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Dairy Production Research by the United States Department of Agriculture, 1895 to 1980

A Historical Review

Abstract

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The organization and growth of research in dairy production in the U.S. Department of Agriculture is traced from 1895 to 1980. Selected contributions by Departmental scientists to milk improvement and to dairy cattle breeding, nutrition, and herd management are reviewed along with key administrative and regulatory developments. Cooperative State-Federal programs and international activities are also discussed. A chronological listing of USDA scientists involved in dairy production research since 1895 is included.

Keywords: milk production, dairy cattle breeding, animal health and nutrition, agricultural history

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Dairy Production Research by the United States Department of Agriculture, 1895 to 1980

A Historical Review

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Preface

The dairy industry has been a vital force in the agricultural and food economy of America from its beginnings. This industry is based on the dairy cow and the milk that she produces, which is one of America's important foods.

Over time, breeds of dairy cattle have emerged that are specialized producers of milk and the increase in their production of milk has been phenomenal, especially in the past four decades. The demand for milk and its products has always been good, and dairy farmers have utilized land, labor, and other basic resources to transfer these resources through the dairy cow into an ever increasing amount of a basic food.

An important aid to this dairy achievement has been the discovery of scientific knowledge and its intelligent application by American dairy farmers. As early as revolutionary times, forward-looking farmers and other leaders supported public inputs for scientific research and the extension of new knowledge to agricultural and dairy production procedures. Such activities led to the establishment of the U.S. Department of Agriculture, the land-grant university system, the Federal and State agricultural experiment station system, the Federal and State cooperative Extension system, and other like organizations serving the public. The U.S. Congress historically has been a strong supporter of this kind of public service and has liberally provided funds, both at the Federal and State levels, to support it.

The dairy farming industry has been a large benefactor of this support. It has responded well to new research and technological findings, to relatively good and stable markets, and to the assimilation and application of information that increased unit production and efficiency.

This publication traces the research and educational phases of dairy production conducted by the United States Department of Agriculture (USDA). The Federal dairy production research and education effort represents only one of many contributions towards the development of technological information and educational programs for dairy farmers, processors, and marketers. The State agricultural experiment stations, their dairy production and other staffs, and the Federal dairy production staff have worked diligently and contributed to the technological advances in this field. Many other Federal, State, and industrial organizations have also made significant contributions to the dairy industry in such fields as animal health, soil productivity, crop production, agricultural engineering, pest control, farm management, soil conservation, and marketing. All through the years, this Federal, State, and industry effort has been one of close mutual cooperation.

The research and information services of the dairy processing, marketing, and utilization phases have made a major contribution to the advancement of the dairy industry. I had difficulty separating production from the processing and utilization phases in this publication, since for about half the period, the two types of work were in the same Division or Bureau of the Department: the Dairy Division and the Bureau of Dairy Industry. I felt, however, that there was merit in confining this review to the dairy production aspects of the Federal efforts in dairy research.

In writing this publication, I traced the organization and research-related activities of the various dairy production units. I made no attempt to detail the results of their many research projects except for a few confined mainly to their earlier work.

Dairy literature is replete with publications describing Federal research, such as various U.S. Department of Agriculture publications, reports in scientific journals, and progress and symposia reports; some of which are cited here.

I am greatly indebted to Charles A. Kiddy and Timothy H. Blosser for their invaluable assistance in reviewing and contributing to this publication and particularly in reporting significant research activities that occurred during the last decade covered by this report.

Contents

Issued February 1986

1. Early Development in Agriculture and Dairying

Colonial Period, 1600-1775

Dairying has been important throughout the history of agriculture in this country. It ranks among the top three or four activities in dollar value of farm income.

The basis of dairying is the dairy cow—her development, care and feeding, and the gathering and care of milk she produces. Associated with dairying and of great importance is the marketing and utilization of milk and its products as food.

Cattle were brought into this country by the earliest settlers—as early as 1611 by the English colonists at Jamestown and 1624 by the Pilgrims at Plymouth (77). The settlers that followed also brought cattle. Most of the cattle were brought into the country from Europe, especially from Great Britain and Spain, and some were from Mexico. These early imports were probably of the Shorthorn and Holstein types and formed the basis of our foundation cattle herd.

In these early years, little emphasis was placed on improving the breeds: the main emphasis being on increasing their numbers. Cattle were used both for work and food. Milk was of immediate importance as a steady supply of food for the family. Most of these early families, whether they lived in towns or in rural areas, maintained at least one family milk cow. Milk not used in the home or peddled to neighbors was sold informally to dwellers in nearby communities.

As population increased, land was cleared, farms and communities were developed, and people started migrating West. By the mid-18th century the livestock industry began to differentiate into dairy and meat-producing herds. The oxen gave way to horse power. The demand for milk increased and marketing of milk, butter, and cheese became more orderly. Early in this period butter and cheese were exported to England (2). By the end of the colonial period, about 90 percent of the settlers were engaged in agriculture. During this period, the more progressive, better informed agriculturalists actively sought improvements both in farming and the marketing of farm products.

Post-Revolutionary Period, 1775-1860

Shortly after the Revolutionary War, progressive agriculturalists began to form societies for the advancement of agriculture, such as the Philadelphia Agricultural Society founded in 1785. In 1796 President Washington recommended to the Congress that funds be provided to promote agriculture.

A proliferation of national and State agricultural societies with various interests followed; all these societies supported programs for agricultural improvement and urged the Federal Government to support them also. To aid in the improvement of livestock, the Federal Government in 1793 modified the Tariff Act to allow animals to be imported duty free for breeding. By 1800, one million pounds of butter and 1.8 million pounds of cheese were exported to England (2). These exports, with other commodities, were important in their use as items to exchange for the purchase of industrial materials and supplies from Europe. This market significantly stimulated increased milk production. The domestic demands for milk, cheese, and butter were also increasing.

Science, Education, and Technology Applied to Agriculture. Interest in agriculture and livestock was stimulated by local fairs, the first of which was held in Washington, D.C. , in 1805 (31). During the first part of the 19th century, despite the War of 1812, agriculture and the livestock and dairy industries developed rapidly. This period is known as the technological age for farming, when manual labor began to be replaced by machines. In addition, roads, waterways, and railroads were improved and extended so that agricultural products could be transported more easily to more distant markets. Farming became important in opening the Midwest.

Science was making itself felt as the servant for improvement. Schools offering specialized training for young people interested in farming began to receive attention. As early as 1810, dairy farmers began feeding their cattle according to standards that had been developed in Europe.

Federal Government Supported Agricultural Development. The people's eagerness for Government assistance to agriculture increased greatly. In response, the Congress established a Committee on Agriculture in the House of Representatives in 1820 and in the Senate in 1825. In the early 1830's, the first direct aid to agriculture began in a limited way in the Patent Office of the Department of State, the only technical unit in the Federal Government. This aid involved gathering and reporting statistics and importing and distributing seeds. In 1839 Congress authorized the expenditure of $1,000 for agriculture. The mowing machine, the reaper, the threshing machine, the steel moldboard plow, and many other machines useful to farmers were introduced about this time.

These mechanical inventions were associated with and stimulated by the migration of people westward who adopted farming and dairying as their principal occupations. Continued improvements in transportation and communications and increased awareness of the value of science and technology to agriculture and marketing encouraged growth on the new frontiers. Dairy farmers needed to become more efficient in producing and, especially, in marketing butter and cheese. Marketing systems and procedures for handling fluid milk in the cities were improved. Results of the use of these improved systems and procedures are shown in table 1.

National support for scientific agriculture continued to increase modestly with congressional appropriations to the Patent Office. Courses in agriculture and some experimental projects were developed in many State colleges and universities.

In the Department's earliest activities little emphasis was directed specifically to dairying. Nevertheless, developments in dairying advanced greatly. The cow population increased from 8.6 million in 1860 to more than 15 million in 1890, and the national milk yield per cow increased about 1,200 pounds (table 1). Cow numbers increased in all regions of the country. Many factors, especially the domestic and foreign market demands for butter and cheese, contributed to these increases.

Organization of Dairy Breed Societies. During the period between 1860 and 1895 breeds of dairy cattle were improving markedly; breeds were becoming more specifically defined. To this end, cattle breeders organized breed registry associations. The dates of the formation of each dairy breed society are listed in table 2. Breeders began registering animals that were purebred imports and descendants of imported animals. They also developed scorecards to describe the physical and anatomical characteristics of particular breeds. In 1896, the Department published a bulletin on dairy breeds which included the type scorecard for each breed (2). Later, at the turn of the century, the breed registry associations adopted performance-recording programs. The exhibition of animals at local, State, and national shows increased during this period.

In 1840 the Census Bureau recorded 4.8 million milking cows in this country (table 1). In the two decades from 1840 to 1860 the Census Bureau reported an increase of 3.8 million milking cows on farms. The Census Bureau also reported that butter produced on the farm

Table 1.—Dairy cattle statistics, selected years 1840-1980

Year	Farmers with dairy cows	Cows nation-wide	Cows by region: North-eastern	North Central	Southern	Western	National milk yield per cow
	Thousands	*Millions*					*Pounds*
1840		4.8					
1850		6.4					1,423
1860		8.6					1,504
1870		9.7	2.9	3.6	2.9	0.3	1,771
1880		11.8	3.2	6.1	3.1	.4	1,997
1890		15.1	3.4	7.4	3.7	.6	2,712
1900	4,514	16.6	3.4	8.3	4.1	.8	3,646
1910	5,141	19.4	3.4	9.6	5.2	1.2	[1]3,650
1920	4,461	21.5	3.4	10.7	5.7	1.7	3,627
1930	4,453	23.1	3.0	12.0	6.0	2.1	4,589
1940	4,644	24.9	3.2	11.6	6.9	2.2	4,622
1950	3,648	22.0	3.0	10.8	6.2	2.0	5,314
1960	1,792	17.7	2.9	8.5	4.4	1.9	7,000
1970	568	12.4	2.2	5.8	2.8	1.6	9,385
1980	335	10.8	2.2	5.0	1.9	1.7	11,875

[1]Estimated.

Source: Alvord (2); U.S. Department of Agriculture (81, 83); National Milk Producers Federation, Dairy Highlights, 1979.

Table 2.—Purebred dairy cattle breed association

Breed	Country of origin	First recorded imports of purebred cattle	Herd book society formed	Record of performance started	Type Score-card adopted
Ayrshire	Scotland	1822	1863	1901	1885
Brown Swiss	Switzerland	1869	1880	1911	1890
Guernsey	Guernsey Isle	1830	1878	1901	1884
Holstein	Netherlands	1871	1872	1900	1883
Jersey	Jersey Isle	1817	1868	1903	1875
Shorthorn	Great Britain	1783	1915	—	—

Source: Alvord (4).

increased from 313 million pounds in 1850 to 460 million pounds in 1860, whereas farm-produced cheese remained at slightly over 100 million pounds for each decade (2).

Dairy farmers and breeders paid increased attention to improving their cattle. Improved purebred animals were imported.

Manufacture and Marketing of Commercial Milk and Dairy Products. During the early 1850's the manufacture of butter and cheese was transferred from farms to factories. In 1851 the first commercial cheese factory was established in New York, and in 1856 the first commercial butter factory was established in New York. The first recorded shipment of milk by rail was in New York in 1842. Wholesale manufacture of ice cream began in Baltimore, Md., in 1851. The first concentrated milk plant was established in Connecticut in 1854. The city of Boston passed the first law forbidding adulteration of milk (largely watering) in 1856 and appointed the first milk inspector in 1859.

The agricultural reports of the Patent Office during this period (1840-60) did not provide much information on dairying, other than occasional brief statistical reports. There were occasional references to the composition of milk and other foods, to problems of quality, and to adulteration of a number of food products.

Increased Pressure for a Department of Agriculture. Despite the impending crisis of the Civil War, interested agricultural groups and the agricultural commissioner of the Patent Office sought greater support for agriculture and the livestock industry. They emphasized the need for a separate Department of Agriculture in the Federal Government. In the Commissioner's arguments for a department to meet the statistical, research, and educational needs of farmers, he indicated that "worthless breeds of cattle must be supplemented with Shorthorns on rich pastures" (31). This, at least, was recognition of the needs of cattle farmers, producers of both dairy and meat products. As a part of a campaign for the new department, the U.S. Agricultural Society was organzied in 1852. It expired after the Department of Agriculture was established.

Expansion and Development Period, 1860-95

Establishment, Organization and Development of the U.S. Department of Agriculture. In 1859, in response to the call for a Department of Agriculture, a board of agricultural advisers to the House Committee on Agriculture recommended the creation of that Department, with a Cabinet member as head. In 1861 the House Committee recommended to the Congress the establishment of a Department of Agriculture but with a commissioner as head. In 1862, the 37th Congress enacted legislation creating the Department with a commissioner as head (80).

Homestead and Morrill Land-Grant College Acts. In that same year, the Congress also passed two other important acts that were companion legislation to that creating the Department of Agriculture—the Homestead Act and the Land-Grant College Act (Morrill Act) (80). All three acts were signed by President Lincoln in 1862. They were great milestones in the development of agriculture in the United States.

The Homestead Act provided for settlement on public lands—primarily in the West and Southwest. The Land-Grant College Act provided for the establishment in each State of an institution for instruction in agriculture and the mechanical arts and support for these institutions through grants and sale of public lands. This act marked the beginning of Federal grants-in-aid to the States.

The charter of the Department of Agriculture was broad and simple: "to gather and diffuse information, including statistical information, on agriculture that will be useful to the people" (80). The new Department assumed the programs of the Commissioner of Agriculture in the Patent Office and the, then, Commissioner became the first Commissioner of the newly created U.S. Department of Agriculture. This task was to develop and expand programs to serve agriculture that would serve as a catalyst to the various agricultural commodity groups and to the emerging colleges of agriculture.

Organization of the Dairy Production Units Responsible for Dairy Research. Within the Department of Agriculture several organizational structures were given the responsibilities for dairy research and related activities. In 1953, the research for dairy production was separated from that of milk technology. A chronological outline of these organizational units along with other important developments within the Department relating to the dairy industry follows.

1862 Establishment of the U.S. Department of Agriculture by Act of Congress. The purpose of the Department was to gather and diffuse information useful to agriculture in the broadest sense. It was given bureau status and headed by a Commissioner of Agriculture.

1884 Establishment of the Bureau of Animal Industry by an act of Congress. The purpose was to acquire and distribute information useful to livestock farming, including dairying. The work included research and education on animal husbandry, disease and parasite control and eradication, meat and livestock inspection and control (domestic, imports, and exports), and dairy product imports and exports. Passage of the Experiment Station Act (the Hatch Act) by Congress. The act provided for establishment of an agricultural experiment station at agricultural colleges in each State. The program support was to be supervised by the Office of Experiment Stations, established in the Department in 1888.

1889 Elevation of the U.S. Department of Agriculture by an act of Congress to an executive department, headed by a Cabinet-rank officer, and enlargement of its powers and duties. The act also vested in the Secretary of Agriculture the supervision of the Bureau of Animal Industry.

1895 By an act of Congress, authorization and funding for the Bureau of Animal Industry to establish a Dairy Division. The purpose was to secure information of value to dairy farmers about the condition of the industry, statistics of production and trade, and marketing; to improve production and handling of milk and dairy products through research demonstrations, and education; and to establish close relationships with dairy organizations.

1910 Establishment of the agricultural experiment station at Beltsville, Md., by the Bureau of Animal Industry.

1914 Passage by Congress of the Agriculture Extension Act (Smith-Lever Act). The purpose was to provide funds for agricultural Extension, education, and demonstration by the land-grant colleges and universities and the Department of Agriculture.

1924 Establishment of the Bureau of Dairy Industry by an act of Congress (conversion of the former Dairy Division into an independent bureau). Its purpose was to continue and expand, particularly by research, education, and demonstration, work on all phases of dairying, including dairy production and milk and dairy products.

1942 By Departmental Executive order, establishment of the Agricultural Research Administration. The primary purpose was to supervise and coordinate research and related programs of the seven scientific bureaus of the Department, including the Bureau of Dairy Industry.

1953 By Departmental Executive order, replacement of the Agricultural Research Administration by the Agricultural Research Service (ARS). Seven scientific bureaus were abolished. The scientific and related work on animal production, both dairy and other animals, was grouped under the heading of livestock research within ARS. The work on dairy production and on milk and dairy products was separated. The work on milk and milk products was incorporated into a utilization research unit, while that on dairy production work was organized into the Dairy Husbandry Research Branch.

1959 By Departmental Executive order, reorganizing the Agricultural Research Service, establishment of an Animal Science Research Division to supervise the production research on all farm animals. The Dairy Husbandry Research Branch became the Dairy Cattle Research Branch as a unit of the Animal Science Research Division.

1972 By Departmental Executive order, further reorganizing the Agricultural Research Service, abolition of the Animal Science Research Division and its branches, along with other divisions of ARS. The research and related programs were organized regionally, and the activities were defined by discipline into institutes and laboratories.

Important Developments in the Dairy Industry. Other important progress in the dairy industry during this period follows.

Year	Development
1872	Wisconsin Dairyman's Association Organized—A first
1873	First silo in America built in Illinois
1875	Refrigerated rail car first appeared
1877	First trench silo built in Wisconsin
1878	Commercial rennet for cheese making introduced
1878	First centrifugal cream separator perfected in Sweden
1880	Armsby's revised feeding standards published
1882	First centrifugal cream separator introduced in Iowa.
1885	*Hoard's Dairyman* established as first strictly dairy farm paper.
1885	Evaporated milk first successfully manufactured
1886	Glass milk bottle invented
1890	Tuberculin test introduced
1890	Babcock test for butterfat in milk invented
1891	First dairy school organized at University of Wisconsin
1892	First municipal dairy inspection law passed by New York City.
1894	First certified milk produced in California
1895	Machines for pasteurizing milk patented
1897	Germ causing contagious abortion (brucellosis) discovered in Denmark.
1900	Mendel's principles of inheritance rediscovered
1900	Official testing adopted by Holstein-Friesian Association of America; also Guernsey, 1901; Ayrshire, 1902, Jersey, 1903; Brown Swiss, 1911.

Source: Glover (26, p. 644-645).

The introduction of the cream separator transferred butter manufacture from farm to factory and contributed to increases in butter production, particularly in the Midwest. Cheese production also increased. The unrestricted demand for butter and cheese, both foreign and domestic, was overly exploited by their adulteration. These practices led to Federal legislation in 1886 defining and providing legal standards for butter, cheese, and filled cheese. By 1880 most States had enacted laws and regulations specifying the composition of dairy products. The market milk industry was developing rapidly to serve city and rural consumers. State and municipal regulatory and sanitary ordinances were issued and enforced. State dairy associations were being organized. A dairyman's association was organized in Wisconsin in 1872, in Illinois in 1874, in New York in 1887, and in most of the other States associations were organized in the 1880's and 1890's. The National Dairy Union was organized in 1894.

Establishment of the Bureau of Animal Industry. By the 1880's the Agriculture Department's research and involvement in the livestock and dairy industries had increased because of the adulteration of dairy products, the general poor quality of dairy foods (and other foods as well), and the incidence and ravages of animal diseases. The Veterinary Division, small though it was, had been working on a rather wide range of diseases. Pleuropneumonia and Texas fever were given much attention. The importance of these two diseases led to the creation of the Bureau of Animal Industry by Congress in 1884, the first bureau in the Department. In 1886 Congress enacted a law providing for inspection of animal food products by the Bureau.

The Experiment Station Act. The Experiment Station Act of 1887 was important legislation that provided Federal grants to each State for agricultural research, and in 1888 the Office of Experiment Station was created in the Department of Agriculture. In 1889, Congress elevated the Commissioner of Agriculture to Cabinet rank as Secretary of the U.S. Department of Agriculture (80).

Establishment of the Dairy Division. Finally, in keeping with the growing importance of the dairy industry and its problems, particularly the poor quality and adulteration of butter and cheese, the Dairy Division was established in 1895 in the Bureau of Animal Industry. Congressional acts followed that made appropriations to the Department of Agriculture specifically to collect and publish information concerning dairying and its products, further justifying the Division's existence (80).

Dairying After Three Centuries

As the 19th century closes with this introductory chapter, a summary of the progress made in the dairy industry from 1860 to 1900 is shown in table 3.

The number of dairy cows on farms doubled from 1860 to 1900, and in 1900 the country still had many dairy cows not on farms producing milk. The percentage of the total cow population classified as lactating remained about the same. The total production of milk increased threefold, whereas the production per cow had increased from 1,504 to 3,646 pounds (table 1). The quantity of butter made on farms greatly decreased as the quantity of cheese and butter made in factories increased significantly, showing the transition from farm to factory-made products. The cream separator, introduced from Sweden about 1880, had a great impact on this trend.

Table 3.—Status of the dairy industry, 1860-1980

Item	1860	1870	1880	1890	1980
Number of people engaged in agriculture (millions)	3.2	5.9	7.7	8.5	10.3
Percentage of total population	13.5	15.3	15.3	13.6	13.5
Number of dairy cows on farms (millions)	8.5	8.9	12.4	16.5	[1 2]17.1
Percentage of all cattle on farms	50.0	60.0	52.9	47.4	[1]48.5
Total milk production (million pounds)	—	20,235	45,579	44,798	[3]62,491
Butter made on farms (million pounds)	460	514	777	1,024	1,072
Butter made in factories and urban dairies (million pounds)	—	—	29	181	421
Cheese made on farms (million pounds)	104	54	27	19	16
Cheese made in factories and urban dairies (million pounds)	—	107	216	238	283
Condensed milk (million pounds)	—	—	13	38	187
Number of butter & cheese factories	5	1,313	3,932	4,712	9,355
Export of butter (million pounds)	3.3	13.9	11.2	19.8	[4]18.3
Export of cheese (million pounds)	7.6	40.5	93.0	107.4	[4]65.4

[1]Excludes calves under 1 year of age and dairy cows not on farms.
[2]The 1900 census reported that 4.5 of the 5.7 million farms had dairy cows accounting for 40 percent of the value of all products.
[3]Did not include milk produced on nonfarms.
[4]Annual average for 1890-99.

Source: U.S. Department of Agriculture. 1903. Bureau of Animal Industry Bulletin 55.

Exports of butter and cheese increased from 1850 to 1880 and then leveled off for various reasons, one of which was poor quality and adulteration of milk supplies. Although there are few statistics on the milk industry, sales of fresh fluid milk in cities increased steadily. Quality was being improved, and pasteurization was accepted during the last decade. A survey of the market milk supplies of 200 communities throughout the country in 1900 indicated that the average per capita daily supply in fluid milk was about 10 ounces. The 1900 census reported that about 8.6 billion pounds of milk were sold for fluid consumption.

The dairy industry entered the 20th century in a strong, progressive condition. Progress was based on steady improvement in the quality of cattle, due to such factors as herd improvement through the use of purebred sires, the beginning of performance testing, and the improvement in the type characteristics of dairy cattle. Feed supplies and feeding and management practices were improving also. Innovations in farming and the processing and marketing of milk included the cream separator, the Babcock test for butterfat, the rapid transfer of butter and cheese making from farm to factory, the manufacture of condensed milk, and the acceptance of pasteurization. The industry knew that improved quality and marketing was needed for continued expansion and public acceptance of factory-produced milk and its products. Federal, State, and municipal laws and regulations were directed toward this goal.

The new Dairy Division of the Bureau of Animal Industry had become well organized; its program was underway and directed towards aid to the dairy industry in all its phases. The State colleges and universities had well-organized educational and research services and were contributing information to the dairy industry.

The following chapters in this publication deal directly with the work of the Dairy Division and its successors in research, education, and Extension, and demonstration of aid to the dairy industry and to dairy production in particular. Much of the dairy research of the Department of Agriculture is in cooperation with State agricultural experiment stations and Extension services and other outside organizations. The intent is to describe the Federal activities and contributions and not to assume undue credit for accomplishments performed by non-Federal organizations; for such credit is deserved by all those involved in such work.

Other divisions and bureaus of the Department of Agriculture assumed some of the responsibilites that formerly were those of the Dairy Division. Bureaus such as Plant Industry, Economics, Entomology, and Soil Conservation as well as divisions of the Bureau of Animal Industry conducted programs of direct benefit to dairying.

2. The Dairy Division, Bureau of Animal Industry, 1895-1924

Organization and Activities

Early Objective and Programs of the Dairy Division. The Chief of the Bureau of Animal Industry, D. E. Salmon, upon establishment of the Dairy Division in 1895, indicated that original scientific investigations in dairying must wait until a foundation had been laid and facilities acquired. He stated

> There is, however, a vast amount of information of the greatest value to the dairyman which may be secured by observation and correspondence. This relates to the condition of the industry, statistics of production and trade, markets, and improvement in the manner of producing and handling dairy products. The present is an era of rapid changes and the dairyman on this account needs a reliable source from which to obtain knowledge of the latest modificatons in the trade and the most desirable improvements which have been suggested. The great dairy interests have so long been neglected by the United States Department of Agriculture that a special effort would now be made to press forward the work outlined above and to establish intimate relations with the dairy organizations of the country (70).

This was the charge given to personnel in the new division. Note that the Bureau of Animal Industry, though it had been giving some attention to husbandry, statistics, and other industry problems, was engaged primarily in the study of animal disease problems and the promulgation of regulations and controls relating to animals and animal products (70). In 1901 the Bureau also established the Division of Animal Husbandry for husbandry work relating to all other farm animals (70).

Major H. E. Alvord, a prominent dairy specialist and scientist, was appointed Chief of the Dairy Division on July 1, 1895. His first priority was to improve the quality and quantity of milk supplies in large cities and the quality of dairy products in foreign trade. Rebuilding foreign trade started with shipments of high-quality butter to selected places in England, and the quality of the butter was traced through the market system to the foreign consumer. This work was expanded to other countries over the next several years; it showed foreign buyers that butter of good quality could be obtained from the United States. In 1900 sanitation of milk supplies was studied in 200 cities. Comprehensive dairy exhibits were displayed at the Paris Exhibition in 1900, the Pan-American Exposition at Buffalo in 1901, and the St. Louis Exposition in 1904; these exhibits exemplified the education work undertaken early in the life of the Division.

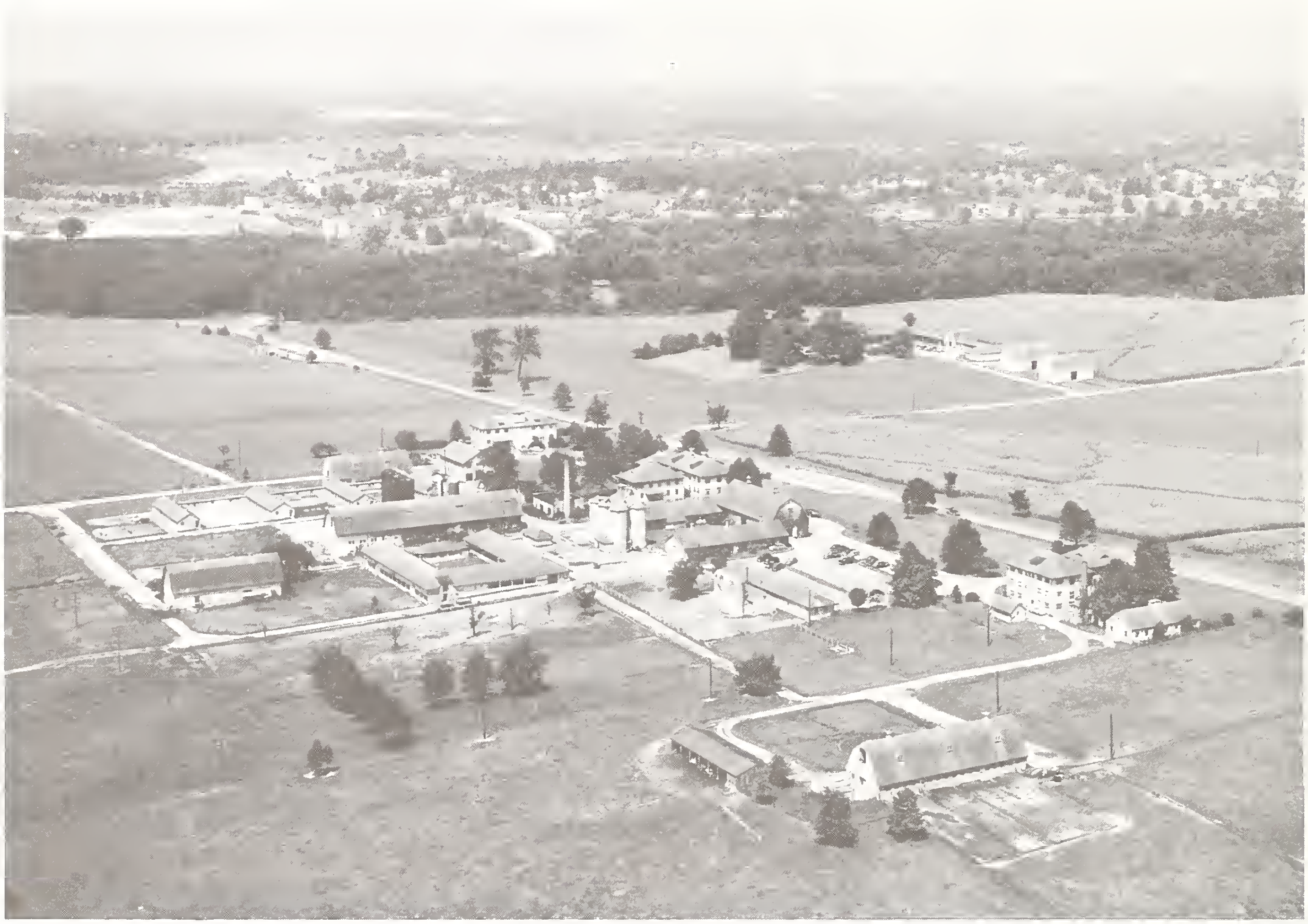
Division Organization and Research Facilities. Because the Division had little laboratory space for research, much of the work was statistical or survey-demonstration, and some was done in cooperation with State institutions and factories. By the turn of the century, with a new agricultural building, some laboratories were available. The scope of work continually broadened, and in 1902 a dairy research laboratory was established. In 1905 dairy farm Extension and market-milk investigation units were established, and in 1906 a dairy manufacturing section was established. In 1910 the Division acquired an expermental farm at Beltsville, Md., later to be known as the Agricultural Research Center, and dairy cattle-breeding investigations were begun in 1911.

With increasing financial support from Congress, the staff of specialists increased and the work developed and expanded within the sectional organization units. The number of publications printed increased each year and were more widely distributed. These publications were Farmers' Bulletins, circulars, leaflets, technical bulletins, and later articles in scientific journals. The technical literature described the Division's own work, whereas the other publications were more educational for the general dairy public. Publications also covered Federal and State laws and regulations affecting dairy production, marketing, and exports. In addition to writing publications, the staff also gave lectures on the work of the Division. These covered the entire scope of dairy farming from the cow and the farm to the milk and farm-produced dairy products. During this period, World War I disrupted the amount and kind of work that could be done.

Production literature emphasized dairy farm management, including housing, cattle care, care and operation of the cream separator and the milking machine, dairy breeds, breed scorecards, judging, production recording and testing, the purebred sire, and the operation of bull associations. Many publications were concerned with various aspects of feeding and with silage and silo construction. A number of publications described the Division's work on the effect of different feeds on the flavor and odor of milk. Some publications described the current status of the dairy industry in various regions of the country.

Technical publications covered a broad range of subjects including milk secretion, bacterial problems of milk and products, and factors affecting the composition of milk. New procedures and techniques in both laboratories and factories were reported. Several publications included statistics on the dairy industry.

A brief review of the early work of the Division emphasizing the sectional contributions follows.



The dairy research facility at the Beltsville Agricultural Research Center established in 1910, as it looks today.

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Dairy, Education, and Extension

When the Division's work was organized, the Extension programs in the States were in their infancy, as were those in the Department. Recognizing industry problems such as the low production per cow, the poorly developed marketing systems, the generally poor quality of milk and its products, and limitations on both domestic and foreign markets, the Dairy Division decided that the first important contribution it could make was to work with producers, marketers, and processors in the field. Plans were directed towards helping dairy farmers, dairy product manufacturers, and the primitive marketing organizations. A large Extension program was first undertaken in the South, later in the West, and then in the Midwest and East.

Dairy Introduction in the South. This work began in 1905 and was broadly based. A special appropriation bore the cost for the work, which was done over about 15 years with the cooperation of the State agricultural colleges in 15 States. At this time dairying was in its infancy; most of it was centered around the city, where there was a potential market for milk and cream. Few producers were in outlying areas. Cotton was the king then, but growers were having trouble with the boll weevil and cotton growing moved west; hence, the interest in alternative farming enterprises.

The emphasis on dairying centered around improving cattle, introducing purebred bulls, forming bull associations, improving feeding methods, developing and managing improved pastures, building silos, managing herds and keeping production records, taking better care of calves and young stock, testing cows, and building and remodeling barns and milk houses. The staff visited farmers to advise them on how to improve their methods. These efforts yielded more profits through increased milk production per cow and per farm, and expanded the number of farmers adopting dairying. The number of dairy cows increased greatly, especially in the south-central region. Freeing this region from the ravages of tick fever favored the expansion of dairying. As dairying developed, some States began to support the work financially. Some accomplishments credited to the Dairy Division's introductory work are shown in table 4.

As milk production increased and the dairy farming area expanded, producers needed expanding markets. Great effort was directed first toward the production of butter. With assistance from farmers and communities, creamery development was promoted. In 1909, for example, several of the seven creameries in Georgia failed to operate for lack of milk. In 1910 the first cooperative creamery was established in Georgia and in Tennessee. These creameries proved successful and greatly influenced the creamery movement throughout the South. By 1924, 217 creameries were operating in the South—with particularly rapid growth in Mississippi.

With the creamery butter project well developed, the Division began work on cheese in 1914. In 1920, 54 cheese factories were in operation. As with butter, the specialists showed the operators how to detemine the quality of milk received from producers and how to evaluate the quality of cheese produced. Marketing dairy products through farmers' cooperatives and independently owned businesses was given high priority.

Table 4.—Accomplishment credited to the work of the USDA Dairy Division in the South by 1921

Item	Number
Purebred bulls purchased by farmers	614
Purebred cows purchased by farmers	814
Creameries organized	217
Cheese factories organized	54
Cow testing associations organized	40
Bull associations organized	58
Milk houses built	364
Barns built (new)	552
Barns remodeled	337
Silos erected	1,741

Source: McClain, J. H. 1921. The activities of the Dairy Division in connection with dairying in the South. U.S. Department of Agriculture, Dairy Division (unpublished report).

As a special project to demonstrate the value of dairying in the South and the relation of dairying to rebuilding fertility in soils, in 1907 a stock company at Denison, Tex., bought a farm. This company also purchased a herd of scrub cows. The Division supervised the project, but all costs except salaries were borne by the company. Purebred Jersey bulls were used, and the herd soon took on the characteristics of that breed. As a result of the Division's management of the land, crops, and dairy herd, the soil was greatly improved and erosion was stopped. The herd's average production of butterfat increased from 139 pounds per cow in 1908 to 241 pounds in 1919, when the project was concluded.

The Division had specialists, working on various phases of dairy farming and dairy products. In 1917, the newly established Federal Extension Service began cooperating to support the work. By then the State Extension services were becoming well established and could take on the major responsibilities for continuing work. On July 1, 1920, the Division discontinued the Extension demonstration work except for work with cheese factories and creameries. One Federal Extension specialist continued Extension education work in the South in cooperation with the Federal and State Extension services. In gratifying testimonial to these Division specialists when the Division's work ceased, nearly all of them were employed by agricultural colleges in the States where they had worked.

Dairy Introduction in the West. Extension demonstration and education work in the West began in 1910. As in the South, it involved attempts to improve production practices on dairy farms and to improve practices and products in milk plants and factories. By 1912 the staff had increased and the work enlarged to the extent that the Division established a western office in Salt Lake City. This office was primarily for local supervision because of the long distance from headquarters in Washington, D.C. The work was carried on in cooperation with the State agricultural colleges and with farmers and milk processors of various kinds in 11 Western States.

The work with dairy farmers emphasized such projects as dairy herd improvement through the use of purebred bulls, organizing bull and cow-testing associations, improving pasture and feeding, building silos, and the care and handling of milk—including improved sanitation, operation of milking machines and separators, and cooling milk and cream. The specialists participated in college dairy conferences and meetings of various organizations in the States where they worked.

During the life of the project, dairy farming was improved. For example, 45 bull associations and 68 cow-testing associations were organized during this time.

Considerable work was done to improve the market milk supplies of many large cities and towns. A novel approach was used in cooperation with local health authorities. Periodically the milk of various companies supplying the market was randomly sampled, tested, and scored according to the Division's scorecard. Where poor milk was found, Division specialists visited and worked with plant operators to remedy faults. Often the specialists had to visit the farmers supplying the plant to identify and correct faults. The great improvement in the quality of the market milk supplies of many western cities as a result of this work led to increased acceptance by the consumer of fluid milk and cream and increased income to the producers and processors.

Considerable work by Division specialists was directed toward improving cheesemaking and the quality of cheese. Specialists visited many cheese factories to give special instruction to cheesemakers. This work often led to visits to patron farms in an effort to improve the quality of milk reaching the factory. As a result of this work, the quality of cheese produced in the West was greatly improved.

Similar but less extensive work was devoted to improving buttermaking procedures and the quality of butter. A cream-grading system was put into use. This system led to much work with creamery patrons to improve the quality of cream reaching the creamery. Two important contributions to improve quality were the installation of cooling tanks on many farms and the general improvement in sanitation.

As services provided by State health authorities and State colleges and Extension services increased, the need for Federal input decreased. Because of this decreasing need and a reduction in Division funds, the western Extension activity was discontinued in 1920 except for one general dairy Extension specialist who served the West from headquarters in Washington, D.C.

Dairy Introduction in the Midwest and East. The Division's dairy Extension work began in the Midwest in 1910 but never gained the importance that it had in the South and West. The reasons for this may have been because State programs were more developed in these regions than in the South and West at this time. The Division's work was in cooperation with the State colleges on a near equal cost basis. The approach was to work with the colleges through the community organizations and with milk plants, factories, and creameries, and through them, with farmers.

On the production side, much effort was expended in organizing cow-testing associations and, to some extent, cooperative bull associations. A project was started at this time at the Algona, Iowa, creamery in which a Division specialist was assigned to work there with patrons and to aid community development through dairying. This specialist advised the farmers and others on herd improvement, recordkeeping, use of purebred bulls, crop rotation, feeding, dairy buildings, and silo construction.

The project continued for 5 years and in 1916 was transferred to the Division's research project at Grove City, Pa. Division specialists, however, continued to advise personnel in dairy plants in Iowa, especially those in cheese factories.

In Grove City, all sections of the Division were able to pursue research on dairy education, market milk, sanitation, creamery management, and dairy products (fluid milk, butter, cheese, dry and condensed milk, casein, and other byproducts) and dairy plant wastes. The creamery project provided a place for community development involving businesses, banks, and farmers. Many patrons were or became members of bull- and cow-testing associations, breed organizations, and service clubs. By 1920 the cooperating farmers owned 3,000 purebred cows, 300 purebred bulls, and 9,000 cows that had been tested for tuberculosis (TB); 350 herds were on the TB-free accredited list. The volume of milk production and the quality of milk were greatly increased. At the same time the Division's research on dairy products developed new procedures that greatly benefited the processing industry. Although the Extension work was discontinued in 1920, the research continued at the Grove City creamery for about 10 years.

Transfer of Dairy Division Introductory Projects to the States. This brief review of an early project of the newly established Dairy Division, directed towards improving the dairy industry, describes a milestone in public service. The dedicated people involved in the work did their best to solve important problems and to bring beneficial programs to dairy farmers, factory and plant organizations, and the public. During much of the time, this activity was affected by World War I. Although the war increased demands for milk and dairy foods, it also imposed severe restrictions on resources for doing the work.

With the passage of the Smith-Lever Agricultural Extension Act by Congress in 1914, Extension services in the U.S. Department of Agriculture and especially in the States developed rapidly. By 1920, dairy Extension was largely the responsibility of these organizations. In 1920 the Dairy Division reduced its number of dairy Extension specialists to four, one for each region of the country, and in cooperation with the Federal Extension Service these specialists worked through the personnel in the State Extension dairy offices. This activity continued until the mid-1940's. However, other Division personnel continued considerable Extension education work throughout the country.

Market Milk Investigations

The section on market milk began in 1905. The project, some of which has already been referred to under regional Extension, covered the whole range of problems relating to market milk from cow to consumer and included farm sanitation, cleaning milking machines and dairy utensils, flavors and odors of milk, transporting milk to plants and from plants to consumers, plant labor, machinery and equipment, plant management and sanitary control, pasteurization efficiency, scorecard inspection systems, and model municipal milk ordinances. The first study dealt with sanitary conditions on the dairy farm and later with the product as it passed through plants to the consumer.

An important accomplishment of this program was the development and wide introduction of a scorecard system for milk inspection. Farms, milk plants, and milk and cream were graded according to the scorecard. The program was widely accepted and tended to unify the official inspection programs of many communities, so that farm production in milk was improved. On the basis of the scorecard and in cooperation with local officials, model ordinances for regulating the milk supplies were adopted. Contests were sponsored in cooperation with many municipal authorities to improve the quality of milk and cream. The program proved to be a popular educational tool.

Also studied extensively was transportation of milk, including the best types of shipping containers and cooling requirements. Detailed studies were undertaken on the care and sterilization of milking machines. An engineering service was made available beginning in 1905 to assist farmers and plant operators with farm buildings, milk plants, cheese factories, creamery equipment, water supplies, electricity, steam, and refrigeration.

One outstanding contribution of this section was the research on feeds, feeding practices, and related factors affecting the odor and flavor of milk. A variety of feed materials such as beet pulp, high-protein meals, and weed-infested pastures and forage were trial tested for their effect on the flavor of milk. This work began in 1912 and continued for several years; it provided the best information available on factors affecting the palatability of milk (6).

Dairy Manufacturing Investigations

This section was created in 1902 and continued to operate throughout the life of the Division and beyond. Personnel worked mainly to improve efficiency of creameries and cheese factories and the quality of products. Much of this work was done with the cooperation and support of Extension workers. The process of making butter from pasteurized sweet cream was developed, made practical, and accepted by the industry.

In 1902 the section acquired the responsibility for supervising the production of butter for use by the Navy. The Navy required excellent quality butter that would keep for long periods on ships. This continuing service was successful. In 1902 the Congress also enacted the Renovated Butter Act. This act called for regular inspection of plants and the use of labels on product packages. The section had the responsibility for carrying out the provisions of this act.

Dairy Research Laboratories

The laboratory section was established to provide information from basic and applied investigations for other programs of the Division, as well as to improve the technology of producing, processing, and marketing milk and its products. Because the facilities were very limited at first, research on milk secretion began in cooperation with the Missouri and Pennsylvania Agricultural Experiment Stations. Research on cheddar cheese was conducted in cooperation with Wisconsin, on soft cheese with Connecticut, and on butter with Iowa. As soon as laboratories were available at Washington, D.C., and Beltsville, Md., and because of the lack of funds, much of this work was consolidated in the Division's facilities.

Basic Research on Milk. The main thrust of this research was to gain understanding of the basic chemical and physical properties of milk, as well as its bacterial content, and to learn how to control and use these properties in the efficient production of foods from milk. The work on milk secretion in Missouri, Pennsylvania, and the Division contributed greatly to the knowledge that milk secretion was continuous and that feed deficiencies decreased milk production and affected the animal's well-being. Amino acids in the blood were determined to be the precursors of milk casein.

Basic Research on Milk Products. Work on butter yielded information on the causes of deterioration in the product and on methods, such as controlling the moisture content, for maintaining quality. The requirement of the Navy for high-quality butter, as mentioned earlier, led scientists to develop methods for making butter from pasteurized sweet cream. This practice later received widespread industry acceptance.

Studies on cheese resulted in practical methods for making domestic Camembert and Roquefort cheeses of high quality and flavor. The micro-organisms essential for producing the characteristic flavors and properties of these cheeses were identified. The low quality of Swiss cheese was recognized. Spoilage could be controlled by using acid-forming cultures and carefully made rennet. Also, the desirable eye-forming bacteria prepared in pure cultures could be implanted into the cheese.

There was considerable research on the effect of pasteurization on the flavor, food value, and quality of milk. Scientists showed that properly processed pasteurized milk was nutritionally the same as raw milk, but without objectionable flavors or pathogenic bacteria.

Results of ice cream studies showed that the defect called sandiness in ice cream was caused by the crystallization of lactose. Waterproof glue was manufactured from casein. Research improved the quality of cottage cheese and led to more efficient utilization of skim milk. Research on condensed and dried milk products advanced them into industrial and consumer channels.

Basic Research on Bacteriology. The work on bacteriology as it related to milk was an important part of laboratory research. In addition to results of immediate value in producing and handling milk and dairy products, important contributions were made to the knowledge of bacteria in general. Investigations on the influence of hydrogen-ion concentration on the growth of bacteria led to advances in microbiology and, in fact, to the development of the pH meter.

Dairy Cattle Breeding, Feeding, and Management

As the work of the Division expanded, work began on breeding and husbandry in 1912 at the Agricultural Research Center in Beltsville, Md., and at Federal field stations. As the research developed, cooperation began with State agricultural experiment stations, farmers, and breeders.

The first cattle available for breeding research at Beltsville were a herd of cows of mixed breeding and a purebred Guernsey bull. In 1913 another group of grade Jersey cows and a registered Holstein bull were added. The purpose of the experiments was to investigate the effects of inbreeding on performance. Each bull was bred to his designated mates and to their offspring. When the bull went out of service, an inbred son of his was used, and so on throughout the life of the experiment.

Organization of Proved Sire Breeding Research. In 1917 a more extensive breeding project began. It concerned what later became known as the proved-sire method of breeding improvement. Production-proved sires were used in each generation to compare the value of inbreeding, linebreeding, and outbreeding, generation by generation. This project involved both the Holstein and the Jersey breeds, with greater emphasis on the Holsteins.

Because the source of production-proved bulls was very limited, and as a part of this experiment, bulls from the project were loaned to some State agricultural experiment stations, farmers, and breeders to prove their value. The lessee had the use of the bull, and through membership in a local cow-testing association, obtained records of his cows to prove the bull. The lessee retained title to all offspring in return for providing the production information to the Division. The Division retained ownership of the bull and could recall him for use in its breeding projects or dispose of him. The results of this program will be discussed later.

Milk Secretion Research. Research on the physiology of milk secretion, mentioned earlier under dairy research laboratories, was expanded at Beltsville as this facility became available. This research was expanded to include long-term studies on external and internal anatomy and udder characteristics related to milk production. Photographic work initiated at this time will be discussed later. Several State agricultural experiment stations cooperated in this research.

Feeding and Management Research. Research on nutrition, feeding management, and related problems affecting milk production began at Beltsville. The first project was to study open shed versus conventional stanchion barn housing for cattle, kinds of stable floors, kinds of silos and materials used for building them, value of different crops for silage, treatment of silo walls, extent of nutrient losses in silos, pasture and its management, and sanitary production of milk. Results of this work will be discussed in chapter 5.

Specialization of Division Work

From 1890 to 1924, the Division programs increased in intensity and scope. At the same time other organizations of the Department of Agriculture were developing and, like the Division, were becoming more specialized. The Federal-State Extension Program had developed enough to take the major responsibility for dairy Extension. Also, the Bureaus of Economics, Statistics, and Marketing assumed these responsibilities for the dairy sector. The U.S. Public Health Service had the major responsibility for national milk ordinances and controls. Because these other organizations had become more specialized, the Division could become more specialized in the research and services related to dairying and technology. At the same time the State agricultural colleges had well-developed research, teaching, and Extension programs in dairying.

The Dairy Division existed during a time of great expansion in dairying. The number of dairy cows had increased from 15.1 million in 1890 to 21.5 million in 1920, and the average milk production per cow had increased from 2,712 to 3,627 pounds in the same time (table 1). Other developments in the dairy industry during this period are in the following tabulation.

1901 Manufacture of dry milk begun but no great increase until 1906, when improved drying equipment became available.

1903 National Dairy Union organized to combat adulteration in dairy products.

1905 National Dairy Show organized.
First cooperative cow-testing association organized in Michigan.
National Dairy Instructors (American Dairy Science Association) organized.

1906 Cooperative tick eradication program began.
First national college students judging contest held at National Dairy Show.
First automatic milk bottling machine used commercially.
First cooperative bull association organized in Michigan.
Haecker feeding standard introduced.
Dairy Cattle Congress started.
National Dairy Council organized.

1914 First tank truck used for transporting milk.
Henry and Morrison feeding standards introduced.
Hydrogen-ion method for determining acidity of milk developed by Dairy Division.
Vitamin discoveries announced.
National Cooperative Milk Producers Federation organized.
Area plan for eradication of tuberculosis began by Bureau of Animal Industry and States.

1918 Proved sire breeding project begun by Dairy Division at Beltsville, Md.

1919 Process for making Roquefort cheese from cow's milk perfected by Dairy Division.
Value of ultraviolet irradiation of animal to provide vitamin D discovered.
Use of casein plastics began.
Refrigerated, insulated, glass-lined tank cars used to transport milk.

1924 Worlds Dairy Congress held in the United States.

Source: Glover, (*26*, p. 644-645).

Division Field Stations. During the later stages of the life of the Division, Congress authorized the creation of a number of regional dairy field stations. These stations, and associated cooperating projects, are listed in table 5. Research at each of these stations involved breeding, feeding, management, and pasture and forage utilization by dairy cattle appropriate to local areas.

Milk Consumption Campaign

As World War I came to a close in 1918, the dairy industry was faced with surplus milk as a result of increased production stimulated by the war. The annual production of milk had risen through the years and in 1919 was about 700 pounds per person. Prompted by the discovery of vitamins, other new knowledge of nutrition, and the realization that milk was one of the most complete foods, Division personnel initiated campaigns to increase milk consumption and thereby improve human nutrition in many cities and rural communities. This effort was started in 1914 with other Departmental agencies, as well as the National Dairy Council, schools, clubs, and other educational groups. Pamphlets supporting the campaigns were issued by the Division, and over many years they proved so popular that it was difficult to meet the demand. Lectures by Division personnel and radio productions were also used in this campaign.

Table 5.—Federal dairy research locations[1]

Location	Year Started	Year Closed	Acreage	Herd size	Breed
Beltsville, Md.	1910	—	500	[2]400	Holstein, Jersey and crosses of several breeds.
Jeanerette, La.[3]	1914	1972	200	150	Jersey, Holstein, Brown, Swiss, Red Sinahi crossbreds.
Huntley, Mont.[3]	1916	1956	100	150	Holstein.
Ardmore S. Dak.[3]	1916	1932	250	40	Holstein.
Woodward, Okla.[3]	1920	1952	150	75	Holstein.
Mandan, N. Dak.[3]	1927	1955	627	60	Holstein.
Pontiac, S. C.[3]	1928	1947	200	100	Guernsey.
Lewisburg, Tenn.[3]	1928		600	200	Jersey.
Hannibal, Mo.[3]	1931	1945	150	75	Jersey.
Willard, N.C.[3]	1938	1952	125	75	Jersey.
Logan, Utah[4]	1930	1943	125	100	Holstein.
	1956	—	125	100	Holstein.
Puyallup, Wash.[4]	1930	1943	100	200	Holstein.
Madison, Wis.[4]	1979	—	1,400	[5]500	Holstein.

[1]Station or project authorized to conduct dairy production research and demonstrations to encourage and improve dairying in the area. Breeding research was a phase of the Bureau of Dairy Industry's coordinated breeding investigations, largely proving sires, in cooperation with the State agricultural experiment stations. At some locations the land, facilities, and cattle were furnished by the Federal Government; at others land and facilities were furnished by the State; and at still others land, facilities, and cattle were furnished by both groups.

[2]The Beltsville herd size has varied over the years from 350 to 500. This figure represents the herd size in 1980.

[3]Authorized by Congress.

[4]Administratively established.

[5]This figure represents a herd-size goal. The herd has not yet achieved this size.

Source: Hodgson (36).

Bureau of Dairying Authorized

With all this activity, various segments of the industry felt the need for a separate, distinct bureau for dairying in the Department. The programs and progress made by the Dairy Division and their acceptance by industry had much to do with this feeling.

The efforts of the dairy industry to establish an independent Bureau of Dairying began early in 1907. Editorials and articles advocating the formation of such a bureau continually appeared in dairy journals. Meetings and conferences were held among industry groups and Department officials and members of Congress. Even though no bill for establishing a Bureau of Dairying was ever presented to the Congress by the Administration, in February 1924 a proposal by Representative Guilbert N. Haugen of Iowa to establish the Bureau passed the Senate and House. It was signed as an act by President Coolidge. Thus, the Bureau of Dairying was established in the Department of Agriculture, effective July 1, 1924.

3. Bureau of Dairy Industry and Succeeding Organizations, 1925 to 1980

Establishment and Organization of the Bureau

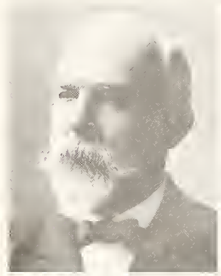
The original act creating the Bureau directed it to "gain and impart knowledge of the dairy industry." In keeping with the objectives, the Bureau's duties consisted largely of investigation and dissemination of information by various means. The investigative programs were developed to continue research projects started by the Dairy Division. As financial support became greater, the research programs were expanded and directed at more diverse problems facing the industry. At the same time the practical record of performance activities involving much of the general dairy cow population was expanded.

Shortly after the Bureau was established, the staff and work were organized as follows: Dairy Research Laboratories, Dairy Cattle Breeding Investigations, Market Milk Investigations, and Dairy Introductions. As the Bureau gained greater status and the work was increased, the internal structure changed several times according to need until 1937 when the staff and programs were organized into the Editorial and Information Services and the following Divisions: Dairy Cattle Breeding, Feeding, and Management; Nutrition and Physiology; Dairy-Herd Improvement Investigations; Dairy Research Laboratories; and Market Milk Investigations. Personnel in the Division of Dairy Cattle Breeding, Feeding, and Management supervised the work at the dairy field stations.

After the Bureau was formed and the work was organized under the several divisions, activities related to milk production and those related to processing of milk and milk products were somewhat separated and well defined. The rest of this review will be confined to production with some reference to other work of the Bureau that seems appropriate.

In 1952 the Department's research service was reorganized. Dairy production research was organized into a Dairy Husbandry Research Branch that included Divisions of Dairy Cattle Breeding and Management, Dairy Cattle Nutrition and Physiology, and Dairy Herd Improvement Investigation. In another general reorganization in 1959, the Branch became the Dairy Cattle Research Branch as part of the Animal Science Research Division. In 1972 the Division was abolished and the dairy production work, along with that on the other animal species, was reorganized into institutes and laboratories.

A detailed review of all this work would be impossible; thus, only the major areas and some results are discussed here. The various areas of work are discussed separately by chapters, although there is some overlapping. Some scientific literature resulting from research in these areas by Department scientists is cited.

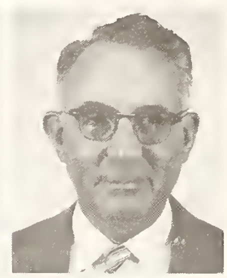

H. E. Alvord 1895-1904


B. H. Rawl 1909-1921


C. W. Larson 1921-1927


O. E. Reed 1927-1952


R. E. Hodgson 1952-1957


L. A. Moore 1957-1961


J. F. Sykes 1961-1965


E. L. Corley 1965-1967


R. D. Plowman 1967-1972

Chiefs of Dairy Division, Bureau of Dairy Industry and Dairy Husbandry Research Branch, and Dairy Cattle Research Branch, U.S. Department of Agriculture, 1895 to 1972.

No picture was available for E. A. Webster, 1904-1909.

4. Dairy Cattle Improvement Research

The low milk yield of the average dairy cow inspired the Bureau to embark on extensive research on dairy cattle breeding. The rediscovery in 1910 of Mendel's principles of genetics afforded new insights into the possibilities of improvement through breeding. The study of cow and herd records, the beginning of official recording by the breed societies, and the beginning of the cow-testing association movement across the country indicated the need for more information on breeding and its systems.

The Bureau had a major responsibility for undertaking investigations to help provide this needed breeding information on a national basis. The Beltsville station and the several field stations, at which large numbers of animals could be maintained over long periods of time under uniform feeding and management conditions, were ideal for dairy cattle breeding research. Breeding studies at other experiment stations were limited in numbers of animals involved and often were only short term.

Systems of Breeding

The major thrust of this work began in 1912 at Beltsville. As the several Federal regional field stations developed their programs, coordinated breeding investigations in cooperation with the local State stations were established. (See table 5 for dates when stations were started and breeds of cattle used.) Also, considerable breeding research was conducted with herds and facilities of some cooperating State stations under the Research and Marketing Act of 1946.

In early work, the value of good pedigreed purebred sires mated with ordinary grade cows was measured. As production-tested bulls became available, they were selected for study. As work expanded, the concept of studying breeding systems became the major thrust of the work.

The first project involved inbreeding. A herd of grade cows of mixed breeding and a highly rated Guernsey bull were assembled in 1912. The following year a herd of Jersey cows and a registered Holstein bull were added. The plan was to mate all the female offspring to their own sire throughout his useful life or to inbred sons of the sire. The results of the study were measured by birth weight and normality of calves, weight at maturity, and production of milk and butterfat. By 1918, disease ended the Guernsey sire line, but the Holstein line continued through six generations of inbreeding. The results of some of these experiments were reported in 1946 (88). The first cross to all purebred bulls resulted in increased production. As the degree of inbreeding increased, production decreased slightly and fertility and general vigor decreased, particularly in the later generations of inbreeding.

A second experiment at Beltsville began with a herd of purebred Jerseys to compare inbreeding and outbreeding. Part of these studies determined whether mating animals of prominent Jersey families could produce offspring with greater uniformity in vigor and production and transmission ability than the offspring produced by linebreeding or inbreeding within these families. Representatives of eight prominent Jersey families were used.

Proved-Sire-Breeding Project. A third, more extensive project tested the methods of breeding that would ensure uniform transmission of ability for high production. The project involved large numbers of cattle at Beltsville and several field stations for the purpose of comparing both line breeding and inbreeding with outbreeding. The same foundation animals were used to begin each breeding system so that results of each system would be comparable in each generation of offspring. By the time this project began, the performance-tested sire concept had been developed and proved sires were used throughout the project which continued through eight generations. This early work and the emphasis that the Bureau, other researchers, breed associations, and breeders placed on the proved-sire concept had much to do with later herd and breed improvement.

Because all cows that could be raised in each sire generation were carried through their lactation life under as uniform feeding and management conditions as could be maintained, the best possible appraisal of a sire's transmitting ability was obtained.

The general results of this long-time experiment indicated that as the outbred generations proceeded, the number of poor-producing daughters were reduced; their disappearance showed a concentration of the genetic factors for high production in the herd. Average production of milk and butterfat steadily increased in each succeeding generation.

Outcrossing, the mating of unrelated animals, proved a more successful mating system than linebreeding. This result suggested that sires could be selected from the whole population of proved sires rather than from related animals only. The lesson here was that a sire's ability to transmit high production is more important than his ancestral relationship to animals in the herd in which he is to be used. Typical results of some of this research have been reported (21).

Other Breeding Studies. In 1925 the effect of age and development on production of Register-of-Merit Jersey and Advanced Registry Guernsey cows was reported. This work involved the comparison of milk and butterfat production by cows of different ages and led to later work on age-adjustment factors that came into general use.

In 1926 another report estimated the transmitting abilities of 23 Holstein-Friesian sires. It concluded that an outstanding sire for production is one whose daughters have a high average yield of milk and butterfat and a high average increase in milk and butterfat yield over that of their dams, with most daughters being better producers than their dams.

A report on a study of 611 daughters of 51 Ayrshire bulls suggested that dairy cattle breeding can be substantially improved only by choosing sires from among those for which there is substantial production information on their daughters compared with that on their dams. Other reports included the average butterfat records of daughters of 108 Guernsey sires, as well as averages for their dams, and estimates of transmitting ability of the sires as determined by an intermediate index.

By the 1930's, scientists generally believed that a cow's ability to produce milk and butterfat was an inherited characteristic, and that sires proved for their ability to increase the daughters' production over that of the dams' carried superior germ plasm and should be used for herd improvement. This belief was supported by data from the bull-lending program conducted by the Bureau from its breeding herds at Beltsville and at several field stations. Bulls were loaned for proving to cooperating farmers, cooperative bull associations, and a number of State experiment stations.

In 1946, an annual report stated that 332 bulls from seven Bureau stations had been proved in cooperators' herds since the bull-lending programs began. Of those bulls, 80 percent sired daughters that produced more milk than their dams. This early information confirmed the advantages to cooperating producers and encouraged the Bureau to continue the program.

The proved-sire program of the National Cooperative Dairy Herd Improvement Program (NCDHIP) confirmed the value of use of production-proved sires for herd improvement. At the same time, the program was most useful in identifying and locating sources of proved sires.

National Germ Plasm Survey. Concern in the Nation at this time about the rate of improvement and how it might be increased in both animals and crops led the Secretary of Agriculture, Henry A. Wallace, to propose a National Germ Plasm Survey. The objective was to thoroughly reexamine methods of breeding improvement and the results thus far obtained and, if needed and possible, to chart new courses for further improvement. The Bureau of Dairy Industry, in 1935, assumed leadership for the dairy cattle part of this survey. Cooperating with the Bureau were the State agricultural experiment stations, the Federal and State Extension services, and breeders and dairy farmers active in local cow-testing associations (29).

Milk yields and butterfat yields were emphasized. Attention was also given to type or body conformation and where this information was available. Investigators recognized at the outset that the data to be obtained in the survey were very limited in terms of total numbers of dairy cows because only about 2 percent of the dairy cow population was involved in production testing. Also, the population to be studied represented the better dairy herds of the country and was not typical of the entire U.S. dairy cow population.

This survey was actually a search for proved sires; that is, bulls that had at least five daughters with lactation records from dams also with records. Therefore, the survey was confined to herds that had been on a production-testing program from 5 to 10 or more years. Information was obtained via a uniform set of forms on which field workers could record data on records of cows from the time testing began. At first, data were collected on agricultural experiment station herds and similar types of herds because these records generally were more complete and covered longer periods than records from other sources. After this experience, the survey with refined techniques was extended to commercial herds. The plan was to survey herds that used at least three sires and had enough data to develop proofs on those sires.

From the data collected, results with 708 herds meeting the established criteria were analyzed. Of these, 157 herds were identified as having shown progress in improving producing ability. In the 708 herds, 4,309 sires were used and 2,242 of those had five or more daughters whose dams also had records. From a comparison of records of daughters and dams, sire proofs could be calculated. Of the sires with proofs, 52 percent were rated excellent, good, or fair for increasing yield; 6.8 percent were borderline, and 41.2 percent were rated poor yield.

The data also were used to analyze the effects of sequence of sires and of using good or poor sires, and to identify outstanding breeding dams on herd production. Findings from the survey indicated that over the period studied many herds did not improve, that many of the sires selected for use in those herds were not good, and that increased attention should be given to the quality of sires used to bring about the desired improvement. When superior sires were used, the herd improved. These findings emphasized again that production improvement resulted from the use of good proved sires and gave added impetus to the sire-proving part of the National Cooperative Dairy Improvement Program that was just getting underway.

Research on and Development of Imported Red Dane Cattle. Secretary Wallace had great concern about the quality of germ plasm available to American agriculture, including the germ plasm in the livestock population. He questioned whether exotic breeds of livestock had germ plasm that would be useful to American livestock producers. In 1935, at his request, the Bureau of Dairy Industry imported a number of breeds of livestock to test and develop. Among those imported were 20 pregnant heifers and two bulls that represented the best of the Red Dane breed from Denmark.

These animals were brought to the Beltsville station to study. Soon after, a group of these cattle were sent to the Waseca, Minn., station; but disease outbreaks and other problems soon caused the group to be returned to Beltsville. The size of the herd gradually increased as performance was evaluated. By 1940 the herd consisted of 40 head, and 118 lactation records had been obtained from the foundation females and their 20 descendants. The daughters averaged about 54 pounds more butterfat per lactation than their dams.

A cooperative project was established in the late 1940's with Michigan State College and a number of farmers in that State interested in the breed. Bulls from the Beltsville herd were made available to those farmers to upgrade their herds to the Red Dane breed. The Bureau obtained data on production of daughters and dams from those bulls. Interest among the cooperating farmers grew so tremendously that a Red Dane Cattle Breeders Association was organized to promote interest in the breed, although later on because of changes in the dairy industry this interest dropped materially.

The Red Dane herd at Beltsville continued to be maintained. When the crossbreeding experiments started, animals of this breed were used as foundation animals for the crosses. In 1950 the herd was moved to the Indiana State Agricultural Experiment Station where it was used in crossbreeding experiments with Holsteins and Milking Shorthorns under a regional Research and Marketing Act project. Some bulls were sent to the U.S Roman L. Hruska Meat Animal Research Center at Clay Center, Neb., to be crossed with beef breeds and evaluated in the crossing system for beef production.

In summary, we can affirm the occurrence of a curiosity on the part of many persons, including Secretary Wallace, concerning the existence of exotic dairy cattle germ plasm that would be useful to American dairy producers. Although the Red Dane breed was one of the best known dairy breeds in Europe the animals had never been imported to the United States. It seemed the logical choice to import and evaluate. These limited imports of Red Dane dairy cattle gave Bureau scientists the opportunity to test this breed and compare them with domestic breeds. Even though the breed did not become widely popular in the United States, the experience gained in working with and evaluating it satisfied curiosity as to the possible merits of the Red Dane breed.

Crossbreeding Investigations

Having learned much about the relative values of inbreeding and outbreeding systems and having shown the merits of the proved-sire system for breeding improvement, scientists next studied the value of crossbreeding as a means of increasing milk and butterfat production. Even though more than 90 percent of the dairy cattle were grades of various kinds and much crossbreeding was taking place, no solid body of scientific information existed to guide producers using this breeding system.

At the same time, crossbreeding in poultry, swine, and, to some extent, beef cattle was progressing well. The use of hybridization in corn and other crops was well established and proved to be of great economic advantage. Although some early scientific research had been conducted with dairy cattle, only a limited number of animals had been involved.

As with other kinds of breeding research, crossbreeding research requires large numbers of animals maintained under uniform conditions over long periods of time. This procedure requires the commitment of extensive facilities, materials, and funds. In 1939 few places other than the Bureau had such committable resources. Funds to support this project were limited and were principally from special Bankhead-Jones research funds.

First Project. Two-breed crosses (reciprocal when possible) of the foundation breeds were planned. All matings were to production-proved sires available in the Bureau's herd. Two-breed-cross females were mated to a male of a third breed, and succeeding matings followed a rotation of three or more breeds in sequence. Eighty-seven foundation females of four breeds (Holstein, Guernsey, Jersey, Red Dane) were assembled from the Beltsville herd and from the Department's field station herds at Huntley, Mont.; Mandan, N. Dak.; Pontiac, S.C.; and Lewisburg, Tenn. The matings continued as planned throughout the project insofar as resources would permit and usually continued through the second cycle of matings. In all, daughter-dam records were obtained for 55 foundation cows, 55 two-breed crosses, 57 three-breed crosses, and 26 four-breed crosses.

Although the project was intended to comprise reciprocal matings in all crosses, this goal proved unrealistic because of limitations on facilities and funds. The concept of this project included the continued use of superior production-proved sires in each generation, ultimately on a rotation or cycle basis. The kind of indiscriminate crossbreeding that had been so commonly practiced in the past could be avoided. The objective was to see whether hybrid vigor could be achieved in the first cross and then maintained or improved upon by the use of proved sires of another breed in later matings.

Several technical reports on this crossbreeding work and a summary were issued (22). The salient results were that when production-proved sires were used for crossbreeding in a three- or four-breed rotation, the increase in milk and butterfat was signficant in the first cross but only slightly in later crosses.

Second Project. Upon completion of this project the work on crossbreeding continued as the Bureau recognized that the results needed to be corroborated with more work. In 1957 a second experiment began at Beltsville and included some of the features that the Bureau did not or could not include in the original project. The new project included foundation females of Holstein, Ayrshire, and Brown Swiss breeds. The animals were selected from the general purebred cattle population by a committee consisting of representatives from the Bureau, State agricultural experiment stations, and breeders. At Beltsville, 57 Holstein, 57 Ayrshire, and 68 Brown Swiss heifers from 85 different herds were assembled. Results were measured on the basis of first lactations adjusted for year and season.

The bulls used were selected proved sires maintained in artificial-breeding organizations. During this study 40 Holstein, 48 Brown Swiss, and 36 Ayrshire sires were used in the matings, all of which included crosses and reciprocal crosses. Information was obtained on milk and butterfat yield, butterfat percentage, solids-nonfat and protein, viability of the animals, reproduction, and feed conversion efficiency. The results were based on records of 125 purebreds, 95 two-breed, 94 three-breed, and 37 5/8-breed crosses among the three breeds, including all reciprocal crosses of the two- and three-breed combinations.

Milk and butterfat yields of the crossbred groups were practically equal to yields of the Holstein purebreds. When yields and other economically important traits were considered, the conclusion was that crossbreds might have been superior to the Holsteins. Yields of crossbred groups increased as the amount of Holstein blood increased. Breeds differed in the general combining ability for milk yield; Holstein additive effects were greater than those of Ayrshire and Brown Swiss. Other important findings included in the published reports of this experiment tended to corroborate the findings in the first experiment (54).

Third Project. As a part of the North Central Regional Dairy Cattle Breeding Project, supported in part by funds from the Research and Marketing Act of 1946, the Illinois Agricultural Experiment Station in cooperation with the Bureau began another crossbreeding project in 1949. The object was to study the effects of the crossbreeding of Holsteins and Guernseys on milk and butterfat production as well as on other traits such as livability, reproduction, milk composition, size, growth rate, and overall economic considerations.

When the results were summarized and all factors such as viability, growth, production, and costs were considered in a total performance measurement in terms of economic merit, crossbreeding resulted in 2.1 percent heterosis. When the means for the breed groups were compared, the Holsteins exceeded the crossbreds by about 10 percent.

Other Projects. Another crossbreeding project included in the North Central Regional Dairy Cattle Breeding Project was conducted by the Indiana Agricultural Experiment Station at Purdue in cooperation with the Bureau. This project began in 1950 and included, the Red Dane, Milking Shorthorn, and Red Poll breeds. The matings procedure was designed to produce all possible purebred and crossbred progeny in three generations of parental and rotational crossbreeding systems.

Analysis of the results, based on 246 records produced on the purebred and crossbred offspring, showed that the differences among the purebreds, two-breed crossbreds, and three-breed crossbreds were not significant. Differences in the general combining ability were highly significant. The Red Danes generally were the highest producing breed and had the highest general combining ability. The breed of dam, breed of sire, and interaction between breed of sire and breed of dam had significant effects on milk yield.

A cooperative crossbreeding project was also conducted at the South Carolina Agricultural Experiment Station. This research, which began in 1947, was a part of the Southern Regional Dairy Breeding Project. Holsteins, Brown Swiss, and Guernseys were used as parental breeds; sires were young, pedigreed selected bulls.

Performance records were obtained on 176 crossbred cows representing 15 groups and were compared with these of their purebred contemporaries. The offspring from Holstein and Guernsey crosses were bred to Brown Swiss bulls to obtain three-breed crosses. A rotational system with Holstein or Guernsey bulls, or both, was followed to obtain third and fourth generation crosses. Records of the crossbreds were compared with those of contemporary purebreds.

Production was greater in the crosses with Guernsey heritage than in purebred Guernseys. The opposite was true for the Holsteins. Production averaged considerably better in crosses with Brown Swiss heritage than in purebred Brown Swiss. The conclusion was that, in general, nonadditive genetic effects were not important for production traits in the crosses studies.

Crossbreeding was also studied at the Georgia Coastal Plains Experiment Station in cooperation with a State prison herd as a part of the Southern Regional Dairy Cattle Breeding Project and in cooperation with the Bureau. Jersey cows were bred to Holstein and Brown Swiss bulls to obtain two- and three-breed crosses. Increases in production over the parents were significant. Production of the Jersey-Brown Swiss crosses surpassed that of each of the two pure breeds and that of the Holstein crosses equaled or surpassed that of the purebred Holsteins.

Bureau scientists cooperated in a number of other dairy cattle breeding projects in the North Central and Southern Regional Dairy Cattle Breeding Projects that were supported by regional Research and Marketing Act funds. A brief discussion on two of the projects follow.

Combining Ability of Inbred Lines. At the Ohio Agriculture Experiment Station a large project was established to determine whether specific combining abilities could be economically used to increase productivity in the Holstein breed. The project started in 1948 with herds of several Ohio Department of Welfare and Correction institutions. Efforts were first devoted to developing relatively pure lines within the herds with the idea of crossing these lines and measuring the effects on the overall performance of the animals involved. Seven mildly inbred lines of Holstein cattle were established for linecrossing.

Traits measured in addition to milk and butterfat production were milk composition, growth, body conformation, udder growth, and blood type. Preliminary results indicate that inbreeding to establish inbred lines reduced production in some lines. Production in linecrossed animals was inferior to that in the linebreds. The results of this long-time project have not been completely analyzed and reported.

In association with this and related projects elsewhere, the Bureau supported the Ohio Blood Typing Laboratory.

Developing More Productive Dairy Cattle for the South. As previously mentioned in chapters 1 and 2, the Dairy Division and later the Bureau of Dairy Industry and the Dairy Cattle Research Branch maintained a dairy field station at Jeanerette, La. Beginning about 1920, a Jersey herd was used to try to develop more productive dairy cattle for the South. This effort was only moderately successful. Factors limiting success were repeated outbreaks of diseases of various kinds; poor forage and feed supplies; and the hot, debilitating climate.

Bureau scientists, in cooperation with State workers, examined the possibility of improving production in the deep South through the development of breeds and strains of cattle more adapted to a hot climate. Among the approaches considered was that of crossbreeding. The breeding research was associated with intensive work on the physiology of adaptability, which will be discussed in a later section.

Recognizing that *Bos indicus,* the Zebu or Brahma, and its crosses with beef types of *Bos taurus* could increase beef production in this region, researchers believed that the use of *Bos indicus* might help in developing better dairy cattle. With this proposition in mind, investigators searched for the best breed of *Bos indicus* for milk production. The Red Sindhi breed of India was selected and two males and two females were imported. Soon after their arrival in Beltsville, one

Sindhi bull was sent to Jeanerette in 1947 to mate with Jerseys and later with Holsteins and Brown Swiss. The two females were kept in Beltsville to mate with the other Red Sindhi bull to increase pure Sindhi stock and to begin study of the heat tolerance research that was being done there. Eventually all the Sindhis and their crosses were located at Jeanerette and at the Louisiana Agricultural Experiment Station in Baton Rouge, where some of the research was being conducted.

The first task was to obtain two-breed crosses, first with Jerseys and later with Holsteins and Brown Swiss. Four Sindhi bulls, two imports and two native bred, became available for sires. The two-breed crosses were backcrossed to the parent females to produce three-fourth native and one-fourth Sindhi offspring at Jeanerette, Baton Rouge, and Beltsville, and at the Homer, La., substation.

In analysis of the data, the crossbreds were compared with their purebred contemporaries. After 15 years of research, results were reported in several publications (9). The introduction of Sindhi blood through crossbreeding or upgrading did not contribute to milk-producing ability. Research on systems of breeding to improve the adaptability and productivity of cattle for this region within the native dairy breeds should apparently be the course to follow. Accordingly, the continuing research at Jeanerette was addressed to this objective. Although the introduction of the Sindhi failed to improve productivity, the project was important in leading the Bureau's scientists and their cooperators into research on the physiology of heat tolerance and climatic adaptability that has been valuable in efforts to improve productive ability of dairy cattle in the South.

Inbred and Outbred Cattle or Crosses. In 1948 a large scale breeding project with Holsteins started at the Wisconsin Agricultural Experiment Station in cooperation with the Bureau. This project involved the establishment of inbred and outbred lines of Holsteins from foundation stock. The lines were then intermated to determine the advantage, if any, from this system of breeding. Milk and fat production, plus milk composition, growth, and development were recorded. Results show that the outbreds produced more milk and fat than did the line breds or the offspring from the intermatings.

Other cooperative breeding projects under the 1946 Research and Marketing Act program in which the Bureau was involved were with the Agricultural Experiment Stations in Minnesota, North Carolina, Texas, and Utah.

Other Beltsville Breeding Investigations. In later years the Beltsville herd was used for additional kinds of breeding research. In 1957 females in the Holstein herd were divided into three comparable groups as foundation animals assigned to three mating systems. A breeding plan was developed so that outcrossing, mild inbreeding (with bulls born within the herd), and crossbreeding could be compared. The outcrossing and mild inbreeding system consisted of four generations, and the crossbreeding system consisted of two- and three-breed crosses plus a backcross of the three-breed crosses to Holstein sires. The other sire breeds used were Ayrshire and Brown Swiss. Because of a continuing interest in breeding systems, particularly crossbreeding, and because of recently developed research techniques, this project was designed to include and evaluate several factors besides production that influence the performance of animals in the outbred, mildly inbred, and crossbred lines.

Proved sires were carefully selected to meet the requirements established for the mating systems. In all, 125 proved sires were used to produce progeny. The project continued through four generations and 437 cows were included in the analysis. Data were collected on growth and development, milk and fat yields, milk composition (including solids-not-fat and protein), peak yield and persistency of milk, and body characteristics, as well as certain economic considerations.

The general conclusions regarding yield and milk composition of the cows in the three mating systems were as follows: Cows in the outcross system outproduced cows in the other two systems in milk and fat, solids-not-fat, and protein. Cows in the crossbred group had a higher percentage of components in milk than did cows in the inbred and outcross groups. Within the crossbreeding system, cows with decreasing percentages of Holstein blood were associated with lower yields and higher percentages of milk components. The backcrosses to Holstein sires were nearly equivalent to the outcrosses. This research demonstrated that production traits should be genetically improved by using proved sires with progeny that have been tested in many herds. It also showed that for production traits, use of the additive effects in the Holstein breed offers an advantage over crossbreeding, which requires heterosis for superiority (59).

A breeding project was established to compare the effect of milk production of selection for milk yield alone with that of selection for milk yield plus several other traits, including yield of fat, protein, and solids-not-fat. Also considered in the multitrait selection group was conformation (type), especially the shape of the udder. The sires were selected on one or the other of these bases.

Results indicated that the progeny from sires selected on the basis of milk yield only produced more milk, fat, protein, and solids-not-fat than the group selected for multitraits. The progeny also were comparable with those of the other group in type and udder structure. This finding indicates that breeders will progress more in improving the production of their herds by concentrating on selecting sires on the basis of high milk yields in their progeny. The practice of selecting on the basis of milk yield only will simplify the selection process (67).

In another research study, semen from 21 Simmental bulls was used to produce crossbred Simmental X Holstein calves. Purebred Holstein calves born at the same time were designated as contemporaries for comparison. The heifers in both groups were raised under the same conditions and milked for one lactation. Simmental-Holstein crosses produced significantly less milk and butterfat than did the purebred Holstein. The purebreds consumed considerably more feed dry matter but had a 15 percent higher gross lactation feed efficiency.

The Simmental X Holstein crossbred steers were raised and feedlot-finished along with contemporary Holstein steers. The crosses gained more weight and produced 20 percent more retail meat product than the Holsteins.

Another breeding project that began in the 1970's was directed at measuring the production and nonproduction traits of offspring of cows with high- or low-pedigree ratings mated to sires selected for high or low production. The Iowa Agricultural Experiment Station cooperated in this research. Progeny of the high-pedigree cows significantly outproduced those of low-pedigree cows in the first lactation. Also, the progeny of high-ability sires outproduced those of low-ability sires (66).

At the Lewisburg, Tenn., field station, in a cooperative study with the Tennessee Agricultural Experiment Station, a herd of Jersey cows selected and bred for the single trait of high milk production significantly outproduced their herd mates selected and bred to randomly selected proved sires.

In the early 1970's, Department scientists, in cooperation with the Holstein-Friesian Association of America, the Food and Agriculture Organization (FAO) of the United Nations, and a number of artificial insemination associations, initiated a breeding project in Poland to improve Poland's cattle for milk and meat production. This project, supported in part by PL 480 research grant funds, compared sires from 10 countries and mated to some 33,000 cows in Polish institution herds. Results indicated that U.S. Holstein sires produced progeny that yielded more milk and as much or more meat than progeny of sires from any of the other countries, a prestigious accomplishment for U.S. Holstein breeding stock.

Other work supported by PL 480 funds included the study of genetic and physiological problems of dairy cattle in arid and semiarid areas in Egypt, and the production of well-adapted synthetic strains of dairy cattle through crossing in Pakistan.

Through close contact with the dairy cattle breed association, artificial insemination associations, breeders, and others, scientists continually focus their resources and talents to find solutions to changing problems that face the dairy industry.

Dairy cattle breeding research conducted by Department scientists for more than 70 years, along with research done by other institutions, has provided a great fund of knowledge on breeding systems and procedures for improving the Nation's dairy cattle. This research demonstrates conclusively that the most effective means of improvement is the continued use of progeny-tested superior proved sires. This principle has provided a solid underpinning for the National Cooperative Dairy Herd Improvement Program and has contributed greatly to the improvement programs carried on by the dairy cattle breed societies and the artificial insemination organizations. Breeding research of various kinds on new and yet unsolved problems continues at Beltsville, and the remaining field stations and in cooperative projects with State agricultural experiment stations.

Record-of-Performance Programs

In the first report issued in 1896 by the Dairy Division, the Chief of the Division pointed out in reference to the low production of cows: "Every possible influence should be exerted to induce dairy farmers to weed out their herds and keep fewer cows and better ones" (2). In a previous report in the 1894 Yearbook of Agriculture (1), he stated that

> It is good advice to the buyer to purchase a bull of some age, whose progeny prove his value, as a breeder, rather than a calf of exceptional pedigree; and to the owner, having a sire of proved excellence, to keep him and use him for years, or as long as he shows himself potent and prepotent.

Further in the report discussing the need for records, he stated that

> The record should include a concise history and description of every member of the herd with a summary of the daily performance. The latter requires a daily record of the milk of every cow, several consecutive milkings as often as possible. Some form of the Babcock test is the simplest and now within reach of every dairyman.

Thus, from the beginning and throughout the activities of the Federal dairy research and education services, improving productivity of the dairy cattle has been emphasized. This emphasis took several forms, but most important was the development, pursuance, and supervision of records of performance of the dairy cattle population. In 1898 the first report describing the breeds of dairy cattle was published (4). In 1900 a circular on the scale of points for judging dairy breeds was issued (5). These publications were revised, reissued, and updated in succeeding years. An early and continuing effort was made to promote the use of good purebred registered sires by breeders and dairy farmers in efforts to improve the quality of cattle. Federal personnel for many years cooperated with colleges and breeders in conducting national student judging contests.

Soon after the Dairy Division was organized, the current status of performance recording throughout the country was studied exhaustively. The purpose was to bring together authentic information on production testing, how it was done, and some of its benefits. Information was gathered from several State experiment stations on testing programs in their herds and in farmers' herds, from various State organizations and patrons of creameries and cheese factories, from breed registry associations that were conducting official tests of various kinds, and from 600 questionnaires that were sent to individual dairy farmers. This information proved most useful to Division personnel in planning programs in their important area of work.

After this study, Division specialists analyzed the data from the first cow census conducted under the auspices of Hoard's Dairyman Magazine. Information was obtained from 367 farm herds and from patrons of creameries and cheese factories at Ellisburg, N.Y. This information was supplemented by similar studies in 13 States with 2,163 herds and 28,447 cows. The information included yearly milk and fat production, yearly cost of feed, returns over feed costs, profit or loss per cow, and feed cost per unit of milk production. The study emphasized the great variation in production and profits and the increased income from proper feed and care of the milk cow. Culling low-producing cows also received top priority.

Beginning of Organized Cow Testing. During the time of these studies, most of the State college dairy specialists were analyzing the use and effectiveness of performance records. As early as 1892, organized cow-testing began in Denmark and was spreading rapidly throughout Europe where there were nearly 2,000 associations in 1908.

In the United States, organized cow-testing began in 1905 in Michigan with a cooperative group of 31 dairy farmers owning 239 cows (68). A supervising tester was hired and the farmer members agreed to have their herds tested once a month. The association elected officers to set up rules and procedures and to manage the entire enterprise. The main activity was to record the production and the amount of feed for each cow, thereby obtaining a complete record for calculating annually the performance and profitability of the herd. The objective was to focus attention on culling, feeding, and selection. This association received the cooperation and support of the Michigan Department of Agriculture, the State college Extension service, and the personnel of the Federal Dairy Division. In fact, the organizer of this first association was employed by the Dairy Division to develop performance recording throughout the United States. The organization of this association set the pattern for others throughout the country and essentially continues as the standard or official plan to this day. By 1910 some 52 associations were operating in 16 States. The growth of the record-of-performance program is shown in table 6.

Nationwide Recording Program. The Dairy Division and its later organizations accepted the record-of-performance program as a major project, working in cooperation with the Federal and State Extension services that promoted and supervised the program. The objective was to have a cooperative and uniform nationwide recording program. Division personnel worked with and through State Extension dairymen to organize associations. Although the individual associations were self-governing, the State extension dairymen assumed, as a part of their Extension educational activities, the overall supervision of the program in their States. To promote uniformity in this nationwide program, the Dairy Division provided, free of charge to the associations and supervisors, the necessary forms and herd books through the State Extension services. In return, the Division received the recorded information for study, research, and educational use. Reports of these studies were made from time to time throughout the years. By 1924 the Bureau had developed and issued a cow testers' handbook to guide association supervisors in their work (50). This handbook has been kept up to date in later years. The Division also provided samples

Table 6.—Growth of performance records of dairy cattle, selected years 1906-80

Year	Number of associations	Number of Herds	Cows	Production per cow Milk	Fat
Standard—Official Plan		*Thousands*	*Thousands*	*Pounds*	*Pounds*
1906	1	0.031	0.239	5,300	215
1910	40	—	25.00	5,730	227
1915	211	—	105.53	—	—
1920	468	11.95	203.47	6,175	247
1925	732	18.68	307.07	7,189	284
1930	1,143	27.89	509.55	7,642	303
1935	809	15.57	364.22	7,977	322
1940	1,300	27.95	676.14	8,133	331
1945	949	21.25	577.20	8,592	346
1950	1,973	40.10	1,088.87	9,172	370
1955	2,288	41.24	1,333.87	9,502	375
1960	1,509	41.29	1,746.75	10,561	409
1965	1,424	40.08	2,087.58	11,976	457
1970	1,267	34.31	2,122.01	12,750	483
1980	1,025	34.45	2,771.38	14,786	547
Unofficial Plan[1]					
1957	—	21.95	426.39	—	—
1960	—	27.39	692.29	—	—
1965	—	27.83	874.98	11,472	425
1970	—	25.37	998.13	12,413	460
1980	—	19.33	953.60	13,969	527

[1]Owner-sampler, weigh-a-day-a-month, alternate AM-PM, commercial, bimonthly, and trimonthly.

Source: U.S. Department of Agriculture (82).

of a contract for local associations, plus other guidelines such as model rules and regulations to aid the program.

Thus, in the decades after the organization of the first association, a firm foundation was built that has continued to support growth of the program in size and importance to dairy farmers throughout the country. This national program is an excellent example of Federal-State-farmer voluntary cooperation in an activity of inestimable value to the dairy industry. The American Dairy Science Association, the purebred breed societies, the National Association of Animal Breeders, and others have supported the program and cooperated in many ways to advance it.

As the program grew and became more important, changes and improvements were made in specific areas. A number of publications were issued by the government and farm magazines to support the program.

Cooperative Bull Associations. Soon after the development of the performance recording program, another association—the Cooperative Bull Association—was introduced in 1908 in Michigan. The objective was to promote the use of purebred bulls for herd improvement by farmers joining in a cooperative enterprise. By pooling their resources, the farmers could select higher quality bulls, preferably with production records, and use them in more herds. This program was sponsored by the Dairy Division and specialists in the regional dairy development programs who were already working with State Extension personnel.

Especially adaptable to small farmers, the program grew in size and importance until around the end of the 1930's, when artificial insemination became generally available. Nevertheless, on January 1, 1939, there were still more than 200 bull associations and some continue to exist (86).

Sire Evaluation Records. In the early 1920's, the recording of information became important from the standpoint of progeny testing and proving bulls for breeding. In 1927, one of the first general reports on this subject was issued. In 1932, a report was made on the value of using selected sons of proved bulls for increasing production. During the late 1920's and early 1930's, much attention was given to methods for evaluating sires. Scientists decided, on the basis of good research evidence, that the lactation records of daughters and dams should be used.

National Cooperative Dairy Herd Improvement Program (NCDHIP). A memorandum of understanding was issued between the Bureau, Federal Extension Service, and each State Extension service, specifying the respective responsibilities for the program in the various States and the Bureau's responsibility for overall coordination. The memorandum also covered procedures for receiving, processing, and reporting the progress and results of the testing, and for conducting the sire proving programs.

The rules under which dairy cows were tested in the local association were contantly reviewed and improved by the cooperating agencies. In 1924 the Testing Committee of the American Dairy Science Association began assisting in this work, and its approval was required before rules were made effective.

Helmer Rabild organized the first cow-testing association in Michigan in 1906. Later as a scientist with the U.S. Department of Agriculture, he organized the nationwide Cooperative Dairy Herd Improvement Program.

National Dairy Herd Improvement Association Investigations. As early as 1928 Bureau specialists in charge of the testing program began developing sire proofs on the data received from the States. The Bureau collected enough data to develop dam-daughter evaluations on 215 bulls.

The work in NCDHIP became so important that in 1929 personnel working on the program were organized into the Division of Dairy Herd Improvement Investigations. In 1937, the Division began publishing a list of sire provings that included provings for 1935-37 (78). This list was published annually through 1951, after which it was published monthly in the DHIA Letter until 1964. Now sire summaries are made on a quarterly or semiannual basis.

The sire proving data from NCDHIP provided records of dairy cattle from which the national germ plasm survey was made. Both Federal and State Extension specialists were responsible for collecting data for the survey, which focused much attention on the value of proved sires and on the authentic NCDHIP programs for locating and identifying superior sires.

The program continued to grow steadily and the number of lactation records received by the Division for processing increased dramatically (table 6). The volume of work became so great that in the late 1930's investigators had to change from manual to mechanical card machines and about 1960 to high-speed, high-capacity data processing equipment. By this time, many States were also adapting records received from individual associations to high-speed data processing equipment, with the result that a large percentage of the records received by the Division came in on magnetic tapes. This practice greatly simplified and accelerated the Division's work.

Artificial Insemination. Artificial insemination of dairy cattle began in an organized way in 1937. With the emphasis placed on the proved sire, it was natural for the insemination organizations to use the best sires available. That program offered the means of spreading the influence of favorably proved bulls to a much larger cow population than could be reached through natural breeding services.

The insemination organizations had to find these superior bulls through information from the several breed-registry production programs and primarily, from the NCDHIP. Thus, a strong working relationship developed between the NCDHIP sire proving interests and the National Association of Animal Breeders to the

Table 7.—Growth of artifical insemination with dairy cattle, selected years 1939 to 1970[1]

Year	Number of associations	Herd enrolled	Number of sires in service	Cows bred during year	Number of cows bred per sire
		Thousands		*Thousands*	
1939	7	0.6	33	7.5	228
1940	25	3.07	138	34.0	246
1945	67	44.0	729	360.7	495
1950	97	409.3	2,104	2,619.6	1,245
1955	79	845.9	2,450	5,413.9	2,210
1960	62	910.0	2,544	7,144.7	2,808
1965	46	591.9	1,867	7,264.8	3,402
1970[2]	31	369.2	1,911	7,308.6	3,641

[1]Since mid-1970, data no longer reported in this form. In 1978 the National Association of Animal Breeders reported domestic sale of dairy semen to be 11,858,425 units.
[2]U.S. Department of Agriculture (81).

benefit of both groups and dairy farmers. The growth of artificial insemination annually reported by the Division up to 1970 is shown in table 7.

Dairy Herd Registry Associations. Similarly, close relations existed between the NCDHIP and each of the breed registry associations through the Purebred Dairy Cattle Associations. As the testing programs grew in size and importance, the breed associations modified their procedures and introduced the herd test known generally as the Dairy Herd Improvement Registry. This registry applied only to herds of registered dairy cattle whereas the NCDHIP included information on both purebred and grade cows and their daughters by purebred bulls. In the mid-1960's, a program was developed whereby both groups exchanged their production information relating to sires.

NCDHIP Policy Procedures. Since the NCDHIP was a cooperative Federal-State-farmer undertaking, broad representation in the policy and procedural aspects of the program was essential. This principle was recognized by the Bureau, which welcomed assistance from the American Dairy Science Association in the procedural aspects of the program. In addition, in the mid-1940's the Bureau set up an ad hoc committee for advice on program policies. This committee consisted of representatives of the Bureau, the Federal and State Extension services, the American Dairy Science Association, the Purebred Dairy Cattle Association, and the National Association of Animal Breeders. This group functioned effectively for a number of years.

NCDHIP Cooperatives. About 1965, there was an active movement to organize statewide dairy herd improvement cooperatives. The Division encouraged this as a means of strengthening programs in the States and improving administration of local associations. These associations grew and expanded into other States. The State associations soon formed the National Dairy Herd Improvement Association, Inc. This development has been of great assistance to the entire program, especially at the State level. It has greatly aided State Extension dairymen in the overall supervision of the program by more effectively assuming responsibility for the administrative management of local associations. But more than this, the State and national association officials gained more of a voice in the overall policies and procedures of the national program.

Coordinating Group for the National Cooperative Dairy Herd Improvement Program (NCDHIP). At the suggestion of the Dairy Branch, a NCDHIP Coordinating Group was established in 1964 to advise Federal and State officials responsible for the policies, procedures, rules, and operation of the program (37). The coordinating group, which replaced the ad hoc committee, was made up of members representating the Dairy Husbandry Research Branch, Federal Extension Service, Extension Committee on Organization and Policy, American Dairy Science Association, Purebred Dairy Cattle Association, National Association of Animal Breeders, and National Dairy Herd Improvement Association, Inc. An Extension dairyman from each of the four regions of the country also served on the group. One item dealt with in the beginning by the group was the preparation of an updated memorandum of understanding between the Federal and State organizations. The group has undergone reorganization since its establishment but has continued to increase its service to the program, its operators, and its users.

The basic testing program on the individual farm has varied very little during the last 75 years. Each cow is tested for milk yield. Butterfat and other related data are recorded monthly or bimonthly. Operating procedures and the manner of processing the data, however, have changed a great deal. Rules and regulations have been improved and new types of forms, herd books, reporting cards, cow identification procedures, and reporting publications have been developed.

NCDHIP Optional Recording. The official plan for evaluating sires provided for an impartial supervisor to do the testing and recording at the farm. Some farmers were interested in a less sophisticated approach, however, and alternative plans were brought into the overall national program. The owner-sampler plan was introduced in the 1930's, and the weigh-a-day-a-month plan in the 1950's. In the former plan, the owner records milk weights and takes samples to a laboratory for testing. In the latter plan, the farmer records the milk weights only. Several modifications of the latter plan also are in use. These methods of testing are considered unofficial and are not used for sire evaluations or publicity; however, they have had modest success and are useful to many dairy farmers.

NCDHIP Research Opportunities. The early emphasis on testing was primarily to help the farmer in feeding, management, selection of his herd, and culling of poor cows. After 1930, increasing interest was directed towards the use of lactation records for locating and identifying favorably proved sires. As the volume of records and the demand and need for proved sires increased, methods for securing the most accurate proofs were improved. The Division, as well as many State researchers, intensified the use of these data for research. The research was directed towards improving application of data processing to needs of the program, sire and cow evaluations, dairy cattle population genetics, assessment of variations in performance of individual cows and bulls, evaluation of rules and procedures, evaluation of practices of supervisors and owners on the farm, and development of weighing and sampling devices.

With the volume of data available, new age-conversion factors could be developed for each breed of dairy cattle. As a result of research in the Branch and at State experiment stations, daughter-herd-mate records made in the same year (contemporary comparisons) were found to be more accurate than daughter-dam comparisons for evaluating sires. Accordingly, in 1964 this new improved procedure was introduced into the sire evaluation program (57). Studies at about this time resulted in the development of a cow index (CI) that was introduced in 1964 as a special part of the system; it is still useful in selecting cows as dams of superior bulls (56). From record data, improved factors for adjusting records from four or three to two milkings per day were adopted in 1968. Further research showed that use of genetic base (breed average) in the contemporary comparison calculatings increased accuracy of bull proof. This procedure became known as the modified contemporary comparison (MCC). The genetic base for 1974 has been used for several years in developing the concept of predicted differences (PD) for milk and income with proved sires in artificial insemination (15, 16, 17).

With the introduction of the PD, MCC and CI procedures into the NCDHIP, the artificial insemination and breed associations and breeders have become increasingly dependent on them for selection and mating procedures. Research continues to make these three procedures more reliable in estimating the worth of sires and cows for breeding. The regular reports issued on the evaluation of sires and cows are quickly available, easy to use, and much sought after by the industry.

To an increasing extent, NCDHIP members are testing for protein or solids-not-fat or both. Procedures are being developed to use this information in genetic evaluations. In 1979, the first reported information was issued as a milk-component sire summary together with a procedure for calculating PD's for production and expected gross income for sires. The program also has given increasing attention to the economic factors correlating the PD's of sires and the CI. Studies show that failure to consider economic factors along with production when selecting sires can lead to errors in choosing optimum genetic plans.

As the NCDHIP program has expanded, it has included services to the dairy goat industry. Many herds of dairy goats are being tested for production in local associations. This information is summarized, and evaluation programs for goats similar to those for cattle are included in the national cooperative program.

Cooperative research is underway with some breed associations to develop genetic evaluations for conformation. The evaluations are based on type characteristics and scores of sires' daughters and their herd mates. When evaluations are fully developed, the program will help improve dairy cattle type.

The use of automatic weighing devices for in-line milking equipment requires detailed evaluation of their accuracy. State experiment stations, manufacturers, and the coordinating group have cooperated in developing procedures to verify the operational accuracy of the devices and to repair them. These procedures have been very helpful to local associations and their members, especially the large herd owners. Research continues to improve and extend the services of this program to cooperating dairy farmers. Use of the program to improve dairy herd management procedures and to evaluate and improve reproduction in herds is currently emphasized.

From this brief review, the record-of-performance programs in dairy cattle obviously have grown greatly in the United States. Still, too few of the Nation's dairy cows are included. The program is unique in its organization and operation, and its importance to the dairy industry is enormous. Many changes have improved the operation of the program and its services to participants. The high status of sire evaluation has set the pattern for genetic improvement of the Nation's dairy cattle. The great progress in elevating the production performance of cows enrolled in the program and the genetic ability being built into the cow's germ plasm guarantees continued improvement in the efficiency and profitability of milk production.

Anatomy Investigations

Anatomy of Cows. Beginning in the early 1920's, the Division undertook research on the dairy animal's anatomical and developmental qualities related to breeding investigations. This research continued until about 1960. Growth and body characteristics were systematically measured on all project animals. Animals were measured while alive, and the size, weight, and shape of most of the internal organs were recorded at slaughter. The udder's shape, size, and internal structures also were noted, and the udder was subsequently sectioned and preserved for microscopic studies. One objective was to correlate the various external and internal measurements with the form and function of the animal. Similar studies were undertaken in cooperation with some State agricultural experiment stations and some of the Bureau's field stations (49). As part of the breeding and anatomical research, a uniform photographic history of all project animals at specified stages in their life cycle was established as a visual reference file.

Research was conducted on the growth and development of dairy cows from 1916 until the late 1960's at the Beltsville Agricultural Research Center. Scientists W. W. Swett and James Book are measuring a Jersey cow as part of the study.

Structure of Dairy and Beef Cows. In 1928 an attempt was made to characterize the differences between dairy and beef cattle. A highly noted Jersey cow and a representative highly prized Aberdeen Angus cow were chosen. External measurements and photographs were taken. When the animals were slaughtered, the internal organs, including the udders, were carefully weighed, measured, and studied.

The two cows varied greatly in external appearances. Differences were minimal in the sizes and weights of the internal organs and in the skeletal structures. The udder of the Jersey had more secretory tissue. The skeletons of the two animals were mounted and, with their research histories, were used extensively in educational exhibits throughout the country. The study indicated that dairy cows might be bred and selected for a large volume of secretory cells in the udder whereas beef cows might be selected for their ability to deposit muscle and fat on their bodies. A similar anatomical comparison of a dairy cow and a dairy bull was reported in 1932.

Early Udder Development. As the anatomical work progressed and techniques were refined, research continued on the developing udder, its growth, and its characteristics. As early as 1924, the growth of the four quarters of calves' udders was observed beginning as early as 10 to 14 days after birth and continuing into lactation. The external measurements and manipulation of heifers' udders during growth became known as the palpation technique; it was continued for many years to correlate udder development with later production performances. There was some correlation between early udder development in calves and their later production performance, but the palpation technique never became practical (75).

Considerable attention was given to accurately determining the capacity of udders. Also, the major arterial and venous blood systems, as well as the secretory, connective, and fatty tissues of the udder, were outlined and described.

Growth Standards. Research on the anatomical and growth characteristics of cows led to the adoption of growth standards for the Holstein and Jersey breeds, showed the relationships of size and type to milk production, and revealed that milk secretion is a continuous process (7).

Mastitis Investigations

Contributing Factors. At the time the original Dairy Division was formed, responsibilities for animal disease research and control remained with the Bureau of Animal Industry. However, the management of dairy cattle to avoid and control certain diseases affecting them was part of the responsibility of the Dairy Division and its later organizations. One of the so-called management diseases of the dairy herd is mastitis, or infection of the udder. Because mastitis was a universal problem of great economic importance in dairy herds, personnel in the Bureau of Dairy Industry conducted research on this problem with veterinarians in the Bureau of Animal Industry.

The research on the udder, its structure, and its anatomy mentioned earlier is important to an understanding of the mastitis problem. Early work in the Bureau concerned the relation of certain feeds to the incidence of mastitis. Another dealt with the effect of incomplete milking on the udder.

Injury to the udder during milking as a result of the machine vacuum pressure makes it more susceptible to mastitis. Division research revealed that the incidence of mastitis increased and the milk yields declined in cows subjected to very high or low vacuum pressures rather than normal pressures or hand milking.

Treatment. The treatment of mastitis-infected cows, first with sulfa drugs and later with antibiotics, was studied. Considerable work was done to identify the specific micro-organisms in normal and infected udders and the effects of various treatments on them.

The prevalent mastitis organisms in the udder were streptococci, staphylococci; and *Pseudomonas aeruginosa.* Infusion of sulfanilimide or sulfadiazine into the udder alone or in combination in one, two, or three successive treatments was highly effective in clearing the infected quarters of the first two organisms, but somewhat less effective on *Pseudomonas.* Milk production was unchanged during the treatments. The addition of urea to the sulpha drugs helped to eliminate *Pseudomonas.*

As antibiotics became more available for general use, their effectiveness in the treatment and control of mastitis was explored. Penicillin in amounts of about 200,000 units in three or four treatments over 2 days eliminated about 88 percent of the infections (76). Changes in the composition of the secretory tissue of the mammary gland and in the constituents and composition of milk, especially the leukocyte content, were monitored.

The widespread use of antibiotics in treating mastitis caused residue problems in milk. Public health officials were concerned, and efforts were made to safeguard the milk supply. At the same time interest grew in a screening test to detect mastitis. The leukocyte cell count appeared to be the logical test. Dairy scientists working closely with U.S. Public Health Service and State officials and with dairy industry associations provided both leadership and research information (73). This collaboration was important since the cell count was tentatively being used in the field to identify milk presumably from cows with mastitis.

Mastitis Control Laboratory. Because management and the surroundings in which animals are kept may influence the occurrence of mastitis, a special environmentally controlled laboratory was established at Beltsville in the mid-1960's to study predisposing factors for mastitis and the way it spreads from cow to cow. Unsanitary stable conditions and poor milking procedures had not been specifically correlated with mastitis infections. Milking operations were studied in relationship to the occurrence of mastitis. Factors including milking time, rate of milk flow, yield of milk, and milking

Scientist P. D. Thompson measuring the heart rate of the udder vein, part of the research on the fundamental efficiency of the milking machine and milking procedures conducted at the Beltsville Agricultural Research Center from 1960 to 1980. 1177B1474-6

machine mechanisms were correlated with the incidence of mastitis. Some States and manufacturers of milking machines cooperated in the study.

The California mastitis test (CMT) and the Wisconsin mastitis test (WMT) were evaluated for estimating the somatic cell count which reveals the presence of mastitis organisms in the milk. The results were compared with bacterial culture counts. Research indicated that fast-milking cows were no more subject to mastitis than slow-milking cows. The incidence of mastitis increased in cows after the second and later lactations and increased as the yield of milk increased (64). The WMT score was associated with the number of mastitis organism and their virulence. In 65 Wisconsin herds the WMT showed high somatic-cell counts in milk from 14 percent of the cows. The milk from infected cows had more than twice the number of organisms as milk from uninfected cows.

At the Utah field station, dry cow therapy, as determined by the CMT, with antibiotics or chemotherapy was most effective in preventing mastitis infections in the next lactation. Results at Beltsville showed that a solution of tertiary amines applied to the teat after milking was more effective than other chemicals currently used to control five mastitis organisms (58). This and related basic research on the cow's defense mechanism against mastitis are continuing.

Currently research is focused on the response of the cow to the machine and to teat cup pressures during milking. Related to this work is study of the muscular responses to teat cup construction, the residue left in the teat and the teat canal, and to conditions that cause bacterial infections. Different machines are being used, some of which are constructed or modified in the laboratory. Genetic and environmental factors that contribute to the cow's resistance to mastitis, as revealed by the somatic-cell count, are being investigated at the Virginia Agricultural Experiment Station and with cooperating dairy farmers.

Physiological Genetics

The knowledge that cattle blood contains genetically controlled antigens and other substances led to a new area of research in physiological genetics. It was logical to ascertain whether certain antigens were associated with desirable or undesirable characteristics that might affect productive and reproductive abilities of cattle. Researchers learned early that blood-typing techniques could be useful in solving parentage disputes in animals. The artificial breeding industry and cattle breeders found typing useful, and all bulls used for artificial breeding must be blood-typed.

Blood-typing Laboratories. Blood-typing laboratories were located at State experiment stations where research on blood-typing was in progress. Breed associations soon learned that different laboratories did not always obtain the same results with blood from the same animals. Differences in results apparently were due to the reagents used in the analysis. At the request of breeders and the artificial insemination industry, scientists in the Dairy Cattle Research Branch in early 1960 became involved with blood-typing problems.

These scientists, in addition to supporting a laboratory in Ohio, developed a procedure to make samples of blood from the same cow available to all typing laboratories for analysis. When the results were reported to Beltsville, steps were taken to analyze and report results back to the laboratories and work with them on any problems that occurred. Within a short time, sample replication brought about uniformity among laboratories in the analysis and reporting of blood types (45).

Blood-typing laboratories in other countries encountered similar problems. Sample replication typing was extended to other countries by voluntary agreements. Its use established unformity in cattle blood-typing throughout the world (46). Responsibility for the standardization and comparison of typing was eventually assumed by the International Society for Animals Blood Group Research.

Genetic Markers in Milk. Genetically controlled variations in milk proteins related to blood antigens were of scientific interest. Extensive research was conducted at Beltsville in cooperation with chemists in the Eastern Regional Research Center, formerly known as the Eastern Regional Utilization Laboratory, in Philadelphia. Fundamentally new information was reported about genes controlling structural differences in milk proteins, especially the caseins (46, 43, 44). Cooperative research was conducted in a regional project titled "Relationship Between Genetic Markers and Performance in Dairy Cattle." No relationships were large enough to be significant in the selection of breeding animals, but the work contributed a better understanding of individual gene affects in cattle.

Adaptability Investigations

With the importation of the Red Sindhi cattle (*Bos indicus*) from India in 1946, work was also initiated on environmental physiology. The objectives were to determine the effect of high temperatures, and methods of alleviating adverse effects. This work was especially important to the dairy industry in the Southern States. The Red Sindhi, a different type of dairy cow, was believed to be useful for breeding. (See previous discussion on breeding pp. 16 to22.) Research on adaptability was conducted primarily at Beltsville and the Jeanerette, La., field station in cooperation with several State experiment stations in the South.

Climate Control Laboratory. Special climate-control laboratories were established at Beltsville, Jeanerette, and the Louisiana Agricultural Experiment Station. First, a satisfactory index to measure heat tolerance had to be developed. Respiratory activity, characteristics of the animal's body surface area, and water evaporation from that surface were used to show heat reactions of animals to various temperatures and humidities (51).

Environmental Adaptability. Broader adaptability studies involved growth, development, and performance of breeds and crosses maintained under existing climates in the South. Some results of these studies have been reported (52).

The introduction of the Red Sindhi breed did not contribute to increasing productivity of dairy cattle in the South; nevertheless, it provided the basis for investigating the animal's adaptability and performance in hot climates. Much was learned about the physiology of the animal's adjustment to hot climates. No measure of heat tolerance was satisfactory to express the animal-climatic relationship. Individual animals of all breeds differed in their heat tolerance.

An important finding of this work was that all dairy breeds performed well in the South. The greatest opportunity to obtain and maintain acceptable performance is gained by providing the best possible conditions through good nutrition and management, including furnishing comfortable shelters.

Research on the response of cattle to climatic stress has continued in cooperation with the Missouri Agricultural Experiment Station in its specialized climate-controlled laboratory. The principles of housing structures that contribute to animal comfort, as well as the physiological response of producing cows to heat stress, are being investigated. Heat stress reduces feed consumption and thereby reduces milk production and growth. The dairy farmer should provide good night facilities to assist recovery from heat stress imposed during hot days, rather than attempt to avoid heat stress during the hot day.

Reproduction and Lactation Investigations

Efficient reproduction in dairy cattle is fundamental to successful dairying. Attention to reproductive research is a logical part of the Federal dairy production program.

Ova Investigations. Fundamental work began in the late 1920's. The first report described was of a basic study conducted in cooperation with the Carnegie Institute in Washington, D.C. In this study, the first known recovery of ova from the fallopian tubes of cows was reported.

These calves were born of foster mothers through embryo transplants. The ova from a high-producing cow (center) were fertilized with semen from superior sires. These calves, all full siblings, are members of a unique research herd of genetically uniform animals for research programs at the U.S. Dairy Forage Research Center in Wisconsin. 1181X1434-12

One fertilized ovum was recovered 48 hours after breeding and developed to the two-cell stage. An illustrated film strip entitled "In the Beginning" was produced. It told the story of fertilization and embryo development in the living animal. The film strip had wide educational use.

In 1932 the reproductive performance of the Beltsville herd over several years was reported. The report covered many conditions affecting reproduction of both males and females. Two items of particular interest were presented. One study demonstrated that feeding sprouted oats did not improve the fertility of bulls. Another study which dealt with the importance of exercise, led to the development of a bull exerciser. The exerciser was never widely used by dairy producers.

A bull exerciser built by the Beltsville Agricultural Research Center in the mid-1900's to study the effect of exercise on the virility and performance of sires. 17866

Artificial Insemination. Cows were being artifically inseminated as early as 1931. In 1930 scientists began collecting and examining semen from bulls in breeding herds. They collected sperm from the reproductive tract and studied their morphological characteristics. Use of fresh semen preserved in artificial media and transported from Beltsville to several field stations was only marginally successful. After these preliminary studies, and as artificial insemination became a commercial reality, Bureau scientists began to support the artificial breeding movement through the NCDHIP sire proving program and directed their research accordingly.

Another project involved the effect of vitamin A deficiency on the fertility of bulls. Semen production and quality were not adversely affected until bulls were in the advanced stages of vitamin A deficiency as revealed by night blindness and inanition.

Endocrine Glands and Secretion. Basic research was conducted on hormones that affect reproduction. Particular attention was directed toward hormones of the pituitary gland. From 1933 through 1947 several papers were published; two are cited (23, 30). Emphasis was placed on identifying pituitary hormones that affected reproduction and lactation. Methodology for hormone assays was developed and refined.

Fertility and Infertility. As information was accumulated on the organ-reproduction complex, research was directed to fertility and infertility of both males and females and more specifically to the hormones that affect reproduction. Nutritional factors that might affect reproduction were high on the research agenda. Studies were conducted in the 1960's with an intrauterine device to learn more about the physiological processes that regulate the interovarian-pituitary complex and means of avoiding conception failures (35).

In the late 1960's, basic research on reproduction was greatly increased because of the significance of infertility as a crucial problem in the livestock industry. New tools and techniques became available for scientists to explore more deeply the physiology of reproduction. New staff members and a new laboratory were provided so that more dairy cattle, sheep, goats, rabbits, and rats could be tested.

Basic research emphasized the pituitary gland, ovaries, placenta, and reproductive tract and their secretions, functions, and interrelationships. Much attention was given to the sequences of ovulation, sperm transport, fertilization, embryo implantation and maintenance, and hormonal, chemical, and physiological relationships of these processes (33, 34).

Some causes of fertilization failure and embryo mortality have been identified. Because embryo mortality is a major cause of reproductive failure, a reduction in this condition could have important practical application.

Another problem associated with poor reproduction is the difficulty in detecting estrus in cows. Accurate detection of estrus is necessary for successful artificial insemination. Research at Beltsville, started in the early 1970's, involved two approaches to the problem. In studies made with pedometers, cows were found to be about four times more active on the day of estrus than at other times. This work led to commercial interest in the approach, and specially designed electronic pedometers for use on cows are being developed (34). Another approach has been to use trained dogs to detect estrus. Because cows in estrus have a different odor from nonestrus cows, dogs can be trained to detect the estrus cows. The odor appears in milk, urine, and blood as well as in secretions from the reproductive tract. This phenomenon, especially if current chemical work results in identification of the active compounds, may eventually provide new approach to the problem of estrus detection (33). Results in other studies show that exercising heifers results in fewer services per conception and a shorter period from calving to the next conception.

5. Feeding and Nutrition Investigations

Dairy cattle must receive proper feeding and care if they are to produce and reproduce efficiently. Dairy cattle nutrition received attention by the Federal dairy establishment from the beginning of the Dairy Division. Before research activities got underway in 1910, much Extension activity on feeding and management became a part of the dairy introduction programs throughout the United States. At the same time, feeding and management information was being written and released from the Washington, D.C., office.

Although some research on feeding was done in the dairy research laboratories in the early years of the Division, the major thrust began in 1910 with the establishment of the Beltsville Dairy Research Station. From this beginning, a very broad and intensive research project on all phases of dairy cattle feeding and nutrition has continued through the years.

Because the dairy animal is a ruminant, researchers have long recognized that pasture and other forages would always be a principal and economically important feed for dairy cattle. Thus, investigators have studied ways of making these feeds more useful in milk production. Other areas of research have been the nutritional requirements of animals, including energy, minerals, vitamins and other nutrients; the composition and nutritional value of feed materials and factors affecting these values; feed analysis; rumen and rumen microbiology; calf nutrition; use of antibiotics in feeding; pesticide residues in feed and milk; thyroprotein as dairy cow feed; composition and nutritional value of milk and factors affecting these values; and feeding and management factors affecting milk secretion. Although the research projects involving these many subjects are intertwined in many respects, this review presents the several areas of research listed above under the separate headings.

Pasture

Because pasture is such a universal feed throughout the country, research to improve its usefulness was an important part of the research programs both at Beltsville and at several field stations. The emphasis was on pasture management, including grazing practices, and on increasing pasture yields and utilization. Forage agronomists and soil scientists at the Federal and State stations cooperated to test new varieties, improve cultural methods, test fertilization practices, and evaluate irrigation of permanent and temporary pastures.

Beltsville Research. In one study, investigators determined how much grass cows will graze. In another the Hohenheim rotational grazing system was compared with open continuous grazing. Yields were estimated by clipping strips of grass within cages on open ground and by the performance of grazing animals. The nutritional value of grasses, their estimated consumption, and the effects of weather on herbage growth were investigated.

In a long-term experiment, the yield and comparative advantages of a rotation pasture incorporated into a 5-year crop-rotation system were compared with those of permanent pasture (72). This study was followed by an experiment to determine the relative efficiency of three pasture utilization systems, including soiling, and the effects of grazing pressures on the performance of milking cows. Also, residues on herbicide-treated pastures were estimated.

Field Station Pasture Research. At Huntley, Mont., continuous pasture research was part of the dairy projects and included experiments on management, including rotational grazing, fertilization, and pasture renovation. Considerable research was done on pasture irrigation because the station was located within the Huntley Reclamation Project. In 1933, results were reported for a large-scale experiment on the feeding value of grasses when used for grazing, when fed green, or when fed as hay or silage (28).

A cooperative pasture research project was conducted during the 1930's with the Washington Agricultural Experiment Station at Puyallup, Wash. The studies included the influence of management on grazing habits of milk cows, comparison of continuous versus rotational grazing, methods of measuring yields, and apparent digestibility of fresh and dried grasses. Other experiments dealt with the accuracy of live weights of cows on pasture, the accuracy of pasture yield estimates as determined by grazing animals, compared with cage-protected clippings and the composition and digestibility of clipped herbage.

Research also determined the value of liquid manure for increasing pasture yields (38). Research at several Bureau field stations determined the feeding values of prickly pear, flat peas, pearl millet, and sudangrass for grazing. Studies also were made on the feeding values of various annual pasture crops in the Southeast.

At the Lewisburg, Tenn., field station, a series of pasture experiments appropriate to that region included studies of management practices to improve permanent pasture yields; effects of early and delayed grazing on yields; effect of supplemental irrigation on yield; and on two varieties of pearl millet. At the Jeanerette, La., station, research determined the nutritional value of pastures for dairy cattle in that region.

As dairy farming systems have changed over the years, many farmers, especially those with large herds, have discontinued pastures and have resorted to drylot feeding. Others have changed to green-feeding systems in which forage from permanent grassland, rotation pasture, and other green crops is field cut, chopped, and fed daily in drylot or put in silos. In recent years the Agricultural Research Service has done relatively little research on green feeding.

Harvested Forages

Federal dairy scientists have conducted much more research on harvested forages than on pastures. Research included the reduction in losses and the maintenance, preservation, acceptability, and nutritional values of the harvested and preserved forages. The work included both dried forage (hay and artificially dried material) and various silages. It also emphasized the ability of dairy cows to maintain themselves and to produce and reproduce well on rations composed principally or entirely of forage. Because home-grown forages generally are the least expensive source of nutrients, they are important in keeping the cost of milk production as low as possible. The forage part of the ration becomes more economically important when the cost of grains is high. In this review, not all the Federal literature on forages is discussed. Rather, some of the early work and the more significant research will be reviewed. In addition, other aspects of feeds and forages specifically related to vitamin values, composition, and nutritional evaluation in light of animal requirements will be discussed.

Corn Silage. Corn silage is a most important forage. Much research was devoted to its making, preservation, and feeding value. A U.S. Department of Agriculture bulletin, published in 1914, described how to build a silo (69).

Other reports involved efficiency of preservation and losses of nutrients; feeding value when silage is fed as a part of the ration or the entire ration to cows and young stock; effects of corn silage on the flavor and odor of milk; nutrient yields relative to that of other feed crops; estimates of the volume of silage in silos; effects of stage of maturity on yield and quality of corn silage; and preservation of silage in conventional upright and gas tight silos, trenches, stacks, and bunkers.

Research continued to increase the efficiency of conservation and to increase the value and improve the supplementation of corn silage with other feeds (85). Comparisons showed no advantage for a liquid protein supplement over the conventional protein meals. Limestone buffer has proved beneficial in rations where corn silage is the principal feed.

Paraformaldehyde and similar preservatives in ensiled corn forage proved of no advantage for milking cows fed the additive containing silage versus normal corn silage. Apparently the composition and physical characteristics of ensiled corn forage include the substrates for efficient fermentations and preservation. This research, the research of many other scientists, and the experiences of dairy farmers confirm that corn is one of the most important feed crops for the dairy herd.

Silage from Hay Crops. The generally poor quality and the high losses in palatability and nutritive value of forage hay crops prompted scientists to study alternative methods of preserving forages. The problem was especially severe in the humid dairy areas of the country.

An alternative to hay-making was preservation of these crops as silages, but this proved to be more difficult than making silage from corn. Division scientists began to study this problem as early as the mid-1920's. Much preliminary research led the way to making good-quality grass or legume silage with high acceptability to cattle. The problem was adjusting the forage to the right moisture content at the time of ensiling to avoid excessive seepage and adjusting to the right composition to promote satisfactory fermentation. The best solution was to allow the forage to wilt in the field, and then to properly pack the ensilaged forage. The procedure is described in two report (87, 89).

The potential value of silage preservatives such as molasses, urea, and formic acid in making silage from grasses and legumes of different moisture contents was studied. Feeding values and quality of preserved grass silage were determined in several kinds of storage facilities. Wilted and high-moisture silages and silages made with preservatives were fed to cows and young stock as a sole ration and as part of a hay or hay-grain ration. Results of these and related studies have enabled dairy farmers to use the silage method for preserving good-quality feed as an alternative to hay-making (27).

High-quality grass silage is more difficult to make than corn silage. Research continues on making silage from direct-cut forage and how it can be made more useful as feed. Emphasis is on the addition of preservatives. Both paraformaldehyde and formic acid additives resulted in an acceptable silage (14) and increased consumption of the silage and production of milk. Heifers attained significantly greater growth when they were fed preserved silage than when they were fed unpreserved silage. The preservatives appear to improve nitrogen utilization and to have little or no effect on energy utilization by heifers. This action is the result of decreased solubility of nitrogenous compounds in the silage.

Because of protein degradation, direct-cut unwilted forage silage (high moisture) appears to be protein deficient even though the nitrogen content is high. Paraformaldehyde tends to prevent degradation. With modern harvesting equipment and procedures, direct-cut forage can be ensiled more efficiently and more economically than wilted silage.

Hay. Research on hay was conducted to determine how to preserve hay with the least loss of nutrients and to evaluate the feeding values of different species and grades of hay. The feeding values of artificial and barn-dried hays and hays used as pelletes and wafers were investigated. The efficiency of preserving the hay crop was studied; resultant feeding values of the forage were compared with those of hay and grass silage. Forage from the same fields were preserved as field-cured hay, barn-dried hay, and wilted silage and was evaluated for field losses, preservation losses, and comparative feeding values (71).

Much work was done on the feeding value of different kinds of hays, especially alfalfa, fed as all or part of the roughage ration and fed alone or in combination with other forages and concentrates. Research was conducted during the 1930's, early 1940's, and other periods when concentrates were expensive to see how well cows would perform on predominantly forage rations or on forage alone.

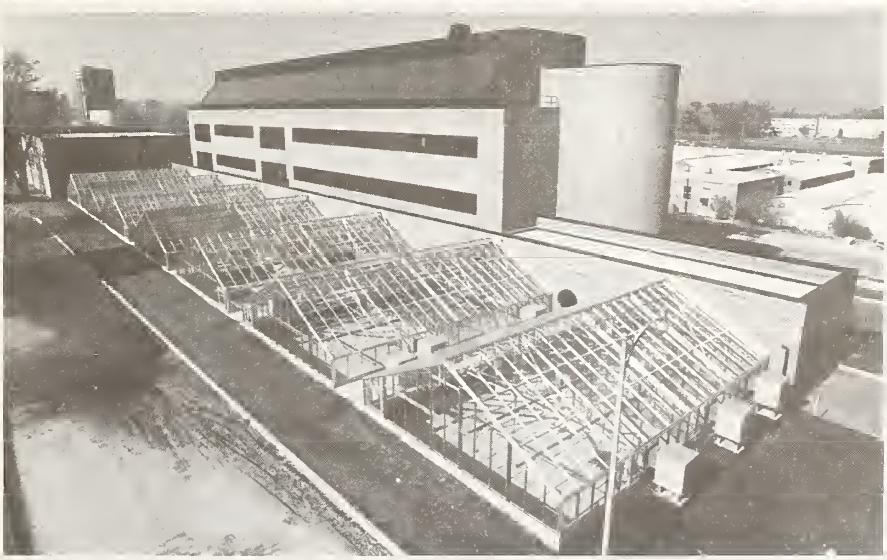
In cooperation with the Federal Farm Management Unit and several State agricultural experiment stations, Federal and State scientists undertook a comprehensive project to determine the input-output relationships of milk production. The project was related to the economic depression of that era in that it sought the most economical feeding level in terms of the value of the milk produced. Cows in dairy herds at a number of State agricultural experiment stations were allotted different rations providing nutrients at, above, or below the feeding standard with various roughage-to-concentrate ratios. The results were reported in 1942 and provided useful information on the economics of providing rations for milk production (40).

The results of this varied and continuing research program, along with those of many other programs, have provided information that enables farmers to produce more and better forages, to reduce losses during harvesting, and to use these most important crops. The programs have also focused attention on the importance of these crops in the economical rationing of dairy cattle. As in all areas of endeavor, the more we learn the more we need to know to improve. Therefore, scientists must continue to improve the use of hay crops, for they truly are the bases of efficient and economical feeds for dairy cattle.

New U.S. Dairy Forage Research Center. The need for a specialized research center to intensively study the forage production and utilization complex in dairy cows had been recognized for some time. Such a Federal center, to be located in the humid north central region where dairying is the most prominent farm enterprise, was first recommended in 1960. Congress authorized its establishment in 1978 on the campus of the University of Wisconsin at Madison. The program will strengthen and expand research on critical problems of production, handling, preservation, and use of forage resources on dairy farms. The Federal staff at the center cooperates with university scientists. The full research staff is made up of soil, plant, engineering, dairy, and economic scientists providing a multidisciplinary approach to broad and complex problems that need to be solved if we are to use forages as the principal dairy cow feed and to reduce the costs of milk production. In addition to the activities at the center, the project includes complementary cooperative research at several other State agricultural experiment stations.

Carotene and Vitamin A Supply and Needs

When vitamin A was discovered in 1916 and found in milk, researchers began to determine its importance in the rations for dairy cattle and means for increasing its content in milk. They soon learned that milk vitamin A content varied greatly with the amount of carotene (vitamin A precursor) in the feed. Scientists also learned that green forages were the principal sources of carotene and that levels of carotene varied greatly depending upon the environment. They found that dairy cattle needed specific amounts of vitamin A (carotene) and that animals could store it in the liver. The Bureau first reported research on vitamin A nutrition of dairy



The U.S. Dairy Forage Research Center was established in 1979 at the University of Wisconsin, Madison, to increase the efficiency of forage use in dairy production. In addition to the University of Wisconsin, the interdisciplinary research program is complemented by research at seven other State agricultural experiment stations—New York, Minnesota, Pennsylvania, Michigan, Ohio, Iowa, and Missouri. The Center consists of a dairy operation near Prairie du Sac (top) and an office-laboratory-greenhouse complex at the University of Wisconsin's Madison campus (bottom).

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cattle in 1934 (55). Between 1934 and 1980, Department scientists published some 42 reports on various phases of vitamin research in dairy production.

Carotene Content of Forages. Intensive studies were reported on the carotene content of feeds in relation to the vitamin A content of the butterfat in milk. Investigators also found losses of carotene from forage during and after harvesting and suggested storage procedures that would minimize losses. Storing forage in silos was one of the best ways to preserve carotene. Methods of storage and factors affecting carotene losses and the quality or grade of hay were compared (41).

Vitamin A (Carotene) Requirements. Requirements of dairy cattle for this vitamin have been investigated. Methods of determining adequacy of vitamin A intake and the relationship of intake to depletion or to the onset of a deficiency were early problems that were studied. Some work dealt with storage of the vitamin in the liver and its rate of depletion. (63)

Vitamin A Content of Milk and Milk Products. Much work was reported on the vitamin A content of milk and butter. As part of the defense effort during World War II, a national survey was conducted with inputs from cooperating State experiment stations on the vitamin A content of the national butter supply (79). The Nation's butter supply proved to be a very good source of the vitamin although the content varied considerably; it was much higher in summer than in winter, and thus reflected the carotene content in the cow's feed. Results from long-term experiments conducted with rats to compare the nutritional value of butterfat and vegetable fats showed no marked differences (18).

Minerals

The mineral requirements of dairy cattle and the means of providing them are an important phase of dairy cow nutrition because milk is high in calcium (Ca) and phosphorus (P) and is an important source of these minerals in the human diet.

Calcium and Phosphorus Research. The Division's research began early with a first report on methods for measuring P in 1918. A series of publications on Ca and P metabolism followed dealing with such topics as effects of these minerals on milk production, consequences of a deficiency of one or both minerals on the animal and on milk production; sources of these minerals in feed, especially roughages; supplementation of the ration with either Ca or P; importance of their ratios and vitamin D in metabolism and utilization; and ability of various forages and other feeds to provide needed Ca and P.

This research continued until the end of the 1930's, when the Division's work and that of many other scientists had contributed a practical understanding of the Ca and P requirements for dairy cattle and methods of compounding rations to provide needed amounts of these minerals. Scientists showed that high-producing cows were unable to remain in positive Ca and P balance, particularly during early lactation, and that such cows drew heavily on body reserves during these periods to maintain normal Ca and P contents in their milk.

Antirachitic Properties of Forages The relative calcification properties of green, artifically dehydrated, and sun-cured pasture grass and of other forages preserved differently were studied. Several other studies on the antirachitic activity of forages were reported. Sun-cured forages were better sources of the antirachitic factor than artificially dehydrated or preserved forages. The principal source of the antirachitic factor was insect-damaged leaves.

Miscellaneous Research on Minerals. The effects of molybdenum on tests histology in young bulls, on magnesium levels in the blood of cattle, on the ability of iron to alleviate anemia in calves, and on utilization of tocopherol from artificially dehydrated alfalfa had been studied. Limestone buffer in rations based on corn silage and corn grain improved the efficiency of production.

Nutritional Requirement—Feed Composition and Nutritional Values

The nutritive requirements of farm animals have been studied for many years. The accumulation of knowledge of the composition of feeds for providing needed nutrients is closely associated with an overall knowledge of nutrition.

Early Work on Energy Value of Feeds. Total digestible nutrients, energy units based on proximate analysis and digestibility estimates, have been most useful in proper rationing of livestock. They do not, however, give a true estimate of energy values, especially for feeds high in fiber. Estimating energy value of feeds and energy requirements is a laborious, expensive task that requires complicated equipment for experimental use with large animals.

A portable respirator, developed in mid-1960's at BARC is tested by scientists D. R. Waldo and W. P. Flott. This apparatus was developed to determine the energy requirements of cows while on pasture. 16-N-24277

Federal researchers interested in energy research supported and cooperated with research scientists at the Pennsylvania Agricultural Experiment Station, where an energy metabolism laboratory had been established. Beginning in 1924, scientists published a series of reports on the utilization of energy for milk production, on methods of measuring nutritive energy, and on the energy requirements of milking cows (24). Net energy and total digestible nutrient systems were compared, the effect on milk production of feeding in excess of the, then, recommended feeding standards was determined, and methods of determining the digestibility of feeds, especially forages, were studied.

There followed intensive laboratory research on the composition and breakdown of the fibrous content of feeds, including lignin and holocellulose. This research offered enough promise for improved methods of analyzing feeds that the Energy Metabolism Research Laboratory was established at Beltsville, Md., to conduct research on this and related subjects.

Energy Metabolism Research Laboratory at Beltsville. The Energy Metabolism Research Laboratory was established at Beltsville in the early 1950's. It included a specially arranged building equipped with six open-circuit respiration chambers and an automatic recording system to record and analyze the data and a chemistry laboratory.

This laboratory provided a new opportunity to investigate the metabolizable and net energy for evaluating feeds and energy requirements of cows at different levels of maintenance and production (20). Information was obtained on energy requirements of dry and lactating cows at different levels of production; energy value of different feeds and levels of feeding; calorimetric operational techniques; effects of ratios of forage to grain on utilization; influence of pregnancy of energy utilization; energy requirements of young stock; partition of nutrients between lactation and body gain; and energetics used for maintenance, lactation, body weight, and gestation (61).

Results in recent studies show that a ration's useful energy value changes with the nutritional level maintained in the animal. When the increased metabolizable energy available from a feed is partitioned into milk, body tissue gain, and heat production, the proportion of increased energy balance in the form of milk energy has varied from 3 to 53 percent. Results in balance studies on nitrogen and energy relationships show that the nitrogen balance increases and the energy balance decreases as the solubility of nitrogen in the ration decreases.

New Standards for Energy Requirments. As a result of this research, scientists developed formulas for estimating net energy that were adequate to calculate rations for both maintenance and lactation and for other physiological functions. In 1978 the National Research Council's nutrient requirements for dairy cattle were revised, largely on the basis of Beltsville work, to include both net energy requirements for animals and net energy values of commonly used feeds. Recommenda-

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A Holstein cow in a respirator chamber at the Beltsville Agricultural Research Center. This chamber, one of six, is used to determine the energy requirements of dairy cows. The unusual facility was established in the 1960's and continues to operate. Scientist Gordon Haaland records data on cow about to be tested.

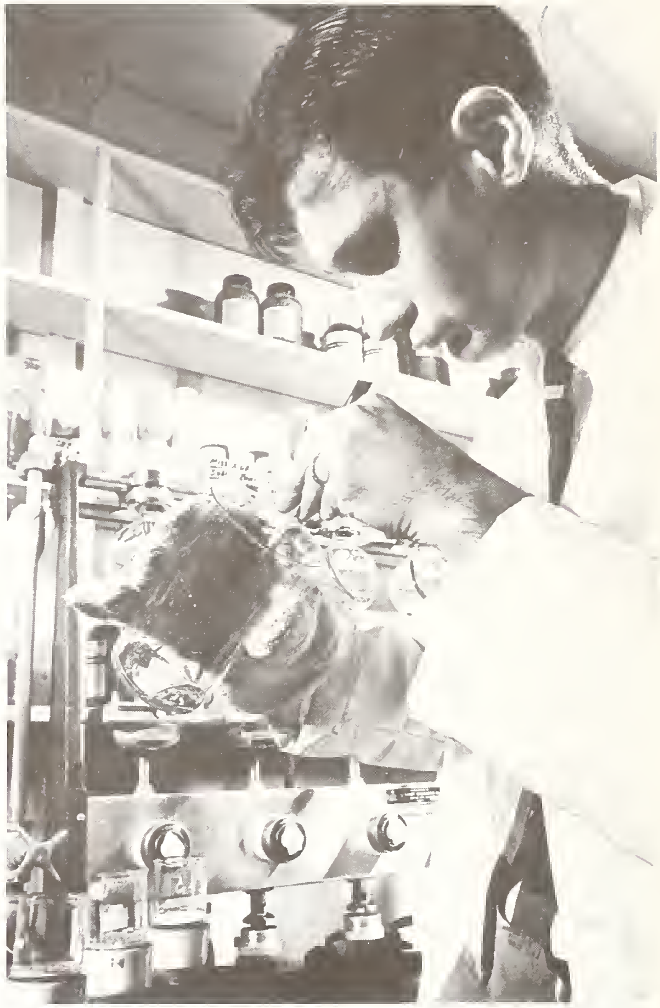
tions on digestible and metabolizable energy values were also included. Thus, progress has been made on more efficient rations for dairy cattle.

Having developed the metabolizable and net energy concepts of animal requirements and having determined the energy content of feedstuffs, scientists turned their attention to more basic research on new methods to determine how nutrients are broken down and used by producing cattle. Labeled carbon and rare earth procedures are used to study the dynamics of digestion. Fermentations occurring during digestion are determined by the basic microbiological techniques, and the role of various enzymes in the breakdown of fibrous materials are studied. This fundamental research is directed towards understanding the dynamics of the digestion of different feeds used in the rations of producing dairy cattle; it is also directed towards measuring the amounts of nutrients absorbed and determining how such absorption can be increased.

New Methods of Feed Analysis. Under "Early Work on Energy Value of Feeds," discussed previously, a special project was set up in 1960 to develop improved methods of feed analysis. Results of earlier research on the fiber complex indicated that available methods for analyzing crude fiber did not reflect its true nutritive value and further complicated estimates of energy values of feeds high in fiber.

After 20 years of research, a method was developed using various detergents that hydrolyzed the cell walls of plants and thereby isolated the components lignin, cellulose, and holocellulose for analysis. The method became known as the acid detergent method of fiber analysis and was incorporated into a new recommended system of feed analysis (84). It is used in laboratories throughout the world to analyze many feeds and was adopted as an official method of feed analysis by the Association of Official Agricultural Chemists. Acid detergent fiber values are used to predict the energy values of feeds.

Research continues to find ways to improve the chemical evaluation of feedstuffs of various kinds and to correlate findings with the actual nutritional values for animal production.



Chemical studies conducted at the Beltsville Agricultural Research Center since the 1960's combine with feeding trials to evaluate forage feed. Scientist P. J. Van Soest developed an improved method of evaluating feed stuffs for energy and other nutrients. ST-480-16

6. Composition and Nutritional Value of Milk as a Food

Early in the life of the Dairy Division, officials recognized that milk and its products were highly accepted as a food by consumers. It was logical, then, to determine how production on the farm and processing and storage in the plant affected the composition, quality, and nutritional value of milk.

Research on Milk Protein

Casein, the principal protein of milk, became known as the most complete protein by virtue of its amino acid content. A report in 1920 established that the amino acids in blood were the precursors of milk protein. Between 1920 and 1942, several published papers compared the amino acids in blood with those in milk. One paper featured the effect of abrupt changes in the cow's diet on the yield and composition of milk and the influence of the diet on the composition of blood and secretion of milk. Two important reviews on milk were published, one in 1939 on variations in composition and the other in 1965 on nutrient constituents (32).

Known and Unknown Vitamins

The importance of vitamin A in milk was discussed previously. Recognizing that milk may contain other nutritive factors, Bureau scientists conducted intensive investigations on the nutritional value of milk. They showed that milk was also an important source of water soluable vitamins that were synthesized in the cow's rumen (32).

The scientists believed from their research, however, that milk contained a yet unidentified water-soluable nutrient, which they confirmed in 1947. At about this time other researchers had discovered vitamin B_{12}. Further research in the Bureau's laboratories determined that the unidentified nutrient in milk was, in fact, vitamin B_{12}. Intensive research that followed established the vitamin's content in milk and its products, its formation in the rumen, factors affecting its content in milk, and its physiological role in the animal (12). While this work continued, the search for other nutritional factors in milk continued, but without positive results.

Changing the Composition of Milk Fat

Dietitians and nutritionists in recent years have suggested that people should include less saturated fats in their diets. Animal foods (including milk products) are a significant source of saturated fats. Animal nutritionists found that fat protected from rumen microbiological activity by a coating of formaldehyde passed unchanged through the rumen and was subsequently digested in the intestines. Research showed that milk and fat yield increased when a protected soybean-tallow supplement was fed. Also, the milk has a higher percentage of unsaturated fats than did the milk from cows fed unprotected soybean-tallows supplement. Thus, the composition of butterfat can be changed to comprise less saturated fat, but flavor and quality of milk and its products are then difficult to maintain during processing and storage.

Tests for Protein and Solids-Not-Fat in Milk

In the early 1960's, there was much interest in using protein or solids-not-fat instead of butterfat content as a basis of milk pricing. Also, there was interest in using protein or solids-not-fat in addition to butterfat yields in the DHIA program to evaluate the productivity of cows.

In response to a recommendation of the NCDHIP Coordinating Group and in cooperation with State Extension dairymen and committees of the American Dairy Science Association, Branch researchers developed practical methods for estimating protein and solids-not-fat in milk of individual cows.

Radioiodine Contamination of Milk

In the mid-1960's, as a result of nuclear bomb testing, radioiodine fallout was widespread in parts of the United States. We needed to examine how the fallout on pastures and forages affected cows consuming such forage and the extent of residues of radioiodine in milk. In cooperation with the, then, Atomic Energy Commission (now the Department of Energy), State experiment stations, and other Federal units, the Branch undertook an analysis of this problem. In addition to surveying milk supplies from different areas of the country and determining the half-life of radioiodine in milk, the Branch set up experiments in which dairy cows were maintained under different systems of feeding and management (25). The results from these studies provided guidelines in farm management for use in future emergencies.

7. General Dairy Husbandry and Herd Management

From the beginning of the Dairy Division in 1895, some research reports fell into the general catagory of dairy husbandry. This chapter reports a variety of research that does not fit well into other sections. Many publications such as Farmers' Bulletins, Circulars, and Leaflets were published on dairy husbandry and periodically revised. In addition, a variety of other publications were written that have contributed to dairy development.

Herd Development and Management

In the early years, some Dairy Division reports concerned dairy introduction research, herd and farm organization and management, feeding, cow testing, calf raising, milk secretion and production, dairy cattle breeds, judging dairy cattle, milk utensils, and care of milk on the farm. Water requirements and methods of supplying water to cows were described in terms of milk production.

How the frequency and regularity of milking affected milk production was reported in 1931, and the effect of the dry period on milk production in the next lactation was reported in 1934. Through the years, a number of reports described the nutritional values of various feeds and byproducts; once-a-day and twice-a-day feeding; and the feeding, care, and management of calves and young dairy stock. Some reports described general herd development and the economics of dairy production systems.

One report described the production of cows maintained in pen and stanchion barns. In 1945, an important report described the functional designs of dairy barns. Also, research contributed information on maintaining cattle in stanchion and open-shed housing and on the use of different kinds of beddings. As herds became larger, combinations of special milking facilities and loose housing for cows became popular and presented management problems. Large herds permitted the use of automatic feeders and associated computer recordkeeping. Computerization improved the orderly assembly and storage of data, permitting more accurate and rapid decisionmaking in management.

Use of Animal Wastes for Feed

In the last 10 to 15 years, disposal of animal wastes without environmental contamination has become an increasing problem. One solution is to use wastes for feed. Investigations were conducted to determine the proper handling of poultry and dairy wastes in preparation for feeding; the feeding value of wastes as part of the ration for sheep, cows, and young stock; and whether wastes when used as feeds had undesirable effects on the animal or its products.

In this research the use of poultry wastes was emphasized. They have been used fresh, dehydrated, and ensiled (74). Fresh or dehydrated poultry litter is equal to soybean meal and urea as a protein supplement to produce gains in lambs. Milk production was satisfactory when cows were fed corn ensiled with dried poultry excreta, but results were better when cows were fed corn silage with excreta added at the time of feeding. The nitrogen in dried poultry excreta proved highly digestible. When used as a protein supplement with growing and finishing Holstein steers, dehydrated poultry excreta was as good as cottonseed meal. Six percent of expressed liquid dairy cow excreta added to an otherwise adequate ration was satisfactory for growing lambs. The digestibility of nitrogen in poultry excreta determined for cattle and sheep was the same as

An experimental solar-heated milking parlor at the Beltsville Agricultural Research Center has been in use since the 1970's.

that in other traditional feeds, whereas the digestibility of nitrogen in cattle excreta was significantly lower than in other traditional feeds. Wastes from poultry operations apparently have at least some possibilities as protein supplements for ruminants, although their potential use will be determined, to a degree, by economical and operational considerations.

Use of Whey for Feed

Disposal of whey from cheese factories has stimulated research on the nutritional value of whey for livestock. When fluid whey was fed as an additional source of nutrients, cows and calves consumed large amounts with no observed ill effects. However, even though whey can be consumed directly by livestock, the mechanics and cost of transporting it from sources of supply to farms limit its use as feed.

When calves were fed whey blocks (liquid acid permeates) with hay, they obtained about one-half of the total dry matter consumed from whey and gained satisfactorily. A new byproduct milk replacer consisting of whey protein, dehydrated chicken manure, and animal fat was developed. Calves fed this replacer gained satisfactorily with no ill effects.

Effect of Aircraft Noise on Milk Production

In 1960, the effect of aircraft noise on animal production was a concern. Researchers investigated this problem for fur-bearing animals, poultry, swine, and dairy cattle. They observed several large herds of dairy cattle near a large airport in Florida. Information was recorded on the reaction of the cows to noise and on their milk yield before, during, and after low-level aircraft flights. Cows were able to cope with the noise; it did not affect their well-being and milk yields (65).

Animal Identification

The problem of identifying individual animals in dairy herds has been apparent for many years. Identification is important not only to the herd owner but also to the NCDHIP and to disease eradication. The ear tag has been the historical method of identifying dairy cattle, but it has limitations. In the 1960's, freeze branding was introduced. Large-scale trials were conducted at Beltsville and several field stations to improve the freeze-branding technique and to compare this method of indentification with others, including various new types of ear tags. Freeze branding, although not problem free, has real possibilities for use (42).

Dairy Cattle Health

The management of diseases is inevitably intertwined with improvement of dairy production. When the tick eradication program was operating in the South, the Division's dairy introduction work was a point of interest. The success of dairying depended to a great degree upon relative freedom from the ravages of tick fever.

The relationship of nutritional deficiencies of cows to abortion and sterility was studied. This work preceded the newer knowledge of nutrition, but served to focus attention not only on nutrition but also on abortion and sterility as important problems with dairy cattle.

Because good health and reproduction are important to breeding and nutrition research in the large Beltsville herds, records of health and breeding were closely studied. In the 1930's, there was a serious outbreak of tuberculosis. Affected animals were isolated, but they were usually kept to the end of their productive life.

From the time the Beltsville herd was assembed until the brucellosis eradication program became effective about 1950, brucellosis had been a problem. The herd was divided into infected and noninfected cattle. The comparative data on breeding efficiency of these cattle were studied. Controlling and eradicating brucellosis from the herd involved close cooperation with the animal disease researchers who were perfecting a satisfactory vaccine for brucellosis. The organism from which strain 19 was perfected came from one of the cows in this herd. This vaccine has been a major factor in the control and eradication of brucellosis.

The question of breeding strains of cattle that are resistant to diseases and parasites was of concern. The subject is controversial, even to the point of questioning the advisability of engaging in breeding research for this purpose. A discussion of this subject was presented in a review paper from Division scientists (53).

8. International Activities

Dairy Scientists Active in International Work

As a part of the varied Department activities, USDA dairy scientists participated worldwide on subjects of interest to the dairy industry. The development of foreign markets for butter and cheese at the beginning of the 20th century was discussed in a previous section of this publication. Later dairy scientists cooperated with other Department personnel and with the purebred dairy cattle interests in the development of foreign markets for purebred dairy cattle and bull semen.

Liaison With International Dairy Federation. In 1903 the first International Dairy Congress was held in Belgium. The Dairy Division, officially representing the U.S. Government, led a delegation representing this country's scientific and industry interests to participate in this meeting. The same kind of representation and participation continued through the succeeding 19 meetings of the Congress. After each meeting, the official delegate made a comprehensive report to the U.S. Government. In 1924 the United States organized, primarily with the Division leadership and in cooperation with the dairy industry, an International Dairy Congress held in Washington, D.C., and Detroit, Mich.

FAO and Other International Organizations. The Department of Agriculture has supported FAO programs. Scientists in USDA involved in activities related to dairy cooperated in FAO's activities. The Department participated fully with the Animal Production and Health Division of FAO in workshops, membership on panels, and regional conferences organized by FAO. The Department has made personnel available for brief assignments to FAO, and FAO has had some of its personnel in the Department's research laboratories for short-time training experiences. This close relationship continues.

In 1963 the World Association for Animal Production was organized and held its first conference in Rome, Italy. An official of the Dairy Cattle Research Branch was active in this movement and was elected its first president, serving from 1966 through 1968. In 1968, the Second World Conference of Animal Production was held in the United States. Federal dairy scientists were involved in this activity.

Public Law 480 Foreign Research. In the 1960's, Congress authorized the Department of Agriculture to use U.S. funds accumulating in certain foreign countries for research that would complement the domestic research programs. Dairy production scientists have participated fully in this program and have had research projects in India, Pakistan, Iran, Israel, Egypt, Poland, and several other countries. Local scientists review, revise, and approve project proposals and supervise the work. A project in Poland compared bulls and semen from the United States with that of several other countries for improving Holstein cattle. The Holstein-Friesian Association of America, the National Association of Animal Breeders, and the FAO cooperated in this project.

Foreign Study Missions. From 1942 through 1944, because of shipping shortages, supplying dry milk and other commodities from the United States to Latin American countries was difficult. The International Cooperation Administration (ICA) sought to assist local governments in improving their milk production. A program in which the U.S. Government would make dairy specialists available to visit countries, survey the local dairy industries, and recommend improvements was offered to each of these countries.

Two specialists (one Bureau and one non-Bureau) were assigned to this work. These specialists worked in seven countries of South and Central America. They made comprehensive reports and recommendations to each government as to how dairy production and the use of the milk supply could be improved.

Following these studies, AID requested the Bureau to prepare a reference book that could be made available for use in Latin America. Subsequently (1945), the book entitled "Handbook of Dairying in Tropical America" was published in Spanish and Portuguese. It has been reprinted several times and has had wide distribution throughout Latin America (39).

Through the years of their existence, the U.S. Government's international assistance agencies and the World Bank and its member regional banks have called on the Department to provide dairy production specialists to undertake foreign study missions in evaluating project proposals and recommending possible action. The Department has always responded to these requests, and its dairy production specialists have served in this capacity throughout the world. In addition, dairy scientists have trained foreign students and scientists from many countries by inviting them to work on current research projects.

Department dairy scientists have always participated in various international congresses, conferences, and workshops. In addition to the International Dairy Congress and World Conference on Animal Production, other meetings include the International Grassland

Congress, European Association for Animal Production Conference, International Genetics Congress, Nutrition Congress, and the Conference of Energy Metabolism. Thus, the Department's dairy production specialists have extended their services and competence far beyond the local scene and have contributed significantly to international dairying.

9. Conclusions

Dairy farming has been a most important part of American agricultural development for the past two centuries. Farmers have found that the development of dairy herds and milk production are good ways to use land, to develop good crop rotation systems, and to provide a regular and steady income. This farm base has been complemented by an expanding human population that has learned to appreciate milk and milk products as essential and economical foods, and by a good market for milk and its products. Dairy farmers have been progressive and quick to adopt new management procedures and to incorporate new technologies into their farming and herd improvement operations. Some significant contributions to dairy progress from 1925 to 1980 follow.

1925	Herd tests begun by purebred dairy cattle associations.
1926	Phosphorus deficiency in cattle demonstrated.
1925-30	Value of proved sire for herd improvement accepted.
1930	Fertilized egg first recovered from fallopian tube of cow.
1932	Method of increasing vitamin D in milk used commercially.
1933	First milk-marketing agreement initiating price support programs for milk established.
1934	Methods established for measuring pasture yields in terms of animal performance.
1934	Unidentified nutrient in milk announced.
1934	Federal Government indemnity for brucellosis in cattle begun.
1935	National Cooperative Dairy Herd Improvement Plan sire proving program begun.
1935	Red Dane cattle imported from Denmark.
1936	Vitamin A requirements established for dairy cattle.
1937	Nation's area testing completed for tuberculosis eradication campaign.
1937	Wilting method announced for making hay-crop silage
1937	National germ plasm survey in animals and plants conducted.
1939	Artificial insemination started in dairy cattle. Synthesis of protein from nonprotein nitrogen demonstrated by rumen microflora.
1940	Purebred Dairy Cattle Association organized.
1941	Cobalt deficiency in cattle demonstrated.
1942	Improved milking machines introduced.
1942	National Association of Animal Breeders organized.
1944	Vitamin A content of Nation's butter supply determined.
1946	Research and Marketing Act enacted.
1946	Red Sindhi cattle imported from India.
1946	Significant increase and continuing expansion in export of American dairy breeding cattle to foreign countries.
1952	First recorded successful embryo transplanted from donor to recipient cow.
1950's	Free stall and milking parlor management of cows began.

1960's	Bulk storage and movement of milk from farm to factory began.
1960's	Trend toward fewer but larger dairy herds and farms rapidly increased.
1960's	Equipment for in-place milking and milk delivery introduced.
1964	Cow-index introduced in NCDHIP program.
1965	National Diary Herd Improvement Association, Inc., organized.
1968	Predicted difference introduced in NCDHIP.
1970's	Testing begun for protein and solids-not-fat in NCDHIP.
1976	Use of embryo transplant technique in breeding expanded.
1978	U.S. Dairy-Forage Research Center established by Congress.
Late 1979	Adoption of data-processing equipment on farms to aid management decisions.
1980	Testing milk for protein and solids-not-fat in NCDHIP greatly expanded.
1980	Value of using growth hormones for increasing efficiency of milk production demonstrated.

The establishment of the U.S. Department of Agriculture, the land-grant college system, the agricultural experiment station system, and the agricultural Extension education system aided materially in providing information and services to the dairy industry and to agriculture as a whole. Specialized agencies within these systems gave particular attention to dairying and provided new technology through research, education, and Extension services. These specialized agencies, along with many others directing support efforts towards dairy and agricultural pursuits, have provided the information and guidance for the dynamic development that has taken place.

For many years the Department provided important leadership and guidance in dairying. The cooperative Federal-State Research, Education, and Extension efforts supervised by the Department have provided essential guideposts to the development of dairy farming and milk production. The establishment of the first dairy research education organization in the U.S. Department of Agriculture in 1895 was a significant recognition of the desire to develop dairying and to aid farmers in this enterprise.

The first Dairy Division, and the later dairy production research education organizations within the Department addressed the important problems facing dairy farmers throughout the years. Attention was first given to Extension education and demonstrations, with much field activity in the States and on farms. Investigators soon learned that more information was needed to advance dairy farming. This information had to come from research. As the Extension activities of the States increased, and as research facilities became available in the Division, added attention was given to dairy production research. A broad basic and applied research program evolved in dairy cattle breeding, feeding, and management.

Over the years, major attention has been given to increasing the amount and efficiency of milk production because these factors are important in determining profit or loss. Early emphasis was on performance recording of cows in cooperating farmers' herds through the establishment of a uniform nationwide production testing program. Since 1906, this program has been an important part of the Department's dairy program and is the accepted basis for national dairy herd improvement. Associated research on breeding, feeding, and management in large measure also supports this program.

The extensive research on breeding and breeding systems has contributed much useful information to the industry. The results of long-time work showed that selection and use of proved sires is the surest system for breed improvement. This system has been the underpinning of the NCDHIP program, the artificial insemination program, and breeders' programs in general. Information on crossbreeding dairy cattle has helped the breeder and dairy farmer anticipate results from this and other breeding systems.

Long-term research on growth and development has provided a great fund of information regarding form and function of the dairy animal—and its relationship to the production of milk.

Also, long-term research on the conservation and use of pasture and forage feeds has provided the basis for more efficient use of these crops in dairy cow rations. The extensive work on carotene and vitamin A has provided dairy farmers with information on conservation of nutrients including carotene in the feed, the vitamin A requirements of dairy cattle, and the maintainence and improvement of vitamin A in milk fat through effective feeding practices.

The basic work on nutrient requirements, especially net energy and nutrient contents of feeds, has contributed to improved recommended standards for dairy cattle rations.

These contributions are only a few of the many that the various Department dairy production research education staffs have provided to serve the American dairy industry.

Through the years, the organization of the dairy production staff has continually reflected the changing needs and conditions of the dairy industry. But the mission has remained the same: to provide the kind of information that will be most useful to the dairy farmers. In all this work, strong cooperative relationships existed between the Federal and State dairy scientists and the various industry groups.

During the past 80 years, the Federal research and education effort in dairy production has made great progress and has been of considerable service to the dairy industry. Some of its important characteristics follow. Today the dairy industry is progressive and dynamic and occupies a strong position in the agricultural and national economy.

Dairy industry statistics, 1980

Item	Number
Number of dairy cows on farms (millions)	10.8
Number of farms reporting dairy cows (thousands)	335
Milk production per cow (pounds)	11,875
Total milk production (millions of pounds)	128,425
Civilian per capita consumption of milk and dairy products milk equivalent basis (pounds)	554
Average price for 100 of all milk sold to plants (dollars per 100 pounds)	13.04
Cash receipts from dairy enterprise (billion dollars)	16.4
Production of butter (millions of pounds)	1,142
Production of cheese, total, except for cottage cheese (thousands of pounds)	3,946
Production of cottage cheeses (millions of pounds)	1,002
Production of frozen dairy products, including ice cream (millions of pounds)	1,181
Production of canned evaporated and condensed whole milk (thousands of pounds)	725
Production of nonfat dry milk for human food (millions of pounds)	1,151
Production of dry whey (millions of pounds)	662
Number of fluid milk processing plants	[1]1,300
Number of dairy products processing plants	[1]2,450

[1]Data for 1978.

Source: U.S. Department of Agriculture, Milk Production (83); Dairy Products, 1981, Da 2-6 (2-81); Outlook and Situation, Dairy, 1981, DS 384.

The dairy industry continues to provide consumers with an increasing amount and variety of high-quality milk and milk products. Dairy farmers have been quick to adopt innovations and to improve not only milk production but also the efficiency of the whole enterprise. As an example, the amount of labor required for producing milk decreased from 144 hours per cow in 1910 to 48 hours per cow in 1974-78, and the amount required to produce 100 pounds of milk decreased from 3.41 hours in 1910 to 0.40 hours in 1974-78. The breeding, feeding, and management of dairy cattle herds and the conduct of farming operations necessary to provide feed have greatly improved. The processing and marketing of milk and its products have kept pace with this improvement.

On a closing note, the dairy industry is currently underpinned with strong Federal-State cooperative research, education, and extension service programs. The industry can face the future with confidence that it will continue to occupy a strong place in the national economy.

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Appendix

Dairy production agencies of the Department of Agriculture, 1895-1980

Year	Agency
1895-1924	Dairy Division, Bureau of Animal Industry. Chiefs: 1895-1904, H. E. Alvord: 1904-1909, E. A. Webster: 1909-1921, B. H. Raul: 1921-1924, C. W. Larson.
1924-1952	Bureau of Dairy Industry. Chiefs: 1924-1927, C. W. Larson: 1927-1952, O. E. Reed.
1952-1957	Dairy Husbandry Research Branch. Chief: 1952-1957, R. E. Hodgson.
1957-1972	(1) Animal Science Research Division. Director: 1957-1972, R. E. Hodgson. (2) Dairy Cattle Research Branch. Chiefs: 1957-1961, L. A. Moore: 1961-1965, J. F. Sykes: 1965-1967, E. L. Corley: 1967-1972, R. D. Plowman.
1972-1978	(1) Animal Physiology and Genetics Institute. Chairman, J. W. Smith. (a) Genetics and Management Laboratory. Chief, R. H. Miller. (b) Animal Improvement Programs Laboratory. Chief, F. N. Dickinson. (c) Reproduction Laboratory. Chief, H. W. Hawk. (d) Feed Energy Conservation Laboratory. Chief, L. W. Smith. (e) Nutrient Utilization Laboratory. Chief, J. Bitman.
1972-1978	(2) Nutrition Institute. Chairman, W. Mertz. (a) Ruminant Nutrition Laboratory. Chief, R. R. Oltjen.
1978-	Animal Science Research Institute. Chairman, 1978-. L. W. Smith. (a) Animal Improvement Programs Laboratory 1978-1980. F. N. Dickinson, Chief. (b) Reproduction Laboratory. Chief, H. W. Hawk. (c) Milk Secretion and Mastitis Laboratory. Chief, R. H. Miller. (d) Ruminant Nutrition Laboratory. Chief, P. W. Moe.

Dairy production staff in the U.S. Department of Agriculture, 1895-1980[1]

Name	Approximate period of service	Location	Area of work
RESIDENT STAFF MEMBERS			
H. E. Alvord	1895-1904	Wash., D.C.	Chief, Dairy Div.
R. A. Pearson	1895-1905	Wash., D.C.	Asst. Chief. Dairy Div.
D. E. Salmon	1895-1905	Wash., D.C.	Chief, Bur. Anim. Indus.
G. M. Whitaker	1896-1930	Wash., D.C.	Dairy tech.
C. E. Grey	1902-1912	Wash., D.C.	Dairy tech., butter
H. Hayward	1902-1904	Wash., D.C.	Asst. Chief, Dairy Div.
C. B. Lane	1902-1932	Wash., D.C.	Asst. Chief, Dairy Div. Leader So. Reg.
L. A. Rogers	1902-1950	Wash., D.C.	Chief, Dairy Res. Lab., bacteriology
C. F. Doane	1904-1925	Wash., D.C.	Dairy prod.
D. Stuart	1904-1940	Wash., D.C.	Dairy prod.
E. A. Webster	1904-1909	Wash., D.C.	Chief, Dairy Div.
B. H. Raul	1905-1921	Wash., D.C.	Chief, Dairy Div.
J. A. Conover	1906-1920	Wash., D.C.	Dairy engin.
W. H. Dexter	1906-1921	Wash., D.C.	Dairy prod., records
J. E. Dorman	1906-1932	Wash., D.C., and Salt Lake City, Utah.	Dairy prod.
J. H. McLain	1906-1924	Wash., D.C.	Dairy prod.
A. D. Melvin	1906-1918	Wash., D.C.	Chief, Bur. Anim. Indus.
G. E. Parks	1906-1945	Wash., D.C.	Dairy engin.
R. H. Shaw	1906-1926	Wash., D.C., and Columbia, Mo.	Milk secret., lacation

See footnote at end of table.

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Dairy production staff in the U.S. Department of Agriculture, 1895-1980[1]—Continued

Name	Approximate period of service	Location	Area of work
H. N. Slater	1906-1915	Wash., D.C.	Dairy prod.
D. B. White	1906-1918	Wash., D.C.	Dairy tech., butter
T. E. Woodward	1906-1955	Wash., D.C.	Feeding Manage.
S. A. Ayres	1907-1924	Wash., D.C.	Bacter.
W. T. Johnson, Jr.	1908-1918	Wash., D.C.	Dairy tech.
H. Rabild	1908-1924	Wash., D.C.	Dairy prod., records
J. G. Winkjer	1909-1948	Wash., D.C.	Dairy prod.
W. M. Clark	1912-1918	Wash., D.C.	Dairy tech.
C. W. Clements	1912-1945	Wash., D.C.	Dairy tech.
E. Kelley	1912-1945	Wash., D.C.	Dairy tech., Div. Head
W. C. Lee	1912-1920	Wash., D.C.	Dairy prod., records
T. R. Pirtle	1912-1930	Wash., D.C.	Economics
C. S. Tompson	1912-1922	Wash., D.C.	Dairy tech. chemistry
L. B. Cook	1915-1930	Wash., D.C.	Dairy prod.
A. W. Dahlberg	1915-1925	Wash., D.C.	Dairy tech.
H. P. Davis	1915-1928	Wash., D.C.	Dairy prod.
R. R. Graves	1915-1950	Wash., D.C.	Dairy prod.
W. R. Hale	1915-1930	Wash., D.C.	Dairy prod.
P. W. Wright	1915-1955	Wash., D.C.	Chem., milk comp.
J. T. Bowen	1916-1922	Wash., D.C.	Dairy tech.
P. W. Clemmer	1916-1925	Wash., D.C.	Bacter.
E. F. Deysher	1916-1945	Wash., D.C.	Dairy tech.
M. H. Fohrman	1916-1965	Wash., D.C.	Breeding
J. A. Gamble	1916-1925	Wash., D.C.	Dairy tech.
J. B. McNulty	1916-1928	Wash., D.C.	Dairy prod.
R. P. Norton	1916-1930	Wash., D.C.	Dairy prod., chem.
G. B. Taylor	1916-1925	Wash., D.C.	Dairy tech.
W. F. Turner	1916-1924	Wash., D.C.	Dairy prod.
J. B. Baine	1918-1950	Wash., D.C.	Gen. dairy prod., records
W. K. Brainard	1918-1925	Wash., D.C.	Dairy prod.
F. R. Cammock	1918-1924	Wash., D.C.	Dairy tech.
H. T. Converse	1918-1955	Beltsville, Md.	Feed. nutr.
R. P. Hotis	1918-1942	Wash., D.C.	Bacter. mastitis
J. R. Mohler	1918-1924	Wash., D.C.	Chief, Bur. Anim. Indus.
J. B. Parker	1918-1965	Wash., D.C.	Ext. dairy prod.
J. R. Posson	1918-1944	Wash., D.C.	Bacter., mastitis
W. W. Swett	1918-1968	Beltsville, Md.	Anatomy, growth
W. White	1918-1950	Wash., D.C.	Dairy tech., butter
C. J. Babcock	1920-1950	Wash., D.C.	Dairy tech., milk quality
L. K. Burgwald	1920-1932	Wash., D.C.	Dairy tech.
K. G. Matheson	1920-1925	Wash., D.C.	Dairy tech.
J. C. McDowell	1920-1935	Wash., D.C.	Dairy prod., records
E. B. Meigs	1920-1942	Wash., D.C.	Nutr.
C. J. Stauber	1920-1965	Woodward, Okla.	Sta. Supt., Dairy prod.
C. W. Larson	1921-1927	Wash., D.C.	Chief, Dairy Div. & Bur. Dairy Indus.
J. R. Dawson	1922-1955	Wash., D.C.	Dairy prod.
A. W. Hartman	1922-1968	Beltsville, Md.	Nutr.
A. B. Nystrom	1922-1950	Beltsville, Md.	Dairy prod., Extension
F. M. Grant	1924-1965	Wash., D.C.	Dairy tech., milk quality
W. A. Turner	1924-1945	Beltsville, Md.	Nutr.
C. A. Cary	1925-1955	Beltsville, Md.	Nutr.
S. L. Cathcart	1925-1950	Jeanerette, La.	Sta. Supt., Dairy prod.
L. P. Ender	1925-1932	Wash., D.C.	Info.

See footnote at end of table.

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Dairy production staff in the U.S. Department of Agriculture, 1895-1980[1]—Continued

Name	Approximate period of service	Location	Area of work
T. S. Harding	1925-1940	Beltsville, Md.	Chem.
J. M. Kemper	1925-1945	Wash., D.C.	Asst. Chief, Bur. Dairy Indus.
F. W. Miller	1925-1935	Beltsville, Md.	Veterinarian
J. B. Shepherd	1925-1960	Ardmore, S. Dak.	Sta. Supt. Feed. manage.
R. H. Smith	1925-1945	Beltsville, Md.	Sta. Sup. Dairy prod.
A. W. Watt	1925-1945	Mandan, N. Dak.	Sta. Supt. Dairy prod.
W. E. Wintermeyer	1925-1955	Wash., D.C.	Dairy prod., exten.
R. C. Jones	1926-1950	Wash., D.C.	Dairy prod., exten.
H. L. Wilson	1926-1940	Wash., D.C.	Dairy tech., cheese
E. I. Evans	1928-1935	Beltsville, Md.	Reprod.
E. F. Faires	1928-1950	Willard, N.C.	Sta. Supt. Dairy prod.
D. V. Kopland	1928-1965	Huntley, Mont., and Logan, Utah	Sta. Supt. Dairy prod.
T. W. Moseley	1928-1965	Huntley, Mont., and Beltsville, Md.	Sta. Supt., Dairy prod.
O. E. Reed	1928-1952	Wash., D.C.	Chief, Bur. Dairy Indus.
J. A. Simms	1928-1945	Lewisburg, Tenn. and Jeanerette, La.	Sta. Supt. Dairy prod.
G. Q. Bateman	1930-1945	Logan, Utah	Dairy prod., pasture
J. F. Cone	1930-1945	Wash., D.C.	Bacter., mastitis
E. A. Kane	1930-1965	Beltsville, Md.	Nutr. chem.
J. F. Kendrick	1930-1962	Wash., D.C.	Dairy Records, Div. Chief
C. A. Matthews	1930-1968	Beltsville, Md.	Anatomy, growth
C. W. McIntyre	1930-1948	Hannibal, Mo.	Sta. Supt. Dairy prod.
L. S. Richardson	1930-1954	Wash., D.C.	Infor.
L. A. Shinn	1930-1950	Beltsville, Md.	Organic chem.
A. V. VanHorn	1930-1958	Woodward, Okla., and Lewisburg, Tenn.	Sta. Supt. Dairy prod.
R. E. Hodgson	1930-1973	Puyallup, Wash., Wash., D.C., and Beltsville, Md.	Animal Husband., Asst. Chief, BDI Chief, Dairy Husband. Res. Br., Director, Anim. Sci. Res. Div.
M. H. Friedman	1932-1942	Beltsville, Md.	Endocrinol.
B.H. Nicolet	1935-1948	Beltsville, Md.	Organic chem.
W.J. Sweetman	1935-1955	Beltsville, Md.	Dairy prod.
H. G. Wiseman	1935-1965	Beltsville, Md.	Organic chem.
R. E. McDowell	1936-1965	Beltsville, Md.	Physiology, climatol., breeding
E. T. Gomez	1938-1945	Beltsville, Md.	Endocrinol.
S. R. Hall	1938-1950	Beltsville, Md.	Endocrinol.
R. Borasky	1940-1950	Beltsville, Md.	Chem.
J. T. Bradbury	1940-1948	Beltsville, Md.	Endocrinol.
L. A. Burkey	1940-1958	Beltsville, Md.	Bacter., mastitis
A. Dury	1940-1950	Beltsville, Md.	Chem.
R. E. Leighton	1940-1955	Jeanerette, La.	Sta. Supt. Dairy prod.
C. G. Melin	1940-1965	Beltsville, Md.	Chem.
P. C. Underwood	1940-1962	Beltsville, Md.	Veterinarian
L. A. Moore	1942-1965	Beltsville, Md.	Feeding, nutr., Br. Chief
J. F. Sykes	1942-1966	Beltsville, Md.	Physiol., Br. Chief
R. A. Hilder	1945-1968	Beltsville, Md.	Dairy prod., breeding
C. R. Bruckner	1948-1950	Beltsville, Md.	Bacter., mastitis
C. H. Gordon	1948-1970	Beltsville, Md.	Feeding, manage., forage
J. Bitman	1950-	Beltsville, Md.	Biochem.
M. P. Bryant	1950-1967	Beltsville, Md.	Rumen microbiol.
R. E. Ely	1950-1962	Beltsville, Md.	Nutr., insect. residues

See footnote at end of table.

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Dairy production staff in the U.S. Department of Agriculture, 1895-1980[1]—Continued

Name	Approximate period of service	Location	Area of work
R. F. Gaalaas	1950-1964	Mandan, N. Dak., and Jeanerette, La.	Dairy prod., Sta. Supt.
B. F. Hollon	1950-	Willard, N.C., and Jeanerette, La., and Lewisburg, Tenn.	Gen. dairy prod., Sta. Supt. Waste Manag.
N. W. Hooven, Jr.	1950-	Beltsville, Md.	Dairy prod., anim. identifi.
T. R. Wrenn	1950-	Beltsville, Md.	Nutr.
R.N. Doetsch	1952-1965	Beltsville, Md.	Rumen microbiol.
S. Moss	1952-1962	Beltsville, Md.	Chem.
M. W. Schein	1952-1960	Beltsville, Md., and Jeanerette, La.	Anim. behavior
C. G. Langston	1954-1968	Beltsville, Md.	Bacter., silage
M. J. Allison	1955-1965	Beltsville, Md.	Rumen microbiol.
N. D. Bayley	1955-1970	Beltsville, Md.	Breeding, Asst. Dir. of Animal Science Res.
J. H. Brook	1955-1970	Beltsville, Md.	Dairy prod.
H. M. Erwin	1955-1970	Beltsville, Md.	Chem.
R. E. Fletcher	1955-1965	Jeanerette, La.	Dairy prod., Sta. Supt.
H. C. Cecil	1956-	Beltsville, Md.	Biochem., physiol.
J. C. Derbyshire	1956-1974	Beltsville, Md.	Feeding, manag., forage
W. P. Flatt	1956-1969	Beltsville, Md.	Nutr., energy metabol.
H. W. Hawk	1956-	Beltsville, Md.	Reprod.
R. D. Plowman	1956-1972	Beltsville, Md.	Breeding, Br. Chief
J. W. Thomas	1956-1965	Beltsville, Md.	Nutr.
P. J. Reynolds	1956-	Beltsville, Md.	Nutr.
F. N. Dickinson	1957-	Beltsville, Md.	Dairy records, statistics
P. J. Van Soest	1957-1968	Beltsville, Md.	Nutr., feed comp.
D. R. Waldo	1957-	Beltsville, Md.	Nutr.
H. D. Baxter	1958-	Lewisburg, Tenn.	Feed. manag.
G. F. Fries	1958-	Huntley, Mont., and Beltsville, Md.	Nutr., chem. residues
J. R. Owen	1958-	Lewisburg, Tenn.	Dairy prod., Sta. Supt.
L. Ratcliff	1958-1964	Lewisburg, Tenn.	Dairy prod.
C. A. Kiddy	1959-1978	Beltsville, Md.	Reprod., genet.
E. L. Corley	1960-1972	Beltsville, Md.	Dairy records, Br. Chief, Asst. Dir. of Div.
B. T. McDaniel	1960-1972	Beltsville, Md.	Stat., breeding
R. H. Miller	1960-	Beltsville, Md.	Breeding, records, stat.
D. R. Caldwell	1961-1968	Beltsville, Md.	Chem., rumen
J. O.Johnston	1961-1967	Beltsville, Md.	Physiol., reprod.
W. D. Schultze	1961-	Beltsville, Md.	Bacter. mastitis
L. W. Smith	1961-	Beltsville, Md.	Nutr.
T. H. Brinsfield	1962-1974	Beltsville, Md.	Physiol., reprod.
R. M. Conner	1962-1968	Beltsville, Md.	Bacteriol., silage
C. E. Coppock	1962-1964	Beltsville, Md.	Nutr.
K. A. Pitman	1962-1968	Beltsville, Md.	Bacteriol., rumen
J. W. Smith	1962-	Beltsville, Md.	Breed., mastitis
W. W. Thatcher	1963-1966	Beltsville, Md.	Physiol., genet.
A. J. Guidry	1964-	Beltsville, Md.	Physiol., mastitis
J. E. Keys, Jr.	1964-1970	Beltsville, Md.	Nutr., milk secretion
R. C. Lamb	1964-	Logan, Utah.	Breeding, manag.
P. W. Moe	1964-	Beltsville, Md.	Nutr., energy metabol.
F. Stormshak	1966-1970	Beltsville, Md.	Physiol., reprod.
G. P. Lynch	1966-	Beltsville, Md.	Nutr.
H. K. Goering	1968-	Beltsville, Md.	Nutr., forages

See footnote at end of table.

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Dairy production staff in the U.S. Department of Agriculture, 1895-1980[1]—Continued

Name	Approximate period of service	Location	Area of work
H. F. Tyrrell	1968-	Beltsville, Md.	Nutr., energy metabol.
R. E. Pearson	1970-1979	Beltsville, Md.	Breed., manag.
P. D. Thompson	1970-1978	Beltsville, Md.	Mastitis, bioeng.
J. F. Keown	1972-1975	Beltsville, Md.	Breeding
R. L. Powell	1972-	Beltsville, Md.	Breeding
C. E. Rexoad, Jr.	1972-	Beltsville, Md.	Reprod.
P. M. Sears	1975-1977	Beltsville, Md.	Mastitis
M. E. Simpson	1975-	Beltsville, Md.	Microbiol., rumen
R. A. Waterman	1975-	Beltsville, Md.	Reprod.
W. E. Wheeler	1976-1978	Beltsville, Md.	Nutr.
J. B. Reeves, III	1978-	Beltsville, Md.	Chem.
A. J. Truitt	1978-1980	Beltsville, Md.	Reprod.
G. R. Wiggans	1978-	Beltsville, Md.	Breeding
G. B. Huntington	1979-	Beltsville, Md.	Nutr.
G. S. Lewis	1980-	Beltsville, Md.	Reprod.

[1]Because of the difficulty in obtaining complete records, some employees, particularly in the early period, may have been missed from this roster.

Staff members who served in dairy introduction and extension work in the Southern and Western States from 1905 to 1920

Southern States Staff, 1905 to 1920

J. A. Arey
E. A. Asrud
S. E. Barnes
G. I. Beckdel
G. Bussfield
J. D. Baker
W. L. Blucker
E. Brentwell
J. M. Burgess
O. M. Camburn
H. J. Childers
S. B. Durham
S. D. Dow
F. H. Dennis
W. H. Eaton
E. L. Elton
C. M. Evans
A. A. Federick
H. C. Ferguson
W. W. Fitzpatrick
J. P. Greybill
J. C. Guthrie
J. W. Hart
W. H. Howell
G. H. Hibbard
L. A. Higgins
C. A. Hutton
J. W. Helveg
H. P. Lykes
J. P. LaMaster
H. S. McKeon
G. H. Moesly
R. H. Mason
J. N. McMaster
L. P. McCann
W. H. Morgan
W. G. McGowen
T. H. Mittendorff
C. O. Metzler
C. O. Moser
H. S. Murry
E. T. McClure
J. C. Nelson
D. A. Negley
J. L. Oliver
A. B. Pyke
C. R. Painter
W. A. Pickens
R. C. Pow
A. K. Risser
J. A. Reed
C. W. Ridgway
G. R. Skinner
C. H. Staples
H. C. Stockwell
C. A. Talbot
H. C. Vetter
H. R. Welch
W. H. Woodley
C. L. Willough
G. E. Wolcott
D. W. Watkins

Western States Staff, 1910 to 1920

W. A. Barr
E. V. Ellington
B. R. Eldrige
O. E. Gibson
N. C. Jamison
R. E. Jackson
F. W. Kehrli
A. J. Lashbrook
H. R. Lockery
H. A. Mathiesen
E. F. Rineheart