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STUDY AND INVESTIGATION OF USE OF MATERIALS AND NEW DESIGN AND METHODS IN PUBLIC WORKS

CONSERVING MATERIALS AND ENERGY IN FARMSTEAD OPERATIONS

PREPARED FOR THE

COMMITTEE ON PUBLIC WORKS
UNITED STATES SENATE

BY THE

AGRICULTURAL RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE



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MEMORANDUM OF TRANSMITTAL FROM THE CHAIRMAN

U.S. SENATE,
COMMITTEE ON PUBLIC WORKS,
July 17, 1962.

To the Members of the Committee:

Pursuant to our committee resolution adopted January 22, 1962, and in response to an invitation to participate in our study on new materials, new uses of materials, and methods used in public works projects, the Agricultural Research Service has submitted a report on conserving materials and energy in farmstead operations.

This report has been prepared by the Farm Electrification Research Branch and the Livestock Engineering and Farm Structures Research Branch of the Agricultural Engineering Research Division, Agricultural Research Service, Department of Agriculture.

The report on conserving materials and energy in farmstead operations reviews new framing methods, and other construction techniques, adaptation of existing buildings for more efficient use, new uses of concrete, development of plastics, and utilization of other materials.

The report contains an excellent discussion on farmstead water supplies and waste disposal. It reviews the many potential uses of solar energy in heating, cooking, drying of harvested crops, insect control, and other such uses. The presentation points up the research and development needs and the possible application of research findings in farmstead operations.

I am sure that you will find the report extremely interesting and informative, and it makes a valuable contribution to our committee study on new materials, new uses of materials, designs and methods in public works.

DENNIS CHAVEZ,
Chairman, Committee on Public Works.

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COMMUNICATIONS

U.S. SENATE,
COMMITTEE ON PUBLIC WORKS,
January 30, 1962.

Mr. BYRON T. SHAW,
Administrator, Agricultural Research Service,
Department of Agriculture, Washington, D.C.

DEAR MR. SHAW: The Committee on Public Works, in executive session on January 16, 1962, approved a committee resolution authorizing hearings, study, and a report on the use of materials in the construction of buildings, roads, water resource projects, and other public works.

To attain the objective of the committee, it will be most helpful if we could obtain the cooperation of industry and the Government agencies in the collection of information called for by the resolution; therefore, it will be appreciated if you will supply us with such information as is related to your interest or activity.

A copy of the resolution is enclosed for your information. If you require further details, please contact Mr. John L. Mutz of the committee staff who is in charge of handling this particular study.

I believe that with the new materials and new uses of known materials being developed and utilized, we should be able to gather considerable information on this subject, thereby making an extremely interesting and constructive contribution to the various producers, fabricators, and users of materials. Furthermore, it would be most useful and helpful if we were to obtain information with respect to new designs and new methods of installation of materials.

It is my hope that your organization will be in a position to appear before the Committee on Public Works to make a formal presentation during the early part of April 1962. After the hearings or presentations are completed, it is planned to have a committee report prepared thereon and submitted to the Senate.

I would appreciate it if you would advise me if you will be able to complete such a report for presentation to the committee at the suggested time, so that we may set tentative dates for the hearings.

Sincerely yours,

DENNIS CHAVEZ, *Chairman.*

[87th Cong., 2d sess., U.S. Senate, Committee on Public Works]

Committee Resolution Providing for a Study and Investigation of Use of Materials in Public Works

Whereas the Senate Committee on Public Works has under its jurisdiction measures relating to flood control and rivers and harbors, roads and highways, public buildings, water pollution control, waterpower, and other matters relating to developments within the Nation; and

Whereas the Senate Committee on Public Works has authority to make investigations into any matter within its jurisdiction; and

Whereas the Senate Committee on Public Works members have been vitally interested in the development, protection, and utilization our Nation's water resources as evidenced by their active participation in the hearing and deliberations of the Senate Select Committee on National Water Resources; and

Whereas there are now being produced and our scientists and technicians, both in industry and Government, are working on and perfecting many new materials and new uses of known materials and it is evident that such materials can be utilized efficiently and economically in the construction of public works, in the protection and operation of such works, in the preservation and proper utilization of our essential water resources and that such materials and their development and use enhance the opportunities for industrial and business growth and strengthening of our Nation's economy; and

Whereas representatives of industry and the Federal Government have shown a keen interest in discussing and disclosing their roles in the fields of research development and utilization of materials: Therefore, be it

Resolved, by a unanimous vote of the Senate Committee on Public Works, That the committee shall institute a study and investigation into the use of new materials, new use of materials, and new designs and methods being used or which may be used in flood control and rivers and harbors, roads and highways, public buildings, water polution control, waterpower and other developments, utilization preservation and protection projects, and that a committee report be prepared thereon and submitted to the Senate.

Sec. 2. Such study and investigation shall include but not be limited to metals, plastics, rubber, coal, petroleum, timber, concrete, asphalt, chemicals and their direct use, uses of their derivatives, or use in combination with each other or other materials, and shall attempt to determine the following:

(a) Description of proposed use of application of the subject material;

(b) General description of the material in terms of physical and chemical characteristics and where possible, obtain a description of the physical or chemical phenomenon responsible for obtaining the desired effect;

(c) Results of laboratory and field tests to prove that the desired effect occurs and prove the durability or duration of the effect of the material;

(d) The limitations of the materials, i.e., problems of toxicity, limitation of effectiveness under certain climate, soil, or physical conditions;

(e) Cost of materials per standard units, i.e., square foot, lineal foot, cubic foot, etc., and cost projection in terms of future production capacity, improved manufacturing techniques, etc.; and

(f) Availability of material both on a current and future basis.

Adopted: January 22, 1962.

Dennis Chavez, *Chairman.*

U.S. DEPARTMENT OF AGRICULTURE,
AGRICULTURAL RESEARCH SERVICE,
OFFICE OF ADMINISTRATOR,
Washington, D.C., February 9, 1962.

Hon. DENNIS CHAVEZ,
Chairman, Committee on Public Works,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This is in reply to your letter of January 30, 1962, concerning a committee resolution authorizing hearings, study, and a report on the use of materials in the construction of buildings, roads, water resource projects, and other public works.

As requested, the Agricultural Research Service will be pleased to furnish information related to the work of this Service. We believe that our part of the report will be completed for presentation to the committee during the early part of April, and members of this Service will be in a position to appear before your committee to make a formal presentation.

Sincerely yours,

B. T. SHAW.

U.S. DEPARTMENT OF AGRICULTURE,
AGRICULTURAL RESEARCH SERVICE,
OFFICE OF ADMINISTRATOR.
Washington, D.C., June 20, 1962.

Hon. DENNIS CHAVEZ,
Chairman, Committee on Public Works,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This is in further reply to your letter of January 30, 1962, concerning a committee resolution authorizing hearings, study, and a report on the use of materials in the construction of buildings, roads, water resource projects, and other public works.

Under separate cover, we are forwarding to you 50 copies each of the following reports: "New Materials and Methods for Water Resource Management," "Conserving Materials and Energy in Farmstead Operation."

If we may be of further service to you, please let us know.

Sincerely yours,

B. T. SHAW, *Administrator.*

FARMSTEAD OPERATIONS
CONSERVING MATERIALS AND ENERGY IN FARMSTEAD OPERATIONS

A REPORT TO THE COMMITTEE ON PUBLIC WORKS,
UNITED STATES SENATE, MAY 1962

PREPARED BY

FARM ELECTRIFICATION RESEARCH BRANCH

AND

LIVESTOCK ENGINEERING AND FARM STRUCTURES RESEARCH BRANCH

AGRICULTURAL ENGINEERING RESEARCH DIVISION

AGRICULTURAL RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE

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ACKNOWLEDGMENTS

This report was prepared in response to a resolution of the Senate Committee on Public Works, Hon. Dennis Chavez, chairman, approved January 16, 1962, providing for a study and investigation of use of materials in public works. More specifically, this report sets forth the use of new materials, new uses of conventional materials, and new designs and methods being used or studied for use on the American farmstead in connection with structures, equipment, utilities, and related facilities.

Mention in this publication of commercial products or their manufacturers does not imply endorsement by the U.S. Department of Agriculture over others not mentioned.

Issued June 1962.
Washington, D.C.

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CONSERVING MATERIALS AND ENERGY IN FARMSTEAD OPERATIONS

A Report to the Committee on Public Works, U.S. Senate, May 1962

INTRODUCTION

We are in the midst of a technological revolution, sparked by scientific and engineering research, that is changing our agriculture and our way of living. It is evidenced in "new and more efficient machines, sources of power, ways of getting work done; in better ways of transporting, processing, storing, and marketing food; and in the wiser and more effective use of resources"(*5*)[1].

The effective and efficient use of farmstead structures, equipment, and energy (the work of the agricultural engineer) is essential to the production of plenty of good food—one of man's basic needs—in a democratic, civilized society such as ours (*22*). The work of the agricultural engineer has been instrumental in providing our agriculture with the power to produce that has made the United States the well-fed Nation it is (*29*).

Agriculture is this Nation's greatest user of energy. Agriculture uses more petroleum than any other industry plus 27 billion kilowatt-hours of electric energy annually. The increasing use of energy, and the resulting depletion of our Nation's supply, presents a challenge not only to make efficient use of what we have but also to devise new uses for our renewable energy.

In the United States today one man on the farm produces the food for about 27 of his fellow Americans, which leaves them free to carry on the industry, commerce, and other facets of our national economy, including its defense (*30*, p. 3). That man—the farmer—needs efficient buildings and he uses many materials to get them (fig. 1.).

Every one of the nearly 4 million (*33*, p. 1) farms in the United States requires some structures and equipment—homes for the workers; shelters and processing buildings for livestock and products; storage for feed, supplies, machinery, and products; and miscellaneous utility and service facilities such as water supplies, waste disposal installations, yard and lot pavements, fences, feeders, and veterinary and handling facilities for stock (fig. 2). On January 1, 1961, these structures and related equipment were being used in handling livestock and poultry having a total cash value of $15.5 billion (*32*, table 9). During 1960, 7.1 million farmworkers (*31*, table 6H) used these structures and equipment in producing livestock, crops, and other agricultural products that had an aggregate cash value of $35.4 billion (*31*, tables 9H and 12H) and from which farmers earned an average net income of $2,056 (*31*, table 6H) each.

---

[1] Italicized figures in parentheses refer to references, p. 41.

	DWELLINGS	ANIMAL SHELTERS	CROP STORAGES	FENCING	PAVEMENTS	FEEDERS	SHOPS & MACH. STOR.	GREENHOUSES
WOOD	●	●	●	●		●	●	O
CONCRETE	●	●	●	●	●	●	●	O
BRICK	●	O					O	
TILE	●	O	●				O	
STONE	●			O			O	
STEEL	●	●	●	●		●	●	●
ALUMINUM	●	●	●	O		O	O	O
ASBESTOS	●	O					O	
ASPHALT	●	●			●		●	
PLASTIC	●	O	●				O	●
GLASS	●	●					●	●

●—COMMONLY USED

O—OCCASIONALLY USED

FIGURE 1.—Major materials used in farm structures and related equipment.

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DOLLAR VALUE OF FARM BUILDINGS IN UNITED STATES

TOTAL INVENTORY, MARCH 1, 1961 --- $28.4 BILLION

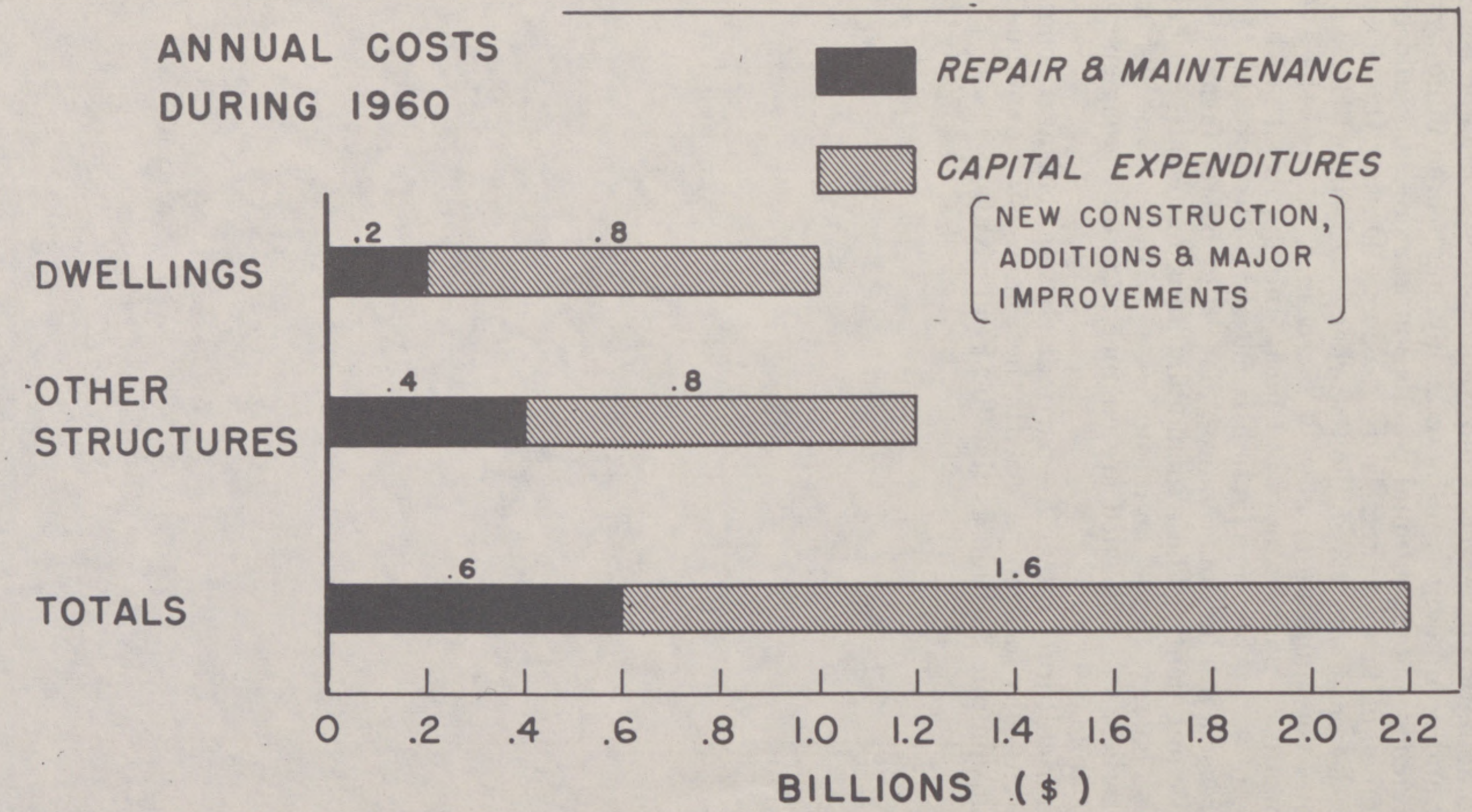

FIGURE 2.—Dollar value of farm buildings in the United States (*31*, Tables 16H and 17H; 32, p. 8).

Total farm production assets (*32*) are increasing, but average assets per farm (*32*) are increasing nearly twice as fast (fig. 3). The increase in assets per farm reflects not only the general rise in prices but also a combination of larger farming enterprises, more and costlier machinery and equipment, and more highly engineered buildings.

Each year our national population is increasing, and each year the number of farmworkers is decreasing. During the decade 1950–60, the decrease was 2.8 million workers (*31*, table 6H). Also, our per capita consumption of meat is increasing; in 1960 the average American ate 33 pounds more red meat and poultry than he did in 1940 (*30*, p. 9). Meat production is closely related to the farmstead and increased production requires more and better farmstead structures and equipment. These include building materials, agricultural chemicals, energy forms and sources, and other types of supplies and materials. Also needed are engineering and management knowledge and ability.

Agricultural research—particularly agricultural engineering research—has to keep pace with these increasing demands if we are to maintain our position as the "best fed" Nation.

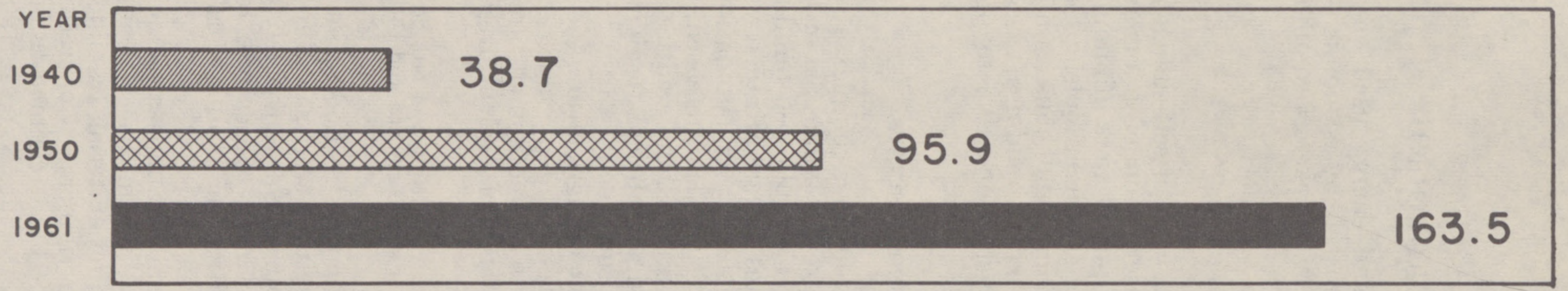

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FIGURE 3.—Farm production assets (*32*, tables 16 and 17).

HISTORICAL BACKGROUND

Materials, structures, equipment, and energy used on the farmstead are developed to meet needs created by economic, sociologic, and technologic changes—changes in markets, communications, power, and construction techniques (*27*).

THE PIONEER PERIOD

The pioneer period in our history was one of self-sufficiency. Survival was a primary objective. Conservation of natural resources was not a factor. Structures and equipment were minimum—native materials (logs, earth, and sod) and a few handtools. The pioneer geared his production to feeding, clothing, and housing himself and his family. Livestock shelters and service buildings were crude or nonexistent. Wood was the major fuel. Incentive to produce for market was lacking.

PERIOD OF EXPANDING MARKETS

The period of expanding markets brought a complex of economic, moral, and technologic advances that greatly influenced farm production and its tools. More advanced and complicated buildings began to appear—first in the Northern States, where winters were severe enough to emphasize the need for shelter. As population density increased in the market areas, competition also increased, and more attention was devoted to improving production facilities. Electric energy began to reach the farm. Designers began to give attention to saving chore labor and using power equipment.

With the creation of the Department of Agriculture and the land-grant colleges research activities were initiated, which eventually progressed into the farmstead structures and equipment area.

In the report of the U.S. Commissioner of Agriculture in 1867, it was said:

> * * * Large and excellent barns have greatly multiplied of late, and many of them are planned and built upon principles of sound science and the most rigid business economy * * *.

Lumber was the principal building material. Logs came from the virgin forests to the lumber mills, where they were sawed for building purposes. Conservation of timber resources was not widely practiced.

In 1878 a unique barn was completed in Muscatine, Iowa, that featured bent, laminated rafters, facilities for handling grain, labor-saving arrangements, and air conditioning.

By about 1900 heavy framing timbers became scarce and builders were forced to seek other materials and means of construction. Although wood remained a major building material, framing methods had to be developed to use the lighter timbers. Concrete began to gain prominence and a truss steel-frame barn (claimed to be the first in the United States) was built in Fayetteville, N.Y., in 1907 (*8*).

About 1900 marked the beginning of the use of electric energy on farms. One of the first farms to be wired was near Philadelphia, in 1898, and about this time the first farm electric motor was used, in California.

THE MODERN PERIOD

The modern period—featuring buildings designed to accommodate machinery and equipment for saving labor and controlling environment—dates from about the period of the First World War. Building materials changed rapidly in this era. Farming trended more rapidly away from the traditional "way of life" toward an "industrial enterprise." By 1919, 1.6 percent of U.S. farms had received electric energy. This figure had increased to 10.9 percent by 1934.

Wood shingles continued to be the primary roofing material through the 1920's, but then gave way to the new composition asphalt shingles.

New framing methods

New framing methods brought into use plywood, laminated rigid-frame bents, insulating board, and pressed board—all aimed at fuller utilization of that important resource, the tree.

In 1923 a farmer in Mulliken, Mich., contracted with a bridge company for an all-steel barn (said to be the first in the United States). Soon thereafter, many manufacturers could furnish steel hay barns, sheds, garages, hog houses, and brooder and chicken houses (fig. 4).

New uses for concrete

Concrete had been used for floors, tanks, slabs, walks, and foundations for some time, but its use for walls had been limited because of the heavy forming and equipment needed for monolithic construction. In 1925, concrete walls made from panels were tilted into position for a house in Iowa. Thus was eliminated the need for heavy forming by casting wall panels in skeleton forms laid on a flat surface. This technique has extended the use of concrete to machine sheds, trench and bunker silos, poultry houses, and dairy and other service buildings. The outlook for developing improved panels and for increasing their use is promising as more research effort is applied.

Development of plastics

Chemical research about the time of the Second World War began to develop a wide variety of plastic materials that have a wide variety of applications to farm buildings. These materials became available for use as cores, coatings, fillers, structural members, tubes, and pipes, and they show excellent promise for increasing application to the farmstead.

New construction techniques

Concurrent with development of new building materials and less wasteful use of materials sources were efforts to develop construction techniques that would more fully and efficienctly utilize the inherent strength of the materials incorporated into structures. Examples are the hyperbolic paraboloid (HP) roof section, which utilizes the tensile strength of thin sheets in contrast to the shear and bending resistance of heavier framing members; and improved joint design, which balances joint strengths with member strengths of trusses and other structural frames. Both of these reduce the amount of material required to support a given load over a given span.



FIGURE 4.—Steel is now widely used in farm structures. This is a modern dairy building under construction.

Pole construction, used for temporary buildings since pioneer days, has recently achieved wide popularity for permanent structures. Improved methods of thoroughly impregnating the poles with preservatives have been discovered and new tractor attachments, such as posthole diggers and lifts, make it possible to erect poles with farm equipment. Pole buildings generally cost less and require less carpentry skill and time for erection than conventional methods of construction. The improved preservatives and methods of applying them have been important in conserving our wood resources. Tests of holding power by USDA agricultural engineers (fig. 5) were helpful in developing design criteria for pole construction.

During the 1950's the livestock farmer struggled in an ever-tightening cost-price squeeze. The margin between production expenses and gross income narrowed by one-fourth during this decade (*31*, table 1H). Efforts to improve production efficiency, and thus lower production costs, gained momentum. Reduction of wastes of all kinds—structures, materials, power, and labor—assumed new importance. Research to improve buildings, equipment, methods, power sources, and their use was initiated and expanded.

Expansion of rural electric lines after World War II by both private power companies and REA-financed cooperatives has resulted in an investment of more than $5 billion to provide service on more than 96 percent of U.S. farms. By 1959, the Nation's farms used 27 billion kilowatt-hours of electric power annually. This is one reason an hour of labor now produces 4½ times as much as in 1910 (*12*).

Materials Handling Conference

Widespread interest led to a nationwide Materials Handling Conference, sponsored by the American Society of Agricultural Engineers (ASAE) and held at Iowa State College, Ames, Iowa, in September 1958. This conference was attended by agricultural engineers, economists, farm managers, and others from all parts of the United States and some foreign countries and provided opportunity for worthwhile exchange of much valuable information. The formal papers presented at the conference were published by the society (*2*).

Conference on Farmstead Engineering

A similar nationwide Conference on Farmstead Engineering, sponsored by the ASAE, the Agricultural Engineering Research Division of the U.S. Department of Agriculture, and the University of Illinois, was held at the University of Illinois, Urbana, Ill., in September 1960. It was likewise broadly attended and the source of much valuable information. The formal papers presented have been published by the society (*3*).

Increased demand for water

Demand for water on the farmstead has increased over the years and will continue to increase in the future. The modern farmstead has piped water under pressure in the dwelling, in the service buildings, and at strategic points around the yards and lots. Developing supplies of satisfactory quality and quantity to meet these demands becomes more and more difficult. The increased use of water increases problems of liquid wastes disposal. The problems are particularly difficult with respect to disposal of liquid manures in the vicinity of metropolitan areas as these areas continue to spread out into formerly agricultural areas. Much more research is needed on these problems.

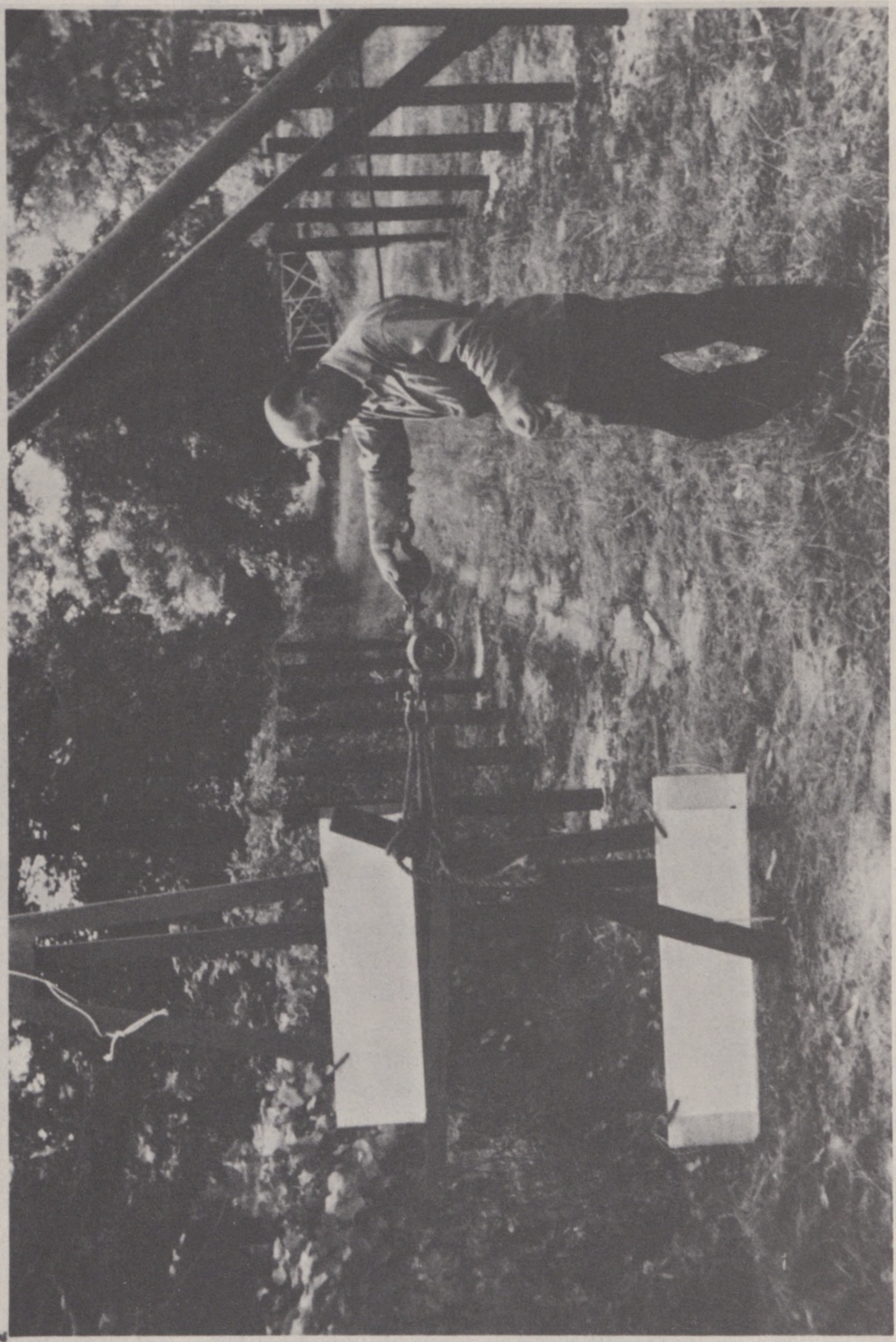

FIGURE 5.—Treated poles make good durable low-cost structures. In this test plot at Beltsville, Md., poles with different embedments were checked for holding power against vertical and horizontal loads.

PROBLEM AREA DOCUMENTATION

Time is running out; our civilization's energy needs will soon outrun nature's declining store of fossil fuels. Before this happens, ways must be found to use solar and atomic energy. Solar energy must be collected and stored. Collection and storage are the keys. New materials are important in the work now being done. Especially important is plastic for solar collectors.

It has been hypothesized (*24*) that nearly 10 percent of our energy will be obtained from solar collectors by 2050. Dr. Abbot of the Smithsonian Institution reported in 1939 that one southwest State could supply from solar radiation, energy equivalent to that currently used for heat, light, and power in all the United States (*1*).

AVAILABILITY OF SOLAR ENERGY

All known energy sources on the earth, with the exception of tides and nuclear fuels, are products of radiation from the sun. Energy stored in the fossil fuels (such as coal, oil, and natural gas) and in growing plants require sunlight for photosynthesis. Winds are caused by variations in the heating of air by solar energy. Even waterpower is available because the sun's heat has evaporated sea water and lifted it to higher levels.

The thermodynamic efficiency of these natural processes, however, is low. Thus, the application of engineering principles may make sunpower much more useful to mankind.

According to a report of the President's Materials Policy Commission (*23*), an average of 1,500 times the present total daily fuel energy requirements of the United States strikes its land area each day in the form of solar energy. In spite of the abundance of this undiminishing source of power the bulk of the energy now used for heat and mechanical power comes from fossil fuels which are virtually irreplaceable.

The intensity of solar radiation at normal incidence, at the outer limit of the earth's atmosphere, and at the mean solar distance, is termed the solar constant. At present the most accurate determinations fix the value of the solar constant at 419.40 B.t.u./(ft.^{2})(hr.) $\pm 3\frac{1}{2}$ percent. The variation is due primarily to the fact that the earth is closer to the sun in winter than in summer (*17*).

Because of several depletion factors, however, solar radiation intercepted by a surface on the earth at a given time is less than the solar constant. The intensity at a given place varies with the latitude, the time of year, the time of day, and the attitude of the receiving surface (fig. 6). On cloudless days when the sun is directly overhead the intensity of direct solar radiation on a normal surface reaches a maximum of about 340 B.t.u./(ft.^{2})(hr.). Insolation rates for a cloudless day on various oriented surfaces at 35° north latitude at the summer solstice are shown in figure 7.

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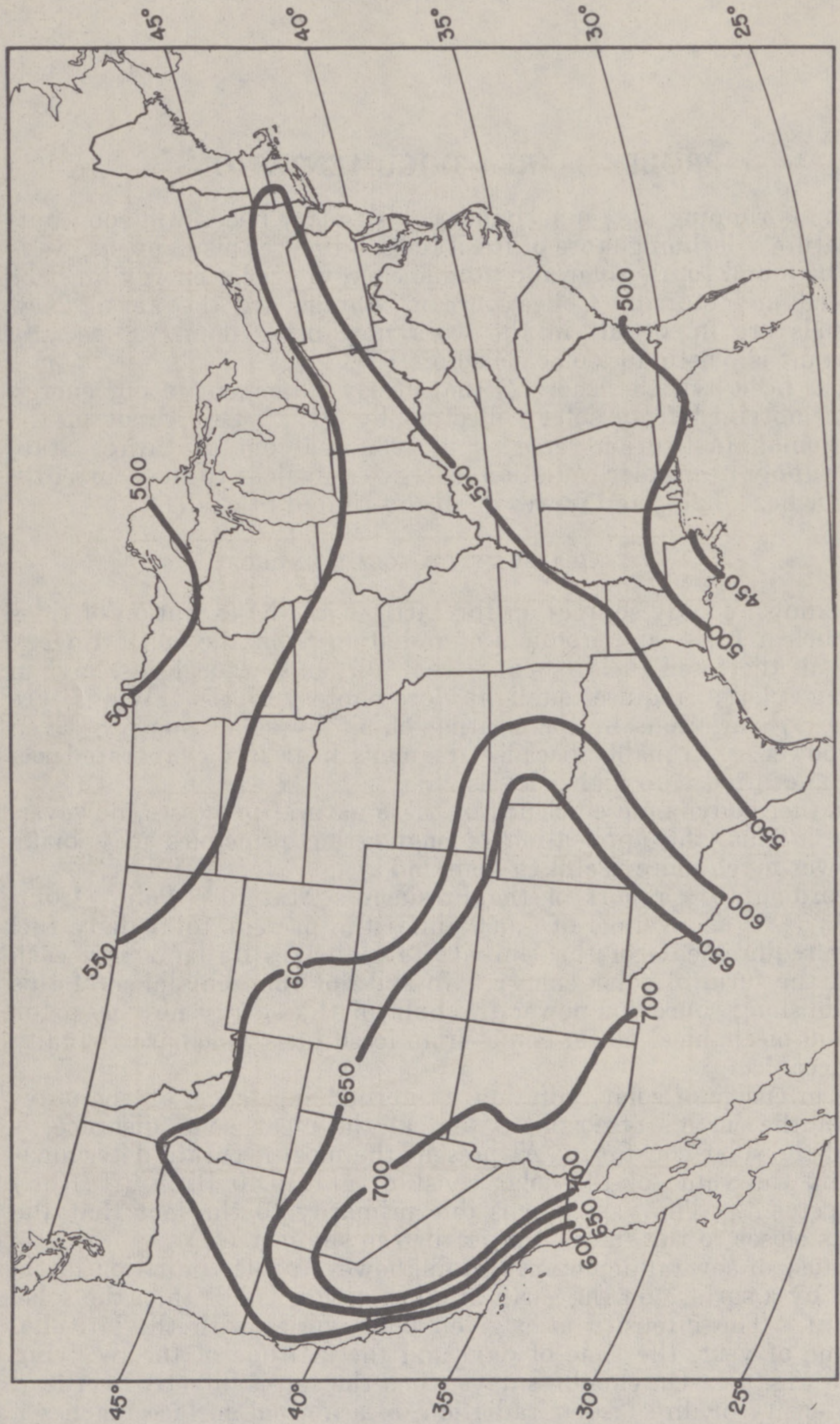

FIGURE 6.—Average total daily insolation rates for June days on a horizontal surface on the ground, langleys per day. (Multiply by 3.69 to convert to B.t.u. (day) (ft.^{2}). Note: Insolation rates are greater in June than in any other month. Source: Fritz and MacDonald (*13*).

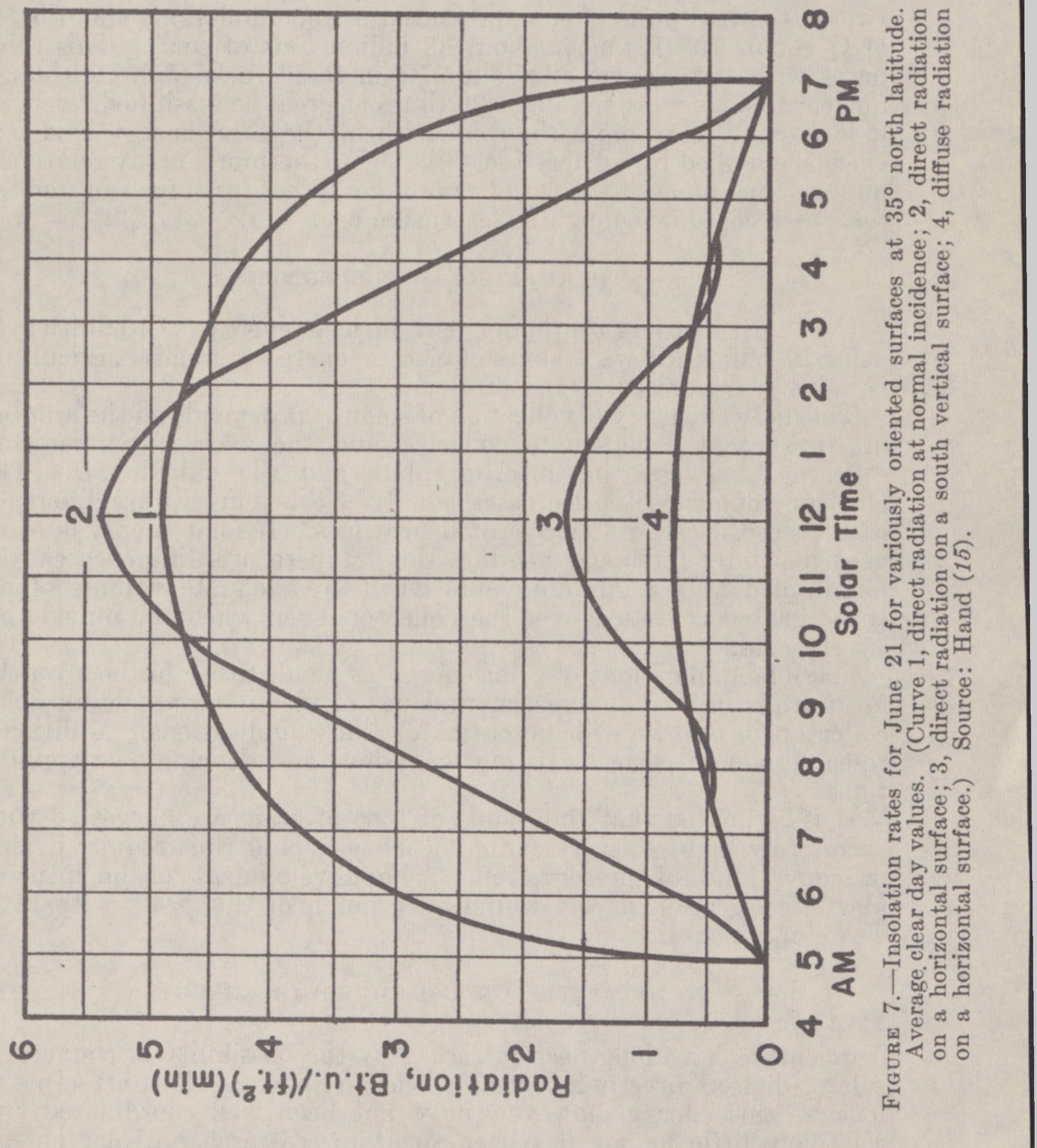

FIGURE 7.—Insolation rates for June 21 for variously oriented surfaces at 35° north latitude. Average clear day values. (Curve 1, direct radiation at normal incidence; 2, direct radiation on a horizontal surface; 3, direct radiation on a south vertical surface; 4, diffuse radiation on a horizontal surface.) Source: Hand (*15*).

IMPORTANCE OF NEW ENERGIES

It has been estimated that our presently known reserves of fossil fuels may be depleted within 70 to 250 years to the point where their low-cost extraction is no longer possible (*17*). Our estimated reserve of low-cost nuclear fuels (not more than double the 1950 cost per British thermal units of coal, measured in 1950 dollars) is about 575Q (1 Q equals 10^{18} B.t.u. or about 38 billion tons of coal). This compares with our reserve of about 27Q in fossil fuels (*24*). Although nuclear fuel reserves are about 20 times as great as fossil fuel reserves, it is unlikely that more than one-fifth of the total energy load will ever be supplied by nuclear fuels (*23*). Furthermore, many relatively undeveloped areas of the world cannot get either fossil fuels or nuclear fuels at a cost low enough for extensive use.

THERMAL SOLAR COLLECTORS

U.S. agriculture is the major user of heat energy. In addition to using 27 billion kilowatt-hours of electric energy annually, agriculture is industry's largest user of petroleum.

The daily efficiency of collection of solar heat depends on the number of transparent covers in a collector and the average temperature difference between the absorber plate and the outside air. The efficiency of a collector decreases rapidly as this temperature difference is increased because of accelerated heat loss. If solar energy is to be used in winter for house heating, this temperature difference can be maintained at a minimum value when an adequate volume of air to be heated is passed over the collector, even when the outside air is very cold.

Possible applications of solar energy as a substitute for heat on the farm are many. The experimental use of plastic materials for solar collectors has shown wide potential for many applications. Additional research should perfect existing know-how and develop new applications.

It is estimated that thousands of tons of grain are harvested with excessively high moisture content each year and thus require drying or some kind of preservation. The development of inexpensive plastic solar grain dryers would save much of this grain with little waste or expense.

NEW IMPETUS ON USE OF SOLAR ENERGY

Past efforts

Scientists have long been intrigued by the possibility of converting solar radiation directly into usable heat and power. Past attempts to harness this energy, however, have not been well coordinated and relatively little money has been spent for research on solar energy applications. Since 1945, however, interest in this field has increased considerably. In 1955, the chairman of the executive committee of the Association of Applied Solar Energy Research stated that the problem of harnessing this energy presents scientific, technological, and economic challenges worthy of extraordinary effort and unusual initiative, before world energy supply becomes a critical problem.

The President's Materials Policy Commission (*23*) predicted that, by 1975, some 13 million dwelling units might be heated with solar

energy if sufficient research and development is devoted to the problem.

Recent developments

Recent developments include the building of experimental houses heated wholly or in part by solar energy (*16*, *21*, *26*); a solar cookstove which can be sold for about $5 (*7*); a Russian solar refrigerating plant producing 250 kilograms of ice per day (*7*); the installation of a solar battery for powering telephone circuits at Americus, Ga.; the discovery of a method of artificial photosynthesis at the University of California (*7*); and the initiation of a research project at Manhattan, Kans., to study the combination of solar heat collectors and heat pumps for farm use (*9*).

NEW SOURCES OF ELECTRIC ENERGY REQUIRED

The generation of electricity for small loads in remote locations has long been a problem. Improved solar thermoelectric generators are needed.

Direct generation of electric power from new sources of fuel is of great concern to the Nation. Some basic research has shown that this is possible for limited applications.

Generation of electric power from new materials that are now useless or from waste material would save our fast depleting supply of fossil fuel—for example, a biochemical cell that would use waste wood, sewage, and so forth.

More than 40 million tons of chemicals are used annually in agriculture. The bulk of these chemicals not used for fertilizer are applied for insect and weed control. When not carefully used these chemicals not only are injurious to man, but they can kill bees and other beneficial insects.

A universal light trap capable of attracting and killing economic insects is needed. In addition, light traps capable of attracting certain specific insects for detection purposes are also needed.

These insect traps require a source of electric energy. In many instances, conventional electric service is not available or is not practical to use.

A small inexpensive portable power supply is needed to operate these insect attractant traps. Some of the potential sources of such a power supply are:

Fuel cell.
Thermoelectric generator—solar operated.
Thermoelectric generator—fuel operated.
Biochemical cell.

Hundreds of traps are presently being used by the Federal Government in surveys of insect infestations to determine control measures. Some are used at ports of entry to monitor foreign infestations.

Other traps are used to check insect migration from county to county and from State to State. A new portable power source is needed for these traps.

ELECTRORECLAMATION FOR ALKALI SOILS

The term "electroreclamation" refers to electric treatment of alkali soils to reduce the sodium content and improve drainage. Some work has indicated intriguing success in using electric treatment of alkali soil while other work has indicated it to be of little value. On an energy basis, the successful use of electric treatment is as yet unexplained.

Irrigation agriculture has been and will continue to be one of the primary factors sustaining the growth of the semiarid and western portions of the United States. But irrigation agriculture has yet to free itself of the serious problem of controlling the salt or alkali conditions which inevitably are present in many irrigated areas.

Land which is, or can be made, productive for agricultural purposes constitutes one of our most valuable natural resources. About 600,000 acres of land in the Western States could probably achieve greater crop production through improved drainage and removal of excess soluble salts and exchangeable sodium. It is not unreasonable to assume that another 400,000 acres of land within, or adjacent to, these reclamation developments have not been brought under irrigation because economic means of reclaiming the soils are not available. On privately developed irrigated land in the Western States about 900,000 additional acres could achieve increased production by removal of excess ions or exchangeable sodium.

A recent survey shows that approximately 28 percent of the irrigated acreage in the Western United States and Hawaii has been damaged by excess salts. In addition to this, thousands of acres of our present irrigation projects could be saved from a complete loss or marginal production caused by increased alkali soil condition.

A research program involving soil and electroagricultural engineering scientists is needed to establish the basic factors involved and to provide authentic information for farmers on the economy of such treatment under varying soil conditions.

FARM STRUCTURES NEEDS

In 1957, the American Society of Agricultural Engineers submitted the following 3 questions to about 25 well-informed persons in each State (*4*):

1. What is the most urgent problem affecting farm buildings or the farmstead as a whole?
2. What major changes in farm practices that will affect farm buildings do you expect by 1965?
3. What major problems related to farm structures or the farmstead will need solution by 1965?

The problems and needs reported most often are listed below:

How to adapt existing buildings for more efficient production

Labor requirements in many farmhouses and service buildings remain excessive because the buildings are not adapted to use of laborsaving equipment or methods. Since it is impractical to replace all obsolete buildings in the near future, ways must be found to improve them. Adaptation of existing buildings for the transition from diversified operations to larger, more specialized enterprises requires special attention.

Lower cost, more efficient, and more flexible buildings for tomorrow

Farmers believe that building costs are out of line with farm income and that ways should be found to lower them. Buildings for tomorrow must be efficient and easily adapted to a rapidly changing agriculture. Suggestions included new structural designs, use of lower cost materials, and the "package building."

Engineered farmstead design

Design of farmsteads for efficient flow of materials, fire safety, and adaptability to meet future requirements.

Mechanization

Development of efficient but not too costly systems for handling materials, coordinated with building design and suitable for inclusion in the building package.

Better utilities

More adequate and sanitary water supplies; waste disposal systems that are sanitary and permit utilization of the wastes; and more adequate electric service.

These replies (from consulting agricultural engineers, representatives of industry, country bankers, extension workers, agricultural specialists in the colleges, leading farmers, rural businessmen, and other leaders of the agricultural community) reflect a widespread recognition of the need for greater efficiency on the farmstead. More particularly, they present a tremendous challenge to the research worker to develop farmstead building design and layout criteria that will conserve manpower and material resources while improving the competitive position of the farmer.

BRIEF REVIEW OF CURRENT RESEARCH AND POTENTIAL APPLICATIONS

CONSTRUCTION MATERIALS AND METHODS

New and improved construction materials and methods are continually being developed by industry, by design and consulting engineers, and by contractors. Agricultural engineers, mindful of the unique requirements of farm buildings, are constantly studying these new materials and methods for their applicability to use on the farmstead. In addition, research agricultural engineers are also experimenting with new materials and better ways of using existing ones for farm construction.

The objectives of the research and development work being done by agricultural engineers in this field include utilization of plentiful materials; conservation of scarce resources; increased strength with less material; simplicity of erection; greater durability; increased flexibility of use, reuse, or both; and reduction of building costs. All these objectives must be achieved while maintaining or increasing the effectiveness and efficiency of the buildings in serving their intended functions. Examples of this research are presented below.

Earth building blocks stabilized with portland cement

Earth building blocks stabilized with portland cement are proposed for use where there is ample labor and little capital (*18*). They are made in a hand-operated press designed by an engineer in Chile and manufactured in Bogotá, Colombia, and Richmond, Va. The blocks are nominally 4 by 6 by 12 inches for modular construction.

The material is organic-free earth, with from 5 to 10 percent by volume of portland cement. The objective is a block that is more resistant to weathering than adobe brick, but lower in cost than concrete block. Sandier soils provide a better base material than soils with clays or organic materials.

Laboratory tests show that the 28-day compressive strength is highly variable, much lower than the strength of brick or concrete but many times that required for the ordinary building wall. Field tests show the block has a tendency to spall when in positions subjected to large changes in moisture.

Hand manufacture of the block is very time consuming. Only about 100 blocks can be made per man-day. Their resistance to weathering is not as good as concrete block or structural clay masonry. They are not satisfactory for use in fully exposed walls in humid climates subjected to freezing and thawing. They should be used only above grade where they are protected from capillary water and splash from the building eave—and not directly on top of floor slabs.

Material costs are low ($0.02 per block), but at wage rates of only $0.50 per hour, a square foot of wall 5½ inches thick will cost about $0.30 in place.

Materials are readily available.

Mortar-surfaced polystyrene building panels

Mortar-surfaced polystyrene building panels (fig. 8) were developed for farm and rural application (*19*, *28*). They can be lifted and placed by two men and do not require heavy cranes. They present a smooth interior finish desirable for milking rooms and similar applications where insulation and sanitation are important. Windows may be cast into the panels.

The panels are 2 feet by 8 feet by 3 inches thick, and have a 2-inch core of expanded polystyrene, foamed glass, polyurethane, or semirigid insulative material. The weathering faces are ½-inch thickness of portland cement mortar, reinforced with 14-gage galvanized prestretched wire, spaced 1 inch on centers. The faces are tied together with reinforced buttons of mortar to serve as a connecting web.

Laboratory tests show reasonably consistent performance under load. Ultimate strength is sufficient to support a uniform loading of about 60 pounds per square foot. In field tests, panels have been mounted horizontally and fastened with a single lag screw to pressure-treated wooden posts placed on the exterior. Calked horizontal joints without ship lapping or tongue-and-grooving have resisted water penetration satisfactorily.

Tests to date have indicated no particular restrictions on use of these panels in normal rural construction.

Materials costs presently are about $0.30 per square foot. Volume purchase should reduce this figure to about $0.20 on the present market.

Availability of the materials going into these panels should increase and their prices should decrease.

Sheet materials for hyperbolic paraboloid (HP) roofs

Hardboard, plywood, sheet metals, and plastics such as polyesters, concrete, or fiberglass reinforced asphaltic materials can be used to span roof areas by taking advantage of the structural properties of the sheet to resist design loads (*20*). Application to rural structures is being studied (fig. 9).

The HP shape utilizes the shear strength of sheet materials by giving them a warpage that subjects one directional element within the material to compression and another, at the same point in the shell, to tension, resulting in only shear stress in the material. This principle causes the shell stress to be a linear (not quadratic) function of the span.

Loading tests on prototype roofs have been used to check computed stresses with attendant deflections. Field trials have been made with roofs fabricated of aluminum, plywood, hardwood, insulation board, and thin shell plaster. Weather coating surfaces of polyester and fiberglass reinforced asphalt are being evaluated. In designing HP roofs with sheet materials, deviations from the true HP shape cause secondary stresses to be of major concern and further studies are being made to formulate expected secondary stresses.

The principal limitation on the use of sheet material in this method of construction is the need for economical fabrication techniques, particularly in fastening the sheets together to obtain adequate shear strength in the joints. Also, weatherproofing problems are greater on curved roofs than on plane roofs.

The cost of materials for a given span is less with HP roofs than with conventional roofs. Fabrication techniques, at present, are more expensive.

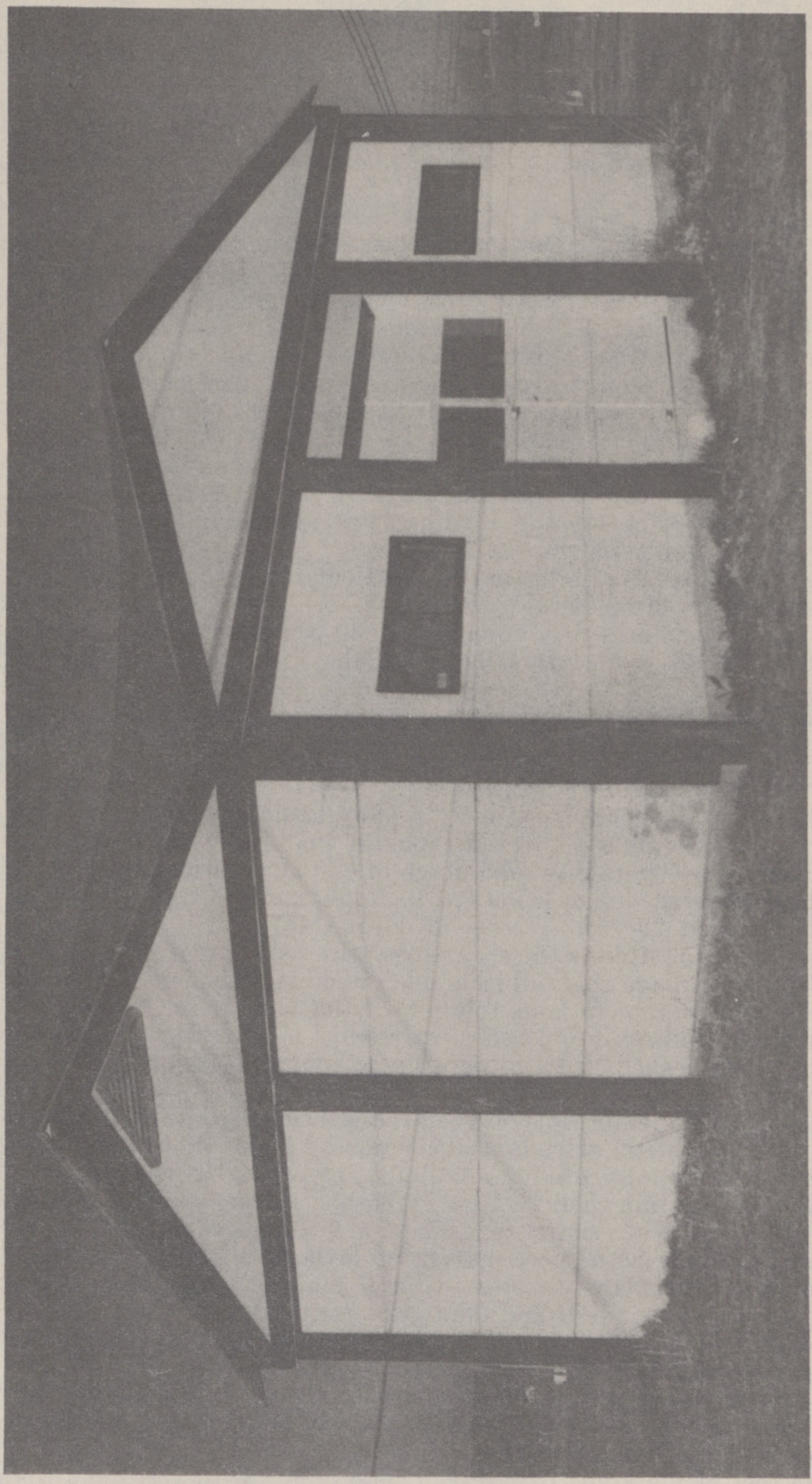

FIGURE 8.—Experimental structure using mortar-surfaced polystyrene building panes under test at Beltsville, Md. These panels are lightweight, durable, and easy to handle.



FIGURE 9.—Agricultural engineers testing experimental hyperbolic paraboloid (HP) roof at Beltsville, Md. The HP roof shape conserves material by using light sheets carrying their load in tension rather than heavier structural members in compression or bending.

Materials for HP roofs of sheet materials are readily available.

Conventional and horizontal silos to store grass crops as low-moisture silage

Perennial grass crops are a desirable deterrent to runoff, and thus help conserve ground water supplies and reduce soil erosion and silting problems.

In the past, most of these grasses were harvested as dry hay; average harvesting and storage losses were high.

Preliminary studies show that these losses can be reduced and the maximum feed value maintained if the crop is harvested and stored as heavily wilted silage in conventional silos with proper procedures to exclude air (fig. 10).

Studies show that both young and old cattle will consume as much dry matter or more when fed heavily wilted silage as when fed top quality hay. The crop must be harvested and treated so that it can be wilted to about 50-percent dry matter in a time period ranging from a few hours to 1 day to minimize weather hazards in humid areas.

Preliminary work indicates that harvesting, storage, and feeding costs can be minimized by using structures, machinery, equipment, and procedures designed to store the material efficiently and handle it mechanically.

A wide range of materials such as concrete, tile, steel, wood, earth, and plastic are readily available for silo construction in all parts of the country. Research is needed to wed materials and methods into easily followed practice.

Farm building plan development

Working drawings for typical farm structures—farmhouses, livestock shelters, crop storages, and related structures—are being developed and made available to farmers.

These plans are developed in close coordination with Federal, State, and private agencies. The plans incorporate research findings on functional and other requirements of farm buildings, and latest developments in building materials and structural practices. They also follow recognized good architectural practices.

Design features that have been proved in laboratory and field tests under actual farm conditions are incorporated into the plans as they are developed.

The plans are developed on a "typical" (representative of a type) basis for farmers in general; they are not prepared on an individual basis for specific individual farmers. An individual farmer may, either on his own or in consultation with extension workers, adapt a typical plan to his individual needs.

Drawings are available to farmers at a nominal cost.

The demand for plans for the numerous types of structures to meet the needs of the wide variety of climatic, market, and other agricultural conditions presently exceeds the development capability. It is expected that the demand will continue to increase so that the availability of current, up-to-date plans may show a decline with respect to the demand.

Paving of farm lots

Studies have been made on the cost and effectiveness of asphaltic and concrete materials for farm barn lot pavements (fig. 11).

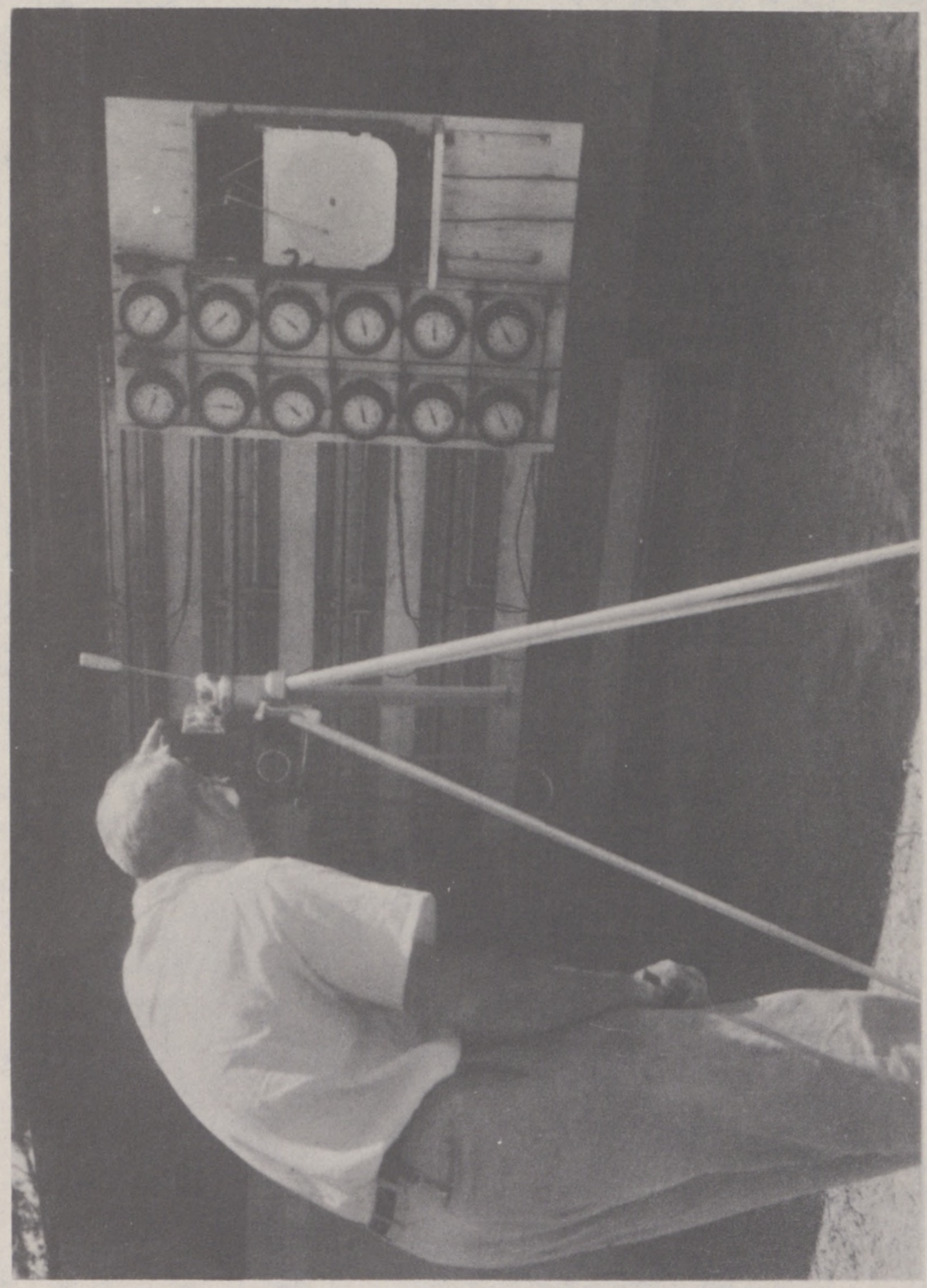

FIGURE 10.—Agricultural engineer checks pressures of silage against walls of experimental silo at Athens, Ga. A good silo preserves the nutrient value of that renewable resource, grass, so that it may be stored for use as feed for livestock.

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FIGURE 11.—Agricultural engineer evaluates pavement strength. Yard and lot pavement materials must resist pressure and abrasion from hooves and manure and other chemical attack, as well as weathering and traffic loads.

Since 1955, comparative tests of limited scope have been conducted on emulsified asphalt, hot plant mix asphalt, cutback asphalt, and air-entrained concrete. Limited studies have been made in cooperation with the University of Maryland on the effectiveness of mixing concrete in place in farm barnyards.

Observations to date indicate that hot plant mix asphalt is superior to the other asphaltic pavements.

Manure dropped by cows feeding on fresh green pasture has caused some trouble when a fine surface finish is rolled into a coarser sublayer of asphalt. In cleaning the manure from the pavement under these circumstances, the surface layer tends to lose its adhesion to the base.

Availability of materials depends largely on the locality, as shipping costs are a major factor in paving installations.

FARMSTEAD UTILITIES AND EQUIPMENT

Water supply

An adequate supply of satisfactory water is essential on the farmstead. Automatic running-water systems, more water-using equipment, new uses for water, higher standards of sanitation, and other factors are continually increasing the demand for water on the farmstead—both in quantity and quality. The "old well" is less and less able to satisfy the demand. Some farm operators have been forced to buy water by the tank or truckload at considerable cost; others are developing farm ponds as sources of farmstead water; some are operating with a supply that is becoming less and less adequate, with the result that they are under a handicap that is becoming greater and greater

In response to the urgent need for information on farmstead water demands and water systems requirements, the USDA has recently initiated a small-scale research project, in cooperation with the University of Maryland, to develop water-use data. Because of limited resources the work is presently confined to only one type of farming enterprise in only one State, but it is an excellent means of developing techniques and equipment that would permit ready expansion to include other areas. Figure 12 shows a schematic diagram of the water-use measuring system developed, and figure 13 shows the water-use data recording equipment mounted in a small van and in position on a farm.

The status of the farmstead water requirements project is briefly presented below.

Equipment has been developed for automatically recording water-usage data on the several branches of a farmstead (house and service building area) water system. These data will be incorporated into a study to determine and compile the water requirements of a modern farmstead.

The equipment sends electric impulses from individual water meters to remotely located scanning and counting switches, which punch the readings on tape for subsequent analysis.

Recorded data on actual farmstead usages will be analyzed and supplemented by results of laboratory studies to develop equipment and methods for accomplishing the tasks with less water and for "reusing" or reclaiming wastes for reuse.

MEASURING WATER USE

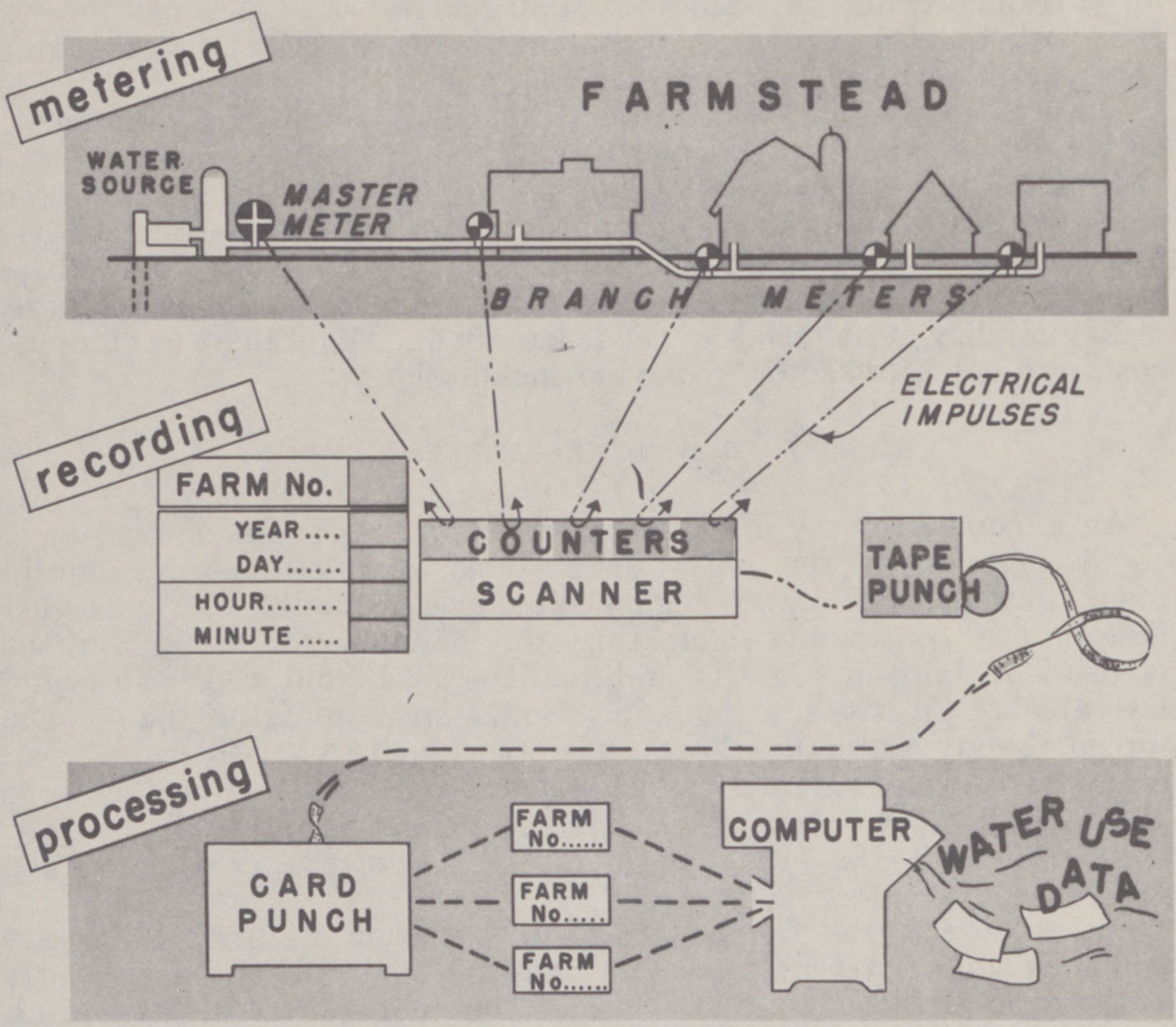

FIGURE 12.—Water is a precious material on the farmstead—precious enough to measure. This schematic diagram illustrates the essential elements of a system developed to measure, record, and analyze its use automatically.

Results of this work are expected to be helpful to farmers and extension workers for planning water systems and selecting water-systems equipment; to manufacturers for guiding equipment development and production programs; and to codemaking authorities in developing suitable codes.

Water as a production and processing material on the farmstead is in continually greater demand and it is likely that this increasing demand will continue into the future. Availability is not keeping pace with the increasing demand.

Wastes disposal

Disposal of organic wastes—principally sewage and manures—is becoming more and more of a problem on the modern farmstead. It has been estimated that the cattle, hogs, sheep, horses, and poultry on farms in 1959 produced more than 2 billion tons of manure (*11*). The problem is particularly acute with respect to disposal of manures from confinement-type livestock operations on the fringes of metropolitan areas (*25*). In this type of operation, the animals are confined to a relatively small area, often paved, to which feed is brought and from which manure is hauled or flushed. Since the animals do not

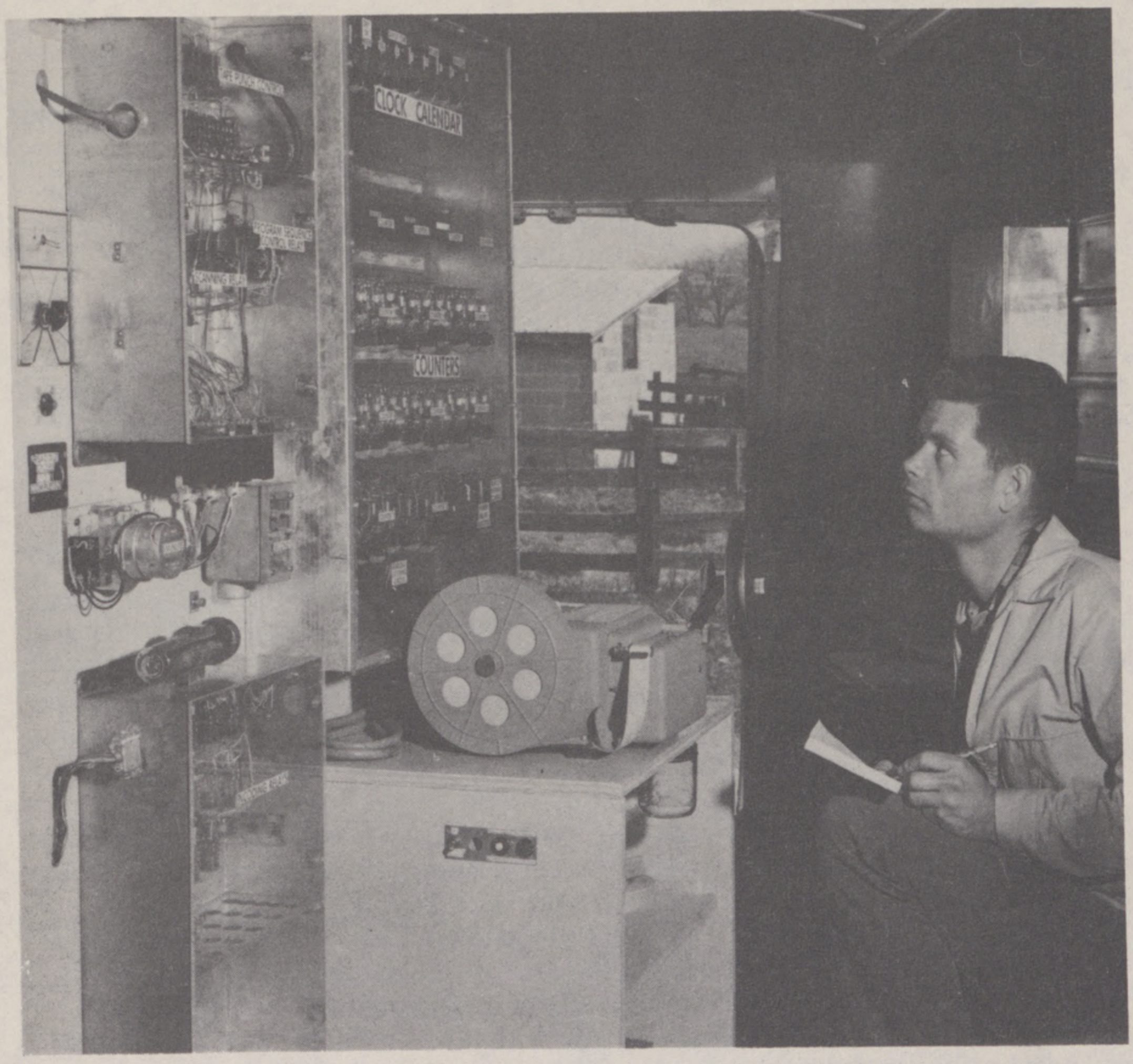

FIGURE 13.—Agricultural engineer checking water-use measuring equipment mounted in recording van.

get out on pasture, the total amount of manure is dropped in the confinement area. Unless properly and carefully handled, the opportunity is excellent for creating a sanitation hazard or an aesthetic nuisance, or both.

There is a decided trend toward more and larger confinement-type livestock enterprises. There is also a marked trend toward discounting the fertilizer value of manures and regarding them solely as wastes to be disposed of in the most expeditious manner.

Where the animals are housed and allowed to "loaf" on pavements, there is growing practice of "flushing" the pavements with water and handling the manure as a liquid. This method of handling is less disagreeable and often less laborious and costly than shoveling by hand or scraping with a tractor-mounted blade, but it presents problems in disposing of the liquid manure.

The practice of allowing the liquid manure to drain to a remote spot behind the barn or in the pasture is not acceptable from a sanitary or aesthetic standpoint in an area that is becoming urbanized, as are many of our formerly rural areas. Subsurface absorption, similar to domestic sewage, has been tried but has two disadvantages. It requires (1) periodic removal of solids from the settling tank, and (2) an absorbent soil, which is not always available. In the arid Southwest, where irrigation is practiced, the liquid manure is sometimes applied to crops to supplement the irrigation water.

A disposal method increasing in favor in many areas is the "lagoon" or "stabilization pond." In this method the flushings are piped to a relatively inconspicuous location and allowed to accumulate in a shallow, open pond, usually referred to as a lagoon (fig. 14). The lagoon has been used successfully for a number of years to handle sanitary sewage from rural and small urban communities, but its application to the farmstead for handling liquid manure is recent. It is not an aesthetically appealing type of facility and is often unsightly and odorous. It is also a potential health hazard.

In an effort to develop information on improved methods and equipment for disposing of farmstead wastes, the USDA has recently initiated research on a small scale, in cooperation with the University of Maryland, to determine the biochemical oxygen demand (BOD) of the various types of livestock manures and to study the performance of a number of experimental lagoons. A brief report of the project is presented.

Studies are in process to develop improved means of disposing of organic farmstead wastes, principally manures. Present effort is being centered on the lagoon or stabilization or oxidation pond.

Confinement housing of livestock is leading farmers to remove manure and other wastes from livestock areas by flushing with water rather than by shoveling or scraping. This creates appreciable volumes of water-carried manure, which can create sanitation problems if they are not disposed of satisfactorily. The hazard is particularly acute where metropolitan population centers are expanding into formerly agricultural areas.

Lagoons have been used successfully for disposing of sewage from numerous rural communities.

Preliminary investigations of the relative BOD of sewage and animal manures indicate the probability that design criteria can be developed for successful manure lagoons.

FIGURE 14.—The "manure lagoon" is becoming increasingly popular on the modern livestock farmstead. It is economical and convenient but a potential sanitation and aesthetic hazard if not properly constructed and operated.

Lagoons are not usually esthetically appealing and their contents constitute a potential health hazard.

Cost figures have not been developed for lagoons, but the chore labor requirement for flushing manure from livestock areas is considerably less than for shoveling or scraping.

The volume of liquid manures produced on farmsteads will probably continue to increase and the metropolitan expansion into agricultural areas will probably continue so that the handling problem will become more acute.

USE AND APPLICATIONS OF SOLAR ENERGY

House heating

Hesselschwerdt (*16*) described a solar collector for space heating in the MIT house, where a 1,200-gallon water storage tank supplied heat during periods of no collection. Floor area of the MIT house was 608 square feet, the collector area was 400 square feet. The collector supplied about 50 percent of the total heat requirement. Efficiency of collection of useful heat averaged about 30 percent and collection temperatures varied from about 100° to 160° F.

Within the past few years two modern residences have been constructed in the vicinity of Washington, D.C., each with a large solar collector and storage system. The solar systems have provided nearly complete heating for these houses.

Supplementing heat pumps

A vinyl fluoride plastic film is being used on a solar collector for storage and to supplement a heat pump being used to heat a rural residence in Kansas. The solar-supplemented system consists of vertical south-facing collectors, a rock bed storage, associated electric controls, and an air-source heat pump. A 14-percent increase in overall heating performance has been observed (fig. 15).

Grain drying

Grain drying requires large quantities of air at a temperature only slightly above ambient. These are ideal conditions for flat-plate air-transfer solar heat collectors, since their efficiency increases with increase in rate of air movement, while their exit air temperature is reduced. The intermittency and varying intensity of insolation would not be a great problem in grain drying because the drying could be stopped whenever the insolation was below the threshold value for the collector. The collector could be an integral part of the drying bin or could be portable.

Chemical dehydration of air for grain drying could be accomplished by using solar heat to reactivate the chemicals. When the air is passed over or through the chemicals, some of its water vapor is absorbed or adsorbed by the chemicals. Heating the saturated chemicals liberates the moisture, which may be vented to the outside air. If two batches of a granular chemical dessicant such as silica gel or activated alumina are used, one batch could be removing moisture while a second batch was being reactivated by heat from a flat-plate air-transfer solar heat collector.

A solar plastic collector to heat outside air for drying milo in 1,000-bushel bins has been used in Kansas. A 45-percent reduction (over natural air drying) in the blower energy required was obtained (fig. 16).

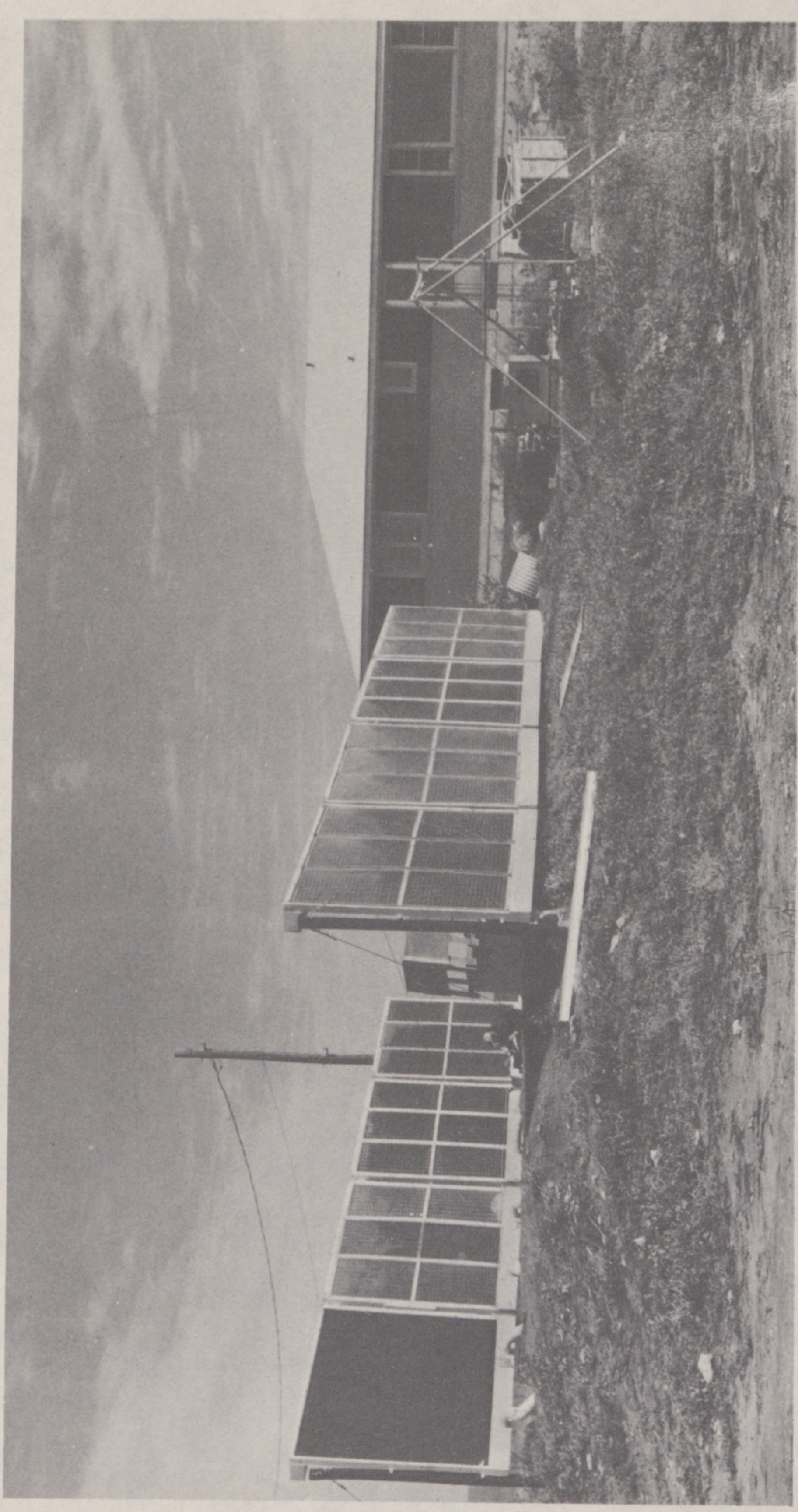

FIGURE 15.—Plastic film covered solar absorber of black-painted corrugated metal to transfer solar energy to rock storage unit below ground and to a heat pump for house heating in Kansas.

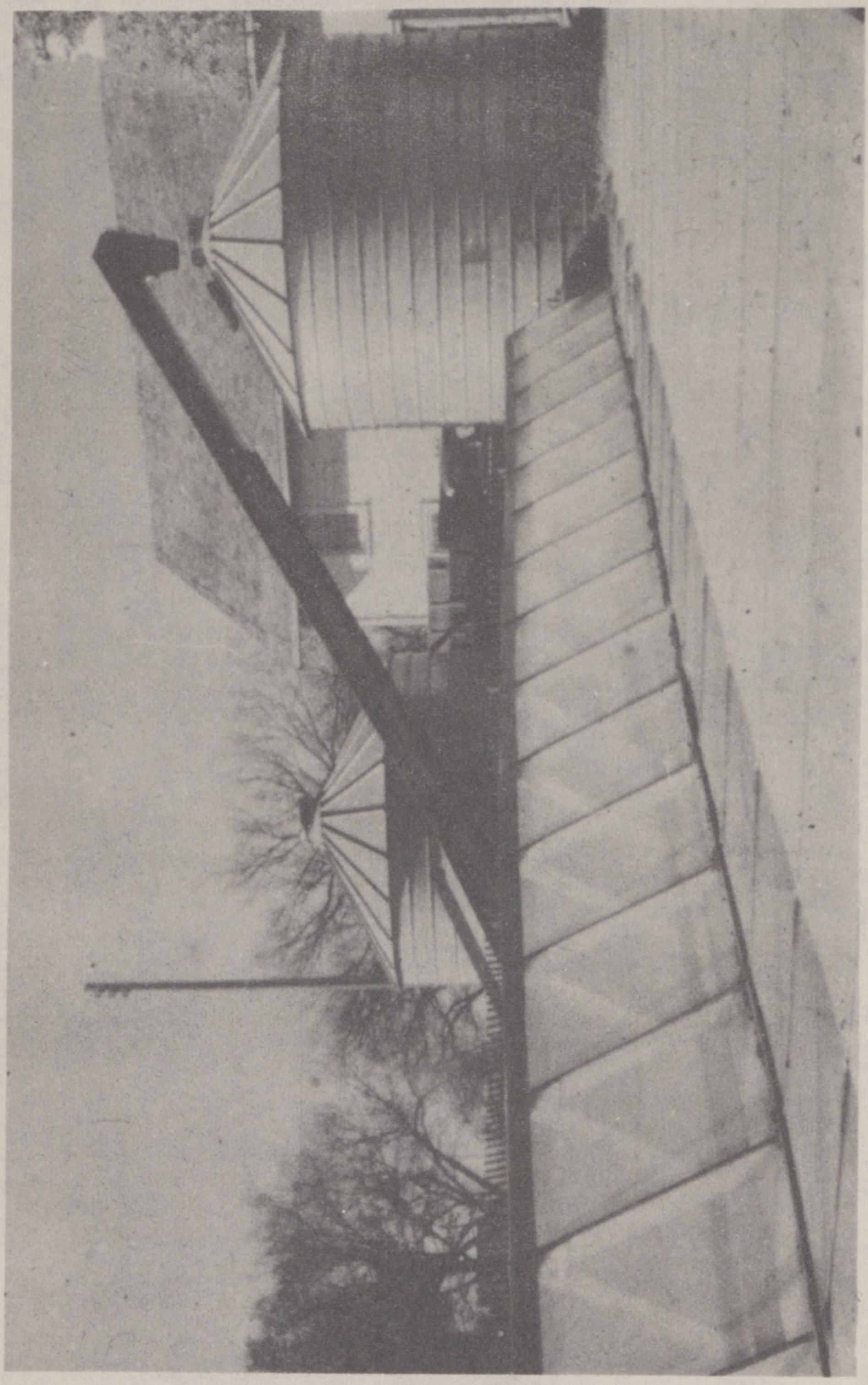

FIGURE 16.—A solar grain dryer constructed of thin clear plastic to heat natural air to dry high moisture content grain.

Grain drying may be the farm process most likely to make practical use of solar heat.

Hay drying

Hay drying is like grain drying, except that even less temperature rise in the air is needed. Therefore, a similar system could be used.

Curing tobacco and sweetpotatoes

Bright leaf tobacco curing requires a considerable quantity of moderately low-temperature heat during the summer when solar radiation is usually high. This heat must be controlled accurately and must be supplied continuously, varying only as the stage of cure dictates. Therefore, some form of heat storage, supplemental heat, or both, is required if solar energy is to be used for tobacco curing.

Sweetpotato curing requires less heat at a lower temperature than tobacco curing. Furthermore, it is permissible to supply heat during daylight only. Otherwise, the heating system would be similar to that for tobacco curing.

Heating other farm structures

The use of heat for livestock shelters in the South, except for brooding poultry and small animals, has not yet been shown to improve production. If such heating is of economic value, it can be accomplished with solar energy and heat storage. Poultry brooding can be done with heat from a flat-plate collector, but heat storage or supplemental heat would have to be provided. An experimental poultry house in Pennsylvania has been heated in winter with solar heat and a satisfactorily low moisture level was maintained (*6*).

Water heating

Various models of solar heaters have been used for heating water. There is no doubt that they will work satisfactorily; the question is whether they are more economical than conventional means. Open waterers for livestock can take advantage of solar heating in winter if the sides and bottoms are painted black (fig. 17).

Heating plant beds and greenhouses

Plant beds and greenhouses generally receive adequate solar heat during daylight, but require supplemental heat at night. Some method of heat storage might prove practical for this application.

Cooking

Solar cookstoves, intended for use in such countries as India, where fuels are scarce and sunshine is abundant, have been designed to sell for about $5. It appears possible that a solar stove could be adapted for cooking feed for livestock since the cooking would not need to be done on as strict a schedule as it usually is for humans.

Cooling farm buildings

The use of heat for cooling is demonstrated in the absorption-cycle refrigeration system, where heat from steam or from a gas flame is applied to the generator. Heat from a solar collector could furnish this energy. Whether a flat-plate or a concentrating collector would be best suited for this purpose depends on the temperature required at the generator of the absorption unit. Such an application of solar heat would appear very desirable, because the insolation rate is highest when the cooling load is greatest. Furthermore, cooling at night is often not required.

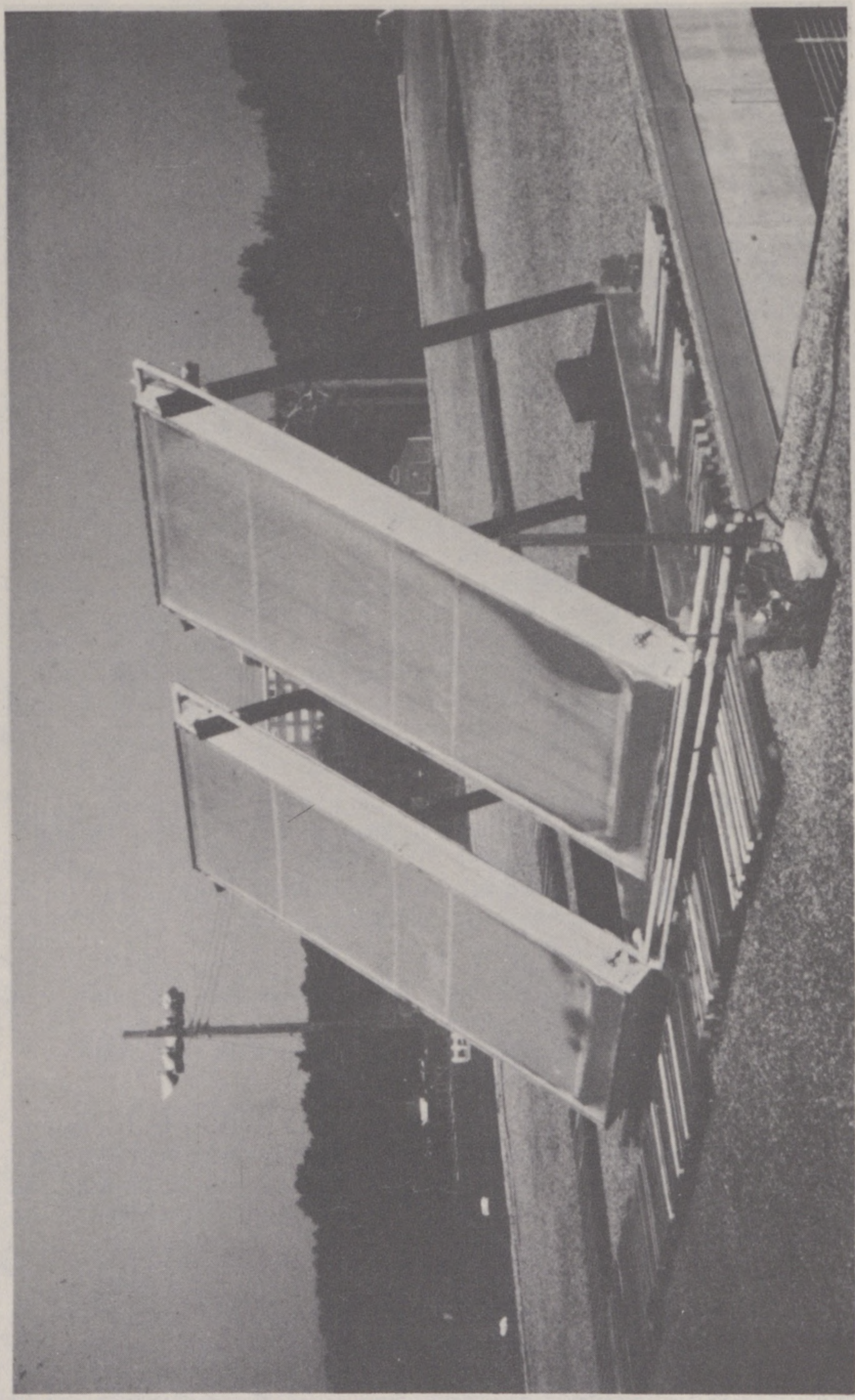

FIGURE 17.—Experimental plastic-covered solar collectors for heating water.

There are indications that summer cooling for poultry and livestock may result in improved production and the economy of artificially cooling farm buildings is now being studied. If cooling proves effective, solar heat may economically furnish the required energy.

A solar-operated absorption cooling system was studied at Purdue University with a 150-square-foot receiver area. This type of unit, which would be applicable to environmental cooling and air conditioning, provided coefficients of performance ranging from 0.50 to 0.63 (*34*).

Storing solar energy

Storage of solar energy may be the key to future survival. The sun does not shine at night, sometimes not for days. Research is underway in Kansas and Georgia by the USDA on materials, methods, and applications of solar energy storage.

INSECT CONTROL WITHOUT CHEMICALS

Electric light traps may provide future insect-free living. Many injurious insects are attracted to ultraviolet light and can be trapped and destroyed before they lay their eggs and before they damage crops. Recent reports from the Purdue Agricultural Experiment Station, based on several years of research on relative attractiveness of various lamps, have indicated that this is a satisfactory way to destroy insects in gardens.

Light in the near ultraviolet region of the sprectrum is most attractive to insects. This light, not visible to man, is called black light.

Research workers found that a light trap with three 15-watt black-light lamps protected corn, potatoes, tomatoes, and cucumbers from insect damage in 50- by 60-foot garden plots.

The black-light traps controlled striped and spotted cucumber beetles, two serious insect pests of cucumbers. Traps also prevented bacterial wilt of cucurbits, since this disease is transmitted only by these beetles.

In North Carolina, 366 black-light traps are being used in a 113-square-mile area to determine their effectiveness in controlling tobacco horn worms. This study is based on a small-scale experiment previously conducted.

ENERGY SOURCES FROM NEW MATERIALS

Fuel cell

Thermodynamically, fuel cells are constant temperature, constant pressure devices, and the maximum energy yield is equal to the change in free energy between products and reactants. For most fuel cells, such as hydrogen and the hydrocarbons, with air or oxygen as oxidant, the free energy change near room temperature is almost as large as the heat of combustion of the fuel. Thus, theoretical efficiencies, expressed as a percentage of the heat of combustion, approach 100 percent.

In practice, efficiencies substantially higher than 50 percent are fairly common in laboratory cells; as high as 80 percent has been reported. High efficiency usually is the most important consideration in choosing fuel cells over other energy conversion devices for a given application. Another important consideration is the possibility of operating at low ambient temperatures.

Fuel cells are not heat engines like thermoelectric and thermionic devices and conventional steam turbogenerators. Therefore, they are not limited by the Carnot efficiency that limits heat engines. High temperatures are not necessary to increase efficiency, but are used in some fuel cells to make ordinarily unreactive fuels more reactive, or to increase the current output.

Since a high-temperature molten carbonate cell currently is the best contender for future large-scale industrial use, problems associated with series connections, corrosion, and electrolyte losses become formidable. Even so, according to investigators at Leesona Moos Laboratories, Jamaica, N.Y., the molten carbonate Carbox (R) cell can be built for about $100 to $250 per kilowatt-hour capacity, or about $2 per pound of weight.

Most current efforts in civilian fuel cell applications involve propulsion of automobiles and other vehicles. It is not yet clear what type of cell is best suited for this purpose, or what type of fuel will have to be produced in quantity to meet the demand. At the moment, propane and methyl alcohol are good prospects because they are liquids and contain large amounts of energy per unit of volume, and they may not be too expensive to produce. A tractor powered by fuel cells that will pull a multibottom plow has been demonstrated.

The advantages of fuel cells for automobiles are lack of smoke and noise, few moving parts, less wear, and a more simplified automobile design. One conceptual design of a mass-produced car has been prepared by Brooks Stevens Associates, Milwaukee, Wis., and is based on the assumption that fuel cells can be housed within the wall thickness of the body shell.

An early return of electric cars has been predicted rather freely. If true, the advent of a fuel-cell car will be speeded, since the two would be similar technologically.

The biochemical fuel cell

The biochemical fuel cell (*10*) is an electrochemical generator in which micro-organisms carry out the chemical reaction to produce electric power.

Organic or inorganic material may be used by a micro-organism in its catebolic process. The current produced is proportional not only to the rate of metabolism of micro-organisms and the number of micro-organisms taking part in the reaction, but also to the number of electrons released in the particular reaction.

Micro-organism fuel cells have an efficiency of approximately 50 percent and they may produce more power than ordinary fuel cells. They can use waste products and for this reason may become important in this Nation's materials and resources.

Thermoelectricity

The thermoelectric generator can use waste heat energy or solar energy to produce electric power.

The first thermoelectric generator made of ceramics (*14*) was developed for the Army by Minneapolis-Honeywell Co. It is capable of operating at unusually high temperatures—up to 2,400° F.—which produces four times the voltage of presently available thermoelectric generators. A pilot model is designed to deliver 100 volts open circuit.

BRIEF PROJECTION OF RESEARCH AND DEVELOPMENT NEEDS

Some of the problems of agricultural engineering in developing and using new materials and energy in this Nation's agriculture have been discussed in this report. Specific needs for a projected research and development program are outlined below.

SOLAR ENERGY AND NEW COLLECTORS

Develop solar collectors, systems, or controls for—

Space heating in structures for human comfort.
Brooding poultry or livestock.
Heating poultry or livestock shelters to improve production efficiency.
Drying grain or forage.
Conditioning fruit and vegetables.
Curing tobacco.
Heating water for household use.
Heating water for dairy and milking parlors.
Heating water for livestock.
Operating solar cooling systems.
Heating plastic greenhouses and growth chambers.

SAVING MATERIALS IN FARMING

Develop a suitable attractant (such as forms of electromagnetic radiation and sonic energy) for attracting economic insects to a trap for capturing or destroying them to save the applications of tons of chemicals likely to endanger our food supply.

Develop a suitable trap for capturing insects for survey purposes.

Develop a suitable killing device to kill insects attracted but not to be retained.

NEW SOURCES OF ENERGY

Develop power supplies that can be used where conventional electric service is not available, including—

Fuel cells that have shown greater efficiency than central station services.

Biochemical cells that have demonstrated the ability to use waste material by micro-organisms to supply electric energy.

Thermoelectric generators capable of operating insect traps a suitable length of time and for operating other agricultural equipment.

Solar photovoltaic cell power supply suitable for powering remotely located equipment.

ELECTRORECLAMATION

Develop a method of reducing alkali soil conditions by passing a direct current under controlled conditions to obtain a suitable ion exchange.

CONSTRUCTION MATERIALS AND METHODS

Develop methods of lowering the cost of construction of comfortable and convenient farm houses

Apply the concepts of pole barn construction to techniques for framing houses.

Study methods of eliminating costs of sheathing sidewalls of houses.

Develop a flooring system that retains the economy of slab-on-grade construction, yet has the warmth and resilience of a suspended wooden floor.

Develop foundation systems for lightweight houses that will prevent the serious damage caused by the swelling and shrinkage of certain clays—particularly montmorillinite—but cost no more than conventional foundations.

Develop a roof-convering material that will permit the general type of builtup roof construction to be used on steeper pitches.

Investigate methods of fabricating hyperbolic paraboloid roofs built of sheet materials. These roofs can use the inherent strength of the sheet, and result in an economy of materials.

Refine the techniques of farm-building design to make construction less wasteful of materials

Restudy the design live and dead loads used for sizing structural members and their connections, using the latest data available from the Weather Bureau, supplemented by measurements of loads imposed on actual buildings by oscillating wind forces.

Analyze the feasibility of a new approach to building design based on the factor of reliability of the structure. This reliability depends on the probability of occurrence of given loads coupled with the combinations of the probability of failure of the structural members and their connections when subjected to the probable loads. The reliability can then be gaged according to the use of the structure. For example, a larger reliability factor is required where human life and limb are endangered by a failure, than for a hay storage shed.

We are approaching a point in our economy where we can give more attention to the refinements of design to accomplish savings in materials.

Review the conventional uses of footings in buildings to justify or eliminate the rule of thumb that footings for lightweight structures should be 16 inches wide and 8 inches deep.

Formulate theories that permit closer design of nailed joints between wooden structural members where proved by tests.

Utilize materials to eliminate the expense of obsolescence in farm buildings

Investigate air-supported structures to compare their performance and economy with conventional construction.

Investigate the construction of barns and houses that can readily be altered or remodeled to take advantage of new developments.

Find methods of lowering the cost of production through better climatic control within animal structures

Determine the role of insulation and ventilation on the incidence of chronic respiratory disease and its attendant condemnations of broilers.

Find methods of insulating animal production structures to eliminate the drastic climatic environments that may cause loss of production or even death of farm animals.

Improve the use of materials and the methods of combining them into structures

Find ways to use the unique properties of heavily reinforced thin section concrete to make lighter weight curtain wall panels.

Incorporate insulation in such panels so the wall will serve a more useful function yet the cost will not exceed masonry construction.

Study the use of heavily reinforced concrete for roofs.

Develop paneled buildings that could be operated similar to the Japanese home. The walls can either be easily removed or slid to one side to open the building for summer production of livestock.

Use new materials to supplement the old to give better structures at no more cost. This process is continuous. Aluminum is widely used in construction. Satisfactory windows have been made of aluminum combined with glass and neoprene gaskets. Use of latex mortars for laying up brick walls may greatly reduce the cost of brickwork by permitting thinner wall sections.

Reduce two major avenues of heat loss from buildings—Infiltration and leakage through windows

Design a window with a closure so that when the window is not functioning to admit light or ventilate it will be insulated to reduce heat flow through it.

Design draperies to make them functional in preventing heat passage and infiltration. They should be both esthetic and useful at little extra cost.

Find ways to better employ heat exchangers to avoid discharging the latent heat of vaporization into the outside air.

Improve greenhouse construction

Improve the construction, use of materials, and the climate within greenhouses. The United States lags far behind continental Europe in the production of high quality vegetables in greenhouses.

FARMSTEAD UTILITIES AND EQUIPMENT

Water supply

Develop comprehensive information on the water demands and design requirements for modern farmstead water supply systems. This information is needed by—

Industry for planning production programs.

Code-making authorities for regulatory purposes.

Extension workers for guiding farmers on water problems.

Farmers for planning water systems and selecting equipment.

Develop simpler, more reliable, and less costly methods and equipment for treating farmstead water supplies to improve their quality.

Sanitary quality.—All surface (pond, stream) supplies must be regarded as polluted and health agencies are finding increasing numbers of wells that are polluted and in need of disinfection before use for domestic purposes. Chlorination, the standard disinfection procedure for municipal and community supplies, has frequently been unsatisfactory when applied to farmstead

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supplies. Means for improving chlorinating equipment and procedures for farmstead application, or development of alternate treatments such as pasteurization, need to be investigated.

Chemical quality.—Many ground waters are hard or contain iron, manganese, sulfur, or other mineral salts that adversely affect their usefulness. Some waters are corrosive, which is also undesirable. Investigations to improve available equipment and methods of treatment are needed.

Physical quality.—Turbidity, odor, or color impair the quality of water for some uses. Means for removal should be studied to develop improvements in equipment and procedures presently available to the farmer.

Wastes disposal

Develop improved methods for disposing of sewage on the farmstead and in small rural communities under 2,500 population. The septic tank system is generally regarded as the best available for the purpose but it is unsatisfactory under such adverse conditions as nonabsorptive soils, ground water or rock close to the surface, and building sites of restricted area. New methods of disposal need to be devised and developed for use under these adverse conditions.

Develop sanitary and economical means for disposing of organic wastes, principally manures, on the farmstead. Our farm animal population drops more than 2 billion tons of manure in and around our farm buildings annually. Practically all of this must be handled by the farmworker. If not handled properly it can become a sanitation hazard, as well as an esthetic nuisance. This is particularly true where metropolitan areas are spreading out into formerly agricultural areas. A number of disposal means should be investigated as follows:

Lagoons (stabilization or oxidation ponds) into which manure is flushed and allowed to oxidize and stabilize.

Irrigation systems in which manure is flushed into a pit, agitated to suspend the solid particles, and pumped as a liquid to irrigation as needed.

Subsurface absorption systems in which manure is flushed to a settling tank for settling out the solids and from which the liquid is drained to subsurface absorption similar to that used in the septic tank system.

Treatments for reclamation and reuse on the farmstead for flushing and other purposes not requiring a potable water.

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