The Effect of Vibration Upon Rate of Sublimation

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Lemlich and Levy (*3*) studied the effect of vibration upon the rate of mass transfer by sublimation from small horizontal cylinders of naphthalene and camphor to air at room temperature. Their results, partly shown on Figure 1, are presented in the form of the ratio of mass transfer coefficients k/k' vs. the *stretched-film* vibrational Reynolds number, defined as

$$N_{ReS} = \frac{(D + H)\,\overline{V}\rho}{\mu} \qquad (1)$$

The stretched-film, with total length $D + H$, derives from a physical picture described previously by Lemlich (*2*), who contends that the film is not carried back and forth with the vibrating cylinder, but rather is stretched along, and surrounds, the entire vibrating path between the extremes through which the cylinder moves (see Figure 2).

Goh (*1*) employed an apparatus in which cylinders of naphthalene were vibrated in sinusoidal motion from a sample cradle at the end of a steel rule, obtained results which are presented in the coordinates of Figure 1. These results, while similar in form to

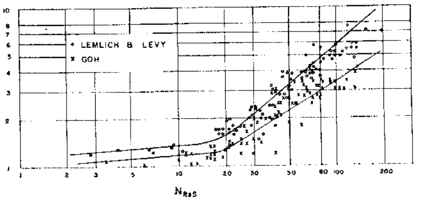

Fig. 1. Ratio of mass transfer coefficients vs. stretched-film Reynolds number.

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Use of a Radio Frequency Plasma Jet in Chemical Synthesis

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Production of acetylene and hydrogen cyanide in a d.c. plasma jet with either an inert or a reactive plasma gas made interesting the use of a radio frequency plasma jet for the production of nitrogen oxides, acetylene, and hydrogen cyanide. The radio frequency plasma jet utilizes the energy of a high-frequency electromagnetic field to dissociate and ionize gas molecules (*4*). When these ions recombine, the absorbed energy is given off in the form of heat.

APPARATUS

Two radio frequency plasma jet units were used for the experiments: a 0.3-kw. unit for low-pressure operation for nitrogen oxides and a 1.5-kw. unit for atmospheric-pressure operation for acetylene and hydrogen cyanide operation.

The 0.3-kw. unit is a 27.5-mc. power oscillator of approximately 350 watts (power input to plate), with a special water-cooled coil for the output resonance tank. The output power can be varied by either grid detuning or plate voltage.

The high-voltage end of the resonance-tank coil is attached to a water-cooled brass tube ¼-in. in diameter and 7 in. long, with a conical molybdenum tip that runs through the center of the coil.

A water-cooled glass tube surrounds the top half section of the tank-coil tube. The plasma gas enters through a glass side tube approximately 1 in. below the tip of the tank-coil tube.

The 1.5-kw. unit is basically a transmitter that operates between 24 and 28 mc. The output-tank coil is suspended vertically on the side of the generator cabinet. The center tank coil electrode is adjustable for various load impedances. Both the center electrode and the tank coil are water-cooled. The plasma gas is injected into the top of a Vycor tube that extends down through the center of the tank coil.

PREPARATION OF OXIDES OF NITROGEN

Since the oxides of nitrogen were successfully prepared using a d.c. plasma jet, (*5*) their preparation under reduced pressure was investigated using the 0.3-kw. radio frequency

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Table 1. Nitrogen-Oxygen Experiments at Reduced Pressure

Gas used	1:2; nitrogen:oxygen	1:1; nitrogen:oxygen	Air
Total gas flow, st. cc./sec.	6	5	6
Total power to jet, watts	375	394	375
Running time, hours	4.5	1	2.5
Run pressure, mm. Hg abs.	117.5	75	110
Amount of material collected			
Dry ice trap, cc.	nil	nil	nil
Liquid nitrogen trap, cc.	0.5	0.2	0.4
% conversion (based on conversion to nitrogen dioxide	1	1¼	2
Average molecular weight of product	58	51.2	56
Identification by infrared spectrum	Nitric oxide, nitrogen dioxide	—	Nitric oxide, nitrogen dioxide

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A' = surface area per unit length of stationary (nonvibrating) cylinder, πD
D = diameter of cylindrical sample
F = frequency of vibration, cycles per unit time
h = heat transfer coefficient, based upon area A'
h' = heat transfer coefficient for no vibration, based upon area A'
H = amplitude of vibration (sometimes also known as double amplitude)
k = mass transfer coefficient, based upon area A'
k' = mass transfer coefficient for no vibration, based upon area A'
N_{Re} = vibrational Reynolds number, given by Equation (3)
N_{ReS} = stretched-film vibrational Reynolds number, given by Equation (1)
Δt = temperature driving force for heat transfer
$\overline{V}$ = $2HF$, average velocity under vibration

Greek Letters

ρ = density of fluid (air)
μ = fluid viscosity

LITERATURE CITED

1. Goh, Tiak Theng, B.Sc.App. thesis, Univ. Queensland, Brisbane, Australia (1963).
2. Lemlich, R., *Ind. Eng. Chem.*, 47, 1175 (1955); correction in *Ind. Eng. Chem.*, 53, 314 (1961).
3. Lemlich, R., and M. R. Levy, *A.I.Ch.E. Journal*, 7, 240 (1961).
4. West, G. D., *Proc. Phys. Soc.*, 64, No. 378B, 483 (1951).

(*Continued from page 370*)

plasma unit. The tank-coil tube was enclosed in a water-cooled glass tube that was attached to two glass traps, one cooled with dry ice-acetone and the other with liquid nitrogen. The entire system was attached to a vacuum pump with an appropriate manometer and valve.

The plasma jet was started by introducing helium at a pressure of about 0.5 atm. and then changing to a nitrogen-oxygen mixture of air. The results of three experimental runs are tabulated in Table 1.

The conversions are low. However, the power level is also low and higher conversions can be expected from higher power inputs. The material collected in the liquid nitrogen trap was blue and yielded a red-brown gas upon evaporation. This indicates the presence of nitric oxide (3). Infrared spectrum and a molecular weight determination showed this product to be a mixture of nitric oxide and nitrogen dioxide. A mixture of 50% nitric oxide—40% nitrogen

INFORMATION RETRIEVAL

(*Continued from page 376*)

Generalization of gas-liquid partition chromatography to study high pressure vapor-liquid equilibria of multicomponent systems, Koonce, K. Terry, H. A. Deans, and Riki Kobayashi, **A.I.Ch.E. Journal, 11,** No. 2, p. 259 (March, 1965).

Key Words: A. Determination-8, K Constants-9-8, Vapor-Liquid Equilibrium-9-8, Gas-Liquid Partition Chromatography-10, Retention Time-10, Retention Volume-10, Ternary Mixture-9, Elution Process-10, Experimental-0, Theoretical-0, High Pressure-0, Equilibrium-2-8, Chromatography-10, Mixtures-9. B. Aliphatic Compounds-9, Alkanes-9, Hydrocarbons-9, K Constants-8, Methane-9, Propane-9, ***n***-Decane-9. C. K Constants-8, Methane-9, Propane-9, ***n***-Heptane-9, Alkanes-9, Aliphatic Compounds-9, Hydrocarbons-9.

Abstract: Vapor-liquid equilibrium coefficients for ternary systems were determined by using chromatographic retention volume data. A previous mathematical description of the elution process is modified to include the case of an N-component elution gas. The ***K*** values for propane in the system methane-propane-***n***-decane and the system methane-propane-***n***-heptane were determined.

An experimental investigation of air bubble motion in a turbulent water stream, Baker, James L. L., and Bei T. Chao, **A.I.Ch.E. Journal, 11,** No. 2, p. 268 (March, 1965).

Key Words: A. Motion-8, 7, Bubbles-9, Air-9, Drag Coefficients-8, 7, Relative Velocities-8, 7, Weber Numbers-8, 7, Eotvos Numbers-8,7, Reynolds Number-6, Velocity-6, Water-9, 6, 5, Demineralized-0, Tap-0, Shape-9, 8, Turbulent-0, Column-9, Vertical-0, Square-0.

Abstract: Individual air bubbles were released into a turbulent water flow in a vertical column of square cross-section. Drag coefficients, relative velocities, Weber and Eotvos numbers were obtained for a range of bubble Reynolds numbers. Demineralized and tap water were used and their effect on the shape of the bubbles determined.

Foam fractionation of colloid-surfactant systems, Grieves, R. B., and Dibakar Bhattacharyya, **A.I.Ch.E. Journal, 11,** No. 2, p. 274 (March, 1965).

Key Words: A. Concentration (Composition)-6, Colloids-9, 3, Surfactants-9, 3, Rate-6, Air-9, Time-6, Aeration-9, Height-6, Foam-9, 2, Volume-7, Removal-7, Flotation-8, Froth-9, Foam Fractionation-8, Mass Transfer-8, Foaming-10, 8, Aeration-10, 8, Experimental-, Dispersions-9, 3, Distillation-8. B. Flotation-8, Froth-9, Foam Fractionation-8, Stannic Oxide-1, 2, Cetyltrimethylammonium Bromide-1, 2, Distillation-8, Oxides (Inorganic)-1, 2. C. Flotation-8, Froth-9, Foam Fractionation-8, Stannic Oxide-1, 2, Alkyl Benzene Sulfonate-1, 2, Distillation-8, Aromatic Compounds-1, 2, Oxides (Inorganic)-1, 2.

Abstract: An experimental investigation is presented of the foam fractionation-flotation of the stannic oxide-cetyltrimethylammonium bromide and stannic oxide-alkyl benzene sulfonate systems. The effect of aeration time, air rate, foam height, and surfactant and particulate concentrations upon foam fractionation-flotation was studied.

Effect of packing on the catalytic isomerization of cyclopropane in fixed and fluidized beds, Ishii, Tadao, and G. L. Osberg, **A.I.Ch.E. Journal, 11,** No. 2, p. 279 (March, 1965).

Key Words: Synthesis-8, Cyclopropane-1, 2, Isomerization-8, Silica-10, Alumina-10, Catalyst-10, Packing-6, Conversion-7, Size-6, Reactor-9, Fluidized Beds-10, 6, Fixed Beds -10, 6, Two Phase-0, Rate-7, Bed-9, Velocity-6, Height-6, Cylindrical Screens-10, Hydrocarbons-1, 2.

Abstract: An experimental study using fixed and fluidized beds in the isomerization of cyclopropane on a silica alumina catalyst is reported. The effects of various cylindrical screen packing on final conversion were determined. Reactor scale effects were also considered.

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tetroxide—10% nitrogen dioxide (room temperature equilibrium) has a molecular weight of 56.4, which is in close agreement with the experimental values. When a sample of the product was allowed to react with oxygen, the infrared spectrum showed the reaction product to be entirely nitrogen dioxide. The ratio of nitrogen to oxygen seemed to have no effect on the oxides of nitrogen found (in all cases nitric oxide and nitrogen dioxide).

PREPARATION OF ACETYLENE

The preparation of acetylene at atmospheric pressure was investigated with the 1.5-kw. unit. Acetylene is formed from methane according to the equation

$$2\,CH_4 \rightarrow C_2H_2 + 3\,H_2 - 95.54\ \text{kcal.}$$

This reaction was carried out earlier in a d.c. plasma jet at the Institute (2). Conversions of 80%, based on the carbon input, were obtained with an electrical-power input of approximately 7 kw.

The reaction chamber used for the production of oxides of nitrogen was inadequate for the preparation of acetylene. As preliminary experiments showed, methane was decomposed into its elements, the carbon formed being deposited on the wall of the Vycor tubing. In a few seconds the plasma formed at the tip of the grounded electrode was distributed, causing direct discharges to the carbon particles on the wall.

The ¾-in. diameter Vycor glass tube was opened to a diameter of 3 in. at the height of the electrode tip in order to overcome these discharges. With this configuration, even when carbon was deposited on the wall of the tubing, no direct discharges to the wall were observed. Figure 1 describes schematically the reaction chamber used.

Since it is impossible to maintain a pure methane plasma with the apparatus described, a mixture of helium and methane was used. The gases were introduced through the top of the tube. The plasma jet was started with helium, the methane being introduced subsequently. The shape of the plasma became "bell-like" when methane was added. The helium flow varied from 1.5 to 25 st. cc./sec.; the maximum methane input was 2.8 st. cc./sec. The highest helium:methane ratio used was 1:1. The average power input to the jet was 350 watts.

The effluent gases were collected over water and analyzed by chemical methods. The infrared spectrum of one of the preliminary samples showed no ethylene or ethane peaks. The gas chromatographic analysis showed only the presence of unreacted methane and acetylene. Results from several gas chromatographic analysis of the methane used in our experiments have shown only methane peaks; no ethane or any other impurities were present. The analysis of the gases was therefore restricted to an acetylene determination by titration with a 0.1 N $Na_2S_2O_3$

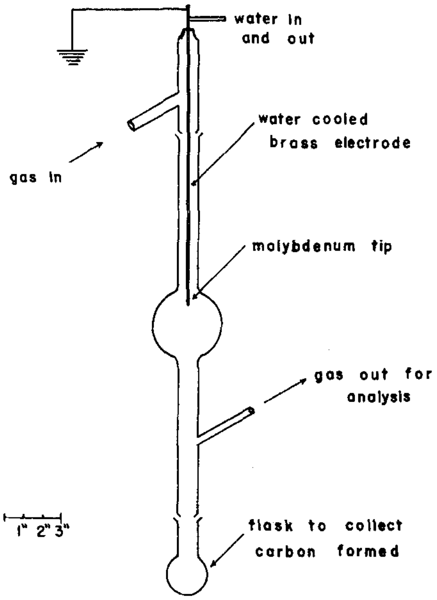

Fig. 1. RF-reaction chamber.

INFORMATION RETRIEVAL

(*Continued from page 378*)

On stress-relaxing solids: Part III. Simple harmonic deformation, Vela, Saul, J. W. Kolb, and A. G. Fredrickson, **A.I.Ch.E. Journal, 11,** No. 2, p. 288 (March, 1965).

Key Words: Solutions-5, Viscoelasticity-8, Polymer-5, Aluminum Soap-5, Sinusoidal Pressure Gradient-1, Movies-10, Mathematical Model-8, Pipe-10, Tracer Streak Motion-2, Frequency Response-9.

Abstract: The viscoelasticity of a number of polymer solutions and an aluminum soap solution was studied by subjecting the solutions to simple harmonic deformations in a pipe. Motion of the materials was driven by a sinusoidal pressure gradient; motion was followed by taking movies of a tracer streak. Experiments at different amplitudes of vibration showed that the response of the materials was linear. Hence, results were analyzed in terms of a modification of the operator equation of linear viscoelasticity. A three-constant model was found sufficient to fit most of the data.

Film instabilities in two-phase flows, Ostrach, Simon, and Alfred Koestel, **A.I.Ch.E. Journal, 11,** No. 2, p. 294 (March, 1965).

Key Words: A. Instability-8, 7, Films-9, Two-Phase-0, Flows-9, Fluid-9, Liquid Phase-0, Stability-8, 7, Break-Up Length-8, 9, Rotation-6, Determination-8, Disturbances-6.

Abstract: The major types of instabilities that can alter a given two-phase flow pattern or lead to the breakup of liquid film are delineated and their physical mechanisms are discussed. A criterion for determining the "break-up" length of a liquid film is developed. The possible influence of rotation of the fluids and large disturbances in the flow on the problem of film instability are introduced.

Excess transport properties of light molecules, Rogers, John D., and F. G. Brickwedde, **A.I.Ch.E. Journal, 11,** No. 2, p. 304 (March, 1965).

Keywords: A. Excess-0, Viscosity-8, 7, Hydrogen-9, Argon-9, Helium-9, Deuterium-9, Neon-9, Nitrogen-9, Critical Point-9, Density-6, Transport Properties-8, Critical Point Density-8, Temperature-6, Critical Point Viscosity-8, Gases-9, Liquids-9, Physical Properties-6. B. Excess-0, Thermal Conductivity-8, Hydrogen-9, Physical Properties-8, Thermal Properties-8. C. Transport Properties-9, Graphs-10, Computation-8.

Abstract: A detailed study has been made of the excess viscosity of dense-phase argon, deuterium, helium-3, helium-4, para and normal hydrogen, neon, and nitrogen and of the excess thermal conductivity of normal hydrogen. A definite temperature dependence for the excess viscosity vs. density has been shown to exist for argon, helium-4, hydrogen, and nitrogen and to be indicated for deuterium. The critical point viscosity values for all the species are given. Graphs are presented for computation of the transport properties.

Measurement of some basic parameters in two-phase annular flow, Quandt, E. R., **A.I.Ch.E. Journal, 11,** No. 2, p. 311 (March, 1965).

Key Words: A. Flow-8, 6, Two-Phase-0, Liquid Phase-9, Gas Phase-9, Waves-7, Air-9, Water-9, Vertical-0, Dispersed-0, Annular-0, Channel-9, Pipe-9, Rectangular-0, Diffusion-8, Momentum Transfer-8.

Abstract: The vertical upflow of air-water mixtures in the dispersed-annular flow regime was studied in a rectangular channel. Dye injection into the wall film was used to determine film and gas core properties along with the rate of droplet interchange between the core and the film. Visual observations demonstrated that the most important characteristic of this flow regime is the surface waves generated by the gas flow over the liquid film. The droplet motion is discussed in terms of transverse diffusion and momentum transfer.

(*Continued on page 382*)

TABLE 2. ACETYLENE PRODUCTION AT ATMOSPHERIC PRESSURE

Gas flow (st. cc./sec.) Helium	Gas flow (st. cc./sec.) Methane	Power input (watts)	Conversion to C_2H_2 (based on carbon input) %	Conversion to C_2H_2 (based on carbon input) mg./min.
1.8	1.6	325	5.9	3.4
3.8	2.3	425	6.7	5.0
3.8	1.2	330	15.65	6.0
7.5	2.0	325	14.88	10.5
7.7	1.6	325	22.4	12.5
12.2	2.8	315	14.15	13.9
12.2	1.9	325	28.6	19.1

solution of the previously oxidized copper acetylide obtained by precipitation from a basic copper (I) solution (*6*) and standard gas analysis. Table 2 gives the data on the conditions and results of some of the experiments. The helium plasma can be maintained, as far as containing materials are concerned, for an unlimited time. The duration of the experiments described ranged between 3 and 7 min. Fast decomposition into carbon and hydrogen occurs when helium is used only in small excess. The carbon particles are deposited on the grounded electrodes restricting the plasma and therefore lowering the acetylene yield and preventing the methane from reacting entirely, either to form acetylene or to decompose into its elements. Only elemental carbon, and no tar, was present as side product. Higher conversions into acetylene were obtained with large excesses of helium. The deposition of carbon on the electrode is then of less significance. At the same helium flow, higher conversions into acetylene are achieved by introducing less methane into the plasma.

METHANE INTRODUCED WITH HELIUM USING A QUENCHING DEVICE

Using the same reaction chamber as in the experiments described previously, the reaction was carried out using a quenching device coupled to the chamber. The quenching device was a grounded water-cooled copper tube introduced at the bottom tube of the reaction chamber. A schematic drawing is shown in Fig. 2. The gases were introduced through the top of the tube. As already described, the plasma jet was started in a helium atmosphere, and the methane was introduced afterward. The helium flow varied from 1.5 to 12.5 st. cc./sec.; the maximum methane input was 2.4 st. cc./sec. The average power input to the jet was 460 watts. The effluent gases from the jet were collected over water and analyzed by the methods previously described. Gas chromatographic analysis

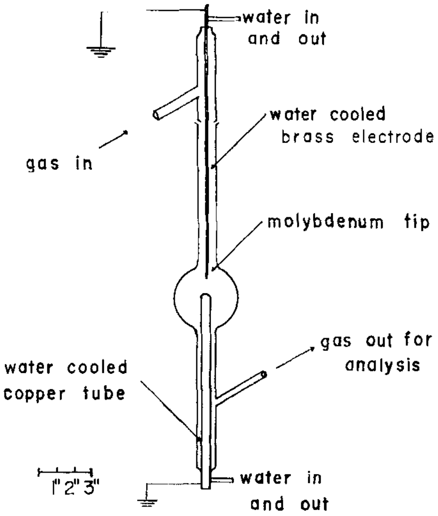

Fig. 2. RF-reaction chamber with quenching device.

of one of the samples showed the presence of acetylene and unreacted methane only; other peaks, such as ethylene and ethane, were not observed. The plasma flame did not have the bell-like shape as before and was directed toward the upper surface of the copper cooling tube.

Table 3 gives the data on the conditions and results of some of the experiments carried out using the copper tube for a distance of 1 in. between the surface of the tube and the electrode tip. Comparing these results with the ones obtained without using any quenching device, one can observe that slightly better yields are obtained by using such a cooling device.

The production rate always increased as the quantity of methane added to the plasma was raised.

By using helium in small excess only, higher conversions into acetylene are achieved by introducing greater amounts of methane into the plasma. With large excesses of helium, higher conversions into acetylene are achieved by feeding lower amounts of methane to the plasma.

TABLE 3. ACETYLENE PRODUCTION USING QUENCHING DEVICE AT 1-IN. DISTANCE

Gas flow (st. cc./sec.)		Power input	Conversion to C_2H_2 (based on carbon input)	
Helium	Methane	(watts)	%	mg./min.
1.8	1.2	319	5.6	2.3
1.8	1.6	323	15.6	8.7
3.8	1.6	472	24.7	13.8
7.7	1.6	530	26.9	15.0
7.7	2.0	523	25.1	17.8
7.7	2.4	472	23.5	19.5
12.2	1.6	517	28.1	15.7
12.2	2.4	529	26.2	21.8

ERRATA

Some minor errors have been found in the paper "Numerical and Experimental Study of Damped Oscillating Manometers: II. Non-Newtonian Fluids" by John C. Biery (Vol. 10, No. 4, pp. 551-557, July, 1964) as follows:

1. Equation (1)—The first term should have a $-\eta_o$.
2. Page 556, E. E. Wissler should be E. H. Wissler.
3. Figures 2, 3, and 4 should be titled across the abscissa—Minus Shear Rate, —Sec.$^{-1}$.
4. The units in Table 4 should be listed in a footnote as follows:

$$\eta_o = \frac{\text{dynes sec.}}{\text{sq. cm.}}, \; \beta = \frac{\text{dyne sec.}^m}{\text{sq. cm.}},$$

m = dimensionless, λ_1 = sec., λ_2 = sec.

In the paper "Solids Mixing in Straight and Tapered Fluidized Beds" by Howard Littman (Vol. 10, No. 6, pp. 924-929, November, 1964), the figures are incorrectly labeled. They should be as follows:

Fig. 6. Activity-time curves, untapered bed, 32-in. nominal bed height. Fig. 7. Activity-time curves, tapered bed, 16-in. nominal bed height. Fig. 8. Activity-time curves, tapered bed, 32-in. nominal bed height. Fig. 9. Movement of activity front in tapered and untapered beds.

INFORMATION RETRIEVAL
(Continued from page 380)

Foam columns for countercurrent surface-liquid extraction of surface-active solutes, Haas, Paul A., and H. F. Johnson, **A.I.Ch.E. Journal, 11,** No. 2, p. 319 (March, 1965).

Key Words: A. Separation-8, Foam-10, Foam Separation Process-9, Difference-10, Measurement-8, Height Transfer Unit-9, Density-9, Development-8, Spargers-9, Gases-9, Distributers-9, Liquids-9, Feed-9, Conditions-9, Drainage-9, Equipment-9, Condensation-4, Columns-10, Sodium Dodecyl Benzene Sulfonate-5, SR-89-1, Stripping-8, Surface-Liquid Extraction-8, Physical Properties-9, Surface Activity-9. B. Foam-9, Condensation-8, Breaker-10, Pneumatic-, Mechanical-. C. Design-8, Pilot Plant-9, Decontamination-10, 8, Wastes-9, Radioactive-0.

Abstract: The foam separation process uses differences in surface activity to separate components of a solution. Foam columns were operated with sodium dodecylbenzenesulfonate solutions to measure HTU values and foam densities and to develop satisfactory gas spargers, liquid feed distributors, foam drainage conditions, and foam condensation equipment. The foams were condensed with four types of pneumatic or mechanical foam breakers. A pilot plant was designed for decontamination of a low level radioactive waste.

Constitutive equations for viscoelastic fluids with application to rapid external flows, White J. L., and A. B. Metzner, **A.I.Ch.E. Journal, 11,** No. 2, p. 324 (March, 1965).

Key Words: A. Viscoelasticity-8, Viscosity Coefficient-8, 9, Predictions-8, 10, Equation-10, 8, Constitutive Equations-8, 10, Non-Newtonian-0, Stresses-6, Kinematics-7, Deformation-9, 7, Reynolds Number-6, Drag Coefficient-7, Rheology-8, Boundary-Layer Theory-10, 8, Elasticity-8, Mechanical Properties-8, Rheological Properties-8.

Abstract: Successive approximations to a very general theory of viscoelasticity are used to develop a constitutive equation. This equation predicts both a non-Newtonian viscosity coefficient and normal stress effects in simple laminar shearing flows. The use of this equation is illustrated by a study of rapid flows of viscoelastic fluids around submerged objects. The results of this study are compared and contrasted to those of Newtonian boundary-layer studies.

Correlation of latent heats of vaporization, Martin, Joseph J., and John B. Edwards, **A.I.Ch.E. Journal, 11,** No. 2, p. 331 (March, 1965).

Key Words: A. Correlation-8 Latent heat of Vaporization-9, 8, 7, Graph-10, Reduced Temperature-9, 6, Reduced Pressure-9, 6, Vapor Pressure-10, PVT Relationship-10, Prediction-8, Critical Point-10, Chemicals-9, Clapeyron Equation-10, Polar-0, Nonpolar-0, Organic-0, Inorganic-0, Metallic-0, Latent-9, 8, 7.

Abstract: The functional relation between latent heat of vaporization and reduced temperature was developed. This relationship allows the prediction of latent heat of vaporization for any substance for which the critical point and one vapor-pressure point are known. Polar, nonpolar, organic, inorganic, and metallic substances were studied.

Estimation of vapor and liquid enthalpies, Yen, Lewis C., and R. E. Alexander, **A.I.Ch.E. Journal, 11,** No. 2, p. 334 (March, 1965).

Key Words: A. Estimation-8, Enthalpy-9, 7, 8, Vapor Phase-9, Liquid Phase-9, Mixtures-9, Nonpolar-0, Digital Computer-10, Pressure-6, Isothermal-0, Lydersen-Greenkorn-Hougen Charts-10, Equations-10, Charts-10, Thermodynamic Properties-9, 7, 8, Computers-10.

Abstract: The Lydersen-Greenkorn-Hougen charts correlating the isothermal pressure effects on enthalpy for pure compounds based on a modified corresponding states principle have been improved with the aid of reliable literature data. Analytical equations have been developed for the charts to facilitate machine computations. This correlation predicts vapor and liquid enthalpies of pure compounds and can also be used for the estimation of enthalpies of nonpolar mixtures.

(Continued on page 384)

TABLE 4. ACETYLENE PRODUCTION USING QUENCHING DEVICE AT ½-IN. DISTANCE

Gas flow (st. cc./sec.) Helium	Methane	Power input (watts)	Conversion to C_2H_2 (based on carbon input) %	mg./min.
3.8	1.6	546	17.5	9.7
7.7	2.0	474	21.6	15.3
7.7	2.4	498	9.8	8.1

Table 4 gives the data on the experiments carried out using the copper cooling tube at a distance of ½-in. below the electrode tip. These results, obtained at a smaller distance between the electrode tip and the quenching device, are much lower than the preceding results; but they are about the same as those obtained with the use of no quenching device. As the plasma flame is formed between the electrode tip and the copper tube, a smaller distance produces a smaller flame.

METHANE INTRODUCED DIRECTLY TO THE FLAME

By using the same configuration of the reaction chamber, a glass side tube was added to the chamber at the height of the electrode tip. Instead of feeding the methane together with the helium, methane was introduced directly to the helium plasma through the side tube

Table 5 shows the conditions and results obtained without the use of any quenching device.

It is evident from Table 5 that better yields are achieved in this manner compared with the results obtained in Table 2. However, they are much lower than the results obtained when methane was introduced with helium and a quenching device was used.

The same experiment was carried out using the same quenching device at a distance of 1 in. below the electrode tip. Table 6 gives the data on the conditions and results of the experiments carried out. By comparing Tables 5 and 6, we can observe that similar yields are obtained by means of the quenching device; but yields are lower than the ones obtained in Table 3 when methane was introduced with helium. The reason for this difference could be that the methane was not properly directed to the center of the plasma flame, because a smaller plasma is obtained when using a cooling device.

PREPARATION OF HYDROGEN CYANIDE

A pure nitrogen plasma was achieved by using the 1.5-kw. unit and the reac-

TABLE 5. ACETYLENE PRODUCTION WITH METHANE FED DIRECTLY TO THE FLAME

Gas flow (st. cc./sec.) Helium	Gas flow (st. cc./sec.) Methane	Power input (watts)	Conversion to C_2H_2 (based on carbon input) %	Conversion to C_2H_2 (based on carbon input) mg./min.
3.8	1.6	291	19.0	10.6
7.7	2.0	500	20.2	14.3
7.7	2.4	330	15.3	12.7

tion chamber that was used for the preparation of acetylene. The plasma jet was started with helium that was replaced slowly by nitrogen. Experimentally, the most convenient gas flows for the nitrogen plasma were found to range between 4 and 8 l./min. The pure nitrogen plasma is purplish in color.

Methane was added to the nitrogen plasma to obtain hydrogen cyanide. The nitrogen plasma, even with only small amounts of methane, has a bright appearance, covering almost entirely the 3-in. diameter reaction chamber. Depending on the amount of methane added, the bright plasma is constricted slowly because of carbon deposition on the grounded electrode.

The experiments described in Table 7 were all carried out in the bright, wide plasma; the duration of the experiments was between 1 and 5 min., depending on the methane input.

The power input to the jet ranged between 600 and 750 watts. The qualitative analysis of the products showed hydrogen cyanide, hydrogen, acetylene, and small amounts of other hydrocarbons, probably largely unreacted methane.

The quantitative analysis was carried out by passing the gases from the plasma jet through a column filled with Raschig rings, countercurrently to a 0.5 N potassium hydroxide solution to dissolve the hydrogen cyanide. The potassium cyanide formed was determined by the Liebig-Deniges (*1*) method, the titration of the potassium cyanide with 0.1 N silver nitrate solu-

TABLE 6. ACETYLENE PRODUCTION WITH METHANE FED DIRECTLY TO THE FLAME USING A QUENCHING DEVICE

Gas flow (st. cc./sec.) Helium	Gas flow (st. cc./sec.) Methane	Power input (watts)	Conversion to C_2H_2 (based on carbon input) %	Conversion to C_2H_2 (based on carbon input) mg./min.
3.8	1.6	338	21.2	11.8
7.7	2.0	385	15.7	11.1
7.7	2.4	338	16.0	13.3

tion. The remaining gases were collected over water, the acetylene being precipitated as copper (I)-acetylide.

Table 7 shows that by increasing the methane input at a given nitrogen flow, a lower hydrogen cyanide conversion results. By lowering the nitrogen flow for the same methane input, the conversion is lowered because of heavy carbon deposition on the grounded electrode. The conversion to acetylene also decreases with increasing methane input, although the amount of acetylene per unit time remains the same.

TABLE 7. ACETYLENE-HYDROGEN CYANIDE PRODUCTION

Gas flow (st. cc./sec.) Nitrogen	Gas flow (st. cc./sec.) Methane	Conversion to hydrogen cyanide* %	Conversion to hydrogen cyanide* mg./mi	Conversion to C_2H_2* %	Conversion to C_2H_2* mg./min.	Total % conversion (hydrogen cyanide + C_2H_2)
88.7	1.3	34.7	33.6	23.4	10.6	58.1
88.7	2.4	28.8	49.6	15.3	12.7	44.1
88.7	3.3	25.6	61.9	11.4	13.2	37.0
88.7	5.0	21.5	77.8	6.1	10.6	27.6
66.7	5.0	15.5	56.2	5.8	10.1	21.3

* Based on the carbon (from methane) input.

DISCUSSION

All the hydrogen cyanide experiments were made without using fast quenching. By attaching a cooling device beneath the plasma, higher conversions into hydrogen cyanide and C_2H_2 could be obtained and the ratio of the end products would be influenced substantially. Further work is being done on this subject. Better yields and conversions were obtained with the high-power d.c. jet (*2*). In the d.c. jet, 80% conversion into acetylene based on the carbon input was obtained. The maximum yield obtained with the radio frequency was 28%, based on the carbon input. In the d.c. jet, at 80% conversion, 6.88 g. of acetylene were produced per kw.-hr., while in the radio frequency jet, at 28% conversion, 3.52 g. were obtained per kw.-hr.

The yields obtained with the radio frequency jet should not be considered the ultimate yields, but they do show the usefulness of the unit for carrying out these reactions. The processes studied have been proven to be attractive and should invite further work to establish the design and method of operation of commercial units, as well as the economics of such units.

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INFORMATION RETRIEVAL

(*Continued from page 382*)

Stability in distributed parameter systems, Amundson, Neal R. and Lee R. Raymond, **A.I.Ch.E. Journal, 11,** No. 2, p. 339 (March, 1965).

Key Words: A. Behavior-8, Catalysts-9, 8, Particles-9, 8, Steady State-9, 7, Transient State-9, 7, Reactions-9, Irreversible-0, First Order-0, Instability-8, 9, 7, Stability-8, 9, 7, Prediction-8, Mathematical Model-8, Differential Equations-10, Integral Equations-10, Mathematics-10, Computer-10, Diffusion-6, Conduction-6, Intraparticle-0, Heat-9, Distributed Parameters-8.

Abstract: Single catalyst particles are studied mathematically to determine their steady state and transient behavior for a simple irreversible first order reaction. Three models of a catalyst particle are examined for existence of multiple steady states depending upon whether intraparticle heat conduction or diffusion is important. Criteria are developed so that instabilities may be predicted in some cases. Computer solutions are carried out to obtain transient behavior.

Effectiveness factors for general reaction rate forms, Bischoff, Kenneth B., **A.I.Ch.E. Journal, 11,** No. 2, p. 351 (March, 1965).

Key Words: Effectiveness Factor-8, 9, Estimate-4, 8, Diffusion-6, Intraparticle-0, Effectiveness-7, Catalysts-9, Isothermal-0, Asymptotic Solution-10, Reaction Rate Form-10, 8, 9, Catalysis-8, General Modolus-10, Reaction Rate-8, Porous-0.

Abstract: A general asymptotic solution for isothermal effectiveness factors is given which leads to the definition of a general modulus. The use of this general modulus tends to approximately bring together all of the curves for various reaction rate forms.

Mass transfer in horizontally moving stable aqueous foams, Weissman, Eugene Y., and Seymour Calvert, **A.I.Ch.E. Journal, 11,** No. 2, p. 356 (March, 1965).

Key Words: A. Absorption-8-7, Desorption-8-7, Gas-1, Mass Transfer-8-7, Foam-10-5-9, Aqueous-0, Stable-0, Duct-9, Pipe-9, Horizontal-0, Pressure Drop-8, Geometry-6, Properties-6, Resistance-6, Interfacial-0. B. Mass Transfer-9-8, Prediction-8, Liquid-Phase-Controlled System-9, Gas-Phase-Controlled System-9. C. Desorption-8, Mass Transfer-8, Carbon Dioxide-1, Water-5, Ammonia-1, Saponin-4, Surfactant-4, Air-10.

Abstract: An efficient gas absorption device has been developed based on a stable aqueous foam moving in a horizontal duct, with a gas-liquid interaction that causes only negligible pressure drops. The study of a liquid-phase- and a mostly gas-phase-control system, carbon dioxide and water and ammonia and water, respectively, indicated that their mass transfer performance can be predicted. The influence of geometry, foaming solution properties, and surfactant-caused interfacial resistance are included in the analysis.