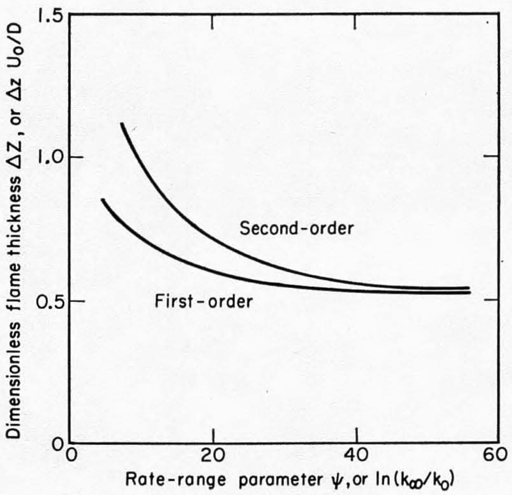

FIGURE 5. Effect of rate-range parameter on flame-thickness group

dimensionless rate constant is used which corresponds to the right U_o.

We let X represent both the fraction converted f and the dimensionless temperature rise θ; Y = 1-X; D, both the mass diffusivity and the thermal diffusivity; z, distance within the flame, measured from a reference plane (e.g., where X = 0.05); Δz, the specific distance between X = 0.05 and X = 0.95; α, the order of reaction, assuming stoichiometric proportions of the reactants; $Z = zU_o/D$; and $C = Dk_\infty/U_o^2$.

The ordinary differential equation is

$$U_o \frac{dX}{dz} + D\frac{d^2X}{dz^2} = k_\infty e^{\psi(1-X)} (1-X)^\alpha$$

In dimensionless form,

$$-\frac{dY}{dZ} - \frac{d^2Y}{dZ^2} = C e^{-\psi Y} Y^\alpha$$

The results of numerical integration of this equation, for $\alpha = 1$ and 2, and for different Ψ, are given in two new plots. Figure 4 gives C as a function of Ψ, and can be used to determine the flame velocity U_o from the rate coefficient k_∞, or vice versa; Figure 5 gives ΔZ, also as a function of Ψ, and can be used with U_o to define the true flame thickness. If one has an experimental flame thickness and does not know D, the figures are used in reverse order.

The ΔZ group has been called the Karlovitz number, after a longtime staff member of the U.S. Bureau of Mines. This group was observed empirically to be always in the vicinity of 1, lending credence to the approximations in our calculation.

The low-Ψ, low-k_∞ end of these curves once more represents the point where the solution vanishes—i.e., the flammability limit, which may involve a flame speed of only a few feet per second. It is a matter of convenience to use k_∞, rather than the starting value k_o, as the rate constant; Figure 4 would show many more orders of magnitude if C contained k_o. The flame velocity increases rapidly with increasing Ψ, and sonic velocity is likely to occur in the rate of 25 to 40 for Ψ.

These few concepts with their accompanying mathematical models go a long way toward eliminating the mystery that seems to surround flames and explosions. Let's work together to examine how and where they might be given increased attention in the undergraduate curriculum. □

REFERENCES

David A. Frank-Kamenetskii, "Diffusion and Heat Transfer in Chemical Kinetics," Plenum Press, New York (1969).

Samuel Glasstone, editor, "The Effect of Nuclear Weapons," U. S. Atomic Energy Commission (1962).

Bernard Lewis and Guenther Von Elbe, 'Combustion, Flames, and Explosions of Gasses," 2nd ed., Academic Press, New York (1961).

Antoni K. Oppenheim, "Gasdynamic Analysis of Gaseous Detonation," Fourth Symposium on Combustion, 471-480, Williams and Wilkins, Baltimore (1953).

Daniel R. Stull, "Fundamentals of Fire and Explosions," AIChE Monograph Series *73*, no. 10 (1977).

A. Van Tiggelen, "Oxydations et Combustions," Editions Technip, Paris (1968).

Lev A. Vulis, "Thermal Regimes of Combustion," McGraw-Hill, New York (1961).

Y. B. Zeldovich and A. S. Kompaneets, "Theory of Detonation," Academic Press, New York (1961).

ChE stirred pots

THE CREATION

And in the beginning there was "Control." And Control created τ. And Control saw that this was good, but that τ was lonely, so Control created τ a mate and Control saw that this also was good. τ's mate was called $\tau s+1$. But before long $\tau s+1$ led τ down the path of sustained oscillation. Control saw this and He was troubled. He granted τ and $\tau s+1$ a transfer function to the land of instability where through the wonders of "Control" $\tau s+1$ begat Gain. And before long $\tau s+1$ also begat Routh. One day while tending the process, Gain became quite angry with Routh and rattled his array but good. And then Gain fled to the caves of Frequency Response, emerging only at odd multiples of τ to wash his B.V.D.'s and read the weekly edition of the "Control Gazette."

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