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Technical Papers on Viscosity Measurement/Control And Texture Analysis

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Contents

All Technical Papers and some of the ASTM methods listed herein are available free of charge from Brookfield. Those ASTMs not available from Brookfield are marked by an asterisk (*) and may be obtained directly from ASTM (see p.16). Please specify the appropriate key numbers on the attached business reply card or use our website to order your copies.

GENERAL INTEREST

AR-5 **Measure Viscosity at Pumping Velocity.** Accurate viscosity measurement is best made at the pumping station with a rotational viscometer operated at two different speeds on samples taken from both the suction and discharge sides of the pump. A. M. Shaw, Chemical Engineering, January 1950.

AR-15A **Viscometer Comparison Chart.** The chart compares viscosity measurements of Newtonian liquids when using flow cups, capillary tubes and rotational viscometers. This convenient reference tool relates various viscosity units to centipoise for Newtonian Fluids only.

AR-15B **Viscosity Conversion Guide.** Table shows correlation for viscosity readings taken with different flow cups (Zahn, Ford, Shell, ISO, DIN) to their equivalent centipoise values. Applies to Newtonian fluids.

AR-15C **Conversion Graph - Seconds Saybolt to Centipoise.** Graph shows the conversion of viscosity readings in Saybolt seconds to centipoise. Applies to Newtonian fluids.

AR-20 **The Structure of Hevea Latex and Its Viscosity. Hevea Latex,** which is comprised of rubber particles and a dispersed phase in aqueous serum known as "viscoids", exhibits significant viscosity change when treated with ammonia, sodium sulphite, formaldehyde or distilled water. G. R. Verhaar. Reprinted by permission of the Institution of the Rubber Industry.

AR-28 **Various methods for measuring paint viscosity are reviewed:** Moving Fluid - flow cups, capillary tubes; Moving Element - falling ball/cylinder; Rotating Element - rotational viscometer. Donald W. Brookfield, as presented at the Annual Meeting of the Federation of Societies for Paint Technology, November 1960.

AR-34 **Thixotropy – Its Effects on Press Performance.** The reversible flow condition whereby an ink will flow under agitation and recover its original physical structure at rest, is best measured using a rotational viscometer. A. E. Price, Flexography, August 1963.

AR-68 **Rheology of Power Law Fluids.** Torque or shear stress data measured with a rotational viscometer can be related to spindle speed or shear rate using the power law relationship $\tau = k\dot{\gamma}^n$. William A. Hyman, I&EC Fundamentals, Vol. 15, 1976.

AR-69 **Rheograms for Power Law Fluids Using Coaxial Cylinder Viscometers and a Template Method.** Data from rotational viscometers with concentric cylinder spindle geometry can be easily modeled for shear thinning and shear thickening power law fluids. P. Haugen and M. A. Tung, Canada Inst. Food Sci. Technol. J. Vol. 9, No. 2, 1976.

AR-70 **Rheological Properties of Aerated Poultry Waste Slurries.** A rotational viscometer was used to measure the pseudo-plastic viscosity of aerated poultry waste slurries which is important in the proper design of pumping systems to handle these products. Y. R. Chen & A. G. Hashimoto, ASAE Vol. 19, No. 1. 1976.

AR-71 **Rheology of Livestock Waste Slurries.** A rotational viscometer was used to analyze the rheology of livestock waste slurries, which must be known in order to design efficient systems to pump, mix and aerate them. A. G. Hashimoto & Y. R. Chen, ASAE Vol. 19, No. 5, 1976.

AR-72 **Pipeline Transport of Livestock Waste Slurries.** A rotational viscometer was used to measure the viscosity of live stock waste slurries at various shear rates; these data were compared to those acquired by pumping the material through a piping system. Y. R. Chen & A. G. Hashimoto, ASAE Vol. 19, No. 5, 1976.

AR-77 **Approximate Rheological Characterization of Casson Fluids – Template Method for the Brookfield Synchro-Lectric Viscometer.** Nomograph method for analyzing Casson fluid data with square root graph paper is appropriate when computerized software is not available. Meyer R. Rosen and William W. Foster, JCT, Vol. 50, No 643, August 1978, pp. 39-48.

AR-80 **Viscosity Measurements of Non-Newtonian Slurry Suspensions Using Rotating Viscometers.** Slurry viscosities for various concentrations of calcium sulfate are measured with a rotational viscometer and analyzed using a shear thinning index method. Subhas K. Sikdar & Fernando Ore, I&EC Process Design & Development, Vol. 18, No. 4, 1979.

AR-82 **Simple Conversion of Brookfield RVT Readings Into Viscosity Functions.** Conversion factors are presented for converting viscosity data taken with the Brookfield RV torque range viscometer and standard RV spindles 1 through 7 into equivalent shear stress and shear rate data. P. Mitschka, Rheologica Acta, Vol. 21. pp. 207-209, 1982.

AR-89 **More Solutions to Sticky Problems.** This popular Brookfield publication explains how to make viscosity measurements, determine appropriate equipment choices, and interpret data.

AR-100 **A Look at Viscometry.** Terms used in making viscosity measurements - "absolute, kinematic, apparent" - are defined and types of flow - "Newtonian, non-Newtonian" - are explained. Considerations for improving the reliability and precision of viscosity measurements are offered. David W. Howard, Brookfield Eng. Labs., Inc.; Food Technology, July 1991.

AR-104 **Viscosity and Thermal Conductivity of Black Liquor.** This method for measuring viscosity involves applying a thin film of silicone oil to prevent evaporation and skin formation on the surface of black liquor contained in a chamber. P. Ramamurthy, A. R. P. van Heiningen, and G. Kubes, originally published: Tappi Journal, November 1993.

AR-111 **Beyond Single-Point Viscosity Measurement.** The non-Newtonian behavior of most fluids requires QC tests which involve multiple rotational speeds or shear rates in order to properly understand flow behavior. David A. Brookfield, American Laboratory News, March 1999.

AR-113 **Window of Opportunity for Automated Viscosity Analysis in Quality Control.** Computerized data analysis enables QC departments to make automated viscosity tests by measuring flow behavior at multiple rotational speeds. Robert G. McGregor, American Laboratory News, July 1999.

AR-117 **Texture Testing Protocols Transfer into the Commercial Environment.** Textural parameters including cohesiveness, springiness and hardness are defined and explained pertaining to breadcrumb quality. Jon Hellyer, European Food Scientist, December 2002.

AR-118 **Yield Testing to Ensure Product Consistency.** Yield stress determination using the Brookfield YR-1 Rheometer with vane spindles is described. Test data for paints, salsas and hair gels are presented. David J. Moonay, American Laboratory News, June 2003

AR-122 **Gelatin Testing - A Starting Point for Food Texture Analysis.** The well-established Bloom Test is described in detail for assessing the textural properties of gelatin. Industria Alimenticia, Jon Hellyer and Robert G. McGregor (Available in English and Spanish), October, 2003.

AR-123 **Measuring Viscosity of Pastes.** A detailed test method for measuring the viscosity of two different ointments is presented using T-bar spindles with Helipath Stand. American Laboratory News, Len Thibodeau, June 2004.

AR-126 **Use of a Brookfield YR-1 Rheometer for Characterization of Viscoelastic Properties.** Yield stress data from the Brookfield YR-1 Rheometer compares favorably with viscoelastic data from the Stress Tech Rheometer for food materials like ketchup and mayonnaise. Lisa Papageorge, Junhua Zhang, Jessica Powell and Javier Gayo, North Carolina State University, Raleigh NC, December 6, 2002.

AR-127 **Viscoelastic Property Determination — A New Application for Brookfield Viscometers.** The Brookfield YR-1 Rheometer produces viscoelastic properties of materials. D. Tanjore and C.R. Daubert, North Carolina State University, Raleigh, NC, 2005.

Related ASTM Test Methods (see page 17 for description)
D1417, D1986*, D2196

ADHESIVES

Related ASTM Test Methods (see page 17 for description)
D1084, D1337*, D1338*, D2556, D3236, D4800*

ASPHALT

AR-4 **Flow Properties of Asphalt Emulsions.** Asphalt emulsions exhibit power law behavior when tested for viscosity vs. shear rate; rheological properties depend primarily on asphalt content, particle size/distribution of the dispersed asphalt and surface condition of the asphalt particle. D. V. Lyttelton and R. N. Traxler, Industrial and Engineering Chemistry, November 1948.

Related ASTM Test Methods (see page 17 for description)
D1074*, D3791, D4280*, D4402, D5018, D6267*, D6373*

BIOLOGICAL

AR-35 **Measurement of Viscosity of Biological Fluids by Cone Plate Viscometer.** Method for rapid analysis of small fluid samples, such as blood and mucus which both exhibit pseudoplastic (shear thinning) behavior. R. E. Wells, R. Denton, E. W. Merrill, The Journal of Laboratory and Clinical Medicine, 1961.

AR-37 **Disturbance of the Flow Properties of Blood and Its Counteraction in Surgery.** A Brookfield Viscometer with Small Sample Adapter is used to characterize whole blood viscosity, which increases markedly at low shear rates in samples taken after severe tissue injury. Lars-Erik Gelin, Acta Chirurgica Scandinavica, 1961.

AR-60 **Viscosity of Exocrine Secretions in Cystic Fibrosis: Sweat, Duodenal Fluid and Submaxillary Saliva.** A rotational viscometer measures the viscosities of sweat, saliva and duodenal fluid from patients with cystic fibrosis and compares these to normal subjects and to patients with gastrointestinal symptoms. Martin I. Lorin, Carolyn R. Denning and Irwin D. Mandel, The Presbyterian Hospital, Columbia-Presbyterian Medical Center, New York, Biorheology, 1972 Volume 9, pp. 27-32, Pergamon Press, Printed in Great Britain.

AR-61 **The Effect of Temperature on the Relative Viscosity of Human Blood.** The effect of temperatures at 23°C and 37°C on the relative viscosity of blood is evaluated using three different viscometers: capillary, co-axial cylinder and cone plate. James H. Barbee, Department of Chemical Engineering, Montana State University, Bozeman, Montana, Biorheology, 1973, Volume 10, pp. 1-5, Pergamon Press, Great Britain.

AR-63 **Fluid Drop-Like Behavior of Erythrocytes — Disturbance in Pathology and its Quantification.** A Wells-Brookfield cone plate viscometer was used to show rheological differences between healthy and diseased blood types such as sickle-cell anemia. H. Schmid-Schonbein, R. E. Wells and J. Goldstone, Department of Physiology, University of Munich, Germany, and Department of Medicine, Peter Bent Brigham Hospital, Harvard Medical School, Boston, Massachusetts, U.S.A.

AR-64 **Hyperviscosity Syndrome in Multiple Myeloma. A Reversible, Concentration-Department Aggregation of the Myeloma Protein.** A Wells-Brookfield cone plate viscometer was used to show rheological differences between healthy blood and diseased blood; the latter was obtained from a patient with multiple myeloma. Herbert Lindsley, M.D., David Teller, Ph.D., Bruce Noonan, M.D., Michael Peterson, M.D., Mart Mannik, M.D., Seattle, Washington, The American Journal of Medicine, Volume 54, May 1973.

AR-74 **Apparent Viscosity of Materials Used for Making Edentulous Impressions.** A Brookfield Viscometer was used with a T-bar spindle to show differences between the rheologies of four different materials used in making dental impressions/molds. A. Koran, J. M. Powers, R. G. Graig, JADA, Vol. 95, July 1977.

AR-75 **Necrotizing Enterocolitis and Hyperviscosity in the Newborn Infant.** A Wells-Brookfield cone plate viscometer was used to determine the rheology of blood from infants suffering from necrotizing enterocolitis with high blood viscosity. D. O. Hakanson and W. Oh, The Journal of Pediatrics, Vol. 90, No. 3, March 1977.

AR-90 **The Influence of Particle Shape and Rigidity on the Viscosity of a Dispersed Suspension.** A Wells-Brookfield cone plate viscometer was used to determine the rheology of blood solutions having different ionic concentrations or osmolarity. R. L. Whitmore, First National Conference on Rheology-Melbourne, May 30-June 1, 1979.

AR-102 **Determination of Total Protein Concentration and Viscosity of Synovial Fluid from the Tibiotarsal Joints of Horses.** A Wells-Brookfield Cone Plate Viscometer was used to determine the shear-thinning rheology of horse synovial fluid. Nancy L. Korenek, DVM, Frank M. Andrews, DVM, MS, Jeanne M. Maddux DVM, PhD., William L. Sanders, PhD., David L. Faulk, BS, American J. Vet Research, Volume 53, No. 5, May 1992.

AR-103 **Viscosity and Rheologic Properties of Blood from Clinically Normal Horses.** A Wells-Brookfield Cone Plate Viscometer was used to show that horse bloods are shear-thinning and that the viscosity at a given shear rate increases with increasing protein concentration. Frank M. Andrews, DVM, MS, Nancy L. Korenek, DVM, William L. Sanders, PhD., Robert L. Hamlin, DVM, PhD., American J. Vet Research, Volume 53, No. 6, June 1992.

AR-109 Viscosity Measurements of Barium Sulfate Mixtures for Use in Motility Studies of the Pharynx and Esophagus. A Brookfield Viscometer evaluated standard commercial mixes of BaSO4 suspensions, showing strong shear thinning behavior at shear rates below 3 sec-1. Meijing Li, James G. Brasseur, Mark K. Kern and Wylie J. Dodds, Department of Mechanical Engineering, Pennsylvania State University, University Park, Pennsylvania, and Departments of Medicine, Radiology, and Surgery, Medical College of Wisconsin, Milwaukee, Wisconsin, USA.

CERAMICS

AR-8 Control Methods for the Consistency of One-Fire Glazes. Various methods for measuring viscosity of one-fire glazes are presented as a means for checking consistency. The Brookfield rotational viscometer and Mariott tube are discussed. H. R. Pinnow and B. W. Merwin, Ceramic Bulletin, Vol. 31, No. 9, 1952.

AR-9 Measurement of Enamel-Slip Consistency by Means of the Brookfield Viscometer. The Brookfield Viscometer affords comparable information to the "pick-up" and "slump" test methods in evaluating the consistency of enamel slips. E. M. Oliver, Journal of The American Ceramic Society, May 1, 1948.

AR-22 Determination of the Fineness and Consistency of Ceramic Glazes. Particle size and rotational viscosity data are correlated to milling time, pick-up, consistency, and effect of electrolyte. Morrison, Draker and Carter, American Ceramic Society Bulletin. April, 1954.

ELECTRONICS

AR-51 Viscometers for Thick Films. A Brookfield Viscometer with cylindrical spindle analyzes the viscosity of thick film inks. R. P. Anjard, Electronic Packaging and Production, December 1971.

AR-73 Analyzing Thick Film Inks. Viscosity measurements with a Wells-Brookfield cone/plate viscometer give a good indication of ink screenability. Phillip Creter, Circuits Manufacturing, September 1976.

AR-105 IPC Test Method for Solder Paste Viscosity-Spiral Pump Method. Test procedure describes use of Brookfield Spiral Adapter to measure solder paste viscosity. Institute for Interconnecting and Packaging Electronic Circuits. IPC-TM-650 Test Methods manual. Sections. 2.4.34.1, 2.4.34.2 and 2.4.34.3.

FOODS

AR-1 Effect of Processing Conditions on the Viscosity of Tomato Juice. Viscosity variations affect taste and are attributable to the number and shape of suspended particles which result from the softening of the chopped tomatoes in the preheater prior to finishing. Hand, Moyer, Randsford and Hening, Food Technology, May 1955.

AR-17 Studies on Dehydrated Potato Granules. The texture of reconstituted potato granules is evaluated using rotational viscosity test methods vs. solids content of rehydrate, temperature, and pH. Cooley, Severson, Peightal, and Wagner, Food Technology, May 1954.

AR-50 Control of Viscosity and Emulsion Stability in Foods Using Modified Micro Crystalline Cellulose. A Brookfield Viscometer was used to measure viscosities of various emulsified foods. Richard D. McCormick, Food Product Development, June-July 1970.

AR-53 Rheological Properties of Single-Cell Protein Concentrate: Dope Formation and Its Flow Behavior. A Brookfield Viscometer was used with cylindrical spindles and UL Adapter to compare the rheological properties of Torula Yeast Protein Extracts in water at 60°C. Frank Huang and C. K. Rha, University of Massachusetts, Journal of Food Science. Volume 36, 1971.

AR-78 Continuous Curd Tension Measurements During Milk Coagulation. A Brookfield Viscometer with Helipath Stand and modified T-F Spindle were used to monitor viscosity changes over time during milk coagulation. G. H. Richardson, N. R. Gandhi, M. A. Davatia, and C. A. Ernstrom, The Journal of Dairy Science, Vol. 54, No. 2, February 1971.

AR-79 **A Quick, Reliable Method for Measuring Yield Value, Plastic Viscosity and "Mac Michael" Viscosity of Chocolate.** Groundbreaking article describes a new technique using the Brookfield HA torque range viscometer with Small Sample Adapter for measuring the yield value and plastic viscosity of chocolate. J. W. Robbins, The Manufacturing Confectioner, May 1979.

AR-91 **Instrument Review: Brookfield.** This article further describes use of a Brookfield HA torque range viscometer with Small Sample Adapter (SC4-13R chamber and SC4-27 spindle) for analyzing chocolates. Edward S. Seguine, Guittard Chocolate Co., The Manufacturing Confectioner, pp. 49-55, January 1986.

AR-99 **Application of the Casson Viscosity Method for Chocolate to the Brookfield Viscometer.** This paper provides the approved method for analyzing chocolate viscosity using the Brookfield HA torque range viscometer with the SC4-13R chamber and SC4-27 spindle. A Committee Report, January 1988 Issue of The Manufacturing Confectioner.

AR-106 **Controlling Viscosity in Dressings and Sauces.** The viscosity of dressings, sauces, and gravies significantly affects both the texture and mouth feel of the product and its processing. Scott Hegenbart, Food Product Design, Sept. 1995.

AR-109 **Viscosity Measurements of Barium Sulfate Mixtures for Use in Motility Studies of the Pharynx and Esophagus.** The non-Newtonian behavior of barium sulphate plus strawberry syrup mixtures is characterized using a Brookfield Viscometer with LV cylindrical spindles and a UL Adapter. Meijing Li, James G. Brasseur, Mark Kern and Wylie J. Dodds (1992).

AR-117 **Texture Testing Protocols Transfer into the Commercial Environment.** Textural parameters including cohesiveness, springiness and hardness are defined and explained pertaining to breadcrumb quality. Jon Hellyer, European Food Scientist, December 2002.

AR-120 **Quality Testing with Instrumental Texture Analysis in Food Manufacturing.** A description of a flexible texture analysis system which objectively assesses core attributes of food products. Jon Hellyer, LabPlus International, September 2004.

AR-122 **Gelatin Testing - A Starting Point for Food Texture Analysis.** The well-established Bloom Test is described in detail for assessing the textural properties of gelatin. Industria Alimenticia, Jon Hellyer and Robert G. McGregor (Available in English and Spanish), October, 2003.

AR-126 **Use of a Brookfield YR-1 Rheometer for Characterization of Viscoelastic Properties.** Yield stress data from the Brookfield YR-1 Rheometer compares favorably with viscoelastic data from the Stress Tech Rheometer for food materials like ketchup and mayonnaise. Lisa Papageorge, Junhua Zhang, Jessica Powell and Javier Gayo, North Carolina State University, Raleigh NC, December, 2002.

HIGH TEMPERATURE

AR-27 **Improved Apparatus for Rapid Measurement of Viscosity of Glass at High Temperatures.** A custom designed platinum alloy spindle is used with a Brookfield Viscometer to measure molten glass viscosities from 6.5 to 13,000 Poise. Ralph L. Tiede, as presented at the Sixty-First Annual Meeting, The American Ceramic Society, 1959.

AR-54 **Viscosity and Structure of Industrial High TiO2 Slags.** An apparatus using a Brookfield Viscometer with a custom-made spindle is described for analyzing the viscosity of molten slags at high temperatures. G. Handfield and G. G. Charette, Canadian Metallurgical Quarterly, Volume 10, No. 3, 1971.

AR-56 **Titanium Bearing Ore and Blast Furnace Slag Viscosity.** TiO2 additions to industrial blast furnace slag cause a decrease in the slag viscosity. G. Handfield, G. G. Charette, and H. Y. Lee, Journal of Metals, September 1972.

AR-58 **Viscosity of Industrial Titania Slags.** Completely molten high concentration TiO2 slags are very fluid melts characterized by high crystallization. G. Handfield, G. G. Charette, and H. Y. Lee. March 1971.

Related ASTM Test Methods (see page 17 for description)
C965

OIL/GAS DRILLING

AR-87 **Evaluation of Frac Fluid Stability Using a Heated, Pressurized Flow Loop.** Tests showed that cross-linked frac fluids degrade with temperature and shear, losing much of their viscosity and proppant-carrying capacity in a few hours. J. A. Lescarboura et. al, SPE 10962, September 26-29, 1982.

AR-110 **Rheologically Enhanced Xanthan System Replaces Invert Emulsion.** The true suspension and carrying capacity of a drilling fluid is best evaluated using low shear rate viscosity (LSRV) measurements. Domingo Rastrilla, Mexpetrol, Argentina, S. A., Johnny Peña and J. Mac Seheult, Kelko Oil Field Group, Hart's Petroleum Engineering International pp. 53-57, October 1997.

AR-124 **Development and Real-Time Monitoring of the Rheological Properties of Frac Fluids.** The importance of LSRV measurements with rotational viscometers and on-line viscosity measurement with the Brookfield TT-100 are described for fracturing fluids used in the oil drilling industry. Charles Wesley, Petro Industry News, June/July, 2004.

OIL/PETROLEUM

AR-116 **Viscosity Pressure Drop Correlation Study in Pipeline Transporting Waxy Crude.** Crude oil viscosity governs pressure drop in a pipeline. Brookfield and Fann viscosity data are compared and used in predicting pressure drops in Oil India Ltd.'s pipeline. S. Sinha, M.C. Nihalani and H. Dubey, as presented at Petrotech-2001. the 4th International Petroleum Conference and Exhibition, New Delhi, India, January, 2001.

AR-119 **Viscosity and Petroleum Products.** Various methods to test petroleum viscosity are described, including flow cups, capillary tubes and rotational viscometers. Viscosity vs. temperature profiling is also discussed. Robert G. McGregor, Brookfield Engineering Laboratories, Inc.

AR-125 **Determining the Low Temperature Properties of Grease with a Brookfield Viscometer.** Ten different greases are evaluated for viscosity behavior at low temperature (-40°C) using a DV-III Rheometer with Helipath Stand and T-bar spindles. Paul A. Bessette, Technical Director, Engineered Custom Lubricants, Plymouth, Michigan, USA, ELGI Annual Meeting, Nice, France, May 16-18, 2004.

Related ASTM Test Methods (see page 17 for description)
D2983, D5133, D6080*, D6895*

PAINTS, INKS & COATINGS

AR-18 **Modified Proteins for Stabilizing Latex Paints.** Casein modified with an enzyme, ammonia or a reducing agent permits formulation of latex paints with good viscosity stability. Ronai and Weisberg, Industrial and Engineering Chemistry, April 1954.

AR-25 **Thixotropic Properties of Paints.** With thixotropic paints, viscosity diminishes with agitation and increases again upon standing. Desirable thixotropic behavior enables good leveling. Dr. J. Rinse, Paint and Varnish Production, July 1958.

AR-28 **Measurement of Rheological Properties.** Various methods for measuring paint viscosity are reviewed: Moving Fluid - flow cups, capillary tubes; Moving Element - falling ball/cylinder; Rotating Element - rotational viscometer. Donald W. Brookfield, as presented at the Annual Meeting of the Federation of Societies for Paint Technology, November 1960.

AR-34 **Thixotropy – Its Effects on Press Performance.** Thixotropy, the reversible flow condition whereby an ink will flow under agitation and recover its original physical structure at rest, is best measured using a rotational viscometer. A. E. Price, Flexography, August 1963.

AR-43 **A New Method for the Viscosity Measurement of Paint in the Settling, Sagging, Leveling and Penetration Shear Rate Range of .001 to 1.0 Reciprocal Seconds Using a Cone/Plate Spring Relaxation Technique.** A relatively inexpensive and routine method for developing precise shear stress, shear rate and viscosity data in the ultra-low shear rate region is presented. Temple C. Patton, Journal of Paint Technology, November 1966.

AR-47 **Measurement of Rheology of Thixotropic Organic Coatings and Resins with the Brookfield Viscometer.** A method for measuring the viscosity of pseudoplastic and thixotropic coatings is described for development & quality control laboratories. Percy E. Pierce, Journal of Paint Technology, June 1971.

AR- 48 **Hydrophilic Clay Gellant.** Evaluating rheological properties of aqueous coatings through laboratory testing with the Viscosity Profile Concept (viscosity vs. shear rate flow curves) serves as an indicator of in-field performance. S. L. Davidson and C. J. Eichhorn, Paint and Varnish Production, July 1971.

AR-59 **Viscosity Profiles of Solvent Based Paints: Their Measurement and Interpretation.** Single data point viscosity measurements are proven meaningless in determining rheological and application properties of paint. Arthur Ehrlich, Temple C. Patton and Armando Franco, Journal of Paint Technology, Volume 45, No. 576, January 1973.

AR-76 **Instrumental Techniques for the Rheological Control of Coatings.** Low shear rate measurement of paint viscosity predicts settling tendencies of pigment during storage. E. H. Erenrich and R. E. Van Doren, Australian OCCA Proceedings and News, November 1977.

AR-84 **Brookfield Viscometers for Determination of Low-Shear Viscosity and Leveling Behavior.** A stress relaxation technique for use with Brookfield Viscometers with standard spindles and coaxial cylinder geometry allows measurements in the 0.001 to 1.0 sec-1 shear rate range. Ronald E. Smith, JCT, Vol. 54, No. 694, pp. 21-29, November 1982.

AR-85 **Rheology Control of High-Solids Coatings.** Viscosity measurements of liquid coatings are correlated with finished product appearance (sag, settling, gloss). D. Miller, W. Moll, V. Taylor, Modern Paint and Coatings, April 1983.

AR-88 **Selecting Solvents for High-Solids Coatings.** Various solvent/coating relationships are examined through viscosity measurement vs. solids content, resistivity, and surface tension. Garland P. Sprinkle, Jr., Modern Paint and Coatings, April 1983.

AR- 94 **Control of Foaming in Water-Born Coatings.** Bulk viscosity is shown to be the strongest single factor controlling foaming. P. Kuschnir, R. Eley, F. L. Floyd, JCT, Vol. 59, No. 744, January 1987.

AR-107 **Ink Monitor Safeguards Against Color Shifts.** Regulation of print color is accomplished through viscosity and pH measurement and control. Lynanne Feilen, Converting Magazine, July 1995.

AR-112 **The Importance of Viscosity Control in Pleasing Print Buyers.** Viscosity control on multi-station printing presses will help control final print color. Steve Litschig, Converting Magazine, July 1999.

AR-121 **Quick, Easy, Accurate, Meaningful: What a Viscosity Measurement Should Be.** Summarizes the viscosity test methods used by industry and provides information on a proposed two-point test method. Diane M. Beltran, Paints & Coatings, August 2005.

Related ASTM Test Methods (see page 17 for description)
D115, D562, D803*, D1076, D1824, D2243*, D2336*, D2669, D3716, D3730*, D3794*, D3806*, D4016, D4143*, D4212*, D4368*, D4400*, D4712*, D5146*, D5324*, D5400*, D6083*, D6577*

PAPER COATINGS

AR-38 **Some Factors That Influence the Viscosity of Paper Coating Compositions.** The effects of particle composition of the pigment, chemical treatment and mixing intensity are evaluated with respect to the viscosity of the coating. N. Millman, TAPPI, November 1964.

AR-66 **The Relationship Between Degree of Clay Dispersion and the Optical and Pore Properties of Starch-Clay Coatings.** Viscosity change of starch-clay coatings when treated with different amounts of tetrasodium pyrophosphate (TSPP) is examined experimentally. Chinu S. Dalal and James E. Kline, TAPPI, Volume 57, No. 5, May 1974.

AR-101 **Relationship Between Flow Instability in Short-Dwell Ponds and Cross Directional Coat Weight Nonuniformities.** Fluid viscosity changes can cause the appearance of streaks on lightweight coated papers which in turn correlate to onset of hydrodynamic instabilities in the pond for short-dwell coaters. N. Triantafillopoulos & C. Aidun; Tappi Journal, Vol. 73, No. 6, June 1990.

PHARMACEUTICALS & COSMETICS

AR-11 **Comparative Viscosities of Coconut Oil Liquid Soaps.** A Brookfield Viscometer was used to show rheological differences between different coconut oil soaps at various temperatures. R. B. Trusler, Journal of The American Oil Chemists' Society, March 1953.

AR-42 **Adaptation to Commercial Viscometers for Special**

Applications in Pharmaceutical Rheology I – The Brookfield Viscometer. A Brookfield Viscometer was adapted to have concentric cylinder geometry, allowing low-shear-rate viscosity measurements of an anti-perspirant lotion. J. H. Wood, G. Catacalos and S. Lieberman, Journal of Pharmaceutical Sciences, March 1963.

AR-83 **A Rapid and Reliable Method for Determining Viscosity on Stability Samples.** A Brookfield Viscometer with Small Sample Adapter analyzes a lotion's storage stability (extrapolated yield stress values) in fresh and aged samples. A. Ball, J. Jaramillo, T. Markowski, Cosmetics & Toiletries, Vol. 97, No. 10, p. 40, October 1982.

AR-115 **A Quick Method for a QC Viscosity Test.** A Brookfield R/S rheometer quickly analyzes various shampoos at both low and high shear rates, providing insights into the materials' behavior during pouring and manual spreading. Robert McGregor, American Laboratory News, June 2001.

AR-123 **Measuring Viscosity of Pastes.** A detailed test method for measuring the viscosity of two different ointments is presented using T-bar spindles with Helipath Stand. American Laboratory News, Len Thibodeau, June 2004.

Related ASTM Test Methods (see page 17 for description)
D1439, D2364

PLASTICS

AR-19 **Quality Control and Application Tests for Plastisols.** The Brookfield Viscometer is recommended for testing raw materials for plastisols. Arnold C. Wasser, Products Finishing, October 1955.

Related ASTM Test Methods (see page 17 for description)
C1276, D789, D3468, D4878*, D4889

PROCESS CONTROL

AR-87 **Evaluation of Frac Fluid Stability Using a Heated, Pressurized Flow Loop (TT-100 Process Viscometer)** Flow loop is used to evaluate rheological properties of frac fluids as a function of time and temperature to simulate actual use conditions. J. A. Lescarboura et. al, SPE 10962, September 26-29, 1982.

AR-96 **Control Devices and Systems.** On-line viscosity control of fuel oil provides improved efficiency to boilers and reduces boiler shutdown. Control Engineering, 1983.

AR- 97 **Viscosity Control Cuts Heating and Cooling Plant's Fuel Bill.** Fuel oil viscosity controller allows use of wide variety of residual oils which provides cost savings to heating plant. Randall L. Harwood and Moses Mendez, Instrumentation and Controls Systems, May 1989.

AR-107 **Ink Monitor Safeguards Against Color Shifts.** Viscosity control system maintains color and print quality throughout press run. Lynanne Feilen, Converting Magazine, July 1995.

AR-108 **Brookfield Provides 10 Years of Viscosity Measurement to Appleton Papers.** On-line Brookfield Viscometer controls light-weight coating viscosity for specialty papers. Tappi Journal, Vol. 81, No. 3, March 1998.

REFERENCES

ASTM test methods are available from:

ASTM International
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Phone: 610-832-9585; Fax: 610-832-9555
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ASTM TEST METHODS

C965 Practices for Measuring Viscosity of Glass Above the Softening Point
C1276 Standard Test Method for Measuring the Viscosity of Mold Powders Above their Melting Point Using a Rotational Viscometer.
D115 Methods of Testing Varnishes Used for Electrical Insulation
D562 Standard Test Method for Consistency of Paints Using the Stormer Viscometer
D789 Test Methods for Determination of Relative Viscosity, Melting Point, and Moisture Content of Polyamide (PA)
D803* Test Methods for Testing Tall Oil
D1074* Test Method for Compressive Strength of Bituminous Mixtures
D1076 Specification for Rubber-Concentrated, Ammonia Preserved, Creamed and Centrifuged Natural Latex
D1084 Test Methods for Viscosity of Adhesives
D1337* Test Method for Storage Life of Adhesives by Consistency and Bond Strength
D1338* Practice for Working Life of Liquid or Paste Adhesives by Consistency and Bond Strength
D1417 Methods of Testing Rubber Latices-Synthetic
D1439 Methods of Testing Sodium Carboxymethyl-cellulose
D1824 Test Method for Apparent Viscosity of Plastisols and Organosols at Low Shear Rates by Brookfield Viscometer
D1986* Test Method for Determining the Apparent Viscosity of Polyethylene Wax Brookfield Viscometer
D2196 Test Methods for Rheological Properties on Non-Newtonian Materials by Rotational (Brookfield) Viscometer
D2243* Test Method for Freeze-Thaw Resistance of Waterborne Coatings
D2336* Guide for Specifying Factory Applied Wood Coatings
D2364 Standard Methods of Testing Hydroxyethyl-cellulose
D2556 Test Method for Apparent Viscosity of Adhesives Having Shear Rate Dependent Flow Properties
D2669 Test Method for Apparent Viscosity of Petroleum Waxes Compounded with Additives (Hot Melts)
D2983 Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by the Brookfield Viscometer
D3236 Test Method for Apparent Viscosity of Hot Melt Adhesives and Coating Materials
D3468 Standard Specification for Liquid-Applied Neoprene and Chlorosulfonated Polyethylene Used in Roofing and Waterproofing
D3716 Method of Testing Emulsion Polymers for Use in Floor Polishes
D3730* Guide for Testing High-Performance Interior Architectural Wall Coatings.
D3791 Standard Practice for Evaluating the Effects of Heat on Asphalts
D 3794* Guide for Testing Coil Coatings
D 3806* Test Method for Small-Scale Evaluation of Fire-Retardant Paints (2-ft Tunnel Method)
D4016 Test Method for Viscosity of Chemical Grouts by the Brookfield Viscometer (Laboratory Method)
D4143* Guide for Testing Latex Vehicles
D4212* Guide for Testing Epoxy Resins
D4280* Specification for Extended Life Type, Nonplowable, Prismatic, Raised, Retroreflective Pavement Markers
D4368* Guide for Testing Poly(Vinyl Chloride) Resins
D4400* Test Methods for Sag Resistance of Paints Using a Multinotch Applicator
D4402 Standard Method for Viscosity Determinations of Unfilled Asphalts Using the Brookfield Thermosel Apparatus
D4712* Guide for Testing of Industrial Water-Reducible Coatings
D4800* Guide for Classifying and Specifying Adhesives
D4878* Test Methods for Polyurethane Raw Materials: Determination of Viscosity of Polyols
D4889 Standard Test Methods for Polyurethane Raw Materials: Determination of Viscosity of Crude or Modified Isocyanates
D5018 Standard Test Method for Shear Viscosity of Coal-Tar and Petroleum Pitches
D5133 Standard Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature-Scanning Technique
D5146* Guide to Testing Solvent-Borne Architectural Coatings
D5324* Guide to Testing Water-Borne Architectural Coatings
D5400* Test Methods for Hydroxypropylcellulose
D6080* Practice for Defining the Viscosity Characteristics of Hydraulic Fluids
D6083* Specification for Liquid Applied Acrylic Coating Used in Roofing
D6267* Specification for Asphaltic Plug Joints for Bridges
D6373* Specification for Performance Graded Asphalt Binder
D6577* Guide for Testing Industrial Protective Coatings
D6895* Standard Test Method for Rotational Viscosity of Heavy Duty Diesel Drain Oils at 100°C

*These test methods may be purchased from ASTM (see page 16).

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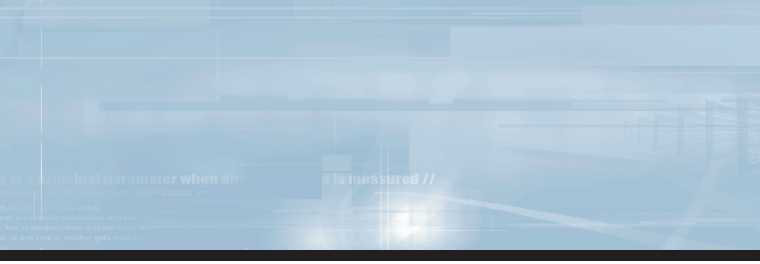

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All Technical Papers and some of the ASTM methods listed herein are available free of charge from Brookfield. Those ASTMs not available from Brookfield are marked by an asterisk (*) and may be obtained directly from ASTM (see p.16). Please specify the appropriate key numbers on the attached business reply card or use our website to order your copies.

GENERAL INTEREST

AR-5 **Measure Viscosity at Pumping Velocity.** Accurate viscosity measurement is best made at the pumping station with a rotational viscometer operated at two different speeds on samples taken from both the suction and discharge sides of the pump. A. M. Shaw, Chemical Engineering, January 1950.

AR-15A **Viscometer Comparison Chart.** The chart compares viscosity measurements of Newtonian liquids when using flow cups, capillary tubes and rotational viscometers. This convenient reference tool relates various viscosity units to centipoise for Newtonian Fluids only.

AR-15B **Viscosity Conversion Guide.** Table shows correlation for viscosity readings taken with different flow cups (Zahn, Ford, Shell, ISO, DIN) to their equivalent centipoise values. Applies to Newtonian fluids.

AR-15C **Conversion Graph - Seconds Saybolt to Centipoise.** Graph shows the conversion of viscosity readings in Saybolt seconds to centipoise. Applies to Newtonian fluids.

AR-20 **The Structure of Hevea Latex and Its Viscosity. Hevea Latex,** which is comprised of rubber particles and a dispersed phase in aqueous serum known as "viscoids", exhibits significant viscosity change when treated with ammonia, sodium sulphite, formaldehyde or distilled water. G. R. Verhaar. Reprinted by permission of the Institution of the Rubber Industry.

AR-28 **Various methods for measuring paint viscosity are reviewed:** Moving Fluid - flow cups, capillary tubes; Moving Element - falling ball/cylinder; Rotating Element - rotational viscometer. Donald W. Brookfield, as presented at the Annual Meeting of the Federation of Societies for Paint Technology, November 1960.

AR-34 **Thixotropy – Its Effects on Press Performance.** The reversible flow condition whereby an ink will flow under agitation and recover its original physical structure at rest, is best measured using a rotational viscometer. A. E. Price, Flexography, August 1963.

AR-68 **Rheology of Power Law Fluids.** Torque or shear stress data measured with a rotational viscometer can be related to spindle speed or shear rate using the power law relationship $\tau = k\dot{\gamma}^n$. William A. Hyman, I&EC Fundamentals, Vol. 15, 1976.

AR-69 **Rheograms for Power Law Fluids Using Coaxial Cylinder Viscometers and a Template Method.** Data from rotational viscometers with concentric cylinder spindle geometry can be easily modeled for shear thinning and shear thickening power law fluids. P. Haugen and M. A. Tung, Canada Inst. Food Sci. Technol. J. Vol. 9, No. 2, 1976.

AR-70 **Rheological Properties of Aerated Poultry Waste Slurries.** A rotational viscometer was used to measure the pseudo-plastic viscosity of aerated poultry waste slurries which is important in the proper design of pumping systems to handle these products. Y. R. Chen & A. G. Hashimoto, ASAE Vol. 19, No. 1. 1976.

AR-71 **Rheology of Livestock Waste Slurries.** A rotational viscometer was used to analyze the rheology of livestock waste slurries, which must be known in order to design efficient systems to pump, mix and aerate them. A. G. Hashimoto & Y. R. Chen, ASAE Vol. 19, No. 5, 1976.

AR-72 **Pipeline Transport of Livestock Waste Slurries.** A rotational viscometer was used to measure the viscosity of live stock waste slurries at various shear rates; these data were compared to those acquired by pumping the material through a piping system. Y. R. Chen & A. G. Hashimoto, ASAE Vol. 19, No. 5, 1976.

AR-77 **Approximate Rheological Characterization of Casson Fluids – Template Method for the Brookfield Synchro-Lectric Viscometer.** Nomograph method for analyzing Casson fluid data with square root graph paper is appropriate when computerized software is not available. Meyer R. Rosen and William W. Foster, JCT, Vol. 50, No 643, August 1978, pp. 39-48.

AR-80 **Viscosity Measurements of Non-Newtonian Slurry Suspensions Using Rotating Viscometers.** Slurry viscosities for various concentrations of calcium sulfate are measured with a rotational viscometer and analyzed using a shear thinning index method. Subhas K. Sikdar & Fernando Ore, I&EC Process Design & Development, Vol. 18, No. 4, 1979.

AR-82 **Simple Conversion of Brookfield RVT Readings Into Viscosity Functions.** Conversion factors are presented for converting viscosity data taken with the Brookfield RV torque range viscometer and standard RV spindles 1 through 7 into equivalent shear stress and shear rate data. P. Mitschka, Rheologica Acta, Vol. 21. pp. 207-209, 1982.

AR-89 **More Solutions to Sticky Problems.** This popular Brookfield publication explains how to make viscosity measurements, determine appropriate equipment choices, and interpret data.

AR-100 **A Look at Viscometry.** Terms used in making viscosity measurements - "absolute, kinematic, apparent" - are defined and types of flow - "Newtonian, non-Newtonian" - are explained. Considerations for improving the reliability and precision of viscosity measurements are offered. David W. Howard, Brookfield Eng. Labs., Inc.; Food Technology, July 1991.

AR-104 **Viscosity and Thermal Conductivity of Black Liquor.** This method for measuring viscosity involves applying a thin film of silicone oil to prevent evaporation and skin formation on the surface of black liquor contained in a chamber. P. Ramamurthy, A. R. P. van Heiningen, and G. Kubes, originally published: Tappi Journal, November 1993.

AR-111 **Beyond Single-Point Viscosity Measurement.** The non-Newtonian behavior of most fluids requires QC tests which involve multiple rotational speeds or shear rates in order to properly understand flow behavior. David A. Brookfield, American Laboratory News, March 1999.

AR-113 **Window of Opportunity for Automated Viscosity Analysis in Quality Control.** Computerized data analysis enables QC departments to make automated viscosity tests by measuring flow behavior at multiple rotational speeds. Robert G. McGregor, American Laboratory News, July 1999.

AR-117 **Texture Testing Protocols Transfer into the Commercial Environment.** Textural parameters including cohesiveness, springiness and hardness are defined and explained pertaining to breadcrumb quality. Jon Hellyer, European Food Scientist, December 2002.

AR-118 **Yield Testing to Ensure Product Consistency.** Yield stress determination using the Brookfield YR-1 Rheometer with vane spindles is described. Test data for paints, salsas and hair gels are presented. David J. Moonay, American Laboratory News, June 2003

AR-122 **Gelatin Testing - A Starting Point for Food Texture Analysis.** The well-established Bloom Test is described in detail for assessing the textural properties of gelatin. Industria Alimenticia, Jon Hellyer and Robert G. McGregor (Available in English and Spanish), October, 2003.

AR-123 **Measuring Viscosity of Pastes.** A detailed test method for measuring the viscosity of two different ointments is presented using T-bar spindles with Helipath Stand. American Laboratory News, Len Thibodeau, June 2004.

AR-126 **Use of a Brookfield YR-1 Rheometer for Characterization of Viscoelastic Properties.** Yield stress data from the Brookfield YR-1 Rheometer compares favorably with viscoelastic data from the Stress Tech Rheometer for food materials like ketchup and mayonnaise. Lisa Papageorge, Junhua Zhang, Jessica Powell and Javier Gayo, North Carolina State University, Raleigh NC, December 6, 2002.

AR-127 **Viscoelastic Property Determination — A New Application for Brookfield Viscometers.** The Brookfield YR-1 Rheometer produces viscoelastic properties of materials. D. Tanjore and C.R. Daubert, North Carolina State University, Raleigh, NC, 2005.

Related ASTM Test Methods (see page 17 for description)
D1417, D1986*, D2196

ADHESIVES

Related ASTM Test Methods (see page 17 for description)
D1084, D1337*, D1338*, D2556, D3236, D4800*

ASPHALT

AR-4 **Flow Properties of Asphalt Emulsions.** Asphalt emulsions exhibit power law behavior when tested for viscosity vs. shear rate; rheological properties depend primarily on asphalt content, particle size/distribution of the dispersed asphalt and surface condition of the asphalt particle. D. V. Lyttelton and R. N. Traxler, Industrial and Engineering Chemistry, November 1948.

Related ASTM Test Methods (see page 17 for description)
D1074*, D3791, D4280*, D4402, D5018, D6267*, D6373*

BIOLOGICAL

AR-35 **Measurement of Viscosity of Biological Fluids by Cone Plate Viscometer.** Method for rapid analysis of small fluid samples, such as blood and mucus which both exhibit pseudoplastic (shear thinning) behavior. R. E. Wells, R. Denton, E. W. Merrill, The Journal of Laboratory and Clinical Medicine, 1961.

AR-37 **Disturbance of the Flow Properties of Blood and Its Counteraction in Surgery.** A Brookfield Viscometer with Small Sample Adapter is used to characterize whole blood viscosity, which increases markedly at low shear rates in samples taken after severe tissue injury. Lars-Erik Gelin, Acta Chirurgica Scandinavica, 1961.

AR-60 **Viscosity of Exocrine Secretions in Cystic Fibrosis: Sweat, Duodenal Fluid and Submaxillary Saliva.** A rotational viscometer measures the viscosities of sweat, saliva and duodenal fluid from patients with cystic fibrosis and compares these to normal subjects and to patients with gastrointestinal symptoms. Martin I. Lorin, Carolyn R. Denning and Irwin D. Mandel, The Presbyterian Hospital, Columbia-Presbyterian Medical Center, New York, Biorheology, 1972 Volume 9, pp. 27-32, Pergamon Press, Printed in Great Britain.

AR-61 **The Effect of Temperature on the Relative Viscosity of Human Blood.** The effect of temperatures at 23°C and 37°C on the relative viscosity of blood is evaluated using three different viscometers: capillary, co-axial cylinder and cone plate. James H. Barbee, Department of Chemical Engineering, Montana State University, Bozeman, Montana, Biorheology, 1973, Volume 10, pp. 1-5, Pergamon Press, Great Britain.

AR-63 **Fluid Drop-Like Behavior of Erythrocytes — Disturbance in Pathology and its Quantification.** A Wells-Brookfield cone plate viscometer was used to show rheological differences between healthy and diseased blood types such as sickle-cell anemia. H. Schmid-Schonbein, R. E. Wells and J. Goldstone, Department of Physiology, University of Munich, Germany, and Department of Medicine, Peter Bent Brigham Hospital, Harvard Medical School, Boston, Massachusetts, U.S.A.

AR-64 **Hyperviscosity Syndrome in Multiple Myeloma. A Reversible, Concentration-Department Aggregation of the Myeloma Protein.** A Wells-Brookfield cone plate viscometer was used to show rheological differences between healthy blood and diseased blood; the latter was obtained from a patient with multiple myeloma. Herbert Lindsley, M.D., David Teller, Ph.D., Bruce Noonan, M.D., Michael Peterson, M.D., Mart Mannik, M.D., Seattle, Washington, The American Journal of Medicine, Volume 54, May 1973.

AR-74 **Apparent Viscosity of Materials Used for Making Edentulous Impressions.** A Brookfield Viscometer was used with a T-bar spindle to show differences between the rheologies of four different materials used in making dental impressions/molds. A. Koran, J. M. Powers, R. G. Graig, JADA, Vol. 95, July 1977.

AR-75 **Necrotizing Enterocolitis and Hyperviscosity in the Newborn Infant.** A Wells-Brookfield cone plate viscometer was used to determine the rheology of blood from infants suffering from necrotizing enterocolitis with high blood viscosity. D. O. Hakanson and W. Oh, The Journal of Pediatrics, Vol. 90, No. 3, March 1977.

AR-90 **The Influence of Particle Shape and Rigidity on the Viscosity of a Dispersed Suspension.** A Wells-Brookfield cone plate viscometer was used to determine the rheology of blood solutions having different ionic concentrations or osmolarity. R. L. Whitmore, First National Conference on Rheology-Melbourne, May 30-June 1, 1979.

AR-102 **Determination of Total Protein Concentration and Viscosity of Synovial Fluid from the Tibiotarsal Joints of Horses.** A Wells-Brookfield Cone Plate Viscometer was used to determine the shear-thinning rheology of horse synovial fluid. Nancy L. Korenek, DVM, Frank M. Andrews, DVM, MS, Jeanne M. Maddux DVM, PhD., William L. Sanders, PhD., David L. Faulk, BS, American J. Vet Research, Volume 53, No. 5, May 1992.

AR-103 **Viscosity and Rheologic Properties of Blood from Clinically Normal Horses.** A Wells-Brookfield Cone Plate Viscometer was used to show that horse bloods are shear-thinning and that the viscosity at a given shear rate increases with increasing protein concentration. Frank M. Andrews, DVM, MS, Nancy L. Korenek, DVM, William L. Sanders, PhD., Robert L. Hamlin, DVM, PhD., American J. Vet Research, Volume 53, No. 6, June 1992.

AR-109 Viscosity Measurements of Barium Sulfate Mixtures for Use in Motility Studies of the Pharynx and Esophagus. A Brookfield Viscometer evaluated standard commercial mixes of BaSO4 suspensions, showing strong shear thinning behavior at shear rates below 3 sec-1. Meijing Li, James G. Brasseur, Mark K. Kern and Wylie J. Dodds, Department of Mechanical Engineering, Pennsylvania State University, University Park, Pennsylvania, and Departments of Medicine, Radiology, and Surgery, Medical College of Wisconsin, Milwaukee, Wisconsin, USA.

CERAMICS

AR-8 Control Methods for the Consistency of One-Fire Glazes. Various methods for measuring viscosity of one-fire glazes are presented as a means for checking consistency. The Brookfield rotational viscometer and Mariott tube are discussed. H. R. Pinnow and B. W. Merwin, Ceramic Bulletin, Vol. 31, No. 9, 1952.

AR-9 Measurement of Enamel-Slip Consistency by Means of the Brookfield Viscometer. The Brookfield Viscometer affords comparable information to the "pick-up" and "slump" test methods in evaluating the consistency of enamel slips. E. M. Oliver, Journal of The American Ceramic Society, May 1, 1948.

AR-22 Determination of the Fineness and Consistency of Ceramic Glazes. Particle size and rotational viscosity data are correlated to milling time, pick-up, consistency, and effect of electrolyte. Morrison, Draker and Carter, American Ceramic Society Bulletin. April, 1954.

ELECTRONICS

AR-51 Viscometers for Thick Films. A Brookfield Viscometer with cylindrical spindle analyzes the viscosity of thick film inks. R. P. Anjard, Electronic Packaging and Production, December 1971.

AR-73 Analyzing Thick Film Inks. Viscosity measurements with a Wells-Brookfield cone/plate viscometer give a good indication of ink screenability. Phillip Creter, Circuits Manufacturing, September 1976.

AR-105 IPC Test Method for Solder Paste Viscosity-Spiral Pump Method. Test procedure describes use of Brookfield Spiral Adapter to measure solder paste viscosity. Institute for Interconnecting and Packaging Electronic Circuits. IPC-TM-650 Test Methods manual. Sections. 2.4.34.1, 2.4.34.2 and 2.4.34.3.

FOODS

AR-1 Effect of Processing Conditions on the Viscosity of Tomato Juice. Viscosity variations affect taste and are attributable to the number and shape of suspended particles which result from the softening of the chopped tomatoes in the preheater prior to finishing. Hand, Moyer, Randsford and Hening, Food Technology, May 1955.

AR-17 Studies on Dehydrated Potato Granules. The texture of reconstituted potato granules is evaluated using rotational viscosity test methods vs. solids content of rehydrate, temperature, and pH. Cooley, Severson, Peightal, and Wagner, Food Technology, May 1954.

AR-50 Control of Viscosity and Emulsion Stability in Foods Using Modified Micro Crystalline Cellulose. A Brookfield Viscometer was used to measure viscosities of various emulsified foods. Richard D. McCormick, Food Product Development, June-July 1970.

AR-53 Rheological Properties of Single-Cell Protein Concentrate: Dope Formation and Its Flow Behavior. A Brookfield Viscometer was used with cylindrical spindles and UL Adapter to compare the rheological properties of Torula Yeast Protein Extracts in water at 60°C. Frank Huang and C. K. Rha, University of Massachusetts, Journal of Food Science. Volume 36, 1971.

AR-78 Continuous Curd Tension Measurements During Milk Coagulation. A Brookfield Viscometer with Helipath Stand and modified T-F Spindle were used to monitor viscosity changes over time during milk coagulation. G. H. Richardson, N. R. Gandhi, M. A. Davatia, and C. A. Ernstrom, The Journal of Dairy Science, Vol. 54, No. 2, February 1971.

AR-79 **A Quick, Reliable Method for Measuring Yield Value, Plastic Viscosity and "Mac Michael" Viscosity of Chocolate.** Groundbreaking article describes a new technique using the Brookfield HA torque range viscometer with Small Sample Adapter for measuring the yield value and plastic viscosity of chocolate. J. W. Robbins, The Manufacturing Confectioner, May 1979.

AR-91 **Instrument Review: Brookfield.** This article further describes use of a Brookfield HA torque range viscometer with Small Sample Adapter (SC4-13R chamber and SC4-27 spindle) for analyzing chocolates. Edward S. Seguine, Guittard Chocolate Co., The Manufacturing Confectioner, pp. 49-55, January 1986.

AR-99 **Application of the Casson Viscosity Method for Chocolate to the Brookfield Viscometer.** This paper provides the approved method for analyzing chocolate viscosity using the Brookfield HA torque range viscometer with the SC4-13R chamber and SC4-27 spindle. A Committee Report, January 1988 Issue of The Manufacturing Confectioner.

AR-106 **Controlling Viscosity in Dressings and Sauces.** The viscosity of dressings, sauces, and gravies significantly affects both the texture and mouth feel of the product and its processing. Scott Hegenbart, Food Product Design, Sept. 1995.

AR-109 **Viscosity Measurements of Barium Sulfate Mixtures for Use in Motility Studies of the Pharynx and Esophagus.** The non-Newtonian behavior of barium sulphate plus strawberry syrup mixtures is characterized using a Brookfield Viscometer with LV cylindrical spindles and a UL Adapter. Meijing Li, James G. Brasseur, Mark Kern and Wylie J. Dodds (1992).

AR-117 **Texture Testing Protocols Transfer into the Commercial Environment.** Textural parameters including cohesiveness, springiness and hardness are defined and explained pertaining to breadcrumb quality. Jon Hellyer, European Food Scientist, December 2002.

AR-120 **Quality Testing with Instrumental Texture Analysis in Food Manufacturing.** A description of a flexible texture analysis system which objectively assesses core attributes of food products. Jon Hellyer, LabPlus International, September 2004.

AR-122 **Gelatin Testing - A Starting Point for Food Texture Analysis.** The well-established Bloom Test is described in detail for assessing the textural properties of gelatin. Industria Alimenticia, Jon Hellyer and Robert G. McGregor (Available in English and Spanish), October, 2003.

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HIGH TEMPERATURE

AR-27 **Improved Apparatus for Rapid Measurement of Viscosity of Glass at High Temperatures.** A custom designed platinum alloy spindle is used with a Brookfield Viscometer to measure molten glass viscosities from 6.5 to 13,000 Poise. Ralph L. Tiede, as presented at the Sixty-First Annual Meeting, The American Ceramic Society, 1959.

AR-54 **Viscosity and Structure of Industrial High TiO2 Slags.** An apparatus using a Brookfield Viscometer with a custom-made spindle is described for analyzing the viscosity of molten slags at high temperatures. G. Handfield and G. G. Charette, Canadian Metallurgical Quarterly, Volume 10, No. 3, 1971.

AR-56 **Titanium Bearing Ore and Blast Furnace Slag Viscosity.** TiO2 additions to industrial blast furnace slag cause a decrease in the slag viscosity. G. Handfield, G. G. Charette, and H. Y. Lee, Journal of Metals, September 1972.

AR-58 **Viscosity of Industrial Titania Slags.** Completely molten high concentration TiO2 slags are very fluid melts characterized by high crystallization. G. Handfield, G. G. Charette, and H. Y. Lee. March 1971.

Related ASTM Test Methods (see page 17 for description)
C965

OIL/GAS DRILLING

AR-87 **Evaluation of Frac Fluid Stability Using a Heated, Pressurized Flow Loop.** Tests showed that cross-linked frac fluids degrade with temperature and shear, losing much of their viscosity and proppant-carrying capacity in a few hours. J. A. Lescarboura et. al, SPE 10962, September 26-29, 1982.

AR-110 **Rheologically Enhanced Xanthan System Replaces Invert Emulsion.** The true suspension and carrying capacity of a drilling fluid is best evaluated using low shear rate viscosity (LSRV) measurements. Domingo Rastrilla, Mexpetrol, Argentina, S. A., Johnny Peña and J. Mac Seheult, Kelko Oil Field Group, Hart's Petroleum Engineering International pp. 53-57, October 1997.

AR-124 **Development and Real-Time Monitoring of the Rheological Properties of Frac Fluids.** The importance of LSRV measurements with rotational viscometers and on-line viscosity measurement with the Brookfield TT-100 are described for fracturing fluids used in the oil drilling industry. Charles Wesley, Petro Industry News, June/July, 2004.

OIL/PETROLEUM

AR-116 **Viscosity Pressure Drop Correlation Study in Pipeline Transporting Waxy Crude.** Crude oil viscosity governs pressure drop in a pipeline. Brookfield and Fann viscosity data are compared and used in predicting pressure drops in Oil India Ltd.'s pipeline. S. Sinha, M.C. Nihalani and H. Dubey, as presented at Petrotech-2001. the 4th International Petroleum Conference and Exhibition, New Delhi, India, January, 2001.

AR-119 **Viscosity and Petroleum Products.** Various methods to test petroleum viscosity are described, including flow cups, capillary tubes and rotational viscometers. Viscosity vs. temperature profiling is also discussed. Robert G. McGregor, Brookfield Engineering Laboratories, Inc.

AR-125 **Determining the Low Temperature Properties of Grease with a Brookfield Viscometer.** Ten different greases are evaluated for viscosity behavior at low temperature (-40°C) using a DV-III Rheometer with Helipath Stand and T-bar spindles. Paul A. Bessette, Technical Director, Engineered Custom Lubricants, Plymouth, Michigan, USA, ELGI Annual Meeting, Nice, France, May 16-18, 2004.

Related ASTM Test Methods (see page 17 for description)
D2983, D5133, D6080*, D6895*

PAINTS, INKS & COATINGS

AR-18 **Modified Proteins for Stabilizing Latex Paints.** Casein modified with an enzyme, ammonia or a reducing agent permits formulation of latex paints with good viscosity stability. Ronai and Weisberg, Industrial and Engineering Chemistry, April 1954.

AR-25 **Thixotropic Properties of Paints.** With thixotropic paints, viscosity diminishes with agitation and increases again upon standing. Desirable thixotropic behavior enables good leveling. Dr. J. Rinse, Paint and Varnish Production, July 1958.

AR-28 **Measurement of Rheological Properties.** Various methods for measuring paint viscosity are reviewed: Moving Fluid - flow cups, capillary tubes; Moving Element - falling ball/cylinder; Rotating Element - rotational viscometer. Donald W. Brookfield, as presented at the Annual Meeting of the Federation of Societies for Paint Technology, November 1960.

AR-34 **Thixotropy – Its Effects on Press Performance.** Thixotropy, the reversible flow condition whereby an ink will flow under agitation and recover its original physical structure at rest, is best measured using a rotational viscometer. A. E. Price, Flexography, August 1963.

AR-43 **A New Method for the Viscosity Measurement of Paint in the Settling, Sagging, Leveling and Penetration Shear Rate Range of .001 to 1.0 Reciprocal Seconds Using a Cone/Plate Spring Relaxation Technique.** A relatively inexpensive and routine method for developing precise shear stress, shear rate and viscosity data in the ultra-low shear rate region is presented. Temple C. Patton, Journal of Paint Technology, November 1966.

AR-47 **Measurement of Rheology of Thixotropic Organic Coatings and Resins with the Brookfield Viscometer.** A method for measuring the viscosity of pseudoplastic and thixotropic coatings is described for development & quality control laboratories. Percy E. Pierce, Journal of Paint Technology, June 1971.

AR- 48 **Hydrophilic Clay Gellant.** Evaluating rheological properties of aqueous coatings through laboratory testing with the Viscosity Profile Concept (viscosity vs. shear rate flow curves) serves as an indicator of in-field performance. S. L. Davidson and C. J. Eichhorn, Paint and Varnish Production, July 1971.

AR-59 **Viscosity Profiles of Solvent Based Paints: Their Measurement and Interpretation.** Single data point viscosity measurements are proven meaningless in determining rheological and application properties of paint. Arthur Ehrlich, Temple C. Patton and Armando Franco, Journal of Paint Technology, Volume 45, No. 576, January 1973.

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Related ASTM Test Methods (see page 17 for description)
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D1439, D2364

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C1276, D789, D3468, D4878*, D4889

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ASTM test methods are available from:

ASTM International
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C965 Practices for Measuring Viscosity of Glass Above the Softening Point
C1276 Standard Test Method for Measuring the Viscosity of Mold Powders Above their Melting Point Using a Rotational Viscometer.
D115 Methods of Testing Varnishes Used for Electrical Insulation
D562 Standard Test Method for Consistency of Paints Using the Stormer Viscometer
D789 Test Methods for Determination of Relative Viscosity, Melting Point, and Moisture Content of Polyamide (PA)
D803* Test Methods for Testing Tall Oil
D1074* Test Method for Compressive Strength of Bituminous Mixtures
D1076 Specification for Rubber-Concentrated, Ammonia Preserved, Creamed and Centrifuged Natural Latex
D1084 Test Methods for Viscosity of Adhesives
D1337* Test Method for Storage Life of Adhesives by Consistency and Bond Strength
D1338* Practice for Working Life of Liquid or Paste Adhesives by Consistency and Bond Strength
D1417 Methods of Testing Rubber Latices-Synthetic
D1439 Methods of Testing Sodium Carboxymethyl-cellulose
D1824 Test Method for Apparent Viscosity of Plastisols and Organosols at Low Shear Rates by Brookfield Viscometer
D1986* Test Method for Determining the Apparent Viscosity of Polyethylene Wax Brookfield Viscometer
D2196 Test Methods for Rheological Properties on Non-Newtonian Materials by Rotational (Brookfield) Viscometer
D2243* Test Method for Freeze-Thaw Resistance of Waterborne Coatings
D2336* Guide for Specifying Factory Applied Wood Coatings
D2364 Standard Methods of Testing Hydroxyethyl-cellulose
D2556 Test Method for Apparent Viscosity of Adhesives Having Shear Rate Dependent Flow Properties
D2669 Test Method for Apparent Viscosity of Petroleum Waxes Compounded with Additives (Hot Melts)
D2983 Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by the Brookfield Viscometer
D3236 Test Method for Apparent Viscosity of Hot Melt Adhesives and Coating Materials
D3468 Standard Specification for Liquid-Applied Neoprene and Chlorosulfonated Polyethylene Used in Roofing and Waterproofing
D3716 Method of Testing Emulsion Polymers for Use in Floor Polishes
D3730* Guide for Testing High-Performance Interior Architectural Wall Coatings.
D3791 Standard Practice for Evaluating the Effects of Heat on Asphalts
D 3794* Guide for Testing Coil Coatings
D 3806* Test Method for Small-Scale Evaluation of Fire-Retardant Paints (2-ft Tunnel Method)
D4016 Test Method for Viscosity of Chemical Grouts by the Brookfield Viscometer (Laboratory Method)
D4143* Guide for Testing Latex Vehicles
D4212* Guide for Testing Epoxy Resins
D4280* Specification for Extended Life Type, Nonplowable, Prismatic, Raised, Retroreflective Pavement Markers
D4368* Guide for Testing Poly(Vinyl Chloride) Resins
D4400* Test Methods for Sag Resistance of Paints Using a Multinotch Applicator
D4402 Standard Method for Viscosity Determinations of Unfilled Asphalts Using the Brookfield Thermosel Apparatus
D4712* Guide for Testing of Industrial Water-Reducible Coatings
D4800* Guide for Classifying and Specifying Adhesives
D4878* Test Methods for Polyurethane Raw Materials: Determination of Viscosity of Polyols
D4889 Standard Test Methods for Polyurethane Raw Materials: Determination of Viscosity of Crude or Modified Isocyanates
D5018 Standard Test Method for Shear Viscosity of Coal-Tar and Petroleum Pitches
D5133 Standard Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature-Scanning Technique
D5146* Guide to Testing Solvent-Borne Architectural Coatings
D5324* Guide to Testing Water-Borne Architectural Coatings
D5400* Test Methods for Hydroxypropylcellulose
D6080* Practice for Defining the Viscosity Characteristics of Hydraulic Fluids
D6083* Specification for Liquid Applied Acrylic Coating Used in Roofing
D6267* Specification for Asphaltic Plug Joints for Bridges
D6373* Specification for Performance Graded Asphalt Binder
D6577* Guide for Testing Industrial Protective Coatings
D6895* Standard Test Method for Rotational Viscosity of Heavy Duty Diesel Drain Oils at 100°C

*These test methods may be purchased from ASTM (see page 16).

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