

FEBRUARY, 1961

APR 12 1961 *Dr. Bennett*

# The Research Engineer

Published by the Georgia Tech Engineering Experiment Station



INDUSTRIAL PRODUCTS  
FROM SOYBEAN MILK

Industrial Products Series

# RESEARCH ENGINEER

VOLUME 16, NO. 1

FEBRUARY, 1961

Published five times a year by the Engineering Experiment Station  
Georgia Institute of Technology, Atlanta, Georgia

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The cover photo shows Herb Burrows in an Industrial Products Laboratory separating oil and protein which has been taken from soybean milk, a chemical source. For more about industrial products see pages 10, 15, 19.

**the cover**

Cover Photo by Van Toole

THE RESEARCH ENGINEER is published five times a year in February, April, June, October and December by the Engineering Experiment Station, Georgia Institute of Technology. Second-class postage paid at Atlanta, Georgia.

## The President's Page

PROJECTING the proper image of any large organization into minds of the people who make up its various publics is at its best a delicate task. In the case of a university, this problem is magnified by the number and diversity of its publics.

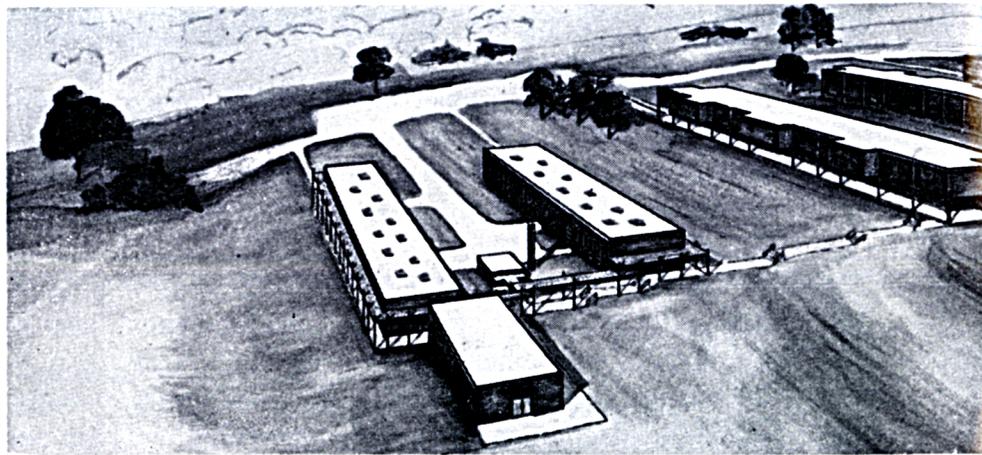
Take the case of Georgia Tech. Here, we have a large, nationally-known, tax supported, technological institution located in the heart of a metropolitan area. Its publics include students, faculty, alumni, taxpayers, parents, state officials, the Legislature, the governing body (in our case the Board of Regents of the University System), the City of Atlanta, the scientific public, the athletic public, industry, foundations, the national general public, and others too numerous to mention.

Each of these publics has a slightly different image of Georgia Tech. The students and faculty see it as it affects their day-to-day existence . . . the alumni like to think of it as it was when they were students . . . the taxpayer looks at it as a custodian of his money and his hopes . . . industry looks to it for its educational and research products. Every one of these publics views the institution from a relatively selfish standpoint, just as you and I do.

But, in the short time that I have worked on this campus, I have acquired the feeling that few of these publics see the real image of Georgia Tech. Most of them seem to regard it more with awe than with understanding. Admittedly, a large number of corporations and even some universities envy us this position—it is almost the ideal “corporate image” of Madison Avenue fame. Yet, with a tax-supported institution, the *understanding*, at least to me, is much more important than the awe.

One of the major functions of *The Research Engineer* is to project the image of research at Georgia Tech. I trust that the magazine is meeting this test.

*E. D. Harrison* President



A photograph of rendering for new Southern Technical Institute to be in Marietta, Ga.

**ROBERT W. HAYS, SOUTHERN TECH ENGLISH PROFESSOR, PRESENTS THE MOST RECENT NEWS ABOUT THE STATE'S MAJOR SOURCE OF NEEDED TECHNICIANS . . . . .**

## Southern

This fall—Southern Technical Institute—a unit of Georgia Tech's Engineering Extension Division will be moving, laboratory and classroom, to a new location in Marietta, Georgia.

When Southern Tech opened in March of 1948, the best available site was the Naval Air Station in Chamblee. Georgia had no institution of higher learning to train technicians. Expediency dictated that the institute should begin operation as quickly as possible. Post-war cuts in military establishments had made part of the Naval Station available; The Technical Institute (as Southern Tech was originally named) moved in.

In the past thirteen years, Southern Tech has grown in enrollment, faculty, and curricula. The first quarter 116

students enrolled; enrollment for 1960-1961 was about 800. Southern Tech alumni now number 2,233, and the faculty has grown from the first two instructors, to a present faculty of 54. The curricula have grown from the first two courses planned, drawing and physics, to eleven programs leading to the Associate in Science degree. Southern Tech now occupies thirteen buildings at Chamblee.

The much-needed new campus will consist of a plot of approximately 120 acres, located in Marietta one block west of U. S. Highway 41 North. Eight buildings are now under construction. About 166 thousand square feet of floor space will be constructed, of concrete, steel, and partial brick facing. Construction has been under-

## Technical Institute

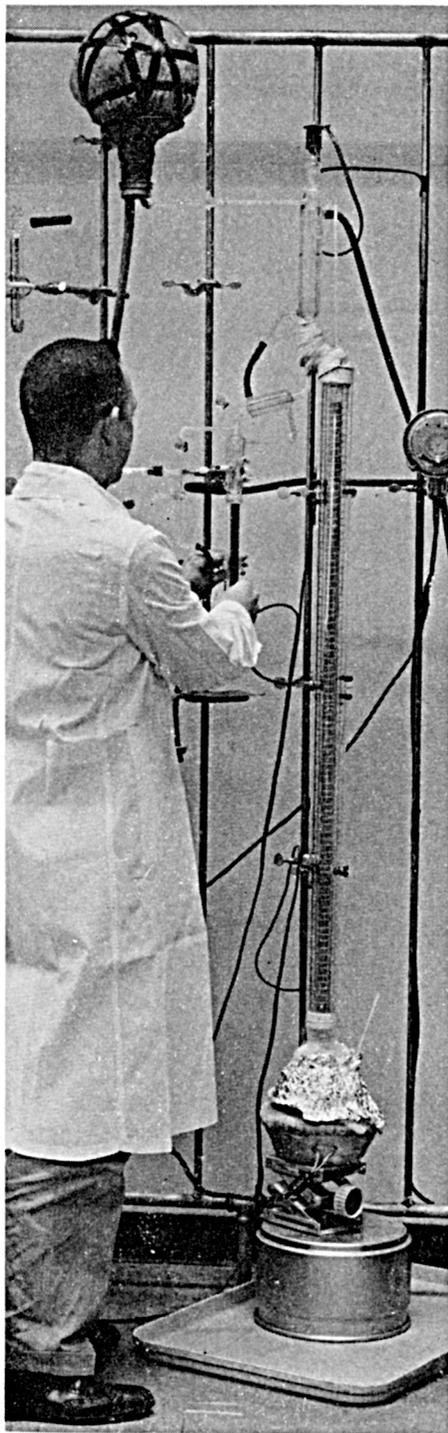
way now for about a year, and is about sixty percent complete.

Much of Southern Tech's present equipment will also serve in the new campus. During its first decade-plus, the technical institute obtained equipment from industry, War Assets surplus sales, and Georgia Tech. The Southern Tech administration plans to continue using its shop and laboratory apparatus.

Since its inception, Southern Tech has enjoyed support from a variety of sources, and the new campus is another example of this diversified aid. The Regents of the University System received an initial allocation, from the governor, of \$2 million for construction. The Regents later authorized the purchase of approximately thirty-three

acres of land for Southern Tech's new campus.

The original site of about 90 acres was provided by Cobb County, and Marietta and Cobb County also pledged water mains, fire plugs, recreational facilities, grading and paving of streets and parking lots, paving of sidewalks and curbs and gutters. A Cobb County Campus Committee has worked with Georgia Tech and Southern Tech officials and with the architects since spring, 1958, in planning the fullest use of city and county facilities. This committee includes representatives of the Marietta and Cobb County governments, news media, and civic clubs. The total value of land, improvements and facilities to be provided by Marietta and Cobb County has been estimated at a value of \$350,000.



Photos credited to Van Toole

## Looking at Georgia Tech's RADIOISOTOPES LABORATORY

Dr. Fred Sicilio, Head  
Radioisotopes Laboratory

At the new Georgia Tech Radioisotopes Laboratory, academic and research programs receive equal emphasis.

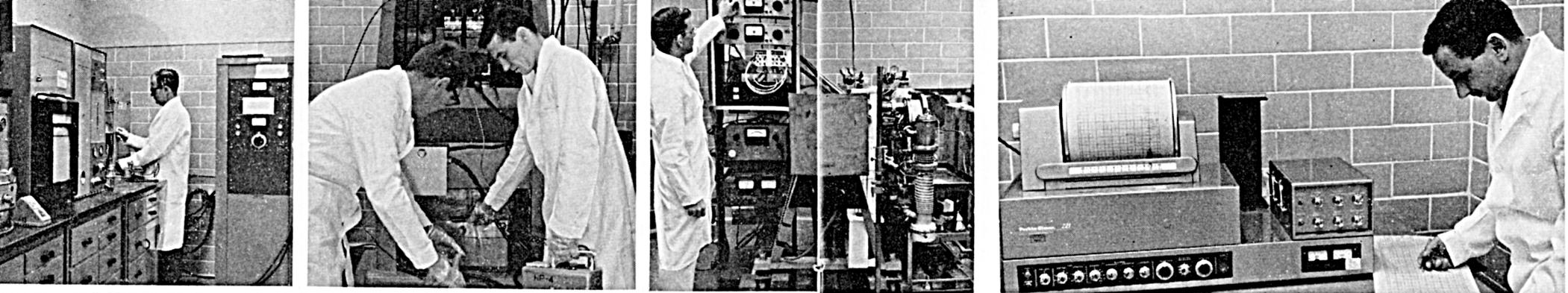
Teachers from the schools on Tech's campus and research personnel have a common interest in one or more of the several phases of nuclear science and engineering. Interest in specialized research is mutually beneficial to the teacher and the student. For example, many items of equipment are too expensive, in initial procurement cost and maintenance, to be considered only for educational purposes.



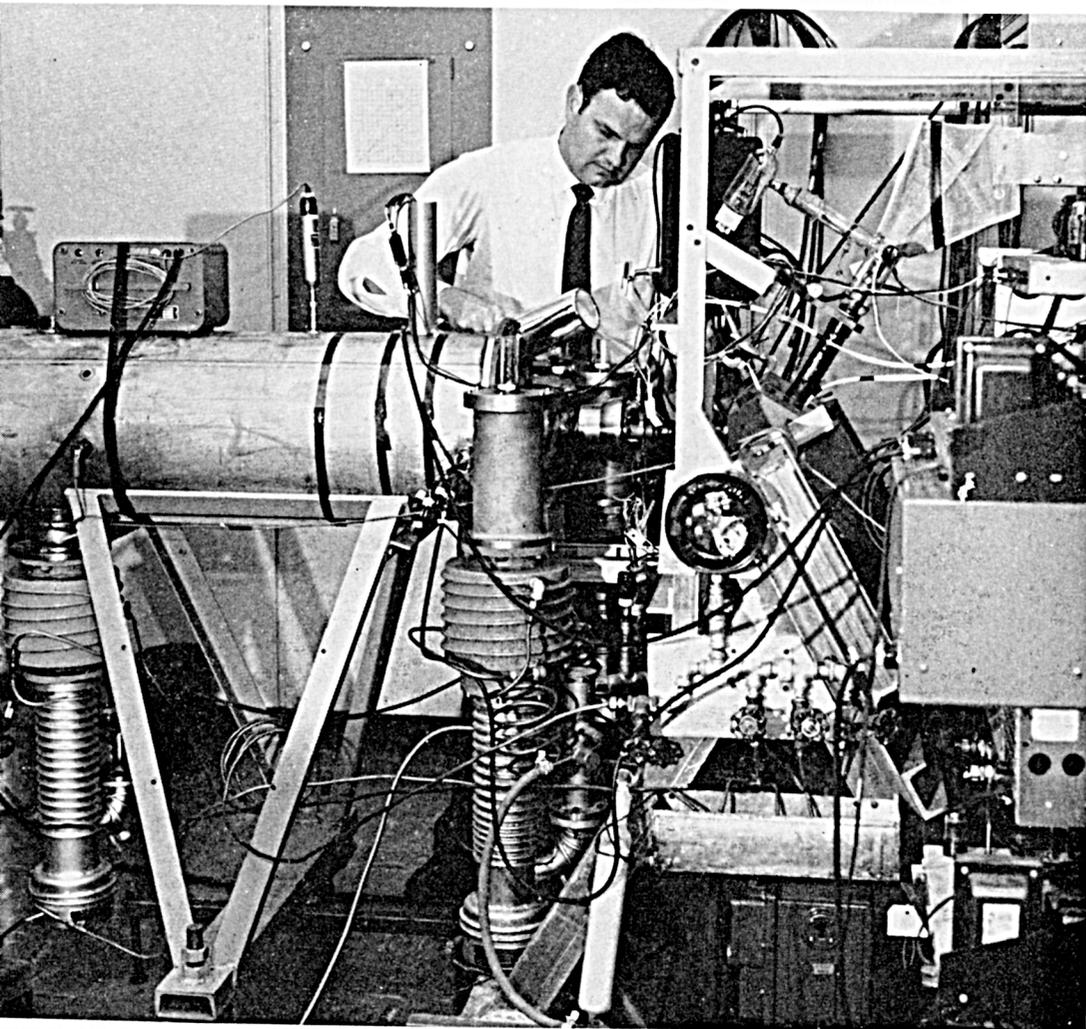
Radiolysis products are characterized by molecular weight determinations using thermistor (above). Counting room shown below contains detectors and electronic equipment.

Nuclear Science and Engineering courses in Applied Biology, Chemistry, Chemical Engineering, Physics, and Electrical Engineering are taught in the Radioisotopes Laboratory. Research programs are of great extent in the fields of radiation chemistry (and synthesis), activation analysis, radiochemical separations, gaseous electronics, kinetics, and cross section studies. A broad complement of instrumentation is used in these diversified programs, and analysis plays a vital role in the functioning of this laboratory. The fields of effort are very





Radiolysis products determined with the x-ray machine (upper left). The radioactivity of a cement mortar sample is checked as it is removed from the thermal neutron irradiation facility (center). Shown below is the drift tube apparatus built for ion-molecule studies.



This special apparatus is used in the measurement of the ionization cross section for protons incident on various types of gases (upper left). The appearance and disappearance of functional groups as a result of irradiation is detected by inspectrophotometry (right). Characteristic absorption by molecule complements retention times in gas chromatography.

demanding in both qualitative and quantitative aspects, and nuclear equipment is being broadly complemented by nonnuclear equipment.

The laboratory's specialized equipment and facilities (high efficiency hoods, glove boxes, radiation sources, etc.) are available for use by any campus department. Thus, the laboratory serves to augment and implement the other campus facilities, in addition to serving as a central facility for services such as health physics and storage of radioisotopes.

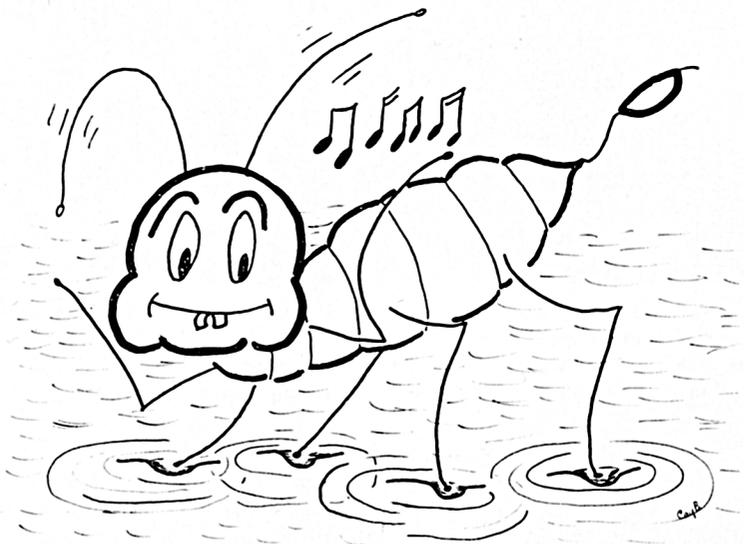
Specialized facilities include a 12 kilocurie cesium-137 source, a one-Mev Van de Graaff positive particle accelerator, subcritical assembly, counting room, underground storage wells, ten fume hoods with high efficiency filters, five portable glove boxes, a service chase allowing for easy maintenance of facilities, and a waste detection system to preclude the possibility of an accidental discharge into the Atlanta sewage system of levels of radioactivity higher than those prescribed by the AEC.

The laboratory, especially designed for work with radioisotopes and radiation, comprises about 60 per cent of

the Radioisotopes and Bioengineering Building. Incorporated in the building are many of the proven and time-tested features of the highly successful principal research building (the "4500" building) at the Oak Ridge National Laboratory.

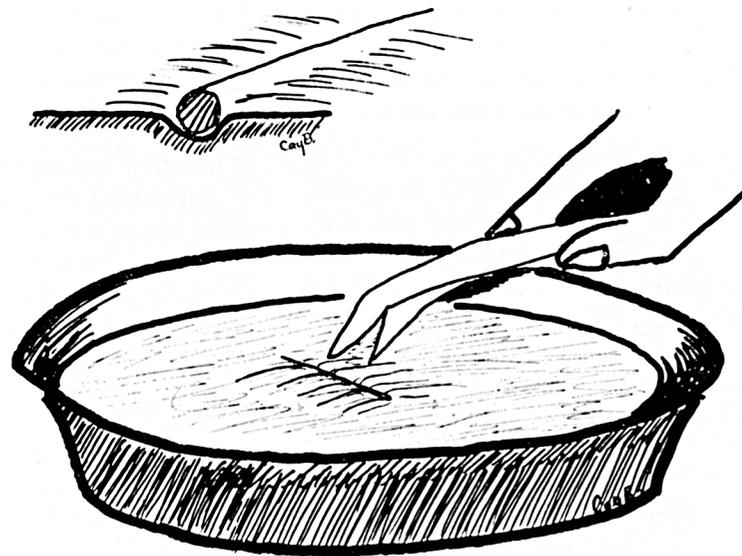
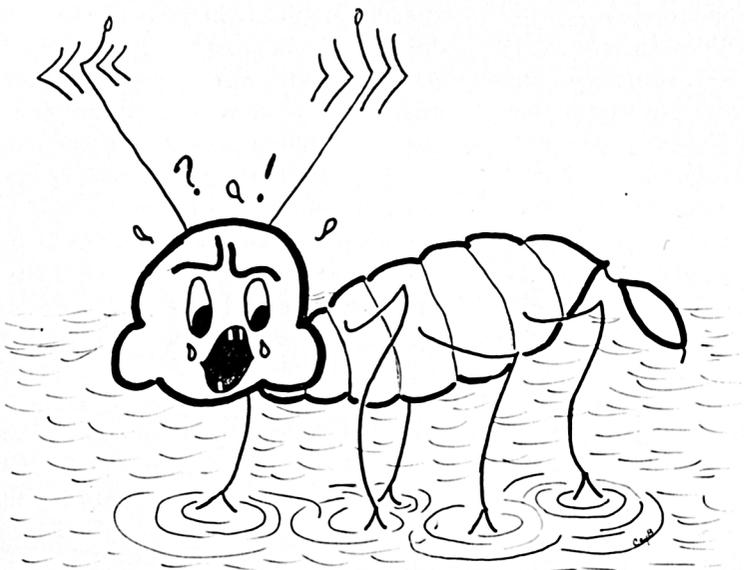
The laboratory building can easily be enlarged by the addition of 4,000 square feet to the existing 16,000 square feet of floor space, prior to the addition of a second and eventually a third floor. The second story floor is already in place underneath the top dressing of the roof, and two future elevator shafts are presently being used as storerooms. For control purposes, all laboratories are situated in the interior, with offices and storerooms lining the periphery.

Even though the Radioisotopes Laboratory predates the Georgia Tech Nuclear Research Reactor by several years, it will serve to complement the latter which is presently under construction. When the reactor facility, valued at \$4.5 million, is completed in the middle of 1962, Georgia Tech will have complete facilities for work with both high and low levels of radioactivity.



# the Bugs in SURFACE CHEMISTRY

by Herb Burrows, Head of Industrial Products Branch



Illustrations by Caren Burrows

As a boy I used to spend many a summer hour along the banks of a canal which channeled the waters of a nearby river to the water works and a small power generating plant. The canal stream moved slowly, and its waters were often quite clear, as contrasted with the muddy waters of the river. One of the most fascinating features of the canal shoreline was the large number of insects and spider-like creatures that skittered about on the surface of the water like many water skiers without boats. Each sent out wave fronts on both sides, but the surface of the water was never broken. Sometime about then I learned that I could do a trick comparable to that of the water bugs; I could float a steel needle on the surface of water without breaking through the surface. If pushed down through the surface, the needle would sink to the bottom, but as long as the surface remained unbroken

the needle would float. I didn't try pushing the bugs down, but presumably, they would sink, also, once they broke through the surface.

Actually, what I was learning was something the bugs had learned in their primordial existence and had made use of ever since. Water is water, except at the surface. There it behaves in a manner quite different from water, exhibiting, among other things, a high tensile strength, which makes the surface of water almost as if a thin plastic film were stretched over it.

In recent years the bugs have disappeared from the canal, although it is still clear and smooth. It seems the housewives in the towns upstream have been discharging detergent solutions from their washing machines into the sewers which run into the river. The minute amounts of these solutions which find their way into the canal are sufficient to lower the sur-

face tension of the water to the point that the bugs can no longer ski. The housewives did not poison the creatures; they just drowned them.

Surface tension, or increased tensile strength of a liquid at its surface, is one of the more familiar and striking phenomena associated with the boundary planes between two phases of matter. One may encounter a true surface only in the case of a solid or liquid in a vacuum; otherwise, this boundary plane is an *interface*. When we speak of the "surface of water" we actually have reference to the interface between the water and whatever gas, usually air, is in contact with it. Many of the physical phenomena exhibited at an interface are dependent upon both materials meeting at the interface; however, this is more true of liquid-liquid and liquid-solid interfaces than it is of interfaces in which one phase is gaseous. Certainly, the wetting of glass by water is dependent upon the molecular structure of both the water and the glass. Mercury, which is of an entirely different molecular structure, does not wet glass.

The wetting of one substance by another, the rise of water in a capillary tube or in the soil, the easy slip of metals over oiled surfaces, the adhesion of one material to another, the formation of foams, fogs and smogs, and many more phenomena observed in everyday life arise from the interplay of molecular forces of two or more substances at their interface. Only in a few instances, such as the corrosion of metals, is surface chemistry concerned with chemical reactions taking place at the interface.

For the most part, surface chemistry is concerned with the physical aspects of the intermolecular forces exhibited at the interface.

Industrial surface chemistry seeks to understand these forces, to utilize these forces advantageously, if possible, and to modify these forces where necessary to increase the usefulness of a commercial product. In some instances the industrial chemist is able to make a substitution of materials in order to substitute advantageous forces for disadvantageous ones. Thus, the molecular structure of a certain detergent compound is such that it favors the formation of foam, or "suds," and performs poorly in automatic washers. A modification in the molecular structure reduces this tendency, while at the same time providing the same detergent action as the original compound. This modification has proved as profitable to the television industry as to the synthetic detergent industry.

The intermolecular forces involved in surface chemistry are electrical in nature. Some idea of the relative magnitude of the several types of forces exhibited by different materials may be gained through comparisons of such properties as surface tension, boiling point, melting point, and vapor pressure of materials representative of the various types. The principal types of forces are the following:

**Metallic forces**—The atoms of a metal arrange themselves into crystal structures compatible with the dimensional and electronic configurations of the atoms. The valency electrons, which form a neutralizing cloud among

the positively charged metal ions, move with little restriction throughout the crystal structure. There is no definite association between individual metal ions and individual electrons; consequently, deformation of the crystal structure of a pure metal is possible. That is, the metal is malleable. Other phenomena, including metallic lustre, are associated with this freedom of electron movement, which is not confined to crystal structures, but is characteristic of amorphous forms and the molten liquid, as well.

This type of bonding is quite strong, as evidenced by the high melting and boiling points of most metals. This force also gives rise to high values of the surface tension of the molten metal. Compare the following values with that of water, which is  $72.9 \text{ g.sec}^{-2}$  at  $20^\circ \text{ C.}$ :<sup>1</sup>

Metal	Temperature $^\circ \text{ C}$	Surface tension $\text{g.sec}^{-2}$
Nickel	1470	1735
Copper	1120	1269
Gold	1200	1120
Zinc	550	778
Mercury	16.5	484

**Electrostatic forces**—The strongest electrostatic forces encountered in chemical materials are those in a special lattice structure which hold together the ions of a salt, such as sodium chloride. Alternate positive sodium ions and negative chloride ions are equally spaced in this lattice, and the magnitude of the force holding these ions together is reflected in the high melting point of the crystal ( $801^\circ \text{ C}$ ) and the surface tension of the fused salt at  $1000^\circ \text{ C.}$ , which is  $102 \text{ g.sec}^{-2}$ .

**Dipole forces**—Dipole forces are also electrostatic, but much less pronounced than those exhibited by ions. A typical dipole molecule is water, whose positive hydrogens are not symmetrically placed with respect to the negative oxygen. A molecule which has no dipole force is methane, consisting of four hydrogens symmetrically spaced about a central carbon atom. It is not surprising to find that much more energy is required to separate water molecules from one another than is required to separate methane molecules. Consequently, water has a much higher melting point, boiling point, surface tension and heat of vaporization than has methane.

It is precisely water's dipole force which makes it a good solvent for salts.

Indeed, solvency is an important phase of surface chemistry. Benzene is a typical non-polar compound. When we attempt to dissolve benzene in water by shaking the two liquids together, we find that the liquids separate as soon as we stop shaking. No dissolution of one liquid in the other can be observed, as the layer of benzene which rises to the top appears to be the same volume as that originally introduced.

**Hydrogen bonds**—A hydrogen atom whose electron is engaged in a covalent bond between the hydrogen and an adjacent atom, such as nitrogen, in a molecule is effectively a highly concentrated positively charged point on the periphery of the molecule. As such, it is strongly attracted to negatively charged areas, such as a pair of unshared electrons on an atom of a

nearby molecule. These oppositely charged areas may approach each other to the point that the hydrogen becomes as closely associated with the one as with the other, assuming a resonant position between the two. The resulting moderately strong bond is known as a hydrogen bond.

The more familiar modifications produced by surface active agents are those affecting a bulk interface. An example would be the interface between water and benzene mentioned previously. While there is no way in which the chemist can get benzene to dissolve in water, or vice versa, to any appreciable degree, he can so modify the interface as to obtain a stable dispersion of one in the other. The surfactant required for this job must be a hybrid molecule, having one portion which is sufficiently polar to dissolve in water and another portion which is sufficiently non-polar to dissolve in benzene. The hybrid molecules seek out the interface, where they align themselves so that their polar parts are in the water and their non-polar parts in the benzene. The water surface thus becomes less polar and the benzene surface more polar. If this mixture is now agitated in such manner as to disperse the benzene into very fine droplets, the suspension thus obtained will be comparatively stable. The water can no longer squeeze out the benzene because of stronger water-to-water attractive forces. The water-to-benzene forces have been increased by the hybrid surface active agent.

Such is the common role of the surface active agent. The agent increases the forces of attraction between

phases where little attraction exists, or in some cases decreases the forces of attraction where too much exists. It is desirable to obtain a better bond between a metal surface and the coat of paint which is to be applied to it. A surface active agent, or *surfactant*, is selected which has one part that can attach strongly to the metal and another part which is of low polarity and mixes well with the paint. It is desirable to prevent the sticking of rubber to the vulcanizing molds used to make tires, hot water bottles, etc. A surfactant is selected which bonds well to the metal surface but presents to the rubber an incompatible chemical surface, such as fluorocarbon. The rubber then has nothing to hold to and releases easily from the mold after the curing process is completed.

The companion articles in this series of the Industrial Products Branch deal with the theoretical and practical aspects of some specific industrial fields of surface chemistry. These fields have entered into the work of the Industrial Products Branch to an extensive degree. Indeed, virtually every industrial research problem which has been handled by the Branch has involved one or more phases of surface chemistry. Success in this type of research comes only to the degree that we understand the intermolecular forces involved at the interface, utilize these forces advantageously if possible, or modify these forces where necessary.

- (1) Bikerman, J. J., "Surface Chemistry," New York, Academic Press, Inc., Second ed., 1958, p. 49.
- (2) *ibid.*, p. 60

## SLIPPING AND SLIDING by Lewis W. Elstron

A satisfactory lubricant must adhere strongly to a surface in order to resist displacement and consequent surface wear. The bond between a lubricant and its substrate must have many of the properties of adhesive-adherent bonding.

Tomlinson<sup>1</sup> in 1929 suggested that the heat of friction rises from molecular forces. In general, there are attractive and repulsive forces acting between molecules. The attractive forces extend to a greater distance from the molecule than do the repulsive forces. When molecules pass other molecules, either species may be pulled out of equilibrium positions and evolve heat on returning to a stable position as they move from the dislocating field or as the dislocating force is removed. A corollary to this hypothesis is that two smooth, clean surfaces brought into contact will weld. This corollary is demonstrated in the galling of accidentally stacked clean gage blocks or in commercial cold welding of non ferrous metals<sup>2</sup>. Parallel argument in terms of wetting, relative chemical bond strengths, and thermodynamic considerations may be found in the literature of adhesives<sup>3,4</sup>. In the most general sense, adhesion may be attained by bringing or forming two or more clean, solid surfaces into the most complete contact their surface geometry permits. Its opposite, lubricity arises from reduction or prevention of contact between these surfaces. The transition from simplicity of principle to the complexity of a specific application has given rise to large volumes of research.

Absolutely smooth, clean surfaces do not exist. Even on the most carefully polished surface there are hills and valleys which are much larger than a molecule. Since the range of molecular attraction is only a few hundred millionths of an inch, the area of actual contact, i.e. the area in which two solid surfaces are in range of molecular attractive forces, is much smaller than their apparent area of contact. Elasticity and plastic flow may increase actual contact area between two solids forcibly pressed together. Unfortunately, added pressure tends to displace either lubricant or adhesive; and the elasticity of a compressed solid creates strains that tend to break a glued joint when the applied pressure is released.

An absolutely clean solid surface is about as rare as an absolutely smooth one. At room temperatures and pressures a thin film of air adsorbed on a surface may be sufficient to act as a lubricant and prevent satisfactory cold welding. Formation of tarnish films on cleaned surfaces exposed to air is all too common. Fortunately, in many cases, the oxide film is strongly bound to its parent metal so that satisfactory adhesive or paint application is still possible. For cold welding it may be necessary to drive off adsorbed air by heating in high vacuum, cooling, and bringing the parts together without further exposure to gases. Where suitable cleaning is difficult or impossible, some substance may be used to penetrate or dissolve the surface contamination and permit formation of a

strong bond. This practice is common to both adhesive and lubricant formulations.

Having noted that solid surfaces are neither clean nor smooth, it is only necessary to observe that the surface of any solid or liquid has chemical and physical properties differing from those found in the bulk of the phase. A successful lubricating or adhesive film is usually applied as a fluid or semi-fluid capable of wetting the solid surface, which permits as many mobile molecules as possible in the fluid phase to come within range of the attractive forces of fixed molecules in the solid phase. As used in this discussion, "wetting" might evasively be defined as the action of attractive forces between the molecules of a solid surface and the surface molecules of another substance in contact with the solid surface. For this phenomenon to occur, the interaction between the surface molecules of the separate phases must be greater than the attractive forces between the molecules of one of the phases.

The term "molecular attractive forces" could also be expanded to any desired degree of complexity. The simplest possible model of any substance would show the atoms bound together into molecules by electrostatic, covalent, metallic, and coordinate covalent bonds—the classical primary bonding forces. Cohesion between molecules could be attributed to secondary or Van der Waals forces. Unfortunately, the designation of bond types is an arbitrary one indicating only the most obvious of the mixture of properties in a specific bond. The assignment of cohesion and adhesion

to Van der Waals' forces is also a faulty assumption, as it ignores such stronger intermolecular attractions as metallic bonding, the hydrogen bond, and electrostatic bonding in crystals.

The Van der Waals forces, as they apply to adherence, have been divided into three convenient groups.

Orientation forces are those attributed to the existence of electric dipoles in certain molecules; i.e. in certain molecules asymmetric structure causes the centers of positive and negative electric charge not to coincide.

Induction forces may arise in molecules having no permanent dipole moment as a consequence of their being near a molecule having a permanent dipole.

Dispersion forces arise from interactions between the electron systems of molecules because of the constant motion of electrons. These forces are smaller than orientation forces<sup>4</sup>. An illustration of the action of orientation forces predominant in hydrophilic or polar liquids (such as water) and the dispersion forces of hydrophobic or non polar liquids (such as benzene) may be found in the failure of benzene and water to mix. The tendency of electropositive centers to approach electronegative centers in water forces out the neighboring benzene molecules.<sup>4</sup>

Having approximated the nature of the forces acting to attract one molecule to another, it becomes possible to select molecules which will be attracted to the surface to be bonded or lubricated or to engage in molecular architecture, if necessary.

The tail of the attracted molecule and its environment determine whether the film will be lubricating or adhesive. A film whose internal layers slip easily over one another would be lubricating. One whose internal structure resists deformation would be an adhesive or glue. Low values of internal dispersion forces are among the most common characteristics of any successful lubricant. Larger dispersion forces, orientation forces, and even the formation of new primary bonds may occur in an adhesive. The film melts the solid surface at these few molecular layers. Polar molecules are attracted most strongly to other polar molecules and non polar molecules are attracted most strongly to other non polar molecules. A polar adhesive forms a strong bond to a polar surface such as wood (which is rich in hydroxyl groups). A non polar adhesive is suitable for a non polar rubber surface.

Since both ends of a surfactant molecule must perform distinct functions, it is convenient to represent one type of surfactant molecule as a small magnet (polar end) attached to a tail (the non polar chain). Assuming the polar surface to be lubricated to behave as a closely spaced array of magnets, the polar ends of the surfactant molecules would attach themselves to the surface, and the tails would flow out behind them into the body of the lubricating film.

Below the melting point of the surfactant, the tails would be held parallel to each other by dispersion forces. As shown in Figure 1, the tails of a second layer of molecules would be attracted to the tails of the molecules adhering

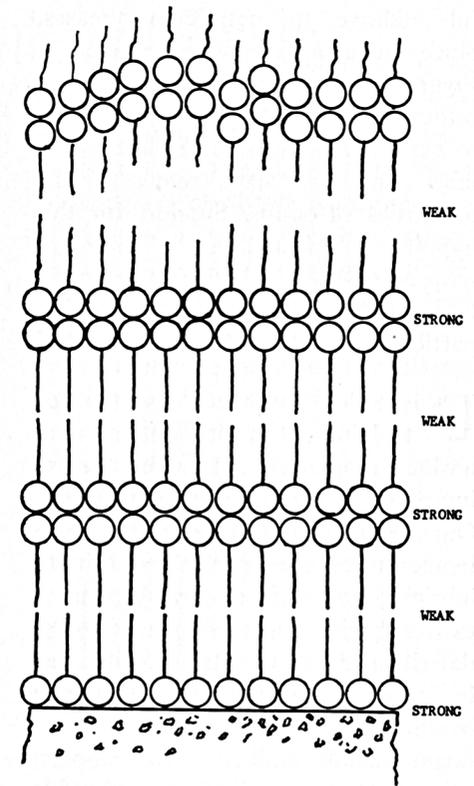


FIGURE 1 BOUNDARY OF LUBRICATING FILM

Illustration by Caren Burrows

and still another layer of surfactant molecules would be held by strong polar attraction to the second layer. Shear within the lubricating film would be expected at the "tail-tail" junction where only weaker dispersion forces are present.

The adherent molecules, if reversed in direction, would look very much like the "motivated molecules" of popular soap advertising. The polar head escaping into the dishwasher would drag along a layer of surface soil attached to its tail and "lift grease miraculously". It isn't surprising that soaps have long been a popular and success-

ful additive to petroleum greases. Since the arrangement represented in Figure 1 is representative of solid soap rather than liquids, it is reasonable to expect that the surface layers of a lubricating film have many of the properties of solids. Support for this hypothesis is found in the failure of soap as a grease additive at temperatures above the melting point of the particular soap used.

**D**ispersion forces are also the key to lubricants which operate over a wide temperature range without freezing or running off the bearing surface. Oils which do not freeze at very low temperatures are usually too thin to lubricate hot surfaces. By suspending extremely fine particles such as colloidal silica in the oil, its viscosity may be increased. A representative grease of the extreme temperature range might include a silicone oil, colloidal silica thickener, molybdenum disulfide solid lubricant, talc filler, and several chemical additives chosen to prevent corrosion of the bearing surface or chemical decomposition of the lubricant. A heavy metal soap might be included where the expected operating temperature does not greatly exceed its melting point. Still another useful technique is to add small amounts of a chemical which stiffen on heating to a petroleum stock that thins on heating to make a "10-20-30" motor oil. The surface active agent in a lubricant for rubber or certain plastics might possess uniform electrical charge distribution and no polar properties at all.

Solid lubricants are often stable at temperatures appreciably higher than

the decomposition point of the most stable oil stock available. Certain silicone oils which break down gradually at elevated temperatures may continuously be supplied to hot bearing surfaces at a rate equal to the decomposition rate of the oil stock in the bearing lubricant. This technique is valuable for jet engines or high speed braking systems. Other variations on the expendable oil technique include automotive upper cylinder lubricants, fuel mixtures for two-cycle lawn mowers, oil impregnated bearings, and the wick connecting a grease reservoir to the bearings in a "lifetime lubricated" electric fan.

Though resembling lubricants in the nature of forces which bind films to substrates and in the possibility of tailoring formulations to specific applications, adhesives are designed to resist shearing and tensile forces. A heavy oil, if cooled could stick two parts together, or a melted thermoplastic glue might lubricate; but these properties of the materials are usable only in special cases.

#### BIBLIOGRAPHY

1. Tomlinson, G. A. "A Molecular Theory of Friction," *Phil. Mag.* *VII*, 905-939 (1929).
2. Fuller, Dudley F. *Theory and Practice of Lubrication for Engineers*. John Wiley and Sons, Inc. New York (1956).
3. Reinhart, Frank W. "Survey of Adhesion and Types of Bonds Involved" (same) p. 9.
4. Eley, D. D., "Some Possible Surface Factors Involved in Joint Strength" (same) p. 21.

# Polka Dot Paint—A Reality

by Raymond Tooke, Jr.

**T**he technology of paint and organic coatings is one of the most important fields of applied surface chemistry. Annual sales of products created by the paint technologist are now well above 1.5 billion dollars. This represents more than 500 million gallons of coatings applied to surfaces to color and decorate, to protect from deterioration, and for other specialized purposes.

Although paint manufacture as an industrial art dates back to the days of the cave man, it is only within the last thirty or forty years that the chemist has begun to apply his "scientific tools" to the solution of coatings problems. Among his earlier successes was the development of durable nitrocellulose lacquers and the alkyd enamels having fast-drying characteristics. Without these products the mass production painting of auto bodies would have been impossible for the volume that was required. (even for Henry Ford's Model T.)

From this very substantial beginning, new and improved finishes have come out of research laboratories at an accelerating rate. Some of the more significant or novel recent developments are to follow. But first, a review of certain paint fundamentals will be helpful to gain an understanding and perspective on these recent developments.

#### PAINT FUNDAMENTALS

All paints are composed of two main ingredients—pigment and vehicle. The pigments are usually in the form

of very fine powders which are thoroughly dispersed but not dissolved in the liquid vehicle. Most paints contain combinations of several pigments which may supply one or more of the following functions: color, hiding, radiation reflection or absorption, corrosion inhibition, controlled chalking and cleanup, film reinforcement, gloss control, rheological properties, and several other highly specialized functions.

The vehicle portion of a paint consists of a liquid which forms a continuous solid film when applied to a surface. The pigments in a dried paint film are incorporated in a matrix of the solid vehicle. In general, a paint vehicle will contain a solid or semi-solid component in combination with a solvent or dispersant. The main purpose of the solvent is to reduce the viscosity of the vehicle to obtain satisfactory application properties. After the paint is applied, the solvent evaporates from the film and thus permits the non-volatile vehicle to solidify. In addition to these major components, the vehicle may also contain small amounts of additives such as catalysts or driers, wetting agents, thickeners, and leveling aids.

Varnish is a particularly important type of vehicle which consists of a drying oil-resin reaction product mixed with solvents and driers. Linseed oil or tung oil are frequently used in varnishes. These oils are cooked with resins such as ester gum (a naval stores derivative), glyceryl phthalate

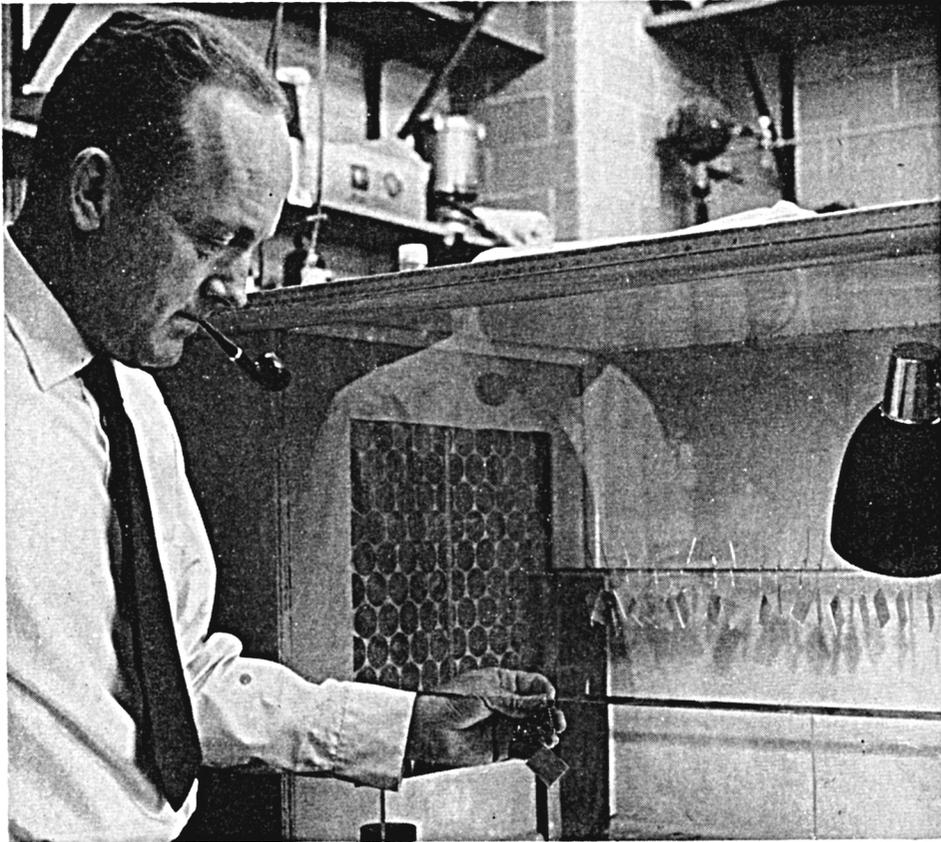


Photo credit Van Toole

Metal specimens are given a coating of temperature resistant lacquer, preparatory to receiving a thin deposit of reflective metal. The combination of metal film and organic coating provides an efficient method of controlling the temperature of space vehicles at Georgia Tech.

(alkyds), or phenolic (Bakelite) to form the varnish base.

Lacquers are distinguished from varnishes by the fact that the final hard film is formed entirely by evaporation of solvent and re-deposition of a dissolved hard resin. (A varnish base must react with oxygen from the air to complete its hardening reaction.) Nitrocellulose is the classical lacquer base; however, numerous other thermoplastic resins together with various modifiers are now being used to produce special types of lacquers.

In recent years, paint vehicles based

on *latexes* or emulsions have grown in importance tremendously. In contrast to the clear transparent solutions of varnishes and lacquers, latexes are characterized by a distinctly milky appearance.

In summary then, varnishes, lacquers, and latexes are the important types of paint vehicles. Also, plain drying oils with little or no modification remain among the best of vehicles for certain types of paints.

The weathering and deterioration of a paint film occurs within the solid vehicle. Proper pigmentation produces

amazing enhancement in paint durability, but pigments cannot overcome inherent limitations in the binder. For this reason, paint chemists tend to concentrate most of their research efforts in the area of vehicle chemistry.

All vehicles are essentially resinous in character. The justification for utilizing the three forms, varnishes, lacquers, and latexes involves numerous chemical and physical principals.

The fundamental distinction between varnishes and lacquers has tended to become somewhat fuzzy in modern practice. Baking lacquers as well as varnishes undergo cross-linking reactions during the bake. Alkyds are normally considered to be varnish resins, however, non-drying oil alkyds are used in combination with melamine resins to produce baking enamels which dry exclusively by solvent evaporation and cross-linking.

Despite a great deal of research effort, paint technologists have been unable to develop a device that is capable of providing reliable quantitative measurements of paint adhesion. Numerous qualitative and semi-quantitative tests are used to obtain comparative data. It has become apparent that "active sites" are necessary to obtain chemical bonding of dissimilar materials. For example, much better adhesion to metal is obtained when the coating resin contains polar groups than when it is non-polar. Yet excessive polar groups in the resin impair its chemical resistance. A proper balancing of these factors can become very critical in applications such as can linings.

Maintenance painting presents additional adhesion problems. In many

cases, proper preparation of a surface for painting or repainting is not feasible or impossible. Thus it may be necessary at times to paint over surfaces which are rusty, dirty and contaminated, or contain chalked and degraded old paint films. Such situations require a paint vehicle which is capable of penetrating the contamination to gain firm adhesion to the substrate. For maximum durability, one would ordinarily select a vehicle of high molecular weight, but high molecular weight vehicles exhibit very poor penetration characteristics and thus cannot gain satisfactory adhesion under these conditions. Latex, lacquer, and even varnish vehicles are seldom adequate in penetration for this use. In many cases a simple drying oil vehicle becomes the only logical choice despite its limitations in drying time, hardness and chemical resistance. Research and development work on this problem may be expected to produce distinct improvements in paint performance, but there is little hope of producing a coating material that will be a fully equivalent substitute for proper surface preparation.

The paint brush and the spray gun are still the primary tools for paint application, and many of the later developments simply involve modifications of these tools. Hand rollers were quickly adopted by the do-it-yourself painter along with the use of latex paints which provided the convenience of water thinning and cleanup. Because of the speed and ease of application, rollers are now being used by professional painters to apply almost every type of coating.

Several new techniques have been

developed for spraying paint. Hot spraying, as the name implies, involves heating the paint prior to spray application. The heat, by reducing the viscosity of the paint permits a reduction in the solvent content. In lacquers particularly, it is possible to gain almost twice the film thickness attainable by ordinary spraying. Thus application cost, drying time, solvent cost, and objectional solvent vapors are substantially reduced.

A modification of the hot spray technique is steam spraying. Steam is used to replace the air normally employed for paint atomization. This method has been found to be very effective in certain production operations, but it has not become widely adopted.

Airless spraying is the most recent development in the spray field. Very high fluid pressures and small spraying orifices are employed to atomize the paint. Overspray is reduced by the absence of the large volume of atomizing air, and the interior painting of small cavity spaces is particularly effective.

Electrostatic spraying is now about fifteen years old and has become widely employed in product finishing. Electrodes surrounding the work or the spray gun itself is used as an electrode to apply an electrostatic charge to the paint particles. The work is oppositely charged and the paint particles are uniformly attracted to its surface. In addition to producing a very uniform coating on complicated shapes in an automated setup, paint overspray is reduced to an absolute minimum.

**D**ip coating is an ancient application method, but two related tech-

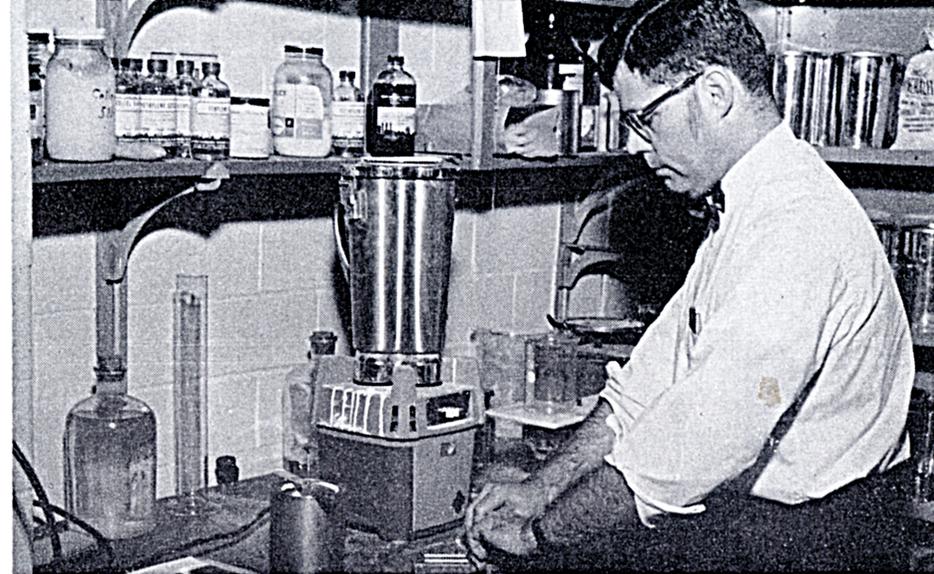
niques have been developed recently. Flow coating employs jets or fans of liquid paint properly directed onto the surface of the work to attain uniform flow-off and absence of sags and streaks. Curtain coating employs a continuous thin vertical curtain of liquid paint which is poured onto a moving horizontal sheet to be coated.

While product finishing has automated rapidly, architectural painting remains largely a manual process in which the labor accounts for several times the cost of the paint material. High painting costs have in many cases impelled the selection of architectural materials which require no painting or are factory prefinished. The economic climate is particularly favorable for all types of materials and methods that will improve the productivity of field painting.

#### PAINT PRODUCTS

Multicolor paints have virtually made a reality of the mythical "polka dot" paint. This product is made by stirring a pigmented lacquer into water to produce a coarse aqueous suspension which is stabilized by addition of a water soluble gum. Any number of distinct colors may be combined in various particle sizes in a single suspension, and each particle remains discrete during low-pressure spray application. Multicolor has gained substantial usage in both architectural and industrial finishes.

Fluorescent paints employ special pigments which enhance the brilliance of colors. Instead of simply reflecting a single color component of the incident white light, these pigments convert other colors in the white light to the desired color and thus reinforce



Large scale "blendor" is used in the dispersion of pigments for laboratory paint studies.

*Photo credit: Van Toole*

the intensity of that color. The Air Force is using fluorescent paint to enhance the visibility of non-tactical aircraft.

Exterior latex paints are now being recommended for use on wood as well as masonry surfaces. Problems of adhesion, as discussed earlier, are solved by recommending the use of an oil based primer under the latex finish.

Custom colors are being produced by the paint retailer utilizing automatic color vending machines. "Universal" tinting pastes have been developed for this system.

High temperature paints based on silicone resins now retain satisfactory properties at temperatures far above those attainable with ordinary finishes.

Paint for aerospace applications is probably the most exotic of recent developments. For these applications the ordinary protective and decorative aspects of paint are of little or no consequence. The main function of the paint is to provide the proper solar radiation reflection and heat emissive characteristics to maintain the temper-

ature of the satellite within specified limits.

#### WORK AT EXPERIMENT STATION

The Coatings Laboratory of the Station's Industrial Products Branch has been active in paint and related research and development work for many years. Beginning in 1944, several series of exposure studies were made on house paints for application to southern yellow pine. The last series was terminated in 1955. Numerous other investigations have been made involving various types of pigments, resins and vehicles and special coatings products. Currently, the laboratory has three active projects in the coatings field. One involves the development of a special clear primer to provide a substrate for a metallic mirror finish. Another is a study of a new type of extender pigment for use in paints. The most recent project is a study of highway paint testing methods utilizing radioisotopes. This research seeks means of further improving highway paint performance.

# Edited in Retrospect

## More Reactor Funds

The Atomic Energy Commission granted \$34,700 to Georgia Tech recently to spend on equipment for the research reactor now under construction on the campus. The AEC also stated that it will lend without charge a quantity of uranium 235 and 8.7 tons of heavy water needed for the reactor. A plutonium-beryllium neutron source will be loaned for instrument calibration purposes. The total value of this material is over \$600,000.

## Almost to Completion

Last summer, the Ceramics Branch began transferring facilities from Area 2 on the Georgia Tech campus to DeKalb Peachtree Airport. Already crowded conditions and needed expansion room necessitated the move. Now with approximately 9,000 square feet of office and laboratory space, the Ceramics Branch has expanded its capabilities as well as its facilities.

New items of equipment recently installed were an 80 KW Arc Plasma Jet, a 60,000 lb Tenius Olsen Universal Tester, a Research Metallograph with 1500° C hot stage, darkroom facilities, and a Tukon Micro hardness tester. Differential Thermal Analysis and Thermal gravimetric equipment was also put into use for studying radioactive and/or toxic materials. Full operation of the branch in the new location began January 1. With the additional space and facilities, the Ceramics Branch anticipates an increase in basic research. An accelerated program in the area of industrial research should help develop uses for the State's mineral resources, and this development in turn will further the expansion and attraction of industry to the State of Georgia.

## Thanks again to Mr. and Mrs. Neely

Through the Neely Visiting Professorship, Mr. and Mrs. Frank Neely have brought distinguished scientists to Georgia Tech for seminars, lectures, and exchange of information about new areas of knowledge. Already two nationally-known authorities, Dr. Frank D. Drake, radio-astronomer, and Dr. George H. Vineyard, solid state physicist, have visited the campus. Ten more scientists from various fields are expected during this year.

## IDB Moves

The Industrial Development Branch of the Engineering Experiment Station has finally received the space and facilities it has long needed to continue its excellent work. The IDB has vacated the fourth floor of the Price Gilbert Library and is now located at 680 West Peachtree.

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