THE RHEOLOGY LEAFLET

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Publication
of the
SOCIETY OF RHEOLOGY

No. 4 February, 1938

AMERICAN SOCIETY
for TESTING MATERIALS

SYMPOSIUM ON CONSISTENCY

Critical Discussion on Present-Day Practices in Consistency Measurement

BECAUSE of the widespread interest in the subject of consistency, the Society's Committee E-1 on Methods of Testing, through a special committee, developed this symposium. Its primary objects were to consider advances in recent years in consistency measurement, including a discussion of theoretical background and existing nomenclature. It presents a critical review and considers the possibilities of standardization; also, the use and advantage to be derived from the use of fundamental units of measurement.

The nine papers comprising the published symposium, each prepared by technologists thoroughly familiar with problems and practices in the materials fields covered, provide a representative cross-section of engineering materials for which the measurement of consistency, plasticity, viscosity and related properties is important.

Since the earlier symposium held in 1923 a great deal of progress has been made in our understanding of consistency and related properties, particularly in their measurement. This symposium provides in convenient form latest authoritative information.

The following list of papers, with authors, indicates subjects covered in the publication:

Recent Progress in Consistency Measurement—E. C. Bingham, Professor of Chemistry, Lafayette College.

The realization of the need for a practical standard of viscosity; errors due to standard; errors in viscosity due to lack of attention to correction factor; advantages of two or three liquid calibration; dust; variable shear necessary for plastic substances.

Definition of Consistency and Theoretical Considerations—M. Mooney, Development Department, U. S. Rubber Products, Inc.

Introduction and definitions; analysis of A. S. T. M. "consistency" and "plasticity" tests; general discussion of materials testing methods.

Consistency Measurements in the Paint Industry—D. L. Gamble, Research Division, New Jersey Zinc Co.

Consistency measurements on enamels; consistency measurements on flat wall paints; general discussion of the rheological properties of paints; standardization of present test methods.

The Flow Properties of Asphalts Measured in Absolute Units—R. N. Traxler, Research Division, Technical Bureau, The Barber Co.

Measurement of low viscosities (up to about 50,000 poises); measurement of high viscosities (above 50,000 poises); measurement of the consistencies of non-viscous asphalts; advantages derived from data in absolute units.

(List continued on the next page)

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Consistency Measurements in the Coal-Tar Industry—E. O. Rhodes, E. W. Volkmann and C. T. Barker, Technical Department, Tar and Chemical Division, Koppers Co.

Viscous flow properties of coal tars; conversion of Engler degrees into absolute units; conversion of float test seconds into absolute units; relation of softening point temperatures to absolute viscosity; penetration measurements and absolute viscosities; conversion of Saybolt viscosity to absolute units; representation of viscosity temperature relationships.

Viscosity Measurement of Petroleum Products and Lubricants—J. C. Geniesse, Research Chemist, The Atlantic Refining Co.

Saybolt viscosimeter; kinematic viscosity; conversion kinematic to Saybolt; viscosity-temperature chart; commercial use of kinematic viscosity units; pour point; grease testing.

Consistency Measurement of Rubber and Rubber Compounds—J. H. Dillon and L. V. Cooper, Firestone Tire and Rubber Co.

Theories of rubber structure; rheological problem for rubber; methods of test for rheological properties of rubber.

Measurements of Flow Characteristics of Thermosetting Resins—H. L. Bender, H. F. Wakefield and H. E. Riley, Bakelite Corporation.

Uses of resin flow; cast resinoids; laminated products; spirit varnishes; elastic resins; changing yield values; hot plate tests; melting point; flow of hot molding plastics; flow under variable pressure; hardening effect; flow against increasing resistance; plasticity as a flow resultant.

Cold Flow of Insulating Materials—Robert Burns and Irving L. Hopkins, members of the Technical Staff, Bell Telephone Laboratories, Inc.

A valuable part of the publication consists of discussion of the papers presented by other technologists.

The publication should be of definite interest and help to a great many technologists including testing engineers, chemical engineers and others concerned with materials for which consistency, plasticity, viscosity and related properties are important.

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CONDOLENCE

At noon on December 29th the "Annex" which housed about half the work of the Physics Department of The Pennsylvania State College burned to the ground. The whole contents of the building, including Professor Davey's X-ray research laboratory and all his data and records, were a total loss. The bright side of the picture is that a new fire-proof building is to be built to replace the Annex and certain other space used by the Department. The new building will be five stories high, 221 feet long, and 71 feet wide with a lecture room wing 93 x 110 feet, and a second wing 125 by 73 feet. This new building, plus additional space in portions of three other buildings, will completely house the Physics Department. In the meantime, undergraduate work is going on "as usual" in emergency quarters with the aid of new laboratory apparatus shipped in by direct truck from Chicago. The interrupted portion of the graduate work of the department is being resumed in still other emergency quarters.

APOLOGY

The losses in the fire included the material which Editor Davey was preparing for the February 1938 number of The Rheology Leaflet. Consequently the February number could not be issued when it should have been. It was our added misfortune to lose, just at this time, the services of our Associate Editor, Dr. E. O. Kraemer. Now that the February number has finally reached you, we hope you will excuse its delay. On the basis of the laws of probability, we believe we can promise you that no similar delay will occur in the immediate future.

M. Mooney
President

DR. ELMER O. KRAEMER

Dr. Kraemer has arranged to return to Sweden to undertake research work with Professor T. Svedburg. We all wish Dr. and Mrs. Kraemer the greatest success in their new venture. Dr. Kraemer was born in Liberty, Wisconsin, in 1898. He graduated from University of Wisconsin in 1918, was a fellow of the Scandanavian-American Foundation at Upsala, Sweden, in 1921 and 22, studied in Berlin in 1922-23, and received his Ph.D. from University of Wisconsin in 1924. He was assistant professor of colloid chemistry at Wisconsin, and in 1927 became research colloid chemist for E. I. duPont de Neours and Co., at Wilmington, Delaware. Dr. and Mrs. Kraemer carry the best wishes of the Society.

CHANGE OF ADDRESS

R. N. Traxler, who has always been a very active member of the Society of Rheology, reports that on February 15th he left the Research Division of The Barber Company, Maurer, New Jersey, to go with The Texas Company, Port Neches, Texas. We wish him good fortune on his new venture, and hope he will continue his interest in our Society.

TIME TO START

Our next meeting will be held during Christmas Week in Pittsburgh, Pennsylvania, at The University of Pittsburgh. Dr. H. R. Lillie, of the Research Division of the Corning Glass Works, Corning, New York, who was such an excellent chairman of our program committee last year, has consented to act again in this capacity for our 1938 meeting. The other members of the program ommittee are:

Professor E. C. Bingham, Lafayette College, Easton, Pa.
Mr. R. N. Traxler, The Texas Co., Port Neches, Texas.
Dr. M. B. Hersey, The Kingsbury Machine Co., Philadelphia, Pa.
Dr. H. F. Wakefield, The Bakelite Co., Bloomfield, New Jersey.
Professor E. Hutchisson, University of Pittsburgh, Pittsburgh, Pennsylvania.

All rheologists are urged to get their papers ready early for this meeting. It always takes longer to get a paper written than one anticipates. Better get started writing that paper now, so that it may be finished in time to get Company approval before the final date. At the same time, lighten the labors of the Program Committee by writing

Dr. Lillie telling him that you are getting started. "Better late than never, but better never late."

THE LEAFLET AS A QUARTERLY

Your attention is called to the action taken at the Akron Meeting with regard to the Rheology Leaflet and the provisions for associate membership. As you all know, publication of the Leaflet was initiated this past year on a tentative and experimental basis. Our success in producing this journal at a reasonable cost led the Executive Committee to recommend to the Society that the Leaflet be scheduled for regular quarterly publication, and that its contents be enlarged to include abstracts and reviews of rheological literature. At the Akron Meetng, the Society approved this proposal and in line with this new policy, changed the provisions for associate membership, reducing the dues to $2.00 (foreign $2.50) and eliminating the subscription to the Review of Scientific Instruments, formerly accompanying such membership.

As of Jan. 1, 1938, therefore, associate members will pay dues of $2.00 annually ($2.50 foreign), and will receive a subscription to the Rheology Leaflet, which will be published quarterly. The dues of regular members will remain unchanged at $6.00 annually ($6.50 foreign) and they will receive subscriptions both to the Journal of Applied Physics and to the Rheology Leaflet. Non-member subscriptions to the Leaflet (from libraries and other organizations) will be priced at $2.00 annually.

Under this new policy, original papers presented to the Society will be submitted for publication in the Journal of Applied Physics as formerly and thus made available to our regular members. In the Leaflet both regular and associate members will be provided with abstracts and reviews of the literature dealing with the deformation of matter and the theoretical aspects of materials testing. The Leaflet will serve also as a medium for news of the Society and other organizations and of special meetings dealing with rheological subjects.

In these days, it is a rare event when the cost of a commodity is reduced. But the action of the Society of Rheology at the Akron meeting does just this with regard to the dues of our Associate Members.. With the expansion in the size of the Rheology Leaflet, our Associate Members will be able to keep up on current events in the field of Rheology more satisfactorily than in the past. It is hoped, with the fulfillment of our plans, to provide an adequate bibliography to the important Rheological literature.

DEFINITIONS AND NOMENCLATURE

After valiant efforts on the part of our Committee On Definitions and Nomenclature to attain a satisfactory degree of unanimity in the matter of definitions, a lengthy discussion at the Akron meeting reveals the persistance of marked difference of opinion. The matter is one of wide-spread interest. Professor Bingham has recently received a letter from the laboratory of N. V. de Bataafsche Petroleum Maatschappij in which the laboratory desires, (1) a more precise definition of "yield stress"; (2) the inclusion of "elastico-plastico-viscous solids" along with elastic, plastic, and viscous solids; (3) substitution of new symbols for F and r; (4) the substitution of "solid" for "body" in the definition of plasticity, (see Rheology Leaflet, No. 1, Page 9.).

RHEOLOGY HERE AND THERE

Our readers will be interested to know that the A.S.T.M. expects to publish the papers in its recent Symposium on Consistency. As a courtesy to the A.S.T.M. and as a service to our members, a prospectus is enclosed with the issue of the Leaflet.

On April 22, 1937 a Discussion on Viscosity of Liquids was held in London.

It is reported in Proc. Roy. Soc. London, **163A,** 319-37, (Dec. 7, 1937).

The six papers may be summarized briefly as follows:

G. I. Taylor: Theoretically sound analysis of turbulence is now possible. The viscosity of suspensions is alluded to.

J. D. Bernal: Theory of pure lquids. Discussion of Eyring's "holes." A theory by Bernal, (see Trans. Faraday Soc. **33,** 27), on viscosity as related to "rate of change of mutual configurations." Viscosity vs. Eyring's chemical kinetics. Batchinsky and free volume receives new significance.

A. C. S. Lawrence: Lyophillic solutions, gelation, solution. Reference to Staudinger and long molecules. Coiling of molecules. Plasticity, (in the sense of Stress — rate of flow). Soaps and micellar structure, Thixotropy.

E. N. Andrade: Viscosity of pure liquids. Temperature coefficient.

E. Hatchek: Anamalous flow in floculated suspensions.

R. K. Schofield: Viscosity of flour dough. Application of Maxwell's equation for plastic bodies. Dough not ideal, since it contracts after stretching force is released, so that Maxwell's equation needed alteration.

ABSTRACTS AND BIBLIOGRAPHIES

Strain Ellipsoid. A. Leith. Am. J. Sci. **33,** 360-368, (1937).—The concept of the strain ellipsoid is described and analysed with the dual purposes of suggesting how it may be used profitably in solving structural problems, and of directing attention to certain misuses of the strain ellipsoid which reflect misunderstanding of its true meaning. S. A.

Effect of Temperature on the Consistency of Asphalts. H. G. Nevitt and L. C. Krchma. Ind. Eng Chem. Anal. Ed. **9,** 199-122, (1937). — The formula given is $S = 0.221 \log (\log \mu_1 + 0.8) / \log \mu_2 + 0.8 / \log (T_2/T_1)$ where S is the viscosty-temperature susceptibility coefficient, and μ_1 and μ_2 are the kinematic viscosities at absolute temperatures T_1 and T_2. S is applicable to a wide range of temperatures and viscosities and can be graphically determined. S. A.

Viscosity-Temperature Susceptibility of Asphalt. S. Mason, R. J. Loomis, S. D. Patterson, H. G. Nevitt and L. C. Krchma. Ind. Eng. Chem. Anal. Ed **9,** 138-139 (1937). — Using the standard Saybolt viscometer it is concluded that the viscosity-temperature susceptibility coefficient is a suitable index to use at the present stage of asphalt technology. S. A.

Rheological Properties of Asphalts. Part IV. C. E. Coombs and R. N. Traxler. J. Appl. Physics **8,** 291-296 (1937). Observations have been made on the anomalous flow characteristics of air-blown asphalts. Data obtained by the rotating cylinder type of viscometer at a low shearing stress show the presence in an asphalt of elastic fore- and after-effect. Several manifestations of thixotropy are shown. Correlations of the Bingham-Stephens alternating stress, the falling coaxial cylinder and the conicylindrical rotation viscometers have been made, at essentially the same mean shearing stresses in all three instruments for a particular asphalt. S. A.

Viscosity, Elasticity and Plastic Strength of Soft Materials (Flour Dough). Part IV. R. K. Schofield and G. W. S. Blair. Roy. Soc. Proc. **160A,** 87-94 (1937).—Experiments are described which support the view that in a flour dough the gluten forms an elastic network which dominates the mechanical behaviour. It appears that when a cylinder of dough is first stretched some of the links in the network are ruptured since it will not return to its original length. Enough remain unbroken, however, for a continuity of structure to be preserved until the cylinder has been extended to 5 or 6 times its original length. The "work hardening" of dough is thus accounted for. The elastic network does not establish itself at once, but continues to build up for some time after the dough is mixed. Its strength is greatly reduced by drastic remixing of the dough but is largely recovered on further standing. The addition of HCl is slight excess of the acid binding capacity destroys the strength of the network. This shows that the electrostatic attraction between oppositely charged groups in neighbouring molecules is an important factor in the strength of the gluten network. The upward bend of the reloading curve up to the point where flow (i. e., the rupture of further links) occurs is probably mainly due to the irregularity of assembly of the elastic members, but may also indicate that individual chains are approaching the limit to which they can be extended. Evidence has been obtained that the starch paste penetrating the gluten network has a "yield value," in consequence of which there is elastic hysteresis even when the cycle is carried out slowly enough to avoid elastic after-effect. S. A.

Flow Around a Cruciform Obstacle. L. Sona, Accad. Lincei Atti **24,** 508-515 (1936). — Continuing the work of a previous paper (see Abstract 1938 1937) the forces acting on a cruciform obstacle in a translatory current are examined. There is a transverse reaction, i.e., one normal to the direction of the current, and in general a direct reaction which may be positive or negative. The moment about the point where the laminae, forming the object, cross is investigated, and there are positions of stable and unstable equilibrium. If the laminae cross at right angles, the moment is always zero. S. A.

Statistical Theory of Turbulence. T. V. Karman. Nat. Acad. Sci., Proc. **23,** 98-105 (1937). — Mathematical See S. A. 2395 (1937).

Flow in Pipes and between Parallel Planes. G. I. Taylor. Roy. Soc., Proc. **159A,** 496-506 (1937). — The mean velocity is calculated for pressure flow between parallel planes and through a circular pipe on both the momentum-tranfer and the vorticity-transfer theory with the mixing length proportional to the distance from a wall. The "modified" vorticity-transfer theory is used, in which a portion of the fluid is supposed to retain the vorticity components of the mean motion at a certain position until it mixes with its surroundings. Also the turbulence is assumed isotropic ($\overline{u^2}=\overline{v^2}=\overline{w^2}$). For two-dimensional mean motion the results are the same as for two-dimensional turbulence; for the pipe flow, however, the equation of motion is — $(1/\rho)\partial P/\partial x = (l^2 dU/dr)(d^2U/dr^2 + \frac{1}{r}\frac{dU}{dr})$. For pipe flow the vorticity-transfer theory is in better agreement with observation than the momentum-transfer theory. For flow between parallel planes there is nothing to choose between the two theories. The comparisons with experiment are carried out by making the velocity the same at the centre and at 0.7 of the distance from the centre to the wall, and the velocity gradient zero at the centre. (It is automatically infinite at the wall.) The constants in the formula for l are much closer to each other for the two- and three-dimensional cases (on either theory) than with Karman's formulae for l, but in all cases the constants are different from the value obtained by considering the velocity distribution close to a wall. S. A.

Similarity Theory of Turbulence, and Flow between Parallel Planes and through Pipes. S. Goldstein. Roy Soc., Proc. **159A,** 473-496 (1937). — Karman's similarity theory of turbulent flow for two-dimensional parallel mean flow leads to the result that the length l which occurs $= K|dU/dy / d^2U/dy^2|$ and the shearing stress $\tau = \rho l^2 dU/dy\,|dU/dy|$. . The derivation of the formulae for three-dimensional turbulence is set out, with a full discussion of the order of magnitude of various terms. It is pointed out that if, instead of τ, the rate (M) of communication of momentum to unit volume is taken from the theory, the equation of motion is the same as on the vorticity-transfer theory with l as mixture length. The first form of the theory gives results which agree much better with experiment than the second for pressure flow between parallel planes. Formulae for three-dimensional turbulence for parallel mean flow symmetrical about an axis are derived. (Consideration of the order of magnitude of the terms shows that the derivation is not as satisfactory as for the two-dimensional case.) The result is $l = K|dU/dr / (d^2U/dr^2 - 1/r \cdot dU/dr)|$, and again either τ or M may be found from the theory; in the former case the equation of motion is the same as on the momentum-transfer theory, in the latter as on the vorticity-transfer theory with symmetrical turbulence,—in each case with l as mixing length. For pressure flow through a circular pipe the results obtained from the second form of the theory agree much better with experiment than the first. The comparisons with experiment in all cases are carried out by making the velocity gradient infinite at a wall, and by making the theoretical and experimental results for the velocity coincide at 0.3 and 0.7 of the distance from the center to a wall. S. A.

Streaming of Liquids Through Small Capillaries. H. B. Bull and J. P. Wronski. J. Phys. Chem. **41,** 463-468 (1937). — The viscosities of the first seven normal aliphatic alcohols are reported. The rate of flow of these alcohols and water is determined through diaphragms of cellulose, carbon, and glass, and in general the rate of flow per unit pressure through a given diaphragm appears to be a function both of the viscosity and of the degree of attraction between the liquid and the diaphragm. In loosely packed diaphragms there is a possibility of dispersion of the daphragm material. Peptisation effects may be important in studies such as these. The average pore radii of the diaphragms is calculated and an estimate made of the critical radius below which anomalous rates of flow occur. S. A.

Use of Elbow in Pipe Line for Determining Rate of Flow. W. M. Lansford. Univ. Ill. Eng. Exp. Sta., Bull No. 289. (33pp.), Dec. 22, 1936. — Tests having been carried out for a number of different elbows (90° bends), the conclusion is reached that the ordinary commercial elbow may be successfully used as a flow meter. The difference between the pressure heads at the inside and outside of the middle (45°) section of the elbow is a constant multiple, C_k , of the mean velocity head of the water passing through the pipe for velocities greater than about 1.5 to 2.0 ft./sec. C_k should be found by calibration in the actual set-up. If this is impossible, a value may be selected on the basis of the data given which should give the discharge with an error not greater than 10% . 25 diameters of straight pipe preceding the elbow was found sufficient to ensure satisfactory performance, and it is stated that the discharge control valve should be at least 10 pipe diameters downstream from the elbow. S. A.

Flow in Highly-Stressed Metals. P. W. Bridgman. J. Appl. Physics **8,** 328-336 (1937). Force-pressure values are plotted for very thin discs of material rotated through 60° between two hardened alloy-steel surfaces under pressure. For a thickness of 0.002 cm. the shearing distortion at the edge is 150 radians. In almost all curves there is a knee, marking the transition from surface slip to internal slip, but in general the curve does not become horizontal. The mechanisms of slip in solids and liquids are essentially different. Single and polycrystalline specimens are considered theoretically. After the specimen has reached a steady state during rotation, hysteresis effects may or may not occur on reversal; in Pb the steady state is reached only after 100 double rotations. Salts, Sr, Ce, hexagonal Ti, As, and Os show a snapping effect on rotating, but some common brittle metals — e.g., Zr, Mo, Ta, W, become ductile at high pressures. Graphite and quartz glass do not appear to yield at all by plastic flow. Probably Sr and Ce show lattice transformations under pressure. Cubic metals probably do not rupture internally. Shearing stress appears to be the force needed to maintain constant flow. Self-welding is almost universal, and under the conditions of test, surface imperfections can play little part since lines of flow are closed curves. S. A.

Generation and Propagation of Elastic Waves. Z. Kinosita. Tokyo Univ. Earthquake Research Inst., Bull. **15,** 41-49 (1937). Some cases of the propagation of torsional waves along wires loaded at equal intervals with wooden cross-pieces are studied experimentally. the waves being generated either by relaxing constraints or by applying impulses. The wave is measured at several points along the wire, and, allowing for the dissipation (mainly due to air resistance to the wooden loads), the kinetic energy of the wave is equal to the potential energy before relaxation, or to that supplied by the impulse. S. A.

Propagation of Waves. T. Sakurai. Phys. Math. Soc. Japan, Proc. **19,** 297-328 (1937). In English. — The paper is concerned with the mathematical solution of a rather general partial differential equation of hyperbolic form, with two independent variables, x and t, representing the propagation of waves in one dimension. In the cases considered ,the characteristics are two real straight lines. A double integral is used of the Fourier-Mellin type, with a kernel which depends on the coefficients in and solutions of the ordinary differential equations obtained by substituting a product of a function of t alone and a function of x alone for the dependent variable. The integral is divided into parts which represent respectively the waves travelling in each of the two directions, and the wave tail. The equations of motion of a stretched string, and the telegraph equation, with given initial conditions, are considered as examples, the region considered so far being infinite. The author proceeds to consider the modification for a finite region, with given boundary conditions, and shows how his treatment of the double integral may be used to obtain the solution either in the form of standing waves, or in the form of progressive waves, with reflections from the boundaries. S. A.

Velocity Distribution near Walls. A. Izakson. Techn. Phys., U.S.S.R. **4,** 2. 155-162 (1937). In English. — In turbulent flow along a smooth pipe or channel, let U be the mean velocity, U_m the velocity in the middle, a the radius of the pipe or half-width of the channel, y distance from the wall, τ_0 the intensity of skin-friction, v the kinematic viscosity, and $V_* = \sqrt{(\tau_0/\rho)}$. The author shows that the logarithmic formula for U near a wall follows simply from the assumptions that U/V_* is a function of $V_* y/v$ only in the neighbourhood of the wall, $(U_m-U)/V_*$ is a function of y/a only, and U_m/V_* a function of $V_* a/v$ only, without any further assumptions as to the mechanism of the turbulence. Certain relations concerning the laminar sub-layer are then discussed, on the assumption that, if a δ is its thickness, and

U(δ) the velocity at its boundary, $\tau_0 = \beta\mu U(\delta)/a\delta$, where μ is the viscosity and β a universal constant. S. A.

Efflux of Air at Supersonic Velocities Through Small Orifices. L. Agostini. Compt. R. **204,** 1311-1313 (1937). — The efflux of air through orifices, of 0.03 - 0.5 mm. dia., at supersonic velocities in air has been investigate experimentally. The incidence of a supersonic velocity of efflux is demonstrated by the occurrence of striae in the discharge; these are made visible by a method due to Parenty. Emden's relation $\lambda = 0.37d\sqrt{(P/p)-1.39}$ for the wave-length λ of the striae in terms of the pressures, P, and p, upstream and downstream respectively, is verified for all diameters, d, used. At pressures near the theoretical critical value, the characteristic striae disappear at the following respective values of P/p: d= 0.06 mm.; P/p = 2.20; d= 0.01 mm. P/p= 2.10; d = 0.2 — 0.5 mm., P/p = 1.95 Emden's relation holds so long as the striae are present. The issuing jet appears therefore to pass uddenly from the supersonic to the subsonic regime. S.A.

Venturi Tubes and the Supersonic Flow of Fluids. J. Chalom. Compt. R. **204,** 1614-1615 (1937). — The efflux of fluid through an orifice at velocities exceeding that of sound and the entrainment of fluid by the jet issuing into a Venturi tube of either the convergent-divergent or divergent-convergent type is investigated by an interferometer method. Values of the jet-reaction produced in both kinds of tubes are tabulated for efflux pressures ranging from 1 to 4 kg./cm.^{2} maximum values of this reaction occur at pressures of 1.5 and 3 kg./cm.^{2} in the case of each tube. S. A.

Problems of Plane Elasticity with Airy's Polydromic Function. C. Tolotti. Accad. Lincei, Atti, **25,** 226-230 (1937). — It is well-known that problems on plane elastic systems, which are acted on only by boundary forces, can be solved by a function F, first introduced by Airy, which satisfies the biharmonic equation $\nabla^4 F = 0$. When the system is multiply-connected, the function F must be many-valued. The present paper shows that such a problem can always be reduced to an analogous problem in which the Airy function is certainly one-valued and hence simplifies the solution. S. A.

Plasticity Measurements at High Temperatures. H. K. Griffin and H. H. Storch. Ind. Eng. Chem. Anal. Ed. **9,** 280-286 (1937). — An instrument for precise measurements of plasticity at high temperatures is described. Adequate apparatus is included for avoiding eccentric loading. Measurements made on Pittsburgh and Alma seam coals show that the truly plastic properties of these coals are very transient, the life period being of the order of 1 min. at 460°C. Measurements of deformations proportional to the load were obtained at 410°C. An analysis of these data indicates that the deformations are elastic rather than plastic in character. Measurements on the deformation of the solid plus oily bitumen (obtained by benzene extraction) of Pittsburgh seam coal at 120°C show that this is a truly plastic material. S. A.

Two-Dimensional Hydrodynamical Theory of Moving Aerofoils. Part I. Rosa M. Morris. Roy. Soc. Proc. **161A,** 406-419 (1937). — In this paper a complete solution is given to the two-dimensional hydrodynamical problem of the motion in incompressible and inviscid fluid of a cylinder of a general type, which includes all those for which solutions are known, and also the most general type of cylinder which is used in the discussions of aerofoil theory. The potential and stream function of the fluid motion are determined, and thence the energy and forces exerted by the liquid on the cylinder, the latter are determined both by the Lagrange-Kirchhoff method and by direct integration of the pressure, the latter determination being rendered tractable by the discovery of generalized forms of the Blasius contour integral expressions applicable when the surfaces are in motion. The effect of variable circulation has been considered but the discussion of the effect of surfaces of discontinuity is postponed for a further note. S. A.

Two-Dimensional Potential Theory. Part IV. Expression for Fluid Energy and its Application. Rosa M. Morris. Phil. Mag. **24,** 47-52 (1937). — In continuation of previous work, the author discusses the interpretation of the field energy in terms of the complex potential for the hydrodynamical cases of (1) an elliptic cylinder, (2) the general cylinder moving perpendicular to its length, for acyclic motion of the fluid about the cylinder. The case of cyclic motion is briefly discussed. S. A.

Velocity-Distribution in a Liquid-into-Liquid Jet. E. N. DaC. Andrade and L. C. Tsien. Phys. Soc. Proc. **49,** 381-390; Disc., 391 (1937). — The distribution of velocity in a liquid-into-liquid jet, issuing from a cylindrical tube with a tapering approach, has been measured by photographing the traces made by suspended particles, with strong illumination and a determined exposure. The results have been compared with the theory for a jet issuing from a point in an infinite plane, and it is shown that, supposing the equivalent point source to be within the orifice, good agreement is found except in the immediate neighborhood of the orifice. An expression has been derived connecting the distance of the equivalent point source from the orifice with the Reynolds number. This enables the loss of kinetic energy of the jet to be worked out. S. A.

Fluid Friction in Roughened Pipes. C. F. Colebrook and C. M. White. Roy. Soc. Proc. **161A,** 367-381 (1937). — Nikuradse, experimenting with flow through uniformly roughened pipes, found comparatively abrupt transition from "smooth" law at slow speeds. Other experimenters using surfaces of the nature of cast iron, wrought iron or galvanised steel, have obtained results which can only be explained by a much more gradual transition between the two resistance laws. The present experiments show that with non-uniform roughness, transition is gradual, and in extreme cases so gradual that the whole working range lies within the transition zone. This closes the gap between Nikuradse's artificial roughnesses, and those normally found in pipes. S. A.

RECENT PAPERS OF RHEOLOGICAL INTEREST ON RUBBER

J. H. Dillon and L. V. Cooper, Rubber Age 41, pp. 306-10 (Aug. 1937) —Discussion of the nature of the rheological problem of rubber and a description of instruments employed in testing rubber's rheological properties.

L. A. Wohler, Ind. Eng. Chem. Anal. Ed. 9, pp. 117-8 (Aug. 1937)— Physical testing of latex mixes.

W. W. C. Everts, Kautschuk 13, p. 68 (1937)—Infuence of time on the extension of rubber under small load.

E. Guth and H. Mark, Naturwiss. 25, pp. 353-9 (1937)—Elasticity of rubber and its connection with the structural model.

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