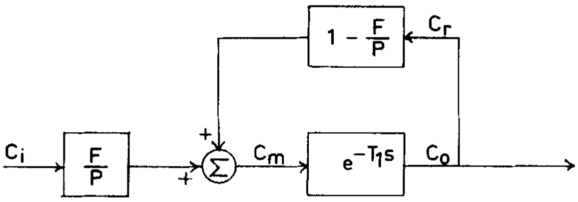

Fig. 2. Block diagram representation of mixer with zero recirculation delay.

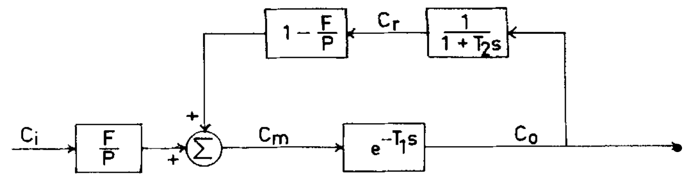

Fig. 3. Block diagram representation of mixer with a perfectly mixed recycle stream.

the most useful models and methods of relating model parameters to the physical dimensions of the equipment.

NOTATION

$C_i(t)$ = input concentration or other additive intensive property
$C_m(t)$ = concentration after mixing
$C_o(t)$ = output concentration
$C_r(t)$ = recycle concentration before mixing
$C(s)$ = Laplace transform of $C(t) = \int_0^\infty e^{-st}\, C(t)dt$
i = $(-1)^{1/2}$
k = T_2/T_1
F = flow rate in and out of the mixing tank, lb/min.
P = agitator pumping rate
T_1 = time delay in the draught tube, min.
T_2 = time constant of the mixing tank apart from the draught tube, min.
ω = frequency of sinusoidal oscillation radians/min.
λ = period of sinusoidal oscillation, min.

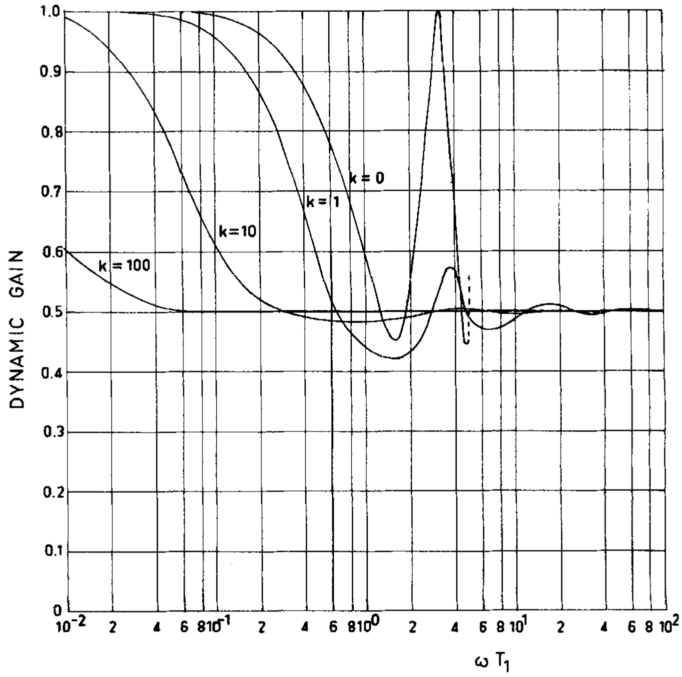

Fig. 4. Dynamic gain of mixer with perfectly mixed recycle stream.

LITERATURE CITED

1. Gutoff, E. B., *A.I.Ch.E. Journal*, 6, 347 (1960).
2. Ceaglske, N. A., "Automatic Process Control for Chemical Engineers," Wiley, New York (1956).

CHEMICAL ENGINEERING PROGRESS SYMPOSIUM SERIES ABSTRACTS

The Chemical Engineering Progress Symposium Series is composed of papers on specific subjects conveniently bound in individual books, which are published at intervals. The books are 8½ by 11 inches, paper covered, and cost $3:50 to members, $15.00 to nonmembers for "Rocket and Missile Technology," No. 33. They may be ordered from the Secretary's Office, the American Institute of Chemical Engineers, 345 East 47 Street, New York 17, New York.

The *A.I.Ch.E. Journal* will publish, from time to time, abstracts of the articles appearing in the Symposium Series volumes. Recently published volumes are abstracted below.

ROCKET AND MISSILE TECHNOLOGY, Vol. 57, No. 33, 1961.

Thermodynamics and Missile Performance, Howard C. Rodean. Chemical energy available in propellants and fuels for ramjets is related to the useful work done in delivering payloads with ballistic rockets, boost-guide rockets, and rocket-boosted cruise ramjets. Energy-conversion processes and gas-flow phenomena are discussed for both rocket and ramjet engines, as are factors involved in converting propulsion-system energy into vehicle energy and then to range. Performance of the three vehicles is related to chemical energy expended. **Aerothermochemistry of Jet Propulsion Liquid-Propellant Rocket Motors**, T. Paul Torda. The phenomena in compressible flow in which chemical and phase changes take place is discussed. One of the least understood phases of aerothermochemistry is the combustion of liquid sprays, and this subject is developed here at greater length. This subject is important in understanding instabilities that develop in rocket motors. Analytical methods are required in successful development, and since nonlinear mathematics is not sufficiently developed, linear theories have been proposed. The theories reported here are believed to be the first successful solution of this highly nonlinear, nonsteady state problem. **One-Dimensional Flow With Chemical Reaction in Nozzle Expansion,** Thaine W. Reynolds and Lionel V. Baldwin. The solution of the one-dimensional flow equations along with a chemical reaction-rate equation is presented for several simulated ramjet flight conditions. At Mach 4, flow is close to frozen throughout, while at Mach numbers up to 10 the flow is intermediate between frozen and equilibrium conditions. A considerable change in the reaction rate constant or residence time is apparently required to affect the flow markedly. Although the results agree with the conclusion obtained by using Penner's near-limiting flow criteria, a large range of conditions exist for which the determination of flow behavior requires the simultaneous solution of the flow and reaction-rate equations. In addition, an expression for entropy change occurring during flow with nonequilibrium chemical reaction is derived. **Problems of High-Energy Propellants for Rockets,** Walter T. Olson. High-energy rocket propellants offer large payloads over current propellants but pose unique problems because either the fuel is liquid hydrogen or the oxidant is liquid fluorine. Selected analytical and experimental results illustrate the problems that these materials create for propulsion systems. Solutions to these problems are presented. **Some Consideratons of Liquid-Propellant Combustion and Stability,** R. S. Levine. The more serious types of rocket combustion instabilities involve interactions between gas disturbances and combustion processes, which cause sustained destructive heating and vibration. In bipropellant liquid rockets the combustion rates are controlled by forced convective heat and mass transfer rather than by kinetics. The Reynolds number as affected by the relative velocity of the droplet and the gas around it is controlling. Weber numbers become large at higher velocities and the burnings drops shatter. **Thermodynamic Properties of Some Gaseous Metal Compounds,** Alfred Büchler. A review of the experimental data now available for gaseous fluorides, chlorides, oxides, and hydroxides, of Li, Na, and Be illustrates some of the thermodynamic and thermochemical problems underlying the calculation of propellant performance. The various problems and their source are discussed in detail. The article concludes with a note on tabulations of thermodynamic data. **A Review of Rocket Engine Heat Transfer,** S. Lafazan and R. D. Turnacliff. The containment and expansion of high-temperature working fluids used in rocket-propulsion systems has presented some challenging problems in heat transfer with temperatures ranging up to 8,000°R. and local heat fluxes as high as 15 × 10^6 B.t.u./(hr.) (sq.ft.). These extreme conditions are further complicated by the fact that containment must be reliably achieved as a minimum weigh. Three methods of containment presently used are discussed. These methods are (1) regenerative cooling, (2) heat-sink cooling, and (3) ablation cooling. Procedures used in applying general heat transfer calculations to rocket-nozzle design and prediction of convective heat transfer coefficients and heating rates in rocket nozzles are presented in detail. **Missiles, Material Selection, and Metallurgical Research,** W. Stuart Lyman. The missile material problem is complicated by many factors, including the following chemical considerations: oxidation, erosion, compatibility with propellants, and other rate processes. Missile configurations cause loads different from those in aircraft. Tensile loading, especially biaxial tension, is predominant. Brittle failure at low temperatures is a problem. The aim of alloy selection is to minimize weight at a supportable cost. Metallurgical research holds the key to the future. This article reviews the present state-of-the-art. **Insulation Materials in Missile Applications,** John H. Lux. The use of plastics as a material of construction rather than metals, ceramics, and graphite is discussed. The effect of material composition and fabrication techniques of plastics, as well as new developments in the field of plastic insulation materials, are presented. **Thermal Protection for Reentry,** Irving J. Gruntfest and Lawrence H. Shenker. This article is concerned with the exacting and distinctive requirements for materials for long-range missiles. In particular it is shown that some reinforced organic plastics which are unstable above 675°F. have outstanding durability when exposed to gases over 12,000°F. Various solutions to the materials problem that have been considered feasible are discussed; also the preflight screening of possible materials.

ERRATA

The heading of column 8 in Table 1 of "Thermodynamic Properties of Air," by E. M. Landsbaum, W. S. Dodds, W. F. Stevens, B. J. Sollami, and L. F. Stutzman, which appeared in the September, 1955, issue of the *A.I.Ch.E. Journal,* should be 68°F.

In Equations (3) and (5) of "Suspension of Slurries by Mechanical Mixers," by Joel Weisman and L. E. Efferding, which appeared in the September, 1960, issue of the *A.I.Ch.E. Journal,* ρ_l should be replaced by ρ_s. The corrected Equation (3) is

$$A = \frac{B^{1/2} V_t \, [g \, (\Delta \rho)]^{3/2} \, \delta^{1/2}}{P_s \, g_c \, \rho_s^{1/2}}$$

In Equation (5) the term (g/g_c) should be (g_c/g_c) and hence should be omitted. The corrected Equation (5) is

$$K(D/d)A^{-1/3} = \frac{N \, d^{2/3} \, (\rho_s/\rho_m)^{1/6}}{\delta^{1/6} \, g(\Delta\rho/\rho_m)^{1/2} \, B^{1/6}}$$

Equation (7) of "A Generalized Velocity Distribution for Non-Newtonian Fluids," by R. S. Brodkey, Jon Lee, and R. C. Chase, which appeared in the September, 1961, issue of the *A.I.Ch.E. Journal,* should read

$$v/v_{\max} = 1 + a_1 \, (r/r_o)^{(n+1)/n} + a_2(r/r_o)^{2m}$$

The parameter in Figure 1 of "Laminar Boundary Layer Flow and Heat Transfer Past a Flat Plate for a Liquid of Variable Viscosity," by O. T. Hanna and J. E. Myers, which appeared in the September, 1961, issue of the *A.I.Ch.E. Journal,* should be *A*. The Notation should read $A = D/\eta$, not $D = A/\eta$. This work was supported by the National Science Foundation under grant G-6318.

Computer Program Abstracts

Readers of the *A.I.Ch.E. Journal* who are interested in programming for machine computation of chemical engineering problems will find in each issue of *Chemical Engineering Progress* abstracts of programs submitted by companies in the chemical process industries. Collected by the Machine Computation Committee of the A.I.Ch.E., these programs will be published as manuals where sufficient interest is indicated. The following abstracts have appeared this year: