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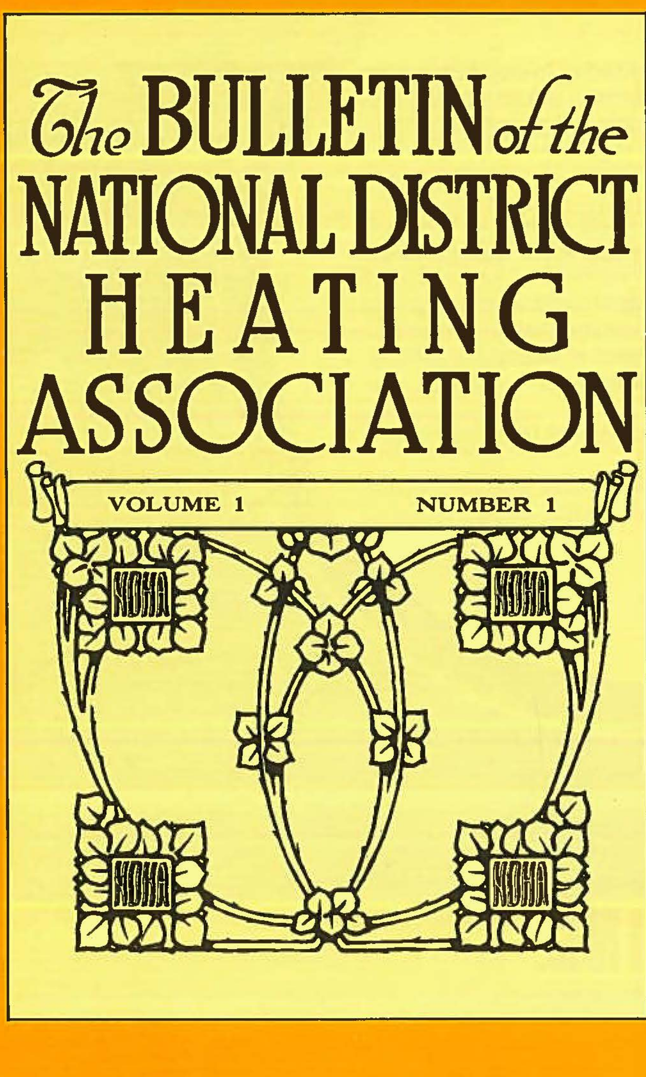
75th Anniversary Issue



75 Years
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Refuse and Coal Fired Boilers Team Up at Duesseldorf To Cogenerate Electricity and District Heat

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Abstract

The Duesseldorf Refuse Power Plant (RPP) has recently been expanded once again to further enhance energy and materials recovery from refuse. New design features which distinctly depart from the equipment previously installed are described. Statistical data is presented which supersedes previous publications in order to establish a continuous 17-year operating record. Integration of the RPP with a conventional coal fired cogeneration plant is discussed, together with an estimate of the amount of primary energy which has been conserved by substituting refuse for coal.

Introduction

The successful long-term operating record of the Duesseldorf Refuse Power Plant (RPP) has previously been discussed in several papers [1, 2]. However, little has been said in the past as to how the energy recovered from refuse is marketed. In fact, unlike some other waste-to-energy projects, the Duesseldorf RPP does not market its energy output directly. Instead, the RPP is closely coupled with the Flingern Cogeneration Station (FCS) where its refuse derived steam is mixed with coal derived steam in a common header. In the end, it is the FCS which operates a complex system of turbines and heat exchangers from which the final output in the form of electricity, hot water and steam is marketed.

The subject paper is to serve a threefold purpose:

(1) To update the RPP's major operating statistics beyond what has already been published.

(2) To summarize important design changes which were made during the last plant expansion.

(3) To describe integration of the RPP into the Flingern Energy Complex and estimate its impact on the City's energy market.

Statistical Data Update

Table 1 presents the major plant operating parameters on a 17-year basis: Waste disposal, energy consumption, energy recovery, ferrous scrap recovery. Figure 1 shows the same data in the form of trend lines.

Inspection of both Table 1 and Figure 1 leads to the same conclusion that final plant expansion in 1980 caused a dramatic change.

Prior to 1980, a leveling off was observed for all parameters, i.e. 305,000 short tons per year (STPY) (2.77×10^8 kg per year) of refuse processed, 15,000 MWh of electricity consumed, 650,000 STPY (5.91×10^8 kg per year) of ferrous scrap sold and 100,000 STPY (9.09×10^7 kg per year) of raw ash produced.

After 1980, with the help of the new and sixth processing line, all major operating parameters resumed their growth. Although it is too early to make a firm prognosis, it appears to be safe to predict that a new performance plateau may be reached in the next few years: 400,000 STPY (3.63×10^8 kg per year) of refuse processed and 900,000 STPY (8.18×10^8 kg per year) of steam exported. Of course, this will depend on stable population levels and undiminished per-capita waste generation rates.

Specific or derived performance parameters are listed in Table 2. Of these, the nearly continuous rise of the lower heating value is significant. Two temporary depressions, one in 1974 and the other 1981, can be related to adverse developments in the national economy. The first was the result of OPEC, while the second coincided with the economic recession. While it is possible that the heating value may rise once again, its unlimited growth is rather unlikely. In all probability, stabilization is expected at a lower heating value, or LHV of 3,700 Btu/Lb. The corresponding higher heating value, or HHV, can be obtained by using the following approximation: HHV$\approx$LHV + 570 (Btu/Lb). The resultant HHV$\approx$4,270 Btu/Lb approaches that of some American municipalities.

For a given boiler design, the boiler thermal efficiency is largely based on lower heating value of the refuse fired. This efficiency experienced a modest improvement over the years, which can be traced to two factors: increased heating value of refuse and improved boiler operation. Additional improvements beyond the present level are not expected.

The specific steaming rate flattened out at about 2.15 ST/ST (2.15 kg/kg), i.e. a value which is close to the design value of 2.25 ST/ST (2.25 kg/kg). The latter is the average for all six processing lines combined.

Limited boiler capacity was the main reason for bypassing waste to the landfill in years past. For example, a total of 420,133 ST (3.81×10^8 kg) of processible solid waste was collected in the Duesseldorf service area during 1980. Because of capacity limitations in

Table 1:
1700 STPD(1) Refuse Power Plant: Annual Flow of Energy and Materials(2)
(in ST × 1000)(3)(6)

Plant	Waste(5) Disposal	Energy(6) Consumption	Energy Recovery		Metal Recovery			Ash Recovery		
			HP-Steam							
Operating Year	Refuse Processed	Electricity Bought	Supplied(7)	Sold(6)	Ferrous Scrap Separated	White Goods Collected	Total Scrap Sold	Raw Ash(9)	Processed Ash	Ash Sold
1966	224	7,927	356	327	8.10	—	6.10	96.7	77.0	55.1
1967	260	8,315	405	393	9.60	0.35	9.95	107.5	97.1	91.2
1968	262	8,736	470	435	9.36	0.42	9.76	125.7	95.5	80.5
1969	290	9,242	495	465	9.35	0.57	9.95	126.8	98.9	92.0
1970	290	9,477	512	471	9.09	0.74	9.53	126.1	104.9	95.0
1971	267	9,420	500	469	8.90	0.95	9.85	106.4	66.9	52.5
1972(10)	295	12,210	567	534	9.24	0.97	10.21	109.7	57.3	74.3
1973	318	13,955	593	564	10.32	0.62	10.94	124.5	100.6	64.0
1974	325	14,143	572	542	9.95	0.56	10.51	124.5	90.7	45.2
1975	327	14,107	650	616	10.10	0.61	10.71	126.3	97.5	53.5
1976	315	14,521	652	621	9.39	0.59	9.95	116.5	55.5	35.2
1977	315	14,563	654	624	6.22	0.57	6.79	109.6	64.5	35.5
1978	303	14,752	649	618	8.75	0.42	9.20	93.2	53.6	17.7
1979	304	15,027	646	615	10.26	0.31	10.57	92.5	69.5	55.6
1980(11)	300	15,910	636	599	10.15	0.34	10.52	102.5	77.2	56.3
1981	362	19,476	793	751	12.17	0.35	12.52	127.4	91.7	70.9
1982	394	20,953	851	808	11.83	0.40	12.23	141.6	100.8	57.8
17-Year Totals	5,174	202,115	10,004	9,452	164.57	8.37	173.64	1,960.1	1,530.4	1,065.6
17-Year Averages	304	11,559	555	556	9.70	0.49	10.21	115.3	90.0	62.9
17-Year Changes	+75.9%	+164.3%	+139.0%	+147.1%	+46.0%	+14.3%	+50.9%	+46.4%	+30.9%	−0.5%

NOTES: (1) Installed processing capacity in short tons of mixed municipal refuse per day when operating continuously; synonymous with nameplate capacity.
(2) Data Base: EDP summaries consolidated into annual report which is submitted by operator to the owner in June each year.
(3) 1.0 HT = 1.1 ST was used for conversion.
(4) Except for electricity which is expressed in Mwh.
(5) Fully corrected tonnages of combustible waste actually processed. During certain years, total tonnages collected and delivered were higher because insufficient plant capacity necessitated occasional bypassing to a landfill site. Also, some waste was removed for compaction and baling as part of a federally funded research project.
(6) Because of local conditions, it was decided to purchase electricity for in-plant use rather than to install own turbo-alternators.
(7) Tons of steam supplied at conditions of actual pressure and temperature, i.e., the "supply ton."
(8) Tons of steam adjusted to reference conditions, i.e., the "accounting ton" with 1,209 psia and 923°F.
(9) Post-incineration ferrous scrap is included.
(10) Fifth processing line installed, started operating August 1972.
(11) Sixth processing line installed, started operating October 1980.

existence at the time only 71.4 percent could be processed by the RPP, while the remainder, or 28.6 percent had to be bypassed to the landfill. This bottleneck should be relieved by the effectiveness of the new sixth line as well as by continued upgradings of the older units. This contention is supported by the fact that already 394,000 ST (3.58×10^8 kg) of waste were processed by the RPP during the most recent year.

Careful inspection of Table 2 reveals that with the increase in heating value there has been a reduction in the ash generation rate, which may be related to changes in the composition of refuse, i.e., more combustibles and less inerts. A commensurate decrease in the density of refuse has been observed by the Duesseldorf Department of Sanitation (see [1]). However, during the most recent years, a new increase is noted in the ash generation rate, because the solids generated by the new flue gas scrubbing system are added to the ask for disposal.

Specific electrical power consumption appears to have stabilized at about 54 kWh/ST (59.4 kWh per 10^3 kg). It is conceivable that a small increase may come about in the future when all processing lines will be equipped with acid gas scrubbers, as mandated by regulatory requirements (see [3]). Other increases are largely due to the installation of larger pumps and blowers which require more power when idling. Also, the installation of a shredder for bulky waste reduction in 1972 had lead to an earlier boost in electrical consumption.

Specific water consumption does not seem to exhibit any particular trend except that during the 1977 to

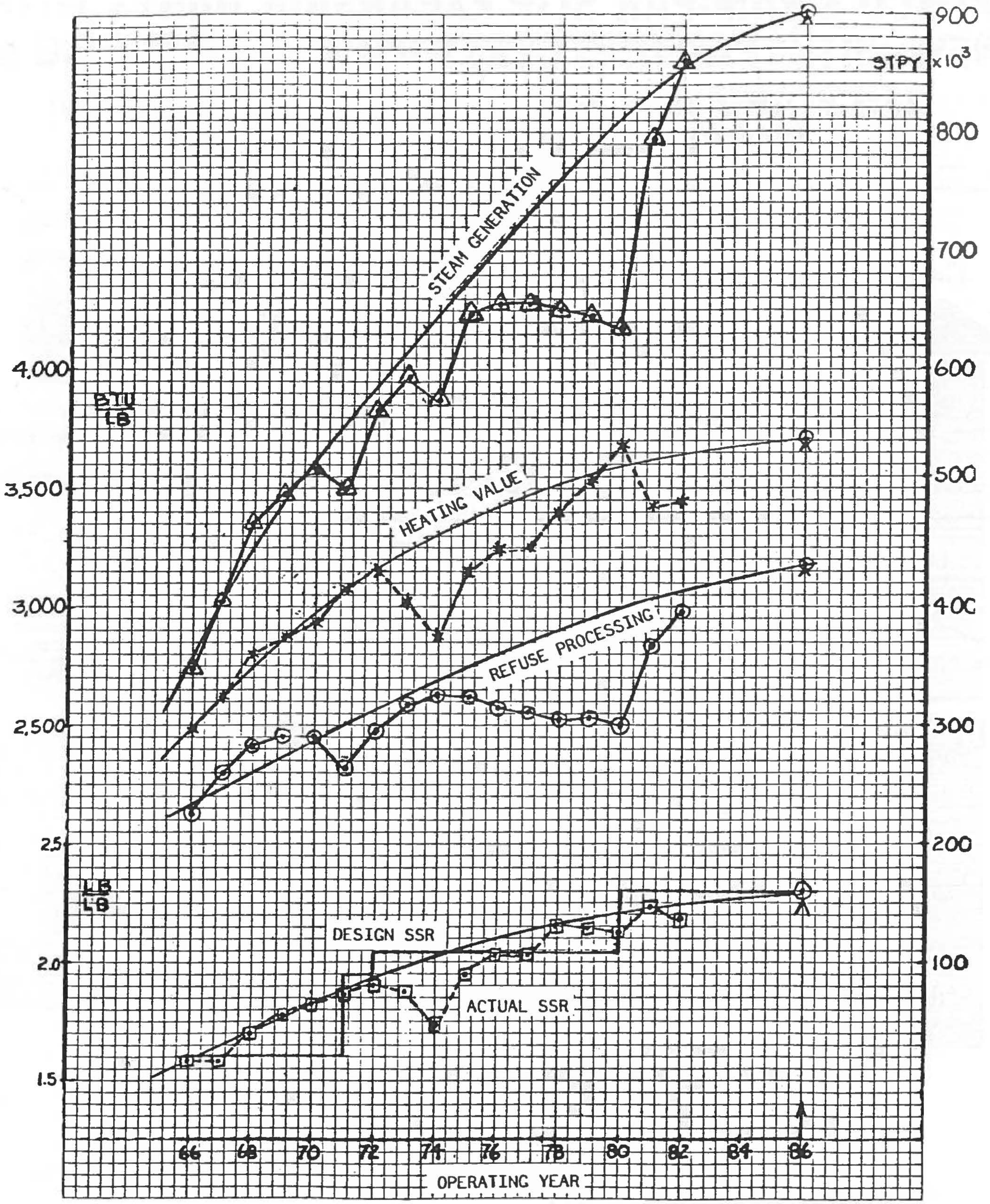


Figure 1
Duesseldorf RPP Performance Trends

Table 2:
1,730 STPD, Refuse Power Plant: Major Performance Parameters[1]

Plant Operating Year	Lower[2] Heating Value Btu/Lb	Boiler Thermal Efficiency %	Specific Steaming Rate[3] ST/ST	Steam Conformance Factor[4] ST/ST	Specific[5] Ash Rate ST/ST	Specific Electrical Power Consumption KWh/ST	Specific Oil[6] Consumption gal/ST	Specific Water Consumption gal/ST	Equipment Utilization Factor[7] hr/hr	Capacity Factor Grates[5] ST/ST	Capacity Factor Boilers[9] ST/ST
1966	2,468	69.1	1.59	0.919	0.432	35.4	(1.570)	566	0.729	0.551	0.462
1967	2,621	68.8	1.58	0.963	0.414	32.1	(0.292)	267	0.742	0.672	0.529
1968	2,792	68.6	1.67	0.926	0.446	31.0	(0.093)	432	0.753	0.732	0.610
1969	2,882	68.4	1.71	0.939	0.437	31.9	0.011	471	0.786	0.752	0.642
1970	2,948	68.6	1.82	0.920	0.442	33.6	0.004	409	0.764	0.732	0.664
1971	3,087	69.5	1.87	0.938	0.399	35.3	0.019	501	0.776	0.693	0.649
1972	3,164	69.9	1.94	0.942	0.372	41.7	0.003	462	0.773	0.743	0.654
1973	3,037	70.8	1.86	0.951	0.392	43.9	0.011	574	0.653	0.626	0.560
1974	2,857	69.2	1.74	0.948	0.380	43.1	0.015	852	0.632	0.646	0.540
1975	3,147	72.3	1.99	0.948	0.386	43.1	0.011	724	0.715	0.644	0.613
1976	3,247	73.1	2.07	0.952	0.371	46.2	0.003	509	0.707	0.618	0.615
1977	3,251	73.3	2.06	0.954	0.348	47.3	0.018	592	0.727	0.621	0.617
1978	3,397	73.2	2.14	0.952	0.308	48.8	0.005	528	0.730	0.596	0.612
1979	3,522	72.4	2.13	0.952	0.304	49.4	0.003	464	0.740	0.595	0.609
1980[10]	3,673	71.3	2.12	0.942	0.344	53.0	0.029	384	0.645	0.596	0.539
1981	3,403	75.0	2.19	0.947	0.352	53.8	0.017	295	0.663	0.573	0.560
1982	3,413	74.0	2.16	0.949	0.362	53.2	0.000	534	0.699	0.624	0.600
17-Year Statistics											
MIN.	2,465	68.4	1.58	0.919	0.308	31.0	0.000	267	0.632	0.573	0.462
AVG.	3,113	71.0	1.92	0.944	0.382	42.5	0.011	504	0.720	0.650	0.593
MAX.[11]	3,673	75.0	2.19	0.963	0.446	53.6	0.029	852	0.756	0.752	0.664
x_{17}[12]	+38.3	+7.1	+35.8	+3.3	−16.2	+50.3	−100.0	−5.7	−4.1	+7.4	+29.9
C.V.[13]	±38.7	±9.3	±31.8	±4.7	±36.1	±53.6	±263.6	±116.1	±21.4	±27.5	±34.1

NOTES: (1) Computations from Table 1 and EDP readouts from the plant operator's annual report.

(2) Approximate conversions can be made by using the relationship: LHV≈HHV - 1,040 (w) with LHV = Lower Heating Value of Refuse in (Btu/lb), HHV = Higher Heating Value of Refuse in (Btu/lb), w = Water Content of Refuse (lb/lb), both free water and chemical water, and 1,040 = Conversion Factor, Assuming w = 0.55 = constant, HHV≈LHV + 572.

(3) Actual tons of steam generated per ton of refuse processed in (ST/ST), i.e., the "supply" tons which refer to indicated gauge pressure and temperature.

(4) The ratio of "accounting" tons to "supply" tons whereby the "accounting" tons represent the amount of steam adjusted to fixed reference conditions of pressure and temperature (1,209 psia and 923°F).

(5) Ferrous scrap and moisture content of approximately 15% by weight are included.

(6) For start-up and stand-by operations. The first three years are excluded from statistical treatment because of their atypical nature.

(7) Cumulative annual operating hours for all processing lines divided by the number of lines installed and the factor of 8,760 hours.

(8) Actual tons of refuse processed divided by the plant's daily nameplate capacity and the factor of 365 days.

(9) Actual tons of steam generated divided by the plant's daily nameplate capacity and the factor of 365 days.

(10) Heavy construction: completion of #6 processing line, modification of #5 boiler. Additional scrubber.

(11) Arithmetic average for 17-year period calculated as:

$$\frac{{}^{52}_{66}\, x_i}{17}$$

(12) Percentage change over 17-year period calculated as:

$$\frac{x_{52} - x_{66}}{x_{66}} \times 100\%$$

(13) Coefficient of variability for 17-year period calculated as:

$$\frac{x_{MAX} - x_{66}}{x_{AVG}} \times 100\%$$

1981 period there was a steady decrease. During 1982 this trend stopped and there was a significant increase. Of course, it takes only one major defective valve to severely upset the flow of water in and out of the quench tanks. Consequently, other fluctuations are likely to occur in the future.

Table 3
Statistical Data Summary
As of December 31, 1982

Parameter	Operating Results
Operating Record:	17 years of continuous plant operation (24/24; 7/7; 365/365 or 148,920 hours)
Unit Operations:	Boiler #1: 110,142 Boiler #2: 103,604 Boiler #3: 110,133 Boiler #4: 112,497 Boiler #5: 55,525 Boiler #6: 16,204
All Boilers Combined:	508,105 hours
Refuse Processed:	5,174,000 ST (Average Grate Capacity Factor 0.650) (4.71×10^9 kg)
Steam Produced:	10,004,000 ST (Average Steaming Rate 1.92 ST Steam/ST Refuse) (9.09×10^9 kg); (Average Boiler Capacity Factor 0.593); (1.92 kg Steam/kg Refuse)
Ferrous Scrap Sold:	173,640 ST (1.57×10^8 kg)
Ash Produced:	1,960,100 ST (1.78×10^9 kg)
Ash Sold:	1,068,600 ST (9.71×10^8 kg)
Energy Conservation from Steam Raising:	1,166,100 ST (10.6×10^8 kg) of standard coal, or 196.5 million gallons (7.43×10^5 m^3) of medium sulfur fuel oil
Energy Conservation from Materials Recycling:	184,700 ST (9.68×10^8 kg) of standard coal, or 36.1 million gallons (1.36×10^5 m^3) of medium sulfur fuel oil.
Total Energy Conservation:	1,350,800 ST (1.23×10^9 kg) of standard coal, or 232.6 million gallons (8.79×10^5 m^3) of medium sulfur fuel oil.
Technology Status:	771 Billion Ton-Hours (7.00×10^{14} kg-h) of Cumulative Plant Operation Experience (This is the product of plant operating hours and the amount of refuse processed.)

Since about 18 percent of the ash weight is water carried over from the quench tanks, any improvement in ash dewatering should also help to reduce the ash rate. As will be discussed in a later section of this paper, the sixth processing line is equipped with a piston extractor which replaces the more conventional drag chains. In the future, if the older processing lines are retrofitted with piston extractors, there may be some new savings in water consumption. Compared to some other plants, the Duesseldorf RPP has a relatively high water consumption. This is somewhat surprising in view of the fact that condensate and/or make-up water is supplied by the FCS. It may be wise to commission a water conservation study in order to find new ways for reduced consumption.

The equipment utilization factor, i.e., the ratio of actual operating hours to theoretical operating hours remains high at the 0.72 average mark. This is especially true in view of the age and the complexity which characterize the Duesseldorf RPP. Other mitigating circumstances are the conditions of pressure and temperature which are exceptionally high for refuse fired boilers. In fact, they are among the highest for any such a system anywhere in the world (see Ref. [4]). A recent drop-off is believed to be the result of construction activities on one hand and a realignment of refuse supply logistics on the other hand.

The capacity factors for the grates and boilers tend to approach congruency, which indicates successful load matching and a general maturing of plant operations. A perfect match appears to be nearly impossible because of the non-homogeneous nature of refuse as a fuel. New boiler controls, like the ones installed with the sixth processing line, are expected to improve boiler performance by minimizing load swings.

Table 3 summarized the lifetime record of the Duesseldorf RPP through December 31, 1982. Even to those who are skeptical of waste-to-energy conversions as a viable technology, the following numbers must look impressive: during a half million boiler operating hours, 5 million tons of refuse were burned in order to generate 10 million tons of high quality steam. The successful sale of 1 million tons of aggregate for construction purposes plus 170,000 tons of ferrous scrap for steel making add further to the appeal of resource recovery. Total energy conservation can perhaps best be described by drawing an analogy to a coal train about 13,500 cars long which would have been required to deliver the equivalent amount of energy.

Completion of Plant Expansion

During September 1980, the sixth and final processing line was completed and started full scale operations. Prior to the design, installation and testing of the sixth line, a major study was performed to examine all important information available from previous design and operating experiences gathered from the Duesseldorf RPP and similar plants elsewhere (see Ref. [5]). The basic idea was to learn from the past and to design a new processing line which would greatly reduce corrosion and increase efficiency and reliability, particularly of the boiler system. At the same time, this new design was to accommodate the ever-increasing heating value of Duesseldorf refuse. A further consideration was the high influx of bulky waste from commercial and industrial sources which needs to be shredded and mixed with the residential waste. A direct correlation between the combustion of such shredded waste and increased corrosion had been demonstrated in previous studies.

Unlike its earlier version, the roller grate system of the sixth processing line features only six rollers instead of seven rollers. This simplification was made possible by beneficial changes in the nature of refuse, changes which permitted shorter retention times. These changes can be characterized as increased heating value, lower moisture content and less ash from residential coal users. Other contributing factors are the substitution of new packaging materials and the fact that an increasing part of the population has switched from coal stoves to district heating. It is also probably that the industrial and commercial waste components, two potentially high Btu components, will grow further. The adequacy of the 6-roller arrangement for Duesseldorf refuse was first tried with the installation of the fifth line. Since this worked out well, the same arrangement was retained for the sixth line.

A hydraulic feed ram has taken the place of the mechanically driven feed tables. The old feed tables were rather sensitive to fluctuations in refuse density, which hampered efforts to maintain a uniform feedrate. The new hydraulic feed rams, on the other hand, not only provide positive displacement, but they also permit partial compression of less dense refuse during feeding. Also, the hydraulic drive is easier to vary and control.

The customary quench tank with drag chain conveyors underneath the roller grate system has been replaced by a new vibratory trough conveyor coupled with a piston extractor. Thus, bottom ash, siftings, fly ash and scrubber residues will be extracted with a minimum loss of quench water. The loss is now approximately 13-16 percent water, compared to 18-22 percent before. Very wet ash tends to interfere with vibratory conveyors downstream of conventional ash extractors and may cause additional problems in the ash processing and materials recovery train. Unlike the old drag chain conveyors which were very susceptible to blockage by large objects such as washing machines and refrigerators, the piston extractors are rugged equipment, quite capable of squashing large objects.

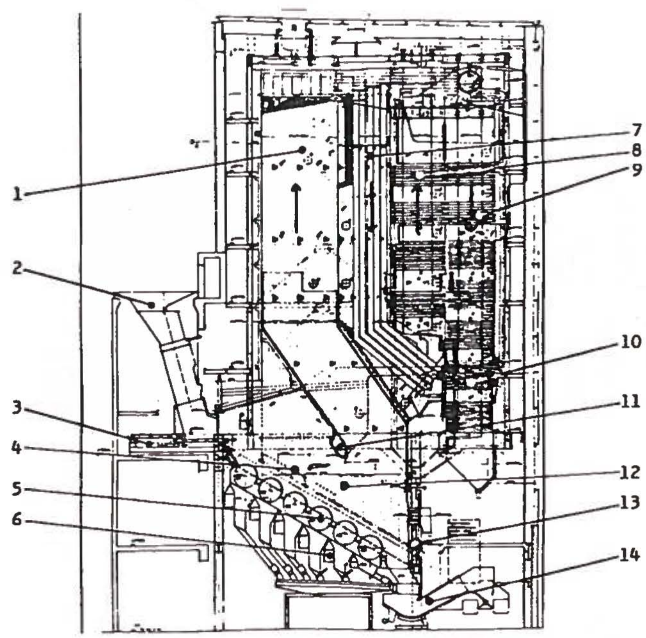
The shape of the furnace chamber has been dramatically altered. The older installations were characterized by counter flow, i.e., the refuse fuel moved downward through the fire zone and the resulting flue gases moved upward. Through a throat section with secondary air injection these flue gases were then admitted to the first pass or radiation shaft of the boiler. As Fig. 2 indicates, this new furnace design features parallel flow, i.e., fuel and gases move in the same direction. Although there is a guide vane at the first pass entrance, there is no discernible throat.

With regard to the new boiler, we need to emphasize that rather severe steam conditions of 1,305 psi (8.98×10^6 Pa or 90 bar) pressure and 932°F (500°C) had to be retained. This was because of the already existing requirements in the nearby Flingern cogeneration plant, i.e., the immediate energy user. In spite of this handicap, the #6 has already passed the 16,000 hour operating mark (as of March 31, 1983) with a utilization factor in excess of 0.8.

The new boiler no longer features platen superheaters such as those that occupied the radiation shafts in the older units. Instead, the first section of the superheater consists of vertical tubes which occupy the entire second pass.

The second superheater section occupies the entire third pass and the upper part of the fourth pass. The remaining part of the fourth and final pass houses the economizer section. All containment and separation walls are made of tube walls which comprise the steam generator section.

Several other new features have been developed. The new design features a full waterwall configuration. This is accomplished by drawing vertical steam generator tubes all the way down to the bottom headers which are positioned directly above the grate beams. Carbofrax M, or silicon carbide, type refractory brick work is erected around and in between these tubes for a mutually beneficial effect: the refractory retains its slag resistance by cooling and the tubes are protected against corrosion. Carbofrax is a special product of the Carborundum Corporation. It contains over 90 percent of Silicon carbide with a special chemical binder. This refractory is not castable and is only supplied in the form of bricks. Still, in the case of furnace temperatures in excess of 1,650°F (900°C) and flue gas atmospheres with a high moisture content, the Carbofrax refractory tends to "grow," i.e., slag buildup occurs. Therefore, additional protection is provided by means of air jets which are connected to the sec-



Legend:
1 Radiation Shaft (1st Pass) with Evaporator Tubing
2 Refuse Feed Hopper
3 Hydraulic Ram Feeder
4 Secondary Air Jets
5 Grate with 6 Adjustable Speed Rollers
6 Primary Air Ducts and Siftings Hoppers
7 1st Superheater Section (2nd Pass)
8 2nd Superheater Section (3rd Pass)
9 2nd Superheater Section (4th Pass)
10 Economizer Section (4th Pass)
11 Flue Gas Guide Vane
12 Furnace Side Wall with Evaporator Tubing
13 Furnace Back Wall with Access Door with Evaporator Tubing
14 Piston Ash Extractor

NOTE: All containment and separation walls of the various boiler passes are furnished with tubing which makes up the evaporator section.

Figure 2
New Boiler Design for Duesseldorf RPP

ondary air supply and penetrate through the refractory. Acting as "air lances," these jets perform the dual function of cooling approaching flue gases and repelling entrained particulates.

The superheaters were moved into a zone of lower flue gas temperatures and as a further measure against corrosion and erosion, a substantial portion of the superheater section is protected by studding and massed refractory. Gas flow velocities have been reduced significantly by the size and shape of the various boiler cross sections allowed.

With a steaming capacity of over 41 stph (3.71×10^4 kg/hr), this new boiler is considerably larger than the older units with 22 stph (2.00×10^4 kg/hr)(#1 to #4) and 33 stph (3.00×10^4 kg/hr)(#5). It fills up the entire space in the existing boiler house. The grate has a capacity of processing 14 stph (1.25×10^4 kg/hr) of refuse which is identical to the capacity of the #5 unit. However, with a specific steaming rate of

$$\frac{41}{14} = 2.93\text{ST}$$

of steam/ST of refuse (kg of steam/kg of refuse), this larger boiler should tolerate additional rises in the heating value of refuse (max. LHV = 4,680 Btu/lb or 10,886 kJ/kg). This latter feature is particularly important because it is expected that most of the shredded bulky waste will be fired in this new boiler. Due to the preponderance of wood, bulky waste generally has an unusually high heating value when compared with residential waste. The main design parameters for this new boiler are listed in Table 4.

While the #6 processing line was being installed, several other important additions were made to the Duesseldorf RPP. Figure 3 shows the updated layout. Accordingly, a large new and fourth electrostatic precipitator was installed between the existing boiler outlet manifold and the existing stack inlet manifold. This manifold arrangement allows for the servicing of any one precipitator out of four at any given time.

Since the commissioning, the Duesseldorf RPP used exclusively precipitators for achieving compliance with existing air pollution control requirements. This changed decisively in 1974 with the promulgation of TA Luft 74, or "Technical Guidelines for Air Pollution Control" by the German EPA (see [3]). In addition to requiring more efficient removal of particulate matter from the effluent flue gases, TA Luft also stimpulated the control of acid gases HC1, HF and SO_2. Because precipitators are not suitable for this purpose, other control devices such as scrubbers had to be added to the more recent facilities. Although not actually a law, TA Luft 74 is being used nevertheless throughout Germany as the basis for implementing West Germany's Federal Clean Air Act. Upon the initiative of the permitting agency, a quasi-dry scrubber type of system was installed at Duesseldorf. Since similar plants may benefit from this particular development, the permitting agency also provided R & D grant monies. While the #6 line had to be equipped for scrubbing immediately, the permitting agency has set December 31, 1983, as the deadline for retrofitting the older lines, #1 to #5, with scrubbers as well. Some further conceptual changes may yet become necessary since TA Luft is being revised and even stricter requirements are expected during 1983.

The present scrubber used an aqueous solution of calcium hydroxide to treat a flue gas flow of 2.83 million ft³/hr (80,000 Nm³/hr). This solution is sprayed into the flue gas stream, where a chemical reaction takes place, resulting in the formation of fine solids

Table 4:
Main Design Parameters for Boiler No. 6

Refuse Processing Rate:	13.8 stph (1.25×10^4 kg/h)
Refuse Heating Value: (LHV)	4,680 Btu/lb (10,886 kJ/kg)
Grate Type:	Duesseldorf Roller Grate System with 6 rollers, each with independently variable drives
Grate Dimensions:	Width: 11.5 ft. (3.5m) Length: 50.4 ft. (15.38m) Projected Surface: 579 sq. ft. ($53.83m^2$)
Grate Heat Release Rate: (Mean)	222,360 Btu/sq. ft. – hr (2.53×10^6 $kJ/m^2 - h$) or (702 kW/m^2)
Grate Manufacturer:	Vereinigte Kesselwerke A.G. (VKW)
Boiler Steaming Rate:	81,620 lb/hr, or 40.8 stph (3.71×10^4 kg/h)
Specific Steaming Rate:	2.96 lb Steam/lb Refuse (kg Steam/kg Refuse)
Feedwater Inlet Temperature:	302°F (150°C)
Superheated Steam Temperature:	932°F (500°C)
Pressure at Superheater Outlet:	1,305 psi (8.98×10^6 Pa) or (90 bar)
Flue Gas Exit Temperature:	446°F (230°C)
Boiler Type:	4-pass with natural circulation
Boiler Manufacturer:	Ferdinand Lentges (under VKW license)

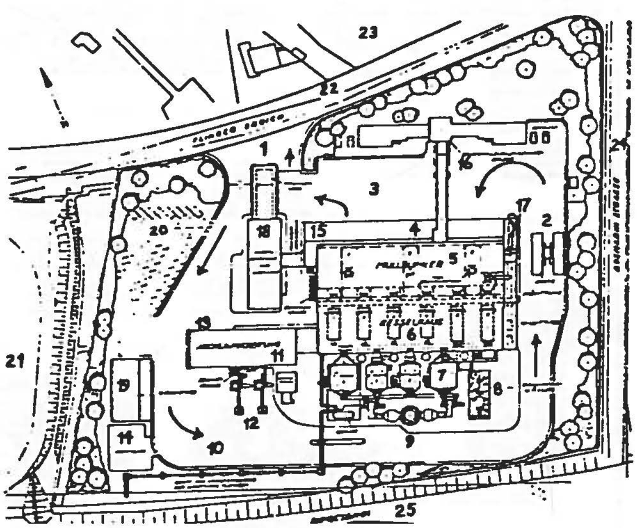


Figure 3
Updated Layout of the Duesseldorf RPP

1 Entrance and Exit
2 Weight Scales
3 Vehicle Turning Area
4 Tipping Area
5 Refuse Storage Bunker with Charge Cranes and Feed Hoppers
6 Boiler House, Boilers #1-6
7 Electrostatic Precipators
8 Pilot Plant for Flue Gas Scrubbing
9 Exhaust Fans and Stack
10 Steam and Condensate Lines Connecting to Flingern Cogeneration Plant
11 Ash Processing Building
12 Scrap Baling Presses
13 Loading Hoppers for Processed Ash
14 Storage for Surplus Processed Ash
15 Shear for Bulky Waste Reduction
16 Shredder for Bulky Waste Reduction
17 Compactor-Baler
18 Administration Building, Cafeteria, Work Shop
19 Repair Shop and Storage Area
20 Parking Lot
21 Sports Field—Area for Future Plant Expansion
22 Access Road
23 Residential and Commercial Area
24 Main Highway
25 Federal Railway—Right of Way for Steam Lines

and the evaporation of moisture. These solids contain the former acids; they are removed together with other fly ash in the electrostatic precipitator and added to the bottom ash coming off the grate.

Several advantages are expected from this type of scrubber when compared to the wet types:

(1) Wastewater treatment problems are minimized or eliminated.

(2) Less water soluble solids are generated, thus reducing leachate problems.

(3) No reheating of the effluent gases is required in order to avoid visible plumes and condensation in the stack.

(4) Calcium hydroxide (i.e., lime) costs about 2.5 times less than sodium hydroxide.

Testing is still in full progress, so that definite results cannot be reported at this writing.

Another important addition was the installation of a third crane of the semi-automated type (automatic travel and positioning, but manual opening and closing of the bucket). This new crane should be advantageous for the control of occasional pit fires. With this installation, the Duesseldorf RPP has now a full complement of three operating cranes and one standby crane. This augmented crane capacity should be able to keep up with increased refuse deliveries during the day shift. This increase is expected as a result of the new boiler capacity.

In addition to the sixth processing line, a new and larger 2,300 ft (700 m) long high pressure steam line has been built in order to beef up the interconnection between the Duesseldorf RPP and the Flingern Cogeneration Station. While redundant to some extent at the present time, this new line will permit a further increase of the steaming capacity in the future.

Also visible from the updated layout, a new storage building and a new repair shop have been added, thus further crowding the already small plot of 7.2 acres ($2.91 \times 10^4 m^2$). When one considers the fact that the sixth line increased nameplate capacity from 1,400 $STPD_7$ to 1,700 $STPD_7$ (1.265×10^6 kg/day), it becomes immediately clear that refuse storage and vehicular traffic management are of the utmost importance.

(The remainder of this article including "Integration of Refuse and Coal Fired Boilers" and conclusions will be presented in the next issue of District Heating)