximately 200,000 Mg (220,400 U.S. tons) or approximately 300,000 Mg (330,600 U.S. tons) of bituminous coal or approximately 140 liters (37 gallons) of fuel oil per ton of refuse.

The Issy-les-Moulineaux Plant

This paper reports on the operating experience obtained at the Issy-les-Moulineaux plant (Figures 3-5). This plant has been chosen because it was one of the first refuse incineration plants equipped with Martin Reverse-Acting Stoker Grates and because its 15 years of operation has yielded a great deal of experience which has been trend-setting for the design and operation of more recent refuse incineration plants. Although Issy-les-Moulineaux is an old plant, it still is a very reliable and economic one.

The plant consists of four refuse incinerator units and two turbines. The installation contains a ramp for refuse vehicles, a refuse bunker with two crane installations, two boiler houses connected by the control room and the turbine house, four electrostatic precipitators, two stacks, an ash pit and a fly ash storage bin.

The steam produced is expanded from 50 bars (710 psig) to 20 bars (275 psig) in a 9 megawatt (MW) back pressure turbine. Steam at 20 bars (275 psig) can be used both for supply into the district heating system and for driving the 16 MW condensing turbine (Figure 6).

Each stoker-boiler unit is designed for a normal refuse throughput of 15 Mg/hr (16.5 T/hr) and a maximum refuse throughput of 17 Mg/hr (18.7 T/hr) at a net calorific value (NCV) of 3,770 to 10,500 kilojoule/kilogram (kJ/kg) (1622 to 4518 Btu/lb) and a maximum refuse heat release of 157 GJ/hr (149 million Btu/hr). The steam production of each boiler is approximately 40 Mg/hr (88,160 lb/hr), and the steam condition at the superheater outlet is 53 bars (755 psig), 410°C (770°F).

Operating Statistics

A ten year survey covering the main plant parameters, that is, the quantity of refuse burned, the amounts of district heating steam and electricity sold and plant availability, is shown in Figure 7 and reveals certain interesting facts.

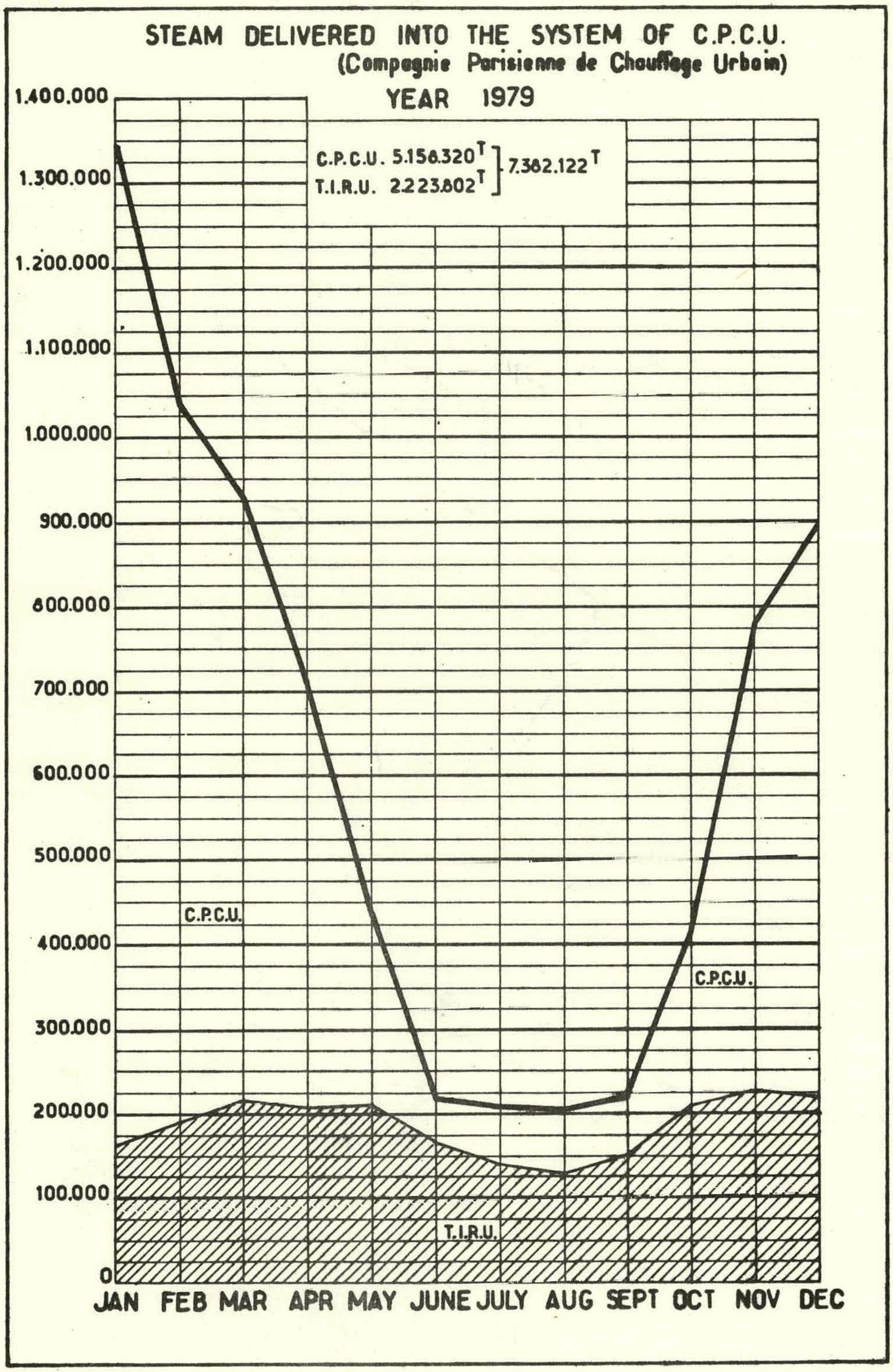


Figure 2. Steam Delivered into the CPCU System.

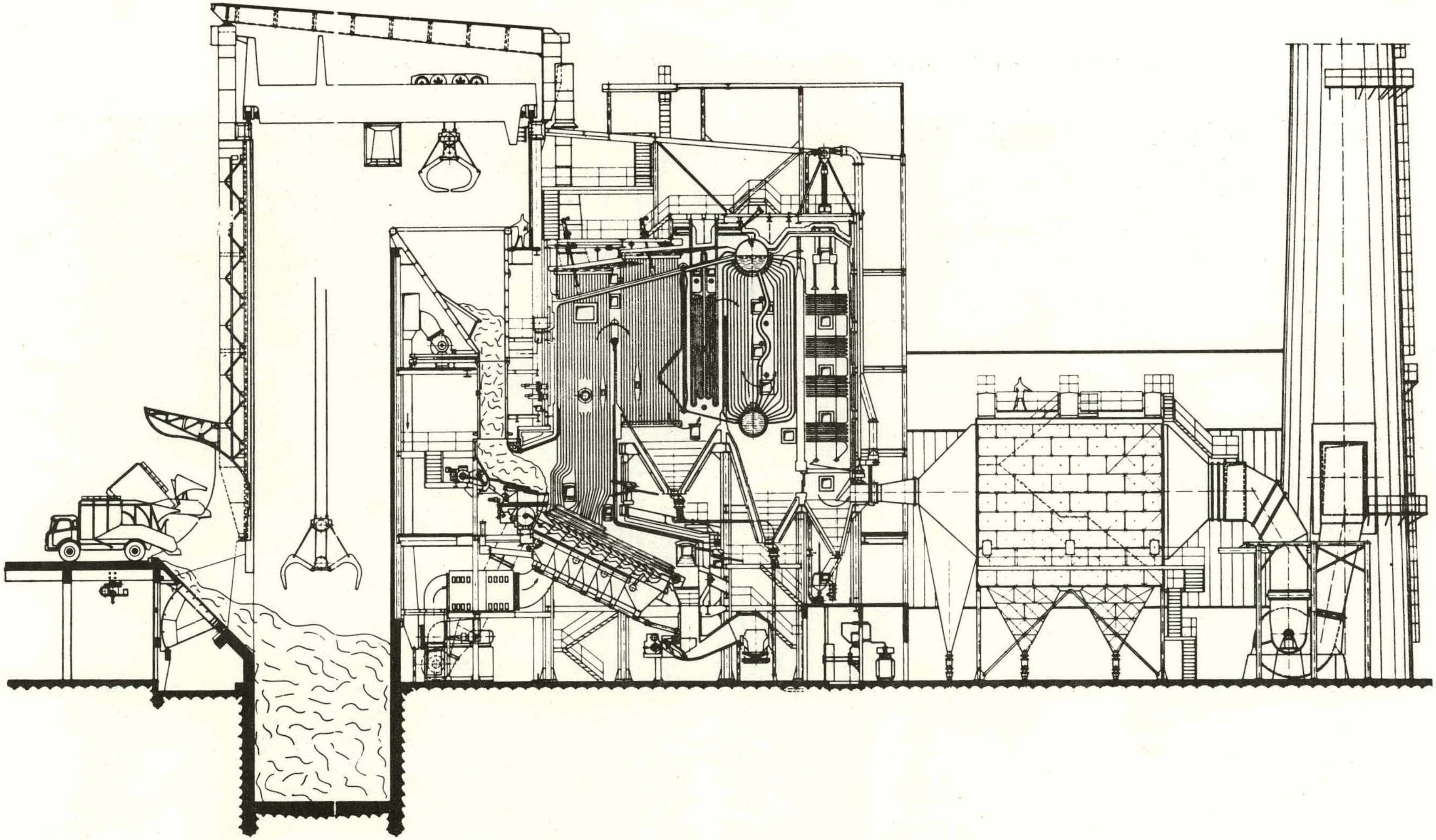


Figure 3. Paris Issy-les-Moulineaux Incinerator.

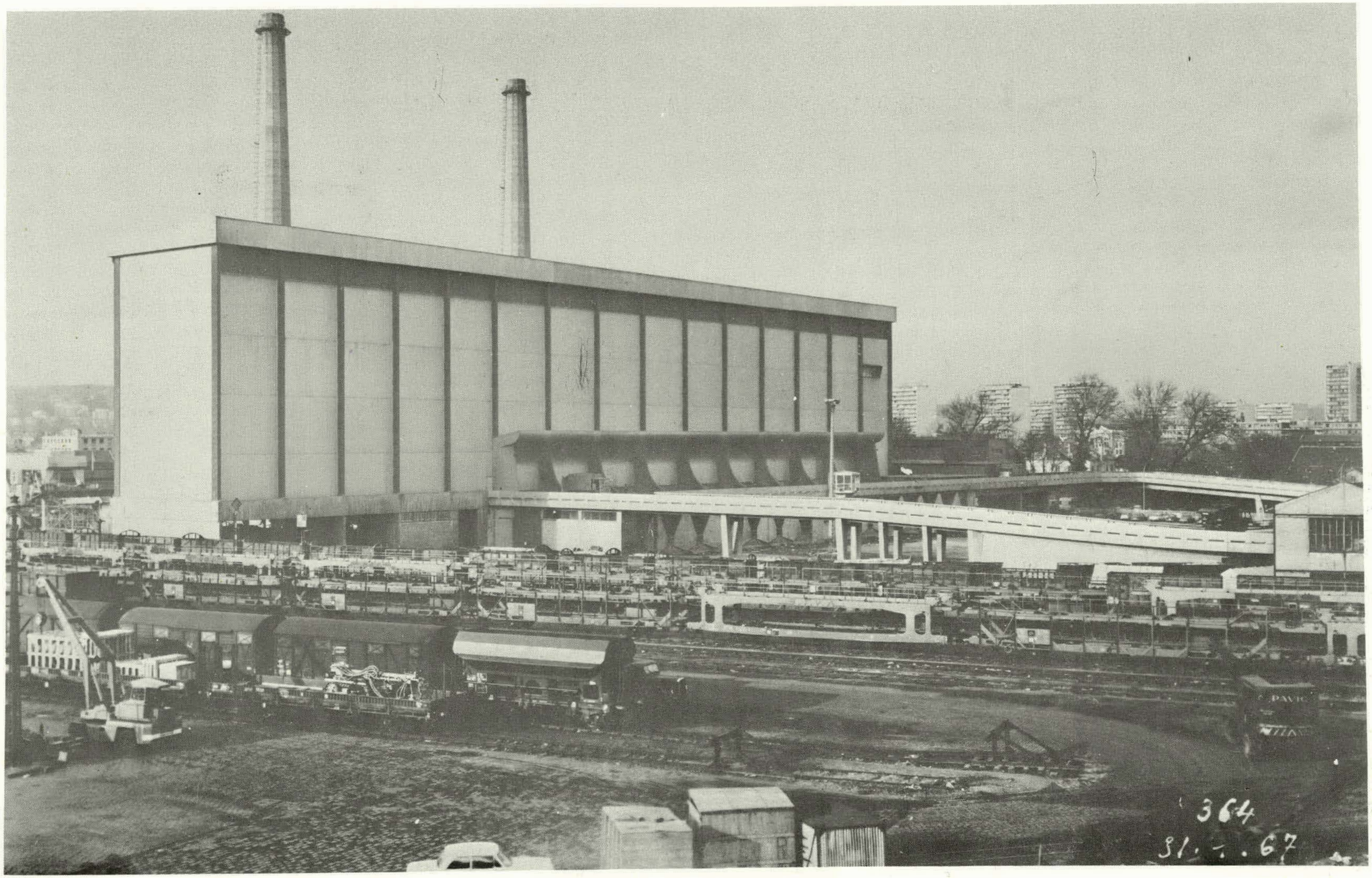


Figure 4. Paris Issy-les-Moulineaux Incinerator (Refuse Delivery Side).

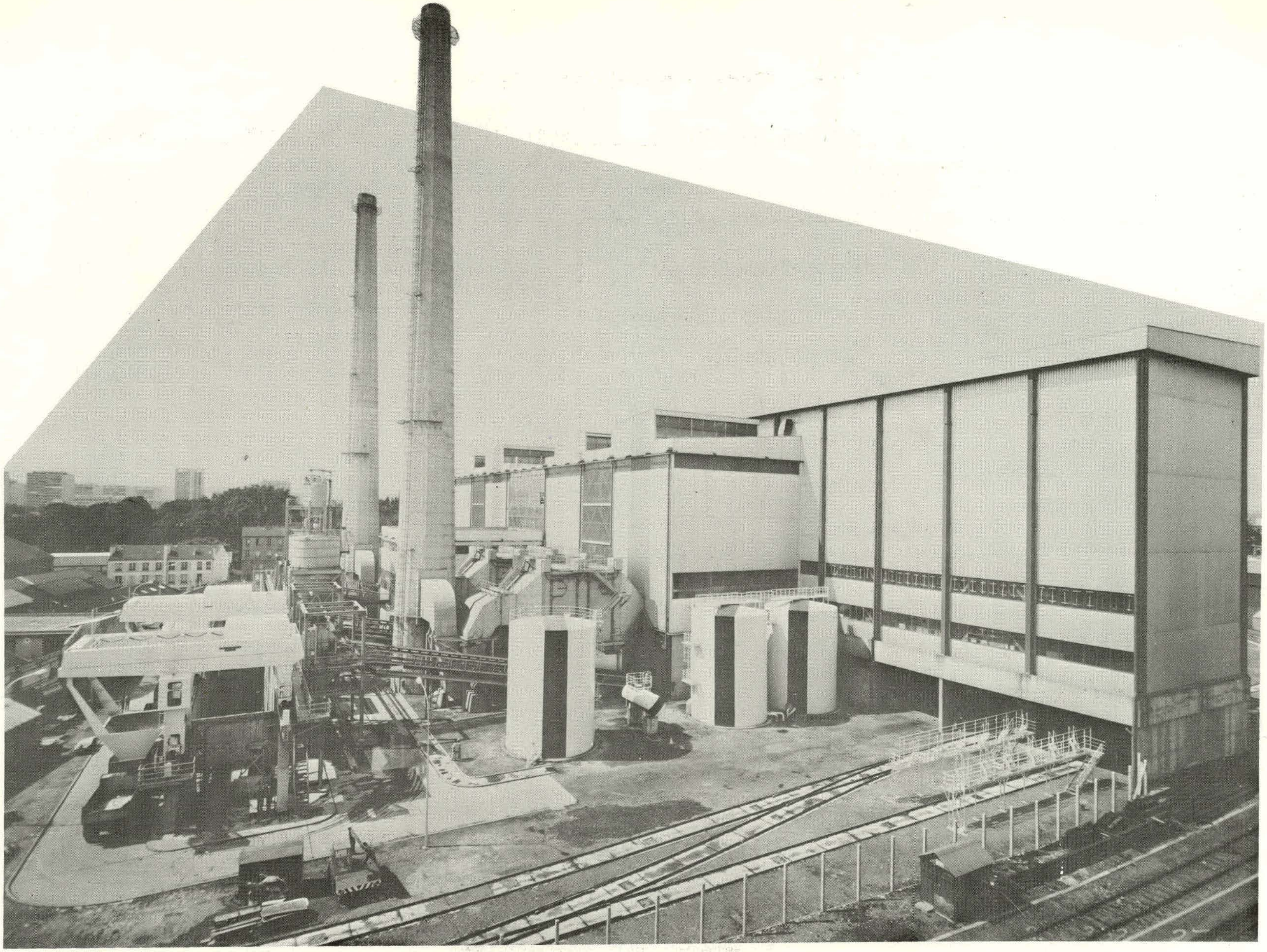


Figure 5. Paris Issy-les-Moulineaux Incinerator Boilerhouse, Electrostatic Precipitators, and Stacks.

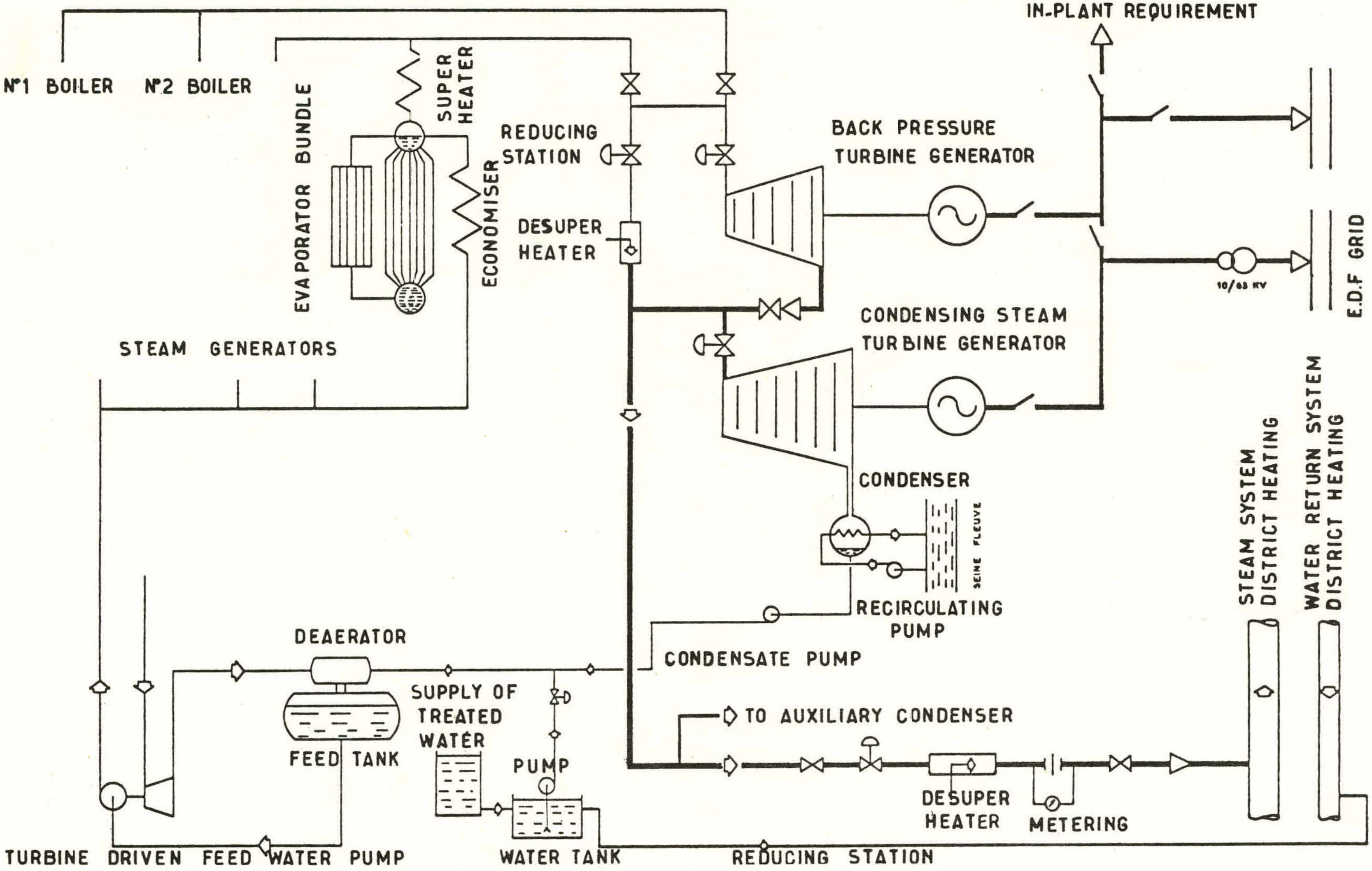


Figure 6. Issy-les-Moulineaux Plant.

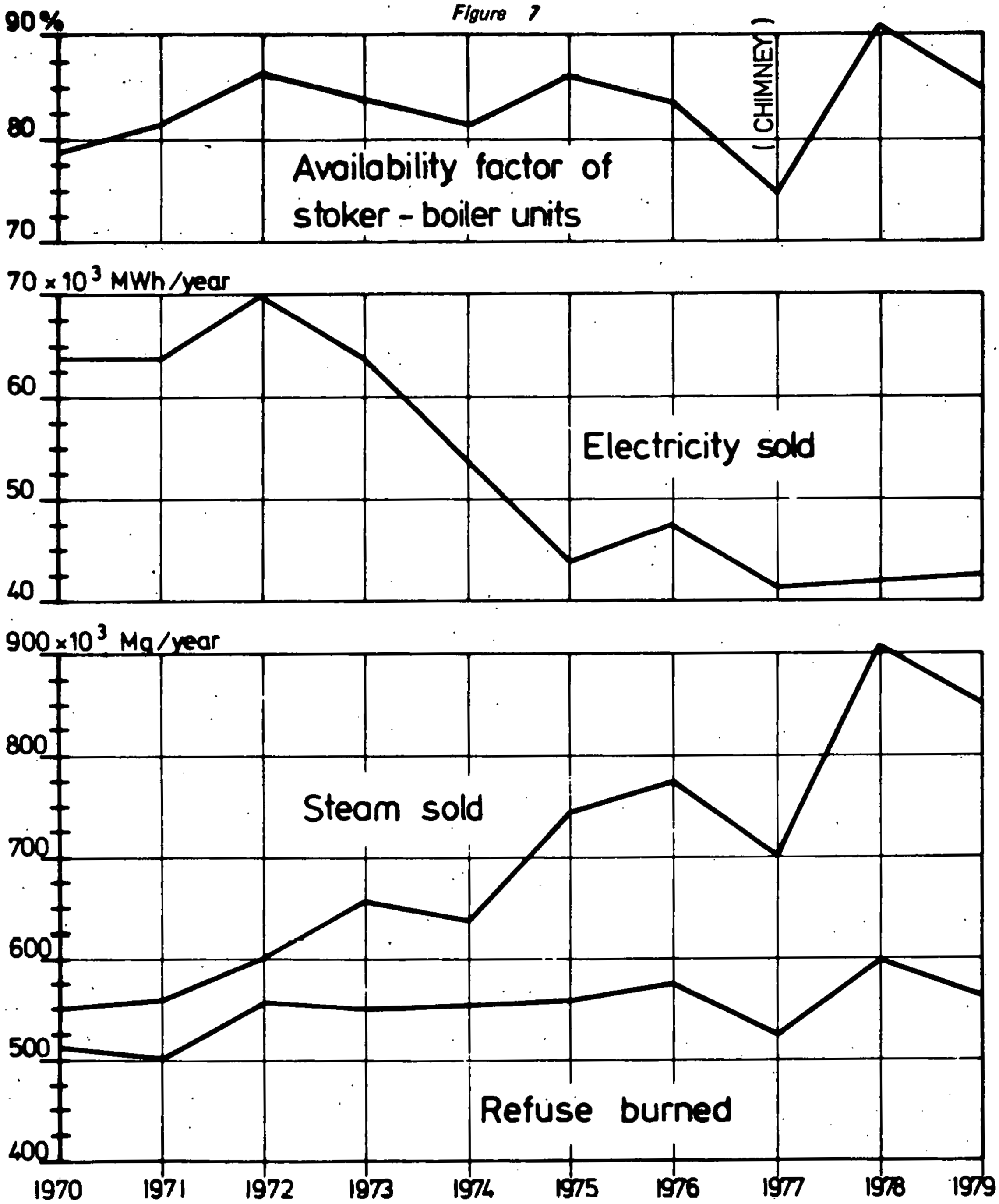


Figure 7. Operating Data from 1970 to 1979 - Paris Issy-les-Moulineaux Plant.

The quantity of refuse burned has increased slowly from the time of the plant's commissioning even though the calorific value of the refuse has increased from approximately 6,500 to 7,600 kJ/kg (2797 to 3270 Btu/lb) (NCV) during the same time. This was achieved by careful operation, increased preventive maintenance and improvement of certain equipment parts.

The year 1977 shows a reduction of the refuse quantity burned. This occurred when both stacks sustained unexpected damage which brought about a complete shutdown of the plant for six weeks. This forced shutdown was advantageously utilized to carry out the maintenance and repair work which had been planned for the following year. This permitted more or less continuous operation during 1978 so that plant availability in that year exceeded 90 percent.

Since the energy crisis in 1972, the purchase of district heating steam has been of greater economic interest. For this reason, the amount of district heating steam sold has been steadily increasing and the amount of electricity sold steadily declining. The basic thermodynamic design (see Figure 6) of the Issy-les-Moulineaux plant - back pressure turbine, 20 bars (275 psig) steam system and condensing turbine, 50 bars (710 psig) - has proved most successful for such an operation by providing the flexibility needed to meet this changing situation.

After the stack problems experienced in 1977 and the particularly favorable year in 1978, the operating year 1979 is to be considered again quite a normal one. The availability achieved was 86.2 percent, which corresponds to an average operating period per stoker-boiler unit of 7,550 hours/year. Detailed operating data for 1979 is shown in Tables I and II.

Operating Philosophy

The operating objective imposed on the plant is to burn the maximum refuse quantity with optimum energy yield. To achieve this goal, great efforts are being made toward the formation and training of the operating staff, on maintenance and on technical improvement of the equipment. Although the plant is already 15 years old, the average availability is still 85 percent, a value corresponding to the availability of similar sized power plants fired with fossil fuel.

Because the district heating steam demand during the summer months (Figure 2) is not sufficient to absorb all of the 20 bars (275 psig) steam available, the generation of electricity is more important during that period than in the winter.

Maintenance Work

During a period of two or three weeks in August, refuse delivery decreases by about 25 to 30 percent due to the holiday season. This short period is utilized for the annual general overhaul and repair of the plant equipment. A great part of the work is carried out by outside firms assisted by the plant personnel.

ABLE I. Main Operational Data from Issy-les-Moulineaux (1979).

- REFUSE QUANTITY BURNED	625,940 US TONS
- AVERAGE BURNING CAPACITY PER STOKER-BOILER UNIT	2.08 US TONS/HR
- AVERAGE REFUSE CALORIFIC VALUE, NCV	3,250 BTU/LB
- AVERAGE REFUSE CALORIFIC VALUE, HHV	3,720 BTU/LB
- STEAM PRODUCTION OF ALL BOILERS	1,118,940 US TONS/YR
- AVERAGE BOILER EFFICIENCY	63.4 %
ENERGY RECOVERY	
- DISTRICT-HEATING STEAM	1.9x10 LB/YR
- ELECTRICITY : GENERATED	61,866 MWH
SOLD	42,604 MWH
BOUGHT	138 MWH
IN-PLANT CONSUMPTION	19,400 MWH
IN-PLANT CONSUMPTION PER MG OF REFUSE	30.4 KWH/US TON
BY-PRODUCTS	
- REFUSE RESIDUE AND SCRAP IRON	210,660 US TONS/YR
- RESIDUE SOLD	168,420 US TONS/YR
- SCRAP IRON SOLD	16,500 US TONS/YR
- ASH	14,360 US TONS/YR

Table II. Operating Hours and Availability Factors - Issy-les-Moulineaux (1979)

Operating hours :	hours/year	% of 8760 hours
Stoker-boiler unit 1	7,450	85.05
Stoker-boiler unit 2	7,396	84.43
Stoker-boiler unit 3	7,774	88.74
Stoker-boiler unit 4	7,376	84.20
Average availability of the stoker-boiler units	7,551	86.2
Average non-availability of the stoker-boiler units due to breakdowns	298	3.4
Average availability of the Martin stoker grates	7,761	88.6
Average availability of the turbine generators	8,629	98.5

The annual general overhaul of a stoker-boiler unit requires a shut-down of 28 days during which 22 members of the plant staff and 40 to 50 outside personnel are employed. Certain work is carried out in two shifts.

The following main equipment parts undergo a special inspection during the annual general overhaul:

Crane installation:	Ropes, brakes, grabs
Firing equipment:	Grate bars, brickwork
Boiler:	Cleaning of heating surface, measurement of tube wall thickness, checking of soot blowers, valves
Electrostatic precipitator:	Cleaning, checking for corrosion, insulators, rotary seal valves
Residue handling:	Conveyor belts, support rollers

Day-to-day maintenance and other routine work during the year are carried out by the maintenance personnel belonging to the plant itself. These maintenance personnel include 23 mechanics, welders and boiler makers and 11 electricians and engineers for controls.

Technical Improvements

The experience gained at Issy-les-Moulineaux over the past 15 years has been trend-setting not only for new refuse incineration plants but also for improvements at the plant itself. These improvements have included:

1. Approximately 5,000 to 6,000 hours after commissioning, corrosion was observed on some of the tubes of the furnace side walls. This damage occurred mainly in the area where the combustion gases are still in the burn-out phase, that is, in the flame area. To provide protection against the oxidizing as well as reducing action of the flames, the furnace side wall tubes were studded and silicon carbide (SiC) plastic refractory was stamped on. The results were very satisfactory.

2. After a longer operating time, the superheaters showed erosion and corrosion on the lower tube bends at the gas-side inlet and on the tubes at the gas-side outlet (see Figure 8). The superheaters were of the pendant type where the hot gases flow from bottom to top parallel to the superheater tubes. It was found that particularly heavy corrosion occurred when the flow of the burning gases was perpendicular to the tubes, which was the case for the lower tube bends and the suspended tubes at the top of the superheater. On the contrary, the corrosion rate was found to be quite low when the gas flow was in parallel with the tubes.

Various improvements have gradually been made in the superheater section of the plant. First, the lower tube bends and the tubes at the gas outlet were protected by shields (Figure 9) made from heat-resistant castings,

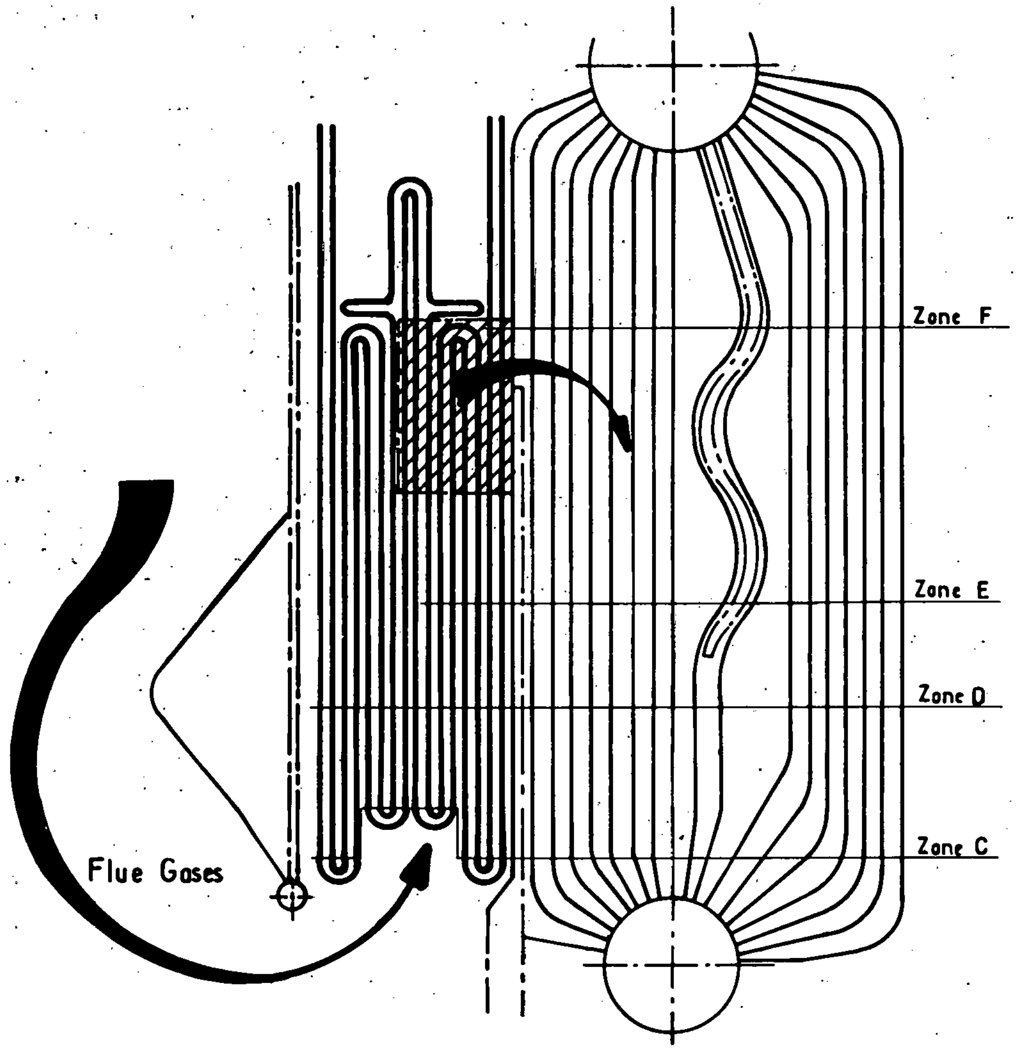


Figure 8. Superheater, Issy-les-Moulineaux.

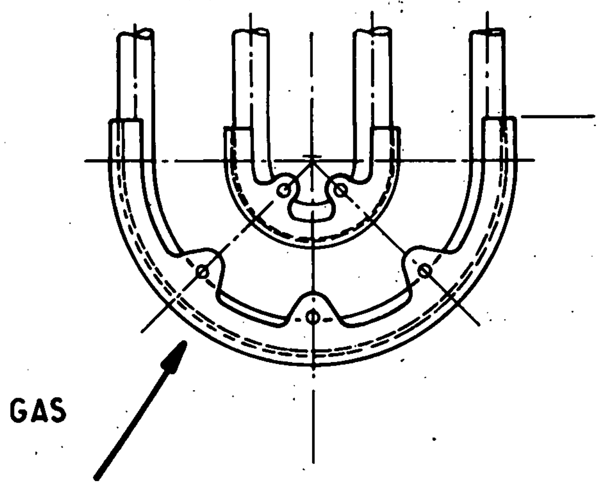


Figure 9. Lower Superheater Tube Bends Protected by Shields.

the life of which is about one year. A deflecting nose (Figure 10) was installed at the outlet of the second pass to improve gas distribution at the inlet to the superheaters and thus to reduce the velocity of impact upon the tube bends. After ten years of operation, when the straight tubes of the superheaters began to show significant wastage, the pendant superheaters were replaced by platen-type superheaters. This permitted, where necessary, the lining of the tubes with a thin coat of silicon carbide (SiC) plastic refractory which was anchored by means of studs as shown in Figure 11.

3. Research work in laboratories and comparative studies both at Issy-les-Moulineax and at Ivry have permitted a better understanding of the phenomena of corrosion and erosion on boiler tubes. It has been found that the corrosion rate is increased:

- when the gas temperature exceeds 650°C (1202°F) and simultaneously the temperature of the tube wall metal reaches 290°C (554°F),
- when the velocity of the fly ash particles impinging upon the tubes exceeds 4 meters (13 feet) per second,
- when the direction of the gas and dust stream is perpendicular to the tube centerline (as is the case in Ivry),
- when the gas distribution is non-uniform so that the tubes are hit by veins of gases at high velocity and possibly with a higher dust concentration,
- when soot blowing or gas velocity provoke an erosion-corrosion phenomenon by permanent suppression of the protective coating on the tubes and
- when combustion conditions are not steady.

In regulating the combustion conditions, the best results have been obtained by partial automatic control of refuse charging and grate movement as a function of the furnace temperature or of the steam rate.

A better knowledge of corrosion phenomena and a thorough study of the progressive fouling factor of the tube banks between two annual shut-downs has permitted the establishment of a certain number of rules which, if applied to the design of an incinerator boiler, will guarantee excellent reliability of the boiler. T.I.R.U. has been in a position to verify the validity of these rules in recent plants where studies and construction have been followed up by T.I.R.U. (Figure 12).

Operating Costs

Each year T.I.R.U. submits to its supervising authority an operating account covering all activities and indicating charges and revenues. Separate accounting at each plant allows the determination of costs for the individual plants. Operating costs of Issy-les-Moulineaux for 1979 in

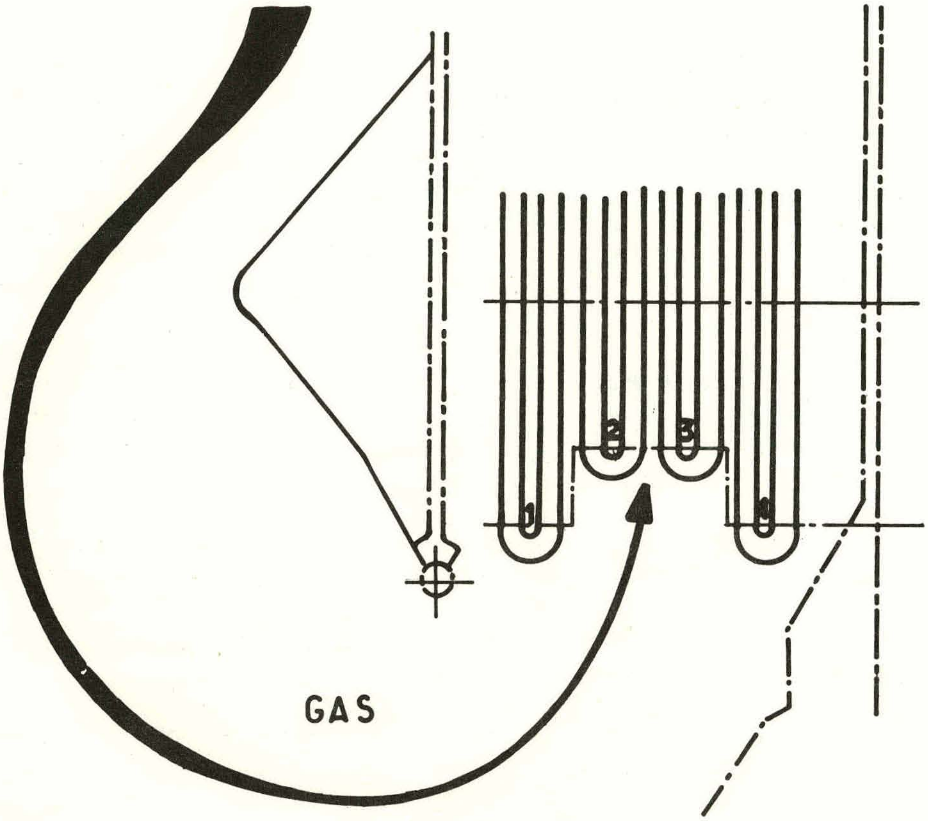


Figure 10. Deflecting Nose to Improve Gas Distribution in Superheater Pass.

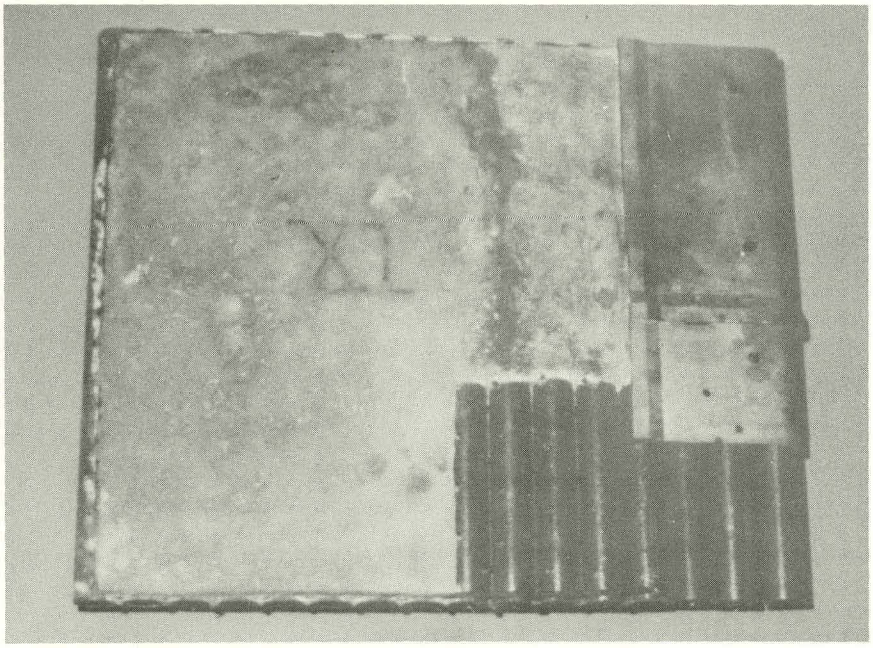


Figure 11. Platen-Type Superheater Tubes Lined with a Thin Coat of SiC Plastic Refractory Anchored by Studs.

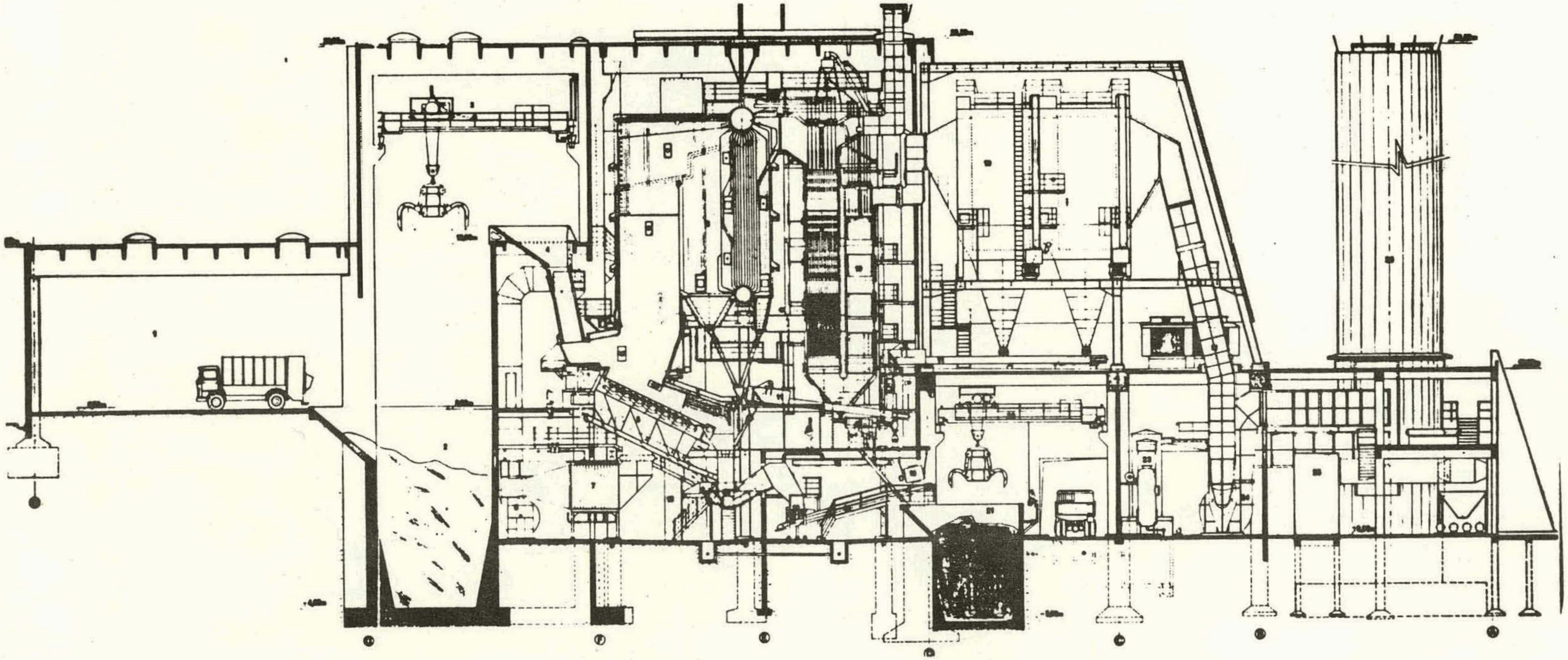


Figure 12. Nice, France Incinerator.

French francs per Mg of refuse burned in the plant are presented in Table III.

The net operating costs at Issy-les-Moulineaux in 1979 amounted to 23.48 French francs per Mg (1.102 U.S. tons). This is equivalent to $5.02 U.S. currency per ton at an exchange rate of one French franc to U.S. $0.24.

It is interesting to note that the direct operating expenses are lower than the revenues received. Calculation of the ratio of direct operating expenses to revenues over the past ten years (Figure 13) shows that this ratio has been steadily decreasing since the beginning of the energy crisis from 1.55 in 1970 to 0.94 in 1979. A ratio of 0.80 is expected for 1980.

Thus, the decision made many years ago by the City of Paris to recover the heat energy contained in the refuse of this capital city has proved to be fully justified. The actual disposal costs are absolutely competitive compared with those of dumping.

TABLE III. Operating Cost - Issy-les-Moulineaux (1979).

EXPENSES	
Costs for operation of equipment	$4.05/ton
Maintenance	$8.73/ton
General charges and general costs for the plant	$1.93/ton
Direct operating expenses	$14.71/ton
Different costs	$0.25/ton
Amortizement and financial charges	$3.31/ton
Proportion of general costs of T.I.R.U.	$2.39/ton
Other expenses	$5.95/ton
	$14.71/ton
	$ 5.95/ton
Total expenses attributable to the plant	$20.66/ton
REVENUES	
Sale of electricity and steam	$14.78/ton
Sale of combustion residue and scrap iron	$ 0.86/ton
Total revenues	$15.64/ton
RESULT	
Total expenses	$20.66/ton
minus total revenues	$15.64/ton
Operating costs	$ 5.02/ton
Operating costs (at rate of exchange = 0.24 US $/FF)	

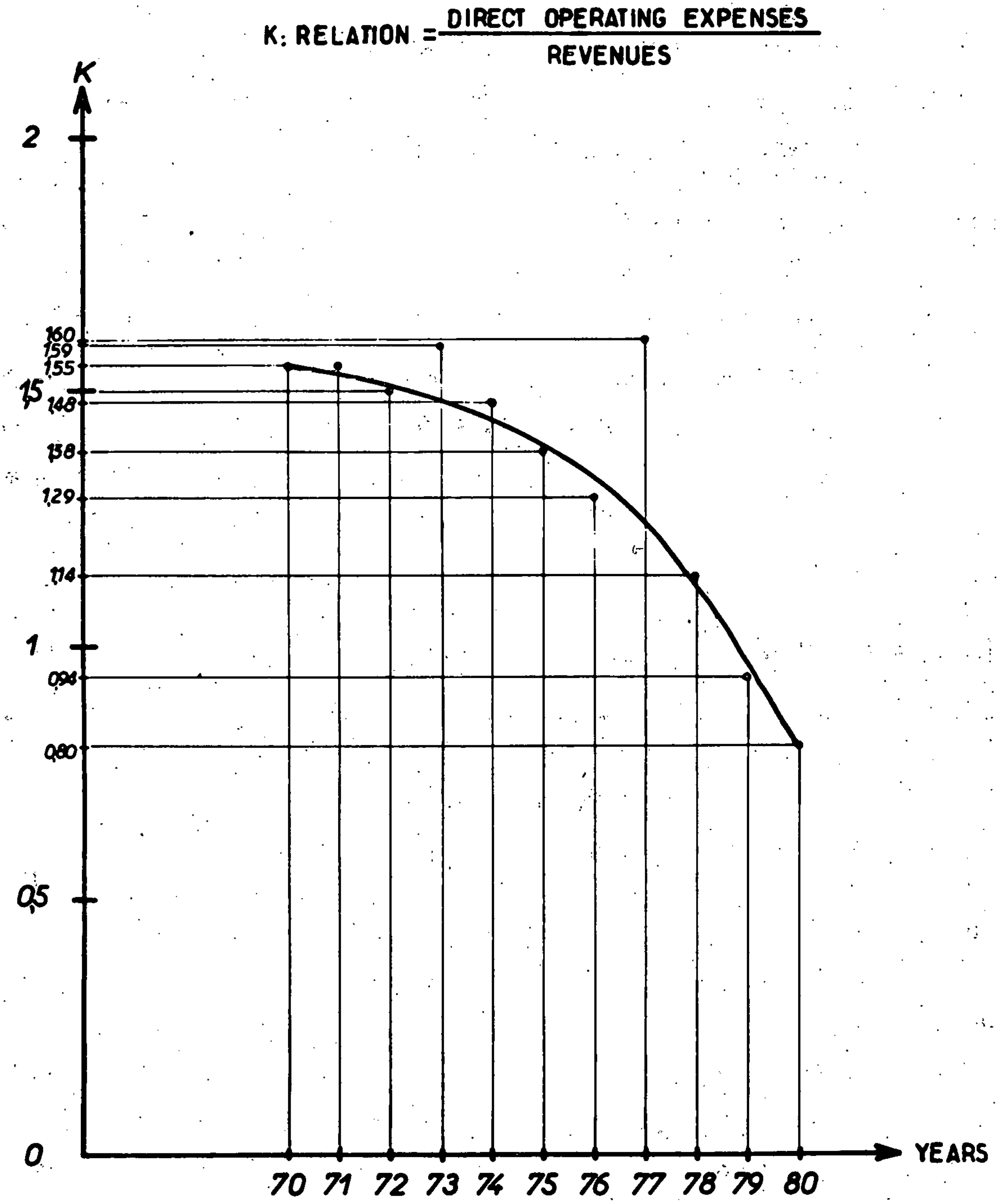


Figure 13. Issy-les-Moulineaux.

THE WHEELABRATOR-FRYE/VON ROLL APPROACH TO REFUSE-TO-ENERGY SYSTEMS

Presentation by Von Roll Ltd., Zurich, Switzerland
N. Dirilgen
(President, Environmental Engineering Division)
and
R. M. Luthy
(Head, Sales Department, Environmental Engineering Division)

BACKGROUND

1. VON ROLL LTD.

1.1 Company Structure

- Von Roll was founded in Switzerland in 1823. At present, the entire group has engaged 6300 employees in more than 20 production facilities and offices. Sales of the group exceeded 1 billion Swiss Francs ($615 million) in 1979.

Von Roll is quite a diversified corporation, operating steel mills and foundries, with manufacturing facilities for heavy machinery and equipment for mechanical handling and, ultimately, the Environmental Engineering Division. This is the division we would like to present to you in more detail.

1.2 Activities of the Environmental Engineering Division

The Environmental Engineering Division with its head office in Zurich, Switzerland, was established in 1933. The division acts as an engineering contractor with proprietary technological know-how in the following five fields:

(a) Municipal refuse incineration: Mass burning of refuse on a grate system with an integrated boiler for energy recovery.

(b) Industrial or hazardous waste incineration: Grate, rotary kiln or fluidized bed incineration of hazardous waste, either for a particular application or for a regional disposal center.

(c) Waste water treatment: Engineering and supply of components for municipal waste water treatment plants as well as conceptual engineering of complete plants.

(d) Sludge treatment: Conversion of the residual sludge ex municipal plants into a hygienic and dry product for recycling or incineration.

(e) Co-Disposal plants: A combined process scheme for the disposal of sludge and municipal refuse (or industrial waste) optimizing the energy recovery.

In most European countries Von Roll's Environmental Engineering Division sells, designs, erects and commissions such plants on a turn-key basis. In other cases, especially overseas (U.S.A., Canada) Von Roll acts through well established licensees. Wheelabrator-Frye, our U.S. Licensee, provides full-service contracts which include: design, construction and long-term operation.

2. Worldwide Activities - Mass Burning Technology

Von Roll's Environmental Engineering Division markedly influenced the mass burning technology. We were the first to design waterwall type furnaces, and in 1954, built the first refuse-to-energy plant.

In total, 157 incineration plants have been built by Von Roll, direct or through its licensees all over the world.

Country	No. of Plants	Capacity t/day
Switzerland	15	4290
Germany	23	7169
Austria	3	1698
Japan	61	18866
Sweden	7	1881
Finland	2	640
The Netherlands	4	1800
France	15	4169
Italy	14	3028
Spain	3	1152
Australia	3	629
Canada	2	2520
U.S.A.	2	1635
others	3	820
Total	157	50297

3. European Systems

3.1 History

For many years now, in Europe, incineration has been considered a safe refuse disposal process, by which solid, liquid and gaseous combustible waste is, through controlled combustion, converted to residue, which contains virtually no combustible matter and no substances dangerous to the environment. In addition to the safety, this well established incineration process reduces the refuse volume to approximately 10%. In the fifties, when incineration costs rapidly increased, additional revenues were created by the sale of energy in the form of heat for district heating and/or electric power. This scheme was first implemented by Von Roll when it built the mass burning plant for the capital of Switzerland, Berne, in 1954. In this plant, steam is used both for district heating as well as for electric power generation.

With the increase in fuel cost in the 1970's, this philosophy was even more strictly adhered to. Currently, only a small number of plants are being built or being discussed, where no energy recovery is considered. It has to be emphasized that the European approach to mass burning points primarily to a safe and controlled disposal of the refuse generated by mankind, and only secondarily does one try to maximize the recovery of energy, be it in the form of steam for heating or industrial applications, or, if none of these are feasible, in the form of electric energy.

3.2 Size Range

In Europe, the size of the units have increased over the years. In the mid-fifties, plants in the range of 100-200 tons a day were normal. In the sixties, units of 300-600 tons a day were built. Nowadays, some projects of up to 1200 tons are under discussion, although such capacities will remain exceptional.

The size of a plant is strongly influence by geographical considerations, traffic restrictions, political feasibilities and many other factors. Due to all these, the major share of the European markets will still be in the medium size range, say 300-600 tons a day.

3.3 Project Arrangements

The owner and operator of a plant in Europe is, with only a few exceptions, the municipality or lately, due to pooling, a group of communities. The financing of these projects is done by municipalities, but backed up by federal, state and local governments through subsidies.

Generally, the municipalities handle these projects as turn-key projects. Civil work might or might not be included in the supplier's bid, depending on local preferences. One specific European peculiarity has to be mentioned in this respect: The European owners of a plant generally expect or even demand from the supplier to mazimize the subcontracting in the region of the project.

Von Roll's Environmental Engineering Division not only supplies a complete process package, from the truck weighing station up to the top of the stack, but also acts as a contractor for designing, erection and commissioning of mass burning waste-to-energy systems in Europe and abroad.

Von Roll's Environmental Engineering Division is represented by VON ROLL INC., in New Jersey. With respect to the mass burning technology for municipal refuse-to-energy projects, Von Roll has a Technical Cooperation Agreement with WHEELABRATOR-FRYE INC., Hampton, New Hampshire.

ECHNOLOGY

1. Design

1.1 General

As mentioned before, Von Roll started in the field of mass burning in 1933. The newer generation of plants was initiated by the design of the first energy recovery type of plant in 1954. But even from then on, various design details had to be adapted to the changes of the waste composition, to new gas cleaning technologies and standards, as well as to the economic considerations.

The change in heating value (LHV) in Europe from 1200 kcal/kg (2150 Btu/lb.) in 1950 to 2000 kcal/kg (3290 Btu/lb.) in 1980 illustrates this.

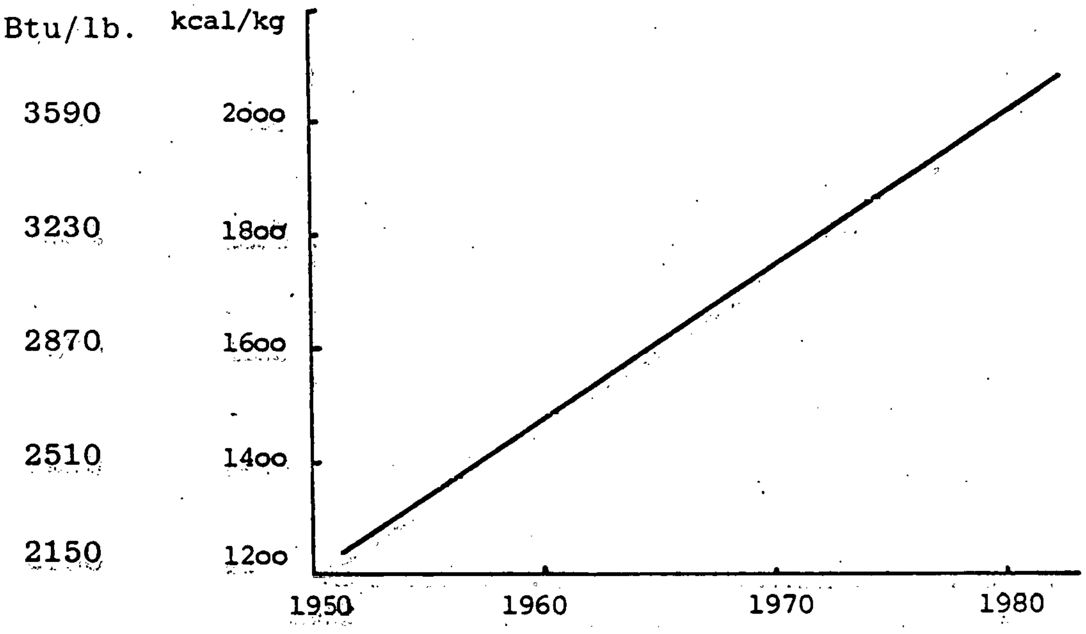


FIG. 1

In this context it is worthwhile mentioning that the actual heating value changes did not follow the prediction. Nevertheless, the change in heating value in and the resulting design modification assist greatly in applying the proper grate design for the various projects. The difference in heating value in the various countries can be illustrated as follows:

- Germany: 1500 - 2000 kcal/kg (2690 - 3590 Btu/lb.)
- Japan: 1200 - 1800 kcal/kg (2150 - 3230 Btu/lb.)
- Spain: 1000 - 1600 kcal/kg (1795 - 2870 Btu/lb.)
- Italy: 1000 - 2000 kcal/kg (1795 - 3590 Btu/lb.)
- USA: 1500 - 1500 kcal/kg (2690 - 4490 Btu/lb.)

Figure 2 shows the typical cross section through a mass burning refuse-to-energy plant for a high heating value (approximately 2000 kcal/kg (3590 Btu/lb.).

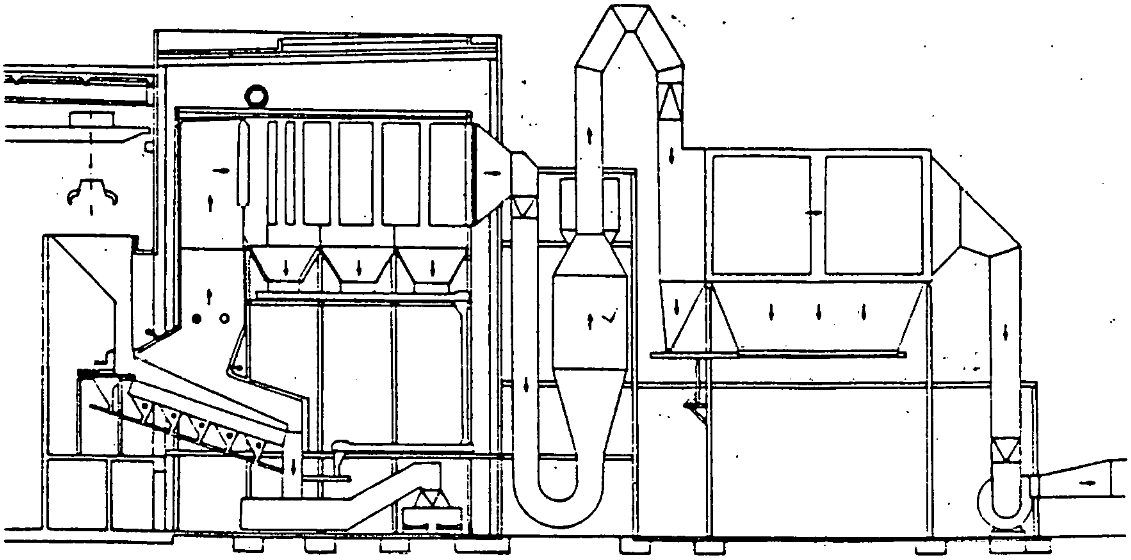
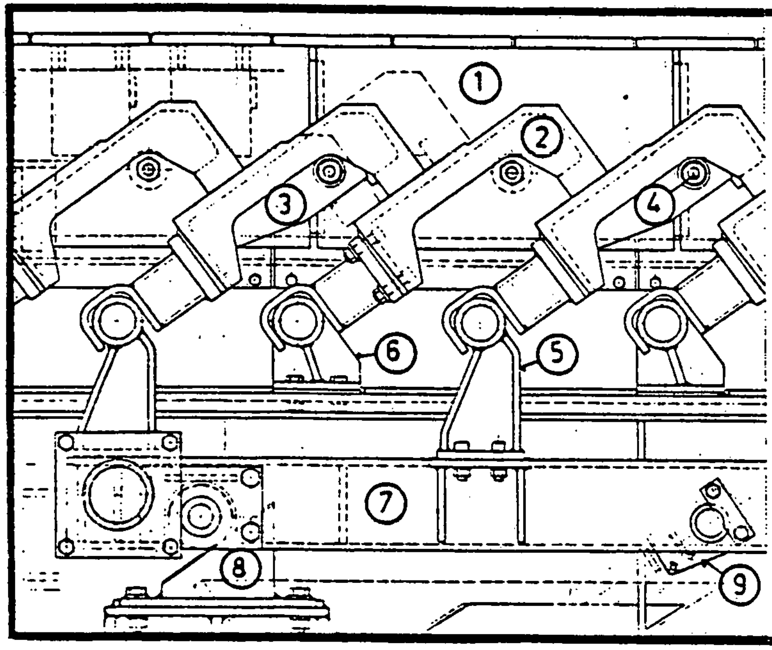


FIG. 2 - VON ROLL MASS BURNING REFUSE-TO-ENERGY PLANT

1.2 Grate Design

The Von Roll grate system consists of a ram feeder for volumetric charging and has a grate surface 6 - 12 m long (19.5 - 39 ft.) at an 18° inclination. The grate consists of 3 - 6 identical grate sections linked together. The system is suitable for capacities ranging from a minimum of 2 tons of refuse per hour up to a maximum of 50 tons per hour. Figure 3 explains the grate construction.



1	sealing plate
2	grate block
3	holding bracket
4	tension rod
5	mobile block support
6	stationary block support
7	grate carriage
8	guide tracks
9	cylinder joint shackle

FIG. 3 - VON ROLL GRATE SYSTEM

A standard grate element consists of 8 rows of grate blocks, 4 of which are movable, 4 stationary. The 4 movable rows of blocks are installed on the so-called grate carriage.

This latter is driven by the hydraulic cyclinders. The supports of the complete assembly are fixed for the first section, all subsequent sections rest on slide bearings, enabling longitudinal thermal expansion towards the clinker channel.

The grate blocks are cooled by primary air. For this purpose the chrome steel cast blocks have internal rectangular channels, through which the air is supplied for combustion to the refuse bed. The channel and opening arrangements are such, as to create sufficient pressure drop through the block. As a result of this, the distribution of combustion air throughout the refuse bed is independent of the refuse layer thickness. Preferential burning or local flame deviations are hence not possible. Cooling the grate blocks considerably reduces wear and increases the life span of the stoker.

The assembly of the blocks into rows of blocks clamped together by a tension rod, eliminates the gaps in the transverse direction. This, plus the fact that the movement of one row of blocks on top of the consecutive stationary row, minimize the riddlings falling through the grate. Another advantage of the construction is, that a grate section can be erected preassembled. In a recent installation, the grate sections were assembled by the manufacturer for final inspection at his works. Then the sections were transported to the site and installed by a crane on the substructure, all without any dismantling of these sections. Approximately 4 weeks of construction time could be saved.

1.3 Combustion Chamber

The normal description of the incineration process shall not be repeated here--rather, we would like to highlight the vital features of the furnace design. Certainly, the generally accepted standards such as minimum temperature and residence time are important. Besides the shape of the combustion chamber, the details of the secondary air injection and, for higher heating value cases, the cooling of the side walls are equally essential.

The shape of the combustion chamber and the injection of the secondary air both have to be looked at together. In order to eliminate corrosion in the downstream waste heat boiler, complete combustion of the gases (virtually all CO oxidized to CO_2) must be achieved. Therefore, the flue gases flowing upwards from the bed are to be thoroughly mixed with the secondary air; no dead corners are to occur. In view of the penetrating depths of a free air jet, cross sectional reduction is necessary. This, plus the attempt to minimize overall heat loss, determine the shape of the combustion chamber.

Furthermore, the perforated ceramic plates have to be mentioned. They are installed in the region of the maximum bed temperature. This is necessary for refuse with a higher heating value and so-called city-type composition. If a plant is operated without these, slag growth on the side walls will result. This is due to the gas temperature just above the refuse bed being higher than the ash melting point. By blowing air through the holes of these perforated plates, the side walls are not only cooled below the critical temperature, but the gas streams are diverted. The experience made with suchlike systems proves the suitability of the components and concept. The total air quantity supplied for incineration is not higher than in units without side wall cooling--a portion of it will be put to the account of the secondary air, the other part to the primary combustion air.

Nowadays, combustion chambers are water-wall cooled. In order to protect these sufficently from the occasionally aggressive flue gases, the lower part is studded and covered with refractory ramming mass. The design practice allows only for unprotected tube walls above the zone, where experience clearly demonstrates that the combustion process is completed.

1.4 Integrated Boiler

Von Roll nowadays designs and installs the so-called tail-end boiler. This is a horizontal pass, pure convection-type waste heat boiler, consisting of gas-tight outside walls and heat transfer surface elements in the form of tube pannels or tube banks.

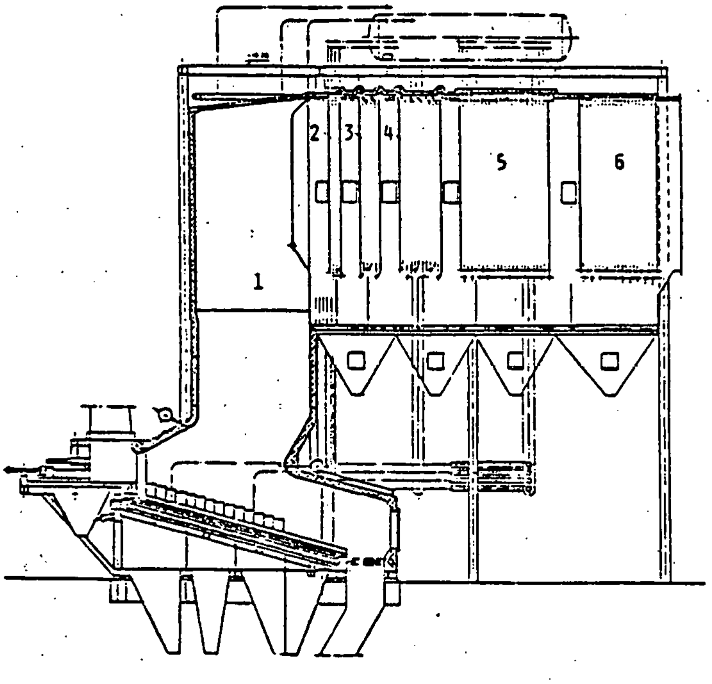


FIG. 4 - VON ROLL (TYPICAL) TAIL-END BOILER

The tube spacing (crosswise) decreases in the flow direction (7" to 3½") while the tube bank spacing remains constant (4 3/4").

Special attention is paid to the inlet section of the boiler with respect to flow evenness and maximum temperature. The sequence of the heat transfer stages is as follows:

- evaporator tube banks
- secondary superheater tube banks
- primary superheater tube banks
- evaporator tube banks
- economizer tube banks

Normal steam design parameters are 50 bar/400° C (725 psi/750°F), in some cases one goes for maximum conditions, which are limited by economic considerations (higher thermal efficiency vs. the use of special alloys for the superheater) to, say, 454°C (850°F). However, especially in this case, the arrangement and design take into account that tube banks are sometimes to be repaired/replaced. In order to maximize availability of a plant, such a removal must be possible through the roof.

Cleaning of the tubes is done by means of mechanical rapping. With this system, hammers mounted on a motor-driven shaft running along either side of the boiler, hit the panel headers via the knocking pin.

1 panel header
2 tube wall
3 knocking pin
4 hammer
5 shaft
6 noise insulation
7 heat insulation

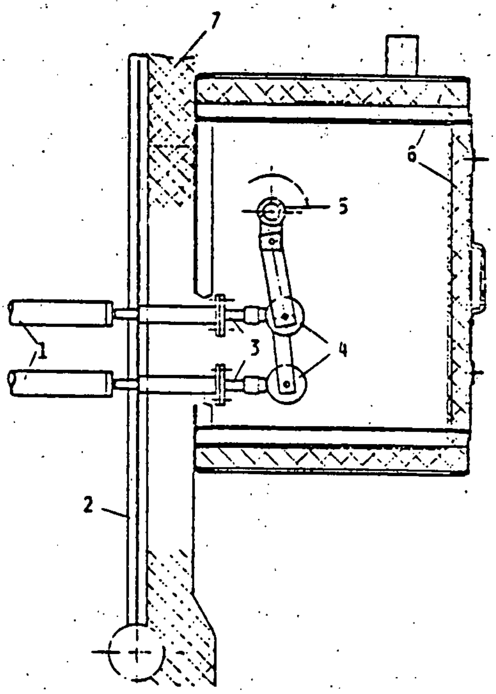


FIG. 5 - VON ROLL BOILER RAPPING SYSTEM

The rapping system is normally activated once a shift, during several minutes. This cleaning device, combined with the overall design features (temperatures, flow, flow distribution) result in riser times exceeding 20,000 hours, actually experienced in quite a number of installations.

SO_2: 200-500 mg/Nm^3 based on 11% O_2 (70-175 ppm)
NO_x: 200-400 mg/Nm^3 based on 11% O_2 (calc. as NO_2) (98-196 ppm)
CO: 50-200 mg/Nm^3 based on 11% O_2 (40-160 ppm)

Obviously, these figures do not only depend on the location, but are also subject to seasonal changes. The most stringent standard presently applied (the above mentioned German TA-Luft) specifies the following limits:

Chlorines (as Cl^-)	max. 100 mg/Nm^3	(63 ppm)
Fluorines (as F^-)	max. 5 mg/Nm^3	(5.9 ppm)
SO_2	depending on location	
CO	max. 1 gr/Nm^3	(800 ppm)

As can be concluded from the above, it is normally only the HCl concentration which is beyond the limits set by this (German) standard. The very often referred to SO_2 content would only be critical in areas where there is already a high industrial concentration (the locally defined limit will be based on the emission). If a plant is to be built in accordance with the above specification, there are at present, two established process technologies to be chosen from:

1.5 Flue Gass Cleaning

(a) Particulate Control

Except for small units in some countries, a refuse incineration plant will be equipped with an electrostatic precipitator. The standard performance of such a unit is at a collection efficiency of 97 to 99%. Series of measurements show that the particulate concentration at the inlet is at approximately 3 - 5 gr/Nm^3 (1.29 - 2.15 grain/Scf) at 11% O_2. With the normally selected 2-stage (horizontal) dry operating type, particulate outlet concentration well under the generally required limit of 100 mg/Nm^3 (0.04 grain/Scf) is achieved.

(b) Chemical Control

Since the German standard "TA-Luft" was implemented, electrostatic precipitation alone is, in certain places, no longer sufficient. Quite a number of measurements of the chemical composition of the flue gas in several plants show the following:

HCL:	500-1000 mg/Nm^3 based on 11% O_2	(310-620 ppm)
HF:	5- 10 mg/Nm^3 based on 11% O_2	(5.6-11.2 ppm)

- wet scrubbing; the flue gases leaving the boiler are quenched with water, and subsequently, pass an absorption stage which operates at an efficiency of 95% with respect to HCL removal. No additional equipment for particulate removal is required, however, neutralization of of the waste stream is necessary. The flue gases leaving the scrubber are saturate--a white steam plume leaves the stack.

- spray-dry absorption, where calcium hydroxide, injected either in a water mix or in dry state, acts as carrier (absorbent). Downstream of this stage, an electrostatic precipitator is to be installed, both for the particulates from the incineration, as well as for the absorption stage. Instead of such a precipitator, a baghouse filter could be considered. This concept operates at an efficiency of say 90% with respect to the HCl removal.

The wet scrubbing system is somewhat lower in capital investment and operating cost, but has the disadvantage of producing a liquid effluent and the saturated flue gases are sometimes objected to. Final selection of the technology has hence to be based on local conditions/ possibilities.

1.6 Other Pollution Considerations

(a) Water Effluents

If the wet scrubbing stage mentioned under 1.5 is disregarded, then a refuse-to-energy plant produces no waste water other than an occasional blow-down from the boiler and demineralization plant, and the surface water collected in the drainage system.

(b) Residues

Solid residues are generated as ash from the grates and ash from the pollution control system. Of all the ash generated, about 10% results from the pollution control system. All ash material is usually landfilled. However, in certain instances, these residues are being recycled. Re-use of the clinker as base material for road construction is still practiced in some cases. In the Mediterranean countries, the iron is removed from the clinker and recycled to the steel mills.

(c) Noise

Special attention is also paid to the noise level of these plants. Levels of 50 - 60 dB at the plant boundaries can be achieved.

(d) Aesthetics

Ever since refuse-to-energy plants have been built in Europe for district heating purposes, they have been located near residential areas. E.g., the one plant initally mentioned in Berne, Switzerland, is surrounded by apartment houses. Therefore, Von Roll is accustomed to working closely together with city planners and architects to make sure that the plants also appeal to the public sense of aesthetics.

2. Design Advantages

Von Roll stands for the complete process technology, comprising the grate, the boiler, the gas cleaning stage and all accessories. One technology for one plant prevents disparity in concept and supplies. In short, some of the advantages can be summarized as follows:

Grate: - Simple erection of the assembly, easy re-

	placement procedure and minimized stock requirement, as only one type of block is used; - proper air distribution and cooling of grate blocks to increase life span;
Combustion Chamber:	- Optimized combination of chamber shape and secondary air injection arrangements; - flexibility with respect to heating value variations due to balanced combination of water wall, perforated plates and refractory mass;
Integrated boiler:	- optimum combination of tube spacing and layout with cleaning device; - sound concept designed to counteract corrosion for the sake of reliability;
Gas cleaning:	- one step ahead of the requirements due to the experience in the even more demanding field of flue gas treatment for hazardous waste incineration plants.

The experience gained in all the Von Roll plants has been continuously incorporated in the design. This ensures that the plants are based on an up-to-date technology, and at the same time, enjoy an extremely high reliability.

3. Co-disposal Units

The disposal of sludge from a municipal waste water treatment plant can easily be combined with a mass burning refuse plant, Five co-disposal plants of Von Roll are presently in operation.

Straightforwad burning of undried sludge, together with refuse, is no solution (maximum amount of sludge, about 5%). Trials to blend dewatered sludge (say 40 - 50% dry substance) with the municipal refuse and to feed this to the incinerator have shown unsatisfactory results. In such a system, approximately 15% of sludge could be disposed of, but problems with odors, burn-out, etc., caused this concept to be dropped.

Two technologies have been established:

- dewatering/drying by means of the steam generated in the boiler, subsequent incineration of the dried substance.
- dewatering and drying of sludge in a dryer/grinder by means of a sidestream of flue gases, subsequent incineration of the dry product in a dust burner. The off-gases, ex dryer/grinder, are recycled back to the incineration unit.

The latter method is more sophisticated and, from a hygienic point-of-view, preferable.

Presentation by Wheelabrator-Frye, Inc., Saugus, MA
L. Kenneth Batton
(Vice-President, Energy Systems Division)

OPERATION

A. Operating Experience of Average Plant

RESCO is a joint venture between Wheelabrator-Frye Inc. and the M. DeMatteo Construction Company of Quincy, Massachusetts. Construction began during the summer of 1973 and in October of 1975 (5 years ago), RESCO received its first ton of refuse.

The facility consists of two 750-ton-per-day refuse-fired steam generators and a storage pit having a capacity of 6,700 tons. RESCO is capable of processing 1,500 tons per day. Today, we receive waste from 18 municipalities and over 60 private haulers.

RESCO produces high temperature/pressure turbine quality steam (875°F/690 psi) which is sold to the General Electric Company in Lynn, Massachusetts. RESCO has the capability of producing 370,000 pounds of steam per hour.

Let me bring you up to date on our current status:

- Tons Processed - 1.5 million
- Steam Sold - 8.7 billion pounds
- Ferrous Metals Recovered - 100,000 tons
- Oil Displaced - 69 million gallons

In addition to these statistics, which, by the way, are unmatched in this country, we have provided uninterrupted disposal service to our contract municipalities and we have exceeded by nearly 50 percent the required emission standards in Massachusetts. The code specifies particulate removal of .05 grains per scf. RESCO was recently tested by the Department of Environmental Quality Engineering at .026 grains per scf. In summary, our RESCO plant has reached a level of normal commercial operations.

1. Personnel

The key to any manufacturing or service-oriented facility is the people who manage and run the plant. At RESCO, we employ 55 people. Forty-eight are responsible for operation and maintenance and seven are involved with the administrative and management aspects of the plant. We are non-union and turnover at RESCO is minimal. In fact, last month, we honored 15 people for 5 years of dedicated service at RESCO.

Twenty-one operators of the facility are all certified by the State of Massachusetts as boiler operators. Many were power plant operators prior to joining RESCO. This, of course, is very important since RESCO is essentially a power plant. However, they have learned to respect the fuel, refuse, which, as many of us know, is a very humbling material. I should add that what it really takes is not just credentials; these people are highly motivated and view the conversion of refuse to energy as an interesting technical challenge.

It is important to note that RESCO will serve as the training center for future facilities and our people will be the teachers of future RESCO facilities operators. Their experience, know-how, and enthusiasm will be passed on to future operating personnel.

2. Maintenance and Replacement

During the past 5 years of operations at RESCO, we have developed a maintenance program which provides reliable service to our customers. Our maintenance program is based on preventive maintenance procedures versus the rebuilding or replacing of components when they no longer work.

During downtimes, whether scheduled or unscheduled, we perform any needed maintenance and thoroughly inspect each refuse unit and all support systems. If possible, we will repair a potential trouble area before it causes any unscheduled downtime.

Major maintenance and replacement projects are performed during scheduled annual shutdowns. Our storage pit is capable of holding in excess of 6,700 tons, allowing us to have a single unit down for extended periods of time.

During the past 5 years, there have been a few problem areas which now are handled by our normal maintenance program. Let me address just a few of them.

(a) Cranes. As you all know, the cranes utilized in these systems are in service 7 days per week, 24 hours per day. During initial operations, we experienced brake wear and cable failures due to high load demand. Through design and operating changes, the cranes now operate with almost one-half the maintenance originally projected. We now have a maintenance program which assures the continuous availability of the cranes.

(b) Grates. During the initial phases of operation, we learned that the metallurgy of the grates was not compatible with the design loadings. Our approach to solving this problem was to refabricate the grate system utilizing one of Wheelabrator's proprietary alloys. In addition, we have redesigned the understructure of the grate support system, which has enhanced the grate operations and extended the grate life.

(c) Corrosion. We had anticipated fireside tube metal corrosion upon the startup of RESCO. We instituted a research program to resolve this from the beginning. Our approach was to solve the problem and not to view it as a normal maintenance procedure of replacing boiler tubes when they began leaking. Through a change in design and metullurgy, we have experienced 3 years of operation without a forced outage resulting from corrosion.

3. Design Versus Actual Throughput

The design capability of RESCO is 1,500 tons per day. This year, we will process, on a yearly average, 1,100 tons per day.

B. Operating Philosophy

The RESCO operating philosophy is based on three commitments.

1. Disposal of Waste for Our Customers

The solid waste disposal problem is the primary reason these facilities are built. Our operations at RESCO focus on providing a reliable waste disposal service to our customers.

2. Energy Production to General Electric

We have a long-term contract with the General Electric Company to supply high temperature/pressure steam. We work very closely with General Electric to ensure that we may be able to met their needs. In fact, we will schedule downtime during periods when General Electric does not need the steam.

3. Financial Return

RESCO is set up as a business center for Wheelabrator-Frye and the M. DeMutteo Construction Company. Since last December, RESCO has been profitable to the partners.

C. Approach to Reliability

1. Redundancy

RESCO is designed with 100 percent redundancy in all major operating components and subsystems. Our scheduled boiler maintenance program has minor impact on the plant's refuse receiving capacity for the following reasons:

- Extra refuse burning capacity is provided. Based on known present-day refuse quantities, the plant is designed to normally operate with two boilers, each operating at 85 percent capacity. With one boiler down, the other boiler can still handle the refuse influx by operating at 110 percent of its refuse design rating. Concurrently, refuse can be accumulated in the storage pit for 16 days.
- Equipment servicing more than one boiler has adequate standby capacity and standby units. It is unlikely that more than one boiler will be down at a time because of auxiliary equipment outage. Spare equipment is as follows:

  Each boiler is serviced by two clinker ash and metal removal systems.

- Boiler feedwater system equipment is spared or can be bypassed.
- Two refuse cranes are provided. Each crane has a capacity of 1,600 tons per day. With one crane down, the remaining operating crane can adequately maintain feed on the two boilers.

2. Derating Throughput

We have observed at RESCO that the nominal capacity of each unit, which was rated at 600 tons per day, is more on the order of the design capacity (750 tons per day). In fact, we believe that RESCO could operate continually at 1,300 to 1,400 tons per day without any changes.

3. Industrial Design Criteria Versus Municipal Design Criteria

The ability to ensure reliable services to our customers would not have been possible without the excellent qualified personnel and the ability to address problems expediously. As I indicated earlier, our operating approach to assure reliability is to monitor all components and subsystems on a continuous basis. Repairs and maintenance will be performed before potential failures can occur. All systems are serviced on a continuous basis.

Our whole approach to refuse to energy is to operate as a business with commercial level demands, including primarily reliable customer service both to muncipalities needing waste disposal and to our energy customer.

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Presentation by Wheelabrator-Frye Inc.
John M. Kehoe, Jr.
(Vice-President and General Manager, Energy Systems Division)

This part of our presentation will describe the Economics and American marketing philosophy for refuse-to-energy plants proposed by Wheelabrator- Frye in the U.S.

ECONOMICS

It is difficult to give "representative" economics for any given project because of the wide variability of local conditions which affect costs for refuse-to-energy plants and because of significantly different revenue streams going to the project from refuse disposal fees and energy sales. Some generalizations, however, can be made regarding the economics of these projects. These are described below.

A. Typical Capital and Operating Costs

1. Capital Costs

The capital and operating costs for a refuse-to-energy plant will vary from region to region. The capital cost has significant differences, depending on such factors as: site acquisition and preparation requirements, availability and rates for construction labor, extent of customer-specific requirements such as aesthetics, redundancy, and energy market needs, and the matching of facility design with energy output required. or example, typically a turbine generation system alone will increase the capital cost by about 15% to 20%.

On a throughput basis, a 1,500 ton-per-day electric power generation refuse-to-energy plant will cost, in today's dollars, in the $80 to $100 million range. This represents a capital cost investment to the project on the order of $15 to $25 per throughput ton, depending upon financing assumptions, cost of debt, and amount of debt required for the project.

2. Operating Costs

Operating costs vary widely with the project, depending on such factors as operating labor, utilities, materials and services requirements, and other project specific costs, such as, land purchase or rental fees, property taxes, host community fees, and residue disposal costs. Typically, the operation costs for a 1,500 ton-per-day refuse-to-energy electric power project will range, in today's dollars, in the vicinity of low-to-mid teens per ton throughput. Included in this figure are all those costs that many times are called pass-thru's; such as taxes (or payments in lieu of), utilities, (water, electric, etc), insurance and the like. If these costs are not looked upon as true operating costs, then the operating cost per ton would be in the single digit range.

3. Reliability and Redundancy

Operating costs can reduce significantly if plant reliability and redundancy is high. It is our experience that the key prerequisite to maintaining a high level of reliability is a well-trained, highly motivated operating staff. We have found at our RESCO plant, for example, although operating personnel are paid premium wages, their efforts more than compensate in the reliability of the facility.

Redundancy is generally expressed as a customer requirement and relates to the availability of alternative disposal facilities. If a customer requires sufficient reliability to guarantee 100% disposal in processing through the plant, then almost without question, significant redundancy will probably be built into the plant. It is our experience again that with a highly skilled operating staff and with dependable technology, significant reliability can be achieved with two operating furnaces, operating at commercial scale with minimal need for backup landfill. However, in those markets having limited alternative disposal available, we would probably suggest consideration be given for at least three commercial-scale units in place to assure reliable waste disposal service. We have seen in some situations where a refuse-to-energy plant might be built on or contiguous to an existing, environmentally approved sanitary landfill. The approach here would be to use fewer units, and use the landfill as the emergency backup during unscheduled and scheduled outages. The philosophical intent here is to conserve the landfill capacity by reducing volume through the energy recovery plant while producing revenues from the sale of steam and/or electric power.

4. Maximizing Energy Production and Revenues

We have noted that a higher temperature and pressure steam product for direct sale to a user/customer, or for electric power production, justifies itself economically. Since the sale of energy is directly related to the heating content of product sold, the higher the temperature and pressure, the greater the revenue potential. This approach is of even greater benefit when high temperature, high pressure steam can be used in a cogeneration application. With cogeneration, the high temperature, high pressure steam can first be used to produce electric power, and subsequently, the exhaust steam can be used in a process application to a user/customer at his specified exhaust temperature and pressure. Consequently, our approach is to produce as high a temperature and pressure energy product as the market dictates, but at temperatures of about 850°F. This also relates to those cases where a local steam user is not available at a reasonable distance from a plant site; then, a condenser turbine may be used on-site for purposes of 100% electric power generation. Since the higher the temperature and pressure, the greater the electric energy output, our ultimate objective is to optimize energy revenues through maximizing steam sales and kilowatt-hour production at high temperature and pressure. I don't mean to suggest that there are not trade-offs in producing higher quality steam; certainly there are. For example, at RESCO, higher temperatures and pressures resulted initially in corrosion. However, we have found that the high quality metallurgy used in our RESCO plant boilers, and to be duplicated in our other plants, can justify turbine quality steam production. It should be noted that the higher quality metallurgy, if included in the initial capital cost of the plant, can be capitalized over the life of the boiler tubes, rather than expensed as a normal part of maintenance. This has the additional benefit of minimizing additional cost in the maintenance budget. Thus, the key factor to minim life cycle cost is to include as long a superheater tube life as possible in the initial design and construction of the boiler, even though its high quality metallurgy is initially expensive.

B. Approach to Optimizing System Economics

1. Financial Commitment

We believe that a major means of optimizing system economics is for the system supplier to contribute his own equity capital to the project, both as an indication of commitment to the project and to lower the overall unit cost to the project. This is achieved by having the tax and depreciation benefits of the project accrue to the private owner, and subsequently distributed in the disposal fee economics. As such, both the private operator and user communities gain the tax-related benefits of this approach.

2. Experience Benefits

A second factor in optimizing system economics is by initiating change through experience. For example, we are able to optimize the design of future RESCO plants through hands-on experience at RESCO. Examples of these changes include: differing pit and crane configurations and operations; optimized design in furnace configuration; and enhancements in both the configuration and metallurgical content of the boiler section of the plant.

Another related operating philosophy which we have adopted, is to utilize and motivate to the fullest extent the operating personnel of the plant. As was mentioned earlier, operating staff is a key factor in determining project success. Also of key importance to the successful operation of the plant, is reliable disposal service and dependable energy supply to the customer. To optimize system economics, we implement a highly structured maintenance program and coordinate this program with the energy customer. The program includes provisions for scheduled and unscheduled outages, and close cooperation with the energy customer such that energy product is delivered when it is most needed and scheduled maintenance is performed when the customer's energy needs are minimal.

3. Maintenance Program

Another philosophical factor which optimizes operating costs is a rigorous and deliberate preventative maintenance program. Significant operating costs savings accrue when a preventative maintenance program can be implemented both during scheduled and unscheduled outages. The key to success here, is the ability to anticipate preventative maintenance requirements such that, when outages do occur, the preventative maintenance can be expedited without undue delay in resuming full operations.

4. Product Quality

Finally, our operating philosophy is to build in quality into the project from its inception. The old addage, "You get what you pay for", is especially true in resource recovery. We have found through experience that the most rugged equipment possible for the materials handling aspects of refuse-to-energy pays off significantly in the final analysis. This is especially true when dealing with a process operating at high temperature and pressure.

To summarize, our objective in optimizing system economics is to provide a commercial service at a competitive price. By commercial, we mean just that ... the ability to provide reliable, dependable, environmentally sound and economical service on a continuous basis. Our objective is to relieve the public works official of the concerns for his solid waste disposal problem once his municipality's waste crosses our scales.

C. Institutional Factors vs. System Economics

Several key institutional factors enter into the system economics of our facilities. Some of the major factors include: environmental requirements, availability of refuse, availability of competing disposal services in the area where the plant is proposed, and the relative economics of the value of the energy product from the plant.

1. Environmental Factors

The environmental factor is key, particularly as it relates to air pollution control requirements and requirements governing residue disposal. In some municipal markets in which we have worked, we have found stringent air pollution control requirements which demand technology which might go beyond the state-of-the-art. Although the removal of particulate emissions is widely proven with electrostatic precipitators, efforts are now underway to reduce particulate emissions through the use of fabric filter installations. Our experience suggests that fabric filters can be effective in significant particulate emission reduction, but not without cost and risk. To date, our experimental fabric filter facility at RESCO has demonstrated that removal can be significant, but that the fabric life of bags is still inconclusive. Consequently, there is some risk in the cost of the fabric filter bag replacements. Also, while the emissions of SO_x and NO_x appear minimal from a refuse plant in comparison to NSPSS standards for coal-burning power plants, there are some movements underway to restrict NO_x and SO_x levels from refuse-to-energy plants. We question first, the extent of removal required, and second, the cost benefit trade-off for the use of technology which has not yet been fully demonstrated at commercial scale for refuse-to-energy facilities.

Another related environmental impact concern is the disposition of residue. We still believe that much of the residue material from these facilities can be used in commercial applications, however, certain legal and institutional impediments may prevent their use. As such, they are viewed as a waste, and must be disposed of accordingly, at increased cost of municipal disposal service. Related to this, is a concern raised that this residue material might be classified, "hazardous". Detailed studies performed in Massachusetts suggest that this material should not be considered hazardous, as its leachate impact may be far less than that of the raw refuse from which it came.

2. Refuse Availability

Another issue related to institutional factors governing economics is the available refuse for the project. If refuse supply to the capacity of the plant is not reached, either because of miscalculations on waste generation, or because of other available alternatives diverting waste from the plant, a heavy penalty incurs the project. We have experienced such a penalty at our RESCO plant; we caution ourselves (and others) not to make the same mistake again. A remedy to this potential problem is the assurance made by the municipality in its RFP that, in fact, a guaranteed quantity of waste will be delivered to the plant, or a "put or pay" provision will go into effect.

3. Availability of Alternatives

Another related issue is the extent to which alternative disposal facilities might compete with the project. It is our experience that alternatives to refuse-to-energy plants have been available throughout the country, primarily because enforcement has been lacking in closing down environmentally unsound alternatives. This is perhaps the major reason why the implementation of refuse-to-energy has been so slow in developing in the United States, as contrasted with Europe or Japan, where land is at a premium and not available for waste dumping. Consequently, to expedite a refuse-to-energy project, a rigorous program to eliminate cheap environmentally unsound alternatives is necessary, since an environmentally sound refuse-to-energy plant cannot compete with dumps.

That is not to say that there is no need for landfill; on the contrary; some amount of sanitary landfill will always be needed. However, ... we believe that we can effectively compete with environmentally complying sanitary landfills, particularly when these facilities are located in remote areas, thereby requiring an additional transfer/haul.

4. Nature of Energy Market

Finally, another institutional factor affecting the economics of these projects is the nature of the energy market. In the northeastern part of the U.S., where oil prices are typically in the $25 barrel range and land disposal alternatives are limited, refuse-to-energy can generally be economically viable. Contrasted with these locations, however, are those parts of the nation where energy can be produced at relatively low cost by burning coal and the energy product from the plant has a lower value to the using customer. In those instances, the economic viability of resource recovery is not as certain. The key point here is that the energy value from refuse-to-energy plants is relative to the alternative values of energy to the using customers.

AMERICAN MARKETING PHILOSOPHY

This dicussion will include our arrangement with Von Roll, our European system developer, our sales and procurement approaches, and our view of the market as it relates to relative risk sharing for refuse-to-energy projects.

A. Arrangement with Von Roll

Our close relationship with Von Roll includes major involvement in both design and overall project economics for our refuse-to-energy facilities. As licensee, we have total and free access to technical innovations and system improvements in the Von Roll furnace and boiler design. Similarly, those technical improvements which we have made in the RESCO process are also readily available to Von Roll. Both our companies' philosophical approach is to freely exchange technical and economic information as it relates not only to our own plant design, but to the total refuse-to-energy market. Typically, for each project that we bid, we will work directly with Von Roll on preliminary design and market approach.

1. Component Supply

Although the ultimate design may be from Switzerland through Von Roll, we do have flexibility in seeking domestic suppliers for components if their prices are cost effective relative to European manufacture and supply. As an example, our RESCO plant includes components from North American manufacture. Our boilers were built by Dominion Bridge Company of Canada, but to the specifications of Wheelabrator/Von Roll. We do have, as an additional resource, the technical engineering staff involvement of Von Roll during construction and operation of future RESCO facilities. In summary, we believe that a close working relationship with our European counterpart, Von Roll, ultimately results in the most effective approach to refuse-to-energy in the U.S. marketplace.

B. Sales Approach

To make a blanket statement, we will consider supplying our technology and operating know-how to any municipality desiring it in the U.S. If a direct procurement approach is desired, we will honor it. However, we are also receptive to evaluating and responding to request for proposals (RFP's) on an individual basis. In evaluating RFP's, we apply certain key criteria to decide whether we feel the particular project warrants significant engineering and other resources. Briefly, we look for assurances that the refuse is available, that a site has been selected and secured for the project, that there is overall public support for the project, and a long-term viable energy market is available for the plant product. We make a determination on a project-by-project basis.

1. A & E Support

Although our engineering support is supplied through our wholly-owned subsidiary, Rust Engineering Company, there are opportunities and examples where sub-systems to our facilities will be provided through A & E and construction firms. Decisions regarding the use of these services are made on a project-by-project basis.

C. Procurement Approach

Our procurement approach is to provide to the fullest extent whatever our customer needs and desires. With respect to the full-service approach, we prefer operation ourselves, but do not necessarily require ownership. I will say, however, that we feel the private ownership approach with equity capital participation by the system supplier will result in the best possible approach for the project. The systems supplier has his money on the line.

Our present posture is to provide full service, including design and construction responsibility, operation and, preferably, ownership. We would seek out a relationship with a local A & E firm for the project on an as-needed basis.

To date, we have not responded to procurements for a turnkey or a "part-and-parcel" bid procurement approach. We will now consider such requests on a case-by-case basis.

1. Competitive Bid Laws

We have noted in some states, certain competitive bid laws restricting the full-service approach. In certain cases, we have declined to bid projects requiring a "low bid". One need only to view the activities of the wastewater business over the last 10 years to explain our reasoning. Although we feel that in most cases an amendment to state procurment laws is necessary to achieve the most cost-effective approach for the municipalities, we have worked directly with several municipalities which legally require a restrictive "part-and-parcel" bid approach. It is interesting that our nation's largest city, New York, elected to seek an amendment to state procurement law prior to the issuance of an RFP. We concur with New York's approach, and are confident that the results will be in the ultimate best interest of its citizens.

D. Other Marketing Approaches

As we indicated earlier, we prefer to own and operate refuse-to-energy facilities, and will make Wheelabrator-Frye equity capital contributions to refuse-to-energy projects, as an indication of our commitment to the project and to the refuse-to-energy business. Again, we believe that we can fully demonstrate that the private own and operate approach will result in the best possible refuse disposal service with minimal risk to the participating communities. Recently, we have been asked our thoughts regarding other financial approaches, such as, a "third party leveraged lease". Certainly all potential financing options should be explored. Regarding third party leveraged lease, one key issue that must be resolved is: "who ultimately assumes the economic penalty associated with the delays for achieving the third party leveraged lease approach"? It's our understanding that the third party leveraged lease approach must have an Internal Revenue Servic rule which could take anywhere from 6 - 12 months, and thus, to justify itself to the private contractor or to the municipality. At the present time, it seems to us, that a much more palatable financing approach is the use of the contractor's own equity capit as an indication of its commitment to the project and to an expedient financing. However, as I stated earlier, all potential financing approaches should be investigated.

E. Risk Sharing

Risk sharing for refuse-to-energy is no different than risk sharing in any other venture; the higher the risks taken, the higher the potential benefit that must be sought. Our view of risk sharing in the refuse-to-energy business is that a private contractor should be willing to assume the ordinary business risks related to ownership and operation of these facilities.

Risks that go beyond these should be shared. Second, the risks should be borne by those entities which are in the best position to assume them. Any resource recovery project is a risk-sharing proposition, and how risks are allocated will be determined in contract negotiations.

We believe that the most equitable form of risk sharing is to guarantee solid waste disposal service at a reasonable price. Technical and operating risks are borne by us. The communities' obligation is to deliver waste and pay the disposal fees. This, we feel, represents a fair and equitable business risk distribution.

With respect to revenue-related benefits, we are willing to share such benefits so long as we also share the risks associated with gaining those benefits. Over the years, we have seen in this market a prevailing attitude that there is "gold in garbage". One and one-half million tons later, let me assure everyone here, we have yet to find any gold. Refuse has no value until it can be economically converted into useful products. Our approach to revenue-related benefits is very pragmatic: we will share revenue benefits, provided that the basic economic integrity of the project is maintained. This is not only our policy, it is a requirement of the prospective bond holders. Therefore, when indicating a preference for revenue sharing in RFP's, one must be prepared to also accept a significant risk-sharing position. In summary, we are prepared to guarantee construction and operation of a refuse-to-energy facility, and are willing to share the revenue benefits and the associated risks.

SUMMARY

Our approach in the refuse-to-energy business is one of enthusiasm, optimism, flexibility, and confidence. Our five years of operating experience has taught us a key lesson: technology alone does not assure success; it also takes operating know-how, financial commitment, reliable customer service, and dedicated hard work. We are extremely confident that our technology, like that of our competitors in this forum, is readily and commercially available to do the job. But it takes more. . .it take knowledgeable people who are highly motivated and willing to devote 100 percent to getting the job done.

Project success, as we know it, also means that our customers are satisfied: municipalities do and should demand long-term, reliable, environmentally sound and economical solid waste disposal service. We are fully confident in our ability to provide this level of service and have demonstrated so at RESCO.

In closing I would like to say, for the record, we are very excited about the refuse-to-energy business in the 1980's. We are confident that there are ample opportunities for ourselves and our competitors, and that we can collectively contribute a cleaner environment to our nation, while conserving valuable energy resources.

BRUUN SORENSEN HEAT RECOVERY EXPERIENCES IN EUROPE AND APPLICATIONS PROJECTED FOR THE UNITED STATES

Frank R. Ulbrich
Aerojet Energy Conversion Company
and
Niels T. Holst
Bruun Sorensen

This paper is not available for publication. However, it will be distributed at the conference.

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SESSION III: EUROPEAN WASTE-TO-ENERGY SYSTEMS PART II

Moderator: Charlotte Rines (DOE)

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THE EVOLUTION OF MASS-FIRED WATER WALL WASTE TO ENERGY TECHNOLOGY AS PRACTICED BY WIDMER + ERNST AG

BY

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ABSTRACT

WIDMER + ERNST AG, a member of the Alusuisse Group, has been a leader in the waste to energy field since, its inception 19 years ago. WIDMER + ERNST INC., a New Jersey corporation, markets the European developed technology in the Western Hemisphere. Fourteen plants are in successful operation in Western Europe with a number of others in the design and/or construction stage. WIDMER + ERNST INC. has been selected by the State of Rhode Island for a waste to energy plant with a daily capacity of 1,200 tons of waste.

WIDMER + ERNST's system can be defined as mass-fired, water wall using an unique grate design now in its third generation of evolution. All plants are capable of, and are currently meeting, the most stringent environmental pollution codes in Europe.

At Ingolstadt, in Bavaria, W+E has in operation a codisposal plant reducing both municipal solid waste and sewage sludge to ash.

INTRODUCTION

Normally a lecture on this theme would begin with the old lamentation about the destruction of our beautiful environment through today's society scourge, the Waste.

Let me say with Archimedes, in contrast to this: Eureka - we have discovered a new energy source!

If we transform the energy carrier "waste" continuously into the much desired form of energy "heat", we will at the same time keep land, air and water cleaner, and thus we will make our world a better place in which to live.

Hence, this conference should not be held in a defensive mood, definitely not. Let us get acquainted with trustworthy technologies, adapt them, and put them into reality. On this account I have nothing sensationally new to expose, no great scientific discovery to reveal, but just to give an account of operating systems that have been built by the hundreds in Europe and have been brought to a peak of perfection through systematic evolution over decades.

BACKGROUND

A) History of System Development

WIDMER + ERNST, a Swiss Engineering and General Contracting Company, is today a subsidiary of SCHWEIZERISCHE ALUMINUM AG (Swiss Aluminum Inc.), Zurich. Only by joining with this internationally active group enabled us to secure growth in the capital-intensive field of general contracting while at the same time conserving our traditional dynamism.

WIDMER + ERNST owns subsidiary companies in the Federal Republic of Germany and in the United States, and has a licensee in Japan, as well as representation in a limited number of industrial countries. Out of these countries we are working on the development of selected new markets which appear receptive to our technology.

Since its formation in 1961, WIDMER + ERNST has been working in the field of environment protection. Our company pioneered the way towards waste incineration technology through the design of air pollution control installations for a wide range of industrial clients, among which were included existing and new waste incineration plants. Thus we had built, by 1968, two refuse incineration furnaces with wet scrubbers and flue gas/flue gas heat exchangers in tandem arrangement to reheat the saturated flue gases, and which are still now in trouble-free operation. (Figure 1)

A comparable milestone was the installation of two waste to energy plants with fibrous filters which were equipped with silicone treated glass cloth hoses. With this filter system an extremely deep residual dust concentration of 30 mg/Nm^3 could be achieved for the first time.

The plants are still to this day operating uninterruptedly on a 24-hours a day operation. To my knowledge, this waste-to-energy plant with a daily throughput of 200 tons, and located in the Swiss city of Neuchatel, is still the largest such plant operating successfully on cloth filters (baghouse).

As a result of this company tradition, the effective flue gas purifying, and thus the control of emissions, are our foremost concern.

When and why we entered solid waste to energy business?

As outlined, WIDMER + ERNST entered into its actual main activity, the Waste Processing Technology through the cleaning of flue gases. The next step was to build turnkey waste-to-energy plants acting as an engineering company, and installing outside grate systems and plant components. This way we were able to collect during the next 10 years valuable experience concerning many different plants and systems.

The fruit of this steady and harmonious development is the WIDMER + ERNST Mass Firing Combustion with its own combustion grate, residue removal system, and boiler concept. 19 years of company history, and the experience of our old collaborators are all reflected in this design.

Under these circumstances the smallest plant with energy recovery ever built by our company, with only a single unit of 120 tons/day, can be justified. It has a back pressure steam turbine whose generator feeds, apart from the plant's demand, energy to the public network. A steam/hot water converter with heat accumulator supplies through a pipe network public buildings and residential areas with heating energy, and a laboratory with process steam. (Figure 2)

This model plant with respect to energy recovery must meet high requirements as to energy availability is concerned and has been in operation for 5 years in the Swiss city of Buchs/SG, and processes also the waste of the Principality of Liechtenstein. It is now being enlarged by us via the addition of a second line. (Figure 3)

B) Geographical distribution of installed systems

According to the just presented development of the company, the largest proportion of the plants we have built are located in Switzerland, the Federal Republic of Germany, and in Belgium. The German market has proved especially receptive to our technology.

WIDMER + ERNST can be very satisfied with its share of the demanding German market.

According to statistics, 92% of Switzerland's total amount of refuse is currently being processed in modern plants. Apart from 5 composting plants and a number of sanitary landfills, these are only incinerating plants, and which operate according to the mass firing principle, namely 41 plants.

The mentioned, proud 92% reveal a clear sign of the market's saturation. In spite of this, two plant expansions will be ordered during 1980, namely one each for Zurich and Buchs.

C) System size

The smallest operating plant equipped by WIDMER + ERNST with a mechanical grate has a furnace capacity of 50 tons/24 hours, the largest one has a furnace capacity of 500 tons/24 hours. The design series of W+E grates actually reach a capacity of 700 tons/24 hours. This capacity is certainly not limited by the design. We set it voluntarily, because we are convinced that plants with a bigger furnace capacity would be, in the case of the shut down of unit too severely impaired. In addition, there is not yet enough experience available with units having capacities ranging substantially above 700 tons/day.

D) European marketing philosophy

It can be said that and this is easily demonstrated by lists, of installed plants in Europe the refuse-to-energy plants according to the mass burning system have become a traditional technology with proven reliability over several decades. This has been accepted practically without dispute. Consequently, actual marketing efforts in the usual sense are only of a limited need. Exhibitions, congresses and technical journals are the usual means for professional marketing. Furthermore, every serious supplier knows the actual projects and can decide, after judging his own market chances, if he desires to participate in the bidding.

Due to the noted traditional approach in Europe perhaps 80% of the projects are turnkey against a lump sum price. As an exception a client still may place the order for the building with surrounding works or the whole electric installation separately. In such cases the overall technical management is provided by the client's engineering company in cooperation with the supplier of the plant's process engineering part should be, without exceptions, in one and the same hand. There is no objection against the separate allocation of the building, provided the responsibility for the planning is clearly defined.

According to my knowledge, during the last years not one waste to energy project was built in Europe on a "cost plus" basis. At the time of tendering (RFP) the following items are usually already settled in advance.

a)
- Constitution of users union or responsible builder
- amount of waste to be processed
- System selection (mass firing or RDF, or compost, etc.)
- Energy consumer
- Site
- Financing
- First phase of license procedures and obtaining of permits
- First phase of subvention procedures

With these important areas of the project determined:

b)
- The project realization is secured
- The number of workers can be reduced
- The decision phase is shorter (the bids remain valid)
- The costs of bidders can be kept within reasonable limits.

According to our experience, in the USA major attention should be paid to this second point, because in many cases the projects are presented for tendering far too early, and before all points under a) are clearly determined. This creates delays and increased costs.

TECHNOLOGY

A) Design Features

As already mentioned in the introduction, our company has decided, after a step-by-step evaluation of operational experience, to adhere to the firing and boiler concept shown in the cross section of a Figure 4. We are convinced that with its design we have found a solution which enables us to reach the reliability of conventional power plants fired with fossil fuels - the operational and sales results confirm this affirmation.

The WIDMER + ERNST grate operates according to the advance cascade principle, whereby it has been decided to renounce fully to the conveyance through gravity (inclination of the grate). Thus, the residence time of waste on the grate depends, independently of the waste composition, only on the mechanical conveyance capacity of the grate. In order to attain an optimum achievement of this aim, every second step has been provided with an independent hydraulic drive. To exercise an optimum influence on the combustion process, e.g. on the arrangement of

- the Pre-drying zone,
- the Combustion zone
- the Burn out zone

on the different grate steps, as well as their stroke and cadence (dwell time), a freely programable control has been provided.

With this high degree of flexibility the adjustment to match the changing composition of waste from plant to plant or from one season to another is efficiently easily done at the control desk, without any intervention in the mechanical part. (Figure 10)

The grate bars are force-cooled from the inside by the flow of primary combustion air. This makes the grate specially suited for waste with a high heating value. The bars of each grate row are pressed together by pressure plates on each side of the grate. These plates also allow for thermal expansion of the grate layer ensures good air distribution even for very different waste bed densities due to highly heterogenous waste which in turn provides for a good combustion. It is easy to understand that air-cooled grate bars have lower material temperatures which result in a longer life span. A compact, continuous grate layer reduces siftings to a minimum which improves the residue quality and, at the same time, the thermal efficiency.

The flue gases ascend with an even CO_2 surplus in the combustion chamber and before they enter the first boiler pass they are intensively mixed with secondary air. The secondary air emerges with high velocity from two opposite rows of nozzles. This secondary oxidation process combusts mainly the carbon which emits from the volatile waste components.

The steam boiler according to the WIDMER + ERNST concept consists mainly of a three pass radiation section (water wall) and a horizontal convection section.

Whereas for early boiler designs short intervals between overhauls and also poor life span expectancies due to erosion, high-temperature corrosion, and heavy fly ash caking (incrustations), were characteristic, these problems can be eliminated with this new design. The relatively long flue gas residence in the radiation section ensures a complete flue gas oxidation. The 180° divertion from the second to the third pass produces a first separation of coarse fly ash particles (about 30%) due to the centrifugal effect. In the three passes a rectification and a relaxation of the flue gas stream takes place which results in a regular flow through the convection zone equipped with tube - bundles.

In the convection zone with horizontal gas flow, the superheater, the evaporator and the economizer are arranged with enough interspace to allow for inspection and maintenance.

All banks of tubes are suspended from the top. Depending on the building configuration, they can be assembled and disassembled either from above or from the side.

Due to the fact that an important amount of energy has already been released as well as fly ash has been removed from the flue gases in the radiation zone, the flue gases enter the first superheater tubes with a temperature of only about 600° C. Furthermore, no flames can reach the tubes. The reduced fly sh quantity which sticks loose to the tubes has lost its devastating fouling and caking characteristics. The cleaning of the tubes can therefore be achieved by using the proven technology of mechanical rappers (as often applied in electrostatic precipitators).

Soot blowers with their erosion effect on the tubes, their high steam consumption, and their high installation and maintenance costs, are fully eliminated.

According to our current experience, the on-stream time between overhauls of a boiler equipped with the described cleaning system is up to three times longer than that of the best up to now installed other boiler designs.

The main characteristics of the WIDMER + ERNST and boiler concept can be summarized as follows:

Combustion

- Cascade feed, step grate
- Independent hydraulic drive for each movable grate bar row
- Air cooled grate bar
- Compact grate layer for optimum primary air distribution and minimal siftings.
- freely programable control of grate movement (independent drives)
- Multi-nozzle input of secondary air (vortex zone)

Steam boiler

- Threepass radiation section (water wall)
- Centrifugal dust separation (between 2nd and 3rd pass)
- Horizontal flow convection section
- Only hanging tube banks
- Tube cleaning by means of mechanical rappers.
- Long on-stream time between overhauls of the boiler

Residue removal

- Hydraulic Ram type

Environmental standards

Instinctively for many people waste incineration plants still are tainted by ugly dust and offensive smell emissions. Poorly designed and improperly operated plants as well as the nature of waste as a fuel have presented this prejudice to our industry. Many waste incineration plants located in residential areas prove that nowadays, with modern and conscientiously operated plants, this annoyance can be and is being eliminated.

Thus the legislators rightly impose strong regulations concerning every kind of emissions. From our experience all up to now demanded emission rates can be attained; it is only a matter of costs. If we compare some European regulations with different American standards it shows clearly that in Europe there is a tendency towards lower emission rates. Especially in the most important market for us at this time, the Federal Republic of Germany, the flue gas scrubbing to eliminate gaseous components is generally required. To be objective it has to be added, however, that all our facilities achieve emission levels that are substantially below these limits and that this goal has not been achieved without taking into account important sacrifices for development costs.

Separation of particulate matter

The way towards the most suitable air pollution control equipment led throughcyclons, wet separators, baghouse filters, which is definitely and uniformly utilized by all plant builders to the electrostatic precipitator. Provided it is correctly dimensioned, the electrostatic precipitator practically maintenance free and fulfills all requirements. Although a large number of companies manufactured electrostatic precipators, the experienced plant designer and filter manufacturer have conserved some of the "tricks" which ultimately will ensure that the later plant operators becomes a really satisfied client. By stating this we think about the correct selection of the gas velocity, the design of the inlet and outlet cones, the inclination, insulation and partial heating of the ash conveying equipment and its dimensioning. For example, fly ash is very erosive, hygroscopic and tends to bridge building in hoppers.

Thick walled, slow running and overdimensioned screw conveyors have proven to be the most suitable equipment for fly ash conveying. Provisions for easy removal and installation have to be made since the conveying screws have to be removed and overhauled every one to three years. (Figure 5)

Gaseous emissions

Halogen-Control

Chlorides and Fluorides are the most common halogens present in municipal waste. According to German (and Swiss) federal regulations the emission of HCl corrected to 7% CO_2 is not to exceed 100 mg/Nm3 or 62 ppm and HF is not to exceed 5 mg/Nm3 or approx. 6 ppm. In practice, lower values than required are achieved by means of scrubbing the flue gases after ESP in wet gas scrubbing systems, e.g. at our designed plant Stapelfeld Hamburg, the HCl and HF emissions during control tests showed the following results:

HCl content before scrubber	1930	mg/Nm3	or	1200ppm
HCl content after scrubber	68	mg/Nm3	or	42ppm
HF content before scrubber	12	mg/Nm3	or	13ppm

F content after scrubber 0.5 mg/Nm3 or 0.6 ppm

Additionally to Chlorides and Fluorides, Bromide and Jodine are present in industrial waste. These halogens can be controlled by incineration of wastes containing halogens with wastes containing sulphur. This way the danger of corrosion damage by halogens is reduced. In industrial waste the HCl content may vary between 1000 - 10,000 mg/Nm3. The available scrubbing systems are able to handle these variations.

Other gaseous emissions

SO_2, NO_x, heavy metal oxides are other air emissions from the combustion of waste. SO_2, emissions from the combustion of waste is usually about 500 mg/Nm3 or 175 ppm, which is lower than coal (approx. 1000 ppm) or oil fired plants (1200 ppm). The temperature in municipal solid waste incineration plants is between 900 to1100 °C, which is not favouring the formation of NO_x. The measured NO_x emissions in our plants varies between 50 to 100 ppm. Heavy metal oxides such as ZnO, PbO, HgO, CdO are also present in flue gases. Their particulate size is so small that they are not separated in ESP. They are in size range of aerosols. For their separation an aerosol separator after a wet scrubber is used. According to our knowledge, aerosol separators achieve efficiencies that are higher than 99%, e.g. if the heavy metal content of the inlet of a wet gas scrubber is approx. 450 mg/Nm3 the heavy metal content at the outlet of a wet scrubber is approx. 2.3 mg/Nm3.

The probability is high that waste containing polychlorinates is with municipal waste (e.g. impregnated wood, pesticide cans, radio condensers, etc.) In this case, if the combustion is not carried out properly, i.e. the temperature is below 800°C, dioxines and furanes are formed. The highly toxic isomer of dioxine and furan (TCDD, TCDF) exist in such small quantities that special instruments for their detection are necessary. However, appropriate design of the combustion process equipment and adequate operating procedures eliminates the emission of these toxics.

Water effluents

The following plant components can produce sewage water, either continuously or intermittent, depending on the system:

Boiler: Blow-down water
Wet residue discharger: Excess Water

Flue gas scrubber: Sludge

Aside from the water consumption as such, sewage from a waste incineration plant always causes concern. Be it because of progressing obstruction of sewage water conduits, the overloading of public water tratement plants with heavy metals and salt loads. WIDMER + ERNST has set itself the task of developing waste processing plants without generation of sewage. This is achieved through the proper selection of plant components and processes as well as appropriate design of the plant.

Residues

Most of the medium-size plants in the capacity range between 200 and 500 tons/day in Europe are equipped only with ferrous metals separation, or the residues are deposited without any further treatment. The sites for residue deposits are selected according to very severe guidelines in order to avoid ground water pollution. Furthermore the leachates are examined periodically with respect to their chemical composition. Comprehensive test series have been carried out to study residue recycling and the equipment and the processes are known and tried out. However, realization failed in many cases due to unfavorable economics. This refers to most of the medium-size plants.

However, recent projects in the capacity range between 1,000 and 2,000 tons/day include often residue treatment processes.

Hamburg has, for example a common residue treatment installation for all three waste to energy facilities. Its main product, road building material is, by the way, in great demand. (Figure 6)

Figure 7 shows the basic layout of such a plant.

B) Design advantages

The construction of waste to energy plants is more than just a handicraft, it is an art. An art is not easy to define and analyze; all of us know this. Before the realizing phase there is the basic idea of the process - the philosophy. Let us look at observations in this context that are generally valid for mass burning Systems as compared to other processes.

1. Refuse as an energy carrier is - considering its calorific value - voluminous, hence its transportation and intermediate storage are uneconomical. WIDMER + ERNST builds, therefore, only plants that lead in one single process step from waste to the final product steam or electricity. The conversion into a fuel of arbitrary composition and grain as a first step followed by the transportation to a second plant with the purpose of burning it and producing energy is economically disadvantageous. Here, from our point of view, are some of the reasons:

a) This kind of fuel production is expensive (investment and operational costs).

b) After the fuel treatment residual matter remains which cannot be readily disposed of and has to be submitted to further costly treatment.

c) Transportation of fuel from the treatment plant to the thermal power plant, considering its calorific value, is a burden for the profitability account and consumes valuable energy.

d) The combustion chambers and boilers of a thermal power plant are basically designed for a different fuel. Refuse derived fuel is, therefore, only an auxiliary or standby fuel for which the system never has been designed. The combustion quality as well as the boiler soiling constitute an additional uncertainty factor which is finally reflected in the price.

e) As far as we know, it is nowadays impossible to obtain long-term contracts with price and delivery taking commitments for RDF. This uncertainty complicates the project financing.

The direct conversion of waste into steam or electricity doesn't encounter all these problems. Furthermore, this process has proven its suitability through a great number of operating plants.

2. A process for the thermal conversion of waste should be designed and built in such a way that no preclassification, homogenizing, and preliminary shredding are necessary. If in special cases a preseparation should be desired for material recycling reasons, it can be done. However, the operator should be aware of the commercial uncertainties involved. In any case, from the point of view of combustion it is unnecessary for the mass burning system. The experience has proven that it is best to <u>leave it fully to the fire</u> to take care of the conversion of heterogenous waste into heat, as nature shows us. The mechanical crushing by means of mills, shredder, or shears requires a great deal of expense, energy, spare parts and maintenance. Also the additional investment costs should not be disregarded.

In full compliance with the guaranteed limits on burn out and emissions and keeping a constant steam or electricity production with a maximum deviation of ± 5%, the mass burning system does not require any preliminary treatment.

3. THE WIDMER + ERNST Mass Burning System

The rightness, or - to put it more modestly - the usefulness of the process philosophy has been confirmed by operational experience.

Let me unfold now some characteristics of the plant building trade, as our company does it built on a foundation of many years experience.

3.1 The grate and, combustion system does not need any waste pretreatment.

3.2 The waste feed can be controlled in such a way that the steam, respectively electricity generation, remains constant within ± 5%.

3.3 The combustion grate is extremely adoptable and can be applied to process any kind of municipal and industrial waste. The main reasons for this wide operational range are:

- Single stage grate drives
- continuously controlled waste conveyance
- poking effect
- efficient primary air distribution
- force-cooled grate bars

3.4 The steam boiler specifically developed for the combustion of waste allows for onstream times between overhauls of up to 20,000 operating hours.

The following design characteristics led to these results:

- generously dimensioned radiation section with 3 empty water wall passes.
- preseparation of course fly ash before the convection section.
- Total burn-out of the flue gases before entering the convection section.
- Low flue gas velocity in the whole boiler.
- Good cleaning effect of the rapping device.

The horizontal arrangement of the boiler results furthermore in lower buildings and thus in more aesthetical building contours.

3.5 We guarantee a residue quality with a maximum content of 5% unburnt matter, whereby less than 1% is normally achieved. This is due to:

- optimum combustion on the grate
- minimum grate siftings thanks to a compact grate layer.

he ram type residue discharger installed in our standard plants has

- low water consumption
- no overflow water
- a residue discharge with low water content, leading to minimal leachates at the landfill.

In accordance with recent practice the fly ash is no longer discharged together with the combustion residues, but stored separately. Fly ash mixed with residues makes their use for road building material difficult. Furthermore, contents more heavy metals than unmixed residues.

3.6 The flue gas cleaning system is the last active treatment stage in the process and determines, in conjunction with the combustion quality, one of the most important evaluation criteria of a plant: the particulate matter emission of the flue gases.

As already mentioned before, the electrostatic precipator has become standard equipment for fly ash separation. If required by law, as is the case in the Federal Republic of Germany, the maximum concentration of HCL, SO_2 and Fl will be guaranteed as well to achieve this, we install low pressure wet scrubbers as a second cleaning stage after the electrostatic precipitator. Actually this device is the only one which has proven its effectiveness in practical service for this demanding task.

Usually in Europe the particulate emissions are limited to 100 mg/Nm^3. However, limits down to 30 mg/Nm^3 can be guaranteed. Our company has - I mention this with satisfaction - complied with the guaranteed emission limits in every one of the plants we have built.

These are some main design advantages of the WIDMER + ERNST refuse-to-energy system. Philosophy and art: in practice both must serve

- environmental protection
- operational reliability
- profitability

and this they have done.

C) Co-disposal of solid waste and sewage sludge

In Europe the treatment of waste and waste water of a city or a region generally falls under the competence of the same authority or administrative branch. The administrative cooperation and eventually the centralization of a resource recovery plant and a sewage treatment plant on the same site is in every ase economically and operationally advantageous.

This fact, as well as the still missing economic solution for hygienic disposal of the great sludge quantities produced by sewage treatment plants, has kept on giving impetus to the common treatment of refuse and waste water.

WIDMER + ERNST designed and constructed 5 years ago two installation for the codisposal of waste. (Figure 8) According to the now available operational experience, the applied process can be evaluated as being reliable and economic because the energy for combustion chamber of the furnace (Figure 9). The vapours from the drying process are brought back into the combustion chamber, where they are thermically treated (burnt) and thus deodorized. The process works as follows:

Sewage sludge is mechanically dewatered to approx. 75% moisture content and conveyed by means of conveyors to all working tank located above the furnace. The sludge is extracted from the working tank, and conveyed to a twin shaft mixer of the screw conveyor type. In the mixer, the wet sludge is mixed with already dried sludge to a mixture with a moisture content of 35-40%. The mixed sludge in trickling form is inserted into the flue gas down ducts. Hot flue gases with an approximate temperature of 750°C (1380°F) are extracted from the furnace and flow through a downcoming duct, to a grinder (hammermill type). Before the hot gases and the sludge reach the hammermill, the heat exchange and the evaporation and drying process starts. In the mill the sludge is disintegrated into very small particles (dust) and dried under the influence of heat.

The gas-sludge mixture flows through a vertical upwards duct, where the final suspension drying takes place.

In the cyclone, the sludge is separated from the flue gases and falls via a rotary valve, and a duct into the dry sludge storage tank. The moist flue gases are reintroduced into the combustion chamber through the secondary air system by the aid of an exhaust fan. The flue gas stream is controlled by dampers and can be by-passed into the extracted flue gas stream to maintain any set temperature.

The separated, dried sludge with a moisture content of 10 - 15% in the dry sludge storage tank, is extracted via rotary valves, and used:

- to be mixed with the wet sludge and
- to be introduced and burned in the combustion chamber in suspension above the grates with dust burners.

A certain amount of dried sludge has to be stored in the intermediate tank for the purpose of mixing to the wet sludge at start-ups.

Wherever necessary the installation is insulated against heat losses.

An automatically operated measurement and control system allows supervision and control of the installation from the main control room. (Figure 10)

Fans generate the necessary air for pneumatic transport of the dry sludge to the refuse incineration combustion chamber. The burners are developed to burn dried sludge and ensure a fast and total thermal reduction of the sludge in suspension above the grates. (Figure 11)

During several years the dried sludge has been analized by the environmental protection authorities of the state of Bavaria in Munich with respect to its heavy metal contents. The results show such a low heavy metal concentration in the sludge produced by this process that the authorities have authorized its use in agriculture.

A remark on the odor question!

All sludge conveying and storage elements are fully enclosed and under negative pressure. The vapours from the drying process are burned in the furnace. After total oxidation any odors are eliminated.

D) Steam conditions

Following Table I shows the steam data of some plants in operation or under construction.

TABLE I

Resource Recovery Facility	Temperature		Pressure	
	^{o}F	^{o}C	psig	bar
Baden, Neuchatel, Werdenberg	752	400	580	40
Fuerth	304	151	72	5
Hamburg	707	375	392	27
Bielefeld	752	400	580	40
Ruhr Mitte II	680	320	464	32
Schwandorf	770	410	1059	73
Nyborg	464	240	174	12

Our general opinion is that it is better to sacrifice some of the turbine efficiency through somewhat lower steam conditions but ensure a high reliability of the installation and a long boiler life span. Based on operational experience, it is general practice in Europe to choose lower steam conditions in spite of major improvement in the design of steam boilers. We recommend the following steam conditions:

Temperature	750°F	400°C
Pressure	600 psig	41 bar

OPERATION

A) Operating experience

1. Personnel requirements

The personnel requirements depend on:

- the technical design of the plant
- the number of process lines
- the operational program (times of delivery, number of shifts)
- the weekly working hours according to law
- the general training level of the employees and, to a limited extent, on the process capacity.

The following table shows the personnel of some plants without considering the plant's management and the commercial employees.

TABLE II

	No. of Process Units	Capacity Per Unit	Plant Energy Production	Country	No. Shifts Per Wk.	No. of Personnel		
						per Shift	Reception Maintenance Cleaning Reserve	Total
A	2	100	No heat recovery	CH	3	2	5	11
B	2	180	No heat recovery Sludge Codisposal	D	4	7	6	34
C	1	120	Electr. Prod. and district heating	CH	4	2	3	11
D	2	100	Electricity production	CH	4	3	9	21
E	2	100	District heating	D	3	4	3	15
F	2	450	Electricity production	D	4	6	21	45
G	2	300	Electricity production	CH	5	4	22	42
H	1	400	Electricity production	CH	5	3	17	32
I	4	600	Electricity production	South America	5	8	22	62
K	3	400	Process steam	USA	5	5	22	47

2. Maintenance and replacement

Should a resource recovery plant with energy production attain the operational reliability of a thermal plant a rigorous inspection program must be carried out. The nature of waste as a fuel requires more maintenance time than a conventional thermal power plant. If the inspections are carried out seriously and according to a program, malfunctions will not occur more often than in a conventional power plant. The inspection program should include the preplanned exchange of spare parts. This work requires a careful control of wearing parts by an experienced professional during the main inspections.

If signs of wear are discovered, they can be appraised and evaluated, and, if necessary, the needed replacement material and personnel can be prepared for the next maintenance shut down.

We recommend to our clients an inspection program based on operating experience because we are convinced that such an approach will pay for itself.

It is obvious that the inspection times of the single process units must be shifted, and the maintenance shut down should be scheduled for periods with reduced waste deliveries (before or during festivity days, during holidays), seasons of low waste generation.

Design versus actual throughput

It is principally wrong, or at least not sufficient, to evaluate resource recovery plant with energy production in terms of its throughput in tons per hour or per day. As a thermal installation,all its active process components are limited by their thermal capacity. Only for the combustion grate design is the weighted refuse throughput relevant. The reduced throughput of resource recovery plants in the course of operational life does not, by all means, signify that the plant capacity has diminished because of aging. According to all researched statistics available it can be proved that the waste calorific value in a determined city or region increases through the years. Therefore, at a later time the same plant must burn less fuel to produce the same amount of energy or, in other words, the plant's throughput could be lower in tonnage.

For this reason every statement about throughput capacity must be coupled with the corresponding waste calorific value, as the combustion diagram shows.

To determine the yearly throughput for planning purposes we calculate the availability for each unit to be max. 7500 hours per year.

The maintenance and personnel qualify, as well as, to a certain degree, the age of the plant can influence this value.

New plants can operate for over 8,000 hours per year. In older installations this value can be reduced down to about 7,000 per year.

ECONOMICS

1) Introduction

Many times experts have tried to establish a general overview of economics of resource recovery in Europe. However it has proven impossible to generalize or even to find a certain range that can be applied to operating costs of existing plants. Our company has often been asked by Americans who visited plants in Europe. How can you predict reasonable costs for facilities in the USA if in Europe your costs per ton are, first of all, very high and secondly differ from place to place.

There are numerous reasons for this. The main ones are listed below:

- Most of the European plants are operated by municipalities or regional government authorities. This makes it in most of the cases impossible to apply correct cost figures to the plant operation.

- Overcapacity: Most plants are designed not only to last for 20 years and more, but also to accomodate expected waste increases over the long term. This leads automatically to an economically insufficient utilization of the plant during the first years and sometimes, if the projections do not work out, for extended periods.

- Philosophy: European countries developed resource recovery earlier than the USA out of pure necessity. Land availability for landfills is scarce and leachate and air pollution problems connected to landfill operations have been recognized a long time ago.

Therefore, socio-ecological considerations were the main factor in promoting resource recovery. Although economics are of course a decision making factor in selecting a contractor, it is accepted that resource recovery costs normally are somewhat higher than landfilling. Resource Recovery is a solution to a serious problem and to pay a price for it should only be reasonable.

The following will give some insight into the economics of resource recovery using costs applied by our company for the US market.

2) Facility costs, finance costs, debt service

For our example we use a medium to large size facility capable of processing approx. 500,000 tons of solid waste per year. Assuming an 85% availability the plant must have a design capacity of 1600 tons per day. We further assume that for reasons of continuous operation 3 independent process lines will deliver 600 psig/750°F steam to a nearby plant that can use all of the steam produced by the resource recovery facility on a continuous 24 hr/day, 7 day/week basis.

The resource recovery plant will have approx. 4,200 lbs. of steam for sale for every ton of solid waste processed, or 2.1 billion lbs. per year. If this steam replaces steam produced by oil fired boilers, a price of about $7.00 per 1000 lbs. should be a reasonable incentive for the steam user to buy it. The steam sales plant revenues would therefore be 14.7 million dollars per year.

Capital costs are estimated at 70 million dollars. Depending on the type of financing, the total capital to be covered will run about 100 million dollars. At a 23 year amortization rate (3 years construction and 20 years operation) the annuity will be 11.26%, assuming a 10% interest rate. The debt service therefore totals 11,260,000 dollars per year or 22.52 $/ton.

3) Tipping fee

The tipping fee, to be paid to the plant operator, has to cover the differential between the operating costs plus debt service and the revenues from the sale of energy. In the following table we show a typical calculation to establish the tipping fee.

If the operator is a private entity (perferably the designer/constructor of the facility) his profit will normally be a percentage of the energy revenues in the range of 10%, plus a fixed fee. Participation in the energy revenues gives the operator the necessary incentive to operate the plant at optimal efficiency throughout the whole contract.

We did not include in the overall plant economics possible revenues from the sale of secondary materials. Markets for these materials tend to fluctuate significantly and unpredictably. This type of revenue stream has to be handled on a short-term basis and any such income normally is split between the operator and the communities on a yearly basis.

TABLE III

CALCULATION OF DISPOSAL FEE (in July 1979 Dollars)

Facility with 3 units @ 535 TPD = 1605 TPD

Yearly throughput: 500,000 Tons = 85% of capacity

COSTS	$/YEAR	$/TON
Personnel	1,500,000	3.00
Maintenance	2,000,000	4.00
Utilities	1,250,000	2.50
Insurance, Miscellaneous	350,000	0.70
Residue Disposal	1,500,000	3.00
Management Fee (fixed part	350,000	0.70
Land Lease	100,000	0.20
Fee to host community, in lieu of taxes	500,000	1.00
Debt service	11,260,000	22.52
TOTAL COSTS	18,810,000	37.62
REVENUES		
90% of steam sales (7.00 per 1,000 lbs.)	13,230,000	26.46
NET TIPPING FEE	5,580,000	11.16

4) Conclusion

This given example, while simplified, represents a fair evaluation of the economics of a resource recovery facility. The figures can of course vary depending on:

- plant size
- energy customer
- type of financing
- type of operation
- utilization of capacity
- others

While the tipping fee could seem noncompetitive to landfill in many cases, a few facts should be kept in mind.

A) The tipping fee at a landfill or a resource recovery facility is only a relative small part of the total disposal costs for waste.

B) Consequent upgrading of existing landfills or preparation of new ones in compliance with RCRA regulations will skyrocket landfill rates in the near future. Many will close and haul distances will increase substantially.

C) Resource Recovery, if the mass-burning water-wall system according to proven European technology is applied, can be placed in locations centroid to the waste generation and eliminate long and fuel expensive hauling distances.

D) Because a large part of the operating cost consists of debt service at a fixed rate, only a part of these costs will escalate due to inflation.

E) Because it can be assumed that energy prices will continue to rise faster than general inflation, revenues from energy sales will contribute more and more over time.

F) Taking into account the facts of D) and E) tipping fees will rise at a lower rate than inflation and might even level off quickly, or go down over time. This cannot reasonably be assumed for hauling and disposal at landfills.

All this should help to convince the public and officials that resource recovery is economically feasible besides being a necessity to guarantee a safe environment and quality of life.

AMERICAN MARKETING PHILOSOPHY

A) Arrangement with European System Developer

On the American market, WIDMER + ERNST works exclusively through its own subsidiary company WIDMER + ERNST INC., New York, and not via a license. The technical management of the company is in the hands of an engineer from the parent house in Switzerland, who in the last 15 years has served uninteruptedly in different positions in the resource recovery field both in Europe and the USA.

The management, marketing and selling are in the hands of American with industrial experience. The basic engineering for each project is worked out in the parent company in Switzerland and put at the disposition of our New York team. Based on this work and keeping constant contact with the parent company, the plant's components are selected among the vast range of products that American industry offers. To guarantee an unchanged quality only the combustion grate and the residue discharger would be delivered from Switzerland.

In the case of an order, an experienced project manager from the parent company, having experience with the latest plant developments in Europe, takes over the supervision on the project relaization. The remaining personnel would all be Americans.

The direction of the start-up and the local personnel training is also reserved to specially trained personnel from Switzerland.

The training of the plant manager and the shift supervisors takes place at similar plants in Europe. We are convinced that in this way we offer our American clients the utmost degree of certainty that our proven technology and experience in

plant engineering,
plant construction, and
plant operation

will be optimally transferred. However, the hardware shall be procured exclusively from American industry.

B) Sales approach

Presently we confine for the most part our activities to projects stemming from RFP's. The development of our own projects from scratch requires too large an investment in people and in particular-time. When in days to come mass burning systems will have achieved a breakthrough on the European scale, the sales approach will certainly have to be changed. The cession of sybsystems to Architect & Engineering and constructors under our general management is realizable, whereby we prefer the cooperation with efficient companies in the area where a plant is to be constructed.

C) Procurement approach

The usual European practice for the construction and operation of resource recovery plants in that the specialized company making the process engineering part acts as a general contractor who builds the plant on a turnkey basis for the client. In most cases, however, the plant is operated by the city or the administration union. In France a larger number of plants are operated by private firms which act on behalf of public corporations like the city's users union. We have built several plants acting as the responsible member of a syndicate. The other members were, for example, local Architect and Engineering companies, manufacturers of main process components (for instance, electricity generating installation), or the civil works contractor. In any case the overall technical management and therefore also the overall responsibility should remain in the hands of the company providing the process technology.

The question if the conventional Architect and Engineering can be applied for the construction of refuse incineration plants should be examined very carefully in each particular case. Basically the question could be answered in the affirmative, provided the overall responsibility for the process technology and financing are legally settled.

The conditions for a successful business for all concerned are:

1. a perfectly functioning plant
2. secured waste delivery contracts
3. secured energy purchase contracts
4. a competent and uninterrupted plant operation
5. compliance with all environmental requirements

if with these five elements a profitable business can be proved, investors will always be found.

WIDMER + ERNST guarantees the capacity and the quality of the plant. This is our accustomed activity.

In addition we also gladly operate the plant on behalf of the client. If a capital participation or a full plant ownership can be realized depends on legal and commercial conditions in each specific case. As businessmen we never would refuse a good deal, knowing, however, that possible success is always coupled with a calculable risk. (Figure 13)

SUMMARY

A) Background

WIDMER + ERNST, a Swiss company and member of the ALUSUISSE group, has an outstanding track record of 19 years in the environmental protection business.

The first refuse-to-energy plant with electricity production that we built was operational in 1970 and is since then working at full capacity and without interruption. Subsequently we realized a considerable number of plants acting as general contractor, partly alone, and partly as the responsible member of a syndicate.

The main markets are at this time Switzerland, the Federal Republic of Germany, Belgium, and recently also the USA.

With satisfaction we state that all plants we have built up to now are working to the full satisfactions of the clients, and comply with the required capacity and emission limits.

B) Technology

The new W+E step grate with single drive, (on 3rd generation of grate design) as well as the steam boiler concept with rappers for the tube cleaning especially developed for the waste energy process have made an encouraging market breakthrough.

Alone in Germany there are at the time three large plants under construction by WIDMER + ERNST.

The electrostatic precipitator proved to be a highly efficient flue gas deduster. Although they are up to now required only in German, WIDMER + ERNST has a wealth of experience with the design and construction of wet scrubber and their demanding auxiliary elements for the separation of the gaseous components HCl, SO_2, and Fl.

WIDMER + ERNST builds also plants for the conversion of combustion residues into road building materials. The Ingolstadt plant with two co-disposal units for sewage sludge and solid waste has finished a five year operation phase and can, therefore, be qualified as a proven and very economic process.

C) Economics

The economics of recovery in Europe is quite different from that of the U.S. Market due to plant ownership, operating philosophy and accounting methods.

U.S. plants have two basic income streams - tipping fees and the sale of energy. That must cover the three major cost considerations namely 1) Capital costs 2) Interest expense 3) Annual operating expenses.

D) Marketing approach

The American continent is exclusively served by our own subsidiary company in New York, WIDMER + ERNST INC. The management and the sales department are in the hands of an American citizen with great industrial experience, whereas the technical management has been confided to an experienced engineer from the parent company.

The basic engineering for every plant comes from Switzerland, whereas the plant design and the selection of components manufactured by the American industry is done from New York.

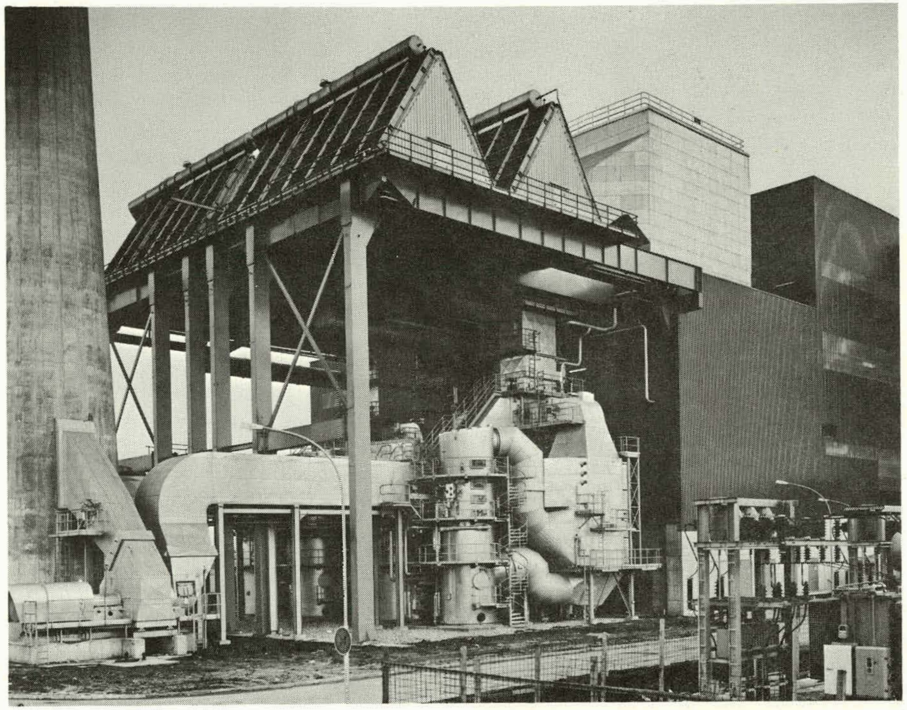

Figure 1. Wet scrubbers and flue gas/flue gas heat exchanger in tandem Hamburg Plant.

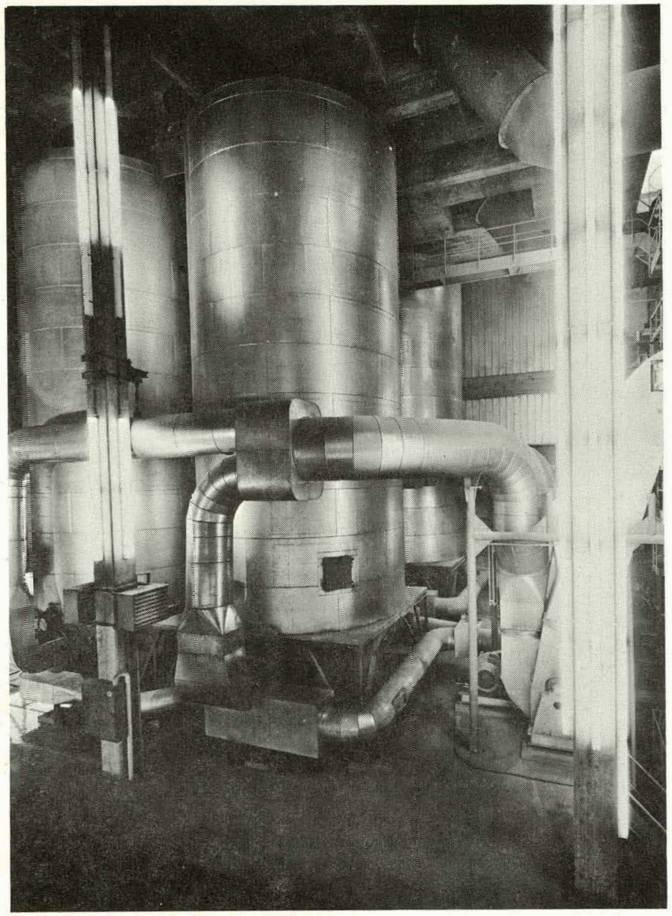

Figure 2. Steam/hot water converter.

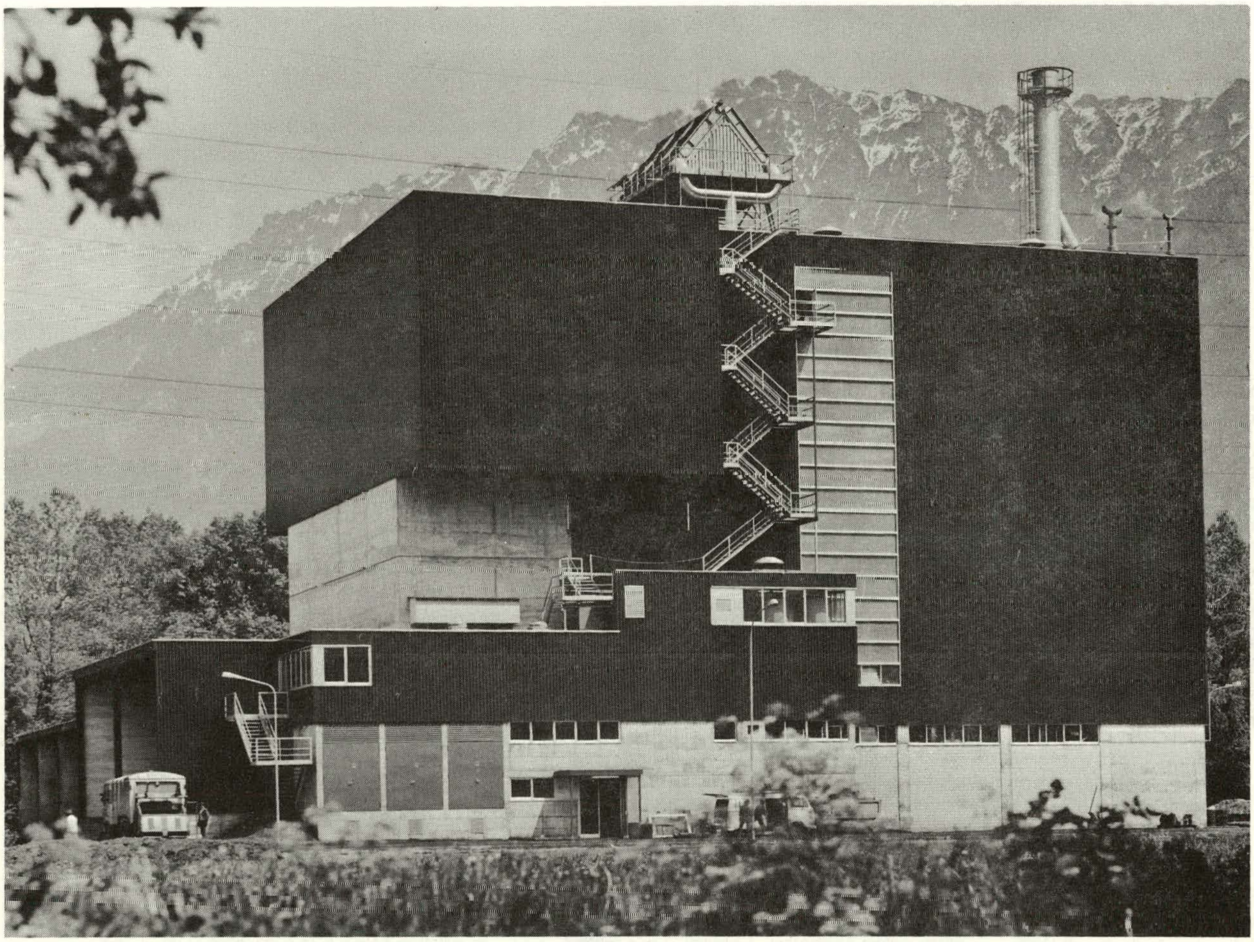

Figure 3. Smallest plant with energy recovery 120 TPD (Werdenberg Plant).

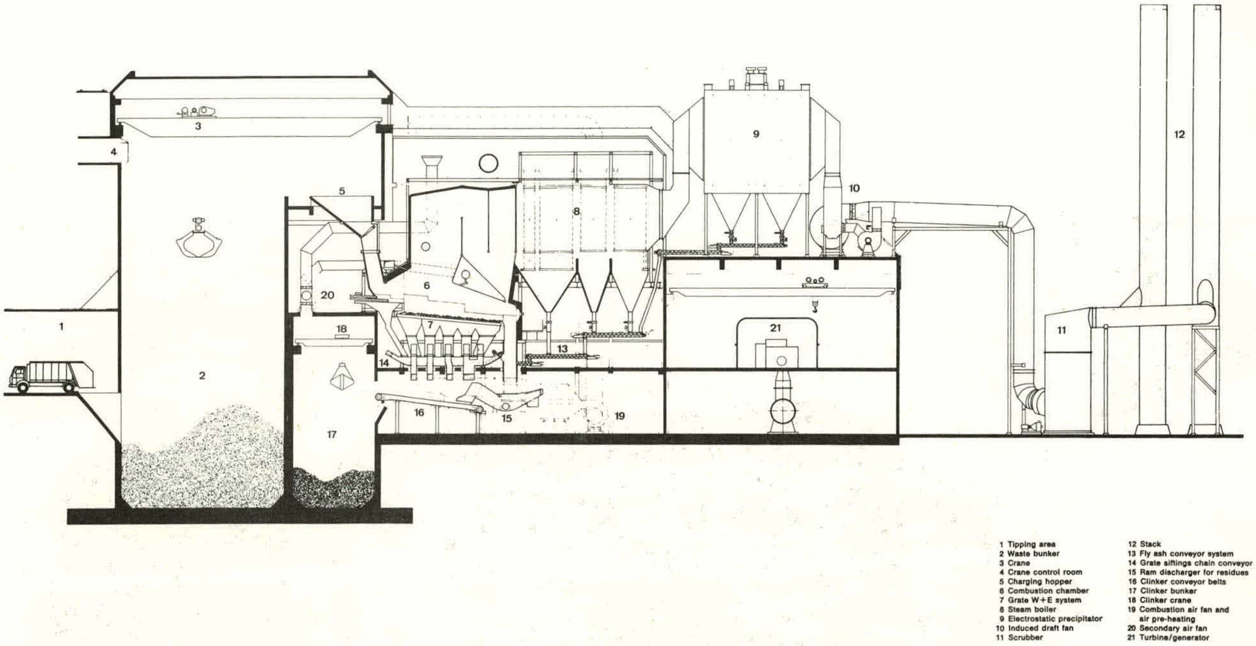

Figure 4. Firing and boiler concept (Bielefeld Plant).

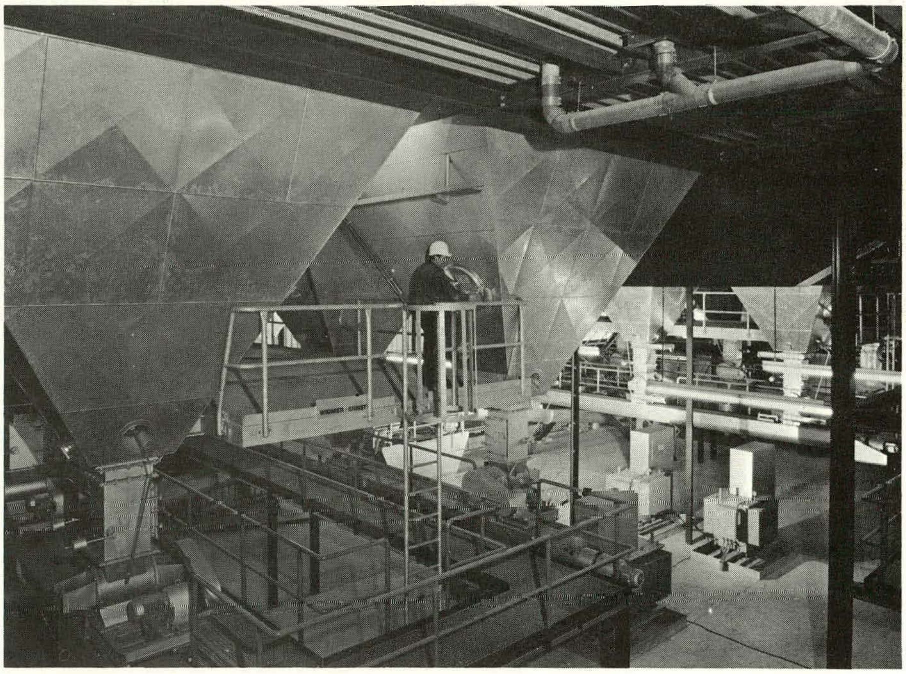

Figure 5. Fly ash hoppers of boiler and electrostatic precipitator.

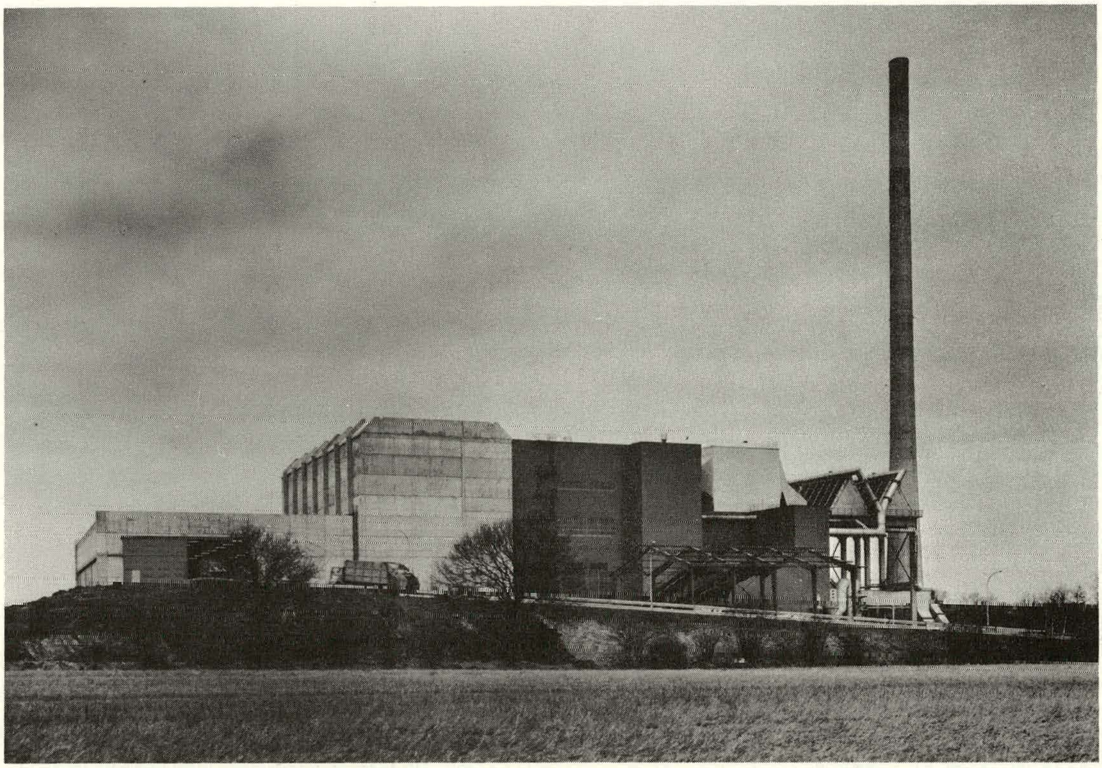

Figure 6. Hamburg Plant.

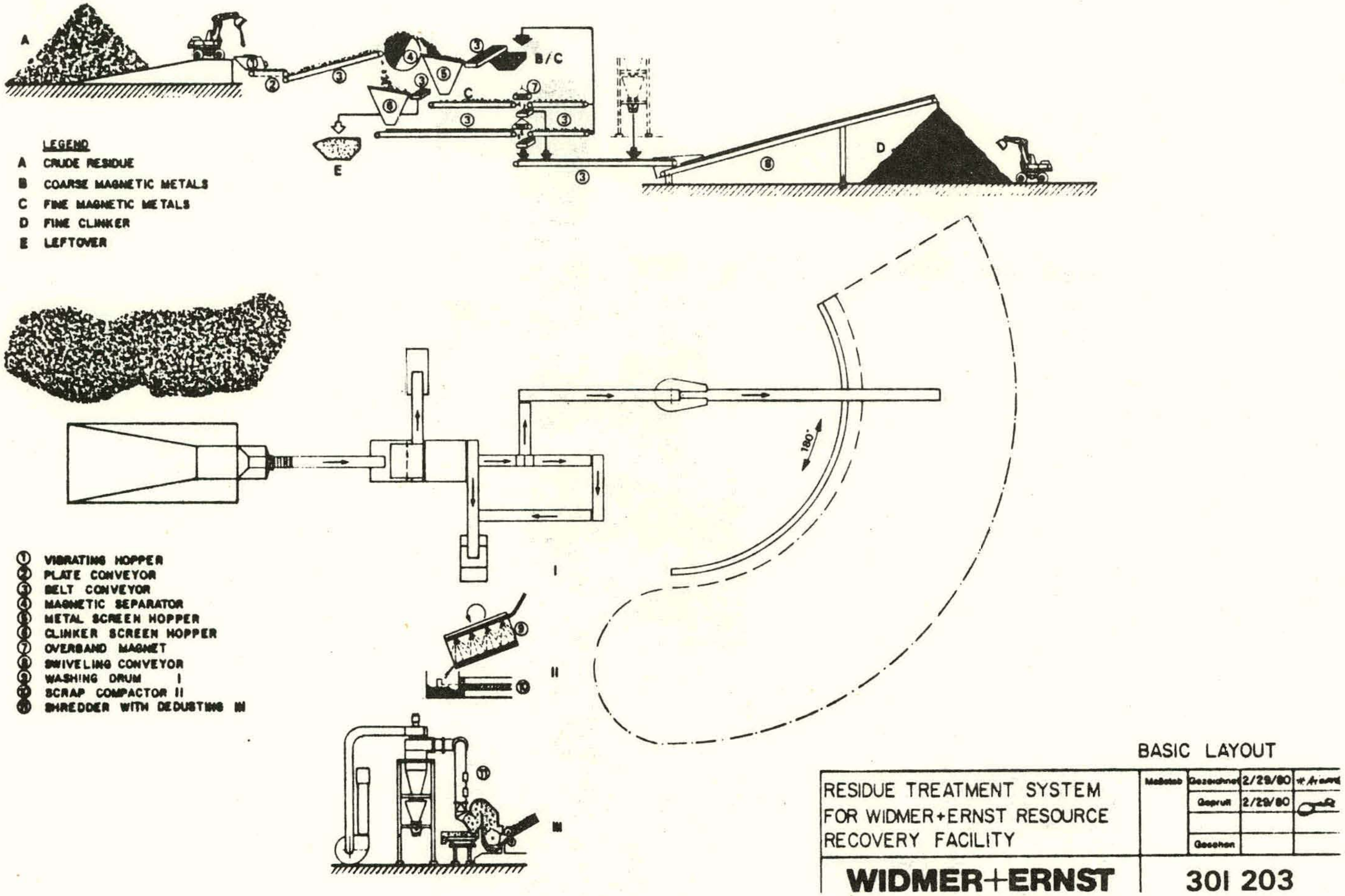

Figure 7. Residue treatment system.

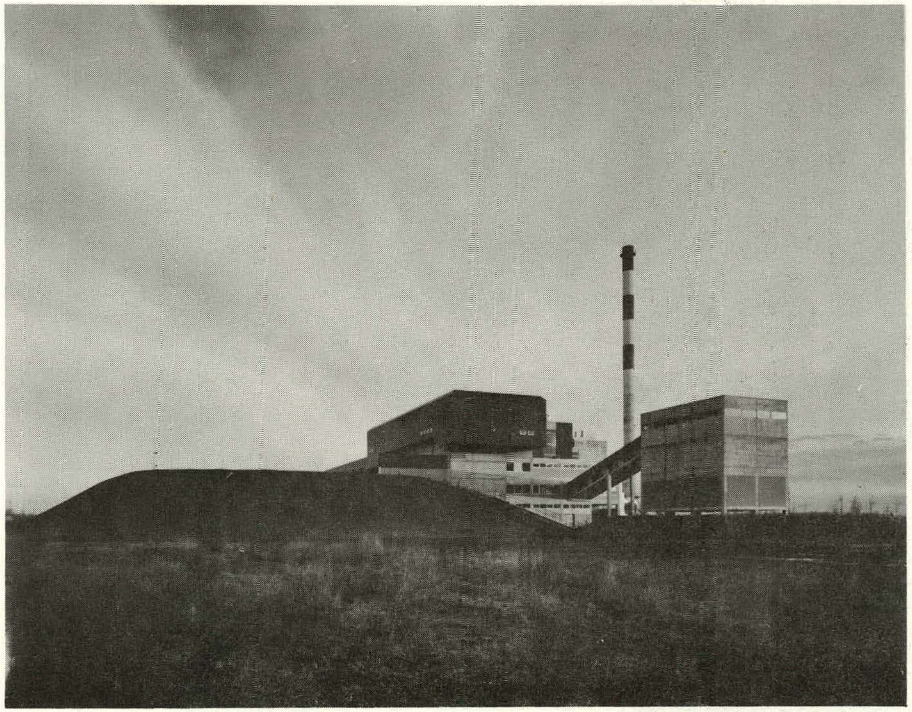

Figure 8. Ingolstadt plant.

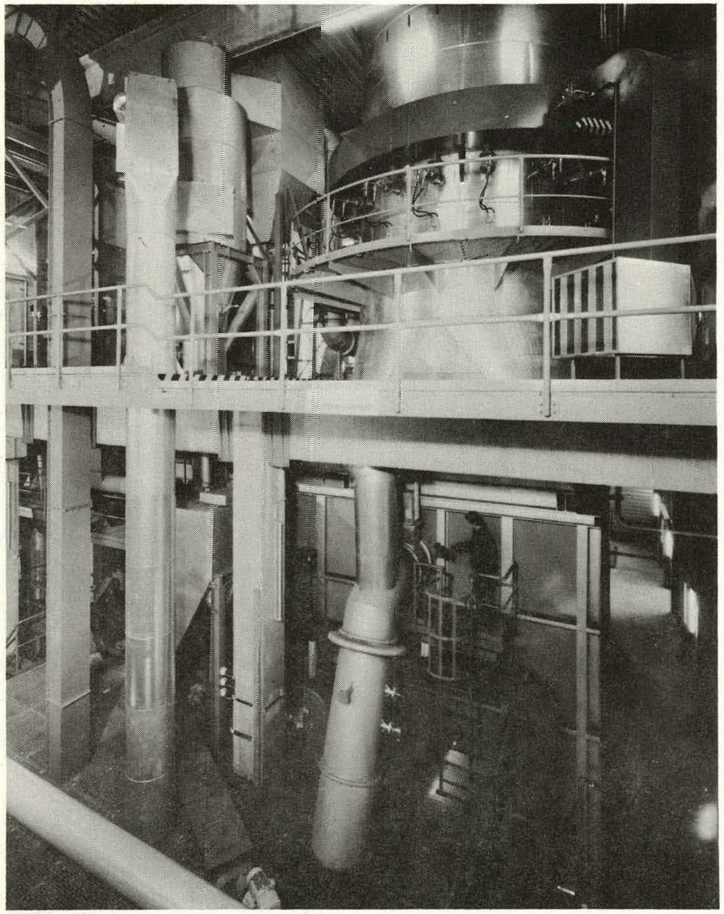

Figure 9. Flue gas extraction from combustion chamber (Ingolstadt Plant).

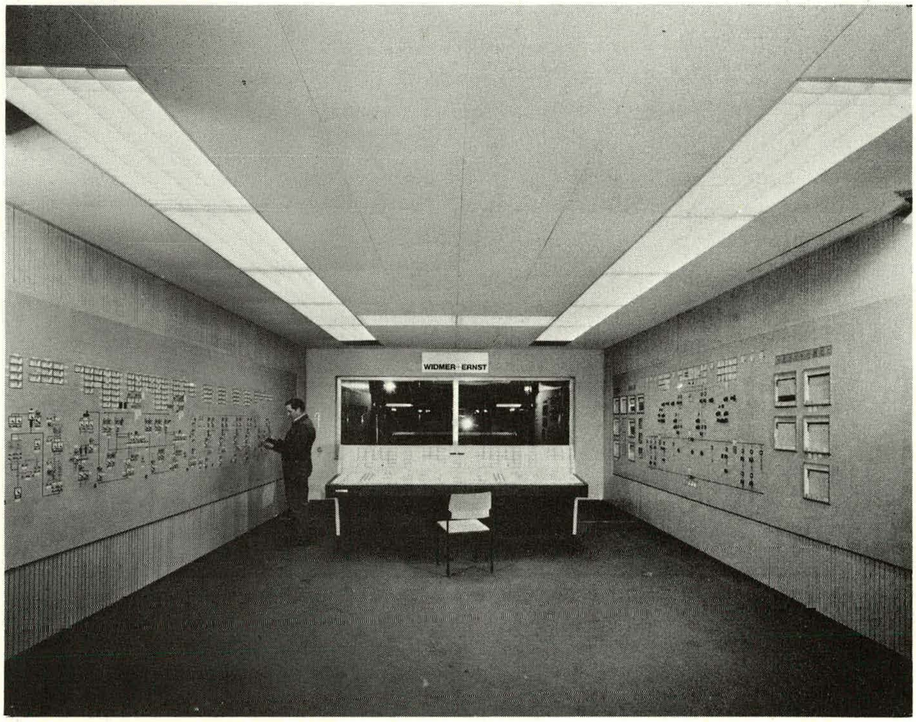

Figure 10. Control room of the Hamburg Plant.

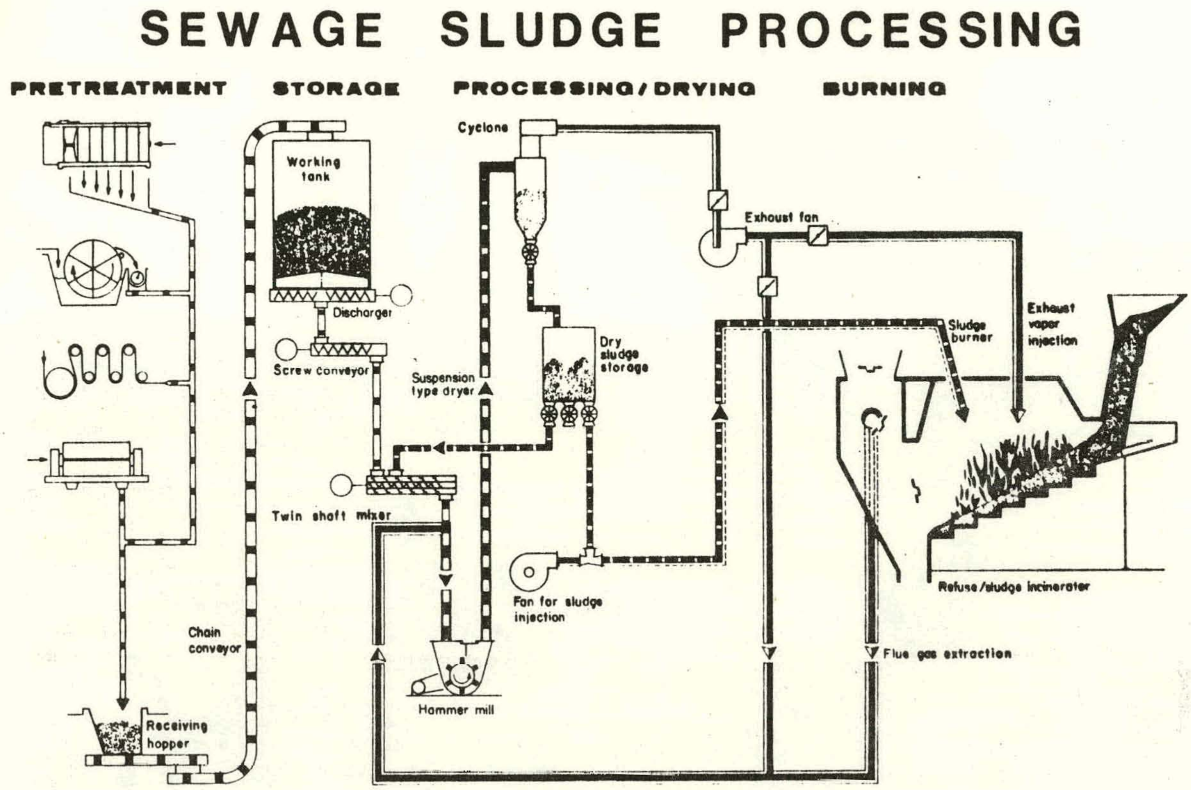

Figure 11. Sewage sludge processing.

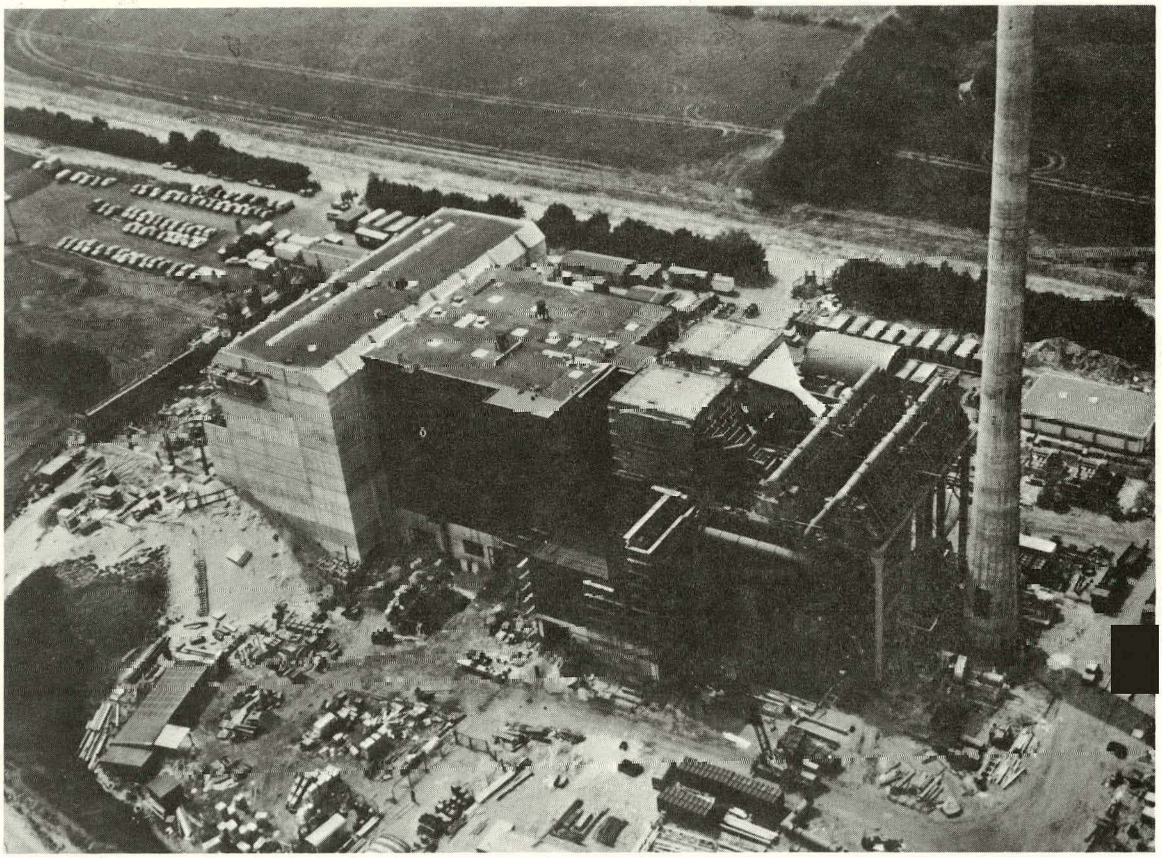

Figure 12. Hamburg Plant under construction.

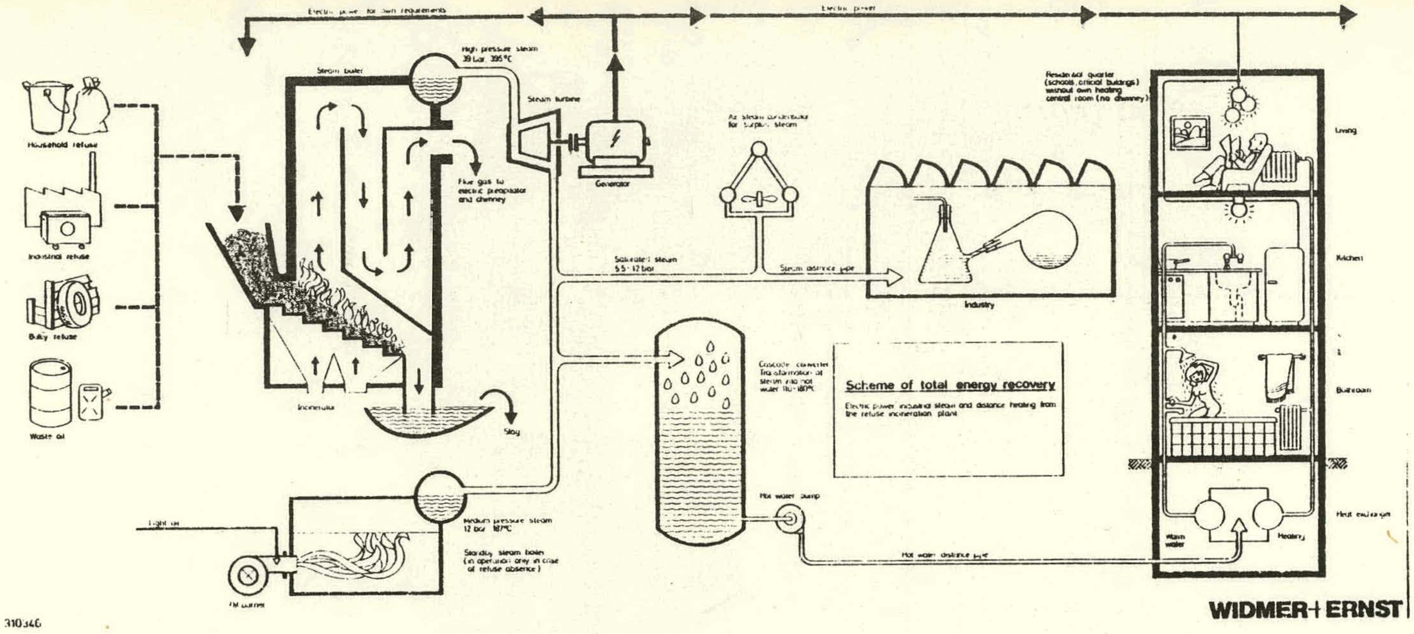

Figure 13. Chart of total energy recovery.

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DOMESTIC REFUSE INCINERATION WITH THE KATY-SEGHERS SYSTEM: PRESENTATION OF THE PROCESS

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ABSTRACT

Incineration is the ideal alternative to landfilling as the final disposition of municipal solid waste. Incineration has the advantages of 90% volume reduction to a completely odorless inert product, potential for recovery of valuable heat energy and existing technology to remove dust and pollutants from the flue gas to meet the most severe environmental requirements. SEGHERS Engineering of Brussels, Belgium owns a proven incinerator oven system which is marketed world wide. The North American licensee is the Katy-Seghers Incinco Systems Div. of Fulton Iron Works. This presentation describes the Katy-Seghers process and includes background information on SEGHERS Engineering, technological description of the system, operation, economies and marketing philosophy.

BACKGROUND

SEGHERS Engineering is a general contractor with their main activities in the field of ecology for:

A. Solid waste handling, mainly mass burning of municipal solid waste

B. Sewage treatment plants

C. Sludge drying and incineration

D. Industrial waste water treatment plants.

As a general contractor SEGHERS Engineering has been involved in all the phases of a project: design, purchase of equipment, construction, erection and assistance in operation and maintenance.

In municipal solid waste a wide variety of systems have been constructed to meet the local needs of both small and large communities. Up to the late 60's most furnaces were not equipped with heat recovery apparatus. Attention was directed to burning waste with the aim of size reduction and converting a potentially polluting waste into an inert slag. The more recent plants are all equipped with a waste heat boiler or heat exchanger for district heating or electricity production. The plant of Antwerp uses the heat of the flue gases to dry sewage sludge which will ultimately be used as a fertilizer or burned together with the refuse.

The size of the plants in operation range from 100 to 700 TPD or translated into unit size of a single oven-line from 2 to 12 TPH, with normally 2 or 3 oven lines per plant. It is our belief that in the near future the most economical sizes will range from 15 to 25 TPH for a single line. With 2 to 4 oven lines this results in a plant capacity of 700 to 2500 TPD.

As indicated later and explained in detail in a separate note, the unique design of the SEGHERS GRATE being composed of identical elements, allows for a wide range in unit capacities without facing problems of scaling-up or scaling-down.

The marketing philosophy of SEGHERS Engineering has dictated us to follow the specific desires and needs of the local municipality; in some instances only the supply and the erection of the equipment was provided, in other cases a turn-key contract including the design and civil works was included. SEGHERS Engineering has also participated in the actual operation and maintenance of the plants.

In almost all cases a contract was awarded after having been selected as the most responsive bidder answering a R.F.P.

It is interesting to point out that extensive programs are in effect to modify existing plants which do not have energy recovery. In most plants a waste heat boiler will replace the existing cooling tower or will be installed in parallel.

The SEGHERS SYSTEMS are in operation in Belgium, France and Switzerland as indicated in the reference list. Marketing in the U.S.A. and Canada is done through a licensee agreement with KATY INDUSTRIES, INC.

TECHNOLOGY

Every incineration facility is composed of a number of individual oven lines. Each oven-line is an independent process unit with the main components being the feed hopper, grate, slag extractor, combustion air system, furnace, waste heat boiler, flue gas treatment unit and exhaust fan. There is a common refuse pit, 2 or more loading cranes, one or two common ash conveyors and a common stack, or more for larger systems. The basic design principle of the SEGHERS system for the furnace - boiler assembly is a physical separation of the burning process and the heat recovery.

The water wall tubing is never extended into the actual oven space. The side-walls and the ceiling of the furnace are refractory lined. Once the hot flue gases (at 1000°C) are produced by the combustion of the refuse they enter the first passage of the waste heat boiler. This passage is "empty", that is, no tubes are installed in the center where they would be encountered by the flue gases. Only the side-walls are formed by welded fin tubes. This first passage of the boiler is a radiation chamber which at the same time provides enough retention time for after-burning.

The main reason for separating the furnace and the boiler is to improve the reliability of the installation.

a- explosions can happen (small gas cans, bullets, etc.)
   Minor damage of the refractory-lined walls does not require a shut-down of the oven.
   Repair can be postponed to a scheduled maintenance period.
   If water tubes are extended into the furnace, the unit must immediately be stopped if a tube is damaged and repair requires a rather long shut-down.

b- The refractory bricks and lining are much less sensitive to wear than the rather thin protection layer applied as a cover for water tubes.

c- The combustion process is stabilized by the buffer action of the heat stored in the thick refractory walls.

d- Scaling-up or down is much easier because the boiler design and construction is independent of the furnace construction.

The SEGHERS GRATE has a number of unique design features. We refer to a separate technical note explaining all the details. The most important characteristics are:

a- The entire grate surface is formed by assembling a number of standard elements.

b- Each element has 2 rows of fixed tiles, 2 rows of horizontally moving tiles and 2 rows of tumbling tiles. With this combination the refuse layer in combustion is perfectly mixed and disentangled.

c- The sequence of the motion of each element can be independently controlled from the dispatch room. In this way the grate motion can be matched to the variation of the refuse quality.

d- The grate tiles are made of highly alloyed refractory steel with 28% Chromium and 12% Nickle.

e- The grate itself is completely closed in horizontal projection. The air inlet openings are arranged in such a way in the nose of each tile that no fine material can fall through. Grate sifting is almost non-existent. This grate design makes it possible to burn very fine material such as coal and dried sewage sludge with refuse.

The waste heat boiler used in our plants is adapted to the particular nature of the flue gases from refuse incineration. To avoid corrosion and erosion all precautions are taken, such as use of welded-fin tubes to form a gas-tight chamber, use of the proper tube spacing to limit gas velocities and avoid clogging, arrange tubes in a non-staggered pattern, locate the superheater in the second or third passage where flue gas temperatures have dropped to an acceptable low value, use of a de-superheater or attemptator inbetween the first and second superheater to closely control the steam temperature and in this way limit the metal surface temperature of the tubes.

In addition to these widely applied design rules, SEGHERS also requires that the boiler be equipped with both a steam and a mud drum with natural external circulation. The total water volume is equivalent to about 2 hours of steam production. These two features safeguard the boiler from damage in case of a power failure.

In order to meet the environmental standards, different techniques can be used depending upon the local requirements. In any case the flue gas purification system is installed at the exit of the boiler where temperature has been reduced to a level of 220-280°C. No attempt is made to inject chemicals in the furnace or boiler.

The particulate matter load is reduced with efficiencies of 97% to 99% with the use of electrostatic precipitators.

As designer and contractor, SEGHERS is well aware of the increasing attention which is given to the chloride and sulfur components in the flue gases. A wet scrubber as commonly used is certainly not the best solution to this problem mainly because of problems with corrosion, clogging and water pollution. Therefore SEGHERS together with the University of Louvain has performed an extensive researched and pilot work to develop a "dry scrubber" unit. The first results indicate that efficiency in removal of 90% chlorides, 70% sulfur dioxyde and more than 90% for fluorides can be obtained.

As already indicated above the SEGHERS grate is particularly well adapted to burning pre-dried sludge together with refuse. The plant of Antwerp has 2 oven-lines rated at 10 TPH each. The heat contained in the flue gases is partially recovered in a heat exchanger with thermal oil. The thermal oil flows in a closed circuit and is used to dry the sludge. The sludge drier design is similar to a multiple hearth incinerator, but is made completely of metal and no combustion takes place. Each hearth is jacketed and heated by the thermal oil. The use of an intermediate fluid allows for a set-up where the energy of the flue gases is used to dry sludge without bringing the flue gases in direct contact with the sludge. In this way all odors are avoided and no flue gases must be recirculated to the furnace. It is of interest to note that two kinds of sludges are processed. First, the sludge from the thickeners of the sewage treatment on the same site as the incineration plant which is mechanically dewatered in centrifuges and then dried. Secondly, the sludge filter cakes of 6 other sewage treatment plants in the area are brought to the incineration plant by truck and handled in much the same way. For a complete description of the Antwerp plant we refer to a separate technical note.

OPERATION

The normal operation schedule of an incineration plant is 24 HPD 7 days per week. For smaller units without heat recovery, a shutdown overnight or on the weekends has been common practice for a long time. Although this practice certainly does somewhat decrease the life of the refractory, the procedure is acceptable. The heat contained in the walls is sufficiently high to keep the temperature in the oven at a high level. After a shutdown of two days, usually spontaneous ignition of newly introduced refuse takes place.

The minimum personnel per shift required for a medium sized plant is 3, one crane operator, one oven operator, in the dispatch room, and one mechanic for inspection of the plant inside. For larger plants with a complex lay-out, the presence of a second mechanic is advisable.

It is important that the crane operator be located in the dispatch room. This improves the working relationship and brings into perspective the important role of the crane operator in mixing the refuse and "preparing" the fuel.

A daytime crew of mechanics and electricians should be available for daily maintenance and repair. It is very important that the personnel has a broad skill and experience so that job rotation can be applied.

In the maintenance schedule, much attention is devoted to preventive maintenance and minor repair. The following example illustrates this principle. Every two or three years, all grate tiles are removed for inspection of both the tiles and the substructure. At that time, the tiles from the middle of the grate surface can be redistributed over the "cooler" part of the grate namely, the inlet and outlet.

SEGHERS Engineering has always kept a close contact and a cooperative spirit with the operation management of the incinerators they designed and built. A common philosophy and excellent feed-back has been the result. It is both SEGHERS' and the operator's conviction that more attention should be devoted to the "effectiveness" of a plant rather than to the plain "efficiency". By effectiveness, we mean the product of efficiency and reliability, the sum of factors like availability, ease of maintenance, redundancy of common components and proper utilization of equipment. In many cases, sophisticated equipment was purposely omitted to simplify the control and maintenance even if a fraction of the efficiency was sacrificed, but the total effectiveness has always been improved. In particular, much attention has been devoted to all the auxiliary equipment both in design and operation. Experience has shown that the oven-boiler assembly rarely causes frequent or fundamental problems. Most unscheduled stops are due to valves, conveyors, cranes, and other auxiliary equipment.

ECONOMICS

It is extremely difficult to compare the total cost for construction and operation on a dollars per ton basis for different existing plants. A great number of factors have to be considered and officials or plant operators are not always able to give the exact figures because sometimes the data is classified or not even recorded.

The actual cost depends on all such elements as:

- year of financing
- type of purchase contract, turn-key, full service or construction
- fixed price contract or contract with price escalation

formula
- payment form
- grants allowed by federal agencies
- construction period
- exchange rate
- interest rate
- income from selling steam or electricity
- redundancy required
- luxury in building
- air quality requirements
- number of operation personnel, as affected by local union rules or laws.
- actual waste available with respect to design capacity of plant.

As a thumb rule the following figures could be applied for plants processing 1000 to 2000 TPD:

- Construction cost = $50,000.00/ton
- Total net operation cost = $10-$20/ton.

MARKETING PHILOSOPHY

Katy Industries, through their subsidiary, the Fulton Iron Works Company of St. Louis, Mo., has an exclusive license agreement with SEGHERS Engineering of Brussels, Belgium to manufacture, use, market and erect the SEGHERS-CEC Domestic Waste Incineration System in the United States, Canada (except Quebec) and certain countries in the Middle East. The operating company is called Katy-Seghers Incinco Div. of the Fulton Iron Works Company.

Katy-Seghers will design, furnish and install incinerator systems per a consulting engineer's basic project design, or we will provide turn-key design and construction for the complete system per consultant's guidelines on quantity of waste, Btu content, etc. On turn-key projects, we will design and furnish all equipment, erect the complete facility and provide final testing, start-up and operating instructions. Also, Katy-Seghers would operate their system under contract if required, or would provide complete full service design-build-operate, systems for responsible parties. Katy-Seghers will assume full responsibility for the facility performance with the consultant providing basic guidelines on quantity and uality of waste.

Construction and erection is by Katy-Seghers Incinco Div. under the direction of our Katy-Seghers Project Manager. Construction supervision will include our construction contractor's Project Manager and Engineer, a Katy-Seghers Project Engineer and a SEGHERS Erection Superintendent with such other staff and engineers as may be required on a particular project. SEGHERS-CEC project engineers and technicians will provide final plant inspections, initial start-up and instruct operating personnel.

Katy-Seghers prefers to provide the complete system, per basic guidelines of the municipal consultant who has researched the city requirements and has contracted for the solid waste supply and energy users. This is the typical request for proposal route, which is our most common approach.

SEGHERS Engineering provides technical specifications, engineering drawings, and erection supervision. All design work on the incinerator equipment and accessories is by SEGHERS Engineering. Modifications to conform to federal, state or local requirements or ordinances are by Katy-Seghers with final design approval by SEGHERS Engineering. The heat recovery boiler employed is a SEGHERS Engineering design, developed after exhaustive studies and operational reviews. It meets the most modern requirements for reliability and corrosion protection. Designs for the building and services (power, water, HVAC, etc.) and ash handling outside the building are by Katy-Seghers.

SEGHERS-CEC will provide the oven grates from Belgium. The supply of the oven grates from the sources now utilized will permit assurance of the metallurgy that is so vital for long wear and elimination of breakage. All other equipment and accessories, including the travelling crane and claw, feed hoppers, combustion air systems, slag removal equipment, heat recovery boilers, and electrostatic precipitators will be of American supply and manufacture.

Katy-Seghers is a nationwide company. Our Washington representative is contacted first on any proposed project to study bid requirements, emission standards, and other items peculiar to a particular location. Our construction contractors have done construction work in every state and Katy Industries' many subsidiaries operate everywhere in the U.S.

Katy-Seghers shall consider partial ownership and operation of the domestic waste to energy plants under contract. Under such a plan, Katy-Seghers would enter into partnership agreement with the city or county and function as a minority owner. Katy-Seghers will, if required, enter into equity agreements wherein the project is financed by revenue bonds. In this arrangement, we would request operational control of the system.

The domestic waste plants that Katy-Seghers designs and builds are completely guaranteed by Katy-Seghers, including capacity, burn-out, steam quality and quantity, and emissions guarantees. All material SEGHERS Engineering furnishes is guaranteed against manufacturing defects and construction and erection is guaranteed to be free of errors under their normal warranty period. Capacities, percent carbon in ash and emissions are guaranteed within certain parameters.

SUMMARY

Katy Industries, Inc. is listed on the New York Stock Exchange, a company of diversified holdings which concentrates its activities within four basic operating groups: The Industrial Equipment Group, which includes Fulton Iron Works, is the largest. Fulton has a long history of service to industry dating back to 1852. Our sugar mill equipment, presses and boring bars have achieved a world-wide reputation for dependability. Our experience in complete sugar factory design and construction may be of interest to you since the sugar factory is a city in itself. All electrical power is generated through the burning of bagasse (the remaining portion of the sugar cane after grinding) and such power handles all the requirements for factory and personnel living functions. The burning of bagasse is performed in a series of large field-erected boilers.

SEGHERS Engineering is a design/construction firm specializing in turn-key projects for government and industry with over 40 years domestic waste incineration experience. SEGHERS designs and builds complete municipal incinerator systems using the Carbonization Enterprise et Ceramique (CEC) Grate System. Since the mid-1960's, most of these plants have included heat recovery boiler systems of SEGHERS' own design. Recently, SEGHERS has developed a process for drying sewage sludge with the "waste" heat from municipal waste incineration. We can point to a specific plant that is just being commissioned near Antwerp, Belgium that utilizes this new technology. We welcome your visit to this new installation.

Katy-Seghers and SEGHERS Engineering continue to grow and expand because they are always improving on existing processes, creating innovative and ingenious new solutions to old problems, particularly for the environment and ecology.

The SEGHERS-CEC Grate is the secret of successful, economical operation. Other systems may be lower in initial cost but our systems have achieved an excellent reputation for low operating and maintenance costs. An equally important factor in high operating efficiencies and low costs is the SEGHERS heat recovery boiler. This boiler is specially designed by SEGHERS for use with the corrosive and high ash flue gas of municipal waste.

Today's incinerator is the result of years of experience and design improvements, a perfect balance of competitive first cost, high efficiency, safety and low operating and maintenance costs.

Every ton of municipal waste has the equivalent heat value of over a barrel of oil. Mass burning with little handling, no pre-sorting, and with heat recovery is the most effective, efficient and economical method of utilizing this valuable resource. Waste volume is reduced by 90% or more, lowering transportation costs and saving landfill space. If ferrous metals, aluminum and ash separate by a sieve system are recovered, the total volume reduction can be 98-99% with only 1-2% of the original waste ending up in the landfill. The recovered heat is sold as steam, hot water or electricity further adding to the economic feasibility. Source separation of paper and aluminum and magnetic separation of ferrous material from ash may be utilized with our mass burning system. The economics of recovering ferrous metals,aluminum and ash depend on the market potential and often recovered materials are not worth the cost of additional recovery equipment.

Every effort must be made to acquaint the various communities and agencies responsible for waste disposal with this time-proven concept. Consultants must be made aware of the economical and ecological advantages of mass burning. Government and the general public must be informed of this alternative to landfilling waste and importing oil for fuel. Our Katy-Seghers marketing efforts are directed to just such goals. Through direct mail, advertisements and the sales efforts of our representatives, we are doing our best to let everyone know about this solution to the problem of solid waste management.

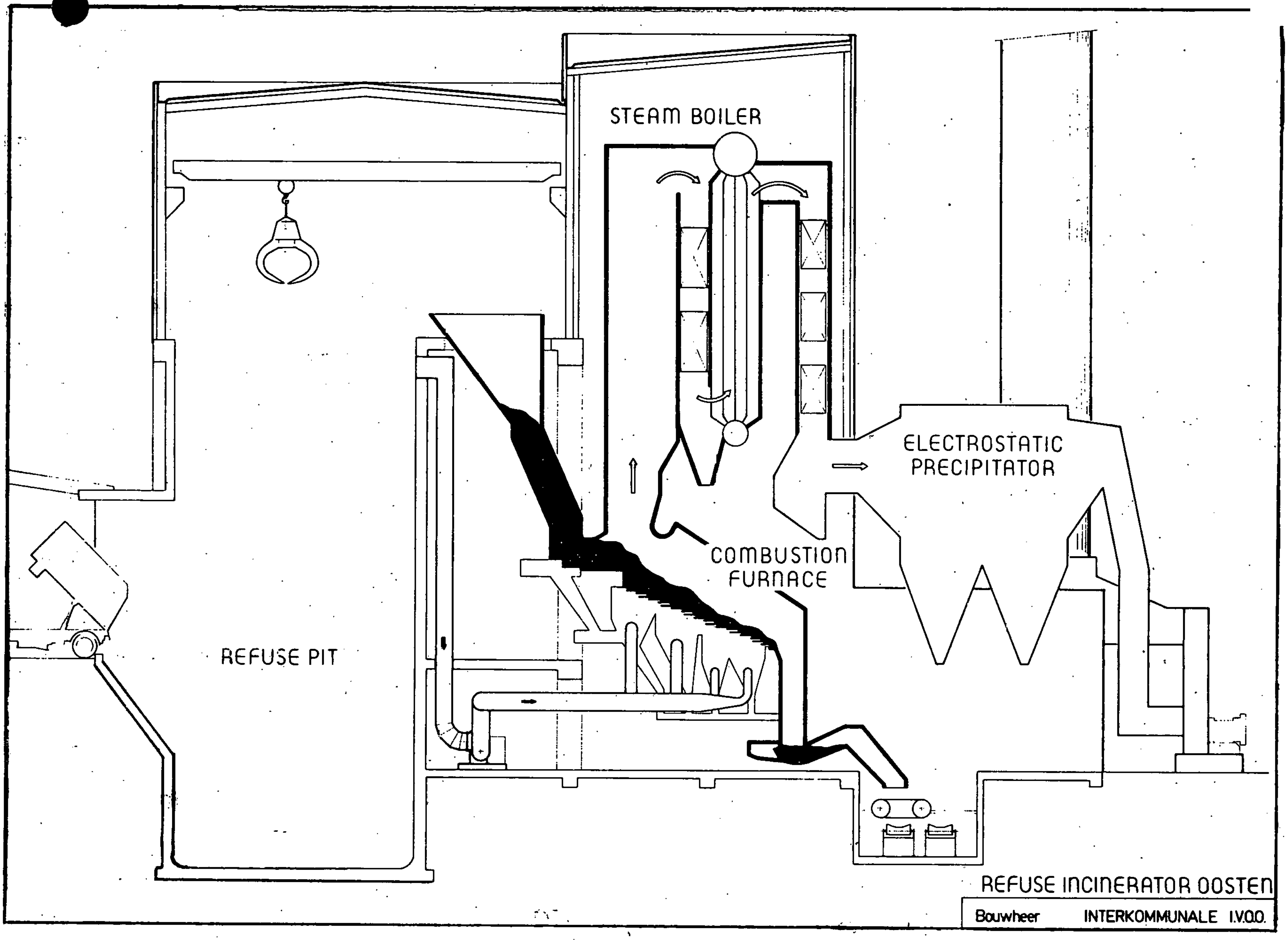
Mass burning in a Katy-Seghers incinerator is the ideal last stage in the consumption circuit:

1. The end product is a solid, odorless, entirely inert small volume (10%) material suitable for construction fill.

2. The thermal energy resulting from incineration can be economically converted into steam for heating, production of electricity or hot water or other process uses.

3. Flue gases can be adequately freed of dust and chemically purified to meet the highest environmental requirements.

We thank you for your time and attention. We appreciate the opportunity to be of service and we invite your questions.



REFUSE INCINERATOR OOSTEN

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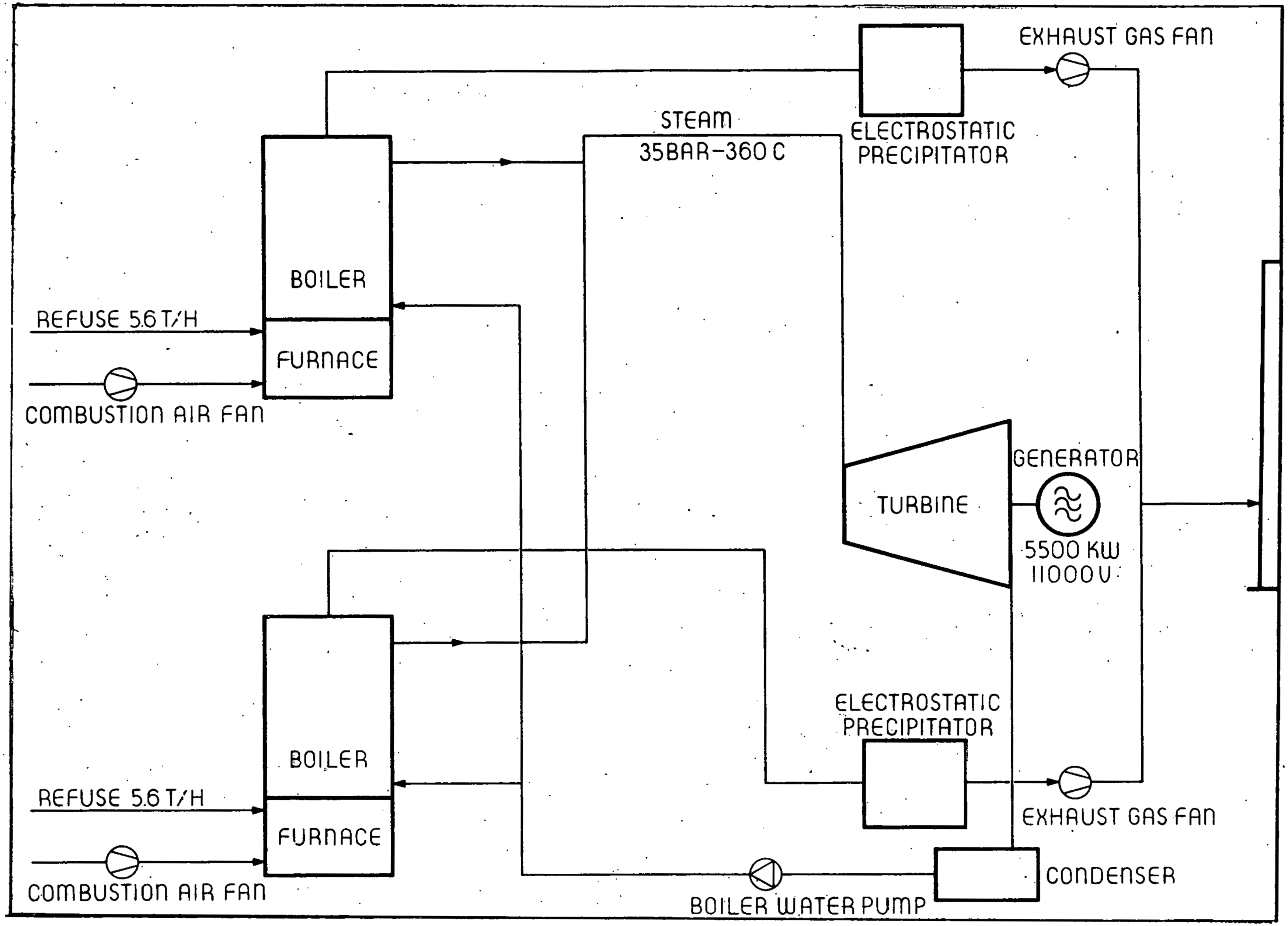
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TURBINE
5500 KW
11000 V
BOILER
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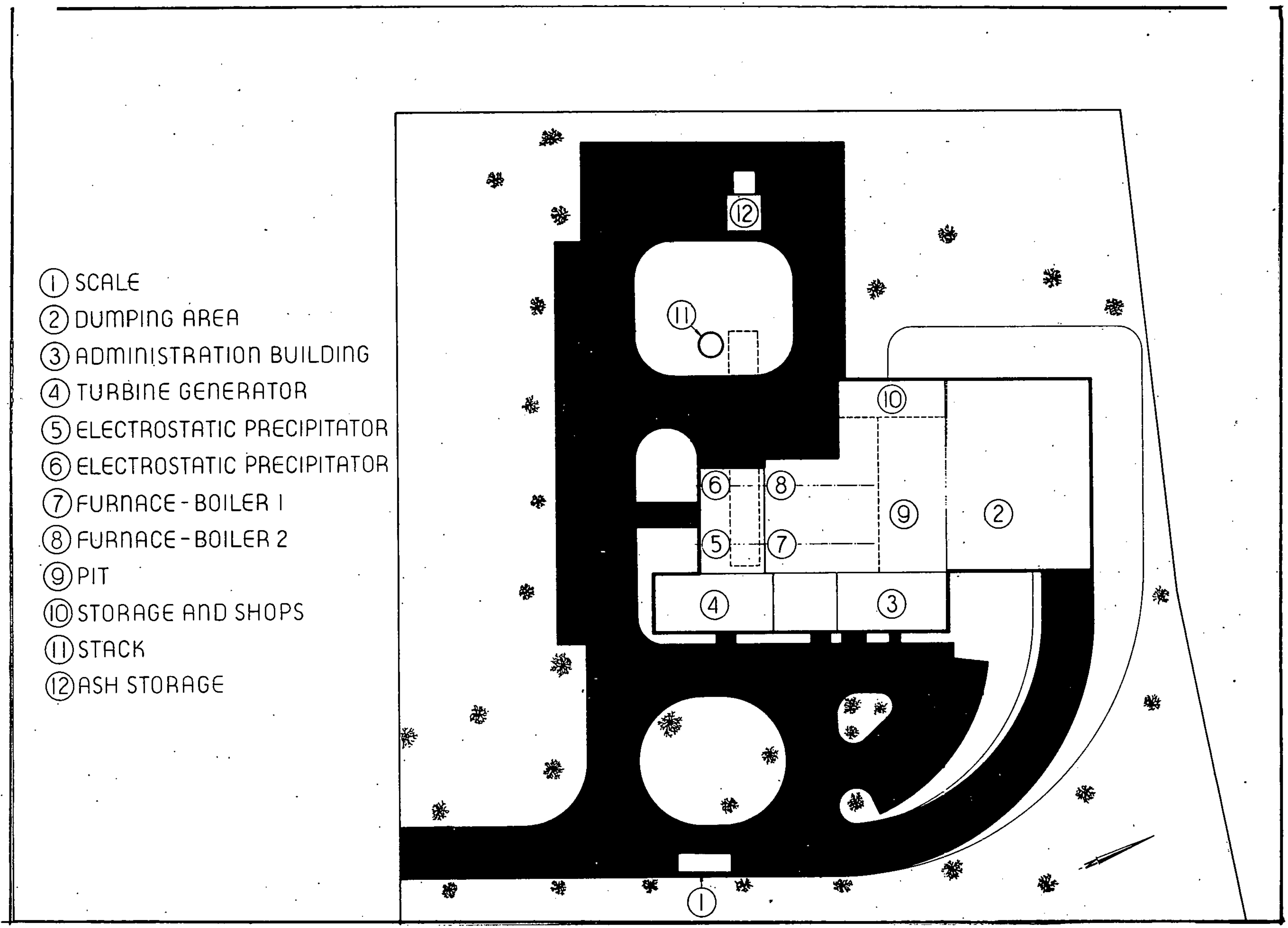
① SCALE
② DUMPING AREA
③ ADMINISTRATION BUILDING
④ TURBINE GENERATOR
⑤ ELECTROSTATIC PRECIPITATOR
⑥ ELECTROSTATIC PRECIPITATOR
⑦ FURNACE - BOILER 1
⑧ FURNACE - BOILER 2
⑨ PIT
⑩ STORAGE AND SHOPS
⑪ STACK
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SESSION IV: EUROPEAN WASTE-TO-ENERGY SYSTEMS PART III

Moderator: Steve Levy (EPA)

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VKW MASS BURNING TECHNOLOGY, ITS HISTORY AND ITS APPLICATIONS

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ABSTRACT

A problem common to all the developed nations of the world has been the disposal of solid waste materials in an environmentally acceptable manner. The problem has been recognized and addressed in different parts of the world, at different times, chiefly from a growing awareness of the environment and the constraints of unavailable or unusable land areas for conventional landfill disposal. These conditions were first manifested in Europe, and European industries responded to the waste disposal problem by successfully developing and implementing, on a large scale, the technology generically called mass burning-energy recovery technology.

BACKGROUND

One of the leaders in the development of mass burning technology is VKW (Vereinigte Kesselwerke AG) of Duesseldorf, West Germany. As a subsidiary of Deutche Babcock AG, VKW's business encompasses the areas of designing, manufacturing and building water and wastewater treatment facilities, sludge handling facilities, residential, commercial and industrial solid waste incineration facilities and in cooperation with Babcock-BSH, air and gas cleaning facilities. These activities are complimentary to other Deutsche Babcock activities in all facets of engineering, manufacturing and construction of facilities for such industries as power generation, textiles, petrochemical and environmental control. As a diversified corporation, the Deutsche Babcock group, with 1979 sales of approximately five (5) billion

D. Marks, can assist in providing solutions to a wide variety of energy and environment related problems.

VKW has a history of over 150 years of engineering and building stoker and boiler systems for a wide variety of fuels. Different grate systems were developed by VKW to burn such fuels as coal, lignite, bagasse, wood chips, peat, etc. These fuels were handled on grates generally described as travelling, inclined and rocking grates. Some 25 years ago, when the problem of solid waste disposal in West Germany became acute, existing grate systems were investigated by VKW, as to their ability to burn this difficult fuel, and it was concluded that existing systems did not provide the optimum solution. Consequently, in co-operation with the City of Duesseldorf, the roller grate - System Duesseldorf was developed.

The development of an incineration system for municipal solid wastes was a logical extension of VKW's basic business and paralled efforts undertaken by the firm to provide specific solutions to other waste disposal problems. These efforts resulted in the completion of the first industrial waste incineration facility in 1953; the first fluidized bed application for industrial waste and sludge in 1975 and the completion of the first co-disposal, sewage sludge and municipal solid waste facility in 1975. Three different systems actually comprise the VKW waste incineration technology, each with its own applications criteria. The systems are known as; (1) Rotary Kiln - System Buttner; (2) Opposed Motion Grate - System Keller-Peukert; and (3) Roller Grate - System Duesseldorf.

The Rotary Kiln - System Buttner is applied for industrial waste incineration projects having flow rates of semi-solid and liquids wastes of up to 6 MTPH (6.6 STPH). While it is possible to design and build units with larger capacities, market requirements do not presently warrant a larger size. VKW has built 37 of these specialized waste incinerators of which more than 50% are equipped with boilers for energy recovery.

The Opposed Motion Grate - System Keller-Peukert is used for intermediate sized municipal and commercial waste applications. Unit furnace capacities of 6 MTPH (6.6 STPH) have been built, but, designs are available for units up to 10 MTPH (11 STPH). Six facilities using this grate system have been built by VKW.

The Roller Grate - System Duesseldorf is applied to municipal and commercial waste disposal applications requiring unit furnace capacities greater than 10 MTPH (11 STPH). Roller grate systems with design capacities of 25 MTPH (27.5 STPH) have been installed although the structure of the roller cage, the supports and drives are designed so as to permit expansion of unit capacities to 50 MTPH (55 STPH). Since VKW's first Roller Grate - System Duesseldorf in Rosenheim, West Germany, in 1964, the technology has been exported to thirteen (13) countries worldwide and is found in over fifty-five (55) facilities which have a total of 145 furnaces. The worldwide applications which encompass all the European nations, Czechoslovakia, Union of Soviet Socialist Republics, Japan and Malaysia clearly prove the adaptability of the technology to varying project configurations and solid waste composition (See Fig. 1).

Procurements of European refuse plants have normally been by means of two methods; turn-key and chute-to-stack. Regardless of the method of procurement, vendor selection has always been a competitive process whereby qualified contractors would respond to a set of specifications generated either by the clients technical staff or by a consulting engineering firm. Contractor responses to the specifications are then evaluated on technical and economic merit for selection. Under the turn-key procurement method, the contractor is responsible to deliver a complete, operable system including all structures and auxiliary mechanical and electrical equipment. To monitor the field activities and equipment deliveries, a project control advisory board is created to relieve the client of the need to use his own personnel, which many times are not available to perform this function. Under the chute-to-stack procurement approach, the contractor is responsible for delivering the specified processing train with any associated controls system. Project management functions are the responsiblity of the client's consultant.

The primary purpose of early municipal waste incineration plants was volume reduction of solid wastes. However, to preserve the environment, the flue gases generated in the incineration process had to be cleansed of particulate. Of the gas cleaning systems available, high energy wet scrubbers and electrostatic precipitators, ESP's were preferred, but application of these units required a preconditioning (cooling) of the flue gases to inlet conditions. Flue gas cooling was effected using either water spray conditioning towers or steam generators. While some VKW plants in France, Great Britain and Italy were configured with conditioning towers, even the earlier projects in West Germany practiced energy recovery and were configured with steam generators. Today, with ever increasing shortages and cost of energy, waste incineration without energy recovery is of little interest.

TECHNOLOGY

Municipal and commercial solid waste is a heterogeneous mixture of organic and mineral components. The heating value of this waste is a variable function of the included percentages of combustible and inert materials and the water content (See Fig 2). Average composition values yield average heating values but during actual conditions, the composition balance is in a constant state of flux, which in turn, results in a fluctuating heating value. Not only are changes seen in the percentages of combustible to non-combustible materials, but the composition of the waste also varies, all of which result in varying ignition characteristics of the waste. The problem of ignition potential has to be circumvented in the refuse feeder. To eliminate the possibility of a backfire in the refuse feed chute, the density of waste in the chute is increased, thereby substantially reducing the availability of combustion air. During the subsequent feeding of the waste onto the grate, it is necessary to again allow the waste to expand so as to expose those wet and hard to ignite components to a predrying phase.

The cross-sectional geometry of the VKW ram feeder and the variable speed capability of the ram now satisfy the three feed requirements of (a) providing an airlock in the chute, (b) allowing the partially compressed wastes to relax and expand, and (c) feeding the wastes onto the grate at a slow controlled speed.

A proper grate design allows for the wastes to be agitated in such a way to expose unburned materials to the fire and to supply required amounts of combustion air in a uniform manner where needed during the combustion process. The magnitude of the mixing action and introduction of air should not be too great since excesses will result in an increase of the particulate content of the combustion gases. The grate design must assure that those difficult to ignite and burn waste components have sufficient residence time in the furnace to assure complete burnout. From a combustion point of view, it is desirable to provide the maximum amounts of combustion air to that area of the grate where maximum agitation and burning are taking place. The feature of the roller grate - System Duesseldorf is that it excels in its ability to satisfy that requirement. Since the speed and air supply of individual rollers can be controlled, the operator can match the residence time and the air supply to the specific waste being burned.

The roller grate - System Duesseldorf is comprised of a set of six (6) rollers of equal diameter inclined at 30 degrees from the horizontal plane. Each roller has its own controllable rotational speed from 0.5 to 12 revolutions per hour. The individual air supply to each roller is controlled by dampers. All drives and supports are located outside of the furnace area. Combustion air is introduced at the bottom of the roller and flows upward into the waste bed in the quantities and pressures required to support the particular combustion phase occuring on that roller (See Fig 3). A unique feature of this arrangement is that as the air travels to the combustion zone it passes through the entire body of the roller. The effect is one of continuous cooling of the roller body and the grate bars to the extent that the maximum grate bar temperature for any roller rarely exceeds 400°C (750°F). As a result, economical, common gray cast iron is used for the bar material. Additionally, as there is a minimum of relative motion between the grate and the waste, grate bar material wastage is kept to a minimum. The grate bars then, easily attain service lives in excess of 20,000 operating hours.

The grate alone, does not control or insure the complete burnout of all the combustible matter in solid waste. Figure 2 shows the high percentile of volatiles in the combustible portion emphasizing the need for efficient burnout of the volatiles which is a function of the furnace design. The geometry of the furnace, the location, orientation and pressures of the secondary air inlet all combine in their effect to completely burn out the volatile gases before they enter the radiation shaft of the boiler. The furnace must be designed so as to maintain temperatures high enough to support waste drying and ignition but not so high as to reach the ash fusion point. It must act as an effective mixing chamber for the products of combustion but the turbulence must not be so high that additional particulates are entrained in the gas stream And, it must be so configured that the gases leaving the furnace and entering the boiler, enter the boiler in uniform and consistent profiles of velocity, temperature and O_2 content.

One of the methods for determining the optimum configuration of VKW furnaces is by means of hydraulic modeling, wherein the geometry of the furnace is changed and various different secondary air injection arrangements are tested. From tests such as these, the furnace designs have been optimized and the results can be seen in Fig 4 which shows the original furnace configuration of the Kiel MVA built in 1975 and the furnace shape of the extension which is currently under construction.

The configuration of the furnace enclosure has changed with time from those having a refractory lining to those having water cooled surfaces. Earlier refractory lined furnaces experienced slagging problems as the heating value of refuse started to climb. The radiant effect of these refractory lined furnaces was too high for the rising heat release rate and the oak fusion temperatures were reached. Since the early refractories were not of the self-shedding type as is silicon carbide, they were prone to slag buildups. However, today there are different refractory materials that can be used, or the furnace can be lined with cast iron or ceramic plates that are air cooled, all of which practically eliminate the slagging problem. As the heating value increases, it also becomes advantageous to line the furnaces with water wall panels which, in turn, are an integral part of the steam generator. To protect these surfaces within the high turbulent areas of the furnace, the water walls are studded and coated with a layer of high silicon carbide content plastic refractory. The effect of the water wall then is to provide a cooled surface which reduces slag buildup and, at the same time, recovers a substantial amount of the energy available within the furnace.

Boilers designed and built by VKW are designed to match the waste that is being burned. For example, boilers that are used in conjunction with industrial waste rotary kiln applications are substantially different from boilers designed for municipal waste incineration applications.

For municipal waste applications, a portion of the boiler forms an integral part of the furnace and secondary combustion zone. The furnace and the subsequent boiler radiation pass are so arranged as to assure burnout of the gases in order to minimize corrosion problems, before they enter the radiation pass. Similarly, to reduce corrosion and erosion problems, the flue gases should undergo a long reaction period and drop in temperature before they come in contact with convection heat transfer surfaces. For this reason, VKW designs high, multiple pass boilers that have up to two radiation passes which are free of convection surfaces. These water wall lined passages allow for the required reaction time and heat transfer to occur prior to entering the corrosion-erosion sensitive convective section. These surfaces too must be designed with wide spacings between tubes to permit free travel of the gases which, in turn, reduces the amounts of soot buildup.

In order to attain high availability, boilers must be designed to contend with problems from erosion, corrosion and alternating erosion and corrosion. The key factors to reducing the effects of erosion are gas velocity and uniformity of gas flow. When convection surfaces are encountered, the gases should travel through the bundles with uniform low velocity profiles and the possibility of higher velocity short circuits should be avoided. As with the development of the proper furnace geometry, proper boiler geometry has been extensively studied by VKW using hydraulic modelling procedures (Fig. 5). To further reduce the potential of erosion, VKW designs have placed the convection surfaces in the third boiler pass (an up-pass). In this configuration,, gravity works against the entrained particulate and has the effect of reducing the velocity head of the particle as it meets the tube surface. To explain the mechanics of the causes of corrosion are beyond the scope and intent of this paper. It suffices to say that today we know of a number of measures that can be implemented to reduce the potential of corrosion. These are:

Waste Composition:

- Restrict the refuse stream to residential and commercial wastes. Industrial wastes which have high HCl content should not be burned in conventional municipal waste incinerators.
- Effect a good mixing of the wastes to reduce the potential of feeding spike loads of harmful materials.

Incineration:

- Uniform feeding and burning of the feedstock through the use of an automatic combustion control system.
- Proper configuration of the furnace and secondary air supply so as to assure proper turbulence and uniform heat absorption.

Boiler Design:

- Design the final superheater stage for parallel flow.
- Maintain lower superheater metal temperatures.
- Protect sensitive tube surfaces with studs and plastic refractory.

With the experience now available, VKW is confident that boilers for refuse incineration facilities can be designed for reliable performance at high steam quality parameters. Superheat conditions of 500°C (932°F) are attainable, and at these conditions, much better thermal utilization factors are realized.

As with any industrial process, refuse power plants generate some side effects, which, if not addressed during the engineering phase, will have an adverse impact on the environment. With refuse incineration these effects are:

- Gas and particulate emissions
- Waste water treatment
- Ash quality
- Noise

Atmospheric emissions are of two types, gaseous and particulates, and both types must be controlled in West Germany. The condensible HCl, HF emissions must meet limits of 100mg/Nm^3, 5mg/Nm^3, respectively. Cleansing the flue gas stream of these contaminants is performed either by wet or dry scrubbing systems. For the past five years scrubber installations were mostly of the wet types where water was used as the absorption medium for HCl and HF. When the need arises to also reduce the levels of SO_2, an additional absorbant is added to the water (Fig. 6). While the wet scrubbers have performed satisfactorily in reducing the emission levels, the resultant waste water flows have often adversly impacted the local sewage system. Consequently, dry absorption systems (Fig. 7) have been developed which react HCl and HF into a dry solid calcium or sodium compound which can then be collected by conventional particulate removal systems. Particulate emision control, in general, has an excellent track record since electrostatic precipitators or bag filters routinely operate at efficiencies between 99.0 to 99.9% insuring that the West German particulate emission limits of 100mg/Nm^3 are met.

Discharges of wastewaters from European refuse power plants are subject to variable, regionally imposed restrictions. In many of the facilities designed by VKW, the water circuit is closed and the plants run with zero discharge of process waters. There is a constant demand for makeup water in the ash quench tank due to the evaporative losses that occur. This makeup demand is satisfied by configuring the facility with neutralization and storage tanks of sufficient capacity to receive process waste flows from boiler feedwater treatment, ash bunker drains and boiler blowdown. After neutralization and settlement, these combined waters are used as makeup flow to the ash quench tank.

Residues that remain from the incineration of municipal wastes on a roller grate or an opposed motion K-P grate have consistently had excellent burnout characteristics with extremely low percentages of putrescible content (less than 0.3%). Consequently, these residues have had no difficulty in being placed in landfills. Frequently, scrap metals are recovered from the ash and the residual clinker is size segregated after which it is used in the construction of roads. For some time, ash landfills have been monitored in West Germany and the results of these studies show that these ash fills do not contaminate the ground water supply.

Therefore, from an environmental point of view, refuse power plants designed and built by VKW have consistently provided environmentally sound solutions to the problems of waste disposal.

Just as a quarter of a century ago the problem of waste disposal in West Germany became acute, the roller grate - System Duesseldorf was developed,now the problem of sewage sludge disposal has become acute. again VKW has provided a solution - with its sludge system designated HGS. The HGS system is a closed cycle adjunct to the refuse incineration system. The plant is sized such that the refuse and sewage sludges generated by a community can be co-incinerated in one facility. While the co-disposal process may be applied in different ways, one example is where the refuse power plant is sited adjacent to the wastewater treatment facility (Fig. 8). In this arrangement, sludge is pumped to the refuse plant at aproximately 4% solids content where it is dewatered mechanically to 25% solids content. The sludge cake is then introduced into the drying-pulverization equipment (Fig. 9) where the sludge is dried using combustion flue gases. These gases are withdrawn from the upper portion of the first boiler pass at approximately 800°C (1472°F) and in the course of the drying process they are cooled to 250-300°C (480-570°F). Solids content of the sludge, during this process, is increased to approximately 90% and the combined flow of gas and sludge powder is pneumatically conveyed to the furnace for incineration. A nominal rating for the co-disposal option allows for 9 MTPH of sludge cake at 25% solids to be incinerated with 12 MTPH of refuse having a LHV of 2400 Kcal/kg (4300 BTU/lb.).

A facility designed and built by VKW which is worthy of review is the MVA Goeppingen.

The MVA Goeppingen is the product of a series of alternate waste disposal studies and conferences that began in 1960. The city initially came to the conclusion that the wastes generated in the city alone did not economically justify an alternate disposal method to the existing landfill although filling capacity was rapidly being depleted. What ensued were a number of years of negotiations and further studies with surrounding communities to develop, on a regional basis, committments to supply wastes to a central facility. Early in 1968 these difficult discussions resulted in the formation of a regional "authority" which comprised the cities of Goeppingen and Eislingen and a number of adjacent towns, which in total, had a population of 152.127 people. A consultant engineer was then commissioned to study the potential energy markets for the proposed facility. The conclusions of these studies resulted in contracts for the sale of electricity to the Neckarwerke utility in 1969, and for the supply of comfort and process heat to the regional hospital in 1970. With the energy market established, a competitive bidding phase for the design and construction of the facility was conducted which resulted in an award to VKW for a turn-key project, on November 29, 1971. The price for the facility was 35.6 million D. Marks. Site construction was started on September 25, 1972 and the finished plant was commissioned and accepted by the client in July 1975.

MVA Goeppingen has two, roller grate - System Duesseldorf furnaces and boilers, each designed for 12 MTPH (13.2 STPH) throughput of municipal and commercial wastes having a LHV range of 1200 to 2850 Kcal/Kg (2150 to 5125 BTU/lb). Each boiler has a rated steam generating capacity of 32 MTPH (70,400 pph) at conditions of 39 Bar, 410°C (560 psi, 770°F). Steam is used either as throttle to an 8.7 MW extraction-condensing turbine generator or as heating medium in high pressure 210°C (410°F) or low pressure 140°C (285°F) heat exchangers. The mix of flows varies around the year as a function of the ambient temperature. MVA Goeppingen supplies approximately 10% of the electrical requirements of the City of Goeppingen but the priority demand is to the 1100 bed regional hospital and surrounding residences which are located 2.2KM (1.3 miles) from the MVA. Present contracts require a guarantee to provide 24 million Kcal/hr (43.2 million BTU/hr). This demand by the hospital will be increased to 36 million Kcal/hr on a guaranteed basis in 1981. In Addition 8.6 million Kcal/hr will be supplied to a nearby police academy on an interruptable basis. The ability of the MVA to satisfy these additional requests for energy results from the fact that additional refuse that is being delivered to the facility. While, during the planning stage, the region had a population of slightly over 150,000 people, the present population stands at 230,000 people. In addition the region of Esslingen (25Km away), with a population of 120,000 is delivering its waste, so MVA Goeppingen now serves a population base of 350,000 people. To satisfy the waste disposal and energy supply requirements of the area, both furnaces are presently being operated full time.

The boilers at Goeppingen are of the 4 pass design where the two stage superheaters are located in the second pass and the evaporator tubes are located in the third pass (Fig. 7). During the initial operating period, the superheater tubes experienced excessive failure rates from corrosion. Flow modelling and stack emission test were conducted and these tests indicated: residual CO content in the gases leaving the secondary chamber (insufficient turbulence in that zone) and an extremely high HCl content in the stack emissions. In 1975 to 1976, HCl emissions in West Germany were limited to 1500 mg/Nm^3, but testing showed emission rates up to 4500 mg/Nm^3 with spikes at higher levels. Two actions were initiated. To correct the CO strains that were present in the flue gases, the furnace shape and secondary air ports were modified. To establish the source for the high HCl content an extensive testing of the plastics delivered to the plant was conducted. It was determined that the source was a very small portion of the total plastics stream coming from a synthetic materials manufacturer in Goeppingen. When analyzed this waste material was shown to have extremely high chlorine content and the manufacturer was subsequently banned from disposing that waste at MVA Goeppingen. With the absence of that particular waste, HCl emissions fell to 800 to 1000 mg/Nm^3 and the severe wastage rate of the superheaters was eliminated. Presently, the superheater bundles have accrued between 12,000 and 20,000 operating hours and have experienced only minor tube failures.

The operating staff, excluding clerical and bookkeeping personnel, totals 51 people. The majority of these people are divided amongst four (4) operating groups (Fig. 8) operating on three (3) shifts (Fig. 11). Each group consists of 8 people although only 6 are required for operations, the remaining 2 being allocated as coverage for vacations, holidays and illness. The personnel at the MVA who are cross-trained as crane operators, boiler operators and turbine operators understand fully the interrelationships of their positions in the overall operating success of the facility.

The MVA maintenance staff is responsible for the everyday upkeep of the facility and minor repairs for such items as cranes, bulky waste shears, pumps, etc. Repairs are not effected by means of a schedule of operating hours but rather repairs are only carried out when a specific piece of equipment fails. For repairs that require longer periods of time or are of a specialized nature, such as the turbine, scales, HVAC equipment or boiler fireside cleaning, sub-contract labor is utilized. Of the maintenance functions requiring sub-contract services, the one occurring most frequently is that of fireside cleaning. Fireside cleanings are signalled by a rise in flue gas temperature and when the threshold is approached, the unit is scheduled to be taken off-line and cleaned. Boilers at MVA Goeppingen are cleaned using the water soak and high pressure water wash method. While the actual cleaning period is only 3 days, preparation and cleanup add 2 days to the schedule. After cleaning, procedures call for a general inspection of tube surfaces before returning the boiler to service.

As stated earlier, with the additional waste flow being delivered to MVA Goeppingen, both furnaces are in operation on a routine basis. Loading of the furnaces is a function of the seasonal variations of the waste flow and ranges from a low of 60% design rating to 100% of design rating. In 1979, 151,000 tonnes of refuse were processed at the facility. Of this tonnage, 86,000 tonnes were residential wastes and 63,000 tonnes were commercial and industrial wastes. Commercial wastes are defined as materials having characteristics similar to residential wastes and industrial wastes consist mostly of such items as oil soaked rags and distillation residues. In 1979, the waste throughput represented 72% of the plants total installed capacity. This will be increased in 1980 to 81% due to a planned refuse flow of 170,000 tonnes. For the first six months of 1980, an availability factor of 78.3% was realized.

MVA Goeppingen is operated on a break even basis typical of the majority of European installations. For 1979, the MVA had a budget of 14.6 million D. Marks which was allocated as follows:

Expenses:

1.	Capital interest and depreciation costs (31.5%)	4,599,000
2.	Collection and transportation of municipal refuse (once per week per household for residential collection and twice per year each for bulky wastes and scrap) (28.5%)	4,161,000
3.	Administrative and payroll costs (23.8%)	3,747,800
4.	Maintenance costs, insurance, residue disposal, vehicles, etc.(16.2%)	2,365,200
	D.M.	14,600,000

Revenues:

1.	Sales of heat and electricity	3,300,000
2.	Municipal waste disposal services (Multi-tenant residences 102 DM/year for one 220 liter container - Single tenant residences 62 DM/year for one 220 liter container)	7,801,000
3.	Commercial and industrial wastes delivered by the waste generator are charged 55 DM per tonne	3,499,000
	D.M.	14,600,000

The relatively low fees that are charged at MVA Goeppingen, in comparison to some other facilities, result from two fortuitous circumstances. The first is that the facility is fully utilized, which was made possible by the committment of waste supply from the region of Esslingen. Before the additional 40,000 tonnes per year were committed, this facility realized only a 50% utilization factor and the costs per residential or commercial tonne were higher. Secondly, but equally as important, the facility's energy utilization factor is very high. The plants ability to generate and sell both district heat and electricity means that the majority of the energy content of the wastes produces revenue. Due to the rising costs of energy and the increased utilization of the facility, a reduction in disposal fees is being planned for 1981.

Until recently, the problems of waste disposal and energy conservation have not been as severe in North America as they had been in Europe twenty years ago. Today we too recognize the value of energy conservation and we are well aware of our environment and the need to protect it. The viability, therefore, of implementing European waste disposal methods (i.e., energy recovery technology) in North America is increasing directly proportional to economic and environmental pressures. VKW, with its experience and proven track record is well suited to providing viable solutions to our waste disposal problems and has made its technology available in North America through an exclusive license arrangement with Browning-Ferris Industries, Inc. (BFI).

BFI is the nation's largest publicly held waste systems company providing collection, transfer processing and disposal services for solid and liquid wastes. The corporation has a single, primary business, that of providing waste related services, which it pursues in approximately 150 locations in the United States, Canada and Puerto Rico. BFI is headquartered in Houston, Texas and operates through eight regional offices (Fig. 13). Project development and implementation of VKW technology applications will utilize the resources of BFI headquarters in Houston and the regional staff applicable to the specific project location. Primary client contact and assessment of project status will generally be carried out by BFI's district and regional staff. However; qualification, proposal and project management functions will be the responsibility of the company's Energy Systems Division in Houston.

Implementation of BFI/VKW projects will be carried out by a team consisting of BFI, VKW and generally, an engineering/construction firm. Under this team approach, VKW will have multiple responsibilities. During the planning and layout phase, VKW will provide inputs as to the most economical arrangement of equipment, reflecting both capital and operating cost inputs. In this capacity, VKW will interface through BFI with the engineer/constructor to establish the engineering criteria for the facility. As detail designs are completed both VKW and BFI will perform a reviewing function to assure the project team, and the client, of compliance to VKW criteria. During the manufacturing and construction phases of the project, VKW will supply certain key pieces of equipment such as the roller grate cages. The balance of plant equipment supply however, will be obtained from local North American sources. As the facility is constructed, VKW will provide experienced supervisory personnel to assist in the erection of key components such as the grate and the boiler and for specific inputs as required. Upon construction completion, specialized VKW personnel will assist in the start-up of the plant. Since BFI has an interest and a committment to the long term operation of these facilities, our license arrangement provides for the training of BFI's key operating staff at one of VKW's facilities in Europe. This capability provides the assurance that when operations commence, the facility will have an operating staff with "hands-on" experience in the day to day operating and maintenance procedures associated with VKW technology.

VKW type waste disposal plants sited in North America will be custom designed to suit project related waste supply and energy utilization criteria, as they have been for all other VKW projects. It is in developing the project plan, that the capital and operating economics are determined. As illustrated in the Goeppingen example, maximum utilization of installed capacity and maximum energy production will certainly result in lowered overall costs.

Factors such as plant size, redundancy, auxiliary steaming capability and local environmental constraints have substantial impact on capital costs. The need to guarantee energy supply, cost of fuel and electricity, and residue disposal method have similar impacts on operating costs. The two key cost factors however are related to equipment redundancies and energy utilization.

The first of these factors, redundancy, evolves from the requirement that the facility always be capable of disposing of all the refuse as it is generated. Since no piece of equipment can claim 100% availability, the probabiity of component failures always exists. Depending on the time of year and the extent of the outage, remaining units on-line in combination with some bunker storage can probably handle the waste flow. However, if the outage occurs during a period of peak refuse flow, there are only two choices; bypass the excess to landfill or dispose of the material in a stand-by furnace. Clearly the latter option is more expensive.

The second factor, and maybe the more important is energy utilization. Utilization not only has to do with the application but also reflects such issues as condensate return and variable flow demands of the steam user. These factors impact on costs for purchase of water, chemicals, possibly auxiliary fuels, and repayment of capital and operations of extensive water treatment systems and condensers. Even so, regardless of the design problems that may be associated with a steam delivery application, steam as an energy outlet provides a much higher energy utilization factor and revenues than pure electrical generation. At utility purchase rates of 25 or 30 mils per Kwh, the potential revenue per thousand pounds of steam is $2.50 to $3.00. On the other hand, with low sulphur oil as a comparison generated steam is worth around $7.00 per thousand pounds. Even if refuse generated steam is offered at a discount, steam generally offers the highest income potential and thus the best overall economics for the project.

BFI believes that the combination prudent plant engineering and proper energy utilization will result in many opportunities for favorable project implementation. We also believe that projects should be implemented through competitive procurements on a total service or chute-to-stack basis. While some facilities are certain to be built by the latter procurement approach, we feel that the industry trend will continue to be towards total service. At times this method may appear more difficult to arrange, but it offers more rapid completion. The effect of this should provide savings to the community at large, and a single source of responsibility.

The requirements and capabilities for total service procurements are well represented in BFI and its approach to project implementation. As stated earlier, each opportunity will result in the creation of a project team consisting of BFI, VKW and a major engineering/construction firm. The specific arrangements will depend upon the project's needs. All technology requirements will be addressed by BFI, with support from VKW. Plant operations will be carried out by BFI. When project circumstances dictate and/or warrant it, BFI is also prepared to take an equity position or full ownership. The conditions for such an investment of resources are based solely on the projects ability to make a fair return on the corporation's investment. Additionally, BFI recognizes the need to make assurances to the client, and the investment community, on certain aspects of the projects performance and will provide appropriate warranties and guarantees on project cost, performance and operations, provided that those items are under its controls. For example, warranties of process performance will, of course, be subject to the quality of waste being delivered as well as the quantities. Construction cost guarantees can be offered only if the project schedule is not delayed by outside forces. In the final analysis any waste disposal project is a cooperative effort between government and the supplier and thus, some risks must be shared by each.

CONCLUSIONS

VKW technology is a mature, well proven technology that has provided solutions to municipal, commercial and industrial waste disposal problems worldwide. Backed by more than a century of experience in engineering and manufacturing grates and boilers, VKW systems have gained a reputation for durability and low maintenance costs. Available through BFI, the North American licensee, VKW systems technology can provide a viable alternative solution to many of our growing solid and liquid waste disposal problems.

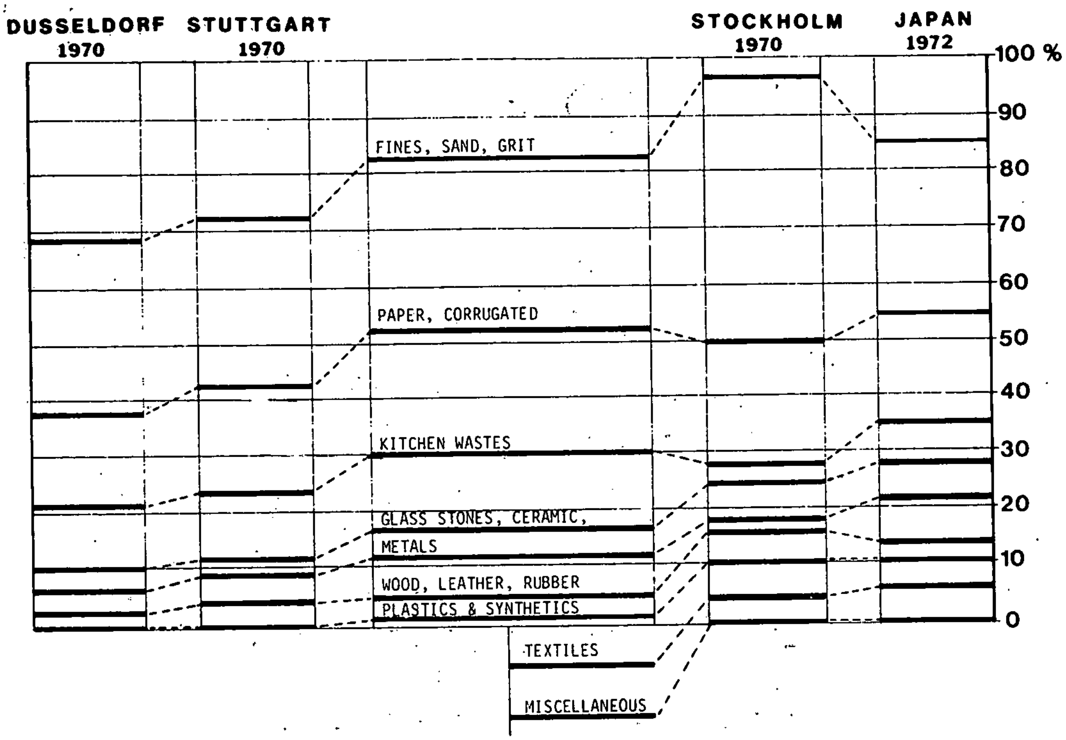


FIGURE 1 • RELATIVE WORLDWIDE WASTE COMPOSITIONS (DRY BASIS)

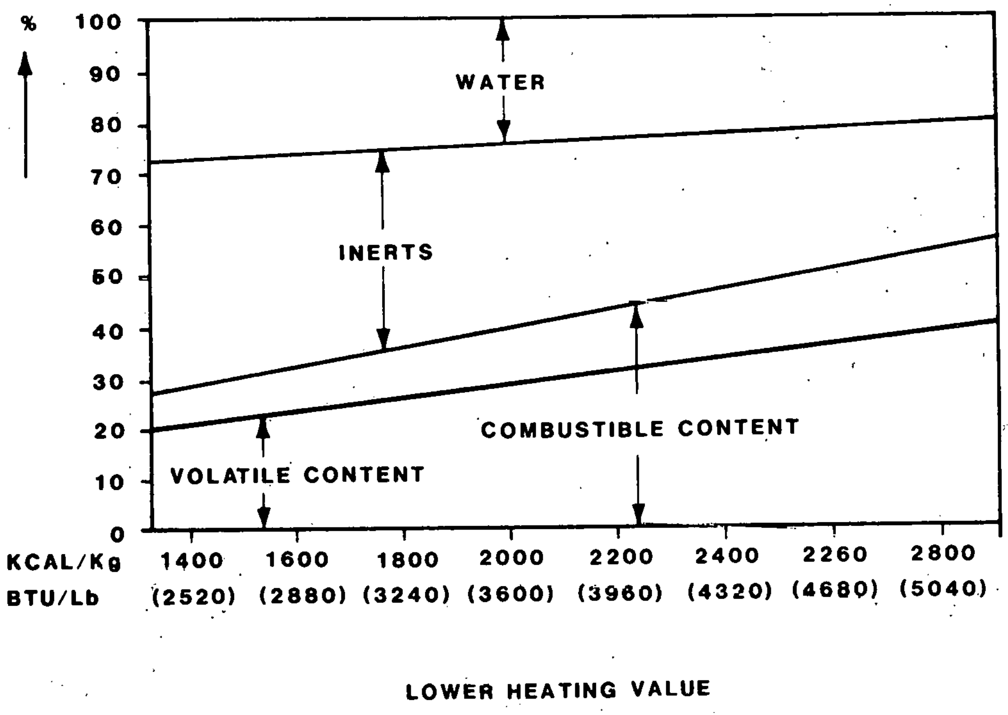
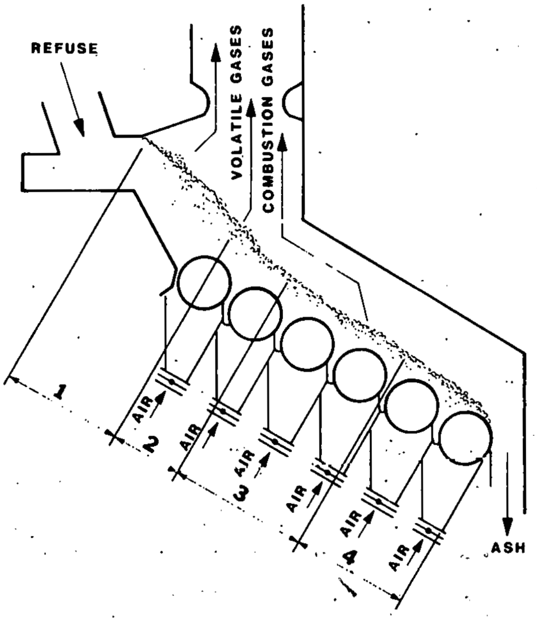
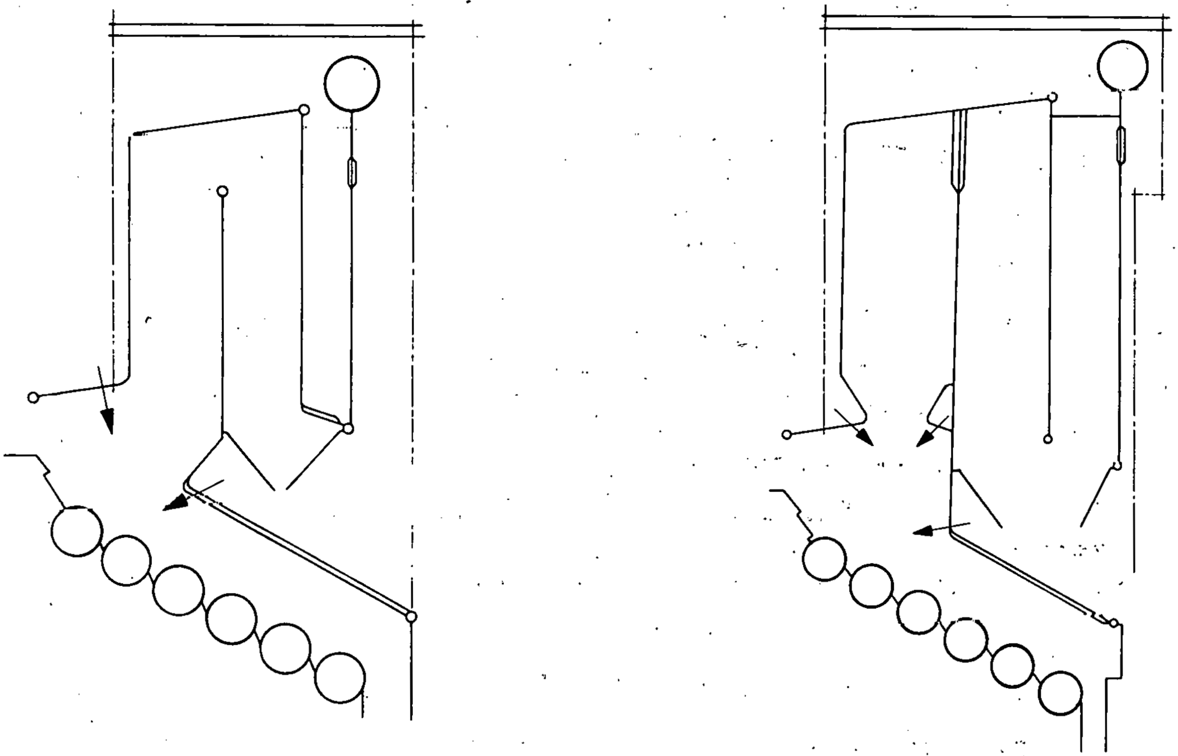


FIGURE 2•RELATIONSHIP OF HEATING VALUES TO WASTE COMPOSITION



ZONE 1-DRYING TEMP APPROX 100 C
ZONE 2-DISTILLATION TEMP APPROX 250 C
ZONE 3-COMBUSTION TEMP 800 C
ZONE 4-BURNOUT TEMP APPROX 300-400 C

FIGURE 3•FURNACE CONFIGURATION



CONFIGURATION OF BOILERS 1 & 2

CONFIGURATION OF BOILER 3

FIGURE 4•BOILER CONFIGURATIONS OF MVA KIEL

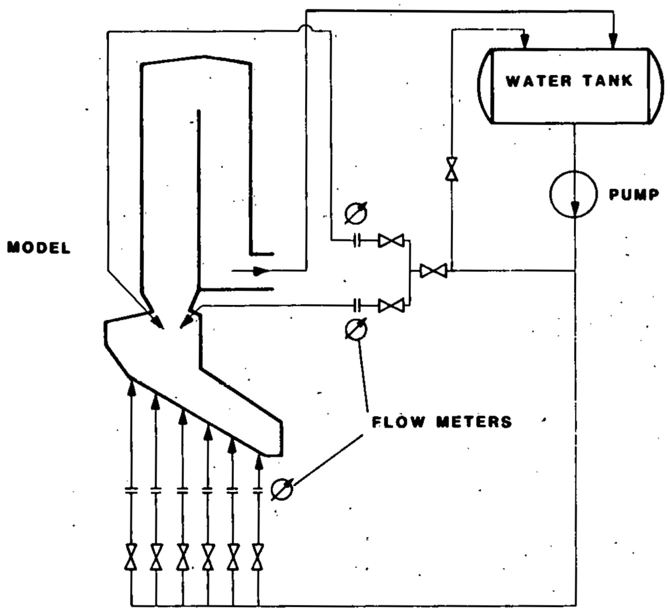


FIGURE 5•CONCEPT OF HYDRAULIC MODELLING FOR OPTIMUM FURNACE AND BOILER CONFIGURATIONS

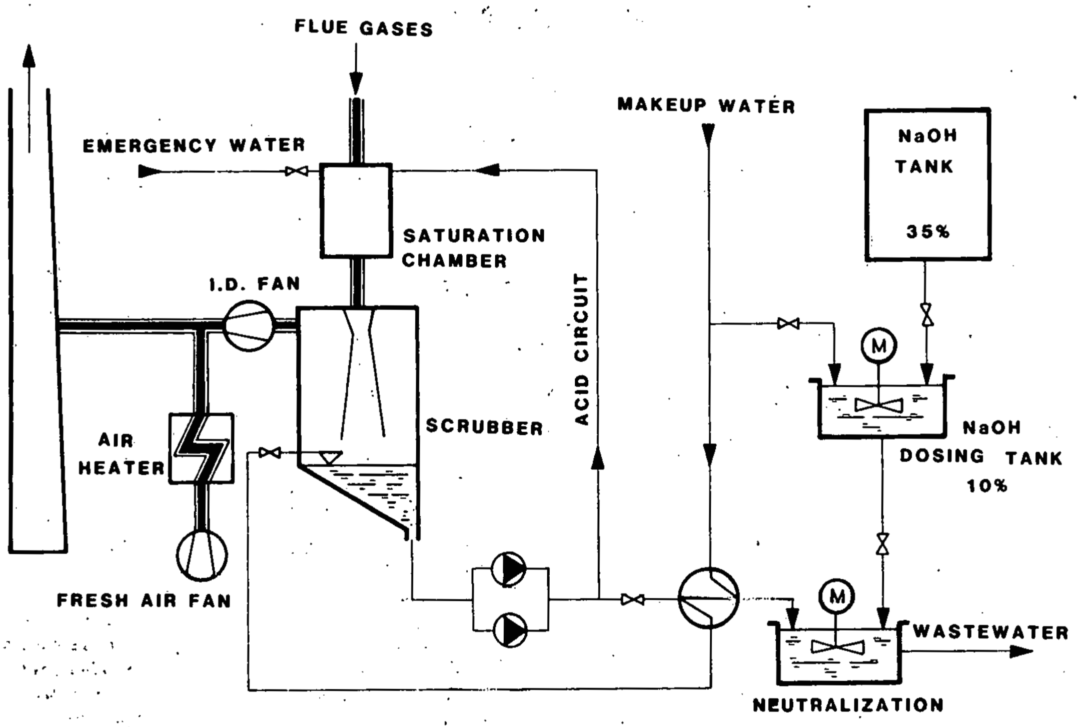


FIGURE 6•FLOW DIAGRAM FOR WET SCRUBBERS

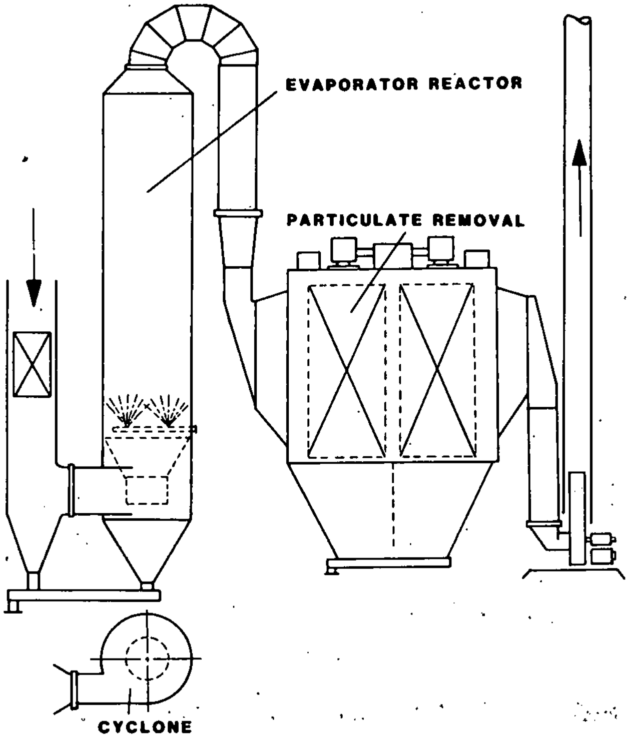


FIGURE 7•DRY SCRUBBING SYSTEM
BABCOCK-BSH

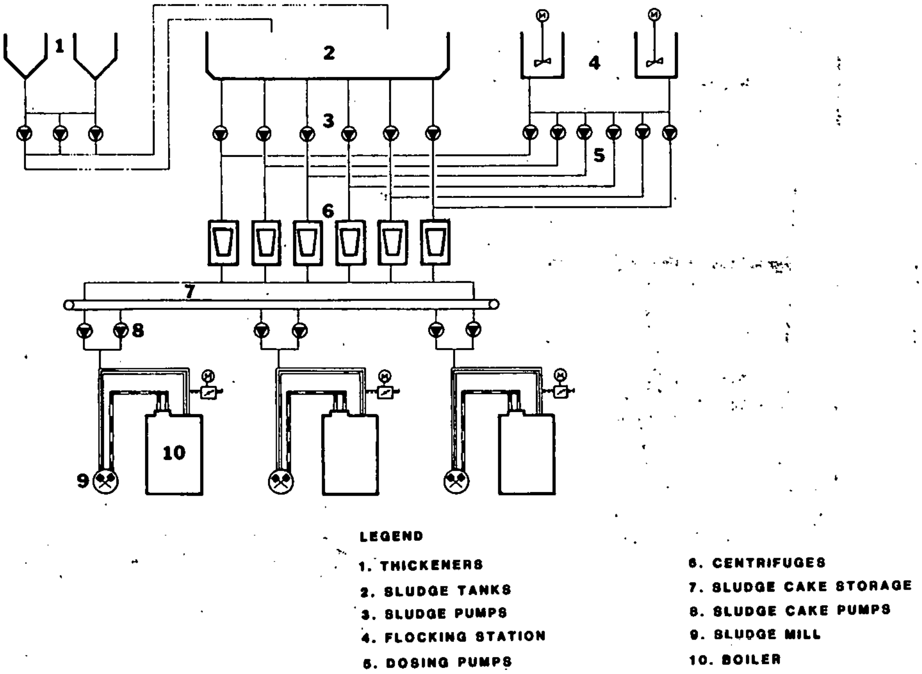


FIGURE 8•SCHEMATIC FOR SLUDGE HANDLING
MKVA-KREFELD

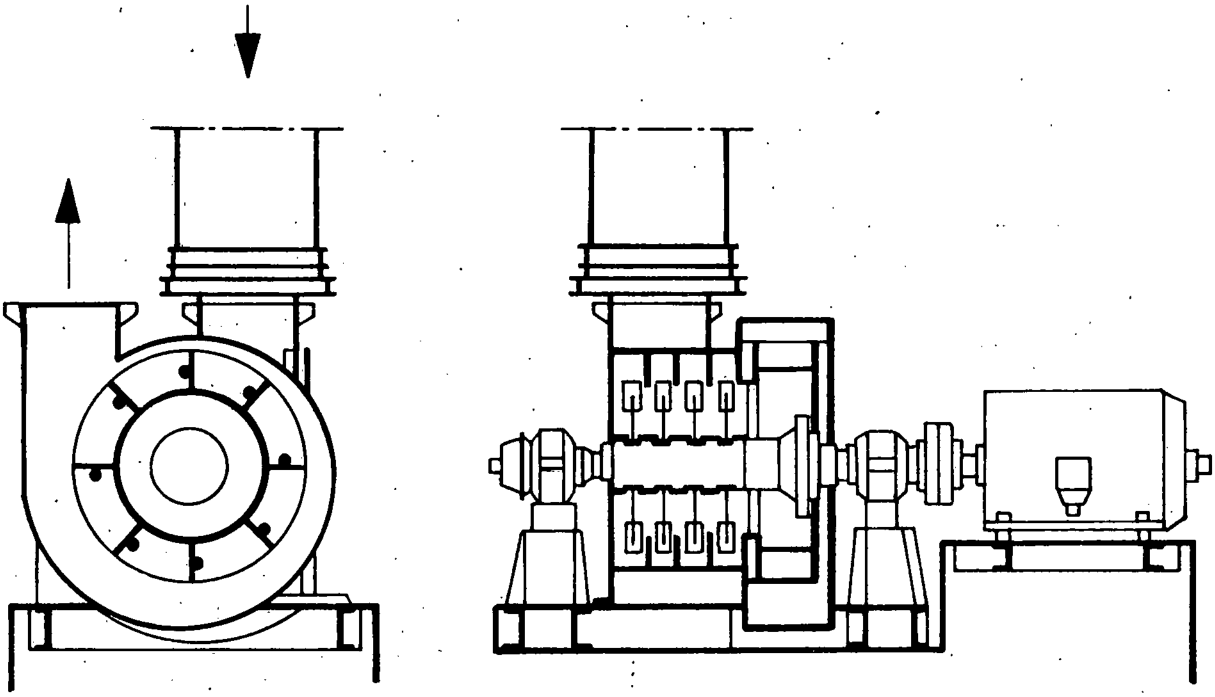
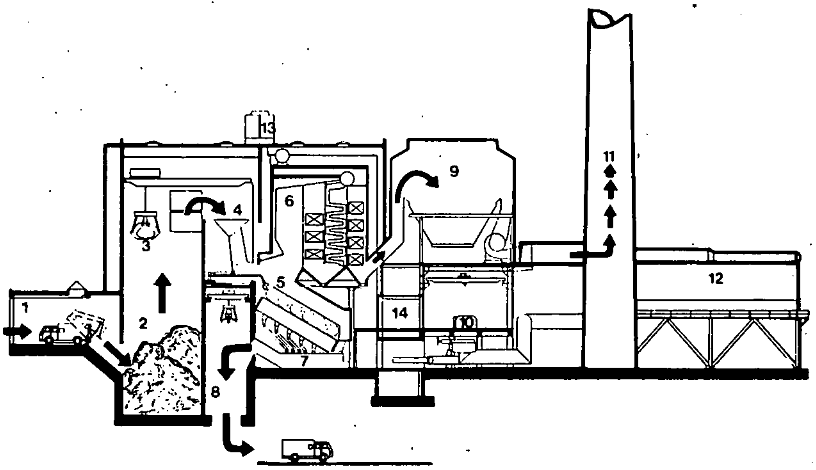


FIGURE 9 • HGS SLUDGE DRYER



1. Tipping Airlock
2. Refuse Bunker
3. Refuse Cranes
4. Feed Hopper
5. Rollergrate - System Duesseldorf
6. Boiler
7. Ash Extractor
8. Ash Bunker
9. Precipitator
10. Turbogenerator
11. Stack
12. Air Condenser
13. Cooling Tower
14. Control Room

FIGURE 10 • CROSS SECTION MVA GOEPPINGEN

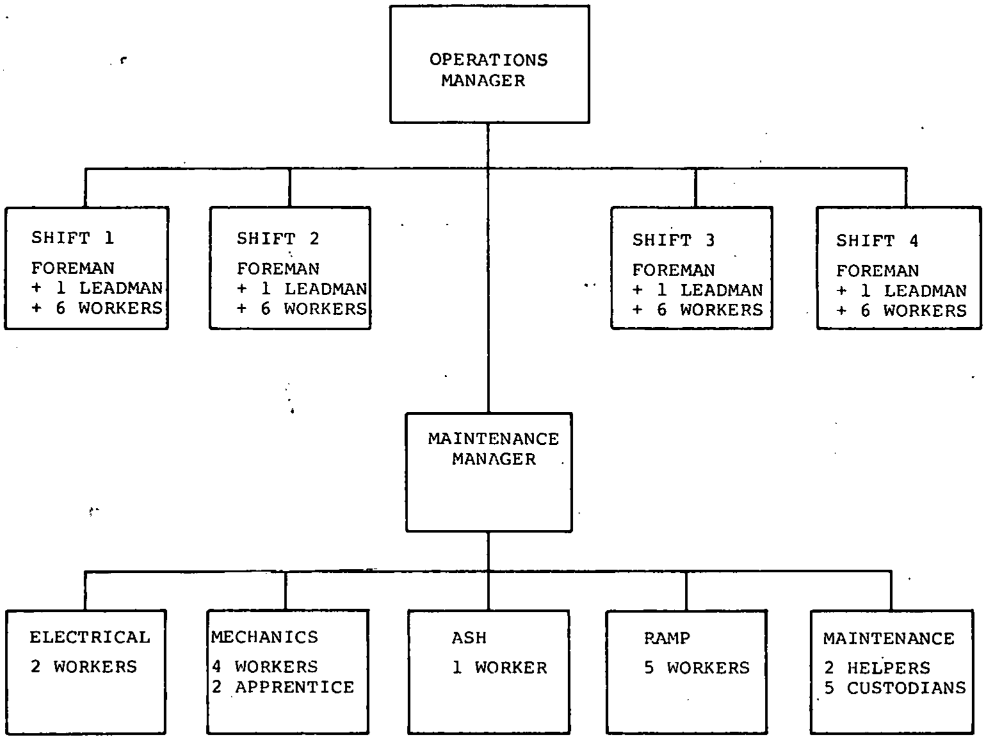


FIGURE 11 • ORGANIZATION CHART
MVA-GOEPPINGEN

O
MORNING SHIFT
Shift Duration:
For Weekdays
= 6-14 Hours
On Sundays
= 6-18 Hours

X
AFTERNOON SHIFT
Shift Duration:
For Weekdays
= 14-22 Hours

▥
NIGHT SHIFT
Shift Duration:
On Weekdays
= 22-6 Hours
On Sunday
= 8-6 Hours

1979

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	SHIFT - GROUP				JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
							I	II	III	IV						
Su	28	25	25	22	20	17	▥	O			15	12	9	7	4	2:30
Mo	1:29	26	26	23	21	18	▥	O		X	16	13	10	8	5	3:31
Tu	2:30	27	27	24	22	19	▥	O		X	17	14	11	9	6	4
We	3:31	28	28	25	23	20	▥		O	X	18	15	12	10	7	5
Th	4	1	1:29	26	24	21	▥		O	X	19	16	13	11	8	6
Fr	5	2	2:30	27	25	22		▥	O	X	20	17	14	12	9	7
Sa	6	3	3:31	28	26	23		▥	O	X	21	18	15	13	10	8
Su	7	4	4	1:29	27	24		▥	O		22	19	16	14	11	9
Mo	8	5	5	2:30	28	25	X	▥	O		23	20	17	15	12	10
Tu	9	6	6	3	1:29	26	X	▥	O		24	21	18	16	13	11
We	10	7	7	4	2:30	27	X	▥		O	25	22	19	17	14	12
Th	11	8	8	5	3:31	28	X	▥		O	26	23	20	18	15	13
Fr	12	9	9	6	4	1:29	X		▥	O	27	24	21	19	16	14
Sa	13	10	10	7	5	2:30	X		▥	O	28	25	22	20	17	15
Su	14	11	11	8	6	3			▥	O	1:29	26	23	21	18	16
Mo	15	12	12	9	7	4		X	▥	O	2:30	27	24	22	19	17
Tu	16	13	13	10	8	5		X	▥	O	3:31	28	25	23	20	18
We	17	14	14	11	9	6	O	X	▥		4	1:29	26	24	21	19
Th	18	15	15	12	10	7	O	X	▥		5	2:30	27	25	22	20
Fr	19	16	16	13	11	8	O	X		▥	6	3:31	28	26	23	21
Sa	20	17	17	14	12	9	O	X		▥	7	4	1:29	27	24	22
Su	21	18	18	15	13	10	O			▥	8	5	2:30	28	25	23
Mo	22	19	19	16	14	11	O		X	▥	9	6	3	1:29	26	24
Tu	23	20	20	17	15	12	O		X	▥	10	7	4	2:30	27	25
We	24	21	21	18	16	13		O	X	▥	11	8	5	3:31	28	26
Th	25	22	22	19	17	14		O	X	▥	12	9	6	4	1:29	27
Fr	26	23	23	20	18	15		O	X		13	10	7	5	2:30	28
Sa	27	24	24	21	19	16		O	X		14	11	8	6	3	1:29

FIGURE 12 • SHIFT ROTATION PLAN
(1979)
MVA GOEPPINGEN

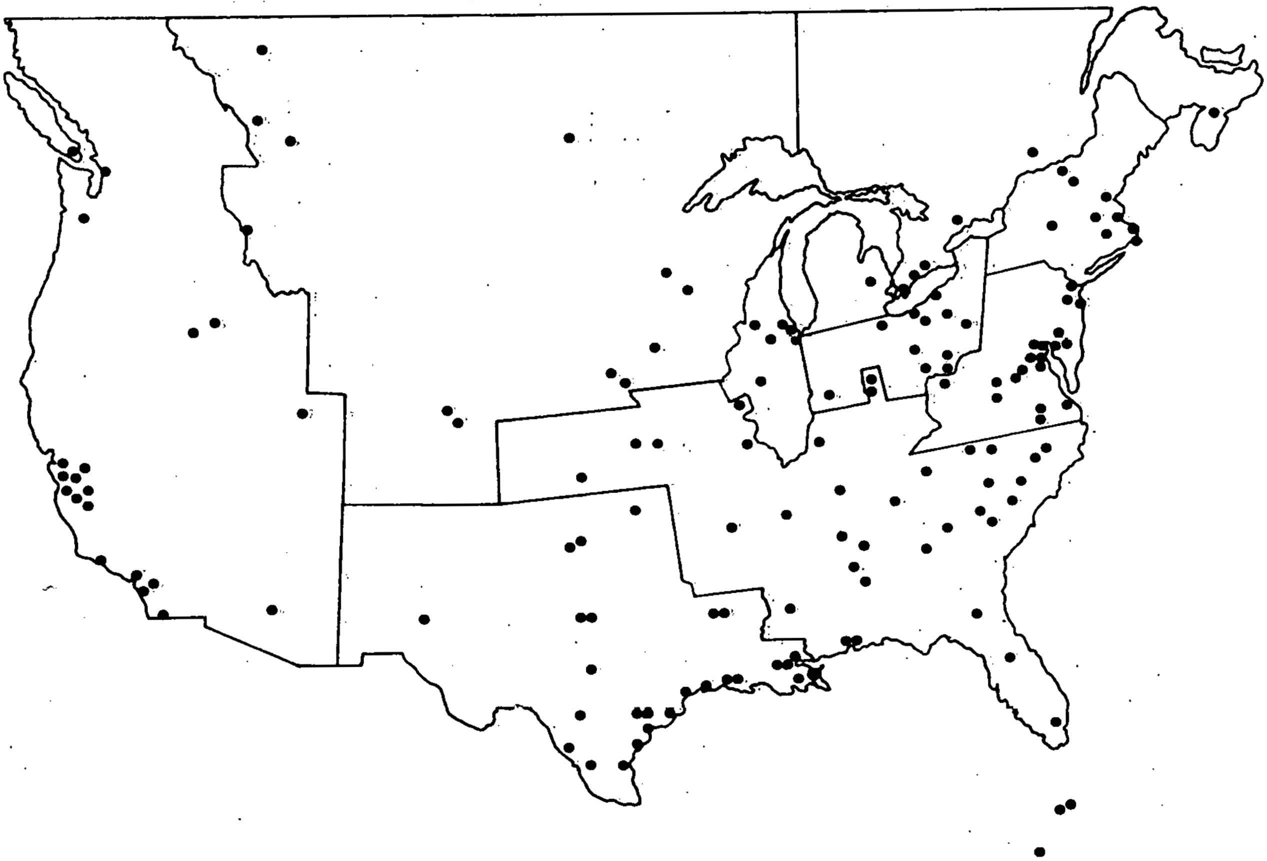


FIGURE 13 • BFI OPERATIONS

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APPLICATION OF SYSTEM VOLUND TECHNOLOGY TO THE NORTH AMERICAN MARKETPLACE

PRESENTATIONS TO THE
INTERNATIONAL EUROPEAN WASTE-TO-ENERGY
TECHNOLOGY CONFERENCE
OCTOBER 29, 30, 31, 1980

Harold Gershowitz, Senior Vice President
Waste Management, Inc.
900 Jorie Boulevard
Oak Brook, Illinois 60521

Gunnar Kjaer, President
Volund U.S.A., Ltd.
900 Jorie Boulevard
Oak Brook, Illinois 60521

Odd Gilbu, Superintendent
Copenhagen West Incineration Plant
Copenhagen, Denmark

ABSTRACT

Waste Management, Inc. is one of the world's largest waste management services companies and has been a leader in the practical development of resource recovery technologies. Waste Management, Inc. holds the North American rights to market, construct, and operate System Volund, the Danish-designed, mass combustion waste-to-energy technology. Waste Management, Inc. operates as prime contractor for System Volund in North America, providing full service contracts which include facility construction, start-up, and long term operation, supported with full construction and operational guarantees.

Volund has more than 50 years' experience in the design of waste-to-energy systems. Volund plants have operated continuously for over 30 years, and with more than 75 plants currently operating, System Volund is a proven, reliable technology. Because of the flexibility inherent in the System's basic design, System Volund can supply high capacity systems to serve major urban areas and can be effectively scaled down to provide smaller capacity systems to serve smaller communities or portions of major urban areas. This provides added flexibility in securing energy customers and in adapting the system to available quantities of waste. Energy recovered from waste can be produced in the form of steam or electrical power. With many plants experiencing better than 85 percent availability, System Volund has a distinguished record of reliable operation.

WASTE MANAGEMENT'S ROLE IN SYSTEM DELIVERY

Mr. Harold Gershowitz

Oak Brook, Il

This afternoon I shall describe Waste Management, Inc., our involvement with various resource recovery technologies, and particularly our commitment to the Danish-designed mass combustion technology, System Volund. My colleagues, Mr. Odd Gilbu, Superintendent of the Volund West Plant in Copenhagen, Denmark, and Mr. Gunnar Kjaer, President of Volund U.S.A. Ltd., will describe in detail the history, design, and operation of System Volund.

Waste Management, Inc.

Waste Management, Inc. is, as our name clearly suggests, a company dedicated to the orderly and complete management of society's waste materials. As one of the world's leading waste management services companies, Waste Management provides a broad range of municipal, commercial, and chemical waste management services in the United States, Canada, and abroad. Since our incorporation as a publicly held entity in 1971, Waste Management has, we believe, developed a reputation as a financially strong and stable enterprise, one that is well-managed, innovative, and in many respects, rather aggressive. Three months ago our corporate debt was upgraded to "A" by Moody's and by Standard & Poors, and our revenue and earnings growth over the past several years has out-paced our industry as well as industry in general. Waste Management sales will exceed one-half billion dollars in 1980, and we anticipate reaching the one billion dollar mark well before this decade reaches its midpoint. The company is owned by more than 6,000 individual shareholders, and our stock is traded daily on the New York Stock Exchange. We believe we are clearly one of those companies that brings strong financial credentials and strong management acumen to the American resource recovery marketplace.

Resource Recovery Experience

Waste Management was among the first to realize that waste can be a resource and not merely a worthless but costly by-product of our society's growth. We believe that resource recovery is a logical extension of our basic business and of our basic experience. This is not a new notion at Waste Management. To the contrary, there has not been a period in our history that has not involved a commitment to resource recovery.

As an example, in the late 1950's, Waste Management's founders constructed and operated in suburban Chicago, Illinois what was at that time the nation's largest privately owned and operated waste-to-energy facility. This waste-to-energy facility, which after nearly 20 years of continuous operation was converted to a waste transfer center, was rated at 500 tons per day. The plant was equipped with twin 250-ton Volund rotary kiln furnaces, and incorporated both energy and ferrous metal recovery systems. Energy recovered as steam was sold to a neighboring industry, and recovered ferrous was sold to the residual metals market as market conditions warranted. The operation of this facility provided Waste Management with extensive experience with steam recovery and a thorough familiarization with System Volund.

Waste Management also engineered, constructed, and currently operates under long-term contract with the City of New Orleans, the 650-ton-per-day Recovery I facility. Recovery I receives approximately one-half of New Orleans' municipally collected solid wastes, shreds the material into small particles, recovers ferrous metals in the waste stream, and disposes of non-recoverable shredded residue in an adjacent landfill. Glass and aluminum recovery development efforts are continuing in cooperation with the City of New Orleans and its resource recovery consultant, the Washington, D.C.-based National Center for Resource Recovery. Also continuing are technical and market development efforts to secure use of the shredded organic waste fraction as refuse-derived fuel. Operation of Recovery I has given Waste Management extensive practical front-end operating experience in the processing of municipal waste.

Another developmental technology is the conversion of waste directly to fuel-grade gas. Waste Management was selected by the United States Department of Energy in 1975 to construct and operate a proof-of-concept solid waste gasification plant. This gasification plant, known as RefCOM, is the nation's first large-scale experimental facility for converting solid waste and sewage sludge to clean-burning methane gas. Located in Pompano Beach, Florida, RefCOM is supplied with 100 tons per day of processed solid waste from Waste Management's adjacent 1,400-ton-per-day Solid Waste Reduction Center. The RefCOM demonstration is providing basic data on the quantity and quality of gas generated by the process, and also evaluation of design and operating parameters.

Our Solid Waste Reduction Center in Pompano Beach and our joint effort with Getty Synthetic Fuels to extract, purify, and market landfill gas represent other interesting aspects of our involvement in the resource recovery field.

Thus, it can be seen that Waste Management's background and experience differs significantly from that of many other companies involved in resource recovery. Our extensive experience with the basic resource - waste - and our experience with developing systems and technologies that can be used to manage and recover this resource, provide us, we feel, with a meaningful understanding of the processes that can be used to implement viable resource recovery systems.

System Delivery

Our operational experience with the various resource recovery technologies has convinced us that the most workable resource recovery technology is the mass combustion, waste-to-energy process. Waste Management resolved to acquire this capability, and in 1978 secured the exclusive North American rights to market, construct, and operate System Volund. Waste Management is committed to System Volund because we are familiar with the system and because it is a proven, workable technology which we can market with confidence to North American communities.

In our role as prime contractor for System Volund in North America, we will provide full-service contracts which include facility construction, start-up, and long-term operation, supported with appropriate construction and operational guarantees.

Waste Management also has the capability to provide complete system integration, including waste disposal support activities such as waste transfer and land disposal. Often overlooked in planning waste-to-energy systems is the requirement for well-planned and well-designed landfill capacity to handle incinerator residue and non-combustible refuse. Also, waste transfer stations may be required to efficiently handle the waste stream.

It must be remembered that resource recovery facilities are not only energy producing power plants, but also waste disposal systems which provide a needed service to the community. If this waste disposal function is interrupted, not only does a required community service stop, but a potential health hazard is created. Proper planning of the entire system is required, a capability for which Waste Management has unique credentials.

We are actively pursuing several project opportunities at this time. Some of these have come through our response to Requests for Proposals. Requests for Proposals are a good source of Volund opportunities in those instances where the issuing agency has done its homework and is, in fact, prepared to move forward with project implementation.

In other instances, we are working with communities to help them develop waste-to-energy systems. We are often in a good position to assist with such projects because of our participation in the community's waste collection or disposal operations.

Waste Management, Inc. and Volund Denmark are both principals of Volund U.S.A. Ltd. which is represented here today by its President, Mr. Gunnar Kjaer. Volund U.S.A. Ltd. is headquartered in Oak Brook, Illinois, and was established to facilitate technology transfer from Europe to the North American marketplace.

Volund U.S.A. Ltd. will help assure that the Volund system is responsive to the conditions of the North American market. It has a professional engineering staff in its own right, but will draw upon engineering experience from Volund Denmark as well. Volund U.S.A. Ltd. is also establishing relationships with reliable domestic equipment suppliers so that North American equipment will be used to the greatest extent possible.

Waste Management's Engineering Department enjoys unique experience in the delivery of a wide variety of solid waste facilities and, when appropriate, we have also teamed with the nation's leading A & E and construction management organizations for projects involving major facility construction. For example, we worked with Bechtel and J.A. Jones in developing our extensive facility in Saudi Arabia and we have been working with the Boeing Company through Boeing Engineering and Construction on various resource recovery projects under development here in the United States.

SYSTEM VOLUND TECHNOLOGY

Mr. Gunnar Kjaer

Volund U.S.A. Ltd.
Oak Brook, Il.

The Volund Group

The Volund Group of Copenhagen, Denmark consists of several wholly owned subsidiaries involved primarily in environmental and energy technology. Volund has had a major role in Denmark's achievements in energy recovery from solid wastes. Denmark leads the world in the utilization of its solid wastes with more than 65% of its wastes being incinerated in energy recovery plants, the majority of which were designed and suppled by Volund.

Throughout its 100-year history, the Volund Company has been distinguished by its commitment to energy and energy-related systems and products and its active role in the solution of environmental problems associated with waste disposal. Of its current 11 divisions, seven are directly involved with energy and the environment, and the majority of the 2,200 people in the Group work for these divisions.

Energy-Related Activity

Volund's Energy Technology and Heat Technology Divisions are widely recognized for their expertise in the design, production, and erection of boilers for residential, utility, and industrial use. Both divisions also are engaged in the development and design of alternative energy supplies, including fluidized bed incineration techniques and heat pump systems, and in continuous research toward the improvement of traditional methods with respect to environmental concerns and combustion efficiencies.

The Energy Technology Division last year completed the largest fossil-fired power station boiler plant in Scandinavia, rated at 1,950 tonnes of steam per hour (4.3 million pounds/hour) with an electric power output of 630 MW. It was designed, manufactured, and erected under a turnkey contract. Under the same type of contract, two large fossil fuel and wood waste-fired boilers were supplied to an industrial plant in East Germany. Presently, two large bagasse-fired steam boilers for a sugar refinery in Vietnam are under construction.

The Energy Technology Division has specialized in the combustion of low grade solid fuels, utilizing its own traveling grate for this purpose.

The Division also includes in its operation the supply of dynamic and electrostatic filters for removal of solid particles in gases and of carbon filters and scrubber plants for removal of odors from air.

The Steel Construction Division is heavily involved in fabrication and erection of steel constructions for the off-shore oil and gas drilling industry in the North Sea. It ecently completed a helicopter platform for a North Sea oil drilling rig in nine weeks rom design to final installation.

The Steel Construction Division is the largest Danish manufacturer of prefab steel chimney stacks, and is also a major manufacturer of electro-hydraulic grapples for transport of refuse, clinker, clay, sand, etc.

Kroll Kraner A/S is a highly specialized manufacturer of tower cranes. These are mainly used in the building and construction industry, in shipyards and on docks.

However, the world's largest crane of this type was supplied to the energy industry. The crane, delivered 1½ years ago, is used for the construction of Forked River Nuclear Power Station, U.S.A. The crane will lift 264 kips on an arm of 269 feet to a height of 270 feet.

Volund's Mechanical Services Division also participates in the Group's energy/environment activities through the marketing of conveying systems for refuse and processed wastes, and the fabrication and installation of piping for utility power stations, incineration plants and large district heating works, including all of the work for Copenhagen's district heating main network.

Finally, the Glass Fibre Division is becoming increasingly engaged in the development and manufacture of glass fibre reinforced wings for the large windmills being installed in Denmark to generate energy from alternative energy sources.

Other Activities

Other Volund Divisions in Denmark manufacture domestic appliances, laundry equipment for industrial, institutional and marine use.

Activities Abroad

Volund has subsidiaries or financial interests in companies in Sweden, West Germany, France, United Kingdom, Singapore and the U.S.A.

Incineration - Energy Recovery

Through its Environmental Division, Volund is one of the world's most experienced companies in the design, construction, and installation of solid waste incinerators with energy recovery. The Environmental Division develops and produces systems for the incineration of solid, liquid, and chemical wastes and sewage sludge, combining the disposal of these wastes with energy production as appropriate.

The world's first continuous-flow incinerators were designed and installed by the Volund Company in Denmark in 1931 and 1932 in the Copenhagen Boroughs of Gentofte and Frederiksberg. Both of these plants made use of the heat released by the incineration of refuse. In Gentofte, electricity was generated and in Frederiksberg steam was supplied to the town's district heating scheme. Both plants operated until 1971 when they were replaced by two large incinerators serving the total Copenhagen area. These plants, Copenhagen West, which Mr. Odd Gilbu will later describe, and Copenhagen Amager, were also designed and manufactured by Volund. They both use the waste incineration process to supply the surrounding area with part of its energy needs.

The Environmental Division of A/S Volund, Denmark is purely an engineering division without any manufacturing facilities of its own. It is, as such, very flexible to nove into far away export markets, where the cost of transportation is prohibitive for ieavy manufactured goods.

The process technology developed by the Volund Environmental Division has been refined over a period of more than 50 years. The modern System Volund process for "Mass Burning With Energy Recovery" is thus backed by solid expertise and experience at the point of its introduction into the North American market.

The Volund technology has formed the basis for a world-wide network of license arrangements and, over the years, more than 100 System Volund incineration plants have been built all over the world, handling the refuse from cities with a total population of close to 30 million people. Plants are in operation under a wide range of climatic and socioeconomic conditions, in the Western industrial world as well as in the Orient, from the Arctics of northern Scandinavia to the tropics of Thailand.

During the past two years, more than a dozen Volund mass burning systems have been installed in five countries and an additional 15 are under construction, most of which are designed for the production of steam for heating, process manufacturing, or electrical generation, or superheated water. Plant sizes range from 50 tonnes per day (55 tons/day) to 1,260 tonnes per day (1,390 tons/day) with unit sizes installed up to 420 tonnes per day (460 tons/day) and developed in sizes up to 500 tonnes per day (550 tons/day).

Most Volund plants in Europe and the Orient have been installed following competitive bidding. In most cases, the contract has included design, manufacture, and erection of the total plant with additional involvement in building design and supervision of construction. In other cases, building and site development have been included with the plant design, supply, and erection in a Volund turnkey contract.

<u>Volund USA Ltd.</u>

A/S Volund of Denmark had been represented in the U.S.A. beginning in 1940 when a license agreement was originally signed with the American subsidiary of the Danish F. L. Smidth Company. A total of 11 plants were built in the United States by a licensee organization formed by F. L. Smidth and the Hardaway Construction Company. These plants were built to achieve maximum volume reduction of the refuse at the lowest possible cost. Energy was cheap and abundant in this period and air pollution standards were non-existent and, therefore, little consideration was given to either energy recovery or pollution control equipment by the licensee. Communication between Volund and the licensee was impossible during the first part of the license agreement because of the war, and very limited during later years when the licensee marketed their own "off the shelf" design without consultation with Volund.

As a result of this, Volund severed the connection when the agreement expired in the mid-Seventies, and started looking for a new partner.

Changes in environmental legislation in the early Seventies made the type of incinerators formerly installed in the U.S.A. obsolete, but at the same time offered new opportunities for the modern Volund technology.

Volund USA Ltd. has been formed to exploit these new opportunities. The mpany became operational in the Spring of 1979.

Volund USA Ltd. is responsible for transfer of technology from Denmark to North America and it is currently building up its staff to enable it to design, engineer, and supply all equipment for major incineration plants with resource recovery. Waste Management, Inc. has the right to market, construct, and operate these plants in the North American market.

Another responsibility of Volund USA Ltd. is to adapt Volund design to the special conditions of the North American market. This includes finding North American suppliers and subcontractors for the different components and equipment needed to construct a modern waste burning facility. It also involves an adaption to U.S. and Canadian standards for pollution control, equipment and plant specification, etc. Finally, it will allow us to provide a feedback to the Danish company which will enable to keep up with the changes in the North American waste and environmental situation.

For equipment supply, we shall, for some time, continue to buy a few special or proprietary components from Europe, but the emphasis is on using North American equipment built to our specifications to the largest possible extent. We expect North American components to exceed 85% of the total in the first plant and to be increased in subsequent plants.

Plant Design and Technology

Disposal of refuse by incineration relies mainly on two technologies: Mechanical Handling and Combustion Technology. The modern incinerator will operate on a 24-hour day, seven-days-per-week basis. It will therefore need storage facilities for the "fuel" needed during the weekend, when refuse collection does not take place. For a large incinerator, the necessary storage required is several thousand cubic yards, taking into account a density of the refuse as off-loaded of about 5 cubic yards to a short ton (250 kg/m^3). As shown in Figure 1, the storage facility required is normally arranged in the form of a refuse pit. The refuse trucks will tip their load into the refuse pit from where it will be lifted by overhead cranes and fed into the receiving hopper of the refuse-burning furnaces. This whole area, including the tipping area, is enclosed and the combustion air necessary for the furnaces is taken from this part of the building. This maintains a slight underpressure which prevents odor and dust from spreading outside the building enclosure.

The refuse is gravity fed from the hopper through a chute into the furnace. The furnace walls are refractory-lined in order to maintain a high and constant temperature in the furnace chamber. A mechanical, reciprocating grate moves the refuse forward and at the same time agitates it and breaks up the larger parts. The combustion grates will normally be divided into three sections arranged in steps. On these sections the refuse will dry out, ignite, and burn. In large furnaces, the last grate section is followed by a rotary kiln which increases the residence time of the refuse from approximately 1 hour up to 2-4 hours, thus ensuring a very thorough burn-out of the residues. Once the combustion process is started, the furnace temperature will be maintained at approximately 950°-1025°C (1750°-1900°F). With today's refuse, these temperatures can easily be maintained without the need for any auxiliary fuel.

Our design incorporates a separate, fully refractory-lined furnace. The heavy refractory lining in the walls will sustain a constant temperature in the furnace chamber under conditions of varying refuse heat values. This allows the furnace tc maintain the proper combustion temperature even when difficult-to-burn refuse owing to high moisture or ash content, is fed into the furnace. The refractory walls, by releasing some of their absorbed heat, will keep the process going.

The result is the maximization of volume reduction and a residue with a minimum content of putrescible matter and unburned carbon.

Furnace/Boiler Design

The advantages and disadvantages of waterwall-cooled incinerators compared with refractory-lined incinerators has been debated in Europe for nearly two decades. Prior to the late Fifties, refuse incineration furnaces were, as a matter of course, built with refractory-lined walls. It was widely accepted that the primary purpose of the refuse incinerator was to dispose of refuse. That refuse incineration is best accomplished in a refractory lined furnace has never been disputed.

Around 1960, incinerator designs incorporating integrated boiler/furnaces with unlined water tube cooled steel walls were introduced in an attempt to achieve a higher theoretical fuel-to-energy efficiency. These designs have been known as waterwall incinerators and were installed in large numbers through the Sixties and Seventies by several incinerator manufacturers.

Volund and others have continued to give priority to high reliability and maximum burn-out because we see the mass burning plants as primarily a means of disposing of the daily amount of refuse. Therefore, Volund still maintains a design incorporating a refractory-lined incinerator with a separate boiler unit.

Volund is a major manufacturer of waste and fossil fuel-fired waterwall boilers for industrial and utility use with experience from boilers with steam outputs up to 4.4 million lbs/hr (2,000 tonnes/hr). Volund was also, for a long time, the only company in Europe with in-house experience in both boiler design and manufacture, as well as in incinerator design and manufacture. As such, we were fully aware of the possibilities and problems inherent in energy recovery from waste, and we were and are of the opinion that the integrated waterwall boiler design is not the best possible solution to this problem.

Early waterwall boiler designs were based on experience gained from boilers for conventional solid fuels rather than on experience with solid waste. Thus, we find that these designs tend to reflect only traditional boiler design requirements such as:

- High efficiency
- High pressure stability, i.e., the ability to withstand the required static pressure on the water/steam side with minimum use of material in boiler tube walls.
- Good steam quality without water droplets.

While these design goals are highly commendable, they are not sufficient for the design of refuse incineration furnaces. Only rarely was adequate consideration given to the inherent properties of solid waste and the special thermal conditions applicable to its incineration. This became even more evident as larger incinerator units were uilt which began to approach the size of small utility boilers.

Serious corrosion problems have plagued many of these systems, along with problems resulting from slagging and sintering of ash and clinker on the boiler surface after only a few years of operation.

The most dangerous hazards to incinerator reliability occur on the gas side of the furnace-boiler system and is scheduled below:

- Fluctuating Gas Atmosphere
- Fouling
- Erosion
- Dew Point Corrosion
- High Temperature Corrosion

Dew point corrosion in plants with heat utilization is rare in boilers and in auxiliary equipment, i.e., gas ducts, electrostatic precipitators and I.D. fans, since exhaust gas temperature can easily be maintained well above the dew point temperature.

High temperature corrosion, on the other hand, presents a serious threat to the availability and also to the operational efficiency of the plant.

The reasons for high temperature corrosion are, today, well understood and it is generally agreed that the following conditions should be avoided:

- The presence of local streaks of incompletely burned gases in the gas passages of the boiler.

- Boiler wall temperatures (metal temperatures) exceeding 350-400°C (650-750°F). (See Figure 2)

- The presence of a layer of flyash or clinker in a melting phase on the boiler surface.

Some investigations indicate that the most dangerous conditions are caused when incompletely burned-out gases come in contact with the boiler walls, thereby causing fluctuation between oxidizing and reducing atmospheres in the presence of high temperatures and corrosive gases.

The occurence of melting temperatures in the flyash and clinker layer, too, is often caused by this local combustion of unburned gases raising the temperature locally above the melting point.

It is, therefore, important to avoid the streaks of reducing atmosphere in the boiler. This problem must be solved before the gas reaches the boiler rather than in the boiler itself.

Despite all efforts to mix the waste properly before it is fired into the furnace, waste remains a very heterogeneous fuel which burns with varying velocities and oxygen requirements. Therefore, local streaks of unburned gases with high carbon monoxide content, as well as temperature fluctuations, will occur immediately above the grate, despite the presence of excess air. These conditions are further promoted by the very wide grate areas necessary in high capacity incinerators.

The combustion gases must be retained in the combustion zone long enough to ensure that the gases are completely burned out and properly mixed so that a homogeneous oxidizing atmosphere is created prior to the gases entering the boiler.

Volund's two-way gas system and the special after-burn chamber allows the time, temperature, and turbulence necessary for complete combustion of the gases before they enter the boiler (without any need for auxiliary fuel).

The flyash particles consist mainly of easily meltable clinker which remain soft down to a temperature of approximately 600°C (1100°F). Even after the suface of the flyash particles is cooled below that temperature, the center remains soft for some time, increasing the risk of the particles sticking to the boiler surface when they flatten on impact.

The degree of clinker slagging and sintering is often the decisive factor in determining when an incinerator must be taken out of operation for maintenance. Therefore, it is important that flyash particles are burned out completely and are effectively cooled down before entering the convection part of the boiler, where the boiler tubes are positioned.

The first objective is achieved in the after-burn chamber. The second is met by designing the gas passages to allow sufficient time in the radiation zone of the boiler (Figure 3). These objectives, we believe, are best achieved through a design incorporating a separate furnace and boiler.

Boiler Conditions

The steam pressure and temperature that can be obtained in the refuse burning plant is a function of the feed water pump pressure and the superheater design and is not, as sometimes suggested, a result of whether the incinerator is designed as a waterwall incinerator or as a separate furnace with a tail-end boiler.

Combustion temperatures in all major waste burning systems are of the same magnitude and, in every case, the design combustion temperatures give ample margin to choose much higher steam temperatures than those customarily used in waste burning.

The steam temperatures, which may prudently be designed for, are a function of the refuse composition and the resulting gas composition which may be more or less corrosive. Increasing steam temperatures beyond 350°-375°C (650°-700°F) add unnecessary risks to the refuse burning process without significantly improving the waste-to-energy efficiency.

When steam is generated for process or heating purposes only, there is no advantage gained from increasing steam temperatures unless specific processes demand a higher temperature.

If electricity is generated in a fully condensing turbine, the total cycle efficiency may gain about one percentage point by raising steam temperatures 55°C (100°F), but at the cost of considerable operational risks. In the case of co-generation in backpressure turbines, total energy gain does not improve at all by increasing the team temperature.

The early Volund plant in Aarhus, Denmark, operated from 1934 to 1955, producing steam at 30 bar (445 psi) superheated to 425°C (797°F) as required by the customer, which was the adjacent power station. Refuse, in those days, however, contained more ash from residential coke and coal-fired furnaces and was generally less aggressive than today.

Modern refuse has a high plastic content, a part of which is PVC that forms hydrogen chloride in the combustion process. Hydrogen chloride also derives from various other constituents in the refuse whereas sulfur connections are more scarce.

Hydrogen chloride is the most aggressive element in the incinerator gases and the most dangerous in respect to corrosion of the boiler walls and superheater tubes. The attached graph (Reference Figure 2) shows the relationship between boiler tube temperature and corrosion rates. Superheater tube temperature is normally about 55°C (100°F) higher than the temperature of the superheated steam. Based on this evidence and on the Volund design philosophy, which gives priority to high reliability, we feel that our customers are best served by maintaining steam temperatures below approximately 350°-375°C (650°-700°F). However, if conditions so require, our design allows us to go to higher steam temperatures.

Rotary Kiln and Residue Treatment

The rotary kiln has been a significant part of the Volund furnace design since the first plant was installed in Gentofte in the late 20's. The rotary kiln serves as the last part of the grate in the larger plants, but is not normally economically justified for smaller plants, say below 5-6 tons per hour capacity. The reasons for installing the rotary kiln are as valid today as they were 50 years ago. The rotary kiln provides a very high degree of flexibility and, thus, allows the plant to handle refuse of widely varying compositions and heat values. The kiln increases the residence time of the refuse in the furnace system up towards 2-4 hours compared with 45-60 minutes for a typical incinerator with grate systems only. During this period, the final burn-out of the residue takes place under a very active agitation. This results in an extremely good burn-out of the residues with hardly any unburned carbon or putrescible material in the residue. The process, furthermore, produces a residue in the form of a sintered homogeneous clinker, in which heavy metals are bound in nonsoluble compounds. The Danish Environmental Protection Agency, consequently, has concluded that clinker from Volund rotary kiln incinerators may be deposited without any special precautions in the form of impermeable layers of clay or plastic sheets in the bottom of the deposit area.

As a result, several large Volund incineration plants have been fitted with a residue treatment plant for the incinerator residues. The volume of the residue has already been reduced in the incineration process to approximately 5% compared to that of the waste received. By residue treatment, the amount which needs to be landfilled is further reduced.

Through screening, all material over two inches is retained. The remainder passes under a magnet which separates the ferrous metals. The non-ferrous clinker is finally separated into a coarse fraction (½" to 2") and a fine fraction (under ½").

The ferrous metal (approximatley 15%) is sold as scrap metal.

The coarse clinker (approximately 65%) is sold as hardcore and road foundation material.

The fine fraction including the flyash (approximately 15%) is sold for use as aggregate in the production of concrete slabs, curbstones, etc.

Only the oversize material will have to be finally disposed of in a landfill and this part represents only approximately 5% of the residue or 1-1½% of the refuse originally delivered to the plant.

Pollution Control

The gas temperature in the Volund incinerator is maintained at 900°-1000°C (1650°-1830°F). This effectively kills all odors in the gases before they are emitted to the atmosphere.

The Volund design, incorporating flue gas recirculation, further lends itself to maintaining an even combustion temperature throughout the furnace system, avoiding temperature peaks and thus reducing the formation of NO_x.

Volund plants are designed to meet all local air pollution control requirements. Particulate matter is the predominant potential pollutant from refuse combustion. Adequate particulate matter emission control has to date been achieved by the installation of electrostatic precipitators. We are of the opinion that the electrostatic precipitator presently represents the only proven technology for highly efficient particulate matter control.

Gaseous emission from a well designed and operated incinerator for municipal solid waste does not represent a serious pollution problem compared to many other pollution sources such as fossil fuel-burning plants, automobiles, industries, etc.

In most instances, the cost of control equipment for gaseous emission is not justified for environmental reasons. In already heavily polluted areas, pollution control equipment for gaseous emission may, however, be required. Pollution control equipment in the form of gas scrubbers is available for this purpose and has been installed in several Volund plants in Japan.

Plant Operation Control

Centralized plant control is a common feature in the modern Volund incineration plant. Remote control of the refuse crane(s) from the central control room, using semi-automatic cranes monitored by closed-circuit television, offers the advantage of more consistent furnace loads. This optimizes plant throughput and will also reduce maintenance costs. An added benefit is the possibility of reducing operating personnel.

Building Design

Refuse burning plants in Europe often provide energy in the form of superheated water (or steam) to the extensive district heating systems in the towns and cities. Because of this, the refuse burning plant is often located centrally in the town -- often on the outskirts of a residential area. This has created high standards of building design for this type of plant, and often considerably higher construction costs than required if a plant is situated in a remote industrial area.

In North America, such high standards of building design may not be required. In these instances, building design can be adopted to meet local requirements, with substantial savings in plant construction costs possible.

Plant Reliability

The Volund mass burning system has evolved and been improved over the years as have other technologies. It has operated successfully through the depression years of the Thirties, the lean World War II years, the affluent Fifties, Sixties, and Seventies, and is serving efficiently in the energy-conscious Eighties. Some of the early plants were in continuous operation for more than 40 years producing electricity and steam for their communities.

Plant reliability and availability has, as a rule been of the order of approximately 85% depending upon availability of refuse. One of the two large Copenhagen plants last year operated at over 86% availability and other Volund plants have, on an annual basis, handled as much as 120% of their nameplate capacity.

It is a thoroughly proven technology that we are now introducing in the North American market.

SYSTEM VOLUND OPERATION
I/S VESTFORBRAENDING

DK

Mr. Odd Gilbu

Glostrup, Denmark

In Denmark, it has been a general rule that the collection, transport, and disposal of waste is the responsibility of each municipality. The collection and transport is handled either by a municipal service organization or through local private enterprise.

Because of scarcity of landfill area in Denmark, the disposal has been carried out mainly by incineration with energy recovery, and this is rather complicated to handle for the single municipality. It has, therefore, been a normal practice that municipalities cooperate by establishing independent joint companies to take over the disposal responsibility by building, financing, and operating incineration plants.

Ownership

I/S Vestforbraending is such a company, formed and owned by 12 municipalities: Ballerup, Birkerod, Farum, Gentofte, Gladsaxe, Glostrup, Harley, Hillerod, Kobenhavn, Nedre Smorum, Lyngby-Tarbaek, Rodovre.

Location

The plant of I/S Vestforbraending is centrally located in the area it is serving, and also near the main roads, giving easy access to the plant. The area served has 600,000 inhabitants and contains a large number of diverse light industries.

Waste Quantity

During one year, approximately 365,000 tonnes (400,000 tons) of waste are generated in the area and transported to the plant. Approximately 15,000 tonnes of domestic waste is transferred to other incineration plants in order to utilize their full capacity for the production of district heating. The remaining 350,000 tonnes (385,000 tons) can be divided into two main groups:

Domestic Refuse	221,000 Tonnes	(243,000 Tons/Year)
Industrial Waste	129,000 Tonnes	(142,000 Tons/Year)
Total	350,000 Tonnes	(385,000 Tons/Year)

Reception

At the reception stage, the wastes are divided into two streams. The domestic waste, as well as the light industrial waste, goes directly into the refuse pits, while all bulky waste goes to a crusher or shear, reducing the waste to a maximum size of 3 x 3 feet.

Three of the 12 municipalities served by I/S Vest Incineration collect the refuse separately at the households in the following categories:

- Household refuse
- Bottles
- Paper/cardboard
- Iron
- Bulky waste

Incineration Plant

The incineration plant consists of three furnaces of 288 tonnes per day per line and one furnace of 336 tonnes per day. These are the nominal capacities.

In the daily operation, the plant operates an average of 3 x 330 tonnes per day and 1 x 385 tonnes per day. In this way, our plant has more than enough capacity to treat the 350,000 tonnes (385,000 tons) of waste per year with only three units in operation.

Heat Recovery

Though the main function of the plant is refuse treatment, the heat recovery has become an increasingly important part of our activities. The heat is recovered in pressurized hot-water boilers and utilized in a district heating system which is made up of two distribution areas.

Today, approximately 210,000 MWH (720,000 million BTU) are sold in the Northern distribution area annually. Within a few years, the Western distribution area will be totally extended, enabling us to sell approximately 470,000 MWH/year (1,400,000 million BTU/year).

Residue Treatment

The residue from the incineration process - the clinker - contains up to 10-15% iron.

Normally, the clinker will be disposed of in a landfill. Through intensive research, we have been able to get approval from the authorities to utilize the coarse clinker as foundation material for parking lots, roads, etc., and the fine clinker as base material in production of concrete products.

After a storage time of 24 hours in the clinker silo, the raw clinker is separated into:

- Fine Clinker, Grain Size	0- 5 mm	(0.0-0.2 inch)
- Coarse Clinker, Grain Size	5-50 mm	(0.2-2.0 inch)
- and Iron		

We produce annually about 88,000 tons of raw clinker, approximately 16,000 tons of iron, approximately 66,000 tons of coarse clinker, and approximately 6,000 tons fine clinker, all of which is sold.

Landfill

In spite of the sale of certain residues, it is necessary to operate a sanitary landfill in connection with the incineration plant in order to dispose of a number of waste types, such as building waste, flyash, sludge, etc.

It is evident that the size of the necessary landfill is very much dependent on the possibilities to utilize the residues from the incineration. Our landfill has a capacity of approximately 180,000 to 230,000 tonnes, which should be compared to the amount of waste we are treating. We expect to have landfill capacity for approximately five to seven years.

Organization

As you will see, we are not only a refuse treatment facility, but also a district heating station and a material recovery facility, all operated on an independent basis.

Our management must, therefore, maintain all external and internal affairs such as general reports, budget, estimates, accounting, sales work, staff management, etc., and our operational staff has to operate and maintain the incinerator plant, the district heating facility, the separate collection system, the clinker treatment system, and the sanitary landfill. In total, we have the following number of employees:

Management	14
Operation staff	30
Maintenance	27
Reception of Waste	12
Clinker Separation	4
Sanitary Landfill	3
District Heating	8
Total	98

The staff involved with incineration accounts for:

Management	9 persons
Operation	30 persons
Maintenance	20 persons
Reception	8 persons
Clinker separation	4 persons
Total	71 persons

At a normal eight hours duty, the direct plant operating personnel accounts for:

Mechanical Engineer	1 person
Furnace Attendant	1 person
Boiler Attendant	1 person
Crane Operator	2 persons
Total	5 persons

Because of Danish limitations on working hours, holiday requirements, sick leave, etc., six full crews have to be allowed for to operate the plant continuously.

Planning of Operation

I/S Vest Incinerator has two main objectives:

- to dispose of waste;
- to produce and deliver energy.

Our planning must, therefore, pay regard to both these objectives which sometimes causes some difficulties.

The amount of waste delivered to the plant and the amount of energy produced does not correspond to the amount of energy which can be sold. The refuse quantities in the summertime are larger than the annual average, whereas the district heating system energy demand is considerably lower in the summertime than the annual average. The annual plant operations plan takes into account seasonal waste variation. Normal operation calls for three furnaces in operation. This allows the objectives of both refuse disposal and energy supply to be covered.

The fact that our requirements nearly always can be met with three furnaces in operation allows us to always have one furnace out of operation and thus schedule preventive maintenance. On a yearly basis, we are planning the period of operation of each furnace according to the refuse amounts. If needed, each furnace operating period could be expanded by approximately three weeeks if a tight planning of the maintenance work is carried out. The reliability of the 10-year-old plant allows us to utilize more than 95% of the pre-scheduled time of operation.

During each scheduled stop, the plant is inspected and its condition is evaluated to determine whether the maintenance program is sufficient or if adjustment has to be made. On this basis, management can prepare a realistic maintenance budget.

Operation Experience

The waste delivered to a mass combustion facility is a very heterogeneous type of material with considerable variation in both composition, physical size and heat value.

The combustion of waste is, therefore, a very demanding type of operation, a fact which has to be taken into consideration when choosing the kind of equipment you have to apply in the process. If the equipment does not meet these demands, unscheduled stops of operation are bound to happen and the total availability of the plant is reduced considerably.

This philosophy was used in the planning of our facility and the design of our process equipment is made with due regard to these facts.

Even though this is the case, and despite the pre-preparation of the bulky waste before incineration, we have experienced that larger items, such as section steel profiles, bicycles, or even parts of car bodies, have caused problems in the chute or the clinker discharge, resulting in reduced operation time. We have, however, never experienced any damage of the equipment as a result of this.

We operate in the temperature range of 140 degrees Centigrade ((284 degrees Fahrenheit) at the boiler inlet and 175 degrees Centigrade (350 degrees Fahrenheit) at the boiler outlet. We have consequently experienced very little boiler corrosion during our 10-year period of operation.

The flue gas temperature after the boiler is between 280 to 350 degrees Centigrade (540 to 660 degrees Fahrenheit), which is the result of operating at greater than design capacity as previously noted.

Our plant has had no difficulties in meeting waste handling design capacity with respect to nominal load through a period of operation, which will be seen from the curves shown. Most of the period we are working above the design capacity and have the capability of operating at a higher capacity than originally planned.

I/S West Incinerator is, of course, subject to strict environmental demands, as shown in Table I.

In order to control our conditions of operation in this respect, we are operating according to an environmental program to ensure that we can meet the demands of the authorities.

In this respect, it is very difficult to generalize and make comparisons from plant to plant as the composition and properties of the waste can vary considerably. We have, while depending on the seasons, experienced clinker formations on the furnace walls, in some cases after only 600-800 hours of operation. While we can eliminate this problem through operational controls, this problem has also been solved by using air-cooled ceramic walls in our new furnace design.

Despite the inevitable minor plant operational problems, the I/S Vest plant has been in continuous operation for almost 10 years, and during that period of time, has processed over 2.4 million tonnes (2.6) million tons) of industrial, commercial, and residential waste.

TABLE I

COMMISSIONING TEST
WEST INCINERATOR PLANT, UNIT 4

Test Date: October 18, 1979
Hours of Operation After Boiler Cleaning: 1400 Hours

	Metric Units	Guarantee Requirement	Actual Performance	American Units	Guarantee Requirement	Actual Performance
Effective Test Period	Hours	7	7	Hours	7	7
Waste Quantity	Tonnes/Hr	14.0	20.2	Short Tons/Hr	15.4	22.2
LHV of Waste	KJ/Kg	5,000-10,500	8165	BTU/lb	2200-4500	3513
Boiler Output	MWH/H	--	26.3	10^6 BTU/Hr	--	89.7
Unburned Carbon in Clinker	% of D.S.	4-6	4.3	% of D.S.	4-6	4.3
Putrescible in Clinker	% of D.S.	0.15	0.11	% of D.S.	0.15	0.11
After Electrostatic Precipitator						
Flue Gas Temperature	°C	--	338	°F	--	640
CO_2	%	--	6.7	%	--	6.7
Solid Particulate Emissions	mg/m^3 at 7% CO_2	150	33	gr/dscf at 12% CO_2	0.11	0.02
ESP Efficiency	%	--	98.7	%	--	98.7

SYSTEM ECONOMICS

Mr. Harold Gershowitz Waste Management, Inc., Oak Brook, Il

As previously discussed, it is the intention of Waste Management to pursue mass combustion, waste-to-energy opportunities as a full-service contractor. Systems which we propose will be constructed and, wherever appropriate, operated by Waste Management. Waste Management is prepared to undertake such commitments for either publicly owned facilities, or for facilities which will be financed through the sale of project revenue bonds and owned by Waste Management.

Market Factors

Having stated our intention to actively pursue these projects, we would like to present our perception of the current market for waste-to-energy systems. Various important events have occurred which enhance the viability of resource recovery. First, the cost of alternative disposal, that is, the cost of environmentally-sound sanitary landfill, has increased dramatically in recent years. The promulgation of regulations under the Resource Conservation and Recovery Act will almost certainly further increase the cost of sanitary landfill. Land disposal sites serving major metropolitan cities are being located greater and greater distances from the cities that depend on them. Consequently, many major urban areas will, eventually, encounter combined waste transfer and landfill costs as part of their disposal program. To further exacerbate this problem, land required for new sites will tend to be many times more expensive than was the land for the equivalent number of original acres being replaced.

Concurrent with these dramatic changes in the cost of land disposal, there has also been a dramatic increase in the cost of fossil fuel. The real prices actually paid by American industry for fossil fuel during the decade of the 1970's, adjusted for all the effects of general price inflation by using the Gross National Product Implicit Price Deflator and stated in 1979 dollars, increased as follows:

- The price of coal doubled from \$.62 per million BTU's to \$1.33.
- The price of natural gas increased nearly 3½ times from \$.65 per million BTU's to \$2.18.
- The price of fuel oil used by industry increased from \$.84 in 1970 to \$3.46 per million BTU's in 1979 -- an increase of 410%.

Please remember that these are inflation adjusted increases, not actual price increases. For instance, industrial fuel oil prices, before inflationary adjustment, actually increased by 750% during the period.

Energy Revenues

Energy recovered from solid waste in a Volund plant can be delivered in several forms, including hot water, low or high temperature steam, or electricity. The state regulations currently being promulgated in response to Section 210 of the Public Utilities Regulatory Policy Act, or PURPA, should tend to increase the energy revenues a waste-to-energy facility would realize from the sale of electricity to a utility. However, the most valuable form of delivered energy will continue to be steam, particularly steam utilized by industry or for district heating purposes. Using certain technical assumptions, the saleable energy from a ton of refuse is about 5 million BTU's. Assuming a fuel oil price of only $.75 per gallon, this refuse energy has a value of about $28.50 per ton of refuse. At the equivalent fuel cost of coal or natural gas, the saleable energy from a ton of refuse is from $15.00 to $25.00 per ton. Since these energy revenues are income which help offset the debt service and operating cost of a facility, net disposal costs, that is, total costs less energy revenues, will obviously be minimized where energy can be sold as steam at fuel oil equivalent prices.

Thus, it can be seen that basic economic forces are moving in directions that enhance the economic viability of mass combustion systems. The increasing costs of energy will continue to increase the income potential of these energy-producing facilities while the increasing cost of land disposal will make the plant's waste disposal function more competitive with land disposal. These economic forces, which enhance the economic viability of waste-to-energy systems, are most pronounced in major urban areas. In these areas, it is most often found that the cost of energy is high and that the cost of land disposal is high. To service a significant portion of a major urban area, a large capacity facility is likely to be required. While it is recognized that capital and operating costs could vary significantly with various specific locations and requirements, we will examine a typical 1,000-ton-per-day steam-producing facility.

Typical Plant Economics

A typical 1,000-ton-per-day Volund plant would have three lines, each rated at about 335 tons per day capacity. The structure housing the equipment would be of steel and concrete construction, with allowance for office and maintenance facilities. While an inordinate degree of architecture is not assumed, substantial construction is. European waste-to-energy technology has proven to be viable as a long-term disposal and resource recovery option. Therefore, the construction of System Volund facilities will be of the quality to support a plant with an extended lifetime, in excess of 20 years.

A Volund facility of this type would cost approximately $45 million in current dollars, or about $45,000 per ton of daily capacity. Bond reserve and other financing costs would add another $15 million. Therefore, the total project cost would be approximately $60 million.

This plant's capacity at 1,000 tons per day is equivalent to 365,000 tons of refuse annually. Using an 82% availability factor, which is somewhat more conservative than Volund experience has demonstrated, annual throughput will be 300,000 tons of refuse. We will use some reasonable assumptions to analyze the impact of energy credits and inflation on a typical energy recovery plant.

Annual debt service on a bond issue financing this facility, assuming a tax-exempt bond issue at an 8% rate, would be approximately $6 million. On a per ton of refuse processed basis, this equals about $20.00 per ton. Experience suggests operating and maintenance costs in the area of $13.00 per ton would be reasonable. Therefore, total facility costs, debt service at $20.00 per ton and O & M costs of about $13.00 per ton, would be about $33.00 per ton of refuse, assuming 300,000 tons of refuse processed annually. (Reference Table II)

Revenues received from energy sales would provide a substantial offset to these costs. If, for instance, total plant steam output, net of internal use, were sold at $4.50 per thousand pounds, energy revenues would be approximately $22.50 per ton of refuse. Assuming total operations cost of $33.00 per ton, it can be seen that the net disposal cost would be $10.50 per ton of refuse. Thus, in those markets where the combined costs of transfer and disposal exceed $10.50 per ton of refuse, such a facility would be considered viable.

TABLE II

Hypothetical
Waste-To-Energy Plant Costs
Typical 1,000-Ton-Per-Day Plant

Capital Costs	
1,000-Ton-Per-Day Plant	$45 Million
Bond Reserve and Other Financing Costs	15 Million
Total Capital Costs	$60 Million
Cost Per Ton (300,000 Tons Per Year)	
Debt Service @ 8% (Tax Exempt)	$20.00
Operating and Maintenance	13.00
Total Cost Per Ton	$33.00
Energy Revenues Per Ton ($4.50/Thousand Pounds Steam)	22.50
Net Disposal Cost Per Ton	$10.50

Using this basic type of analysis, one can, by adjusting the data for specific plant sites, energy customers, and existing disposal costs, in general terms, determine the viability of a mass combustion waste-to-energy system.

Effect of Inflation on Plant Economics

Reviewing the costs of a waste-to-energy plant, It can be seen that a major portion, about 60%, of the total operating costs will be debt service, which is fixed and will not vary with inflation. Let's assume energy revenues, which are tied to fuel equivalent costs, will increase with a rate at least equivalent to the rate of inflation in general. For example, if we assume overall escalation of 10% per year, then gate fees and energy revenues will double every seven years, while over one-half of the facility's cost structure (that is, debt service) will remain fixed. The beneficial consequences of inflation when applied to a high fixed cost facility are obvious. The escalation of the revenue stream should far outstrip the escalation in variable costs which will be experienced in such a plant, enhancing the cost performance of a waste-to-energy plant in later years.

If one accepts the assumptions that land disposal costs will continue to rise, that land available for landfill will continue to diminish, that the price of fossil fuel will continue to escalate, and that resource recovery facilities will continue to have a high ratio of fixed to variable costs, then, by definition, the economic performance of resource recovery plants will improve in the future.

Economies of Scale in Plant Size

Waste Management and Volund have studied the capital and operating costs of smaller scale Volund plants, i.e., 300 to 800 tons per day, and are convinced that such facilities can be economically competitive with larger scale plants. Without question, both capital and operating costs increase on a per ton basis as the facility is scaled down in size. However, we believe that these slightly higher costs can often be more than offset by certain economies that are associated with smaller plant size.

While some of the world's largest mass combustion plants are Volund plants such as the new 2,000-ton-per-day facility under construction in Moscow, it is interesting to note that, worldwide, over 70 Volund-designed facilities have been constructed, or are currently under construction, that have capacities less than 500 tons per day. Most of these smaller-capacity plants have multiple process lines, enhancing availability and reliability. This same technology can be transferred to North America, and a significant body of economics supports its use.

One significant factor in developing a viable resource recovery system is arranging for an energy customer that is willing and capable of purchasing steam or other energy products at a fair price under long-term contract. The energy customer must have energy requirements that correspond to the energy that can be produced from available refuse. If a waste-to-energy facility can sell only a portion of the energy it produces, the economics of the entire system is degraded. It does little good to find an energy customer that requires 100,000 pounds of steam per hour when the system will produce two or three times that quantity, or when seasonal or daily fluctuations in steam use require that significant portions of steam produced by the facility be dumped.

Those with experience in attempting to locate energy customers know that stable industrial steam users that regularly consume over 150,000 pounds of steam per hour are difficult to find. On the other hand, there are many more steam users that consume 50,000 to 100,000 pounds of steam hourly. Ideally, the resource recovery plant will be sized to provide base load steam demands with the energy customer generating his own peaking needs. Such an arrangement allows the resource recovery plant to sell a high proportion of its available energy, and the economics of the entire system will therefore significantly benefit. The value of energy is such an overwhelming economic factor in the net cost of a waste-to-energy plant that it can easily overcome the relatively minor differences in cost related to a reduced economy of scale. For example, a $1.00 per thousand pound difference in steam price is equivalent to more than $5.00 per ton of solid waste processed, a difference in revenue that would cover a major part of any cost variance resulting from economies of scale. Therefore, solid waste planners should give careful consideration to sizing plants to meet energy customer needs even at the expense of some loss in economies of scale.

Similarly, the cost of hauling waste to a large centralized facility should be taken into consideration. If we assume a cost of solid waste transport of 15¢ to 20¢ per ton mile, and that a centralized plant increases the average haul distance 10 miles over that which would be experienced with two or more smaller plants located closer to waste generation, we see that added hauling costs of up to $2.00 per ton will be incurred. The elimination of this added hauling cost will greatly diminish the differential in cost between small and large energy recovery facilities.

Waste availability is a further consideration. A number of waste-to-energy plants are struggling today, or have not gotten off the ground, because of the difficulty of marshalling the large quantities of waste needed for economic operations. And smaller communities have often not seriously considered resource recovery because they have only 100,000 or 150,000 tons of waste.

We urge consideration of smaller systems for larger communities when it is evident that there will be difficulties in obtaining sufficient waste to justify the ideal, large-scale system. Since less waste is required for the smaller system, there will be fewer institutional problems in obtaining the waste needed and, consequently, implementation delays will be reduced. With the rate of inflation we have been experiencing in recent years, a reduction in the time for system implementation can often result in a smaller facility in place at no more dollars per ton of capacity than the larger system built some time later. As an example, a delay of two years in implementing a resource recovery facility will increase its capital cost at least 20% due to inflationary increases in costs. This may more than offset the extra costs of the smaller plant.

We would also urge smaller communities to look at waste-to-energy systems. We believe that systems designed for around 100,000 tons per year can be as economically viable as larger systems if the energy customer is carefully selected. Cities and other waste producing areas with this quantity of refuse available should study waste-to-energy systems carefully rather than be discouraged by those who say that resource recovery is only for major urban areas.

Project Financing

Financing of capital intensive waste-to-energy projects is clearly a key issue, upon which the success of a project depends. Waste Management is prepared to play a major role in providing the guarantees that are necessary for financing these facilities with project revenue bond financing. Of course, guarantees of energy purchase, refuse availability, and tipping fees must be provided by other project participants. However, Waste Management will participate in project financing and provide various important guarantees.

Waste Management, as prime contractor, will be responsible for delivering the facility at the price agreed upon.

Waste Management, as long-term system operator, will stand behind the operational integrity of the plant. We will provide assurance that the system will deliver the quantity and quality of saleable energy products that are key to achieving planned for energy revenues. We will guarantee to operate and maintain the plant for the duration of the operating agreement. This role requires that we assume significant operating risks, the assumption of which are key to financing the project. We are prepared to assume these risks because of Volund's operating track record which is proven and because of our own experience operating this technology.

And finally, Waste Management is prepared to take an appropriate equity position when such a contribution improves overall project economics. As most of you know, many financing scenarios are predicated on a limited equity contribution by the operator in return for which beneficial tax ownership is obtained by the operator. In principle, all or most of the return on equity investment required by the operator will be obtained from tax credits and accelerated depreciation. In this case, the amount of financing needed for the project is reduced and, therefore, project economics are improved.

Summary

Waste Mangement, Inc. is pleased to represent System Volund in North America. System Volund, as discussed by Mr. Kjaer and Mr. Gilbu, is one of the more proven technologies of its type in the world. It is the result of hundreds of thousands of engineering man-hours devoted to the design and refinement of a waste-to-energy system that has processed millions of tons of waste over the span of half a century.

As indicated, Waste Management will provide System Volund waste-to-energy plants on a full service basis and we will guarantee the operational integrity of the facility. And, where appropriate, we can offer the capability for design and management of the entire solid waste system including transfer and residue and non-combustible refuse landfill.

Figure 1

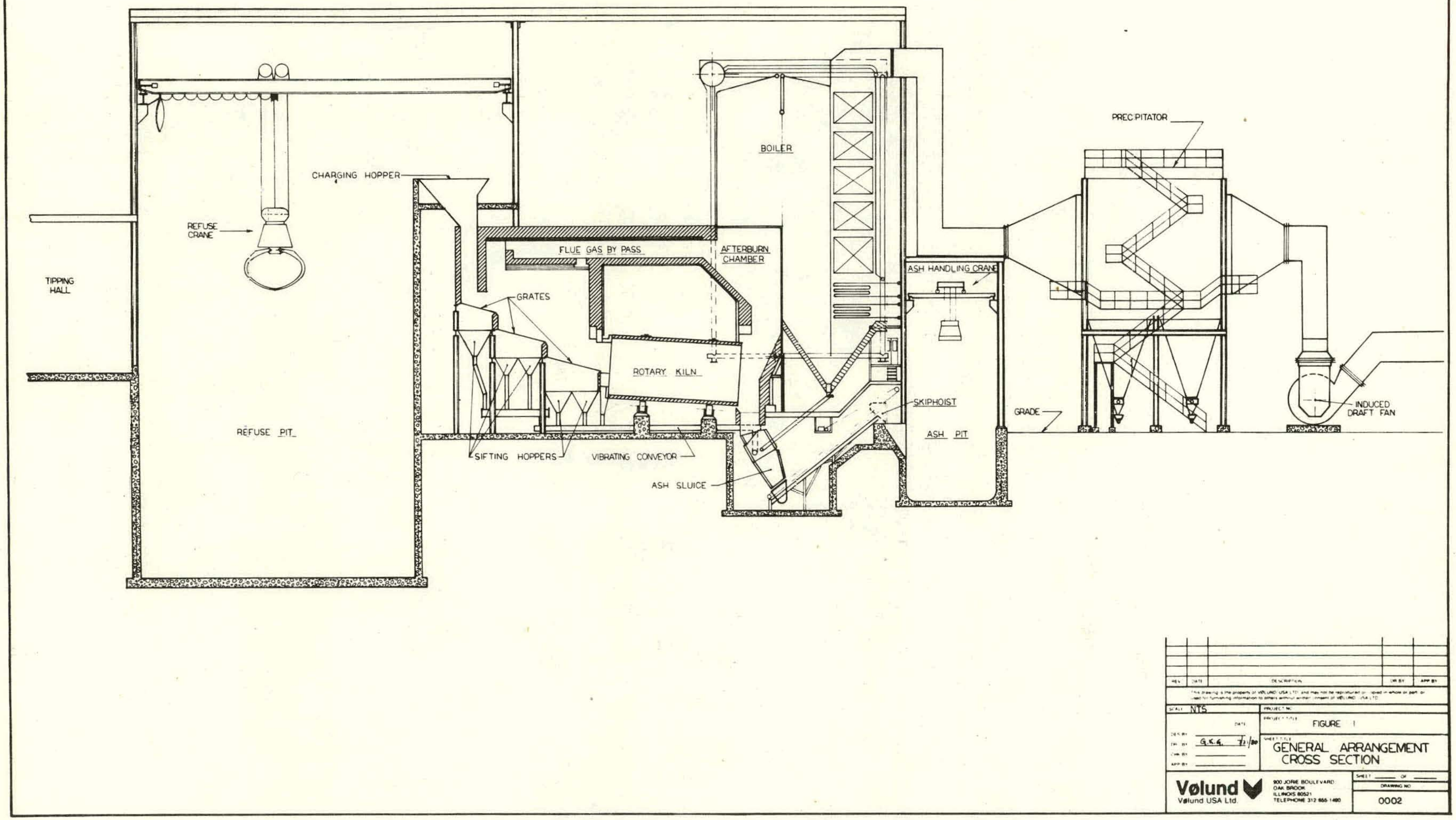

Figure I: System Volund General Arrangement Cross Section

FIGURE 2

TEMPERATURE CORROSION GRAPH

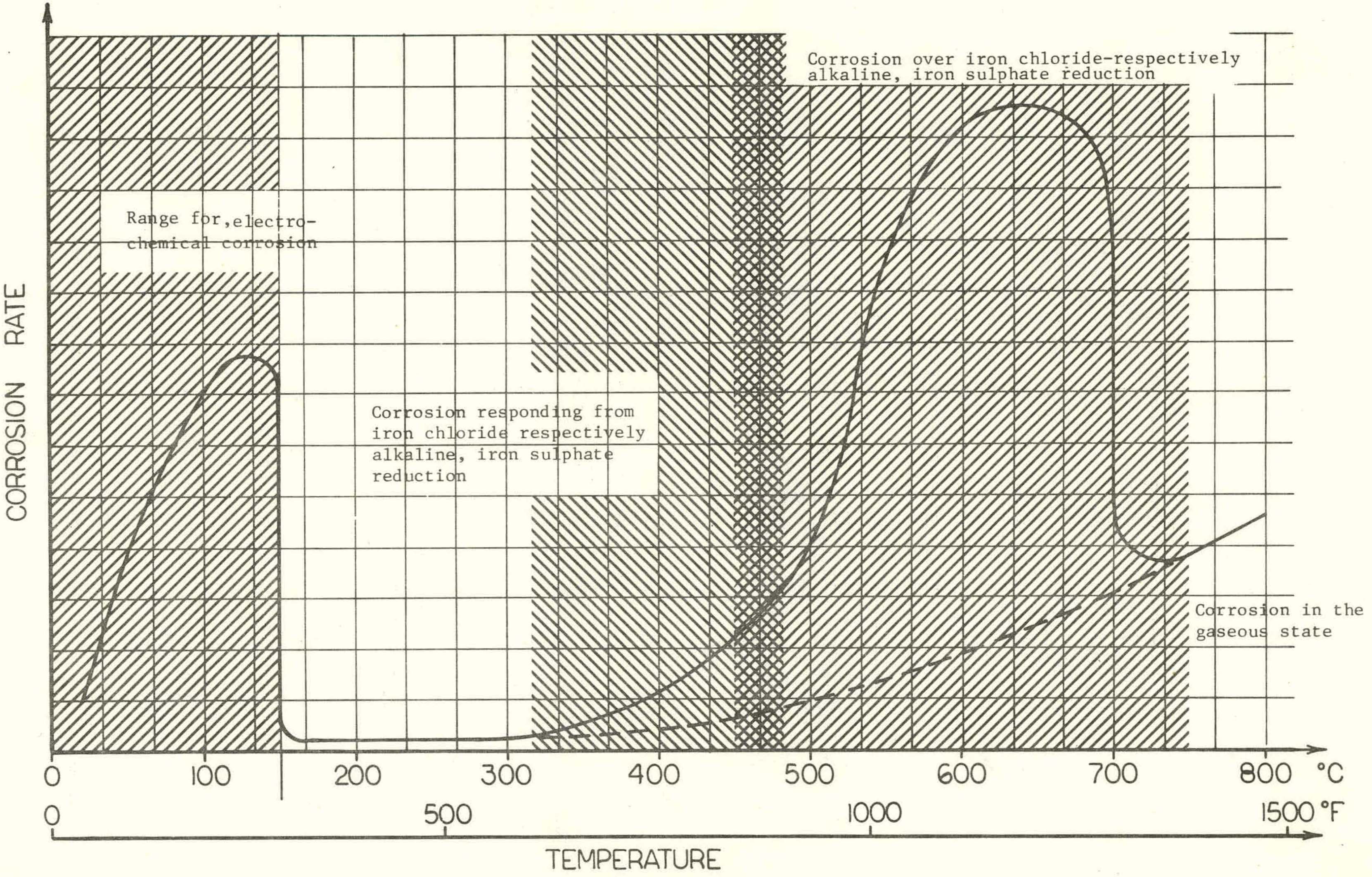

Figure 2: Temperature Corrosion Graph

FIGURE 3

BOILER TEMPERATURE DISTRIBUTION

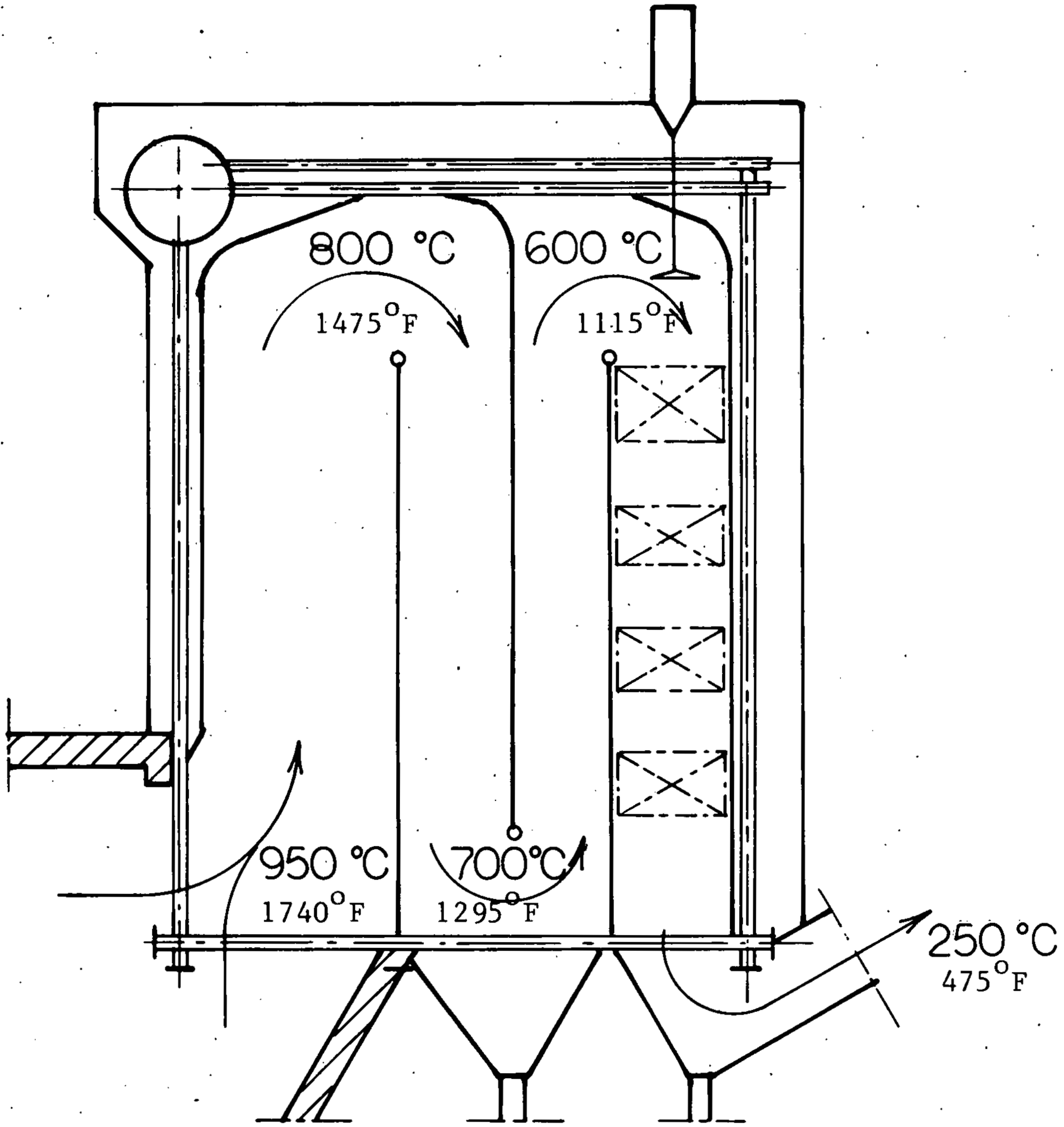

Figure 3: Boiler Temperature Distribution

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SESSION V: CONFERENCE WRAPUP

Moderator: Lanny Hickman (Hickman Assoc.)

Panelists: Henri-Claude Bailly
Richard B. Engdahl
Steve Levy
Charlotte Rines

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This final session provided an opportunity for systems representatives and meeting participants to exchange information and address questions to speakers from each of the three Waste-to-Energy Sessions. Mr. Hickman gave a brief summary of the conference and thanked all participants.

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CORPORATE INDEX