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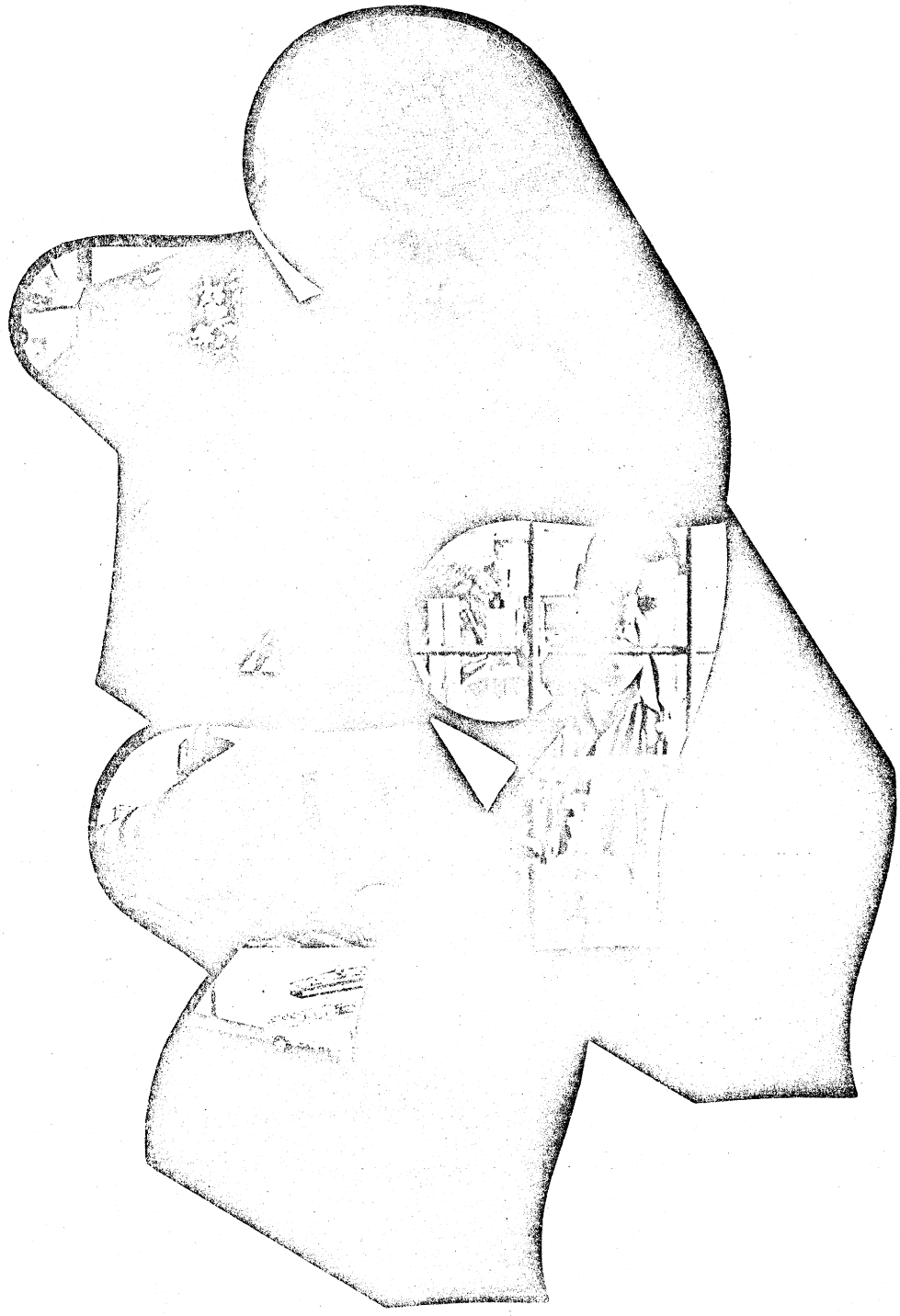

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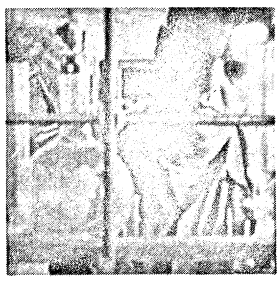

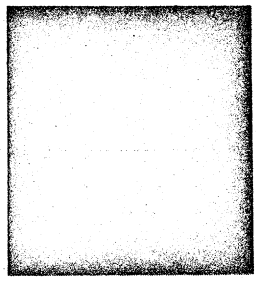

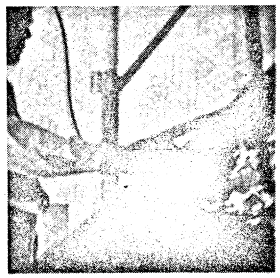

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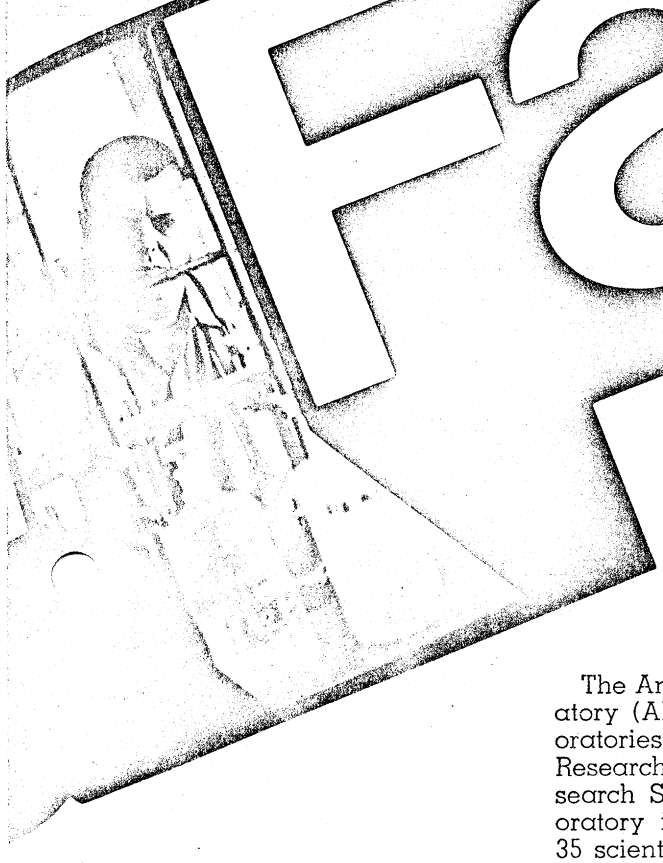

What was regarded as a "prudent and advantageous" project in 1940 has become an urgent national need as government and industry seek ways to conserve our country's resources . . .

BY GERHARD MAERKER

The Animal Fat Products Laboratory (AFP) is one of seven Laboratories of the Eastern Regional Research Center, Agricultural Research Service, USDA. The Laboratory is presently staffed with 35 scientific personnel, mostly organic chemists, and is probably the world's only major research unit devoted entirely to research on animal fats.

For the past 35 years it has been a goal of AFP to stimulate the industrial utilization of animal fats, principally tallow. In this endeavor the Laboratory has amassed a solid record of achievements in terms of processes and products invented by AFP and adopted by industry, as well as in the number and quality of the publications and patents that have been produced. The need for a research program to provide new technologies for converting tallow into products of higher value and usefulness was recognized at the inception of the Laboratory in 1940. What was prudent and advantageous then is now considered an urgent national need, for, as a result of the recent energy and materials crisis, it is now generally recognized that it is essential to conserve all of the nation's resources.

The United States produces about five billion pounds of inedible tallow and grease annually as a by-product of the meat industry. About 40-50% of this amount is exported and is therefore used in part to pay for petroleum which is imported. Domestically, tallow is used as an ingredient of animal feed, as a source of fatty acids and derivatives, and as a raw material from which soap, lubricants, and other industrial products are made. Fatty acids and their derivatives are used for a myriad of applications including plastics, chemical intermediates, cosmetics and toiletries, laundry products, textile lubricants, rubber ingredients, lubricant components, textile softeners, industrial emulsifiers, metal working compounds, protective coatings, drugs and pharmaceuticals, humectants, gasoline additives, and many, many other uses.

Chemically, tallow is principally hydrocarbon in nature and hence

it is closely related to petroleum. The latter is a source of a bewildering number of chemicals, some of which could also be manufactured from tallow and other fats and oils. The conversion of animal fats, especially tallow, to additional chemicals now derived from petroleum is feasible, logical, and advantageous to the United States. If tallow were not used in this profitable way it would soon become an expensive disposal problem and an ecological headache.

A further goal of AFP has been to serve as a source and repository of scientific and technical information on tallow and fatty acids. In this role AFP interacts with industry, universities, and other research organizations to provide information on the current state of the art. The Laboratory aids and encourages these organizations in their fat research and development efforts.

The Animal Fat Products Laboratory conducts a highly diversified program of basic and applied research to increase the value and industrial utilization of animal fats, thereby expanding market opportunities and providing improved market alternatives. Organizationally, the Laboratory is divided into four research groups whose efforts have been directed toward the areas of plastics, lubricants, surfactants, and exploratory research. It is not possible to describe here all or even most of the research projects undertaken recently by AFP scientists, but a few typical examples will illustrate the scope of these investigations. Complete lists of publications are available to those interested, and reprints of all papers can be supplied to those who have an appetite for greater detail.

Research results achieved in the last several years by the Surfactants Research group have evoked a large amount of interest in the United States as well as abroad. The project has to do with the modification of the properties of tallow soap as a cleaning agent for use in modern applications, including household detergents. Soap has a long record as a safe and effective cleaning agent, and it was only as recently as 1953 that the production volume of soap was first exceeded by that of petroleum based synthetic detergents. The poor solubility of soap in hard water as well as in cold, soft water, places it at a disadvantage compared to synthetic detergents. It was the aim of AFP research to overcome these difficulties related to soap and at the same time to avoid the use of phosphate builders. The latter are common ingredients of petroleum derived household detergents and have been implicated in the pollution problem associated with the eutrophication of lakes and streams.

The AFP research goals were indeed achieved by the development of phosphate-free soap based detergent formulations that are soil removers as effective as the best detergents available to the consumer. In addition to the major ingredient, tallow soap, these formulations contain one member of a group of chemicals that has the effect of preventing the precipitation of soap in hard water and that also increases the solubility of soap in cold water. More than 30 such chemicals, called lime soap dispersing agents (lsda), have been synthesized and tested by AFP. Most of the lsda are derivatives of tallow, but some are made from other raw materials. The detergent formulations contain, in addition to soap and lsda, nonpolluting, inorganic builders and a number of minor ingredients. The soap based detergents are highly biodegradable, nonpolluting, and nontoxic. The development of these agents is considered a major achievement. This research was aided materially by postdoctoral research fellows supported by the Fats and Proteins Research Foundation.

To date, soap based household detergent formulations are not yet being manufactured commercially in the United States, as far as can be determined. It is anticipated, however, that increasing prices

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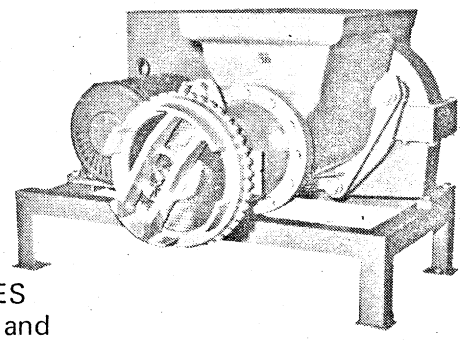

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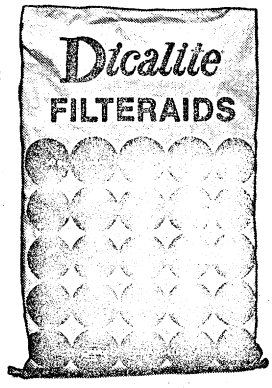

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ANIMAL FATS

(Continued from page 36)

and decreasing availability of petrochemicals may favor the tallow based materials in future markets. The potential United States market for this application may easily approach 1 billion pounds of tallow. Meanwhile, several Japanese detergent companies have started manufacturing and marketing such products based on AFP research. The sale of similar products is also being promoted in several countries of the Far East. Hopefully, the use of soap based detergents will continue to spread to the Near East and to Europe. In a world whose petroleum reserves are decreasing, it is eminently logical to base detergent manufacture on a yearly replenishable supply of agricultural products and byproducts that are cheap and plentiful and whose total availability is increasing. Tallow is the obvious candidate material.

Tallow fatty acid molecules have a distinctive structure characterized by a long, flexible, hydrocarbon-like tail that is chemically fairly inert and is hydrophobic in nature. The head of the molecule, on the other hand, is a rather reactive carboxyl group. AFP research has tried to capitalize on the peculiar molecular architecture of tallow fatty acids in several projects, one of which, soap-based detergents, has already been mentioned. The AFP Plastics Research group has also taken advantage of the tallow acid structural features by incorporating them in the polymer network of plastics. Polyvinyl chloride is a polymer that is used in very large quantities throughout the world. Polyvinyl chloride resin, however, is a brittle material that becomes flexible only when a considerable amount of "external" plasticizer is mixed with it intimately. Upon aging, articles made from "externally" plasticized polyvinyl chloride, e.g., floor tiles, shower curtains, and garden hose, slowly lose the "external" plasticizer by migration and volatilization, and eventually the flexibility as well as the usefulness of the article decreases. AFP research has demonstrated that a derivative of tallow, vinyl stearate, acts as a plasticizer that

can be bound chemically into the polymer network and thus cannot be lost by migration and volatilization. Vinyl stearate is rather expensive to manufacture and so the Plastics Research group searched for a more economical substitute and found that allyl stearate, a much less expensive derivative of tallow, could be used as well. Incorporation of the tallow derivative affected some of the mechanical properties of polyvinyl chloride adversely, but further research revealed that this obstacle could be overcome by polyblending the internally plasticized polyvinyl chloride with certain nitrile rubbers.

In another polymer application, hydroxyl functions were attached to the fatty acid chain, and the resulting polyhydroxy compounds, polyols, were used as ingredients of polyurethane foams. Foams of low, medium, and high density have been prepared and have been found to have excellent physical and mechanical properties. Such foams have a multitude of uses ranging from insulating materials to ornamental substitutes for wood.

There is still another way in which AFP researchers have capitalized upon the molecular structure of tallow fatty acids to produce highly useful products. By combining tallow fatty acids with a commercial welding gas, MAPP gas, scientists of the Exploratory Research group have produced a new and highly reactive series of derivatives called isopropenyl esters. The isopropenyl group attached to the reactive carboxyl function makes the latter even more reactive, and as a result isopropenyl esters can be used to attach tallow fatty acids to numerous chemical compounds. It is visualized, and some AFP research confirms this, that isopropenyl esters can be used to make cellulosic materials, such as paper, cotton and wood, water repellent. Another conceivable application is in the preparation of fat-derived polymers. Both batch and continuous processes for the manufacture of isopropenyl esters have been developed by the Center's Engineering and Development

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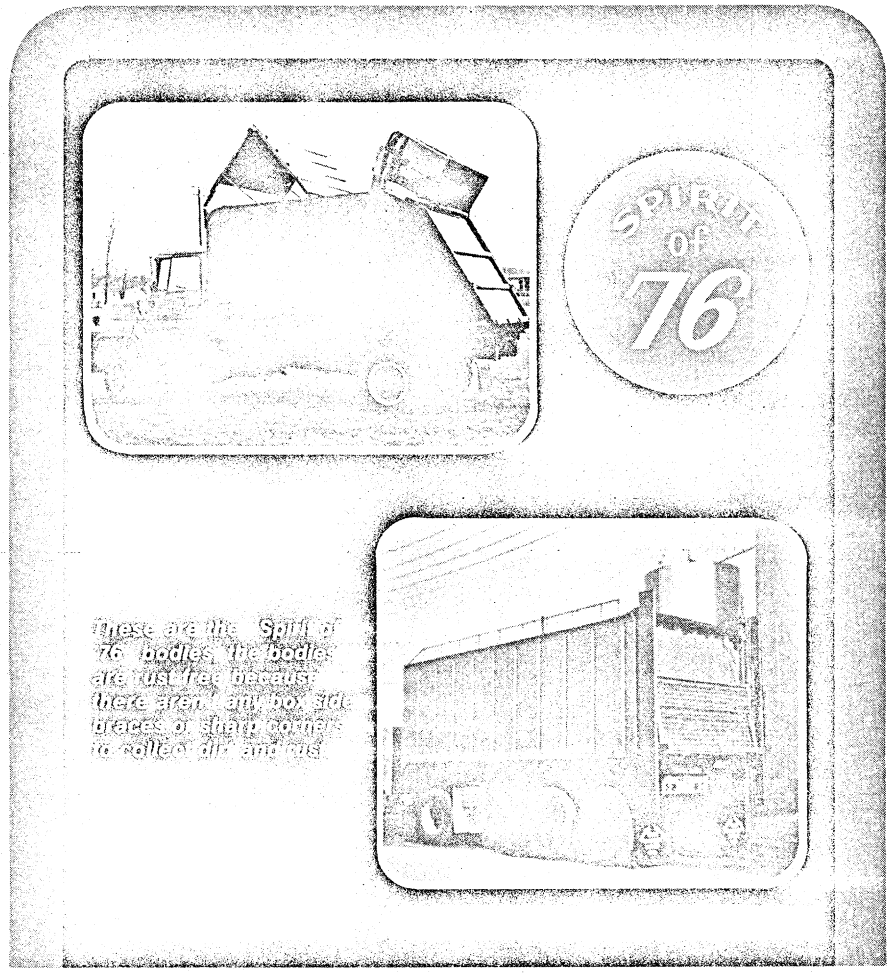

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ANIMAL FATS

(Continued from page 49)

Laboratory, and early cost estimates are very favorable.

The AFP Lubricant Research group has investigated methods by which the molecular structure of tallow fatty acids can be changed from long straight chains to mixtures of shorter branched chains. The objective has been to change the physical properties of tallow without affecting the chemical properties too much. Tallow, of course, is an excellent lubricant and has been used for that purpose since the dawn of civilization. However, the melting point of tallow and of tallow fatty acids is too high to satisfy the lubrication demands of modern machinery, hence the attempts of the Lubricants Research group to lower the melting point of tallow without decreasing its advantageous lubricant properties. One way this is being done is by removing the carboxyl group from the end of the tallow fatty acid chain and attaching it again at random points along the chain.

What about the future of research on the industrial uses for animal fats? Has all the worthwhile research been done? Far from it. Current technology is capable of converting fats and fatty acids to a wide variety of derivatives as is testified by the great diversity of applications which these compounds have found in industry. However, the number of chemical products which it is economically practical to produce is very small compared to the number that could be conceived and designed for specific purposes.

One barrier to further progress toward new oleochemicals is the lack of agents and methods capable of attacking the long chains of methylene groups of fatty acids at any desired specific location. The specific site attack, or regiospecificity, is theoretically possible but has been achieved in only a few activated positions.

Another need in designing and constructing new and highly active and useful derivatives of fatty acids is the ability to attain not only regiospecificity, but in some cases also to specify the point in space from which the fatty acid molecule is to be attacked, i.e., to gain stereospecificity. Some of the most active and effective chemicals found in nature are those in which the location of the active function on the fatty acid chain, as well as its spatial arrangement, is rigidly prescribed.

A further need in the creation of new chemicals from animal fats is the refinement and improvement of analytical methods. Present methodology is often incapable of pinpointing with accuracy the location of substitution on long chains or to define with certainty the stereochemistry of a newly created product.

Yet another need which exists is a lack of sufficient knowledge of the nature and mechanism of certain chemical reactions. In some cases new chemical products can be produced by uneconomical laboratory processes, but insufficient fundamental knowledge of the chemical reaction concerned prevent its exploitation for industrial scale processes.

It is apparent, then, that ample opportunities for further profitable research exist. The Animal Fat Products Laboratory will continue to play a role in this research, although its activity in this area is expected to be somewhat reduced. It is anticipated that some of the industrial use research of Animal Fat Products Laboratory will be redirected to other high priority areas in fiscal year 1977. Nevertheless, AFP is expected to maintain a vigorous, imaginative, diversified research program concerned with the discovery and development of better uses for tallow and other animal fats.

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