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

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Discussion by

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This paper can become a very useful guide for the successful conversion of some other old, center-city power plants to MSW as their primary fuel. The conversion is never easy, in some cases it is infeasible, but this example illustrates, in detail, how it can be done.

The derating of the three old 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) was wise in view of the threat of chlorides to exposed tubes at high temperatures. The subsequent record of 40,000 hr without "any damage of consequence," is impressive. Are measurements being made regularly of tube-wall thickness? What is the trend?

The addition of a sloping water-tube roof above the sloping grate was a wise design, and the provision of welded studs supporting silicon carbide covering for those tubes was certainly essential to protect them from chloride corrosion. This protection is necessary not only because they operate slightly above saturation temperature of 530 F (276 C), but also face intense flame and radiation. An especially useful discovery is that originally that refractory coating cracked and failed because of stud corrosion, not tube corrosion. Also, since the time that the clever pre-sintered, silicon-carbide stud-caps so successfully demonstrated a solution to the support problem at this plant, they have helped greatly at other plants to reduce tube-covering repair and maintenance.

The absence of superheater tube corrosion during 40,000 hr is a major advance over other plants despite the relatively high superheat temperature of 932 F (500 C). In my opinion a major cause of that success is that the superheater is in the transverse, second pass, following a vertical bank of evaporator tubes in the first pass. With that arrangement the hottest steel in the system, the superheater, is well protected from high temperature flame and furnace radiation which, where they do occur, raise the temperature of the ash deposits to the level where the chlorides in the deposit, decompose and attack even alloy steels. This opinion is based on the extensive corrosion research results of Miller, Vaughn, Krause and Boyd plus a study of the superheater-corrosion experience of many plants.

The formation of rock-like sulfate deposits on the economizer surfaces is attributed to moisture from soot blowing. If this is the case, some additive introduced only when blowing soot should be feasible for softening these deposits.

The detailed discussion of many of the well-known problems with flue gas scrubbers left out any specific information on where scrubbers stand in Germany today. Have any been abandoned? Is any progress being made in solving the major problems listed?

Then an impressive case is made for "dry
scrubbers." Are some being tried in Europe? How well are they performing?

While cost data for this impressive conversion could not be translated reliably to any other plant, nevertheless, one cannot really evaluate the project unless some general costs are known. How much did the conversion cost? If a new plant had been built on the same site, how much would it have cost?

This technology is appreciably advanced and matured by such a detailed description of an outstanding conversion from coal to refuse as fuel.

Discussion by

James A. Fife
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The authors have done an extremely complete job of describing the design and operation of this project—a most unusual instance in which a coal-fired boiler plant with only an accumulated prior 10-yr. service was made available to a solid waste management authority for conversion and continued service. Even though this set of circumstances may never occur again, the paper reports on experiences which are of use to us all.

In utilizing this experience, however, we should recognize that design and construction were completed 8 years ago (1972), when European refuse was undergoing a rapid change in characteristics. One effect of these changes, for instance, is refuse density in storage. The authors report a capability to store a 4-day supply of refuse, based on a density of 25 lb/ft³. U.S. design practice is based on a figure of about 13 lb/ft³ (350 lb/cubic yard) for this purpose. Based on the available (stacked) storage volume of 423,600 ft³ and the installed design refuse burning rate of 1,742 tpd, available storage, as present-day refuse, is about 1½ days, rather than 4.

The experience with the polyp type of refuse grapple is of interest, too. Polyps are almost in universal use in European plants, having the advantage of a large circular shape when open. The symmetry of the circle provides better stability as the grab digs into the refuse, and polyps theoretically do not tilt to the same degree as the grapples used here. This would reduce the wear on cables, and is the reason for choosing the polyp.

In the U.S., we choose the grapple for its good point—there are only 2 moving sections rather than 6, and therefore far fewer pinned bearings to be maintained. Of possible interest is the fact that some European operators have inserted short lengths of chain between the blocks at the lower ends of the crane cables and the grab, to reduce the wear on cables caused by grab tilting. Such chains are not used at Oberhausen, apparently, and even with the stability of the polyp, cable life seems very short. This is perhaps a result of need for continuous stacking due to the minimal storage space available.

The authors, in describing furnace configuration, allude to freedom from chute “burnback” fires due to parallel flow of the refuse fuel bed and the overfire gas stream. We wonder here if the furnace configuration might have been dictated by the existing, re-used boiler/building configuration, but more often is caused by refuse feed or power failure. In these instances, burnback would probably occur in a parallel flow furnace as well, particularly if the chute cutoff gate were not closed.

Steam conditions in the boiler superheater are such that tube metal temperature is well above that at which chlorine-caused corrosion would be expected to begin (500-550 F). Steam leaves the derated superheater at 932 F, and the tube metal near the superheater outlet must be then at about 980 F. Unless the refuse has an abnormally high sulfur content to offset the effects of chlorine from plastic, corrosion like that experienced at the Flingern plant at Dusseldork would be expected. The protective shields described for Oberhausen seem to be the same approach to the problem as was successful at Flingern. Even though tube metal loss is said to be slight, the strong statement that it was all attributable to erosion appears questionable.

One of the features of the Oberhausen operation not covered by the paper was the supporting economic structure. The project should be interesting from this standpoint, as it differs significantly from the usual “start from scratch” situation. Recognizing that German solid waste services are totally collection-free-supported, understandably makes comparison with our split-revenue system difficult. Perhaps, during discussion, the authors could provide additional insight in this area.

The authors should be congratulated for a fine piece of work, and for a real contribution to the 1980 Conference.
Discussion by

G. Stabenow
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Stroudsburg, Pennsylvania

It takes a lot of courage and engineering ingenuity to retrofit an existing power plant from cyclone coal firing to refuse burning and it must have been a great satisfaction for the engineering and design team to have achieved the successful performance of the Oberhausen R.P.P. as outlined in this paper.

The authors are to be congratulated for the excellence of the paper presented and especially for their frankness in explaining the difficulties encountered during the initial shake-down operations.

It is especially interesting to note the restructuring of the boiler furnace from the coal fired cyclone system to the refuse fired Duesseldorf type roller grates by VKW, which have presented many challenging design problems for the suspended furnace chamber ceiling to achieve proper water side circulation.

This development raises the question of whether this design approach is the ultimate solution to achieve the most advantageous combustion performance. The suspended roof over the roller grates doubtlessly achieves a parallel gas flow in direction of the refuse flow which, due to the low ceiling heights causes initially relatively low temperature gasifications (pyrolysis) with the less desirable formation of CO and other corrosive gases. The first attempt to apply this parallel gas flow design at Unit #5 in Duesseldorf Flingham proved that it was detrimental to expose bare boiler tubes in this area. Later experiments with studded waterwall surfaces and application of various types of silicon carbide resulted only in a limited success. It is apparent that the studs with ceramic caps and plastic SIC refractory applied to the suspended waterwall are now a considerable improvement in this respect. Whether the parallel gas flow over the roller grates represents a significant improvement over the competitive mass fired stoker systems remains to be seen. This raises the question of why the later installation in Kiel, Wuppertal and others were designed similar to the original furnace lay-out at Duesseldorf Flingham for gas counterflow. It will be interesting to observe whether VKW will repeat the more expensive furnace construction for parallel gas flow on future projects.

The originally coal fired boilers had a maximum continuous output rating of 110,400 lb/hr (50 t/hr), which, for conversion to refuse firing were derated to 24.3 tons/hr. The actually achieved refuse burning rate (annual mean) was 39,300 lb/hr or 19.65 tons/hr. The actually achieved mean steaming rate was 68,775 lb/hr or 34.58 tons/hr.

TABLE 1 PERFORMANCE EVALUATION – OBERHAUSEN REFUSE POWER PLANT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler steaming capacity</td>
<td>110,400 lb/hr</td>
</tr>
<tr>
<td>Pressure (60 Bar)</td>
<td>853 psia</td>
</tr>
<tr>
<td>Superheat temperature (500 C)</td>
<td>932 F</td>
</tr>
<tr>
<td>Assumed feedwater temperature</td>
<td>250 F</td>
</tr>
<tr>
<td>Enthalpy superheated steam (850 psia) - 930 F</td>
<td>1470.80 Btu/lb</td>
</tr>
<tr>
<td>Enthalpy feedwater</td>
<td>218.59 Btu/lb</td>
</tr>
<tr>
<td>Enthalpy difference</td>
<td>1252.21 Btu/lb</td>
</tr>
<tr>
<td>2.0 percent blow-down = (525.39 - 218.59) × 0.02</td>
<td>6.14 Btu/lb</td>
</tr>
<tr>
<td>Heat required per lb steam</td>
<td>1258.35 Btu/lb</td>
</tr>
<tr>
<td>Total design heat output (coal fired)</td>
<td>138,921,840 Btu/hr</td>
</tr>
<tr>
<td>Anticipated efficiency</td>
<td>64.0 percent</td>
</tr>
<tr>
<td>Mean HHV</td>
<td>3.400 Btu/hr</td>
</tr>
<tr>
<td>Anticipated peak refuse burning rate</td>
<td>48,576 lb/hr</td>
</tr>
<tr>
<td>Anticipated peak refuse burning rate (annual mean)</td>
<td>24.29 tons/hr</td>
</tr>
<tr>
<td>Actually achieved refuse burning rate</td>
<td>39,300 lb/hr</td>
</tr>
<tr>
<td>Actually achieved refuse burning rate (annual mean)</td>
<td>19.65 tons/hr</td>
</tr>
<tr>
<td>Heat required per lb of steam</td>
<td>1258.21 Btu/lb</td>
</tr>
<tr>
<td>Actually achieved steaming rate (1975)</td>
<td>68,775 lb/hr</td>
</tr>
<tr>
<td>Equivalent heat output</td>
<td>86,533,392 Btu/hr</td>
</tr>
<tr>
<td>Total heat input</td>
<td>133,620,000 Btu/hr</td>
</tr>
<tr>
<td>Resultant efficiency</td>
<td>64.76 percent</td>
</tr>
<tr>
<td>Actually achieved mean steaming rate</td>
<td>68,775 lb/hr</td>
</tr>
<tr>
<td>Design steaming rate (coal fired)</td>
<td>110,400 lb/hr</td>
</tr>
<tr>
<td>Refuse fired boiler rating</td>
<td>62 percent</td>
</tr>
</tbody>
</table>
TABLE 2 PERFORMANCE OF THE OBERHAUSEN REFUSE INCINERATION PLANT 1972-1976

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Incinerated Refuse Quantity (ton/yr)</td>
<td>88,430</td>
<td>292,726</td>
<td>317,086</td>
<td>332,872</td>
<td>356,002</td>
<td></td>
</tr>
<tr>
<td>Generated Steam Quantity (ton/yr)</td>
<td>142,280</td>
<td>506,635</td>
<td>497,853</td>
<td>521,687</td>
<td>624,568</td>
<td></td>
</tr>
<tr>
<td>Steam generated per lb of refuse (lb/lb)</td>
<td>1.61</td>
<td>1.73</td>
<td>1.57</td>
<td>1.57</td>
<td>1.75</td>
<td></td>
</tr>
<tr>
<td>Lower heating value (Btu/lb)</td>
<td>2,606</td>
<td>2,803</td>
<td>2,543</td>
<td>2,538</td>
<td>2,840</td>
<td></td>
</tr>
<tr>
<td>Equiv. High Heating Value (20 percent Moist.) (Btu/lb)</td>
<td>3,128</td>
<td>3,363</td>
<td>3,052</td>
<td>3,045</td>
<td>3,408</td>
<td></td>
</tr>
<tr>
<td>Refuse Throughput Per Boiler (Mean) (Ton/hr)</td>
<td>23.63</td>
<td>23.09</td>
<td>23.85</td>
<td>21.09</td>
<td>19.65</td>
<td></td>
</tr>
<tr>
<td>Total Steam Generated in Plant (average) (lb/hr)</td>
<td>76,089</td>
<td>79,891</td>
<td>74,889</td>
<td>66,223</td>
<td>68,775</td>
<td></td>
</tr>
<tr>
<td>Average throughput of plant (average) (ton/hr)</td>
<td>18.55</td>
<td>33.34</td>
<td>36.21</td>
<td>37.98</td>
<td>39.52</td>
<td></td>
</tr>
<tr>
<td>Average Annual Availability (percent)</td>
<td>34.0</td>
<td>48.0</td>
<td>50.0</td>
<td>60.0</td>
<td>69.0</td>
<td></td>
</tr>
</tbody>
</table>

Achieved continuous steam output capacity was 68,775 lb/hr. The resulting derating of the boiler was 68,775/110,400 = 62 percent. In other words, the output of a converted coal-fired boiler is limited to 62 percent capacity when burning refuse.

Table 1 shows the Oberhausen performance evaluation which was not indicated in this paper. Also, Table 2 shows the Oberhausen annual performance converted to the conventional U.S. system of values.

These comments are not intended to detract from the excellence of the paper but are merely meant to serve as clarifications for the American incinerator designer.

A few additional comments are outlined in the following which may also be helpful.

1. The Chapter entitled: “What is the EVO” contains some figures in the bottom left hand column which are utterly confusing. It would probably be clearer if these figures were written as follows:

1978 EVO Energy Sales

- Gas: \[ 2.13 \times 10^9 \text{ Btu} = 2.246 \times 10^{12} \text{ J} = 22.4 \text{ percent} \]
- District heat: \[ 2.032 \times 10^9 \text{ Btu} = 2.143 \times 10^{12} \text{ J} = 21.4 \text{ percent} \]
- Electricity: \[ 1.562 \text{ MWh} = 5.626 \times 10^{12} \text{ J} = 56.2 \text{ percent} \]
- Total: \[ 10.015 \times 10^{12} \text{ J} = 100.0 \text{ percent} \]

2. The chapter entitled, “Justification of the Retrofit” under paragraph 3 would be easier to understand if the land area was expressed in acres rather than in square feet and should therefore read, “additional land was available for purchase so that the existing acreage could be increased from 10.63 acres (43,000 m$^2$) to 13.59 acres (55,000 m$^2$).”

3. Under the chapter “Pit Crane System,” it is indicated, “the grabs must discharge their loads approximately 16.4 ft above the pit floor.” This should probably read, the refuse trucks must discharge their loads approximately 16.4 ft above the pit floor.

CONCLUSION

In conclusion it may be said that too little attention is paid by the U.S. incineration system designer to the boiler output rating when it comes to attempts to retrofitting existing coal fired boilers for refuse firing. Design parameters such as refuse heat input per foot of boiler width, volumetric heat release per cubic foot of furnace volume as well as furnace height and combustion gas turbulence and many other important factors must be carefully considered when considering such a conversion from coal power to refuse power as was successfully accomplished at Oberhausen and as so well described in this paper.

Discussion by

Robert S. Rochford
Babcock & Wilcox Company
North Canton, Ohio

The authors give a very detailed account of the conversion of an existing coal-fired power plant to municipal refuse firing. We agree that the project certainly appears to have been both a technical and economical success. The cooperation exhibited by the partners in this venture — namely, the municipality and the electric company — is certainly commendable. The many different ways that the refuse energy can be converted into useful energy — that is, in plant use, steam for industry, district heating and electric power generation — make the described facility a very flexible and efficient system. The
equivalent oil savings are also very impressive.

Producing steam from refuse at 932 F apparently without significant corrosion problems is a noteworthy accomplishment. More information on how this was achieved would be of general interest.

Converting existing units from coal to refuse is being considered by many in the United States. Generally speaking, boiler manufacturers use much more conservative parameters in designing a 100 percent municipal refuse fired boiler than a 100 percent bituminous coal fired boiler. Specifically, this refers to such things as gas velocities, furnace residence time and furnace exit temperatures. It would be interesting to know more about the comparison in this case.

Adding scrubbers to reduce noxious emissions certainly complicates the system and makes it more expensive. Eventually regulations in this country will probably mandate similar controls on these types of emissions. With this in mind, it would be prudent for designers of future plants to consider making provisions in space and fan sizing to permit additions of this type of equipment should conditions make them a requirement.

AUTHOR'S REPLY

To Richard B. Engdahl

1. Occurrences of Superheater Corrosion:
   It is safe to say that even with a coal or heavy fuel oil fired boiler one cannot expect to operate entirely without experiencing corrosion.

   One must remember that the Oberhausen boilers had already accumulated an additional 43,000 operating hours without the need to replace any of the superheaters.

   By comparison with some of the other plants, these results were surprisingly good. It is expected, however, that during the next 8 years several superheater sections may need replacement.

   Thus far, tube damage in the superheaters has been generally confined to the flue gas side, especially where tubes dislocated themselves into the flue gas channels. Thus the evidence indicates that erosion was mostly responsible for this tube damage.

   Extensive measurements have not been performed as yet in order to determine the reduction in tube wall thickness.

   In spite of the fact that 870 psig (6.0 MPa) and 932 F (500 C) were selected as steam output parameters, corrosion did not play a major role, mostly because of the following considerations:
   a) Parallel flow combustion.

   Refuse and flue gases flow over the grate in the same direction, a method which prevents incompletely combusted flue gas streamers from reaching the tubes.

   b) Operation with high excess air.

   By providing significantly more air than is theoretically required, a reducing atmosphere is avoided in the area where flue gases contact the tubes.

   c) High rise boiler pass.

   The relatively high first boiler pass is a key element in that it induces intermixing and secondary combustion of the flue gases; this occurs prior to their entry into the superheater which is mounted in the subsequent horizontal pass, a fact which was appropriately recognized by Mr. Engdahl.

2. Sootblowing:

   The idea of feeding additives into the sootblowers is an excellent one and it should be investigated in the future.

   When planning new plants it is important to arrange the steam lines which supply the sootblowers in such a manner that only superheated steam can be blown into the boilers.

3. The Status of Scrubbers for the Removal of Gaseous Pollutants from the Emission of Refuse Power Plants:

   Generally, wet scrubbers were installed during the last few years for the removal of HCl, SO2 and HF from flue gases.

   This type of equipment involves the cooling of the flue gases to a saturation temperature between 122 F (50 C) and 140 F (60 C) together with absorption of the pollutants, mostly in the form of dissolved salts.

   This approach is associated with certain disadvantages:
   a) Wastewater treatment by means of neutralization and—in extreme cases—by evaporation thickening.

   b) Provisions for additional flue gas treatment by reheating.

   c) Use of corrosion-proof materials in all parts of the equipment.

   d) Applications of pumps, pipes, safety mechanisms and controls which, for the better part, are costly.

   This approach has been committed to large scale practice in the FRG in that approximately 14 municipal and industrial waste incinerators
are using no scrubbers which collectively clean an hourly gas volume of approximately $53 \times 10^6$ standard ft$^3$/hr ($1.5 \times 10^6$ Nm$^3$/hr).

Operating experiences with these incinerators demonstrate that gas purification as required by law ("TA Luft 74") can be accomplished without difficulty.

In order to alleviate the aforementioned disadvantages such as wastewater treatment problems, flue gas cooling, etc., new dry processes were developed which also permit the type of pollutant reduction as demanded by law. Two methods were applied:

a) Injection of alkaline dust into the reactive tract, together with a solids separator on the outlet side.

b) Injection of an aqueous absorption medium into evaporative coolers with subsequent solids separation.

This latter option has already been tested with production type of equipment in full scale plants. In 1978 the first two large units were started up in the Hamburg II Refuse Power Plant ("Stellinger Moor"); utilizing NaOH these units have an installed capacity of 3,180,000 standard ft$^3$/hr (90,000 Nm$^3$/h) each.

It is interesting to note that one manufacturer above has currently five large projects in the FRG either in the design, construction or startup phase for a combined capacity of 27,560,000 standard ft$^3$/hr (780,000 Nm$^3$/h).

Ongoing attempts towards optimization are geared to minimize the consumption of chemicals by utilizing the continuous measurement of pollutant concentration as the means for controlling the feed rate of the absorption medium.

Parallel developments deal with genuine dry absorption which, on account of the shower reaction kinetics when compared to the quasidry scrubbing, requires increased dwell times and favors the application of a baghouse filter. Several pilot plants of an intermediate size based on this approach are presently either under construction or in operation.

Present studies concerning the separated and dried salts have a two-fold objective: stabilization for safe land filling and investigation of recycling potential.

During 1977, the German EPA arranged for a colloquium in Berlin where government, industry, technical societies and universities exchanged their views on the design and operation of scrubbers for refuse power plants.

This colloquium has been documented and is available as compendium #13 to the magazine *Mull and Abfall* (Erich Schmidt Verlag, Berlin 1978). The compendium, in which much valuable information may be found, is entitled "Abgaswasche bei Müllverbrennungsanlagen."

4) Cost Comparison:

Retrofitting of the old coal fired power plant for refuse firing cost DM 55 million in 1970/71 exclusive of the 23 MW turbine. The cost of a comparable new plant at that time was estimated at approximately DM 110-120 million ($31-34 million). It can therefore be concluded that the retrofit resulted in a 52 percent reduction in capital cost.

To James S. Fife

The polyp type of refuse grabs have proven themselves well and the associated wear and tear on the cables is judged to be acceptable by the plant operator. These cables are routinely exchanged as part of scheduled maintenance and the resultant costs are insignificant when compared with the overall operating costs of a refuse power plant.

The 150,000 plays per grab and operating year refer to stacking and transfer operations as well as to mixing throughout the storage pit in order to convert the refuse into a more homogeneous fuel. "Burnback" fires have not been experienced in the refuse feed hoppers up to date. Because of the parallel flow arrangement, the first and adjacent roller indicates a relatively low temperature zone. Even during failures of the refuse feeders, "burnback" fires did not occur. In fact, during these episodes it never became necessary to close the feed hopper locks.

As Mr. Fife suggests, the parallel flow arrangement was originally a consequence of the existing boiler configuration. Because of its demonstrated success, this same arrangement will be retained unchanged for the all-new #4 unit.

One can never preclude the possibility of boiler corrosion, especially not in refuse power plants. In spite of the fact that not a single super-heater thus far has had to be replaced after 123,000 operating hours (65 percent with coal and 35 percent with refuse firing), the replacement of some super-heater sections is expected during the next eight operating years. The culprit is most likely to be the relatively small sectional spacing in the old coal fired boilers which may be conducive to severe erosion.
The superheated steam temperature set at 932 F (500 C) is not believed to materially affect the spread of corrosion. This belief is reinforced by the EVO’s 10-year experience with the operation of a closed-loop, coal-fired gas turbine. In this case, the temperature of the working fluid in the closed-loop gas turbine was 1,310 F (710 C) after the heater.

Consequently, a significant amount of tubing inside the combustion chamber was exposed in the critical area of high temperature corrosion. During long-term operation it was observed that proper combustion control is of the utmost importance in order to avoid exposure of the tubing to half-burnt materials, or even streamers of unburnt flue gases.

Good, homogeneous combustion can be achieved by intimate mixing in the first boiler pass and by providing a long enough passage for after-burning. Such homogeneous combustion is further enhanced by the admixture of high excess air. The parallel flow arrangement in particular lends itself to a good burnout, even before the gases leave the furnace chamber.

To Robert S. Rochford

1. Corrosion on Flue Gas Side:
The steam temperature set at 932 F (500 C) has shown satisfactory results during the first eight years. Proper care must be exercised in order to admit only uniformly burnt gases to the superheater. This is a problem which can be controlled by proper combustion and by proper configuration of the first boiler pass and high excess air.

This subject is covered in more detail elsewhere in this discussion.

2. Flue Gas Velocities:
The length of the operating periods in between boiler cleanings on the flue gas side is mainly determined by the division of the individual tube bundles.

For the new fourth boiler unit, a continuous path of 11.8 in. (300 mm) in width is planned between the tube coils of the economizer. Similarly, superheater spacing in the horizontal pass will amount to 11.8 in. (300 mm) as well. This new spacing should compare favorably with the 4.33 to 8.66 in. (110 to 220 mm) used in the existing three boilers.

In order to minimize wear on heating surfaces of the new boiler, all flue gas velocities are limited to 1,517 ft/min. (7.7 m/s).

3. Steaming Rates:
Originally, the old boilers when fired with coal were able to produce steam at a rate of 88 tons/hr (80 t/h). Today the boilers have been derated for refuse firing with a maximum output of 55 tons/hr (55 t/h) each.

4. Determination of Heating Value:
An average boiler efficiency of 70% was assumed for calculation of the lower heating value (LHV) of refuse. Thus the determination was indirect.

For example: During 1976 a total of 354,713 tons (322,466 t) of refuse was burned, resulting in the generation of 622,305 tons (565,732 t) of steam. The feedwater entrance temperature to the boiler was set at 365 F (185 C), a temperature which was lowered during the last few years to 266 F (130 C).

Thus, the average annual LHV can be calculated for the three boilers:

\[
\text{LHV} = \frac{710,278 \times 10^6 \text{lb refuse}}{1,248,308 \times 10^6 \text{lb steam}} \times \frac{1,467 \text{ Btu/lb}}{333 \text{ Btu/lb}} \times 0.70 = 2,840 \text{ Btu/lb}
\]

\[
\text{LHV} = \frac{322,466 \times 10^6 \text{ kg refuse}}{565,732 \times 10^6 \text{ kg steam}} \times \left( \frac{3,415 \text{ kJ/kg}}{775 \text{ kJ/kg}} \right) \times 0.70 = 6,616 \text{ kJ/kg}
\]

5. Pitcrane System:
The feed chutes to the three boilers are located in the upper part of the wall which separates the boiler house from the refuse storage pit. In order to charge a particular boiler, the grab must lift refuse from the pit below up to the feed chute entrance. The amount of lift depends on the degree to which the pit is filled with refuse.

To George Stabenow

The parallel flow arrangement for refuse and flue gases was a natural outgrowth of the structural elements already existing at the old power plant.

The excellent past operation results do not, however, permit the conclusion that the retrofit did not suffer from some initial growing pains.

For example, the furnace chamber was fitted with a relatively low ceiling because of structural
limitations in the form of an existing cross beam, part of the boiler support frame which could not be removed.

At the beginning, large and hard clinkers formed between adjacent rollers which, after breaking loose, fell off the grate into the quench tanks. These clinkers then damaged the respective extractors and caused disruptions of boiler operation. This situation was improved only after the wiper blades in between rollers were raised by about 7-7/8 in. (200 mm), thus eliminating most of the deep pockets which previously had promoted the formation of these large clinkers.

Originally the primary air admitted from below the rollers was preheated to 374 F (190 C). Several years later, the composition of refuse changed, so that occasionally molten materials accumulated which blocked some of the air spaces between adjacent grate bars, thus blocking and imbalancing the flow of combustion air. By switching to a supply of ambient air, this problem was satisfactorily resolved.

In the view of the Oberhausen operator, the parallel flow approach has sufficiently proven itself so that it will be incorporated into the design of the fourth boiler, even though this unit will be dedicated entirely to the firing of refuse. This fourth unit consisting of a new grate and boiler combination is required for the expansion of plant capacity.