

I/EC Briefs

The why, what, and significance of technical articles in this issue. Clip these Briefs for ready reference and easy filing on a 3 X 5 or other suitable card

Ind. Eng. Chem. 48, 1803 (1956)

Granulated Triple Superphosphate

Production of triple superphosphate in the United States last year exceeded 1,500,000 tons. The major portion of this production came from the State of Florida. And near Bartow, Fla., Davison Chemical Co. has built a modern plant producing, directly, a granulated triple superphosphate by a continuous process. In that respect, it is a unique plant in this country. Design capacity of the Bartow plant is 200,000 tons annually.

Phosphate rock from nearby Davison mines is treated with sulfuric acid to produce phosphoric acid. The phosphoric acid, in turn, reacts with additional phosphate rock under specially controlled conditions to form triple superphosphate. No additional curing is required; only a brief cooling period is necessary before the concentrated fertilizer product is ready for shipment.

GORDON C. INSKEEP, WILLIAM R. FORT, and
WILLIAM C. WEBER

Ind. Eng. Chem. 48, 1817 (1956)

Efficiencies of Mixing Tanks in Smoothing Concentration Fluctuations

Equations and plots are given for calculating the efficiency of a tank with perfect mixing in order to reduce sinusoidal concentration fluctuations, such as would be introduced by an automatic controller. Tank efficiency is defined as the relative reduction in magnitude of the fluctuations. The equations and plots given can be used to estimate the size of a new mixing tank, as well as to determine the efficiency of agitation in an existing tank by comparing the measured tank efficiency with the theoretical efficiency if the tank had perfect mixing.

EDGAR B. GUTOFF
Brown Co., Berlin, N. H.

Ind. Eng. Chem. 48, 1819 (1956)

Radiant Heating of Dispersed Particles

A theoretical analysis is presented of the temperature history of a dispersion of small spherical particles subjected to a radiant flux. The results have application in the ignition and combustion of powdered coal and atomized fuels, and in the attenuation of thermal radiation from a fire or a nuclear fireball. The temperature of nonvolatile particles rises rapidly to a pseudo-equilibrium value and finally rises more slowly as the finite amount of air associated with each particle is heated by conduction from the particle. The temperature difference within a particle is negligible at all times. Expressions are also derived for the rate of evaporation and for the effect of evaporation upon the temperature of volatile droplets.

Illustrative calculations are presented for dispersions of powdered coal, dodecane, and fog oil. A dispersion of absorbing particles is very efficient in transferring radiant energy to the surrounding air.

CHARLES A. SLEICHER, Jr., and STUART W. CHURCHILL
The University of Michigan, Ann Arbor, Mich.

Ind. Eng. Chem. 48, 1825 (1956)

Plug Flow and Lubrication of Polymer Particles

A knowledge of the pressure transmitted through a bed of particles is of importance in the fabrication of high polymers. The only available data are for a static bed, and little is known about the effect of many variables that are met in practice.

The pressure transmitted through a moving bed of unlubricated polystyrene particles is given as a function of pressure, bed length, particle size, and velocity. The results are similar to those obtained by Spencer and co-workers for a static bed, but the apparent coefficient of friction is lower. The addition of a lubricant to the particle surfaces may either increase or decrease the transmitted pressure, depending upon the specific conditions. A theory is proposed which explains most of the results in terms of a buildup of a lubricating film on the wall and a varying force relationship inside the bed.

H. L. TOOR and S. D. EAGLETON
Monsanto Chemicals, Ltd., Fulmer Hall, Fulmer Bucks, England

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Ind. Eng. Chem. 48, 1831 (1956)

Oxidation of alpha-Pinene

Pinic acid esters have potential uses as lubricants and plasticizers. Pinic acid is now prepared from pinonic acid produced by the permanganate oxidation of α -pinene. Its preparation by ozonolysis of α -pinene also has been studied.

A series of screening experiments employing peroxides and nitrogen-containing oxidants for the conversion of α -pinene to pinic and pinonic acids, and some further experiments using hydrogen peroxide with and without catalysts are described.

While some of the vapor-phase reactions with the nitrogen-containing oxidants were of interest and might warrant further investigation, the results of the screening tests indicated that hydrogen peroxide was the most promising oxidant of those tested. However, while pinic and pinonic acids are formed, the yields are generally low, and complex mixtures of acids are obtained.

NATHAN SUGARMAN and PHILLIP M. DAUGHERTY
Engineering Experiment Station,
Georgia Institute of Technology, Atlanta, Ga.

Ind. Eng. Chem. 48, 1836 (1956)

Heat Transfer Rates for Cross Flow of Water through a Tube Bank at Reynolds Numbers up to a Million

Heat transfer coefficients have been obtained at high Reynolds numbers for cross flow of high temperature, high pressure water through a bank of 200 tubes, 0.810 inch o.d. and spaced on an equilateral triangular grid $1\frac{1}{2}$ inches between centers. In the range investigated, the coefficients were considerably greater than those predicted by extrapolation of the Colburn equation. In the Reynolds number range 10^5 to 10^6 , the coefficient varies approximately as the 0.8 power of the Reynolds number instead of 0.6, as indicated by the Colburn equation.

The effects of pressure, heat flux, and flow rate on the inception of nucleate boiling and on the heat transfer rate in the transition stage between nonboiling and full surface boiling were studied. Pressure drop results were consistent with data obtained at lower Reynolds numbers.

O. E. DWYER, T. V. SHEEHAN, JOEL WEISMAN, F. L. HORN
Brookhaven National Laboratory, Upton, Long Island, N. Y.
R. T. SCHOMER, Gibbs and Cox Co., New York, N. Y.

Ind. Eng. Chem. 48, 1847 (1956)

Radioactivity in Stream Pollution

The manufacture of fissionable materials, increasing peacetime uses for atomic energy products, and projected development of nuclear power facilities introduce new problems into the field of environmental sanitation. One of these problems, of direct concern to many state and local health departments and to others, is the possible contamination of surface streams.

This article, based on studies by the U. S. Public Health Service, discusses the effects of low-level radioactive effluents on physical, chemical, and biological characteristics of surface waters along with techniques used to approach and define this type of problem.

R. C. PALANGE, G. G. ROBECK, and C. HENDERSON
Robert A. Taft Sanitary Engineering Center, U. S. Public Health Service, Cincinnati, Ohio

ADDITIVES IN FUELS

Ind. Eng. Chem. 48, 1853 (1956)

Fuel Additives—Problems and Progress

The use of fuel additives is growing in scope and complexity. Nine different kinds of gasoline additives are in commercial use, at a volume of some \$300,000,000 a year. In heavier fuels, the usage is small at present but is increasing rapidly. Borderline additives of dubious merit have long been on the market. A review of the field shows areas where more basic knowledge will aid development. Problems in research and testing also arise from the complexity of fuels themselves and from the variety of conditions under which they are stored and used. Examples show the unexpected results often found in tests of additives. Means to overcome some of these difficulties are suggested. Many needs for improvements are already evident, and new needs will appear.

GRAHAM EDGAR and H. A. BEATTY
Ethyl Corp., Detroit, Mich.

Ind. Eng. Chem. 48, 1858 (1956)

Effect of Boron Compounds on Combustion Processes

The presence of a boron compound in gasolines modifies the combustion characteristics during the preflame period and also the combustion zone deposits in reciprocating engines. These effects may explain the improved performance of these engines, particularly with gasoline containing the all-bromide tetraethyllead mix along with the boron compound.

Surface ignition frequency is reduced as observed by several techniques. The F-1 octane number of the gasoline is increased by the boron compound. The combustion zone deposits, particularly in the valve areas, are lowered, and exhaust valve life is substantially improved.

E. C. HUGHES, P. S. FAY, L. S. SZABO, and R. C. TUPA
The Standard Oil Co. (Ohio), Cleveland, Ohio

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Ind. Eng. Chem. 48, 1863 (1956)

Influence of Diborane on Flame Speed of Propane-Air Mixtures

A substance was sought which would accelerate hydrocarbon combustion significantly when present in the flame in relatively small amounts.

Additive amounts of diborane, that is less than 5 volume % of the fuel, produced no significant increases in the flame speeds of propane-air mixtures. When diborane was present in larger amounts as a secondary fuel, substantial increases in flame speed were achieved especially with rich mixtures.

It appears that diborane burns preferentially in rich mixtures and that propane inhibits the combustion reaction between diborane and air when diborane is present in small relative proportions in the mixed fuel in both lean and rich mixtures.

PHILIP F. KURZ
Battelle Memorial Institute, Columbus 1, Ohio

Ind. Eng. Chem. 48, 1869 (1956)

Evaluation of Alkylated *p*-(*p*-Nitrophenylazo)anilines as Gasoline Dyes

In a program of developing dyes of high tinctorial strength for gasoline, a series of alkylated *p*-(*p*-nitrophenylazo)anilines was compared with currently used yellow and orange gasoline dyes.

Alkyl substituents on the ring and on the anilino nitrogen had pronounced effects on dye color and tinctorial strength. Yellow dyes, having tinctorial strengths varying from 32 to 455% of the yellow standard, were found in the *N*-alkyl-*p*-(*p*-nitrophenylazo)aniline series as the alkyl group increased from methyl to butyl. Orange dyes having about twice the coloring power of the orange standard were obtained in the *N,N*-diethyl-*p*-(*p*-nitrophenylazo)aniline series when the alkyl substituents were larger than methyl. Some of the test dyes may have application in coloring various hydrocarbons because unusually low concentrations are required.

J. W. THOMPSON and F. E. JOHNSON
Tennessee Eastman Co., Division of
Eastman Kodak Co., Kingsport, Tenn.

Ind. Eng. Chem. 48, 1874 (1956)

Effect of Alkyl Phenols on Storage and Manifold Stability of Gasolines

A glass manifold test has been developed which correlates very well with the heated manifold engine test in comparing gasolines and inhibitors. The simple induction period test has been criticized as lacking predictive value. The induction period method is reliable for comparing closely related alkyl phenols in a gasoline, but not for comparing an alkyl phenol with a phenylenediamine inhibitor, which has a more pronounced effect on induction period than on other properties. A good alkyl phenol inhibitor, 2,6-di-*tert*-4-methoxyphenol (26B4M), appears better than the phenylenediamine type for both manifold and storage stability.

The need for antioxidants in gasoline is emphasized by data indicating that the equilibrium octane requirement of a Lauson engine is increased on the average by one octane number for 1 mg. per dl. of ASTM gum in the gasoline.

A. C. NIXON, H. B. MINOR, and G. M. CALHOUN
Shell Development Co., Emeryville, Calif.

Ind. Eng. Chem. 48, 1881 (1956)

Mechanism of Antioxidant Action in Gasoline

The various hypotheses on the mechanism of antioxidant action are considered in the light of experimental evidence obtained with antioxidants in cracked gasoline. The efficiencies of derivatives of *p*-phenylenediamine, *p*-aminophenol, and phenol, are discussed in connection with their structures. It is concluded that antioxidants inhibit the autoxidation of gasoline by several mechanisms, depending on their structure—by donating an electron to the chain-carrying peroxy free radical, by donating a hydrogen atom to the peroxy radical, by adding a peroxy radical before or after being partially oxidized, and by some other methods yet undetermined which possibly do not involve the peroxy radical.

C. J. PEDERSEN

Jackson Laboratory, E. I. du Pont de Nemours & Co., Inc.,
Wilmington, Del.

Ind. Eng. Chem. 48, 1885 (1956)

Evaluating Distillate Fuel Oil Additives: Storage Tests

Although distillate fuels containing unstable cracked stocks tend to deposit gums during storage, these fuels can be stabilized effectively with additives. Because additives are often specific in their effectiveness for stabilizing fuels, reliable test methods are essential for predicting this specificity.

Two methods are presented for evaluating additives—an accelerated aging test involving storage of the fuel sample for 4 weeks at 140° F. and a full scale pumping test carried out at ambient temperature for several months. Using these tests, a number of commercially available additives were evaluated in several base oils. Some of the additives were remarkably effective in preventing the formation of insoluble gum during storage, but none of the additives was consistently superior.

L. H. DIMPFEL, J. E. GOODRICH, and R. A. STAYNER
California Research Corp., Richmond, Calif.

Ind. Eng. Chem. 48, 1882 (1956)

Evaluating Distillate Fuel Oil Additives: Stability Tests

The use of dispersants and stabilizing additives in the production of high quality heating fuels has become widespread. To make a suitable selection of additives, laboratory tests must be used which truly reflect field performance. The evaluation methods presented enable the determination of the stability and antiscreen clogging properties of the fuel. Also included are methods designed to reveal any disadvantages an additive may impart.

Results of this evaluation are given for several commercial additives. In most cases, a direct connection can be shown between these results and field performance.

F. L. NELSON, D. P. OSTERHOUT, and W. R. SCHWINDEMAN
Socony Mobil Oil Co., Inc., Paulsboro, N. J.

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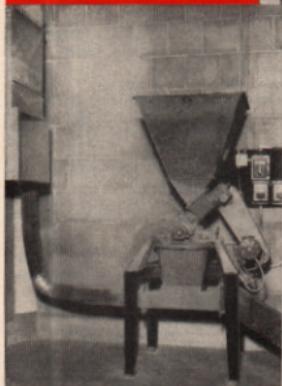
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Ind. Eng. Chem., 48, 1899 (1956)

Evaluating Distillate Fuel Oil Additives: Field Tests

Stability, detergency, and protection against rusting are the most important properties that additives impart to distillate fuels.

A study was made to determine whether any of the bench tests for additive evaluation is significant in terms of field test results. Appraisal can be made by a combination of two simple tests: accelerated aging followed by the ASTM filterability test, and a new static rust test. Further information can be learned from the interface deposit test and from observation of the adherent gum that deposits on accelerated aging of the fuel.

Use of these four tests has given valid predictions of the performance of additives in field tests involving both heating and Diesel fuels.

R. A. HUNT, Jr., T. B. TOM, and J. A. BOLT
Research Department, Standard Oil Co. (Indiana), Whiting, Ind.

Ind. Eng. Chem., 48, 1917 (1956)

Kinetic Studies of Petroleum Antioxidants

Antioxidant data in white mineral oil are interpreted to show:

Two classes of antioxidants are in common use as petroleum additives—*inhibitors* and *peroxide decomposers*. All inhibitors are a compromise between the sensitivity necessary to terminate oxidation chains, and the stability to withstand direct attack by oxygen. Screening tests that increase oxygen pressure overemphasize the direct attack by oxygen. Peroxide decomposers become relatively more effective than inhibitors as the treating concentration is raised. Combinations of peroxide decomposers and inhibitors show synergistic effects.

G. W. KENNERLY and W. L. PATTERSON, Jr.
Research Division, Stamford Laboratories,
American Cyanamid Co., Stamford, Conn.

Ind. Eng. Chem., 48, 1904 (1956)

Ignition Accelerators and Autoignition Environment

Ignition improvers are needed to upgrade the ignition quality of some Diesel fuels. The cetane-number improvement from use of these additives may be determined. This information alone does not give an adequate indication of the ignition-promoting effectiveness of the additives under different conditions of engine operation. This study was undertaken to obtain basic information on the response of several ignition-promoting materials to changes in fundamental pressure, temperature, and concentration conditions that prevail during the period of autoignition.

Results of the studies show how these fundamental variables influence the response of three fuels to treatment with each of four additives—*amyl nitrate*, *2,2-dinitropropane*, *ethyl-N-isopropyl-N-nitrocaramate*, and *di-tert-butyl peroxide*. These data to supplement engine cetane ratings and provide a basis for predicting the effect of ignition improver under abnormal temperature-pressure conditions.

R. W. HURN and K. J. HUGHES
Bureau of Mines Petroleum Experiment Station,
Barstowville, Okla.

Ind. Eng. Chem., 48, 1909 (1956)

Effect of Additives on Jet Fuel Stability and Filterability

The effect of commercial and experimental antioxidants, a metal deactivator, and various dispersants on ambient and high temperature (450° F.) stability of jet fuels has been examined. The specification (and an aminophenol) inhibitors are ineffective in prolonging storage life or decreasing high temperature fouling tendency. Ambient temperature filterability is improved by a trialkyl phenol.

Of about 250 compounds examined, only one has shown significant benefits as an ambient temperature antioxidant; it is only slightly effective against high temperature instability.

The metal deactivator is effective, at ambient temperatures, in eliminating the catalytic effect of soluble copper and copper-bearing steel but is not effective against copper surfaces. It is somewhat beneficial at high temperatures. Dispersants do not promote jet fuel stability but improve ambient and high temperature filterability.

A. C. NIXON and H. B. MINOR
Shell Development Co., Emeryville, Calif.

Ind. Eng. Chem., 48, 1925 (1956)

Evaluating Lubricating Oils Containing Additives

A laboratory test method for evaluating lubricating oils containing "heavy duty" additives was used to determine the response of five different oils to three different types of additives. The test findings compare favorably with results obtained from engine tests.

The investigations reported show that different oil types vary considerably in their response to additives and that not all additive types behave in the same way toward a particular oil. There was some correlation between additive response and the constitution of the oil, as determined by structural group analysis, with some additives, but with others response appeared to be a function of total sulfur content of the oil.

L. G. WOOD and HERBERT BUCHWALD
Manchester Oil Refinery Ltd., Manchester, England

Ind. Eng. Chem., 48, 1931 (1956)

Fireside Deposits in Oil-Fired Boilers

Fireside deposits and corrosion in oil-fired boilers reduce efficiency and cause premature failure of boiler parts.

A general pattern relating location of deposits and their chemical composition was developed to aid in treatments for deposit prevention. Fuel oil impurities, deposit locations, and analytical procedures are briefly reviewed. Methods of deposit formation are tabulated for each impurity and location in the boiler.

The hypothesis that the basic principle underlying fireside deposit formation and deposition in the various sections of the boiler according to a definite and predictable pattern is presented.

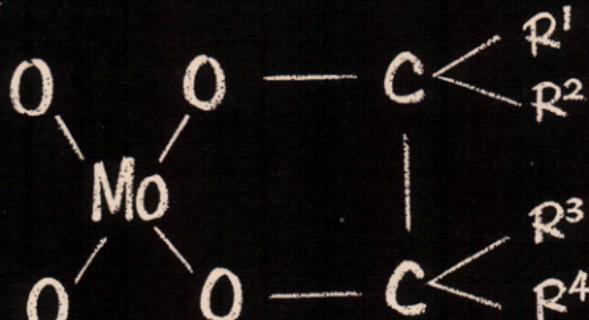
CLARENCE JACKLIN, DONALD R. ANDERSON, and
HARRIS THOMPSON
National Aluminite Corp., Chicago, Ill.

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Mo^{III} oxalates are non-ionic. Examples are the water-soluble $\text{Mo}_2\text{O}(\text{C}_2\text{O}_4)_2 \cdot 6\text{H}_2\text{O}$ and the insoluble $\text{Mo}_4\text{O}_5(\text{C}_2\text{O}_4)_2 \cdot 12\text{H}_2\text{O}$.

Mo^{IV} oxalates are both ionic and non-ionic. Ionic complexes of the type $\text{R}_2\text{Mo}_3\text{O}_6(\text{C}_2\text{O}_4)_3 \cdot 2\text{H}_2\text{O}$ are strong reducing agents. They are red in acid solution, blue in alkaline. Among non-ionic complexes are the purple $\text{Mo}_5\text{O}_6(\text{C}_2\text{O}_4)_4$ and the brown $\text{Mo}_4\text{O}_5(\text{C}_2\text{O}_4)_3 \cdot 10\text{H}_2\text{O}$, both soluble in water but insoluble in organic solvents.

Mo^V oxalates are highly colored. Salts of the type $\text{RMoO}_5(\text{C}_2\text{O}_4)_2 \cdot \text{H}_2\text{O}$ are red in concentrated water solution, but turn yellow on dilution. Mineral acids convert them to other highly colored compounds; for example HCl yields green complexes of the type $\text{R}_2[\text{MoOCl}_4]$. Other Mo^V complexes include the orange $(\text{C}_6\text{H}_5\text{NH})\text{MoO}_5(\text{C}_2\text{O}_4)_4 \cdot 6\text{H}_2\text{O}$, the red $\text{KMoO}_5(\text{C}_2\text{O}_4)_2 \cdot \text{H}_2\text{O}$, and the yellow $(\text{C}_6\text{H}_5\text{NH})\text{MoO}_5(\text{C}_2\text{O}_4)_2 \cdot \text{H}_2\text{O}$ and $\text{Mo}_2\text{O}_5(\text{C}_2\text{O}_4)_2 \cdot 4\text{H}_2\text{O}$.

Mo^{VI} oxalates are water soluble, but their amine salts are not. These complexes are apparently ionic.

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Ind. Eng. Chem. 48, 1956 (1956)

Ind. Eng. Chem. 48, 1935 (1956)

Separation of Aryl Sulfonic Acids

Sulfonic acids show retrograde solubility in aqueous sulfuric acid. In this work the solubilities of *p*-toluenesulfonic acid, *p*-xylene sulfonic acid, and a technical mixture of sulfonic acids from straight-run petroleum naphtha in 0 to 85% sulfuric acid have been determined for different temperatures. The quantitative data are presented in the form of triangular phase diagrams from which the conditions for the separation of sulfonic acids from the sulfonating acid can be read.

For the sulfonic acids studied, the region of optimum separation corresponds to a spent acid composition of 65% sulfuric acid and 35% water. The availability of these data will make possible more precise control during the spent acid separation step in the manufacture of these and closely related sulfonates.

HANS FEILCHENFELD

Research Council of Israel, P.O.B. 5192, Jerusalem, Israel

Ind. Eng. Chem. 48, 1938 (1956)

Difunctional Acids by Petroleum Hydrocarbon Oxidation

A mixture of difunctional acids can be produced inexpensively by the catalytic oxidation of petroleum hydrocarbons in the liquid phase. As a result of a study of the reaction variables and of optimum experimental conditions, higher oxidative conversions can be obtained than have been heretofore reported.

A preliminary report on the composition of the oxidation products and a suggested mechanism for their formation is given.

The primary oxidation product obtained in the laboratory as well as in a pilot plant shows promise in such applications as alkyl resins, polyesters, plasticizers, and other uses requiring a difunctional molecule.

C. N. ZELLNER and FRED LISTER

Research and Development Department,
Tide Water Associated Oil Co., New York, N. Y.

Ind. Eng. Chem. 48, 1949 (1956)

Reduction of Bismuth Chloride by Stannous Chloride

Polonium-210, a useful alpha-emitter of 138-day half life, can be produced by the neutron irradiation of bismuth. It is readily reduced to the metal by stannous chloride, and its separation from bismuth is feasible if the reduction is carried out under conditions in which bismuth chloride is not also reduced.

To determine these conditions, the equilibrium between bismuth chloride and stannous chloride has been studied at various temperatures and chloride concentrations.

The reduction of bismuth is shown to be favored by low chloride concentration, high bismuth concentration, and low temperature. A wide range of conditions is available for the separation of polonium from neutron-irradiated bismuth.

H. W. KIRBY, G. D. NELSON, and J. H. PAYNE, Jr.
Mound Laboratory, Monsanto Chemical Co., Miamisburg, Ohio

Flame- and Heat-Resistant Epoxy Resins

The Diels-Alder adduct of maleic anhydride with hexachlorocyclopentadiene [$1,4,5,6,7,7'$ -hexachlorobicyclo-(2.2.1.)-5-heptene-2,3-dicarboxylic anhydride] is an effective hardener for epoxy resins. The rate of hardening is rapid and the cured resins are characterized by unusually high thermal yield points as well as fire resistance.

The above named adduct, used as a hardener with a liquid epoxy resin such as Araldite 6020 or Epon 828, gives optimum thermal yield points when present in amounts of approximately 34% by weight. The thermal yield points increased within the range of 50 to 57% of the adduct anhydride by weight, with increasing cure temperatures and cure time. Curing at 180° C. produced castings which gave ASTM D 648-45T heat distortion temperatures in the vicinity of 200° C. and glass cloth laminates which retained about 80% of the flexural strength and stiffness at 177° C.

P. ROBITSCHEK and S. J. NELSON

Hooker Electrochemical Co., Niagara Falls, N. Y.

Ind. Eng. Chem. 48, 1954 (1956)

Solubility Phenomena in Dilute Solutions of Alkyd Resins

Properties of alkyd resin paint vehicles are altered by manufacturing procedures. Controlling reproducible reaction cycles is difficult; improved methods are needed for detecting variations between different lots of resins.

Intrinsic viscosity and light scattering measurements were made on solutions of linseed-glycerol, soyapentaerythritol and coconut-glycerol types of phthalic alkyds. Linear correlations were found between intrinsic viscosity, viscosity of the undiluted alkyd vehicle, acid value, and the stroke cure time. For the nine alkyds studied, a modified Staudinger type of equation correlates the intrinsic viscosity with apparent light-scattering molecular weight, where the empirical constants are dependent on diluting solvents. The viscosity and molecular weight relations provide a sensitive differentiation of the solubility characteristics which influence other paint formulation properties of the alkyd vehicles.

EDWARD G. BOBALEK, ROBERT L. SAVAGE, and
MILTON C. SCHROEDER

Case Institute of Technology, Cleveland, Ohio

Ind. Eng. Chem. 48, 1960 (1956)

Vapor Pressure of Phosphoric Acid at High Temperature and Pressure

In industrial applications of heterogeneous catalysts, the type of equilibrium between the reactants and catalyst and the temperature-pressure dependence of that equilibrium determine reactor performance. A method for measuring such equilibria is given and illustrated by data for a phosphoric acid on Celite catalyst at 300° C. under steam pressures up to 1300 pounds/square inch absolute. The data show that this catalyst, used for polymerization and hydration of olefins, is essentially a solution of phosphoric acid on the support. The equilibrium form at low partial pressures of water is metaphosphoric acid.

The method could also be used to measure the absorption of reactants on other types of catalysts such as are used for cracking and hydrogenation. By using an inert gas, the apparent surface area under operating conditions can be studied.

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