# ESTIMATION OF BURNING RATES IN SOLID WASTE COMBUSTION FURNACE

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**Discussion by:**

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The author provides an interesting one-dimensional application of Essenhigh's bed combustion models to municipal waste combustors. Some of the model's limitations are recognized when the author explains that this work only considers chemical heat release and that radiative and convective heat release may be significant and should be considered as well. In the mid 1970s, I was part of a team that used Essenhigh's model frame work and finite element techniques to model the Landguard Process (a counter-current rotary kiln gasifier). The Landguard modeling was part of the EPA-sponsored technical evaluation of the Baltimore plant to help us understand why the roughly 30:1 scale-up from prototype to commercial unit failed.

We learned that the Essenhigh model had to be expanded to separately consider the heat transfer modes and losses the author notes, solid- and gas-phase reactions, and that the solids had to be modeled along the lines of conventionally defined combustion zones (i.e., drying, ignition, rapid burning, char burn-out, and cooling) before we could get the model to match the measured end conditions. This means that we had to consider volatilization (gasification) effects as well as the diffusion-limited fixed carbon burn-out.

Consequently, I believe that the author's conclusions should be considered preliminary until further work is done to incorporate, at least on a heuristic basis, additional known significant parameters into the model. I also suggest that the model be compared to field data on furnace residue carbon and the chemistry of the off-gases at the system boundaries.

Such comparisons and validations becomes particularly important if the author wants to compare modular (starved air) combustors and conventional mass burning units. Modular combustors are designed to introduce 80–90% of theoretical air into the primary chamber to gasify the waste and inherently produce a carbon-rich char as residue. In the case of a mass burning unit, more than theoretical air is introduced into the fuel bed, albeit in a series of zones, and a low-carbon residue results. Consequently, the author's conclusion that poor mixing is the cause of high fixed grate carbon is easily explained by a design decision and cannot necessarily be taken as a valid teaching of the model.

Because this paper brings together a number of often forgotten combustion principles, it makes an important contribution. The paper's utility would be greatly enhanced if the author would provide a list of symbols, keyed to equation, or graphs. Unfortunately, the same symbol is used to mean different things in different parts of the paper. For example, $V$ is defined as a volatile fraction in Eq. (4), but must have a different meaning — possibly volumetric heat release rate in kcal/m3/h — for Fig. 3 to make any sense. Similarly, types 0 and 1 waste are carry-overs from the now defunct Incinerator Institute of America, and need to be defined so that a modern reader can realize that the author is comparing garbage and commercial waste in Figs.1, 2, and 3.

## AUTHOR'S REPLY

The original intention of this work was trying to provide fundamental answers as to why the bed burning rates quoted by incinerator manufacturers vary so significantly from small, fixed-grate batch-fed solid waste incinerators to mechanically-stoked continuously operated central waste burning facilities. Grate burning rates are related to air supplies as those indicated in Eqs. (4–6). Since application of these equations pose no specific restrictions as far as the size of the grate is concerned, the differences in grate burning rates among different grate designs must be buried in the factors of $F_{\pi s}$ or $F_r$ [Eqs. (10 and 11)]. These factors presumably could be influenced by different furnace grate designs and methods of air supply and distribution. On the other hand, of course, Eqs. (4, 6, or 9) account for only the oxygen reaction part of the burning processes, other factors such as drying and volatilization, as Mr. Rigo pointed out in the discussion, could be important and may pose additional limits on grate burning capacity.

We have performed tests with a batch-fed fixed-grate furnace burning municipal solid waste. Each individual test ran about 4–6 hr, the variations in average burning rates ranging from 40 to 120%. Moisture contents had a significant effect in reducing the overall bed burning capacity. Refuse with high moisture content could severely hamper the grate burning capability. The test ran with good stoking, showed marked improvement in combustion efficiency, and an increase in grate burning capacity.

Recently, in the laboratory, we have run bench-scale tests using a cylindrical furnace with a circular fixed grate of 25 cm in diameter, burning wood cubes with sizes ranging from 3 x 3 x 3 to 5 x 5 x 5 $cm^3$. The $a_pLs$, the product of $a_p$ , the wood cube surface area per unit bed volume , and the bed height $L$, of the wood cube beds cover the range from 13.2 to 53.5. These $a_pL$ values, assuming $jD$=0.1 and $Sc$=1, would give $k_r$ from 1.3 to 5.35 [from Eq. (14)]. The measured grate burning rates were in the range of 14–37 kg/$m^2$/h for air supplies from 5.5 to 16.5 moles/$m^2$/h. This range of experimental results seems to be in agreement with the range of grate burning rates indicated in Fig. 9.

The symbol $V$ in Fig. 3 denotes the volume of furnace; perhaps it would be better to change it to $V_c$ to avoid confusion. $I_s$ and $I_v$ stand for grate area heat release rate (kcal/$m^2$/h) and volumetric heat release rate (kcal/$m^3$/h), respectively. As to the waste classification, type 0 wastes represent trash with principal components consisting of waste paper, wood, etc., and including up to 10% of plastics or rubber scraps from commercial and industrial sources. The as-fired heating value of type 0 wastes is about 4700 kcal/kg. Type 1 wastes are classified as refuse consisting of approximately 80% trash and 20% garbage with an as-fired heating value of 3600 kcal/kg.