FROM COAL POWER TO REFUSE POWER: THE SUCCESSFUL RETROFIT AT OBERHAUSEN

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ABSTRACT

In 1968, the important Ruhr district city of Oberhausen, together with eight other municipalities formed a regional solid waste management authority. The idea of building a Refuse Power Plant (RPP) was especially appealing, because of the existence of a utility-operated district heating network.

Several years earlier, the local coal mining company had decided to close down its mine shaft operation and retire its adjacent coal-fired power plant. Subsequently, the City of Oberhausen purchased this plant and ordered its retrofit with special grates to permit the firing of solid waste as the sole fuel for the generation of electricity and the supply of district heat.

This retrofit was completed in 1972, and ever since that time, the Oberhausen RPP has provided uninterrupted waste disposal services for a population in excess of 1 million people. Sized for 1,740 tons/day waste input and 23 MW of electrical output, this RPP has compiled an outstanding 7-year operating record. Based on this success and the increased needs of the population served, the authority decided recently to further expand this RPP by installing a fourth processing line.

The Oberhausen RPP is the only plant of its type in the world and it is the purpose of this paper to report on the planning, construction and especially on the operation of this unique plant.

It is the belief of the authors that similar circumstances may exist in some locations in the U. S. and Canada which would also favor such an undertaking [1].

INTRODUCTION

Oberhausen is an important industrial city in the western tier of the Ruhr district, which is the most densely populated industrial region in the Federal Republic of Germany. The Ruhr district is also the largest area of industrial activity in Europe.

Within this densely populated and budding industrial region, the yearly increasing generation of refuse created perplexing disposal problems for the cities and communities involved. If satisfactory landfill spaces could be found at all, they were usually located far away from the refuse collection centers.

Several communities, especially the large cities of Duisburg and Oberhausen, decided to join together in forming the "Solid Waste Disposal Authority of the Lower Rhine" (Zweckverband Gemeinschafts-Müllverbrennungsanlage Niederrhein). This collaboration resulted in the construction of a Refuse Power Plant (RPP) to service the disposal needs of 1.1 million people as well as those of many of the commercial and industrial establishments in the area, provided that their wastes were similar to residential refuse.

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Currently the aggregate of refuse collections amounts to approximately 374,000 tons (340,000 t) per year.

While the Energy Supply Company of Oberhausen was performing a feasibility study for a Refuse Power Plant on behalf of the Solid Waste Authority, a coal mine located within the confines of the City of Oberhausen was closed and its associated power plant became a surplus.

Upon completion of a thorough investigation, it was decided to acquire this conventional, coal-fired power plant and convert it to refuse power [2].

**WHAT IS THE EVO?**

The Energy Supply Company of Oberhausen, or Energieversorgung Oberhausen (EVO) is a stock holder owned company with a founding capital of $35 million (or DM 64 million at the July 1979 exchange rate). This stock is held in equal parts by the Municipal Works Company Oberhausen (Stadtwerke Oberhausen A. G., or StOAG) and the Rhineland-Westphalia Electric Power Company (Rheinisch-Westfälisches Elektrizitätswerk A. G., or RWE). Formation of the EVO clearly demonstrates that a municipality, StOAG, can cooperate fairly well with a private enterprise, RWE, to establish a total energy supply company [3].

Figure 1 shows a map of the City of Oberhausen which is cut by the Rhine-Herne Canal into a northern and southern half. Spreading over a 29.7 square mile (77 km²) area, the city contains three major energy supply installations which are operated by the EVO: Point No. 1 is the site of corporate headquarters as well as of Cogenerating Power Station I. Going in a northerly direction across the map, point No. 3 locates the Oberhausen RPP at the south shore of the Rhine-Herne Canal. In the northern half at point No. 2, Cogenerating Power Station II may be found. The latter attracted world-wide attention in recent years, because it houses the first helium gas turbine built in the world.

The EVO serves a complement of 240,000 residents, 1,500 businesses and 80 industrial plants with over 45,000 employees by supplying all of their gas, district heating and electrical needs. During 1978, the EVO sold gas with an energy content of 2,130 billion Btu (2,247 TJ) and district heat with an energy content of 2,032 billion Btu (2,143 TJ) together with 1.562 million MWh of electricity.

By making the appropriate conversions from thermal energy to equivalent electrical energy, total energy sales by the EVO amounted to 2.78 million MWh of which 43.8 percent were for heat consumers and 56.2 percent for electrical consumers.

**JUSTIFICATION OF THE RETROFIT**

Several reasons mitigated in favor of retrofitting for refuse power rather than constructing a separate and entirely new facility:

1. Substantial structural elements of the existing power plant could be retained and incorporated, thus permitting a significant reduction in the requirement for investment capital.

2. The central location of the existing site afforded easy access to the other participating communities via the turnpike, or Autobahn network.

3. Additional land was available for purchase so that the existing acreage could be increased from 462,850 ft² (43,000 m²) to 592,000 ft² (55,000 m²).

4. Closeness to other EVO-operated energy facilities permitted the sale of all the energy to be generated from refuse power, be it in form of electricity or steam. No new service connections such as construction of a thermal transfer system were required.

5. The incorporation of existing structural elements would lead to a sharp reduction in the construction period, thus extending the life of existing landfills.

6. Simplification of the licensing process could be accomplished by continuing power generation at a site already permitted for that purpose rather than obtaining a new site and initiating a separate and more tedious licensing process.

7. Organizational efficiencies could be utilized by contracting with the local utility company with proven capabilities to perform both the planning and the engineering tasks and to provide construction management thereafter.

**CONSTRUCTION PLAN AND REQUIREMENTS**

In the following, the requirements for the incorporation of existing and the construction of new structural elements are discussed.

The boiler house, the heart of any steam power plant, could be retained, complete with three existing boilers. The firing system, however, had to be changed.
1. Corporate Offices & Cogeneration Station I at Danziger Strasse
2. Cogeneration Station II With Helium Gas Turbine Friedrichstrasse
3. Refuse Power Plant Buschhausener Strasse

FIG. 1 ENERGY SUPPLY COMPANY OBERHAUSEN – SERVICE AREA
The derating of boiler operating conditions from 986 °F (530 °C) and 1218 psig (8.4 MPa) to 932 °F (500 °C) and 870 psig (6.0 MPa), respectively, promised long equipment life after the retrofit. This promise would hold true even for the highly stressed boiler parts and, in the face of the encumbrances usually associated with the firing of refuse, a rather difficult fuel.

Considering the fact that the existing boilers had already accumulated 80,000 operating hours, this retrofit would pose a tough challenge to the new plant operator.

The existing turbine house with two back-pressure turbines of 2 x 16 MW = 32 MW installed capacity could be taken over in the same condition in which it was left by the coal mine operator. The same applied to the high and low voltage switch gear.

The feedwater system remained intact, complete with demineralizers, degasifiers, storage tanks and pumps. Likewise, a new piping system interconnecting boilers and turbines would not be required, because of the existing one.

The old facility was already connected to the city water supply as well as to the nearby Rhine-Herne Canal for its supply of cooling water. City sewer connections provided for the collection and treatment of waste waters.

Social accommodations, including offices, lunch rooms, shower and dressing rooms together with storage spaces and repair shops were also left by the previous owners.

On the whole, it can be estimated that the retrofit, when compared to a new plant of the same size, saved at least $12.5 million (DM 40 million at average 1972 currency exchange rates).

New construction encompassed the following elements: scale house, refuse storage bunker, roller grates and ash extractors, new electrostatic precipitators and a chimney (the old equipment could not meet the new environmental protection requirements), instrumentation systems for process measurement and control and an air condenser unit (to reduce thermal pollution and to improve turbine control).

In accordance with the plans outlined above, the EVO succeeded in delivering an operable, new plant in only 22 months, which must be considered as record time. This included project planning, detailed design and final assembly.

Figure 2 is an aerial photograph of the Oberhausen Refuse Power Plant after its completion.

After this accomplishment in 1972, it came as no surprise that the owner of the plant, i.e. the Solid Waste Disposal Authority, also contracted with the EVO for the long-term operation of the plant.

DESCRIPTION OF MAJOR FACILITIES

In the following text, several major facilities within the RPP complex are described by highlighting important structural features and by discussing significant operating experiences associated with these features [4].

TIPPING AREA AND REFUSE STORAGE PIT

Up to 600 vehicles per day dump their refuse loads into 10 ram feeders which are mounted in front of the refuse storage pit. In each case, two dump positions are combined into a single concrete walled box and the hydraulically actuated ram pushes the dumped refuse into the storage pit. This ram feeder approach is convenient and quick and it permits discharging of at least 120 vehicles per hour; its performance has been entirely satisfactory and no problems have been encountered.

There are a total of seven such boxes, five of which are used for regular refuse and two of which are reserved for bulky wastes or serve as access ways to the pit.

Besides moving refuse, the ram feeders also provide positive means for closing off the entrance ways to the storage pit. Since combustion air for the furnaces is constantly drawn off the storage pit, closure action by the rams results in a negative pressure of approximately 0.4 in. of water column (100 Pa) inside the pit.

This method is superior to dumping through wall openings, as is evidenced by a notable absence of the odor usually associated with the tipping of refuse.

Figure 3 provides a view of the tipping area, and Fig 4 plots the number of vehicles which annually pass through the tipping area for processing. While the trendlines indicate a steady growth in the total number of vehicles, the most pronounced increase is in the number of residents and small businesses who haul their own refuse in small vehicles, i.e. passenger cars and pickup trucks.

BULKY WASTE REDUCTION

Bulky wastes are reduced in size by two hydraulic shears. As in the case of the aforemen-
tioned five boxes for residential wastes, the bulky wastes are dumped into a receiving chamber from which a hydraulic ram moves them towards the pit by gradual motion. Inside the chamber, a hold-down blade and a cutting blade work in unison to shear apart the bulky wastes (Fig. 5).

The first shear develops a downward force of 275 tons (250 t) and permits a throughput of 157 cubic yards (120 m³) per hour with a power draw of 150 kW for medium waste densities. The receiving chamber is 11.5 ft (3.5 m) long. Because of increased deliveries of bulky wastes, it was necessary after only 4 years to install a second shear. This new shear develops a maximum downward force of 440 tons (400 t), permits a throughput of 294 cu yd (225 m³) per hour and draws 300 kW. The receiving chamber is 19.7 ft (6 m) long in order to accommodate large bulky waste transports, so that discharging can be accomplished — without waiting — in a single shot.

In the Oberhausen RPP, bulky wastes account for about 12 percent by weight for all deliveries. Up to 150 vehicles a day feed into the two shears and by the end of 1979, a total of 264,000 tons (240,000 t) of bulky wastes will have been reduced in this fashion.

Both shears have performed well. Thus far, little maintenance has been required and, aside from considerations of operating economics and questions regarding equipment availability, the shears have demonstrated a decisive advantage over shredders: dust generation is kept to a minimum, unlike shredders where increased dust generation leads to fires and explosions in the refuse storage pit.

REFUSE STORAGE PIT

The refuse storage pit represents one of the major pieces of new and heavy construction required at the old mining power station. Unlike coal which can be stored outdoors in the so called coal pile, the refuse fuel must be stored inside under carefully controlled conditions to avoid odor, dust, moisture and vector problems.

The useful pit storage volume inclusive of provisions for stacking amounts to 423,600 ft³ (12,000 m³). When using a density of 25.0 lb refuse/cubic foot (400 kg/m³) this storage capacity corresponds to the delivery of refuse during a four day interval.

As Figure 6 clearly indicates, additional stacking space can be made available in case of disturbances in plant operations simply by temporarily prohibiting the dumping into several of the boxes. The cranes can then be used to stack high and across the entire width of the pit to gain additional capacity if required.

PIT CRANE SYSTEM

The two bridge cranes in the refuse storage pit can carry 11 tons (10 t) each and span 73.2 ft
Both cranes are fitted with poly grabs which consist of 6 individual arms. Once half way closed, these grabs can hold 9.2 cu yd (7 m³). The grabs must discharge their loads approximately 16.4 ft (5 m) above the pit floor into the furnace feed chutes. A trough must always be kept clear of refuse in front of the discharge position in order to minimize fire hazards.

The drive mechanism for the grab is semi-automated in such a way that the crane operator merely needs to initiate downward motion. As soon as the grab bottoms, the lift motor is switched off automatically regardless of refuse height and slope. In this manner, slackening of the cable is avoided, so that the grab is stabilized. A slackened cable is wear-prone and permits toppling of the grab. This automatic control relieves the operator since he no longer needs to concentrate on switching off the lift motor upon bottoming of the grab.

Both cranes, each of which can supply every boiler, are electrically interlocked, so that collisions are excluded. If a minimum separation is not maintained, then the drive motors for both cranes will shut off.

Initially, relatively high wear of the cables was experienced, but this situation was alleviated by improvements in cable guidance and better operator training. The following determinations can be made for cable life:

- **Crane holding cable**: 111.5 ft long x 0.75 in. diameter (34 m x 19 mm): 1.5 - 2.0 months
- **Upper closure cable**: 121.4 ft long x 0.75 in. diameter (37 m x 19 mm): 3.0 - 4.0 months
- **Lower closure cable**: 52.5 ft long x 0.75 in. diameter (16 m x 19 mm): 12 - 15 days

The crane system is designed for the following operating speeds:

- **Lifting/Lowering**: @ 197 ft/min (1 m/s)
- **Closing of Grab**: @ 197 ft/min (1 m/s)
- **Grab Movement**: @ 164 ft/min (0.83 m/s)
- **Bridge Movement**: @ 262 ft/min (1.33 m/s)
REFUSE GRAB

The four-cable poly grab with a shell capacity of 9.2 cu yd (7 m³) was a good choice both for feeding the boilers and for transferring and/or mixing of refuse in the pit. By constructing the grab of 6 semi-open blades, a high degree of filling is guaranteed. Each grab can hold between 3.3 and 3.9 tons (3.0-3.5 t) of refuse. Because of steady use, the moving parts and the surfaces of the 6 blades are especially exposed to increasing wear. A spare grab permits necessary repairs on the two primary grabs without restricting operations. During rush hours, 9 AM to 2 PM, up to 10 grab loadings are performed each minute.

In the course of a year, the three boilers are fed with about 100,000 grab loads at an average weight of 3.5 tons (3.2 t). To this, one must add approximately double the number of grab loads for refuse transfer and stacking operations. It follows that the total number of grab movements per unit and year reaches about 150,000 operations, whereby each operation consists of one complete lowering, opening, closing, lifting and opening sequence. During the first years of operation, wear was accordingly rather high.

In order to reduce wear of the blades, honeycombed plates made of hard manganese steel were welded to the outside and bars made of a steel commonly used in construction for structural members were welded to the inside. This modification was highly successful.

FIRE CONTROL SYSTEM FOR REFUSE STORAGE PIT

For the purpose of extinguishing pit fires, four fire fighting cannons are positioned so that each cannon can reach every corner of the pit. By adding a foaming compound to the flow of water through the cannon, a blanket of foam can be laid over the refuse surface near the fire center. As a result, fires are smothered rather than drenched. This tends to minimize the influx of water into the boiler fuel.

The water supply for fire fighting has several backup arrangements. The first choice would be to draw water off the nearby Rhine-Herne Canal, but failing to do so, the switch-over could be made to the city water supply. As a final resort, water from a storage tank with a 45,000 gal. (170,000 l), capacity can be used.

In case of a fire in the refuse feed chutes leading to the boilers, foam water nozzles can be actuated which are arrayed above the chutes.

All fire fighting equipment is controlled by hand from positions either in the crane control rooms or from the hallways outside the storage pit. During a monthly fire drill, operating personnel check the performance of the system.

Another important feature for fire control is the installation of 10 flaps for the exhaust of smoke and heat. These flaps have gas powered actuators which respond rapidly to signals originating either in the crane control rooms or from the shear control consoles outside the storage pit.

During fire fighting, smoke often impedes the operator's ability to aim straight into the center of the fire. In spite of the effectiveness of the flaps in exhausting smoke, new smoke evolving around the fire center reduces visibility to the point that much water streams past the fire and into the pit. In order to improve equipment targeting, instrumentation is being deployed which can properly locate a fire center.

Actual experience indicates that if a fire center is located deep below the surface, attempts to exclude air by the foam blanket method are usually futile. This happens because the refuse contains sufficient oxygen and water does not penetrate well enough.

The most successful method has been to deploy the cranes for removal and lateral deposition of cover material until the fire center is fully exposed. Thereafter, the fire center can be attacked directly.

Up to the present time, large fires have not occurred.

REFUSE FEEDING

Before charging refuse into the furnace feed chutes, it is the responsibility of the crane operators to mix the refuse in the storage pit to a reasonable consistency. This task requires visual acuity and good judgment because well mixed refuse facilitates complete burnout and steadiness of steam production, two requirements which make the crane operators the key to successful RPP operation. It is also the duty of these operators to spot foreign and oversized objects in order to avoid chute blockage and/or grate damage.

Figure 7 shows a typical feeding system of which there are three, one coupled to each boiler. The feed chutes must always be kept filled by the crane operators who can look directly into the
Refuse chutes by means of television monitors mounted in their respective control rooms. A feeding table serves as the bottom to the feed chutes as well as the transition piece to the upper part of the roller grates. Two hydraulically driven rams move across these tables to push refuse out of the chutes and onto the upper rollers.

After reinforcement of the guide rails for the rams, no unusual problems have been observed in the feeders. Fires have not occurred inside the feed chutes. This fact, as well as the cooling of the chutes, is mostly due to the fact that the Oberhausen RPP uses the parallel flow principle for the furnace, i.e., refuse fuel and hot flue gases are moving downward together and away from the feed chutes. As a result, the combustion zone is kept ostensibly out of the area adjacent to the feeders. Most RPP's, however, do not enjoy this advantage because they are built for counter-flow.

ROLLER GRATE SYSTEM

The roller grate system of the type "VKW Düsseldorf" was selected as the firing system for all three boilers. This type of grate system has found application in over 120 refuse incineration units around the world today. Each grate system is furnished with six consecutive rollers which are mounted at an angle of 30 deg. down from the horizontal plane, see Fig. 8.

All rollers are of identical construction with a diameter of 4.9 ft (1.5 m) and a length of 16.4 ft (5 m). Each roller consists of a hollow shaft which terminates in a bearing on either side external to the furnace chamber. Each shaft is surrounded by a cage on which curved grate bars are fastened, about 1000 pieces per roller.

Combustion air is admitted to the rollers from individual supply ducts underneath each roller.

The rotational speed of each roller can be individually adjusted from the central control room in a stepless fashion. This approach permits the matching of roller speed, and with it, refuse retention time to variations in refuse composition, thus optimizing the combustion process.

The roller system proved its excellence because of the following characteristics:

1. Loss of ash or riddlings through the rollers is extremely low.
2. Only 50 percent of the roller surfaces are exposed to the high temperatures of the furnace chamber while the other 50 percent are being cooled by the incoming combustion air.
3. The grate is insensitive to foreign particles in the refuse, such as sharp edged steel pieces, because there is no relative motion in between adjacent grate bars.
4. Wear on the grate bars is low because the refuse is evenly distributed and is transported from the feeder through the fire zone to the ash tank largely without friction.

In addition to long grate life, this method of firing limits dust loading of the raw flue gases to 2.2 gr/standard ft³ (5 g/Nm³).

The rates are designed for a processing rate of 24.2 tons/hr (22 t/h) of refuse with a lower heating value of 3956 Btu/Lb (9200 kJ/kg). It is interesting to note that, much like in other European RPP's, Oberhausen experienced a rather steady growth in the heating value of refuse. From 2600 Btu/Lb (6062 kJ/kg) in 1972 the average annual heating value climbed to 2910 Btu/Lb (6765 kJ/kg) in 1979.
FURNACE CHAMBER CEILING

The former coal mine operator had used slag tap furnaces underneath his boilers. During the retrofit, these furnaces were removed while the existing boilers together with their supporting steel structures were retained. This arrangement necessitated construction of new furnace chambers of a particular shape: a ceiling made of studded membrane tubing which slopes downward at the same angle as the roller grate system and terminates at the entrance to the first boiler pass.

Major parameters for the construction of the furnace chamber ceiling are presented in Table 1.

Originally, plastic refractory (Stampfmasse) of the formulation SIC 90 (a silicon carbide material with fire-proof clay as a binder) was tamped into place in a manner which covered the ends of the studs with a 0.08 to 0.12 in. (2-3 mm) thick layer. After approximately 2,000 operating hours, incipient cracks appeared which spread in a honeycomb pattern from stud to stud causing peeling over wide areas.

During an extensive investigation, different formulations of the SIC material were tested ranging from SIC 70 to SIC 90, however, all these efforts were unsuccessful.

Upon close examination of the failed materials, it was observed that separation and peeling of the refractory was mostly due to corrosion on the studs themselves.

Because of the relatively low temperature in the ceiling region, sufficient protection of the studs through sintering of the plastic refractory cannot be achieved. Therefore, a manufacturer of plastic refractory was asked during May 1975 to produce little protective cups made of pre-sintered and highly fired SIC 90 material. These special, half-ceramic cups were then slipped over the studs and fastened with a special, fire-proof cement which has a high alumina content.

Pre-sintered cups of this type (see Fig. 9), were installed for the first time at the Oberhausen RPP to cover several test patches. After 10,000 operating hours, it was concluded that portions of the ceiling which had been fitted with the protective cups and the SIC 90 plastic refractory did not show any visible alterations.

Based on this success, the entire furnace ceilings of each of the three boilers were fitted with the protective SIC - cups and the SIC 90 plastic refractory.

When covering the tubing lined ceilings with protective cups, only 74 studs per square foot (800 studs/m²) are required in contrast to the old method without protective cups which required 279 studs per square foot (3,000 studs/m²).

The extra cost associated with the use of protective cups is more than compensated for by the reduction in boiler downtime and the lower studding density. After 5 years of operating with this new type of ceiling construction, it can be stated, without reservations, that this method was an outstanding success.

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**TABLE 1 OBERHAUSEN RPP – FURNACE CHAMBER – CEILING CONSTRUCTION**

<table>
<thead>
<tr>
<th>Tubes</th>
<th>1.75 inches outside diameter X 0.177 inch wall thickness (44.50 mm X 4.5 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>92</td>
</tr>
<tr>
<td>Spacing</td>
<td>2.17 inches (55 mm)</td>
</tr>
<tr>
<td>Maximum width</td>
<td>16.4 feet (5,000 mm)</td>
</tr>
<tr>
<td>Contiguous length</td>
<td>27.2 feet (8,000 mm)</td>
</tr>
<tr>
<td>Area</td>
<td>452 square feet (42 m²)</td>
</tr>
<tr>
<td>Tubing material</td>
<td>Steel Number 35.8 III</td>
</tr>
<tr>
<td>Studs</td>
<td>0.39 inch diameter X 0.47 inch length (10 mm X 12 mm)</td>
</tr>
<tr>
<td>Number</td>
<td>280 pieces per square foot (original design) (3,000 pieces/m²)</td>
</tr>
<tr>
<td>Stud material</td>
<td>Sicromal 10</td>
</tr>
</tbody>
</table>
Fouling of the heat transfer surfaces on the flue gas side of the boilers is a major factor due to deposits. Maximum times between required mechanical cleanings are limited to between 2500 and 4000 operating hours per boiler. On their way through the boiler, the flue gases encounter the following arrangement:

a. First vertical pass, pointing upward and furnished with evaporator tubes.

b. Transverse pass, furnished with superheaters 1, 2 and 3.

c. Second vertical pass, pointing downward and furnished with four economizer bundles and two preheater bundles.

Fourteen steam-powered soot blowers are mounted in front of these heating surfaces and they are operated once per shift and boiler. Blower steam conditions are 752°F and 363 psig (400°C and 2.5 MPa).

The flue gas originated deposits grow during the times between mechanical cleanings to a thickness of several inches and exhibit increasing hardness in the direction of the boiler exit. The hardest deposits are found on the economizer bundles where they form a tough fly ash skin which is difficult to dislodge. In contrast, deposits on the preceding superheater surfaces are loose and soft; they separate easily from the tubes and can be manually pulverized.

In the opinion of the operator, these strong and durable deposits are caused by the addition of moisture during soot blowing, a detrimental effect which cannot be avoided in spite of thorough measures for dewatering.

Deposits from heating surfaces coupled to the outlet side of the boilers were subjected to chemical analysis which showed that their composition is essentially one of zinc, calcium and iron sulfates. The sulfate compounds especially promote sintering or hardening at temperatures around 752°F (400°C) which, in extreme cases, demonstrates a rock-like quality.

Because of this negative experience, the new and fourth boiler which is presently in the design phase was originally configured with soot blowers powered by dry air. However, because of the higher investment and operating costs involved, the decision was made to continue with steam powered blowers.

The boilers are cleaned mechanically between 3 to 4 times each year, a procedure which requires one week if done on a single shift basis.

**PROTECTION OF BOILER TUBING AGAINST CORROSION AND EROSION**

The pressure parts of the boilers were originally installed in 1954 and they had already experienced 80,000 operating hours prior to the retrofit. After the retrofit and an additional 40,000 operating hours, it can be reported that corrosion did not cause any damage of consequence.

Small tube damage which occurred in the superheaters could be attributed, without doubt, to erosion. Critically exposed tube sections were armored with half shells so that few tubes needed replacement thus far.

However, tests are underway to further improve this situation. During 1979, several superheater tubes, armored with half shells to ward off the brunt of flue gas-induced erosion were removed. In their place, studded tubes with protective cups were installed upon which type SIC 90 plastic refractory was tamped to form a shield similar to the furnace ceiling construction method described above.
Superior protection is expected against dust erosion from this plastic refractory because the half shells previously used did not establish a tight fit around their carrier tubes. Because of poor heat transfer properties, this inevitably resulted in substantial flaking and abrasion.

Considerable tube failures occurred in the 180 deg. bends of the economizer tube bundles. A spacing of 2.76 in. (70 mm) in between adjacent tubes was satisfactory for coal firing, but it did not suit the needs of refuse firing. Increased tube deposits narrowed down clearances between tubes, accelerated the flow of flue gases and diverted the flow of flue gases into the passage ways between boiler wall and tube bends.

As a remedy, protective sheet metal strips made of Sicromal were mounted above the economizer bundles to cover up the passage ways between boiler wall and tube bends. This method has been successful, as is evidenced by the fact that to date, no damages of significance have been observed.

The fact that the Oberhausen boilers showed little, if any corrosion can be attributed to the parallel flow of refuse fuel and flue gases along the grate, the stable combustion on the rollers and high excess air (typically 90%) which the operator prefers to use. Air flow to the boilers is controlled so that an oxygen residual of 13 percent is maintained in the flue gases at the boiler exit. It is realized, of course, that increased volumetric flow in consonance with increased gas velocities could conceivably cause accelerated erosion. The operating results reveal, however, that a good compromise has been effected by the aforementioned choices.

**FLUE GAS COMPOSITION AS A FUNCTION OF BOILER LOCATION**

The relationship between CO and O₂ content of flue gases varies as a function of distance from the boiler entrance. This relationship is illustrated by Fig. 10.

Actual measurements prove that flue gas streamers with incomplete combustion cannot be excluded from the immediate vicinity of the roller grate system. Especially at measurement point 1 directly above the third roller, the CO₂ excursions clearly followed the rhythm of the rams feeding refuse onto the first roller. This phenomenon was equally pronounced further down at measurement point 2 which was positioned above the end of the grate system.

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**FIG. 10 OBERHAUSEN RPP – MEASUREMENT OF CO AND O₂ IN FLUE GAS AT DIFFERENT BOILER & GRATE LOCATION**
At the entrance to the first boiler pass, wall projections are provided which are shaped in a certain way to induce turbulence. This turbulence is further augmented by the injection of secondary air through an array of nozzles placed in the same restricted area. Such strong turbulence produces flue gas mixing and effects a two-fold reduction in CO content. Measurements at point 3, which is located high up in the first boiler pass at the border of the plastic refractory, indicate that the average level of CO concentrations is sharply reduced, both in terms of its average level as well as in terms of excursions from this level. The CO content of the homogenized flue gases is maintained between 0.01-0.08 percent by volume.

Flue gas flow per boiler was measured at 5,300,000 standard cubic feet per hour (150,000 Nm³/h) with a CO₂ content of about 8 percent by volume.

**REFRACTORY MAINTENANCE**

During reconstruction of the three slag tap furnaces, all remaining refractory walls were carefully examined and defective parts were repaired. The brick work which makes up the side walls rests on pedestals and is fastened to the boiler frame with anchors. The boiler roof consists of fire bricks and insulating masonry which is held in place by tubing in the ceiling. Tubing penetrations and fasteners are sealed with injected plastic refractory. The side walls, for the better part, are constructed as hollow walls and serve as the receptacles for the downcomer and riser tubes which connect into the upper steam separation drums.

The converted boilers did not operate for long before the first failures appeared in the masonry. The trouble spots were identical for all three boilers: fly ash had entered into hollow spaces of the side walls and caused bulging towards the inside. This was especially true for the transverse pass. A fix was made by installing fire-proof plastic refractory in lieu of the fire bricks, and by filling insulating concrete into the hollow spaces.

After about 18,000 operating hours, strong gas leaks developed at the boiler ceilings. Lining the ceiling with spray insulation of 2.76-3.94 in. (70-100 mm) thickness proved to be a highly effective countermeasure together with a fine and sintered coating of 0.20 in. (5 mm) above the fire brick, or rather insulating concrete layers.

All tubing penetrations and fasteners in the boiler ceiling could be successfully sealed gastight by such spray insulation of high elasticity.

Figure 11 shows a special rig holding a test block which was covered with spray insulation. The right half was also cemented with the fine sintered coating while the left half was not. After spreading soap and water over the entire surface, nitrogen gas was blown into the block from below. As can be seen from Fig. 11, the coated side on the right definitely remained impervious to gas penetration. These positive test results were confirmed later on in the boilers under actual operating conditions.

**AIR CONDENSER FACILITY**

The air condenser facility (better called “air cooled” condenser facility) consists of two parallel trains in which a total of 132 tons/hr (120 t/h) of steam can be condensed.

The purpose of the air condenser facility is to ensure that even during the summer when customers purchase a minimum of steam, the RPP will live up to its primary responsibility which is to dispose of all the refuse delivered into its pit. The same would apply in the event that the condensation-extraction turbine needs to be shut down for service.

The condensate is collected and returned to the boilers as feedwater. The heat given up by the condensing steam is rejected to the atmosphere by means of 12 pole reversible axial flow fans which
force cooling air over the finned tubing of the radiator panels.

This finned tubing is spirally wound and made of St 35.8 which is hot galvanized on the outside in order to provide protection against corrosion. This galvanized layer, however, is only stable at temperatures below 428 F (220 C). On account of this limitation, the steam entering into the condenser must be cooled by injection coolers to 392 F (200 C).

During failure of the injection coolers in one of the trains, increased temperatures destroyed the galvanized layer and subsequently the fins of the now exposed tubing corroded with increased frequency. In order to avoid such trouble in the future, the damaged tube bundles were replaced by finned tubing made of aluminum, a method which has shown excellent results.

During the past years, the air condenser facility served mainly as a back-up system since it was used only during a few days each year, a fact which also speaks highly of the success of energy marketing by the EVO.

Figure 12 presents a view of the air condenser facility.

ENERGY RECOVERY FOR COGENERATION

Figure 13 shows the heat flow diagram of the Oberhausen RPP. During the first phase of construction, the three original boilers were modified for a refuse processing capability of 24.2 tons/hr (22 t/h) each for a plant total of 3 x 24.2 x 24 = 1,742 tons/day, (1,584 t/d). Each boiler is of identical construction and has a maximum steaming capacity of 55 tons/hr (50 t/h), or 110,000 lb/hr (49,900 kg/h) at conditions of 932 F (500 C) and 870 psig (6.0 MPa). Space is provided for a fourth and new boiler which is presently undergoing licensing procedures.

The first owner of the power plant had provided two 16 MW back-pressure turbines, but their selection was keyed to coal fired boilers which operated at higher steam conditions, i.e., 986 F (530 C) and 1218 psig (8.4 MPa). However, after conversion of the plant to refuse firing, the lower steam conditions discussed above were preferred.

As a result, only a maximum of 8 MW could be generated with either turbine. Furthermore, because of appreciable fluctuations in the flow of refuse derived steam, the air condenser facility had to be operated at all times. This was necessary in order to reject excess heat during flow peaks and to protect the steam customers against surges.

It was then decided to replace one of the 16 MW back-pressure turbines with a 23 MW condensation-extraction turbine so that operations could be simplified. Since this turbine permits optimum use of all steam for electrical and thermal energy...
delivery, the potential for energy conservation was also enhanced.

The other remaining 16 MW back-pressure turbine was derated to 8 MW and retained as a back-up unit. Due to the flexibility of this revised arrangement, nearly all the steam generated flows through the turbines.

Steam for industry and utility use can be withdrawn from two points, either downstream of the high pressure section of the condensation-extraction turbine or from the discharge side of the back-pressure turbine. In either case, the steam at 662 F (350 C) and 145 psig (1.0 MPa) is delivered via a cross country line to industrial consumers including the headquarters and manufacturing complex of Deutsche Babcock A. G., the manufacturer of the boilers and grates used in the Oberhausen RPP.

At the terminus of the steam cross country line, approximately 1 mile (1.5 km) from the Oberhausen RPP, is a thermal transformer station which couples the steam line with city-wide thermal transfer system operated by the EVO. Steam which is not needed by the industrial customers, who always have priority, is fed into condensing heat exchangers on the primary side of this transformer station while pressurized hot water from the district heating loop circulates through the secondary side. In this arrangement, steam coming from the RPP gives up its heat while condensing and then returns as condensate to the RPP feedwater system. The heat given up, however, is absorbed by the hot water loop and transferred to a large number of residential and commercial customers elsewhere in the city.

Surplus steam which is not needed for heating purposes continues on its path through the low pressure section of the condensation-extraction turbine to generate more electrical power. It is also possible to utilize the entire steam production for electrical power generation in the 23 MW turbine. Generally, the back pressure turbine is held in reserve and will be operated only during downtime of the condensation-extraction turbine. This turbine is depicted by Fig. 14.
This cogeneration concept is extremely flexible and assures the Oberhausen RPP that all the energy recovered from waste disposal can always be sold in the market place, a concept which next to high equipment availability and outstanding plant productivity, has been the cornerstone of the Oberhausen success story.

Figure 15 relates the history of refuse derived steam generation at the Oberhausen RPP. The production time for 1973 shows the split in the usage of steam for electrical power generation, district heating, industrial needs and RPP in-plant requirements. This split is typical and is, therefore, not repeated for the other years.

The fact that annual steam production rates increased with every consecutive year can be explained by referring to the increase of calorific value of the refuse, which was previously discussed, and high equipment availability. The latter is the result of good operator performance and the many structural improvements previously described. In other words, the persistent efforts by the EVO not merely to replace failed components, but to substitute new and better components paid off at the production end.

AIR POLLUTION CONTROL: PRESENT AND FUTURE REQUIREMENTS

Each of the existing three processing trains is equipped with an electrostatic precipitator (ESP) just downstream of the boilers; these ESP's are rated at 99.5 percent particulate removal efficiency for an influent loading of 2.18 gr/standard cubic foot (5 g/Nm³). After filtration, the flue gases are conducted through a 459 ft (140 m) high chimney into the atmosphere. The ESP ratings are set for a volumetric flow per boiler of 4,690,000 standard cubic feet per hour (130,000 Nm³/h).

Table 2 deals with the limits for pollutant emissions from this stack as they were stipulated by the local licensing board. The column “Past Regulatory Requirements” lists the limiting values which govern the first three processing trains completed in 1972.

Measurements performed on a regular basis confirm that actual emissions stayed well below their limiting values. For example, the concentration in the effluent flue gas stream averaged approximately 0.033, 0.349 and 0.066 grains/standard cubic foot (75, 799 and 150 mg/Nm³) for particulates, HCl and SO₂ respectively. The maximum emissions measured are also within limits as is shown in the third column of Table 2.

Several years ago, measurements were taken at different points of the flue gas stream within the boilers which indicate that the HCl content decreases along the boiler path. A drop of 20 to 25 percent was measured between boiler entrance and exit, a phenomenon which can be best explained by referring to the absorptive qualities of the fly ash.

Tougher emission requirements are expected for the fourth and new processing train, i.e. with the exception of particulates, all other limits have been lowered and new parameters have been added for monitoring. This new development, presented in the fifth column of Table 2, is the result of new technical guidelines promulgated by the German Federal EPA in 1974 which are known as “TA Luft 74”. These guidelines will be augmented with requirements set forth by the local licensing board. In this regard, the requirements for NOₓ, CO and organic C are particularly noteworthy [5].

In order to meet these extremely low concentrations, special scrubbers need to be added to the ESP's previously used. Two types of scrubbing systems were carefully investigated prior to making any equipment selections: wet scrubbers versus dry scrubbers.

The basic wet scrubbing system consists of one or more washing towers through which the flue gases must flow. These towers are filled with layers of packing materials upon which atomized water droplets are sprayed in a direction counter to the flow of flue gases.
TABLE 2 OBERHAUSEN RPP - FLUE GAS EMISSIONS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Past Regulatory Requirements</th>
<th>Recent measurements</th>
<th>Future Regulatory Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Units</td>
<td>Range</td>
<td>Averages</td>
</tr>
<tr>
<td>Particulates</td>
<td>mg/Nm³</td>
<td>N.A.</td>
<td>75</td>
</tr>
<tr>
<td>HCl</td>
<td>1,500</td>
<td>300-1,400</td>
<td>799</td>
</tr>
<tr>
<td>SO₂</td>
<td>2,500</td>
<td>180-410</td>
<td>150</td>
</tr>
<tr>
<td>SO₂ + SO₃</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>NO₃</td>
<td>10</td>
<td>N.A.</td>
<td>9.8</td>
</tr>
<tr>
<td>CO</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>C (Organic Compounds)</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

Reference Conditions: 0°C, 101,325 Pa, 7% Vol. CO₂

Notes:
1. For conversion to grains per standard cubic foot multiply by 0.437 × 10⁻³.
2. N.A. means either "not available" or "not applicable".
3. For conversion use, 101.325 Pa = 1.01325 bar = 760 Torr.

While washing with plain water is sufficient for HCl removal, the addition of caustic or lime to the water prior to atomization is required for SO₂ removal. Special care must be given to the selection of scrubber construction materials in order to provide protection against damage from corrosion and temperature effects. Often this goal is accomplished by providing protective liners or coatings.

During the scrubbing process, the flue gases are cooled down to saturation temperature, a condition which would prevent their induction into the existing chimney. Therefore, the flue gases need to be reheated by means of a flue-gas-to-flue-gas regenerative heat exchanger. This means that in the heat exchanger, gases discharged from the scrubber are being heated by gases entering the scrubber. Because of high corrosivity, the heat exchanger tubes must be made of glass and the bottoms of especially refined alloy steel.

During wet scrubbing, some of the particulates are deposited by the flue gases in the scrubber water in the form of salts. The dumping of such scrubber water into the city sewer will no longer be permitted, a restriction which would force the furnishing of an evaporator facility.

Evaporators of this type would require the withdrawal of 25-30 percent of the entire flue gas stream from the boilers at a temperature of 1112 F (600 C) in order to provide the latent heat of vaporization. Obviously, for the purpose of steam generation, this energy would then be lost.

The dry scrubbing system exhibits significantly different characteristics in that flue gas purification is started by removing approximately 90 percent of the particulate load in mechanical filters. Flue gases, precleaned in this manner, continue then into evaporator-reactors in which a spray of lime solution or dilute caustic soda solution is generated. Due to heat transfer, these solutions will give up their water and leave chemicals behind to react with the contaminants carried by the flue gases. Consequently, salts are formed which can be separated in dry form by the ESP's which are provided downstream of the reactors. A major advantage of this approach is the absence of significant corrosion problems. An additional advantage is posed by the fact that pollutants removed in dry form may be taken to special landfills and do not require further treatment.

From this discussion, it follows that because of increased environmental safety and decreased oper-
ating cost estimates, the dry scrubbing approach is preferred.

**OPERATING RESULTS**

During the first six complete years of its operation, the Oberhausen RPP showed a steady improvement in the operation of its steam generation system. This trend is reflected in the column "Annual Totals" in Table 3 by the steady rise in annual operating hours. By 1978, average boiler equipment utilization reached 73.6 percent on a time weighted basis, while boiler No. 2, with 76.9 percent, reached an all time high of any boiler in operation. These accomplishments attest to the degree of maturity of the Oberhausen RPP operating plan.

Table 4 deals with the two major assignments of the Oberhausen RPP in their order of importance: first - refuse disposal, and second - steam production. Annual refuse disposal rates, with only the first three processing lines installed, reached their ceiling after 4 years of operation at approximately 355,000 tons/year (323,000 t/y). No further growth is expected until the fourth line is installed.

During 1978, out of a total of 378,221 tons (343,837 t) collected, as much as 351,486 tons (323,000 t) were incinerated. The remainder of 26,736 tons (24,304 t) was bypassed either to a landfill or to the nearby Krefeld C-RPP (Codi­posal-Refuse Power Plant). The split was 16,130 tons (14,663 t) for the landfill and 10,606 tons (9641 t) for Krefeld.

On the output side, both steam sales and electrical sales increased with every consecutive year, with the exception of 1978. That year, ironically, was a year during which annual total boiler hours accumulated their highest mark in the history of the plant. This apparent contradiction is still under investigation and will be reported on a later date.

Table 5 shows the expected annual rise in the energy content, or lower heating value, of the refuse fed into the boilers. This upward development was interrupted only by the effects of actions taken by the OPEC price cartel during the 1974 to 1975 period.

Table 5 also lists the annual capacity quotient for the steaming rates. This can be expressed as the ratio of actual steaming rate to design steaming rate.

<table>
<thead>
<tr>
<th>Operating Year</th>
<th>Steam Generation(1)</th>
<th>Power Production(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boiler #1</td>
<td>Boiler #2</td>
</tr>
<tr>
<td>1973</td>
<td>4,315</td>
<td>4,408</td>
</tr>
<tr>
<td>1974</td>
<td>4,740</td>
<td>4,812</td>
</tr>
<tr>
<td>1975</td>
<td>4,813</td>
<td>5,463</td>
</tr>
<tr>
<td>1976</td>
<td>6,174</td>
<td>5,851</td>
</tr>
<tr>
<td>1977</td>
<td>5,921</td>
<td>6,640</td>
</tr>
<tr>
<td>1978</td>
<td>6,157</td>
<td>6,734</td>
</tr>
<tr>
<td>6-Year Totals</td>
<td>32,120</td>
<td>33,908</td>
</tr>
</tbody>
</table>

Notes: (1) Average Equipment Utilization = Actual, annual totals hours/year X 100%
(2) Average Boiler Equipment Utilization = Actual annual totals hours/year X 100%
TABLE 4 OBERHAUSEN RPP – REFUSE DISPOSAL AND ENERGY RECOVERY

<table>
<thead>
<tr>
<th>Operating Year</th>
<th>Refuse Disposed</th>
<th>Steam Production (gross)</th>
<th>Steam Sold (Net)</th>
<th>Condensation Back Pressure</th>
<th>Combined Internal</th>
<th>Export to Grid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TPY</td>
<td>MWh</td>
<td>MWh</td>
<td>MWh</td>
<td>MWh</td>
<td>MWh</td>
</tr>
<tr>
<td>1973</td>
<td>291,665</td>
<td>544,400</td>
<td>-------</td>
<td>18,735</td>
<td>18,735</td>
<td>13,000</td>
</tr>
<tr>
<td>1974</td>
<td>315,938</td>
<td>496,049</td>
<td>-------</td>
<td>19,685</td>
<td>19,685</td>
<td>14,500</td>
</tr>
<tr>
<td>1975</td>
<td>331,667</td>
<td>567,914</td>
<td>120,541</td>
<td>27,878</td>
<td>13,623</td>
<td>41,501</td>
</tr>
<tr>
<td>1977</td>
<td>361,401</td>
<td>640,020</td>
<td>256,497</td>
<td>64,990</td>
<td>3,117</td>
<td>68,107</td>
</tr>
<tr>
<td>1978</td>
<td>351,486</td>
<td>626,190</td>
<td>205,431</td>
<td>60,577</td>
<td>3,000</td>
<td>63,577</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>2,006,874</strong></td>
<td><strong>3,516,125</strong></td>
<td><strong>827,779</strong></td>
<td><strong>216,890</strong></td>
<td><strong>61,382</strong></td>
<td><strong>278,272</strong></td>
</tr>
</tbody>
</table>

Notes: (1) To convert the heat content of steam to equivalent electrical energy, use the approximation of 1 ton of steam = 0.7361 MWh.

TABLE 5 OBERHAUSEN RPP – ANNUAL AVERAGES OF SPECIFIC OPERATING PARAMETERS

<table>
<thead>
<tr>
<th>Operating Year</th>
<th>Lower Heating Value</th>
<th>Specific Steaming Rate</th>
<th>Specific Electrical Power Consumption</th>
<th>Time Utilization Quotient</th>
<th>Capacity Quotients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Btu/lb</td>
<td>lb/lb</td>
<td>kWh/ton</td>
<td>h/h</td>
<td>Grates ton/ton(4)</td>
</tr>
<tr>
<td>1972(1)</td>
<td>2,606</td>
<td>1.609</td>
<td>----</td>
<td>0.340</td>
<td>0.139</td>
</tr>
<tr>
<td>1973</td>
<td>2,403</td>
<td>1.867</td>
<td>44.6</td>
<td>0.481</td>
<td>0.459</td>
</tr>
<tr>
<td>1974(2)</td>
<td>2,543</td>
<td>1.570</td>
<td>45.9</td>
<td>0.504</td>
<td>0.497</td>
</tr>
<tr>
<td>1975</td>
<td>2,538</td>
<td>1.712</td>
<td>54.0</td>
<td>0.602</td>
<td>0.521</td>
</tr>
<tr>
<td>1976</td>
<td>2,040</td>
<td>1.809</td>
<td>60.6</td>
<td>0.699</td>
<td>0.558</td>
</tr>
<tr>
<td>1977</td>
<td>2,880</td>
<td>1.771</td>
<td>61.5</td>
<td>0.707</td>
<td>0.576</td>
</tr>
<tr>
<td>1978</td>
<td>2,909</td>
<td>1.762</td>
<td>61.5</td>
<td>0.736</td>
<td>0.553</td>
</tr>
<tr>
<td><strong>Averages</strong></td>
<td>2,752</td>
<td>1.752</td>
<td>54.0</td>
<td>0.620</td>
<td>0.526</td>
</tr>
</tbody>
</table>

Notes: (1) Only start-up operations, not a complete year.
(2) Abnormal behavior related to effects of OPEC price cartel.
(3) Exclusive 1972, because of start-up not a typical year.
(4) Grate Capacity Quotient = Annual tons of installed processsing capacity
(5) Boiler Capacity Quotient = Annual tons of steam actually generated
(6) Steaming Rate Quotient = Actual, specific steaming rate

SUMMARY AND CONCLUSIONS

The Oberhausen RPP started up in the middle of 1972 and it can be estimated that by the end of 1979 it will have processed approximately 2,448,000 tons (2,225,000 t) of refuse. This corresponds to a volume of 7,275,000 cu yd (5,562,000 m³).

After subtracting the appropriate amounts of electricity and steam consumed for in-plant requirements, 217,000 MWh of electricity and 1,358,500 tons (1,235,000 t) of steam were left over for export to the supply networks of the EVO.

By converting the heat content of this steam into equivalent electrical energy, the steam export can also be expressed as 1,000,000 MWh, thus permitting summation of all the useful energy exported:

\[ E_{\text{export}} = E_{\text{electrical}} + E_{\text{thermal}} \]

\[ E_{\text{export}} = 217,000 + 1,000,000 = 1,217,000 \text{ MWh} \]
Of this total, the larger amount (i.e., 82.2 percent) was in the form of thermal energy, and the smaller amount (i.e., 17.8 percent) in the form of electrical energy.

Using an average heat content of 2770 Btu/lb (6453 kJ/kg) for the refuse fired during the life of the plant, a total heat release of $6.17 \times 10^9$ Btu ($14.4 \times 10^9$ TJ) can be calculated over the life of the plant, a figure which can also be expressed as 4.0 million MWh of equivalent electrical energy.

From the above, a rather respectable average energy utilization efficiency of:

\[
\frac{1,217,000}{4,000,000} \times 100 \text{ percent} = 30.4 \text{ percent}
\]

can be established for the life of the plant.

During any particular operating year, however, the annual energy utilization efficiency may deviate from this average. Depending mostly on changes in the heating value of the refuse fired, more or less steam may be generated per unit of refuse fired. Thus any increase in the heating value will tend to cut down boiler losses and drive up the specific steaming rate, which should result in more electricity and steam being delivered to the energy market per hour of turbine operation.

For example, inspection of Table 5 indicates for 1976 a fairly high heating value together with a high specific steaming rate. Corresponding values for the net thermal and electrical outputs may be taken from Table 4. After the appropriate calculations and conversions are performed, an annual energy utilization efficiency of 38.2 percent can be derived.

Since the current trend at Oberhausen is towards continued growth in the heating value of refuse, additional gains may be realized, provided, of course, that the present waste habits of the population persist!

Operation of the Oberhausen RPP has had a considerable impact on energy conservation. When comparing the RPP with a conventionally fired power station and applying an average fuel utilization efficiency of 70 percent, it can be estimated that thus far the Oberhausen RPP has conserved approximately 165,000 tons (150,000 t) of fuel oil. This quantity corresponds to a line of 5000 tanker tractor-trailer rigs with a capacity of 33 tons (30 t) each. To this, one would have to add the benefits of secondary energy conservation, accomplished by the sale of ferrous scrap and construction aggregates recovered from residues.

Of all parameters discussed, the time utilization factor of more than 0.7 in recent years provides ample testimony to the fact that conversion of the old coal mine power station at Oberhausen into a modern Refuse Power Plant was an unqualified success.

However, more impressive than any of the statistics cited above is the fact that during its entire operating life of over six years, the Oberhausen RPP has never shut down, nor did it fail to discharge its primary obligation, which is the dependable and safe disposal of all refuse delivered.

REFERENCES


Key Words

Boiler
Combustion
Refuse
Resource
Roller
Waterwall