

“BURN-OUT BEAM” FOR THE QUANTITATIVE AND QUALITATIVE IMPROVEMENT OF MUNICIPAL COMBUSTOR ASH

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INTRODUCTION AND BACKGROUND

The Bamberg codisposal and cogeneration refuse power plant (C-RPP) in Germany features three furnaces with a unit throughput capacity of 6.61 stph. Total plant capacity is 480 STPD₇. Each furnace is equipped with an articulated 3-step grate system. Flue gases are cleaned by electrostatic precipitators followed by wet scrubbers. Part of the refuse is delivered by a rail haul system. Thickened and digested sewage sludge is pumped over from the wastewater treatment plant next door. Mechanical dewatering is accomplished by a high solids centrifuge. The resultant sludge cake is added to the refuse in the storage pit for mixing and feeding into the furnaces. The Bamberg C-RPP has a service population of 400,000 people.

NEED FOR AIR CLASSIFYING THE ASH

During thermal waste reduction, ash is generated at a rate of about 300 kg of ash/Mg of refuse (0.300 Lb/Lb). Its final disposal has been and continues to be a major concern. For years, the ash has been processed in a yard adjacent to the C-RPP. The basic steps are ferrous scrap separation and screening. Much of the end product is being sold for road construction purposes. This is in line with legislative efforts which demand that ash be converted into useful products.

New governmental regulations have now established the loss-on-ignition (LOI) test as a key quality parameter. For ash which is landfilled, the maximum permissible LOI is 5% by weight. On the other hand, for ash-derived products, the LOI is limited to 3% by weight [1].

Generally, the Bamberg C-RPP meets the first requirement, however compliance with the second is marginal at best. In fact, the future sale of its ash product is in jeopardy. In order to cope with this problem, the idea of air-classifying the ash was introduced. Initially, a pilot system was set up in the yard for the purpose of segregating those components which are mostly responsible for the LOI. These experiments had only a modest measure of success [2]. It was then decided to move air classification directly into the furnace and integrate it with the combustion system.

Towards this end, a special device was developed which is called the “burn-out beam” In the subject paper, the salient features of this unique device are described. The results of comparative, full-scale testing with and without the device are discussed. In the end, it was demonstrated that the 3% LOI limit can be met with air classification.

BURN-OUT BEAM FOR AIR CLASSIFICATION OF RESIDUE IN FURNACE CHAMBER

Based on the experience and knowledge obtained to date, a special beam consisting of two concentric pipes was installed in the number 1 furnace. This beam is not only water-cooled, but it is also clad on the outside with refractory in order to resist corrosion, abrasion and fire.

The basic features of this burn-out beam (approximately 2,500 mm or 98.43 inches in length and 250 mm or 9.84 inches in diameter), including the protected nozzles, are illustrated in Figure 1.

An important design aspect was the correct selection

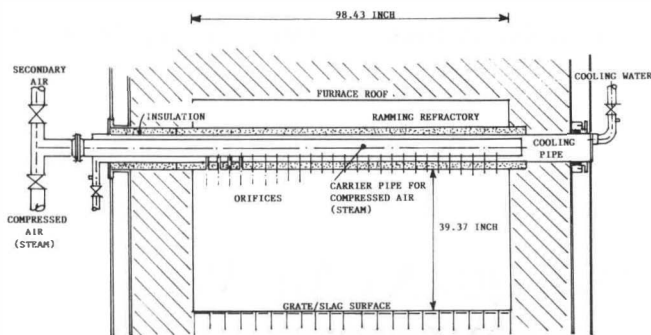


FIG. 1 MULTI-PURPOSE BURN-OUT BEAM ARRANGEMENT

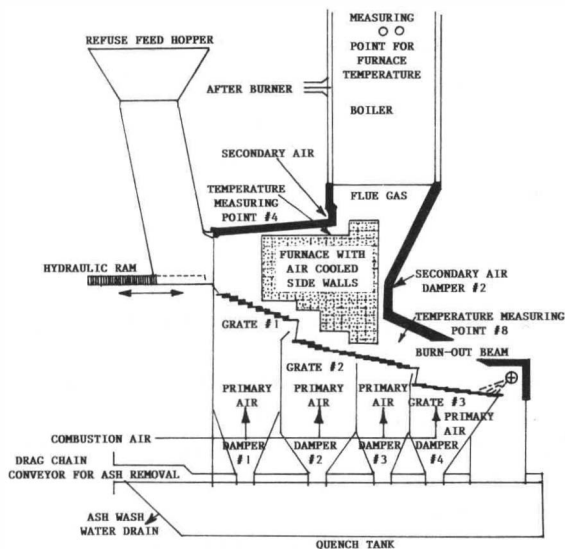


FIG. 2 BAMBERG C-RPP—LOCATION OF BURN-OUT BEAM IN FURNACE #1

of the nozzle diameter (approximately 15 mm or 0.59 inch) because—depending on the pressure—these nozzles must permit a spot air exit velocity of up to 400 m/s or 1,300 ft/s. This is necessary so that even with a length of the center streamer (situated above the grate) of 1.0–1.2 m (39–47 inches), a satisfactory jet velocity on the grate can be guaranteed. For the air classification and turbulence effects, approximately 25–30 m/s (82–98 ft/s) are sufficient. For the blast effect on the surface, a jet velocity of about 7–10 m (23–33 ft/s) is required. The installation of the burn-out beam inside the furnace is shown in Figure 2.

The burn-out beam can be rotated about its axis, which leads to a variation of the angle under which the air jets impact on the surface of the grate. It is most effective if the air jets hit the transition zone between ash which still glows lightly and ash which is already cooled down. Even a short distance downstream is still acceptable. All of this is accomplished in a manner which minimizes the addition

of air because a negative impact on combustion control must be avoided. The same holds true for the application of compressed air (3 bar or 43.5 psia), which is expensive. Also, a blowing period which is too long interferes with the pressure relationships in the furnace chamber.

The burn-out beam was built by Wärmetechnik Dr. Pauli GmbH and is the result of joint efforts between the Bamberg C-RPP and Dr. Pauli. The latter has applied for patent protection.

OPERATIONAL SCHEME FOR MULTI-PURPOSE BURN-OUT BEAM

For the rotation, whirling-up and simultaneous air classification, the ash must be stirred and lifted off the grate. This whirling-up must not be limited to the fine fraction, but instead it must affect all ash, including cans and the like, along the entire width of the grate. Duration of the needed compressed air impulse can be restricted to a few seconds (5–10 s). However, the sequencing of the impulses must be adjusted to the speed by which the ash travels along the grate. In order to make the whirling-up effect penetrate about 400 mm (15.75 inches) into the ash bed above the grate, an interval length of 5–10 minutes between successive impulses was determined as the optimum. All time components can be selected and adjusted freely.

As a consequence of the compressed air injection, the whole furnace chamber above the grate will darken. The negative pressure which prevails in the furnace chamber causes mainly the organic component of the fine fraction to migrate into the fire and the post-combustion zone where it encounters high combustion temperatures. This migration is facilitated by the fact that the organic particles are slow in settling. Only a small portion of light mineral particles is pulled along with it.

The whirling-up and air classification effect is accomplished by adding compressed air to the combustion process at a rate of about 80 m³/h or 2,825 ft³/h. In between the impulses of compressed air, the burn-out beam is also used as an afterburner. For this purpose, a portion of the available secondary combustion air (at 700 mm WS or 27.6 inches WC) is blown at a rate of about 500 m³/h or 17,657 ft³/h at the ash bed. The latter is nearly completely burnt-out. This air comes from above and contacts the ash at an oblique angle.

The changeover from one air supply to the other is fully automatically controlled by pneumatically operated valves.

For test purposes, medium pressure steam at 3.2 bar (46.4 psia) was substituted for the compressed air. This approach yielded similar results, except that the water cooling system had to be switched off. Otherwise, the steam would condense immediately in the burn-out beam and block the steam nozzles.

PARTICLE SIZE DISTRIBUTIONS OF ASH WITH AND WITHOUT AIR CLASSIFICATION

For the purpose of testing, the ash was prescreened. As a matter of convenience, a dominant size of 54 mm was selected as the cut-off point for dividing the unders from the overs. The unders were then screened further into 12 different particle size ranges. On a given test day, 12-hour composite samples were collected from the ash removal conveyor. This was done first while the burn-out beam was in operation. Afterwards the compressed air supply was switched off and sampling was repeated. Each composite sample amounted to approximately 120 kg (264 Lb).

Thus, on each test day, there were two sequential series. In order to minimize the effects of seasonal variations in waste and ash composition, the test days were repeated three times with each being scheduled during a different month.

The results are presented in both tabular and diagram form. (See Table 1 and Figure 3.) A shift towards smaller particle sizes is clearly discernible because of air classification. For example, without air classification, only 30% by weight of all ash particles fell into the $0 < x < 3$ mm size range. In contrast, 40% of the air-classified ash fell into the same size range.

Prescreening had a similar effect. Without air classification, an average of 6% by weight exceeded 54 mm. For air-classified ash, the comparative average was about 2%. However, the relatively low percentages for both indicate that prescreening introduces only a small bias.

A positive side effect of air classification is more uniformity of the particle size distributions. In Figure 3, this is demonstrated in that the lines for the air classification series fall closely together. Without air classification, more of a lateral spread is experienced. From the viewpoint of product quality control, this is a desirable feature.

LOSS ON IGNITION OF ASH WITH AND WITHOUT AIR CLASSIFICATION

In Table 2, the losses of ignition values are presented for the various particle size groups which were previously investigated by fine screening. Columns 2, 3 and 4 are without air classification and columns 5, 6 and 7 are with air classification. In this table, the separation between fine and coarse particles was arbitrarily drawn at a dominant particle size of 3 mm. Thus, the first field in Table 2 deals with particle size groups ranging from 0–3 mm. The second field covers only one size group between 3 and 54 mm. The LOI is expressed as percent loss of initial dry weight. As in Table 1 before, three tests were performed on separate days which were spaced several weeks apart from each other. Again, on each test day one series was run with air classification and another without air classification.

TABLE 1 BAMBERG C-RPP — SHIFT IN ASH PARTICLE SIZE DISTRIBUTION USE TO AIR CLASSIFICATION (Basis: 10 kg Dry Ash)

| Particle Size Range [mm] | Weight Fraction [dkg] | | | | | |
|------------------------------|--|---------------|---------------|---|---------------|---------------|
| | Without Air Classification Test Series/Date | | | With Air Classification Test Series/Date | | |
| | #1 July 21 | #2 Sept. 8 | #3 Oct. 13 | #4 July 21 | #5 Sept. 8 | #6 Oct. 13 |
| $0 < x < 0.05$ | 1.3 | 0.8 | 0.8 | 1.3 | 0.9 | 1.0 |
| $0.05 < x < 0.1$ | 2.3 | 0.7 | 1.9 | 2.9 | 1.5 | 2.3 |
| $0.1 < x < 0.2$ | 4.9 | 1.5 | 3.0 | 5.1 | 3.2 | 6.1 |
| $0.2 < x < 0.5$ | 9.0 | 5.1 | 6.2 | 12.3 | 10.3 | 11.7 |
| $0.5 < x < 1.0$ | 6.8 | 8.1 | 8.0 | 7.6 | 9.8 | 8.5 |
| $1 < x < 2$ | 5.5 | 7.7 | 3.7 | 5.9 | 8.8 | 5.6 |
| $2 < x < 3$ | 5.4 | 4.7 | 3.2 | 5.3 | 5.1 | 4.9 |
| Calculated Subtotal $0 < 3$ | 35.1 | 28.6 | 26.8 | 40.3 | 39.6 | 40.1 |
| $3 < x < 6$ | 13.1 | 9.3 | 12.3 | 12.8 | 10.3 | 11.6 |
| $6 < x < 10$ | 10.6 | 11.8 | 14.8 | 11.8 | 12.3 | 14.7 |
| $10 < x < 19$ | 20.7 | 18.8 | 19.1 | 20.6 | 17.0 | 18.3 |
| $19 < x < 31$ | 9.3 | 11.8 | 14.4 | 5.4 | 12.6 | 9.2 |
| $31 < x < 54$ | 5.4 | 8.4 | 10.6 | 6.1 | 6.3 | 4.6 |
| $x > 54$ | 5.8 | 11.4 | 2.0 | 3.0 | 1.9 | 1.5 |
| Calculated Subtotal $3 > 54$ | 64.9 | 71.5 | 73.2 | 59.7 | 60.4 | 59.9 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

- Notes: (1) Twelve wet ash samples were removed at one-hour intervals from the ash removal conveyor. Each sample weighed about 10 kg (22 lb). The twelve samples were mixed into one composite sample of about 120 kg (264 Lb). A 10 to 15 kg portion of the composite sample was then dried and shipped to a contract lab for screening and LOI analyses. Safety concerns prevented the taking of ash samples directly from the furnace. Typically, the moisture content is 15–20% wt. On any given test day, the air classification series was performed first. This was followed by a one-hour rest period before sampling resumed for the series without air classification.
- (2) Each test series represents the average of a 12-hour operating period.
- (3) The subtotals have been adjusted slightly to compensate for small rounding-off errors.

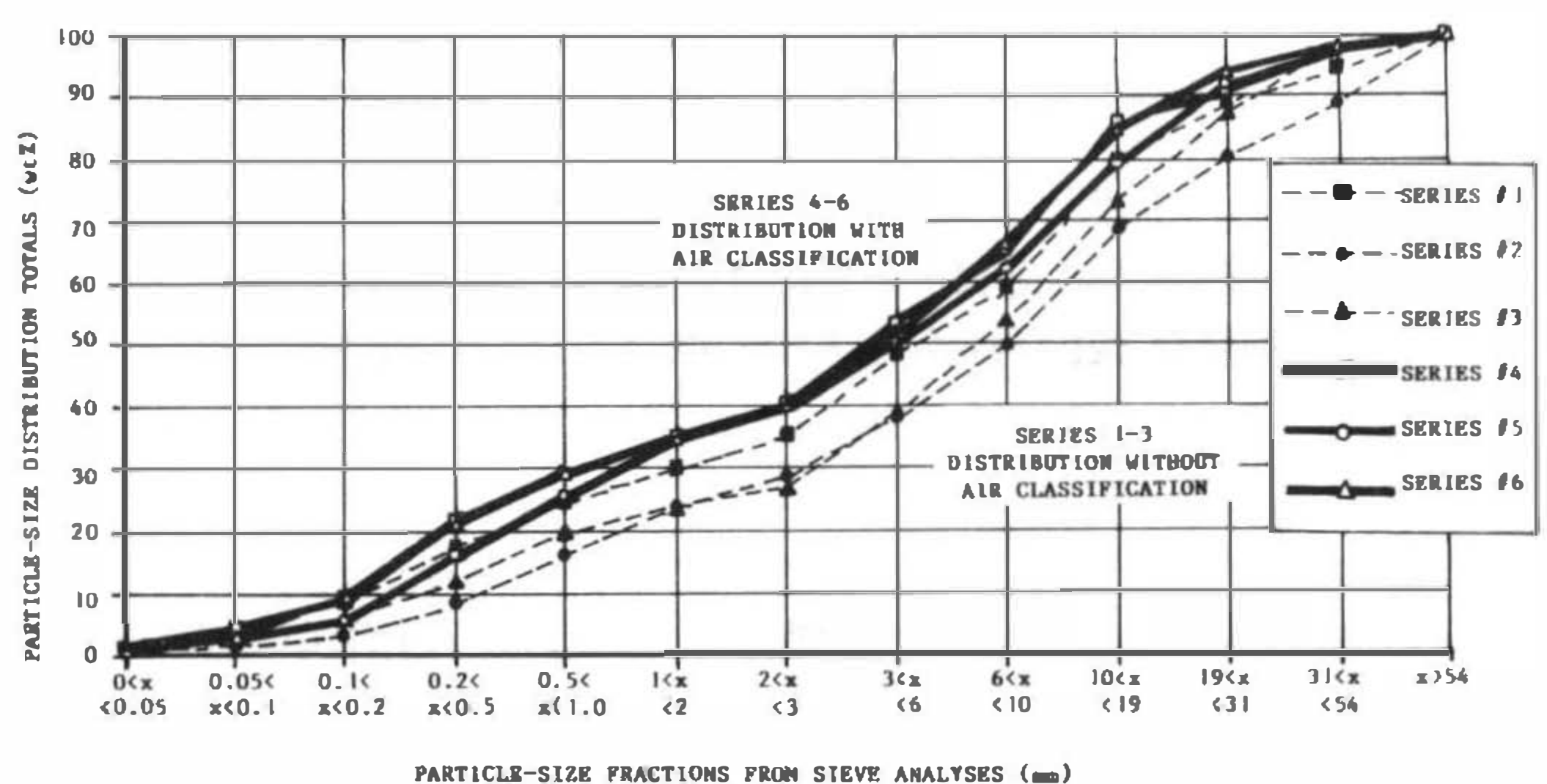


FIG. 3 SHIFT IN PARTICLE-SIZE DISTRIBUTION CAUSED BY AIR CLASSIFICATION OF ASH IN FURNACE CHAMBER

Air classification reduced the LOI in all particle size ranges, however this effect was most pronounced at the small end. For example, in the $0 < x < 0.05$ mm size range, a 67% decrease in LOI was observed on the average. By comparison, in the $2 < x < 3$ mm size range, the downward shift amounted only to an average of 33%.

The relationship between air classification and ash quality as expressed by the LOI works out well. Figure 4 conveys this message in a simpler way. For the finest particle size groups under 0.2 mm, the LOI was extremely high with 8–14%. With the help of air classification, the LOI

TABLE 2 BAMBERG C-RPP—SHIFT IN ASH LOT DUE TO AIR CLASSIFICATION⁽¹⁾⁽²⁾

| Particle Size Range [mm] | Weight Loss [%wt] | | | | | |
|--------------------------|---|---------------|---------------|--|---------------|---------------|
| | Without Air Classification Test Series/Date | | | With Air Classification Test Series/Date | | |
| | #1 July 21 | #2 Sept. 8 | #3 Oct. 13 | #4 July 21 | #5 Sept. 8 | #6 Oct. 13 |
| 0 < x < 0.05 | 12.7 | 14.0 | 7.9 | 5.2 | 2.1 | 4.0 |
| 0.05 < x < 0.1 | 12.4 | 12.0 | 8.2 | 3.7 | 1.8 | 3.2 |
| 0.1 < x < 0.2 | 8.1 | 8.4 | 9.4 | 4.3 | 1.9 | 3.6 |
| 0.2 < x < 0.5 | 8.7 | 6.2 | 6.2 | 2.6 | 1.7 | 1.2 |
| 0.5 < x < 1.0 | 5.9 | 8.1 | 5.6 | 3.0 | 2.5 | 2.0 |
| 1 < x < 2 | 5.3 | 6.2 | 4.0 | 3.8 | 3.1 | 2.1 |
| 2 < x < 3 | 3.0 | 5.1 | 2.9 | 3.1 | 2.6 | 1.7 |
| 3 > 54 | 2.9 | 5.0 | 2.0 | 1.8 | 2.2 | 1.4 |

Notes: (1) Twelve wet ash samples were removed at one-hour intervals from the ash removal conveyor. Each sample weighed about 10 kg (22 lb). The twelve samples were mixed into one composite sample of about 120 kg (264 Lb). A 10 to 15 kg portion of the composite sample was then dried and shipped to a contract lab for screening and LOI analyses. Safety concerns prevented the taking of ash samples directly from the furnace. Typically, the moisture content is 15-20% wt. On any given test day, the air classification series was performed first. This was followed by a one-hour rest period before sampling resumed for the series without air classification.

(2) Each test series represents the average of a 12-hour operating period.

TABLE 3 BAMBERG C-RPP—SHIFT IN SPECIFIC ASH LOI DUE TO AIR CLASSIFICATION

| Particle Size Range [mm] | Specific LOI ⁽¹⁾ $\frac{\text{kg LOI}}{100 \text{ dkg Ash}}$ | | | | | |
|--------------------------|---|---------------|---------------|--|---------------|---------------|
| | Without Air Classification Test Series/Date | | | With Air Classification Test Series/Date | | |
| | #1 July 21 | #2 Sept. 8 | #3 Oct. 13 | #4 July 21 | #5 Sept. 8 | #6 Oct. 13 |
| 0 < x < 0.05 | 0.1651 | 0.1120 | 0.0632 | 0.0676 | 0.0189 | 0.0400 |
| 0.05 < x < 0.1 | 0.2852 | 0.0840 | 0.1558 | 0.1073 | 0.0270 | 0.0736 |
| 0.1 < x < 0.2 | 0.3969 | 0.1260 | 0.2820 | 0.2193 | 0.0608 | 0.2196 |
| 0.2 < x < 0.5 | 0.7830 | 0.3162 | 0.3844 | 0.3198 | 0.1751 | 0.1404 |
| 0.5 < x < 1.0 | 0.4012 | 0.6561 | 0.4480 | 0.2280 | 0.2450 | 0.1700 |
| 1 < x < 2 | 0.2915 | 0.4774 | 0.1480 | 0.2242 | 0.2728 | 0.1176 |
| 2 < x < 3 | 0.1620 | 0.2397 | 0.0928 | 0.1643 | 0.1326 | 0.0833 |
| 3 > 54 | 1.8821 | 3.5750 | 1.4640 | 1.0746 | 1.3288 | 0.8386 |
| Total 0 > 54 | 4.3670 | 5.5864 | 3.0382 | 2.4051 | 2.2610 | 1.6831 |

Notes: (1) The specific ash LOI's were obtained by multiplying the results of Table 1 with those in Table 2. The product was then divided by 100%.

TABLE 4 BAMBERG C-RPP—COMPARISON OF CALCULATED AND EXPERIMENTAL SPECIFIC ASH LOI'S

| Particle Size Range [mm] | LOI $\frac{\text{kg LOI}}{\text{kg Ash}}$ | | | | | |
|-----------------------------|---|---------------|---------------|--|---------------|---------------|
| | Without Air Classification Test Series/Date | | | With Air Classification Test Series/Date | | |
| | #1 July 21 | #2 Sept. 8 | #3 Oct. 13 | #4 July 21 | #5 Sept. 8 | #6 Oct. 13 |
| Calculated ⁽¹⁾ | 4.37 | 5.59 | 3.04 | 2.41 | 2.26 | 1.68 |
| Experimental ⁽²⁾ | 4.53 | 5.41 | 3.30 | 2.26 | 2.37 | 1.45 |
| Difference ⁽³⁾ | -3.53 | +3.33 | -7.88 | +6.64 | -4.64 | +15.86 |

Notes: (1) The calculated specific ash LOI's were taken from Table 3.

(2) The experimental determinations were made for check purposes. They involved portions of the same samples which were previously tested after fine screening into 8 different fractions. Except in this case, all particles which passed a 54 mm screen were kept together for a single LOI test.

(3) Difference = $\frac{\text{Calculated LOI} - \text{Experimental LOI}}{\text{Experimental LOI}} \times 100\%$

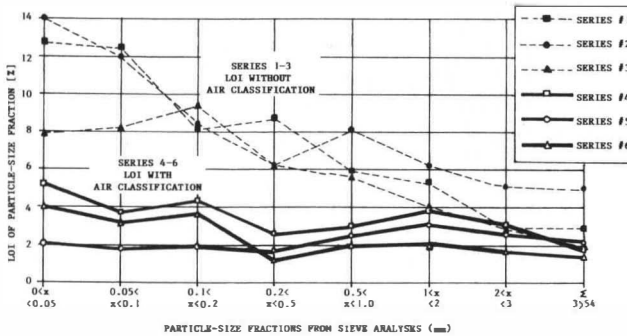


FIG. 4 SHIFT IN LOI DUE TO AIR CLASSIFICATION OF ASH IN FURNACE ROOM

was reduced to 2–6%. Although less pronounced, a similar trend was established for the other particle size groups. This picture was fairly consistent from one test run to the next. Furthermore, air classification also cut back the spread from one series to the next. This is especially noticeable at the extreme ends.

SPECIFIC LOI OF ASH WITH AND WITHOUT AIR CLASSIFICATION

The specific LOI is expressed as kg LOI per 100 dkg of ash. It is obtained by multiplication and division of the test values found in the preceding Tables 1 and 2. A size of 3 mm was arbitrarily selected for distinguishing between fine and coarse particles. The result of the calculations is contained in Table 3. While the fine particles are sorted into seven different ranges, only a single range is used for the coarse particles.

For future ash product sales, the totals for the specific LOI are the most significant parameters. The bottom line in Table 3 clearly shows that an overall reduction of about 50% is achieved across the board. Consequently, it can be concluded that Bamberg's air classified ash is burnt out better and meets the new regulatory requirement.

In order to be sure that this is the case and that extensive screening did not alter the final result, yet another set of tests was performed. Accordingly, a portion of each composite sample was diverted after screening and subjected *in toto* to separate LOI testing. In Table 4, the totals for the specific LOI's, obtained by either working with fractional or composite specimens, are compared.

With one exception, the differences between the two are under 10%. Negative and positive differences change from one test series to the next, suggesting randomness. For series #6, the difference comes to 16%. This seems high, but by recognizing that the LOI's involved are rather low to begin with, this fact can be understood.

SIDE EFFECTS ON COMBUSTION CONTROL, EMISSIONS AND FILTER DUST QUANTITY

During the test program, special attention was given to observations concerning a potential increase in the amount of flyash collected by the electrostatic precipitators. Could any other changes in the combustion process or in the flue gases be detected? During simultaneous measurements, it was determined that the combined air flow of pulse and blow air (about 600 m³/h or 21,188 ft³/min) did not have a discernible effect on the combustion process. The latter has a total air demand of about 30,000 m³/h or 1,059,400 ft³/h.

Stack measurements, which were taken at the end of the whole gas cleaning train, indicated that there was no increase of dust concentrations above the less than 10 mg/m³ or 0.0044 grain/ft³ normally encountered. However, these particular measurements do not permit a statement regarding a potential increase of the dust loadings in the raw gas itself. Therefore, during all the tests, the amounts of flyash collected from the boiler and the precipitator were measured separately. Boiler flyash collection amounted to 3.5 Kg per Mg (3.5 Lb per 1,000 Lb) of residue compared to 19 Kg per Mg (19 Lb per 1,000 Lb) residue for precipitator fly ash. Both values fall within the range of normal fluctuations. Furthermore, no increase of the LOI was observed in the residues from the flue gas cleaning system beyond the usual 1–2%.

Based on these results, it can be concluded that there were no effects of significance which impacted the combustion process, the flue gas composition, dust concentration and dust accumulation as a consequence of operating the burn-out beam. Of course, this presupposes that all other operating parameters are held to within their normal limits. This conclusion is reinforced by the fact that the long-term operation of the modified furnace number 1 was quite satisfactory.

SUMMARY

The installation of the multi-purpose burn-out beam provided for the first time the opportunity to reduce the usual ash LOI by 50% directly and consistently in the furnace chamber. The air classification effect, which is limited to a few seconds at a time, agitates the dry and hot ash directly on the grate inside the furnace chamber. In this manner, the finest particles and the light fraction are whirled up. However, the mineral fine particles quickly settle down almost completely. On the other hand, only those fines and light particles which are heavily laden with organics and which are slow to settle will be returned through the negative pressure into the hot fire zone for final combustion. The fine particles, which were previously separated, are now burned out into new ash. They constitute a relatively small quantity and they follow two path-

ways. One part rejoins the old ash on the grate and the other part is carried off as dust with the flue gas.

In addition to the LOI reduction, the second function of the burn-out beam is just as successful. This is the blowing of secondary air against the surface of the ash bed, interrupted only from time to time by the air classification impulses. Even paper parts such as singed books and magazines or other partially burned or agglomerated residues can be opened up by the pulse jets of expanding compressed air. The light particles are whirled up in such a way that even the burn-out quality of the coarse ash is noticeably improved.

Neither the combustion process nor emissions or filter dust quantity and quality are impaired by this air classification and surface blowing. Instead, whirling-up by repeated application of the sharp air classification jets leads to refinement and homogenization of the entire ash, both with respect to grain size distribution and LOI reduction.

The costs for supply and installation of such a burn-out beam for a furnace with a waste mass flow rate of 6 Mg/h, or 13,220 Lb/h, came to about DM 100,000 (\$62,500.). This included all piping, control elements and wiring. Both in terms of the external and internal provisions, the installation of such a burn-out beam can take place during a regular furnace maintenance period. The work can be done within 2–3 days without problems.

The multi-purpose burn-out beam discussed here is suitable for primary treatment of ash directly in the furnace, which houses all types of grates and combustion systems. It is equally compatible with parallel, middle and counter-current flow systems [3, 4].

Application of the burn-out beam achieves substantial enhancement of ash quality in the simplest manner, opening the way to beneficial use of the final ash in construction and landfill operation. According to the full-scale operating experience in the Bamberg C-RPP, the burn-out beam should be considered as state-of-the-art even in situations where ash burn-out is already relatively good to begin with.

For this reason and in view of the excellent operating results, it has been decided to equip Bamberg's furnaces 2 and 3 with this type of multi-purpose burn-out beam in the near future. Other facilities may wish to follow suit.

Besides municipal solid waste, designs have been prepared to apply the burn-out beam to combustors for medical and special wastes. Unit processing capacities range from 0.5 to 5.0 Mg/h (1.10 to 11.00 stph). It is anticipated that the burn-out beam will enter the North American market through licensing agreements.

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