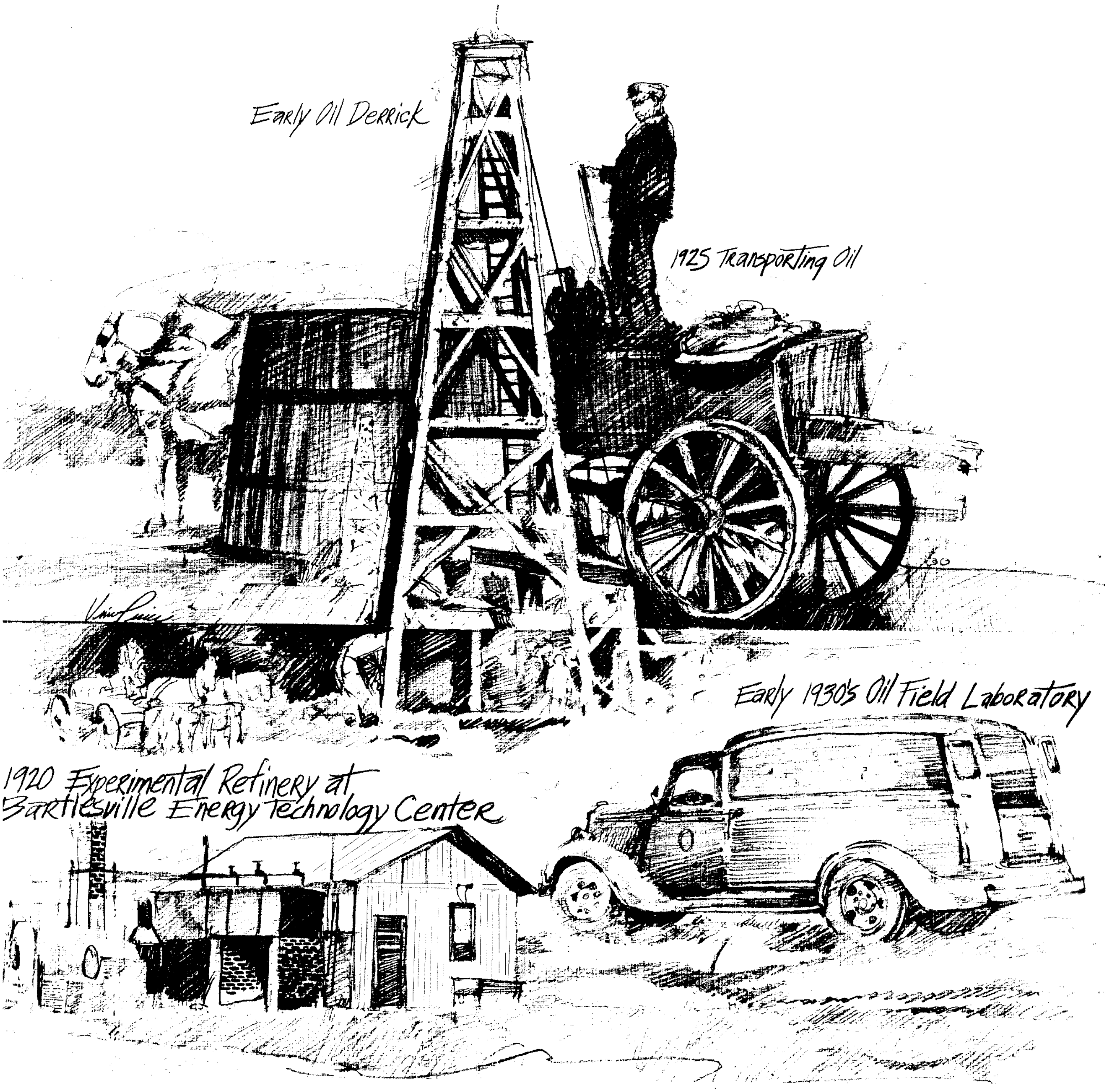
DOE/BC/10126-1

(DE85000134)

Bartlesville Energy Research Center

The Federal Government in Petroleum Research 1918-1983



Birthplace of Petroleum Technology

By Rodney P. Carisle and August W. Giebelhaus

DOE/BC/10126-1
(DE85000134)
Distribution Category UC-92

Bartlesville Energy Center

The Federal Government in Petroleum Research 1918-1983

By
Rodney P. Carlisle
August W. Giebelhaus

C&W Associates
Box 73
Westmoreland, New Hampshire
03467

Prepared Under Contract to
United States Department of Energy
Bartlesville Energy Technology Center
CE-AC19-80BC10126

Published by
Office of Scientific and Technical Information
United States Department of Energy
1985

ACKNOWLEDGMENTS

The authors wish to thank a number of individuals whose help was invaluable in the research and writing of this book. Many current and retired Bartlesville Center employees gave freely of their time for both formal, taped interviews and informal discussions. Their names and the dates of their interviews are cited in the chapter footnotes. In addition, special recognition should be given to Harry R. Johnson and Robert L. Folstein, who provided not only information, but advice and assistance along the way.

Special thanks are also due to John S. Ball, who brought not only his knowledge as former Research Director of the Center to the project, but also his vast knowledge of the oil business and his critical eye for points of style. Both authors enjoyed several lengthy discussions with him and found his ideas, comments, leads, and insights extremely helpful. Kenneth J. Hughes at the Center also provided both formal and informal help in tracking down financial and personnel details.

The work was performed under a Department of Energy contract through C&W Associates/Historical Consultants. As a result, several additional sources of assistance came through the contractual relationship. Elizabeth Mohr at the Center served as Technical Project Officer on the contract, and was very helpful. The contract received further oversight from Jack Holl of the Department of Energy's History Division, and his suggestions and comments on the evolving drafts of the chapters were much appreciated. Philip L. Cantelon, senior partner in C&W Associates, provided close editorial readings of each chapter with a good eye for detail. Ruth Harris, senior historian with C&W, assisted in the research. Felicity Skidmore did a magnificent job of copy editing on short notice.

Thanks are also owed to Richard G. Hewlett, former Chief Historian of the Department of Energy, for his encouragement and practical suggestions.

A variety of others, both in and outside of the Department of Energy and the Bartlesville Center, helped in one way or another. Roger M. Anders and Alice L. Buck of the DOE History Division helped in tracking down elusive pieces of data. Joseph A. Pratt of Texas A&M University assisted in the early research stages. Gail Mathews and DyAnn Smith handled the word processing; Ms. Mathews did excellent work in untangling and incorporating the various changes and keeping straight the multiple drafts.

Carlisle also wishes to particularly thank the Hoover Presidential Library Association for a grant which made possible a stay in West Branch, Iowa, for work in the Hoover papers.

Errors which slipped past all these able people are, of course, the responsibility of the authors.

We also wish to thank our wives, Ann Carlisle and Barbara Giebelhaus, for their forbearance with our Oklahoma and Washington trips and our immersion in petroleum history over a three-year period.

This publication is available as DE85000134 from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy $11.00
Microfiche A01

TABLE OF CONTENTS

Chapter 1

THE BARTLESVILLE CENTER: HISTORICAL OVERVIEW

The Bartlesville Energy Technology Center is housed on four square blocks of the west side in Bartlesville, Oklahoma. Surrounded by small homes in a modest residential district, it is not a physically impressive place measured by the standards of the Department of Energy which administers it. The technology center's main building, a solid 1936 red brick structure, might pass for a junior high or high school. Across the street, a new laboratory and office structure has the anonymous modernity of the 1960s. Temporary structures, outbuildings, and office trailers fill the small compound. Yet the BETC has a unique institutional history, including the sparking of a heated local controversy in 1982 which extended to Oklahoma's congressional delegation, the Department of Energy headquarters in Washington, and powerful lobbying groups and institutions in the oil business throughout the nation.

As a federally owned and operated facility, the center is something of an anomaly in the 1980s—a survivor of an earlier era, in which government played an internationally recognized role, which was welcomed and supported by private enterprise, in the advancement of petroleum technology. Even as recently as the 1982 controversy, surprisingly, some strong free-enterprise advocates from the oil industry were arguing that *this* federal facility should *not* be closed down as part of the fulfillment of Ronald Reagan's campaign pledge to dismantle the Department of Energy and reorganize its functions.

The center has always been warmly supported by local and regional oil interests. When, in 1916, the Bureau of Mines announced its intention of establishing a petroleum experiment station somewhere in the United States, oil men in Bartlesville lobbied intensively to have the station built there, in hopes of achieving official recognition of their community as an oil metropolis. Through the Chamber of Commerce, local oil executives pledged $50,000 to assist the government in construction; and one of the town fathers, George Keeler, promised to donate a plot of land for the station. In 1917, the Bureau accepted both offers and sent a representative to take possession of the property and to supervise construction. Once established, the small facility survived through drastic changes in national politics and the economic vicissitudes of the local and national oil industry.

The evolution from 1918 to 1982 of the Bureau of Mines' experiment station into the Department of Energy's technology center provides glimpses of crucial issues in the history of technology. How does the process of innovation take place in an institutional setting? What are the important factors influencing the dynamics of laboratory research? Just as the biography of a long-lived individual can illuminate the history of an era, so the 65-year span of the center offers insights into questions of regional and national significance. How did national political philosophy affect the government's role in petroleum research? How could a federal role be established in an essentially private industry? How did the center fit into the oil industry's own internal politics—the divisions between the major multinational corporate giants and the independents, between refiners and producers, between East Coast and Mid-Continent companies?

Although shaped inevitably by such larger forces, the center is also the product of its community. The town of Bartlesville lies in the gently rolling "Green Country" section of northeast Oklahoma, fifty miles north of Tulsa and some twenty miles south of the Kansas border. To a visitor, Bartlesville at first seems a model of mid-America. A downtown section boasts a few high-rise office buildings, punctuated by one- and two-story retail shops. Quiet neighborhoods with neatly trimmed lawns house the thirty-five thousand residents. Truck-mounted campers and boats on trailers stand next to carports in the residential sections; fast-food outlets and discount markets line Highway 75 as it stretches north through the eastern side of town.

On closer examination, the small city is almost too much like Sinclair Lewis' *Mainstreet* to seem a completely typical 1980s community. For one thing, Oklahoma remains "dry," the last state to prohibit the sale of liquor by the drink. For another, eighty churches, twenty of them Baptist, dot the neighborhoods, attesting to the survival of an earlier generation's values. Crime is rare, and the local radio station treats occasional reports of juvenile vandalism, domestic strife, or auto collision as news.

This air of preserved stability is enhanced by evidence that Bartlesville is a company town—headquarters of Phillips Petroleum—which far overshadows the presence of the small federal facility. The familiar "66" signs over gas stations outnumber emblems of competing brands. Frank Phillips Boulevard leads from Highway 75 into the town center, past the Jane Phillips Memorial Hospital, past the company's corporate headquarters downtown, west to the Phillips Company's own research center, which is a set of massive structures on the city limits. A few miles to the south lies Woolaroc—once the private estate of Frank Phillips, now a tourist attraction with a museum housing Phillips' personal collection of Western art and Indian artifacts and a small herd of American buffalo.

The community reflects its petroleum heritage also in other ways and remembers when, in the early decades of this century, it was the center of the first oil boom in Oklahoma. Outside the town, dotted through pastures and fields, oil pumps slowly drain the once-rich stratum called the Bartlesville Sand. And in the middle of Bartlesville, on the banks of the Caney River, stands a restored wooden derrick, a monument to "Nellie Johnstone Number One," reputedly the first commercial oil well in Oklahoma.

The technology center, like the town, has always carried an imprint of the era of its birth. The Bureau of Mines, first established in 1910 within the Department of the Interior, had been created out of the political philosophy of the Progressive era. Progressives in the Bureau of Mines held that the natural resources of the nation should be managed in the national interest and argued against the followers of John Muir who sought to preserve nature from man's exploitation. For the Bureau in 1910, management of natural resources did not imply eternal preservation; but it did mean the wise development and use of those resources. Natural resources, even when privately owned, should be exploited in a way that stretched their use over the longest possible period. Although viewed as conservation, such a rationale differed markedly from the environmental preservation style of conservation advocated by Muir and taken up as a popular cause by later generations. Progressives warned against pollution, arguing that pollution from the unwise exploitation of one valuable resource could damage or destroy another. But the avoidance of pollution, like the avoidance of waste, served the purpose of wise exploitation, not static preservation.

The Bureau of Mines, in the spirit of the Progressives' search for social justice, also reflected a concern for the industrial safety of workers and sought to advocate and promote safety measures. Businessmen who prided themselves on enlightened development of resources could regard such efforts by government as supportive. Dissemination of information about new methods to eliminate waste and enhance worker safety did not contradict the businessman's pursuit of profit; on the contrary, such information could help earn even greater profits. Good information meant good business. To further this objective, the Bureau of Mines established experiment stations which, like the Agriculture Department's demonstration stations, would bring technical experts to the field. The Bureau's stations specialized each in a different extractive industry—stations for coal, quarries, clay pits, and iron mines were all established in different appropriate locations, close to the major centers of each resource.

The decision by the Bureau of Mines on the location of a station for the oil industry represented an official definition of the oil industry's center—making it imperative that the choice be made with care. Rockefeller had based the Standard Oil Trust on Pennsylvania and Ohio oil, and had built refineries in New Jersey and New York. By 1916, however, the center of oil activity and production had shifted westward. The wide popularity of the automobile had created a demand for petroleum which was met at least in part by new discoveries in Texas and Oklahoma. In addition, in 1911 the government's anti-trust suit had broken the Standard Oil Corporation into thirty-five companies. But even before the suit, fiercely independent producers of the Mid-Continent region were already proud of their new competitive system of oil production, as opposed to the monopolistic situation represented by Standard Oil. The already independent producers in Oklahoma, therefore, viewed the selection of their own territory for the Bureau's oil station as an affirmation of the industry's new center.

The selection of Bartlesville, Oklahoma, thus reflected the internal politics of the oil industry in 1916. The rationale and allegiances developed at that time have remained its legacy.

Over the years since 1918, the small center has produced a steady stream of innovative articles and reports, inventions, patents, demonstration projects, and research studies. Since the 1920s, the work of the station has achieved recognition in a range of technical disciplines related to petroleum—including the mechanics of raising crude oil and natural gas to the surface and transporting those fluids; the chemical techniques of rendering crude resources into finished products; and diverse work in engine design, pipeline engineering, emission studies, basic petroleum chemistry, alternative fuels, synthetics, and surveys of particular petroleum fields, pools, and resources. As petroleum technology evolved during the twentieth century from a relatively primitive, "hands on" approach to a more systematic and scientific one, the Bartlesville center was often in the forefront of development. In carrying out its essential mission of conservation and efficiency, it became a propagandist for new ideas and approaches as it worked *with* private interests to create a sophisticated technological base for the entire petroleum industry. In the decades from the 1920s through the 1960s, oil industry journals reflected a tone of respect and sometimes direct admiration for the technical excellence of the work of the Bureau of Mines' engineers at Bartlesville and at its sister institution at Laramie.* And that respect has been earned by the steady production of direct research from the two centers.

The history of the Bartlesville center provides a good case study to illustrate the progress of technology. Technological research decisions made throughout Bartlesville's history—questions of where to put money, where to assign staff, what device to invent, what process to improve—were by no means self-propelled innovations that proceeded outside human control. As in most human affairs, the advance of technology cannot be readily explained according to a pre-set formula, in spite of widespread fears to the contrary. Rather, individual men make those decisions, because of a host of usually very mundane factors. Particular staff members might find themselves with time and the need of a "problem;" the oil industry might be interested in a particular new development for financial reasons; Washington might support a local decision if it appeared politically sound and if budget constraints could be met. All these occurred in BETC's case. In addition, the demands of war and emergency suddenly altered priorities, redirecting progress to stimulate new lines of work or to retard developments that were already underway. Outside institutions, agencies, and corporations often sought particular work, to which the center responded in varying ways (according to staff, equipment, and policy dictates). Each particular research and development decision reflected a specific mix of factors at work at a particular time and place.

In 1918, as the Bureau established the station, the mix of factors at work on the petroleum industry included a greatly increased demand for gasoline. Most of the innovation stimulated by this increase came, as noted, not from laboratory settings but from trial and error by practical men in the field. Few trained geologists had yet joined oil firms, and the search for drilling sites was mostly a hit-or-miss, intuitive process. Gradually, university-trained researchers began to make contributions. A handful of engineering graduates from Stanford University began to concentrate on methods of improving drilling equipment; the University of Pennsylvania initiated a program in petroleum chemistry. Yet the number of technically trained geologists, engineers, and chemists in the oil industry remained limited.

In the search for methods to drill to deeper depths, the rotary drill bit, invented by Howard Hughes, began to supplement the traditional method of drilling with a chisel-like tool attached to a cable or rope. Refinery processes innovated by William Burton, a Ph.D. chemist at Standard of Indiana, held out the promise of alleviating the gasoline demand. Standard Oil Development Company, founded in 1922 as a research arm of Jersey Standard, set out to find a refinery process to compete with Standard of Indiana's Burton method. Both Texaco and Gulf set up similar research efforts later in the 1920s. Cities Service, successor to Empire Fuel and Gas in Bartlesville, established a research laboratory there under the leadership of Henry Doherty.

Yet the bulk of oil continued to be drilled and recovered by relatively small, often individually owned firms who marketed their oil to the refining companies. In the hasty, boom-and-bust world of oil drilling, independent drillers simply could not consider sponsorship of research. As the Bureau expanded the Bartlesville experiment station, it became one of the first settings for the systematic application of engineering and scientific methods to the oil business.

Responsiveness to outside pressures did not prevent the center from having its own internal institutional life. Staff currently at the center have worked with colleagues who came to it in the 1930s; they, in turn, some of whom live in retirement in Bartlesville, remember working with the first generation of staff from the 1920s. Continuity in ways of doing things, in relationships with industry, in personal compatibility, and in likes and dislikes have created a distinctive institutional personality. Growing slowly from a staff of three, to forty in its first decade, and eventually to two hundred by the late 1970s, the institution's personality reflected the continuity of influence of old-timers on newcomers. For the most part, the institution's personality did not change suddenly. Even when a new division was added, the effect of such growth spread over months and years. Dismissals, resignations, and the hiring of individuals altered the patterns slightly, but the institution and its ways of cooperating with industry continued. Although its name changed—from Experiment Station to Petroleum Research Center, to

*In 1922, the Bureau of Mines established another petroleum field station at Laramie, Wyoming. As oil fields came in throughout the Wyoming area, the Laramie station served the producers of that region. The two stations at Laramie and Bartlesville kept in close touch, sometimes exchanging personnel, and survived together, through various bureaucratic reorganizations, as sister institutions.

Energy Research Center, to Energy Technology Center—its institutional continuity remained.*

Each Superintendent or Director worked to provide leadership and direction, but sometimes the institution's own inertia seemed to limit the impact of particular individuals. After an initial period of rapid turnover of Superintendents, N. A. C. Smith directed the center from 1926 to 1946. Smith, a specialist in refining chemistry, sought—with gradual success—to convert the station from a field demonstration center into a research laboratory with its own scholarly publication and achievement record. By the end of World War II, the station had established a national reputation in oil field engineering studies, thermodynamics of petroleum compounds, and characterization of fuels and products, as well as in production methods. From 1947 to 1963, Harry Fowler, a safety engineer, served as Superintendent and provided considerable autonomy to internal division leaders whose groups sought outside funding to pursue research. In this period, the center's reputation among oil men for research and innovation continued to grow, with projects frequently linked through cooperative agreements to the activities of national industrial associations and other government agencies.

From 1963 through 1978, director John Ball, a research chemist with a long record of Bureau of Mines work at the sister facility in Laramie, led the center to a new style of work—building teams which supervised government-funded research contracts performed by outside contracting firms and institutions. From 1979 to 1982, Harry Johnson, a petroleum engineer, sought to preserve and expand the center's role as a lead center for all liquid fossil fuel research and for enhanced oil recovery work, and to protect the center's internal and contracted research from the political and budgetary storms that struck Washington during his tenure.

Under the leadership of these four men, the center retained much of its initial character, providing research services to oil producers, disseminating information on technology, and providing analyses of crude oils. By the 1950s, under Fowler, its field of service had expanded from the Mid-Continent to the whole nation and had begun to reach overseas. By the administrations of Ball and Johnson, the center was engaging widely in international activities. Through the period of expansion of role and acceptance of new responsibilities, the center continued to maintain its unique relationship with industry—a service center which cooperated actively with private firms, yet avoided any interference in the competitive marketplace, either as a regulator or as a patron of particular firms. That principle of cooperation without favor accounts at least partially for the continuing good relations between the center and the private oil industry.

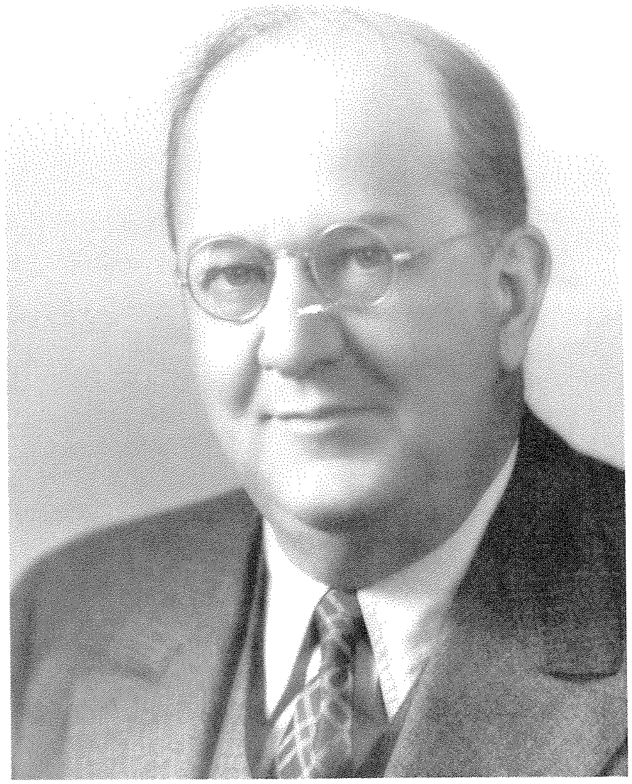
The very acceptance by industry of the significance of the center's work served as a stimulus to innovation—not only in the abstract sense of moral support but in dozens of practical ways. Staff from the center sometimes resigned to take positions in industry, often remaining in contact with their former colleagues. Private companies frequently provided facilities, samples of crude oil or products, personnel on loan, and data, knowing that proprietary information would remain protected. Industrial conferences provided settings for the delivery of technical papers authored by center staff. Commercial and scholarly journals, subscribed to and supported by the private sector, served as other outlets for research. Industrial associations such as the American Gas Association entered into cooperative agreements with the Bureau of Mines, offering funding to assist the government in particular research projects along specific lines agreed to be of interest to the member companies of the association. The rich variety of liaisons between industry and government through the center, initiated under the Progressive good-knowledge-makes-good-business philosophy of the Bureau of Mines, continued through the changing political environments of successive decades. The continuity of liaison, the tradition of cooperation, and the apparently fixed heritage of a place in the heart of the oil country and the oil industry, rather than stifling innovation, provided an environment that fostered it.

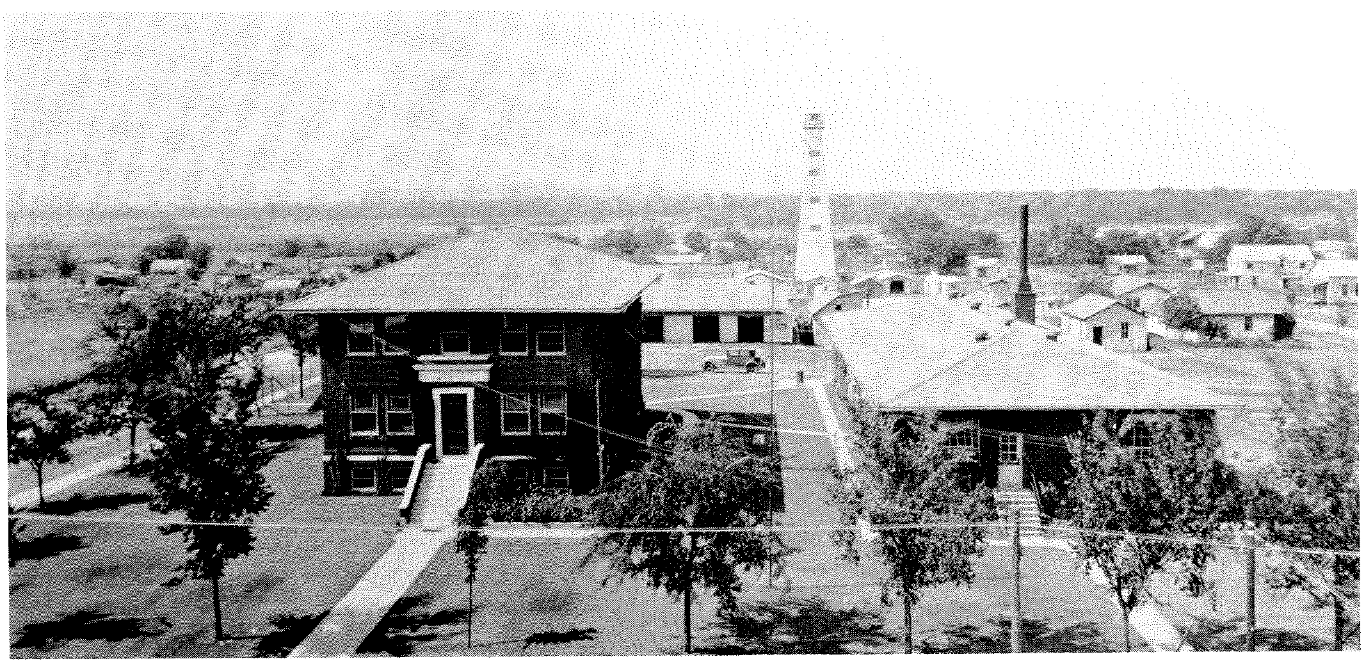
The story of innovation in response to industry needs and interests did not always place the center at the frontier of progress. Limitations of budget and constraints of personnel and background sometimes resulted in a perpetuation of projects and studies past the time of their immediate application. Like all research, much of the petroleum work of the station necessarily involved the pursuit of blind alleys, repetition of numerous unsuccessful alternate solutions, and simple, hard, all-night drudgery with no positive results. The story of the center, therefore, is necessarily a story of setbacks, disappointments, and periods of low morale and stagnation as well as technical progress and advance.

No one has yet written a history of the Bureau of Mines, nor of the Energy Research and Development Administration (ERDA)—the agency which, from 1975 to 1977, combined the energy research and development efforts of the Atomic Energy Commission with energy research facilities from the Bureau of Mines—nor of the Department of Energy, which followed ERDA and took over its mandate. This book's close focus on the story of the Bartlesville Energy Technology Center cannot substitute for such agency

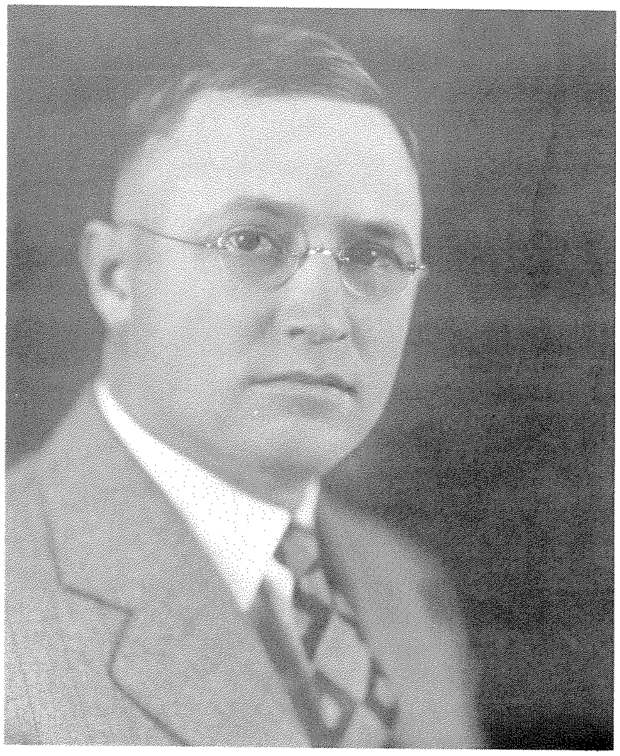
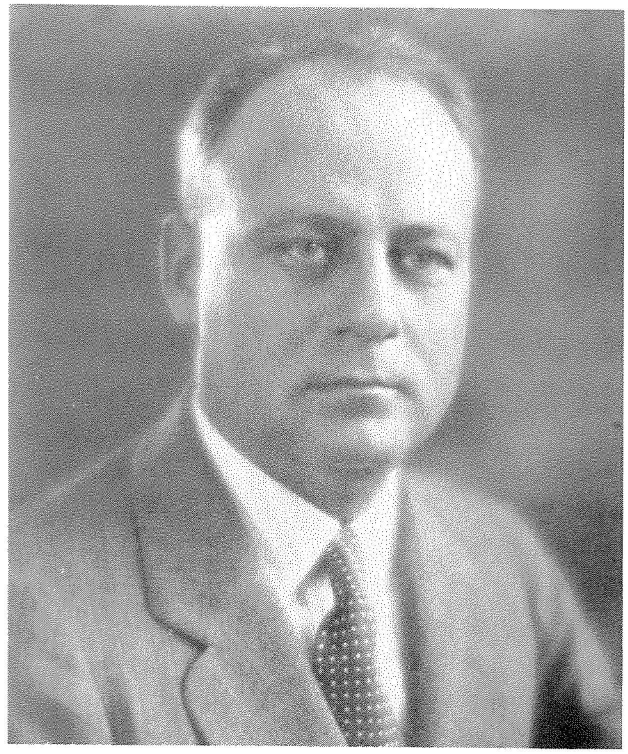
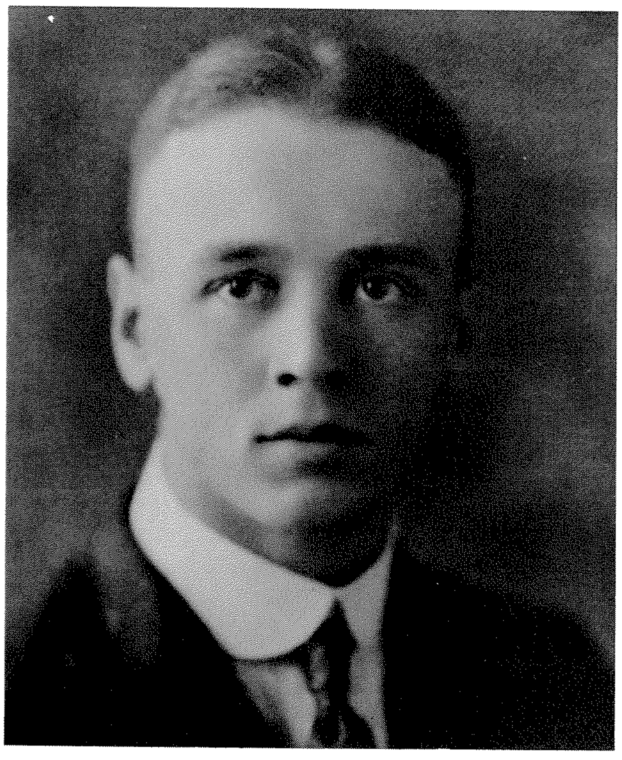
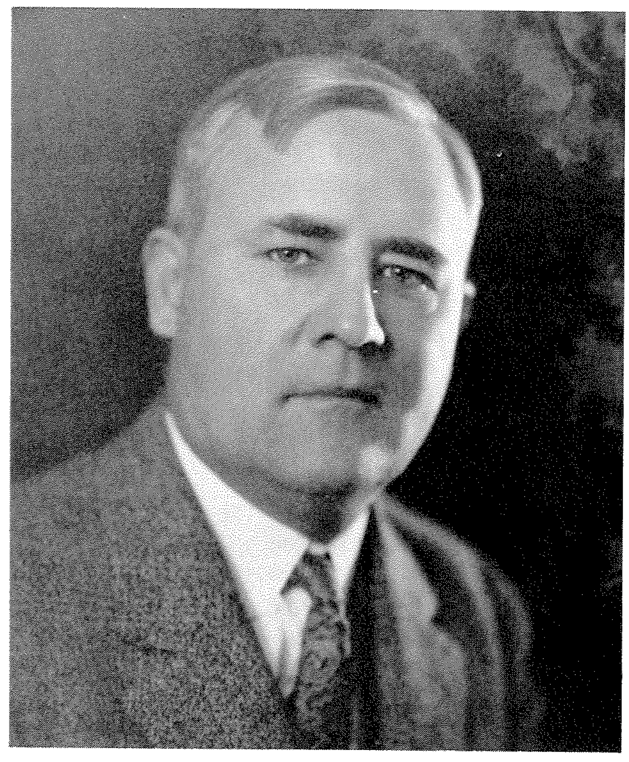
*In the chapters that follow, the Bartlesville institution will be referred to as "the station" or "the center" according to its name during the period being discussed.

or departmental histories, which could trace the interaction of government policy and practice on a grand scale. But the study of a single facility may illuminate particular problems and thus contribute importantly to our knowledge of how petroleum technology, petroleum policy, and national political priorities have interacted through seven decades of the twentieth century.





J. O. Lewis (upper left) was first Superintendent of the Bureau of Mines Petroleum Experiment Station, serving from 1918–1919. He later founded an international petroleum consulting firm. N.A.C. Smith (upper right), Superintendent, (later Supervising Engineer) from 1926–1945, was the first long-time Director and led the station to a new role as a research laboratory. The Station in 1928 (lower) consisted of the first two buildings constructed in 1918 plus various auxiliary buildings and an experimental oil well.

Training Ground for Industry

Many of the early superintendents of the Petroleum Experiment Station served only short times as they left to take their expertise to industry. A. W. Ambrose (upper left) served in 1920 before going to Washington as Chief Petroleum Technologist of the Bureau of Mines. He was later with Cities Service Oil Company, rising to Chairman of the Board. H. H. Hill who served in 1921–1922 (upper right) also served in Washington and then went with Standard Oil Company of New Jersey. T. E. Swigart (lower left) served in 1922–1924 before leaving to join Shell Oil Company where he later became President of Shell Pipe Line Company. M. J. Kirwan (lower right) was superintendent in 1924–1925 and left to join the Indian Territory Illuminating Oil Company, later merged into Cities Service Company.

Chapter 2

SEARCH FOR A ROLE, 1919–1930

The research and service work undertaken by the Bartlesville Experiment Station through the 1920s responded to the needs of oil producers in the "Mid-Continent region" comprising Oklahoma, Kansas, the Texas panhandle, and north-central Texas. Several factors gave elements of the Bartlesville station's early research agenda national and even international significance.

Defining a Role—Ideology and Technology

Discoveries in the Osage Indian Nation (by then Osage County, Oklahoma), directly to the west of Bartlesville, between 1917 and 1922 alleviated fears of a severe oil shortage in the United States and catapulted Oklahoma to the forefront as an oil boom region and as a potential solution to the national fuel crisis. Other fields in Oklahoma developed through the early 1920s, including the Hewitt, Comanche, Deaner, Slick, and Chickasha fields, continued to increase known reserves and further ease the shortage. By 1925–1926, two-thirds of American oil production (including earlier Oklahoma discoveries such as the Glenn, Cushing, and Healdton fields) was in the mid-continent region served by Bartlesville.[1]

Even so, the demand for gasoline to run the burgeoning numbers of automobiles in the 1920s threatened to outstrip the booming oil production of Oklahoma and the surrounding region. Although statistics were difficult to gather, and the mechanics of oil field "production decline curves" were understood only in an approximate sense—making secure projections of supply against demand extremely difficult—the potential problem of insufficient supply was clear. Staff at the Bartlesville station worked on a wide variety of local projects for improving production techniques which, because of the importance of the local environment to the overall oil picture, had national significance. As they journeyed into the newly opening fields, such as the major Seminole field in 1925, to assist individual drillers in solving problems including underground water invading wells, they rightly saw these particular local services as having potentially wide importance.

Service to the oil producers in the region had considerable national importance; however, a number of ideological and practical factors limited and constrained the station's choice of projects and activities. First, at the national level, Bureau of Mines personnel expressed a conservationist philosophy that dominated the outlook of specialists throughout the Department of the Interior. "Conservation," as applied by Bureau personnel to the oil industry, conveyed a meaning similar to its application to forestry, water resources, soil, and minerals. As noted in Chapter 1, the Bureau of Mines specialists concerned with oil and natural gas believed that they should develop information and techniques which would lead to more efficient recovery and better utilization of resources. Those specialists thought they should study ways to find reserves, effectively utilize gas pressure to bring crude oil to the surface, make use of the gas that the oil industry treated as a waste product to be vented, and prevent loss through evaporation or leakage. Their argument was that such studies could aid the individual producer while at the same time serve the national interest by protecting the natural resources of petroleum or natural gas. Businessmen would become scientifically informed, would use the most enlightened methods, and thus would serve both the private and the public interest.

Henry Doherty, who headed Empire Fuel and Gas, the predecessor of Cities Service Corporation, at that time maintained company headquarters in the town of Bartlesville. Doherty, who had pledged half of the Chamber of Commerce's original $50,000 for the experiment station, was regarded throughout the oil industry as an advocate of such enlightened, scientific business practices. In particular, Doherty hired technicians and scientists, including some who worked briefly for the Bureau in Bartlesville, and he advocated conservation of resources as a means of protecting both price and the nation's resources.

Similar principles from the "gospel of efficiency" lay behind the work of agricultural experts in soil conservation and behind the approach of government experts in general to the technical problems of resource development through the 1920s. If an individual oil producer could be convinced to undertake a technique because of its potential profit, which would at the same time enhance conservation, so much the better. Of course, it would be nearly impossible, without restrictive or regulatory legislation at the state or national level, to encourage conservation measures that were counter-profitable. Although Bureau personnel did feel free to advise that such rules be passed, the Bureau did not regard itself as an enforcement agency, and was careful to maintain a cooperative rather than controlling relationship with industry. To the extent possible, Bureau of Mines personnel sought voluntary cooperation in conservation techniques (which tended to be profitable for the producer), with the ultimate objective of serving the national interest in the efficient use of natural resources.[2]

As the Bureau of Mines technicians at Bartlesville developed techniques and studies with the emphasis on profitability, they won a warm reception and an excellent reputation with some of the producing companies of Oklahoma, particularly the Phillips Petroleum Company and Doherty's Empire Fuel and Gas Company, both based in Bartlesville, the Pure Oil Company, based in Tulsa, as well as with a number of smaller firms.

Relationships with industry were helped further in 1925, when the Bureau of Mines was transferred to the Department of Commerce (then under Herbert Hoover), following the exposure of Secretary of the Interior Albert Fall for taking bribes for the release of Teapot Dome Naval oil reserves in Wyoming for private production. The Bureau of Mines was able to use this transfer to shift the few regulatory tasks performed by the Bureau—such as supervision of drilling and production on public land—to the U.S. Geological Survey. This decision left the Bureau, in its new role as a Department of Commerce agency, free to cooperate with and serve private industry with no taint of regulation. R. A. Cattell, who was responsible for this decision, later regarded it as one of the smartest moves he ever made. It permitted the Bureau of Mines engineers to have access to proprietary information and to private oil sites that never would have been shown to a representative of a regulatory body.

Secretary Hoover, himself an engineer seeking to apply engineering procedures to a variety of government problems, advocated organized cooperation between government and business. Hoover believed that government experts, working with private experts in industry-wide associations, could secure voluntary cooperation and adherence to standards. Hoover hoped that the government could play a mediatory role in the public interest and insure that working technical solutions and standards with industry-wide application would be established. His favored method of structuring such cooperation was through joint industry-government committees throughout his Department. But a high degree of cooperation, through a less structured form than Hoover sought, already existed at the Bureau of Mines experiment stations.

It was the practice of the day for associations of businesses on opposite sides of particular markets to engage in negotiations, sometimes amicable, often contentious, to determine price arrangements, quality, and standards. Where government experts could be called in, they sometimes took the role of witnesses or observers, with the hope that their presence would add a quality of legitimation or objectivity to a procedure advocated by one side over another. But they were not in a position to advocate effectively any particular method or to secure the adoption of any procedure they regarded as objectively more accurate or fair. Business associations, by their nature, sometimes negotiated settlements of national importance, often representing countervailing sectors of the economy. In such negotiations, neither side was concerned to advocate the "public" interest.

Hoover's ideal was of an impartial government role that would meet the need for an objective voice to represent the national or public interest. Some technical men throughout government hoped that they could play just such a role of advocate of the national interest, and the issue of exactly how to insert the government into association negotiations was a major ideological and political issue from the years of the Harding administration (1921–1922) through the First New Deal of Franklin Roosevelt (1933–1934). Although engineers at the Bureau of Mines had the knowledge and political awareness to become involved in the early 1920s, the record shows that their participation was limited, tangential, and sometimes forced upon them for reasons they regarded as unscientific.

Through the 1920s, two philosophies or ideologies, not always compatible, lay behind the work undertaken at the Bartlesville station. On the one hand, the Progressive-era conservationist philosophy predominant at the Department of the Interior dictated a leadership role for the station in finding and advocating efficient practices which would conserve natural resources in the national interest. On the other hand, efforts to play a mediating or consulting role to industry associations, in accord with the Hoover philosophy of mediation and interindustry brokerage predominant at the Commerce Department, often led Bureau men into the politics of pricing and standardization. In other words, the transfer of the Bureau of Mines from Interior to Commerce resulted, not in a clean break in "ideology," but rather in a blend of the two approaches. At Bartlesville, the blend was reflected in a kind of inertia, as the older personnel, committed to the conservation doctrine and to the "gospel of efficiency" in the national interest, stayed on at the station in the new situation and with the new pressures. When opportunities to cooperate with industry came along, or instructions came from Washington which would engage the station's technical personnel in the politics of pricing or the politics of standard-making, they sought to find a path which would avoid "taking sides" or making enemies in any sector of the petroleum industry. One way to do this was for station representatives to structure their cooperation with industry on a local, practical basis. Whenever contention or controversy between different sides of the market in industry or between industry and government threatened to disrupt such cooperation, Bureau men in this period voiced a preference for staying clear of the debates in the interest of preserving good relations—relations that had derived from the successful efforts of the station to develop profitable means of conserving oil and gas and the resulting willingness of oil producers to work with them.

This desire on the part of station staff to secure and continue a cooperative working relationship with local producers was conscious and explicit, and had begun several years before the requests issued by Hoover as Commerce Secretary for more formal implementation of procedures for cooperation. As we examine the specific technical projects undertaken from the station through the period, we shall see that the station's technical people worked strenuously to keep such cooperation within the ethical standards of the era.

The ethical issue of exactly what form government service to industry should take concerned Bureau of Mines personnel from the beginning. On the one hand, the use of funds derived from general taxation to assist an individual oil man in making a profit would be unconscionable unless it could be adequately shown that the results of work would benefit the industry more widely, and that the resulting techniques and information could result in more efficient utilization of natural resources—that is to say, in conservation. On the other hand, publication or even public discussion of proprietary information derived from close cooperation with a private firm could easily damage that firm's profit expectations and would represent an abuse of the power of the state over the individual. Oil men guarded jealously details of drilling depth, production figures, and decline rates of individual wells. Such information might enable competing drillers on nearby leases to drain a field. Under the "law of capture," whoever first recovered oil owned it just as, under game laws, whoever owned the land into which game wandered was entitled to the profit of its capture. If Bureau personnel published details that allowed a competing driller to secure oil from a driller who had cooperated with the government, such cooperation would clearly be endangered in the future, as the individual's right to a fair profit on his investment would clearly have been abused. The Bureau charted its path carefully to avoid either pitfall.

As men at the station worked with producers in an attempt to encourage such pooling of information, they entered a new area of activity. If information could be pooled under the guidance of technically trained but financially disinterested government experts, cooperation between enlightened businessmen under government leadership could accomplish greater production. The most notable achievements of the station in its first years were in precisely such activities.

Other dilemmas constrained the activities of the researchers at Bartlesville. Under the General Order establishing the experiment stations, each laboratory was instructed to cooperate with local producers, educational institutions, and experts in its field. Further, the station was to cooperate with other federal agencies in the region that were assigned responsibility for related matters. In the case of Bartlesville, before the 1925 shift to the Department of Commerce, this provision meant that the station acted in an advisory capacity to the Indian Agents throughout Oklahoma who were responsible for tribal lands leased to private companies for oil production. Located less than twenty miles from Pawhuska, county seat of Osage county and national capital of the Osage Nation, the Bartlesville station coped with a series of issues for the tribe. Techniques that aided conservation through efficient production would assist both the tribe and the oil producers working on tribal land; but disputes over measurement of production, the value of production, and the method of calculating royalties to be paid to the tribe could clearly place Bureau of Mines personnel in the difficult position of advocating the interests of one side against the other. Where did the national interest lie? How could the station suggest reforms that would aid the Indian side without endangering cooperation and good relations with the producers? How could the Bureau of Mines, one branch of the Department of the Interior until 1925, side against the Bureau of Indian Affairs, also in Interior, without creating a violent intradepartmental dispute? Again, such practical political problems reflected deep-seated ethical issues. The national government had to serve simultaneously as guardian of tribal holdings and as advocate of efficient use of national resources. When such objectives appeared to conflict on a specific case, what was the proper role of a government laboratory?[3]

Practical Problems in Getting Started

Such limitations shaped the broad outlines of research and service at the Bartlesville station through the 1920s. Even more mundane day-to-day considerations affected the start-up and termination of specific projects. As the station opened, it suffered not only from the constraints of policy and practical difficulties derived from slow acquisition of equipment and the loss of personnel, but also from limited funds. The construction of the laboratory and the accumulation of equipment proceeded slowly, limiting the activities of the station in its first three years to the application of published information, or safety and engineering principles which were well-known to trained engineers. Station advisors faced vast travel requirements to drilling sites often located up nearly inaccessible dirt tracks that made the field work akin to desert exploration. Despite such handicaps, however, the station engaged in a number of research projects in its formative years and produced a highly creditable record.

Even before the station opened, however, Bureau of Mines staff had begun field work in Oklahoma. In 1915, for example, water began flowing into wells in the Cushing field and prevented recovery of gas. The *Oil and Gas Journal* noted that W. F. McMurray of the Bureau of Mines visited Vera, Oklahoma, and recommended that mud (cement) plugs be used to prevent flooding; his advice benefited both the producers and the local farmers, who complained that the briny water was damaging their crops. By 1916, the reports of cement plugging procedures, published as a Bureau of Mines bulletin, were in wide demand; and an earlier brief report, published as a pair of Technical Papers, sold out.[4]

J. O. Lewis, appointed as first Superintendent of the station, headed a staff of six who, in the first months of operation early in 1918, worked out of temporary offices provided by the Bartlesville Chamber of Commerce. During this period, Lewis concerned himself with ordering equipment, lining up a contractor for construction of buildings on the lands provided, going over floor plans, and discussing plans for research and technical work with local oil men. The first contractor was unable to post bond, and Lewis arranged for another. In the rush of such business, he filed brief ten- or fifteen-line reports giving only an outline of his efforts. Dorsey A. Lyons, head of the Bureau of Mines office supervising the experiment stations, insisted on fuller reports spelling out the exact nature of discussions, the parties involved, and other details. By April 1918, Lewis's monthly reports were conforming to the request. Thus, even before the station formally opened, the station began the tradition of comprehensive monthly reports by the Superintendent to the Bureau in Washington, D.C. Year after year, such reports, although self-consciously written to put the best light on the station's work, would provide a steady and continuous core of documentation of the station's operation.

In the April report, Lewis noted that he was studying responses to a questionnaire sent to the local oil company officials regarding the sort of work they thought the station should undertake, and he commented on the high degree of support and interest the station received. In particular, Empire Fuel and Gas and the Gypsy Oil Company sought Lewis's cooperation in a "campaign looking to the shutting off of water from oil wells and prevention of damage to oil wells by water infiltration, similar to the campaign conducted by the Bureau on the conservation of gas."

Lewis soon supplemented his staff with the addition of an expert oil driller, Thomas Curtin, who transferred from the Indian Service to the Bureau of Mines. Beginning in May 1918, Curtin began to consult with drillers in Butler County, Kansas, on methods of cementing wells to cut off intruding water. R. O. Neal, on the staff of the station as an Assistant Chemical Engineer, wrote and published two papers on methods of tracing the sources of intruding waters, and Lewis noted that the purpose of the papers was "to attract the attention of operators to [the need for] shutting off water."[5]

Thomas Curtin continued to work as a field agent through 1918, giving advice on methods of shutting off water in crude oil wells. Curtin's adventures and problems illustrated a variety of issues which would continue to plague the facility over the coming years. At first, Curtin found his position somewhat ambiguous on a couple of counts. By weekly letter, he reported directly to Washington, sending a copy to Lewis at the Bartlesville station. By November, he suggested that he report through Bartlesville alone. Lewis agreed, telling Curtin that he need keep Charles Naramore, his supervisor in Washington, posted only on important developments.

A more serious difficulty was that Curtin's work often took the form of direct personal assistance to oil drillers in correcting their problems and resulted in lengthy stays in isolated spots—on government salary—assisting the private drilling companies in work that had little or no long-range regional or national purpose. In a trial-and-error fashion, Lewis sought a path between government service in the interest of Mid-Continent producers in general and private assistance to a single profit-making enterprise. Curtin commented from Sulphur, Oklahoma, that "[I] am decidedly impatient about this whole affair and it would be very easy to put a wrong construction upon my stay here, but I see no way other than rank desertion, of pushing the work faster than I am at present." Physical conditions contributed to Curtin's displeasure—he scrawled at the bottom of one of his typed reports: "I have not shaved for seven days. Almost impossible to do so." More seriously, he was troubled by the insistence of oil well operators that he stay on to solve their problems.[10]

Early in 1919, matters got worse for Curtin. One of the companies with which he worked in Murray County insisted that he give some further help. The company wanted him permanently assigned, for they found that his solutions to waterflooding problems were only temporary and, whenever he left, their production soon ground to a halt. Curtin also found that, in discussing the matter over party-line telephones, he needed a "code," because the information was leaked and land prices began to climb. Lewis did not think it was Curtin's role to save private firms the expense of hiring someone to do the same work, telling him that "our work is dealing with conditions that are new or methods that are not familiar to the ordinary producers in the Mid-Continent." In line with this view, Lewis finally wrote to the firm, withdrawing Curtin's services. He told them that Curtin felt any competent driller could handle their well, and that he was cutting off any further funds for Curtin's work with them.[11]

A more successful early project was that of W. P. Dykema, Assistant Petroleum Engineer, who undertook a study of the method of recovering gasoline from natural gas by absorption. Natural gas occurring in crude oil wells contains gasoline in vapor form, which usually has large proportions of compounds with octane numbers high enough to approximate what is now called 100-octane gasoline. Such gasoline, commonly called casinghead gasoline (since the vapors are now collected at the well casing head), was far too explosive when used directly in the engines of the early twentieth century. Typical practice, therefore, was simply to vent it to the atmosphere, particularly in areas not served by collecting gas pipelines. When used as a blending agent, however, it could serve to enrich and raise the quality of the lower octane gasolines produced either from cracking crude oil or from straight-run fractional distillation. Thus, an extremely valuable product was simply wasted in a great many wells devoted to producing crude oil. Dykema was allowed under a cooperative agreement to study two plants, both at Bartlesville, as they were being constructed: one using a compression (or refrigeration) method set up by the National Oil and Development Company; the other using an absorption method set up by Phillips Petroleum. Dykema's work and resulting Bureau of Mines bulletins on the methods of recovering this product met the ideal of the Bureau in publicizing a technique that would lead to conservation as defined by the Bureau. Signal Oil Company of California, founded in 1919 by Sam Mosher, was established on the basis of the application of Dykema's absorption method as reported in the bulletin. Casinghead gasoline previously wasted at the flush new field located on Signal Hill in Los Angeles became the product of the new company and the basis of a rapidly growing fortune for Mosher.[6]

This and other early cooperative projects demonstrated how the two-way relationship with industry would work. Although the profits to be derived from casinghead gasoline were potentially vast if the natural gas vapors were rich in gasoline, construction for both absorption and compression methods was quite simple. And the technology, if carried from Oklahoma to other areas, would benefit the nation as a whole. In explaining the results of his investigation into casinghead gasoline plants, Dykema noted that experiments with the compression method for obtaining the gasoline seemed wasteful and, for the same reason, recommended a charcoal absorption method over an oil absorption method.[7]

In the mid-summer of 1918, the first two permanent station buildings were constructed on the two-block site in a residential section three blocks from Bartlesville's main street on the west side of town. Surrounded by small bungalows housing workers at the nearby Phillips Petroleum company, the small red brick buildings resembled the grammar schools found throughout smaller communities in mid-America.

Even as the buildings were under construction, the Mid-Continent Oil and Gas Association took an active interest in the research agenda items for the emerging station. Director of the Bureau of Mines, Van Manning (who later served as research director for the American Petroleum Institute), noted in a written outline of the projected research concerns of the station that the new station was to be "a laboratory for practical research for solving problems, devising new methods, preventing wastes, effecting economies and for collecting and disseminating information." Excerpts from Van Manning's outline were sent to the members of the Association by the organization's vice president, J. F. Darby, with the note that all the topics were of "particular importance in the Mid-Continent." Van Manning's list included:

- capacities and characteristics of oil and gas sands;
- inquiry into properties of oil not extracted under present methods;
- effects of shooting (using explosive charges to fracture the oil-bearing formation around the wellbore);
- methods for stimulating production and increasing the extraction of oil; and
- use of waterflooding for increasing the extraction of oil.[8]

Van Manning also included a number of topics related to pumping of wells which, Darby noted approvingly, were of particular interest in Oklahoma. The excerpts sent to the Mid-Continent producers did not mention Van Manning's interest in the national implications of the work, however, or the Bureau's dedication to conservation. A section of his statement which the Mid-Continent Association did not quote states that investigations would not be limited to any one branch of the industry nor to any one part of the country. Rather, research would go on wherever opportunities appeared for increasing efficiency, whether in the drilling of wells, in the producing or transporting of oil and gas, or in the storing, refining, or utilization of oil and its products.

Ignoring these national elements of Van Manning's statement, the Mid-Continent producers instead chose to emphasize only the local and regional significance of the station. This tension between the regional and the national emphasis persisted, to be resolved neither formally nor informally in either the station's planning or the oil industry's perception of the station's role.[9]

Avoidance of Technological Controversy

In 1918, the Bartlesville station and, through it, the Bureau of Mines were drawn into a controversy surrounding the pricing of casinghead gasoline derived from oil wells on the Osage lands. Under a proposed regulation change issued by the Bureau of Indian Affairs, royalties were to be paid on casinghead gasoline to the leaseholder on the basis of the price paid for regular gasoline in Chicago. In the opinion of Dykema, the Bureau's expert on casinghead gasoline, such pricing was the worst possible deal for the Indian. Among other reasons, the price of casinghead gasoline should be higher than regular gasoline, because it was used as a blending agent to raise the quality and the price of the gasoline to which it was added.[12] Dykema's opinion in this case ran counter to the oil producer's position, but the station, under Lewis's supervision, was careful to avoid taking a local role as mediator or policymaker, for fear of any controversy that might endanger relations with local oil men.

In December 1918, Lewis suggested a guideline on controversial issues. Lewis believed it would be desirable for the experiment station to restrict its activities absolutely to experimental work and to keep out of anything "that savors of a political or regulatory nature." Lewis did not think that the "two lines of work [research and mediation]" were going to mix well. He hoped to keep the station "absolutely free" from taking a position and to make it clear to oil men that the station refused to do so. In this way, Lewis believed he could get their "fullest cooperation in experimental work."[13] Dorsey A. Lyons, Supervisor of all the Bureau's experiment stations, agreed that "it is desirable for the Bartlesville station . . . to restrict its activities absolutely to experimental work and to keep out of anything that savors of a political or regulatory nature."[14]

Despite the agreement to stay clear of the issue, the station finally did submit its opinion on Osage pricing through an internal memorandum. By June 1919, Lewis had moved to Washington as Chief Petroleum Technologist, and he sought to obtain Dykema's opinion on the casinghead gasoline pricing regulation for relay to the Director of Indian Affairs. Dykema, now Superintendent of the Bartlesville station, sent his frank objections about the regulation to both local and national Indian Affairs officers.[15]

Dykema's eventual report was an exception, however, to the general principle developed by Lewis and Lyons, which did place useful limits on the Bureau's involvement in controversies. In order to avoid endangering relations with technical men in the oil industry, opinions, especially if they ran counter to oil industry positions, were henceforth submitted through Washington. For the next two decades, the station would avoid taking a position, especially at the local level, which could savor of regulatory behavior or of politics.

Oil Production Problems–An Emerging Specialization

In January 1920, Dykema left the station to take a position in private industry; A. W. Ambrose, who headed a Production Problem Department at the station which had been set up in May of the previous year, was appointed station Superintendent. During his tenure as Superintendent, Ambrose emphasized continuing field work and saw to the preparation of a series of oil field studies. He personally authored a Bureau of Mines bulletin, *Underground Conditions in Oil Fields* (#195) that, due to lack of government funding, was printed in serialized form in the *National Petroleum News* early in 1920.[16]

Shortly after he became Superintendent, Ambrose prepared a brief history of the station from its founding. He discussed with obvious pride the oil field development problems pursued by the station, outlining, in particular, the studies made in 1920 of the Walters oil and gas field and the Hewitt field. In both of these studies, petroleum engineers from the station gathered all possible information—including well logs from cooperating drillers, and with "elevation" or well depth information—to develop cross sections through the oil field.[17]

Ambrose justified these activities, which clearly favored particular producers, by reasoning that limited personnel and funds dictated concentration on one subject and one local area. He planned to "work up" a field, turn the results of the investigation over to local operators, and then move on to a new field. By "working up" a field, Ambrose meant the preparation of structure contour maps, geologic cross sections, and peg models which would show the three-dimensional nature of the underground formations, the layers of producing sands, and the presence of underground waters. Such information would allow drillers to know the exact depth to which they should drill and at what depths they should explosively fracture the formation, or "shoot the wells," to get access to producing gas or oil strata.[18]

T. E. Swigart of the station staff, assisted by F. X. Schwarzenbek, spent three months in the Hewitt field, gathering information on every well in it. A peg model, with a peg representing each well and labeled to show the depths of producing regions and other geologic information, was constructed at Bartlesville and then shipped to Ardmore. Swigart placed the model on display in the lobby of the Hotel Ardmore, where he and Schwarzenbek maintained offices for consulting with drillers.[19]

The cross sections of the field indicated a severe dip in the producing or "pay sands." Using this information, Swigart could tell particular well owners when to drill to a deeper level. A number of operators used station advice to make profitable discoveries. The Hewitt investigation ran from April through July 1920, when the crew headed by Swigart was ordered back to the station. At that point, the Ardmore Chamber of Commerce, using $1,000 in funds provided by several local operators, funded the return of the team to Hewitt for an additional two months.[20]

Ambrose saw the contribution of company funds as more than simply a convenient way to extend station services. The money served to demonstrate, Ambrose believed, the interest and support of producers in the use of scientific information. Ambrose's missionary tone in spreading the gospel of progressive drilling techniques is clear in his description of the Ardmore Chamber of Commerce decision "to contribute voluntarily this sum of money" as "very gratifying." Further, he noted that the commitment reflected considerable credit on Swigart and Schwarzenbek and proved that Bureau engineers were "demonstrating to the operators the value of engineering practices in oil field development work."[21]

The Ardmore oil men understood very well the profits to be made from Swigart's and Schwarzenbek's information. The unexpected dips and steep inclines in the Hewitt field made it an excellent demonstration of the utility of pooling information and of the benefit of a peg model in illustrating the drop-off of the producing horizon and potential areas for new discoveries. The chairman of the fund-raising committee made no secret of the fact that "the advice of these men may be worth $100,000 to my company."[22] And the Ardmore Chamber of Commerce, with Ambrose's blessing, used its own funds to publish the report on the Hewitt field.

The Bartlesville Chamber of Commerce published a similar report on the Walters field. In both cases, the local Chamber of Commerce was used to channel funds from the oil companies involved. This use of the Chamber as an intermediary for funds allowed a small number of cooperating firms to provide money to the government agency under the umbrella of the Chamber of Commerce, rather than revealing their individual identities to Bureau staff in Washington by signing a check to the Bureau directly.[23]

Information so clearly usable for the profit of a particular company was easy to "sell." Techniques which would benefit a whole field of drillers but required a capital outlay from only a single driller were far more difficult to promote. Ambrose soon confronted such a situation. The Empire Gas and Fuel Company asked him to examine the rapid decline of production in the Duncan field. Ambrose concluded that the problem stemmed from water seeping through certain higher, nonproducing wells into oil-bearing horizons and flooding out the producing wells. The wells that drained water into the oil sands (called water-strings) would have to be sealed. Since the cost of such work would be disproportionately borne by individual operators, but be of equal benefit to all working the oil sands, no one would voluntarily cement off the wells. Ambrose outlined the problem to the Oklahoma State Corporation Commission, which subsequently required the cementing to be done. In this case, therefore, the station acted counter to its desire to stimulate more efficient techniques entirely through encouragement of profit, by suggesting state government regulations which *forced* conservation measures—measures which were themselves not profitable to individual companies. The Oklahoma Corporation Commission moved cautiously in this period to establish rules to prevent excessive oil field waste; technical reports and recommendations such as those produced by Ambrose provided the specific guidelines. The station tried to "stay clear" publicly of regulations that would impair good cooperative relations with affected companies. But when the conservation ideal could not be linked to a profit-generating improvement, station engineers were willing to pass on suggestions quietly to the state regulatory body.[24]

By 1920, the staff of the station had grown from six to fifteen, and the diversity of projects reflected the staff's rich background in chemistry, petroleum engineering, reservoir study, oil field experience, and refinery engineering. Ambrose, using this enlarged staff, supervised studies on the loss of gasoline fractions from crude oil by evaporation and the possible further recovery of gasoline from residual gas vented after initial processing through compression plants deriving casinghead gasoline from natural gas.

Ambrose also started several projects which came to fruition later, including a study of the use of low-pressure natural gas to fuel oil field steam engines used to drive pumps. He supervised the construction of a small-scale experimental refinery with the object of developing methods to reduce refinery loss and a range of products, including lubricants, which could be obtained from Mid-Continent crude.

During this early period, the search for a clear-cut agenda took the station into a wide range of diverse areas. For example, the station sent a home economist, Miss Olga Elifritz, on a tour of local communities to explain consumer methods of conserving natural gas. Other projects included the building of a small-scale fractionating tower for refining studies; experiments on the absorption coefficients of crude oil to determine the proportions of natural gas, air, and casinghead gas absorbed by various crude oils; and the preparation of exhibits for the state fairs held at Oklahoma City and Muskogee and for the Independent Oil Men's Association meeting to be held in Denver. On a more scholarly level, Ambrose and his staff also gave papers at the Denver meeting. H. H. Hill, a specialist in refining work, gathered information regarding fractionating towers used in the cracking of crude oil mixtures into useable products.[25] But despite the apparent diversity, most of the research projects proposed and undertaken during 1920 did have a common thread—to increase production and to conserve against losses, with particular emphasis on the Oklahoma area.

In January 1921, Ambrose went to Washington to take the position of Chief Petroleum Technologist at the Bureau of Mines; Hill succeeded him at Bartlesville. Patterns had now been set which were to shape the development of the research facility over the following five decades.

In accord with the general order establishing the experiment station, the first three Superintendents developed considerable autonomy in setting the station's research agenda and in determining the station's function. Cooperating with local oil men, Lewis, Dykema, and Ambrose all sought to persuade producers of the value of an organized engineering approach to the problems of oil production, storage, and transportation. While the Bureau's Van Manning had indicated that the station would serve no particular section of the country nor sector of the oil industry, the emphasis that emerged under the tenure of the first three Superintendents during the first years was that preferred by the Mid-Continent Producers Association—that the station would serve primarily Oklahoma and, to a lesser extent, the surrounding areas of Kansas and Texas.

Cosponsorship of the experiment station by the Bartlesville Chamber of Commerce, representing local oil companies, and the State of Oklahoma reflected a financial and organizational blending of federal, private, and state interests. Other, national organizations had good reason to be interested in the work of the station as well. From time to time, the station received inquiries or worked towards cooperation with such regional organizations as the Mid-Continent Producers and the Independent Oil Men's Association, and professional organizations such as the Society of Automotive Engineers (SAE) and the American Institute of Mining and Mechanical Engineers (AIMME). But the real operative connection was with the Bartlesville firms of Empire Gas and Fuel and Phillips Petroleum, and smaller firms in the surrounding counties of northern and eastern Oklahoma.

Local Reputation for Objectivity and Cooperation

The rapid turnover of Superintendents and Acting Superintendents continued from 1920 through 1924, but did not prevent the station from expanding and flourishing. Good relations with local oil men paid off, not only in continued cooperative work, but also in increased contributions by the State of Oklahoma to the finances of the station, which allowed the staff of the station to increase to forty by 1925. This expansion in staff allowed for further diversity in projects and services and the preparation of a variety of written reports, published as Bureau of Mines technical papers, as bulletins, and as articles in oil industry trade journals.

The pattern of work continued to be dominated by two major areas—study of production on a field-by-field basis, and further work on various aspects of casinghead gasoline production. Station staff undertook a variety of smaller projects designed to utilize waste products or to reduce losses. Individual researchers worked on methods of recovering gasoline from vented still vapors, gas loss from pipelines, methods of producing carbon-black from gas that would otherwise have been simply vented, and the use of low-pressure gas to run steam engines used in oil field pumping, as planned by Ambrose. While such individual projects proceeded, the longer-range field work assisting on the development of oil fields through collection of data and reports on casinghead gasoline continued to build the station's reputation in these two areas of achievement.[26]

The effort by Lewis to avoid regulatory controversies was continued by subsequent Superintendents and succeeded to a large extent, although the multisided nature of the oil industry made absolute abstention from controversy difficult. For example, natural gasoline manufacturers and the refiners who purchased the product for blending disagreed on methods of evaluating the product. The Bureau avoided siding, at the national level, between the claims of industry associations on two sides of a market. The American Petroleum Institute (API) (representing the refiners) established a set of research committees with the declared purpose of establishing an objective method of evaluating the quality of gasoline; natural gasoline manufacturers suspected, however, that the procedures being tested by the committees were inaccurate. The API proposed to use the "bomb" method. This was simply a sealed vessel lowered into a tank of gasoline, opened and filled with gasoline, resealed, and removed. The contents were then heated to two pre-agreed temperatures, 90°F and 100°F, and the resulting pressure was measured by a standard pressure gauge mounted on the vessel. Both Hill and N. A. C. Smith, specialists in petroleum products, agreed from the beginning of the project that the API-proposed method of testing gasoline vapor pressure would be less accurate than laboratory distillation and hesitated to allow the Bureau to be drawn into the API-sponsored research.[27]

Early work by D. B. Dow at the Bartlesville station had spelled out a distillation method of determining gasoline volatility and vapor pressure. Natural gasoline manufacturers preferred the distillation method, but agreed to cooperate with the API's bomb tests—believing the refiners represented by the API would institute their own system of measurement even if natural gasoline people did not cooperate. Bureau personnel, despite their inclination to sympathize with the natural gasoline producers and their Natural Gas Association formed in 1921, however, hoped to avoid being drawn into the dispute on either side. Station staff member F. W. Lane doubted whether the natural gasoline people for their part really sought to establish the accuracy or usefulness of the bomb test. Rather, he believed they wanted a test which could be accepted as a standard regardless of its scientific validity, and for that reason was wary of the possibility that Bureau reports would be used politically. "The approval of any federal department," he said, would help them politically.[28] The laboratory procedures used by the private laboratories in testing the bomb methods were to Lane grossly inaccurate, because the same sample of gasoline would be used to run the two separate temperature tests rather than using a fresh sample for the second test. Bureau technicians found themselves being made to sign off as witnesses to such tests, taken inaccurately, of procedures they regarded as fundamentally unsound, in order to help resolve a controversy. Eventually, the API bomb method was adopted, but with no recognition of Bureau objections to its accuracy.

A case of interindustry potential bargaining that raised fewer hackles was one that developed between two sides of the domestic heating business. Both refiners and oil burner manufacturers hoped to develop standards for home heating oil—which would lead to efficient use of both fuel and heaters. The Bureau of Mines sent station engineers Kirwan and Youker to observe discussions held in Tulsa. The Western Petroleum Refiners Association, the Osage Oil and Gas Lessees Association, the Mid-Continent Oil and Gas Association, and the American Association of Oil Burner Manufacturers proposed to pool funds for a research project to be conducted by the Bureau of Mines itself. Through 1924, however, the proposal did not get beyond the discussion phase.[29]

In the period before 1925, only when dealing with government-held or government-administered lands did the Bureau men find themselves forced into a regulatory role. At Salt Creek, Wyoming, Bureau recommendations for evaluating the value of natural gasoline (in this case, setting the value of five cents per gallon below Chicago tank wagon price) were implemented. The Director of the Bureau of Mines in this period, H. Foster Bain, on advice from experts at the Laramie and Bartlesville stations, recommended the price set by the Secretary of the Interior. The price upon which government royalties would be charged represented "relief," to encourage the utilization of the casinghead gas which oil producers had been simply venting or burning off. Again, the Bureau used a profit incentive to discourage a practice it viewed as wasteful.[30]

The occasional disputes into which station personnel were drawn, often against their better judgment, did not prevent the main research effort of the station, which continued to result in publications designed to assist producers in eliminating waste, preventing loss, and improving efficiency. The major frustration of Superintendents and researchers alike appeared to originate from the difficulty of getting producers to adopt conservation techniques even when they were clearly profitable.

The most consistently usable work from the station in the early 1920s continued to be direct field advice. In 1924, Kirwan reported to the International Petroleum Exposition and Congress work on sixteen station research projects, including work on refinery technology, problems of gas pipeline leakage, evaporation losses from field storage tanks, and cementing studies. He noted, however, that public attention came to the station for spectacular field service such as bringing under control a cratered wild gas well in the Chickasha field, for closing a wild gas well in the Depew field in seven days after the owners had worked on it unsuccessfully for forty days, and for assisting in extinguishing a gas well fire in the Cromwell field. Kirwan noted that such work, while serving particular owners, had value to the industry more generally because it would serve as a "demonstration" of good technique. Kirwan was explicit in his hope "to cooperate with the petroleum industry in the interest of efficiency and true conservation of our natural resources."[31]

Through the early 1920s, men who had moved on from the station to industrial jobs made a practice of returning to visit. Visits of such individuals and of other industry personnel, only summarily reflected in the monthly reports, appeared to be one of the major means by which business came to be conducted at the station and one of the early methods of building the station's reputation. Through such contacts, cooperation with industry proceeded quietly and effectively on a strictly local level, without reference to the advocacy positions taken by the national or regional associations. As early as July 1921, the monthly visitor list had grown to include Bureau personnel from Washington, personnel from other stations, company officials interested in technical issues relating to natural gasoline or seeking drilling or mudding advice, as well as former station staff members.

Although government experts had the objectivity and the technical training to allow them to play a mediating role between conflicting business associations, their reluctance to be drawn into industry politics, which has been stressed repeatedly here, limited that role. The petroleum industry associations often fought one another for position and price advantage, using technology and science as arguing points, but not as tools for "objective" or impartial solutions. When Hoover and his followers advocated the application of engineering principles to administrative issues, they assumed that science and technology would provide solutions that were above political concerns and the dictates of self-interest. Government engineering provided the appearance of impartiality or national purpose, itself useful as an arguing point, but alleged government objectivity was used by industry, not as a source of independent brokerage or of mediation between conflicting sides, but as a political tool.

The Bureau's own ideal of service in the interest of conservation and efficient utilization of resources was itself not an "impartial" position, of course, because it could and did lead to advocacy of methods—sometimes costly in the short run—that industry figures would hesitate to adopt. However, brokerage or mediation, especially when the issue at stake was one of profit on one side, loss on the other side, could only result in the Bureau's losing the trust of the loser group and thus endangering the Bureau's ability to secure cooperation on field conservation techniques. Despite pressures to participate in such issues, the Bureau and its engineers hung back, preserving their credibility by abstention from policy.

The projects undertaken most successfully at the station, thus, continued to be ones that particular local oil producers could see as potentially profitable or that would solve a particular costly problem. The preferred practice of station personnel had not changed from that established by Lewis in the first year of the station's operation.[32]

The Creation of a National Reputation

In 1924, N. A. C. Smith came to the station from Washington to serve as Petroleum Technologist and Acting Superintendent. Smith, a meticulous writer with a concern for the Bureau's scholarly reputation, insisted on retaining an editorial role for all publications on oil and gas from the Bureau. Smith was appointed Superintendent of the station in 1925.* He settled into organizational and administrative tasks and remained as Superintendent, and later as Supervising Engineer, of the station through 1944.

Smith's personality, his concern for excellence in research and writing, and his attention to administrative detail were all good for the station. He led it into a period of physical growth and into a position as an independent and professional petroleum research center, continuing service work, yet publishing independent research work sometimes in advance of the needs and demands of the national oil industry. Such publication continued to put the work of the station before national audiences in the petroleum industry. Smith continued the tradition of response to local and regional demands, although he worked to prevent the station from becoming a strictly local service center. And, like his predecessors, he remained skeptical of any mediating role in disputes, whether between sectors of the petroleum industry or between government and industry. Smith's disdain for the mire of policy went further than that of his predecessors, however. A brilliant technical man, he had little patience with individuals who needed to be convinced of what he saw as an obviously technically correct procedure. Perhaps for this reason, Smith devoted less effort than had been done previously to "proselytizing" the petroleum industry to get them to adopt conservation techniques. His approach, as it developed over the late 1920s and on into the next decade, was much more academic. He would insist that a report or bulletin be accurate, that it be well printed, and that it be widely distributed. He expected, rightly or wrongly, that if the material were scientifically correct, it would be respected and used. This quality of impatience or skepticism about advocacy, and his preference for reputation based on quality, led the experiment station in a scientific rather than strictly service direction, and attracted a group of energetic researchers who made their careers at the station. Like Van Manning before him, Smith emphasized the national potential of the station and, whenever not otherwise constrained by economic and

*Smith was preceded as Superintendent for a brief period early in 1925 by E. P. Campbell.

practical concerns, kept the work of the station before a national audience.

At the beginning of his term, starting in fact during Campbell's brief tenure, a disagreement arose between the station and the Commerce Department over the question of a national advisory committee. The problem started when the Bureau of Mines, in response to recommendations by an interdepartmental committee reporting to Secretary of Commerce Hoover, began to establish a set of formal industry-government advisory committees. At the Bartlesville station, Campbell and Smith responded to the suggestion of a formal committee with skepticism. In a letter to Hill of the Bureau's national headquarters, Smith said the idea of an advisory committee "is a rather poor proposition," although he was careful to note that "an informal group of advisory or consulting engineers is very valuable, and they can call it a committee if they want to." He believed that the station should continue "to formulate our own program of work" and only consult with outside engineers after setting the program. "If we have a definite committee, I am afraid that we will have one or two members who will show a rather impertinent interest in some detailed phases of our work." Smith said he preferred to work with former Bureau and station men, now in industry, and he specifically mentioned Lewis, Ambrose, and Kirwan as "alumni."[33]

Hill had already told Folsom, the interdepartmental committee representative assigned to the Bureau, that the Petroleum Division of the Bureau of Mines had never had a formal advisory committee, but that the Division frequently obtained ideas and suggestions through informal conferences and was closer to the industry that it was intended to serve than almost any other branch of the government service (an assertion that Folsom accepted). Hill noted that some of the other experiment stations had formal advisory committees but that Bartlesville's "old plan of discussing the work only with people that are directly interested in it" was a good alternative that should be kept.[34]

Campbell was both more skeptical and more analytic than Smith. He thought an advisory committee would be politically, practically, and even financially useful to the station; however, he feared the ideal would not be achieved in practice because he doubted whether such committees could ever work well. "The average representative of the industry," he argued, "even of technical mind," could not grasp the need for a national perspective. Campbell believed that even former station personnel, now in industry, lost "sight to some degree of some of the factors that influence the selection of work that is carried on."

Campbell believed an advisory committee, if formally constituted, would be dominated by one or two individuals, and that it would not take the long view necessary to predict future needs of the industry. If a committee was required, he suggested that it include not only technical men, but men from the business side of the oil industry; technical men would keep the research too theoretical, he feared. Campbell argued that industry had accepted station work precisely because it was well-rounded, including practical, theoretical, and reporting work. Because the "gang of engineers" at the station had come from industry, they maintained contact very well without an "intermediary body." Like Smith, Campbell preferred to work with the consulting engineers, often former station men back in industry. Campbell summarized his belief thus: "An advisory committee is the 'bunk'."

The station prevailed. No formal committee was established, and the station continued to set its own agenda, with suggestions from "alumni," informal feedback from industry figures, and in response to Petroleum Division suggestions from Washington. Despite the efforts of Herbert Hoover to place liaison into a formal advisory committee structure, the station succeeded in keeping its informal contacts and its business-as-usual approach.[35]

Continuity and Publication

Through the late 1920s, Smith concentrated on response to personnel changes and research publication. Smith's monthly reports never referred to the degree to which the station's work received local acceptance or support, stressing instead the production of quality published work which would stand or fall on its own merits.

The difficulties of producing work despite personnel turnover in the year 1925–1926 were spelled out in detail. Researchers who left the station to take other positions left their projects and reports to be finished by succeeding researchers. In some cases, reports were finished by departing researchers immediately prior to their moving on; in at least one case, a researcher submitted a draft of his report and his resignation the same day.

Several examples from the station's 1925 experience illustrate the complexity of bringing research to completion during a period of extremely high personnel turnover. W. L. Williams was transferred to the United States Geologic Service on July 1, 1925, and his field work in the Cushing Field was simply discontinued. Cattell was promoted to Assistant Superintendent in October; E. Rawlins left a post with the Natural Gas Association to work for the station and take charge of Cattell's gas pipeline transmission work. Rawlins finished for publication four papers which reflected the work of himself, Cattell, and Wosk. D. B. Dow started a study of methods of increasing recovery of oil in March 1926, then resigned in two weeks. E. O. Bennett took over the project, then resigned within three months, leaving the project in the hands of B. E. Lindsly.[36]

Through 1925 and 1926, the total complement of staff averaged about forty. Of the forty members of the staff in July 1925, fourteen had left by April 1926, and twelve new men came aboard. As Smith put it in July 1926, "During the past year this station has seen the arrival of three superintendents and the departure of two." The overall "turnover" rate in one year was about one-third of the station. From July 1925 through July 1927, the number of staff departing was twenty-one, or over 50 percent, not counting newcomers who both came and went within the period.

Although the record is not sufficiently detailed to develop a profile of the positions taken by all the departees, it is clear that several took positions with the oil industry, particularly those who had served as Superintendent, including Scott and Campbell, who both went to work for Pure Oil Company in Tulsa, and Bennett, who took a position with the Marland Oil Company. In the booming oil industry of the mid-1920s, the demand for trained chemists and engineers with practical experience was at its peak. Despite the difficulty engendered at the station in the form of half-finished projects, however, Smith and those who stayed behind did not appear to resent the departure of their colleagues; indeed, a touch of pride showed up in comments about the alumni who took responsible and high-paying posts in business.[37]

Ironically, the station's very success posed a threat to its continuity. As the technical men at the station proved to industry that their ideas and methods were valuable, companies established their own research departments and recruited their own research staff. This trend was intensified as the station, trying to address national rather than local issues and to avoid controversy, found it increasingly difficult to set a specialized agenda that filled a specific need. As the companies competed for scientists and engineers, the salaries offered soon exceeded the government levels of $2,400 to $3,000.

Smith's chosen method of combating the problems of continuity and competition from the private sector for staff was to concentrate on research that would merit publication in the best technical journals and to secure a national repute and continuity of effort by that avenue. Smith's concern for publication, in both quality and quantity, was in fact the dominant feature of his early administration. He gave details of the publication status of reports and technical papers, reporting on works that were "in preparation" or "in press" as well as those that were published. In 1925–1926, Smith listed three papers published and another four in press. In 1927–1928, he could claim twenty publications from the station, including eleven Reports of Investigations published as Bureau of Mines serial items, four Bureau of Mines Bulletins, and five articles in journals, not counting duplicate publication. In a style foreshadowing the "publish or perish" mania of colleges and universities of the 1970s, Smith credited individuals' completion of work in a public fashion that rewarded the more diligent researchers and made a matter of public record the cases of dilatory progress.[38]

As Smith encouraged publication through items worked into journal articles and reports of station investigations, he took care to work out a system of crediting both senior and junior authors. His concern to grant individual credit to authors, even project assistants, contributed to a sense of high-powered intellectual demand, which was noted by a number of the veterans of this period in oral interviews compiled for this book. During the 1920s, few petroleum researchers held doctorates; apparently the only Ph.D. on the staff through the decade was F. W. Lane, who departed in 1927. The station was most successful in its recruiting of college graduate engineers and technicians, however, as the degrees of some of the staff who moved through the center indicate:

Fowler	A.B. Eng., C.E. (1915)	Stanford
Cattell	B.S. Eng. (1912)	U. of Calif.
Bennett	A.B. (1911), M.E. (1919)	Stanford
Smith, H. M.	A.B. (1921), A.M. (1922)	Clark
Smith, N. A. C.	A.B. Eng. (1909)	Clark

The research atmosphere generated by concern with publication and quality of work had several analogs to academic departments. Smith referred to staff members who moved to industry as "alumni" so often that he soon dropped the use of quotation marks. Senior authors and technicians, like senior scholars in the best academic settings, trained and "sponsored" junior specialists. Smith's policy was explicit in allowing junior researchers credit as co-authors in order to strengthen their careers and their reputations. Junior researchers sought to be placed in charge of their own projects and, after time in service, earned increased responsibility. The publication pressure mounted by Smith was well understood and, to an extent, appreciated by the researchers who came to the station through these years. Smith himself reviewed both style and content of all the items written at the station, and he was a tough critic on both counts.[39]

The sheer volume of work generated in the latter part of the 1920s makes it difficult to review each project. During 1927–1928, however, Smith assigned all work at the station to subject categories according to a project decimal code—a system that continued for nearly two decades. Different categories of projects resulted in different publication rates, as shown in

TABLE 1

Technical Work, Bartlesville, 1927–1928

Problem No.	Topic	Papers: In Prep.	Papers: In Press	Papers: Pub'd.	No. Staff
100	Safety Work in the Mid-Continent Fields			1	2
102	Investigation of Methods of Handling Producing Wells	1			2
103	Investigation of Mud Fluid for Oil and Gas Well Use				1
104	Application of Vacuum to Oil Wells	2			2
110	Study of Crude Petroleum	6	2	2	9
114	Treatment of Light Petroleum Distillates	1		1	2
117	Methods of Increasing the Recovery of Oil	6			6
118	Investigation of Sulphur Compounds in Crude			3	3
120	Engineering Study of the Seminole Oil Field			1*	4
121	Investigation of the Use of Gas for Lifting Oil			1*	2
122	Study of the Flow of Natural Gas through Pipelines	2	4	3	5
123	Routine Laboratory Work†		1	7	10
124	Study of Oklahoma Asphalt				2
125	Study of the Disposal of Oil Field Waters				2
126	Study of Evaporation Losses of Petroleum and Gasoline				2
	Total	24	7	20	‡

*Published in two journals.

†Publications of this section included fuel surveys, analyses of fuels and crude oils, and a paper describing a system of analysis of oil field waters.

‡Staff total ranged from 39 to 41; individual entries do not sum to the total because staff members were often assigned to two or three different problem areas.

Source: Box 224315 101.1 "History of the Bartlesville Station, 1927-28."

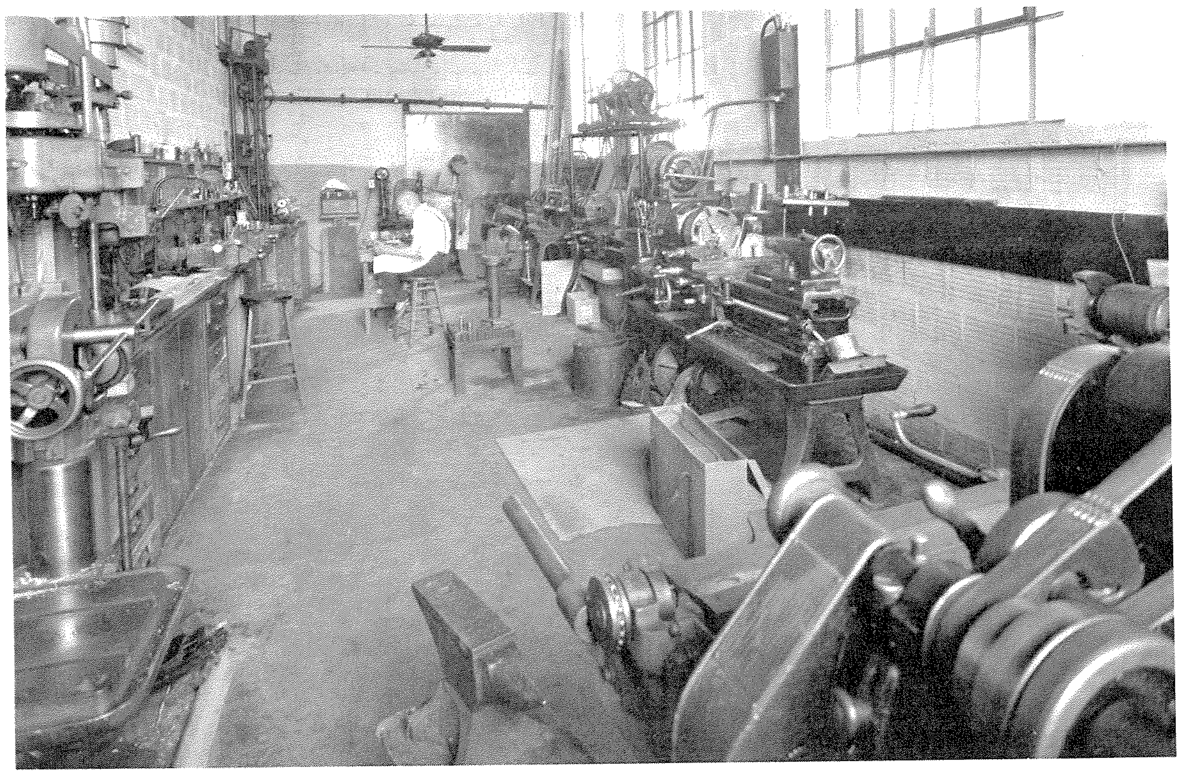
Table 1. As can be seen from the table, by 1927–1928 the station was involved in a wide variety of projects. Large teams of nine to ten members worked on chemical analysis of crude oil and fuels. Medium-sized teams of four to six members worked on methods of increasing recovery, studying natural gas flow through pipelines and conducting engineering studies of producing fields, as set up by Lewis and Ambrose. The other areas were characterized by small teams of one to three members. Individuals often served on several teams. There was no formally established set of research sections or divisions; specialists were assigned and reassigned as changing opportunities and needs dictated. The greatest number of publications came from the study of crude petroleum (Problem 110) and routine laboratory work (Problem 123)—the two areas to which the largest numbers of staff were assigned.[40] The gaps that appear in the petroleum problem number series in the table are because of problems taken up, then dropped, and sometimes taken up again. For example, Problem 109, "Separation of Wax from Wax Distillates," had been studied in 1925 and then dropped until 1928–1929. As new problems were added, new numbers were assigned.

Most of the studies undertaken through the period 1926–1929 had implications for "conservation" as defined in the early years of the station; however, Smith gave less emphasis to such policy implications of his work than did his predecessors. As the laboratory became more established, there may have been less need to restate its *raison d'être* in policy terms; but it is also clear that Smith, with his emphasis on technical proficiency, assumed that good research work was an end in itself. By constant attention to the completion of work, he had established a kind of institutional momentum. He insured that work continued despite transfers, promotions, and resignations, and he saw that notes taken and partially completed by one researcher were turned over to successors and converted into publishable papers.

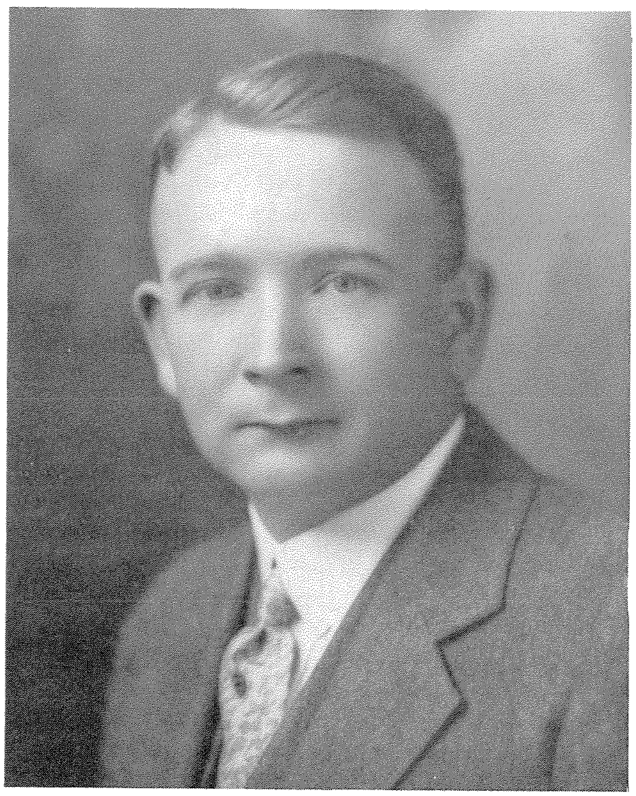
In any case, the philosophy of conservation as applied to oil research began to undergo a subtle change through the late 1920s, a change that would affect the station and the industry as a whole in the coming decade. As the oil crisis of the early 1920s eased with new fields in Oklahoma and California, the oil industry grew careless about production methods. In flush times, concern over vented gas, wasted potential casinghead gasoline, and methods of wringing the last cent from an oil well seemed less important. As wells came in, the profits would go to the producer who could get the leases, get in on the early production, catch the crude oil under natural pressure, and then move on. Pumping wells would continue to produce revenue, but high profits went to the fast-moving wildcatter who could get in on the "plays" developing throughout the region and in California and Texas. By the late 1920s, surplus threatened to reduce the price of crude, and some producers, like Henry Doherty, anticipated the need for a rational system of production limitation. Then, within a year after the Great Crash, oil fields in east Texas flooded the market—bringing a precipitous drop in oil prices. Oil entrepreneurs struggled over the coming years to develop methods of limiting production to bring prices back up. Eventually, they would accept Doherty's reasoning, call such methods "conservation" and, like Doherty, turn to the Bureau and its stations for support. Agreements to limit production, whether voluntary or state-imposed, would face severe legal battles. And new kinds of measuring equipment and detailed information about the nature of oil reservoirs would be needed to find legally acceptable methods of limiting production and the means to enforce agreements. When their help was finally asked, Superintendent Smith and the Bartlesville station were in a good position to give it.

NOTES

1. Gerald Nash, *The United States Oil Policy* 1890–1914 (Pittsburgh: Pittsburgh University Press, 1968).
2. Conservation as a "philosophy" for the station became explicit in 1937 when the following quotation from Joseph A. Holmes, the first Director of the Bureau of Mines, was placed on a plaque over the fireplace in the station library: "True conservation is a wiser and more effective use of our natural resources."
3. General Order 224311/1990, "Explanation of General Order on the Organization of the United States Bureau of Mines Affecting the Mining Experiment Stations." Documents in the National Archives and Records Center, Fort Worth are cited here with a six-digit box number and file title or number.
4. *Oil and Gas Journal,* September 2, 1915, p. 32; December 7, 1916. Cited in Box 224315/101.1. Technical Papers #65 and 66; Bureau of Mines Bulletin #134.
5. Box 224310-1072/057.2 Reports for February through May 1918.
6. Walker A. Tompkins, *Little Giant of Signal Hill,* (Englewood Cliffs: Prentice Hall, 1964), pp. 10-11.
7. Dykema to Marshall, December 23, 1918, Box 224310/507.5/1563.
8. *National Petroleum News,* July 3, 1918, cited in Box 224315-101.1.
9. Ambrose to Hill, October 13, 1920, "Petroleum Experiment Station, U.S. Bureau of Mines, Bartlesville, Oklahoma," Box 224311/101.
10. Curtin to Lewis, November 2, 1918, Box 224311/101.
11. Lewis to J. A. McClur, February 6, 1919, Box 224310/524-1528.
12. Dykema on Osage pricing; Dykema to Cato Sells, Commissioner of Indian Affairs, June 13, 1919, Box 224311/506-11.
13. Lewis to Naramore, December 29, 1918, Box 224310/ 524-1528.
14. Lyon to Lewis, December 31, 1918 (same folder).
15. See note 11 above.
16. *National Petroleum News* publication of *Underground Conditions,* February 18, 1920; February 25, 1920; *NPN* cited in Box 224315/101.1, History of the Bartlesville Station.
17. Ambrose report, July 1920, in Box 224311/017.4. Hereafter, Ambrose Report.
18. *Ibid.*
19. Report on peg model at Ardmore, Box 224311/049 Press Notice, Hewitt Field.
20. $1,000 advanced by oil men, Box 224311/017.41.
21. Ambrose Report.
22. *Ibid.*
23. Source: Publication of report of Walters Field with Chamber of Commerce money; *ibid.* Box 224311/017.41.
24. Ambrose on shutting off water-strings by regulation. Ambrose Report.
25. Box 224310-050/Annual Report, 1920.
26. Ambrose Report.
27. Source on API "bomb." From Lowe to H. H. Hill, November 18, 1920, Box 224314/632.1; Minutes, Meeting Atlantic City, September 18, 1924; Hill to Smith October 18, 1924; Smith to Hill October 28, 1924.
28. Lane to Hill, November 18, 1924, Box 224314/632.1.
29. Box 224314/Oil Burners 720.4.
30. Pricing of Casinghead Gas, Wyoming, Box 224312/793 Salt Creek Gas Situation.
31. "Recent Activities of the Petroleum Experiment Station of Bartlesville, Oklahoma," by M. J. Kirwan read before International Petroleum Exposition and Congress, Tulsa, Oklahoma, October 8, 1924.
32. For the efforts of Hoover to establish a special brokerage rule for government with regard to business associations, see Ellis Hawley, "Herbert Hoover, the Commerce Secretariat and the Vision of an Associative State," *Journal of American History* 61 (June 1974), pp. 116-40.
33. Smith on advisory committee. Smith to Hill, January 12, 1926; Box 224315/017.401 Tough, F.
34. Hill on Folsom. Hill to Campbell et al., January 5, 1926 (same folder).
35. Campbell on committee. Campbell to Hill, January 21, 1926 (same folder).
36. Report 1925-25, "General History of the Bartlesville Station for the Fiscal Years 1925–1926"; Box 224315/101 Organization of the Bartlesville Station.
37. *Ibid.*
38. 1927–1928 Report, "General History of the Bartlesville Station for the Fiscal Years 1927–1928"; Box 224315/101 History of the Bartlesville Station.
39. Report. Interview Carlisle-Rall, 1981.
40. Box 224315/101.1 History of the Bartlesville Station, 1927-28.



In the early 1920s, equipment was meager and much of it was constructed in-house. The upper picture shows the Chemical Laboratory with Dr. F. W. Lane at left desk, John Devine in background and H. M. Thorne at right. The crude oil analysis laboratory was the forerunner of the present crude oil analysis data bank that contains 12,000 analyses of oils from throughout the world. The machine shop (lower) constructed much of the equipment used in the research projects at Bartlesville.



Interchange of personnel between Bartlesville and the Bureau of Mines headquarters in Washington and industry was frequent during the 1920s. H. C. Fowler (upper left) was at Bartlesville as a safety engineer from 1923–1928, when he moved to Washington as Chief Petroleum Engineer of the Bureau of Mines. He returned to Bartlesville in 1945 as Director and continued until 1963. R. A. Cattell (upper right) joined the Bureau of Mines in 1921 and was Superintendent of the Bartlesville Station in 1925 moving to Washington later that year. W. W. Scott (lower left) was also superintendent in 1925 and resigned to join Humble Oil and Refining Company. E. P. Campbell (lower right) was superintendent in 1925–1926 and left to join Standard Oil Company of California.

Chapter 3

EMERGENCE OF SCIENTIFIC RESEARCH, 1930–1941

During the 1930s, the Bartlesville station encountered and overcame a series of challenges to its jurisdiction, its funding, and its role in government. The Great Depression, in addition to an oil glut in the early years of the decade, imposed severe difficulties. The oil industry's drive to develop new methods of discovering and recovering oil slowed as prices plummeted. Crude oil sold in East Texas, for example, sank to ten cents a barrel. At such prices, only the large producers avoided the danger of economic disaster. Since the courts viewed limitations on production as illegal restraints of trade, industry was powerless to set production limits or even to set a price floor. Oil companies sought legal and technical means of limiting production. In this atmosphere, it appeared the Bartlesville station could have little role. Further, the declining federal and state revenues meant that the station's budget would be severely chopped. In 1931, the federal budget for the station was cut from $101,000 to $94,000, while the state appropriation was reduced from $62,500 to $57,500. Further cuts followed in 1932 and 1933. The oil industry, too, cut its expenditure for research, and fewer station technicians received offers of private employment. The Bureau of Mines faced the awkward dilemma of reduced budgets, lowered demand for research, and a tight job market that reduced staff attrition in response to job offers elsewhere.[1]

Assisted by friends in Washington and by the industrial network of Bartlesville alumni, Smith and Ludwig Schmidt—a petroleum engineer who was at the station from 1921 to 1947 and served increasingly as Smith's right-hand man—worked to find a continuing place for the Bartlesville station amid the swirling changes in the oil industry, the economy, and the emerging new institutional arrangements of the New Deal. In particular, they sought new sources of private funding and new justifications for state and federal government aid.

Not surprisingly, therefore, despite constant planning conferences and correspondence within the Bureau in Washington and Bartlesville over proposed work, the resulting publication list of the 1930s reflected not so much a pre-planned research agenda as the results of changing access to funding influenced by a host of difficult pressures. First, rivalry and disagreement between associations continued to put the station in a difficult position. Second, over a period of years, the oil glut made "conservation" and "more efficient utilization" of petroleum appeal as never before to the leaders of oil-producing corporations. If, in the name of conservation, states would establish rules and regulations leading to effective limitation on production, which the states themselves could enforce, then the legal deadlock over exactly how to put a stop to massive overproduction could be achieved. But this, of course, meant the threat of an increased federal role in regulatory activities, however, which aroused potential resentment among some oil industry leaders towards any federal role, even in research. Station technicians viewed such developments as endangering the close cooperation between government, station, and private industry which had been built up with such care during the 1920s.

"Conservation" now not only meant the avoidance of physical waste, but also the avoidance of inefficiency and waste that resulted from economic conditions—"economic waste." Although the oil glut rendered any research into improving recovery methods needless, industry did seek new devices which could measure and detect the rates of production and determine the size of underground reserves, in order to justify and enforce agreements and regulations to limit production. But measuring procedures imposed on resources or products entering a market were inherently controversial, since a refinement of measurement would usually reduce profits on one side of an exchange and raise those on the other. Measuring production or reserves in order to limit production appealed to the industry as a way to stabilize prices. The public, however, suspected that such measures might be contrary to consumer interests. Because of its concern with precise technical measurement, the station was in an excellent position to participate in the development of measuring devices. Yet station administrators approached participation in the commercial application of measuring devices with considerable trepidation because, like their predecessors in the early 1920s they sought to avoid controversy.

Thus, the period 1930–1941 was a dangerous one for the station. Bartlesville faced a tangle of conflicting pressures and threats to its funding that arose from the industrial disarray, the oil glut, and the Depression. Despite a constant fear of budget cuts and the difficult task of defining research work that would not endanger the station's standing in the conflict-ridden and volatile oil industry, the station not only survived but expanded its programs and physical facilities.

Support from New Deal programs and state relief projects, for example, enabled the station to engage in a major building program, adding laboratory space, a library, and administrative offices. And its good relations with Oklahoma continued, enabling the station to conduct field studies of Oklahoma oil fields, giving favorably disposed state legislators material which could be used to defend continued state appropriations. Research on a variety of projects also proceeded, including studies of liquid petroleum gas products, hydrogenation of liquid gases, studies of combination oil and gas wells, refining techniques, methods of casing and plugging wells, and safety techniques with hydrogen sulfide associated with oil field drilling.

Changing Relationships with State and Federal Government

During the 1930s, increased funding constraints forced the center to focus on its finances. A reduction in funding in 1931, for example, forced the cancellation of a biennial survey of the brands of motor fuel on the market even though it was of great use and much appreciated by the industry. Also, increasing attention was paid to which employees were on federal and which on state funds. The latter were regarded as less secure and were, therefore, used primarily to pay clerical, maintenance, mechanical, and some of the lower-paid technical staff.

Schmidt and Smith nurtured carefully the relationship with the State of Oklahoma in order to preserve what funding they could from that source, which never sank below $40,000 annually in the 1930s despite the cutbacks in the early years of the decade. Recognizing that oil men who were friends of the station would be able to influence the station's state appropriation, Schmidt sought in particular to promote *local* research in order to justify Oklahoma state funding. In March 1936, for example, he warned Cattell at the Bureau's Washington office of Petroleum and Natural Gas that the state legislature was considering appropriations when it met in January 1937 and that, unless the station got to work on a solid, local project, there would be no publication from the researchers bearing on Oklahoma matters. Schmidt linked the need for local research explicitly to funding, noting that the current biennial appropriation was $41,840. He recommended some kind of report be prepared on the newly flourishing Oklahoma City field: "Frankly, it seems to me that unless we have some recent work pertaining to Oklahoma fields or Oklahoma problems, our state funds are very likely to be jeopardized."[2]

The appropriation was further endangered when, during the election campaign later in 1936, the state Democratic Central Committee's Secretary-Treasurer, L. T. Cook, requested the help of Smith in raising funds from employees at the station. Very diplomatically, Schmidt (replying for Smith) informed Cook that, as a federal facility, the station was under civil service rules prohibiting solicitation for political funds by supervisory personnel. Schmidt thought it was better he reply rather than Smith (the Superintendent), as an official letter might embarrass the station when the appropriations came up in the state legislature.[3]

When the appropriations were under consideration the following January, Schmidt noted in a report to Cattell that the station's state funding was, indeed, endangered. Constitutional amendments and initiatives had created a local real estate tax exemption for homes valued under $1,000. The reduction in municipal and counties' revenues from this exclusion led to an increased demand for state funds for school districts. Governor Lew Marland, himself an oil man, passed on to the legislature increased school budget demands but made no recommendations as to revenue source. A bill was introduced in February 1937 to the lower house to cut the budget for the Bartlesville station. Schmidt's careful planning paid off however, as the station survived committee hearings and the budget held at the prior level.[4]

Men at the station sensed that a new kind of bureaucrat was coming out of the new federal agencies established by the New Deal—one who set the government and the agency against industry, and who would sacrifice cooperation and an advisory role for a regulatory and often more self-serving role. The contrast struck Schmidt particularly when he encountered some of the younger, new breed of bureaucrats from the Department of Agriculture at an interagency meeting in 1937, at which he reported to the interagency Basin Committee for the Southwest Mississippi River District (part of the New Deal planning effort for various river basin areas). In Schmidt's judgment, the Department of Agriculture representatives at the meeting appeared to stack the reports to emphasize their pet soil conservation projects, raising anger among both state and municipal officials.

In spite of this perceived trend, however, Schmidt and the other engineers at the station continued to view their agency as a focal point for intelligent intervention in business through cooperation and advice, following the philosophy of the Hoover-Coolidge New Economic Era well into the New Deal period. Such hints suggest that the delineation between the political philosophy of the two eras was never a sharp cleavage at the practical level of operations, but more an overlapping of slightly different emphases.[5]

In any case, despite the growth of federal agencies and bureaus perceived as building their own empires and neglecting service to the industry, New Deal funds provided an opportunity for the Bartlesville station to build a facility which incorporated a vast array of "dream features." Using Public Works Administration funds, the station constructed a permanent laboratory that went far beyond the earlier facilities in convenience, scientific equipment, and design. The new building contained laboratories with such features as tap distilled water, acid-proof and fireproof surfaces, and custom-designed desks and tables. A handsome, wood-paneled library with a fireplace in the reading room gave an element of quiet repose and stability. Completed in 1937, the new building brought the physical embodiment of permanence and modernity the station had sought for two decades.[6]

The dedication of the new laboratory provided an opportunity for the station to repay a whole range of political debts in both industry and government. Schmidt requested that personal letters of invitation to the most important guests come from the Director of the Bureau of Mines. The guest list was designed consciously to pay back debts, including some that had been neglected in recent years. Schmidt made particular mention of United States Senator Tom Anglin, who served as the Governor of Oklahoma's representative on the Interstate Oil Compact Commission. He also requested that a personal invitation go to Alf Landon, because he had initiated cooperative work between the station and the State of Kansas while Governor. The fact that he was the defeated Republican candidate for the Presidency, and therefore titular head of the Republican party, remained an unspoken additional reason for his inclusion.[7]

Among private oil men, Schmidt particularly wanted H. L. Doherty invited, since he had arranged for the largest contribution to the original Chamber of Commerce fund which had financed the construction of the station in 1917. In the mid-1920s, Doherty had advocated compulsory limitations on oil production through cooperative agreement—the process eventually called unitization. His plan had met general opposition in the oil industry, and Doherty had won many enemies. Despite the controversy surrounding his name, however, Schmidt wanted him invited, noting that old friends should not be forgotten. In all, the invitation list was constructed with a nice awareness of the political debts of the station, and the new building was officially opened in October 1937, with appropriate speeches, tours, and attendant publicity.[8]

The effort to develop acceptable projects and to lay down plans for future work that met government needs and priorities was sometimes hampered by the internal committee structures within the station. To identify ways to provide a better focus for the station, Cattell authored a comprehensive study of the organization and the technical or scientific problems being worked on in 1937. He noted that the problems studied at the station were selected from a much larger number being suggested by industry. The problems that the station chose to undertake were selected because of their usefulness, the staffing configuration of the station, and funding limitations. Cattell did not believe, he wrote, that industry dictated the choice of problems. He outlined a complex structure of committees at the station, with Schmidt and Smith either serving on, or co-chairing, three separate planning committees. Contemporary correspondence reveals, however, that although Smith remained nominal Superintendent of the station, Schmidt undertook increasingly most of the liaison with headquarters over policy matters such as external politics, the search for cooperative funding, and research choices. No evidence suggests that the elaborate committee structure outlined by Cattell ever really functioned as a research coordination effort. Instead, loose conversations, and hints from alumni and journal articles helped formulate research decisions. When these had been made and a tentative research agenda established, the heads of the various sections of the station tried to match personnel skills and funding with the potential research topics.[9]

By the mid-1930s, refinery practices and refinery chemistry financed by major oil companies in their own laboratories had moved beyond the station's capacity to make major contributions. The role to be played by the small facility at Bartlesville could no longer be central, Smith recognized. Further, the development of proprietary practices in refining and petroleum by-products made it difficult to define a role for the government-operated station. In contrast to the producers, which were usually small firms or individual operators lacking elaborate engineering research efforts, the refiners were typically large, vertically integrated companies with ample funds for their own research and development. As long as these major oil companies continued to purchase a large percentage of their crude oil from small producers, the opportunities would exist for government and cooperative research in production engineering problems but not in refining problems. Smith understood the increasing distance between the station's work and the state of refining technology, and could only recommend that the station try to stay in touch with developments in the field.[10]

Smith also recommended maintaining better contact with refiners and with relevant professional associations, but did not think the station should pursue refining process research. He rightly recognized that this research would run the very real risk of involving the station in proprietary squabbles with industry.[11] In petroleum chemistry and refining, therefore, Smith basically pursued a holding action, being content to design some long-range analytical research efforts that would help justify staffing levels. Smith believed that his chemistry and refining group needed a good, solid, long-term project, and recommended that the station undertake an analysis of crude oils from each oil-producing area in the nation. Consequently, the station sharpened its methods for the analysis of crude oils and lubricating oils, which would later prove valuable under wartime pressure.

Cooperation with Industrial Associations

Through the 1930s, the Bureau of Mines continued to cooperate with industrial associations, a policy that had begun in the previous decade. Nongovernment funding could provide for travel to conferences, publication expenses, and research laboratory costs, but never to pay direct labor costs of government employees. In a time of stringent government budgets, however, association work could provide an attractive, even if partial, solution to the station's financial need for resources. In addition, it provided a valuable opportunity for station scientists and technicians to work closely with private industry on projects and problems that private industry held in high priority, in a way that avoided the risk of compromising impartiality by working on projects of clear benefit to particular companies. Particular oil companies were engaged in specific, profit-related research; the associations, in contrast, were interested in funding research into industry-wide problems. Thus, cooperation between the Bartlesville station and industry-wide or regional trade associations demonstrated a potential solution to the dilemma posed by public service to the privately operated and owned oil industry. Service and research for particular companies, as shown by the Lewis incident in 1918, could lead the government into a trap of performing work which carried no broad implications, which benefited but a single company, and which compromised the station's reputation for impartiality. However, work which an industrial association suggested, on a problem which the association decided to be of an industry-wide character, avoided such pitfalls while at the same time allowing the choice of direction of research to remain influenced by the private sector and avoiding the danger of becoming out of touch because of central planning by a government bureaucracy. The relationship between Bartlesville and the National Gas Association provides a good example. The Natural Gas Association sought answers to questions about the flow of natural gas through transmission lines, leakage from those lines, the specific physical properties of natural gas, and methods of measurement of gas well deliveries. The station contributed in each area in a close cooperative relationship with the gas industry that began as early as 1922, when R. A. Cattell prepared Technical Paper 325, "Natural Gas Manual for the Home," in cooperation with the Natural Gas Association. In 1928, Bureau of Mines Bulletin 265, using station work, covered "Leakage from High-Pressure Natural Gas Transmission Lines." And through the late 1920s, the Bureau studied the issue of the rate of flow of natural gas through pipelines under various conditions, both using published data and conducting experiments to determine the effects of various changing factors. Shortly thereafter, a 100-page document prepared by the station, "Factors Influencing Flow of Natural Gas through High-Pressure Transmission Lines," was issued both as an American Gas Association product and as a government report.

The question of measuring deliveries from gas wells could be treated as a classic issue in the effort to disseminate conservation methods that had characterized engineering approaches to economics through the 1920s. As E. A. Rawlins, gas engineer at the Bartlesville station, suggested in his report on gas well measurement, such research "will make it possible not only to prevent much actual gas wastage to the air, but will also make it possible for operating companies to plan definite depletion and gas-storage programs . . . with maximum recovery . . . and maximum efficiency."[12]

The measurement of gas well capacities in the early 1930s did, however, take the station into controversy despite their effort to avoid it by serving the industry as a whole. The occasion was the pursuit of what the Bureau believed to be one of their proper functions—"elimination from the lay mind" of "erroneous" views (in this case, erroneous views of gas reserves). State conservation laws required the measurement of gas well production rates at "open flow," in which gas flow would be measured in an open or uncapped well. This was because measuring pressure against a shut off or "closed-in" well gave very little indication of the volume of gas which might be present in the underground reserve. The publication of "open-flow" measurements by several states created the public impression of vast reserves and artificial price setting which station personnel believed was unjustified. Bureau men viewed as part of their function an effort to help the industry explain to the public that open-flow measurements, required under state law, did not necessarily imply huge reserves, and station technicians pursued that objective by advocating a better understanding of the underground formations in order to judge accurately the size of reserves.

Through the 1920s, Bureau cooperation with the Gas association had consisted of working on projects of interest to the Association, with an occasional arrangement for co-publication. Between 1930 and 1934, the station continued work on two cooperative projects with the American Gas Association, including a study of mathematical formulas for gas pipeline flow and an investigation into methods of gauging and controlling natural gas wells. As it turned out, however, the Gas Association contributed only about 20 percent of the funds spent on these projects, as shown in Table 2.

TABLE 2

Relative Federal and AGA Cooperative Funding

Fiscal year	Federal funding	AGA cooperative funding	Total funding
1929–30	$12,000	$ 3,000	$15,000
1930–31	12,000	3,000	15,000
1931–32	12,000	2,500	14,500
1932–33	8,000	1,500	9,500
1933–34	6,000	1,500	7,500
Totals	$50,000	$11,500	$61,500

Source: RG 70, Box 224318/022.7, Natural Gas Section, AGA.

With the hope of preventing further decline and perhaps even improving the situation, Bureau officials began to lobby the association to increase their research funding. In May 1935, the Bureau outlined for the AGA all the work accomplished under the cooperative projects over the previous years, a record which an Association subcommittee presented at the annual meeting of the Association in Memphis. At that meeting, the American Gas Association proposed an industry code on gas well delivery measurement as part of the National Industrial Recovery Act establishment of industrial codes for each industry. Staff members at Bartlesville, on invitation by the Association, had reviewed the code and made minor suggestions for revision.[14]

The same year, the Association's Main Technical and Research Committee endorsed a proposed cooperative project with the Bartlesville station concentrating on methods of measurement of combination gas and oil well. The Association set aside $3,000 for this project for fiscal year 1936, at which time a separate agreement to work on the formation of hydrates (ices) in gas pipelines was funded for $1,500, to be conducted at the Bureau's helium plant in Amarillo. The total of $4,500 was the lion's share of a total of $6,000 which the AGA had budgeted for research in 1936. In short, the Bureau's lobbying paid off, and both the Bartlesville station and the Amarillo facility benefited.[15] At the same time it was decided that a Bureau man should serve as liaison on this main research committee. From 1934–1936, Eddie Rawlins from Bartlesville filled that role, which he left to work for the United Gas Public Service Company of Houston. W. B. Berwald, also from Bartlesville, replaced Rawlins on the committee in 1937–1938, when he, too, left government work for an industry job.[16]

From his position at United Gas, Rawlins, as was typical of the alumni, continued to provide help to the station, making suggestions for reports from the Bureau to the Association well into 1940. Even after he had moved on from Houston to the Union Producing Company in Shreveport, Louisiana, Rawlins kept in touch, supplying the station with suggestions and ideas.[17]

Through 1940, the station continued to work on gas problems, using additional funding from the Association. The problem of gauging and controlling combination oil and gas wells engaged M. A. Schellhart, natural gas engineer, assisted by R. J. Dewees and W. H. Barlow, associate petroleum engineers, and E. M. Tignor, junior natural gas engineer. These men produced a Report of Investigation, published March 1940, on work done between 1938 and 1939. They demonstrated that well test data could detect the level of a layer of sand which allowed loss of gas—called a "thief sand"—and recommended well recasing to eliminate the problem. The Association's monthly newsletter summarized the report and recommended it to Association members.[18]

Another project using Association funding, headed by Kenneth Eilerts as an associate physical chemist and assisted by R. V. Smith as a junior gas chemist, calculated optimum rates of recovery of a high pressure field. Using laboratory analysis, the chemists measured the physical properties of certain naturally occurring fluid hydrocarbon mixtures at pressures up to 5,000 pounds per square inch and at temperatures from 70°F to 270°F. In order to study the properties of a particular mixture of hydrocarbons at the naturally occurring pressure and temperature, Eilerts and Smith developed an "equilibrium cell" which could maintain the fluid at original temperature and pressure conditions for study. This work resulted in the publication of two papers. Such research proved extremely useful in promoting greater recovery of liquids from gas-oil mixtures extremely low in liquid content at surface temperatures.[19]

In 1937, Holley Poe became executive secretary of the American Gas Association. Poe was a native of Oklahoma and resident of Tulsa, who had worked in both gas and oil production in Oklahoma and for

Central States Power and Light Company in Tulsa. This was of great benefit to the station, because Poe's knowledge of the Bartlesville work and his commitment to Oklahoma institutions increased the support of the station by the Association. In early 1941, Poe recommended the highest Association support level up to that time for gas research—$5,000 to Bartlesville and another $1,500 to Amarillo.[20]

Hoping to make Poe's recommendations a reality, Cattel suggested that several nearly completed research papers from the station on gas topics be prepared for presentation at the 1941 convention of the Association. At the station, Smith reviewed the possible avenues of expenditure for the $5,000, either continuing work already underway or, alternately, beginning new defense-related surveys of all the gas reserves in the United States. Poe's recommendations were accepted by the AGA, at least in part.[21]

The Search for Technical Solutions to Nontechnical Problems

During the 1930s, several devices were developed by the Bartlesville station to meet industry's need for precise data for production limitation. This development can be viewed as a "technocratic" solution to an economic issue.

Hoover himself advocated the rationalization of industry through standardization, elimination of waste, and a variety of efforts to rationalize marketing, labor relations, and capital expenditures. A number of self-styled "liberal engineers" associated with him in the 1920s had hoped to solve a wide range of economic and social issues by rationalizing industry, hoping to go beyond the complex and unpredictable political process and solve problems through more rational, "technocratic" methods. By the 1930s, the support that Hoover had marshalled for this movement had largely dissolved, although some of his followers worked through the New Deal to implement their ideas. While such developments were proceeding in the form of major policy discussion at the national level, they also proceeded in a small way at Bartlesville. There, engineers consciously provided technical assistance to help resolve major economic problems well into the 1930s.[22]

The development of particular measuring devices which could accurately determine pressure, temperature, saturation, and porosity conditions in oil- and gas-producing strata, they thought, might provide the key to the problem of oil production control. Under the "law of capture," a first-come first-served philosophy favored rapid, or "flush," production and development of every field. Whoever got the oil out first and captured it was entitled to it. As long as demand exceeded supply, flush production would lead to flush sales and profits. But with the opening of East Texas in 1931 and the resulting overproduction, the fall in prices threatened the whole oil industry. In Oklahoma, Governor William H. Murray declared the taking of oil when there was no market demand an illegal act and prohibited it by force of arms, using the Oklahoma National Guard to declare principal oil fields "off limits." In Texas, Governor Ross Sterling used the Texas National Guard to close the East Texas field from August 1931 through mid-February 1932, until he was overruled by federal court. Neither governors nor producers could agree to limit production, however, since this would mean collusively agreeing to restrain competition in order to maintain prices.[23]

The logical way around the dilemma was to declare all producers drilling a single field as members of a producing cooperative or association—a solution that had been proposed in the 1920s by Doherty but not supported by industry at that time. Under this system, the "unitized field" limited production and paid those producers who held off drilling or producing on their leases from a pooled fund. Such limitation, instead of being a price-maintaining measure, could be presented to the courts as scientifically advisable in the interests of rational conservation techniques. Another method of controlling production was prorationing, in which production would be rationed on a daily basis. Prorationing could be established on a production-per-acre or well-by-well basis. When organized and enforced by state agencies such as the Texas Railroad Commission and the Oklahoma Corporation Commission, these kinds of limitations eventually withstood legal challenges. By 1936, the cooperation of the state commissions through the Interstate Oil Compact Commission, backed by federal legislation creating the Compact and outlawing interstate sale of hot oil (that is, oil produced outside the prorationing systems), finally put in place a workable national system of production limitation.

Yet such a rationale and system could only be enforced if producers could accurately determine such specifics as variations in well pressure. Clearly, a producer whose well tapped a high-pressure, richly saturated pocket would be entitled to a greater share of the prorated profits than a producer whose well tapped low-pressure, relatively unproductive strata. Such differences had to be accurately and consistently measured by standard, widely accepted devices.

Furthermore, the courts remained reluctant to endorse production limitation when the only purpose of the agreement was to hold up prices. To justify the limitations as "conservation," some technical determination of "optimum" production rates had to be made. Pressure-sensing devices were needed to show that flush production reduced natural pressure at a wasteful rate, while controlled production held the pressure in reserve and resulted in greater production of the resource over time.

To further this objective, in 1934 Scott Turner, Director of the Bureau of Mines, told Congress about the research work at the Bureau and especially at Bartlesville, and hinted that research there could help resolve the problems of overproduction. He outlined the studies of energy reserves (in the form of pressure) in oil reserves, the behavior of fluids under different conditions, and the effects of moving fluids against resistance. "It is the belief of our engineers, after years of study, that an understanding of these fluid-energy relations is basic to the solution of many difficulties now confronting the industry, some of which are nontechnical in character." The phrase "nontechnical" was a massive understatement to describe what the oil industry appeared to be going through—ruinous overproduction in the midst of legal struggles to determine an acceptable system of controlling production.[24]

Even though Smith's years of work in establishing the station's scientific and technical reputation and the scrupulous concern for not showing favoritism in disputes could at last help the station, Cattell, Schmidt, and Fowler were all cautious. The first participation of station engineers in the process was tentative and exploratory. Through 1931 and 1932, station engineers engaged in field work to evaluate pressures in shut-in and flowing wells. In particular, Reistle worked in the East Texas field closed by order of the Texas Railroad Commission. Rather carefully, Bureau men tested their instruments, at first taking care to stay out of cases which might be tested in court or before the commission. As Reistle noted in 1931:

> In the East Texas area there seems to be a need for bottom hole pressure data covering the entire field in order to supply data from which engineers hope to obtain more accurate information on the ultimate production, potential production and the relationship of pressure decline to rates of oil and gas withdrawal. This information is desirable primarily because the field is subject to proration and it is the desire of at least a part of the operators to regulate the entire field so that each individual receives his equitable share of the oil.[25]

Reistle then explained that the test of the instrument was done on a north-south axis and an east-west axis, thereby producing a pressure and temperature survey of the field which provided a valuable and useful description of an underground formation as part of the test.

A similar tentative awareness that scientific work might bear on economic controversy showed up in 1932. In a report on the Oklahoma City Gas Reserve, Rawlins noted that the Lone Star Gas Company was having trouble with both the Texas Railroad Commission and the Oklahoma Corporation Commission:

> The result is that the Lone Star has undertaken a complete study from a gas reserve standpoint of all their properties in Texas and Oklahoma. Such instances are bringing the gas reserve problem to the forefront, and since the data and analyses have to withstand court procedure, the technical problems connected with such estimations are receiving considerable attention.[26]

The Bartlesville team established a field office in Oklahoma City to conduct studies of the gas reserves there. The study was not funded by cooperative agreement with the American Gas Association, but as a part of the Bureau's general investigation of reservoir conditions and of the operation of flowing wells. Once again, station engineers tried carefully to establish themselves as an independent and objective observing group in a highly controversial area. In a letter sent out to all the operators in the field, Superintendent Smith explained how the study would proceed. Ben Lindsly, as Senior Petroleum Engineer, would study bottom hole samples. The amount of dissolved gas that was liberated from the samples, the shrinkage of oil due to liberation of gas, and the potential energy of the liberated gas would all be obtained. Carl Reistle would study the mechanics of flowing wells using bottom hole temperature and pressure recording instruments. Smith explained to the producers that the object was to find a means of producing oil using minimum gas-pressure energy. Without stating it explicitly, an implied objective of the study was to develop a conservation justification—that of minimum use of gas-pressure energy—for holding down production.[27]

By 1934, the need for bottom hole sampling devices, both for pressure and temperature, was increasing as the movements to unitize fields voluntarily and to move in the direction of state-ordered prorationing caught on. The station received numerous requests from private operators for the instruments used by the engineers which, of course, brought up the question of patents.

The Bureau shifted from the Department of Commerce back to the Department of the Interior in 1934. This compounded the issue of patentability, leaving the Bureau with no recent precedents, since the Department of the Interior had had no scientific research responsibilities for the previous eight years. Cattell favored individual patents for the pressure recorder and the temperature gauge, allowing federal "shop-rights" in the devices to allow government use of the patented devices for the government's own purposes, without payment of a royalty, on the grounds that the devices had been developed within the government "shop."

Cattell advised Reistle and Lindsly that they might be able to patent their inventions as individuals, but left the matter of whether or not to seek patents up to the two individuals in question. Their original instructions had not included development of the instruments. But because the project they had worked on had been assigned and the devices had related to that project, a court might find that the patents should be assigned to the government. At the same time, their personal claims would also be strong.

Lindsly subsequently filed for a patent, with the expectation that he would receive royalties from industry. This attempt failed due to other research that overtook him. Reistle moved more slowly on registering his pressure recorder, looking into the complexities of patent law. By late 1935, the issue had become moot for Reistle. In order to insure that no private concern would copy the pressure measuring device and patent it for private profit, the Bureau published a report on the pressure gauge (Report of Investigation No. 3291), making the details of the device public. Bureau staff members were not displeased to learn that the publication of the report upset plans by Gulf Oil to develop their own pressure gauge, since placing the details in the public domain through a report of investigations blocked the corporation from obtaining a patent.[28]

Reistle left the station to work in the Texas fields for the producers' association there and, later, for Humble Oil. He took his skills, abilities, ideas, and "know-how" to the field, transferring the principles of determining bottom hole pressure to a field where prorationing or limitation on production was crucial. In the 1920s, engineers and chemists had moved from the station into the producing companies to improve production; in the 1930s, Reistle moved on to help limit that production. The station, thus, still operated as a training ground for the industry.

Through both the 1920s and 1930s, this movement to the private sector was encouraged and contact continued with the alumni in the 1930s as it had in the 1920s. Through the 1930s, "alumni" working in industry continued to meet at annual conferences of the API at an "alumni breakfast" to discuss informally the research direction of the Bureau of Mines and the Bartlesville station in particular. In later years, some of the technicians who stayed on, perhaps with a touch of jealousy, began to look back at their departed colleagues as having "sold out" to industry. Others, however, were able to view the movement of technicians to industry more objectively as an extension of the government's cooperation with industry. As a training ground, the laboratory could develop a person's knowledge and experience. By working under the supervision of a senior specialist, junior staff could mature and hone their skills. Then, when they moved on, they not only made personal career moves but also moved a body of knowledge and experience from the government-funded laboratory to the private sector in a way which was far more complete and effective than publishing an article or report and hoping it would be read and digested by others already in industry. The alumni phenomenon through this period can be and was seen as a direct mechanism for technology transfer.[29]

In 1936, the producers' association in the Fitts pool in Oklahoma, worked out a cooperative agreement with the Bureau to devise a method of obtaining an accurate sample with bottom hole pressure intact. Bartlesville engineers first took a survey of the producers to get records of pressures and temperatures in both flowing tests and shut-in or capped tests. Pete Grandone and Berwald collected the data and conducted field tests. Through October and November 1936, the team varied between seven and nine men, both part time and full time, with the Bureau paying 77 percent of the cost and the Fitts Operators Committee 23 percent of the total $4,900 in salaries and expenses. As Grandone explained to Charles Richardson of Carter Oil, discrepancies in measurement of gas–oil ratios might stem from a loss of pressure on oil–gas mixtures brought to the surface in samplers. Station staff had calculated a method of extrapolating from the amount of gas dissolved in oil at surface temperatures what the saturation at the strata level would be using pressure and temperature gauges. However, Grandone believed that this method was quite unreliable, and that the possibilities for multiplying errors were considerable. The new research would solve the problem.[30]

The accuracy and independence of station work, established over the past decade, had the beneficial effect of drawing industry attention to Bureau publications and research. The Mid-Continent Committee on Production Technology provides one example. It appointed a subcommittee to investigate the different methods of determining oil-sand saturation of core specimens. T. W. Johnson, the station representative on the committee, passed on to Fowler some suggestions from the committee which could increase the station's role in these matters, precisely because industry men saw the station work as "independent" or "objective." Johnson noted that industry members of the committee did not want to share confidential information among themselves, especially since it would reveal where richer leases might be obtained in newly opening fields. The committee hoped "some uninterested body such as the Bureau of Mines" could resolve this dilemma by carrying on the work and developing an "absolute" or accurate method of determining oil-sand saturation. Various laboratories in the industry could then continue their own methods of testing but could adjust their results to the "absolute method" developed by the Bureau.[31]

The American Petroleum Institute provides another example. Fowler served on the Institute's Eastern Committee on Production Technology. When Morris Muskat of Gulf Oil, who chaired the committee, asked for material dealing with the accuracy of depth pressure measurements, Fowler referred Muskat to the

Bureau's report describing Reistle's pressure work and to a follow-up article in the *Oil and Gas Journal.* Since this work was continued by Berwald at Bartlesville, Fowler enjoyed suggesting to Muskat, at a large, Eastern-based refining company, that he should expect to find the experts on production in the Bartlesville station, in the heart of Mid-Continent producers' territory.[31] He was also careful to be delicate in handling the question of government technicians becoming involved in controversies with a financial and policy aspect, expressing the difficulty of serving both the industry and the Bureau thus:

> As a member of your [API] committee, I am in full agreement with the desirability of working toward the standardization of a method for determining the oil saturation of reservoir rocks, similar to the previous work on porosity and permeability . . . . Our men in the field have told me of several instances where disputes have arisen with reference to valuation of oil properties because different methods of determining saturation gave discordant results.[32]

Fowler indicated that Bureau staff would face the issues squarely, but since they were aware that industry viewed Bureau results as objective, they were determined to be cautious in publishing figures on disputed oil-sand saturation. To the "boys at Bartlesville," he put it a little differently. He was well aware that both bottom hole pressure readings and oil-sand saturation determinations were controversial in that they could play crucial roles in justifying and reinforcing limitation agreements. Consequently, he recommended that station staff keep working but remain sensitive to the "way of the wind" at the API.[33]

Through 1936 and 1937, at the urging of the Interstate Oil Compact Commission, the bureau received an appropriation from the federal budget to conduct a survey of crude oil storage. The commission needed statistics showing the total volume of crude oil held in storage and an analysis showing what percentage of the lighter fractions of the crude oil, suitable for refining into gasoline, had evaporated. The IOCC believed that, if long storage of crude oil resulted in the loss of lighter fractions, then an argument based on conservation could be made for limiting production to current needs. As Schmidt put it:

> A fundamental trend in the evolution of state oil conservation laws has been the recognition of the maintenance of a reasonable balance between the current production of crude oil and market demand, as a means of preventing physical waste, by avoiding unnecessary above-ground storage of either crude or refined products.[34]

The survey was difficult to conduct, since it required the cooperation of dozens of oil companies and the running of hundreds of tests on crude oil samples. The effort involved sampling and testing by Petroleum and Natural Gas Division personnel in San Francisco, Laramie, Amarillo, and Bartlesville, as well as at the Bureau headquarters in Washington. However, since Congress had increased the budget for this purpose, the Bureau enthusiastically backed the project and sought permanent additions to its staff as a result of the funding.

This survey for the IOCC led to a jurisdictional debate between the Bureau of Mines and the Petroleum Conservation Division (PCD) of the Department of the Interior. G. W. Holland, the Director of the PCD, expected to handle all liaison with the newly formed IOCC. At the urging of the IOCC, $55,000 was appropriated to allow the Bureau of Mines to conduct the survey of crude oil inventories in storage. Holland expected a full accounting of the appropriation and hoped to channel the reports to the IOCC. The Bureau ignored this interpretation of his authority and simply continued to report directly to the IOCC until 1938, when the IOCC established its own permanent staff and the Bureau's role in providing assistance declined.[35]

In 1937, the Cooperative Fuels Research group (CFR), a cooperative structure of the Society of Automotive Engineers representing the automotive industry, and the API representing the petroleum refining industry, sought to have the Bureau publish a gasoline survey similar to those conducted in the period 1921–1931. But unlike the earlier situation, the API now planned to use private industry members to collect the information for the survey. Bureau staff was hesitant to go along with the plan, because such a procedure would run the risk of giving Bureau endorsement to industry figures—something the Bureau had always scrupulously avoided. The CFR proposed a complex system of information safeguards in which one firm would report on three of its competitors. By comparing overlapping information from different refiners, some degree of verification could be developed on details such as octane rating, Btu content, and other characteristics of gasoline. Despite hesitations, however, Smith took on the coordination of the survey information collected by private firms and its publication for the CFR.

The gasoline survey turned out to be troublesome to administer under the company-gathering method, and eventually had to be discontinued. The firms in California were particularly difficult to work with. The intent was for the companies to provide the station with the information they collected, in the form both of coded comparisons among the individual companies and the coded sheets that allowed identification of individual companies. The latter was necessary to allow station analysts to resolve any apparent inconsistencies among overlapping reports. The California companies consistently failed to turn over the code sheets, making reconciliation of their data impossible.[36]

Both these surveys—the survey of crude oil in storage conducted by the Bureau with congressionally approved budget for the IOCC, and the motor fuel survey conducted for the Cooperative Fuel Research committee—demonstrated the orientation of the Bureau in the complex internal politics of the oil industry through this period.

The oil industry remained divided between integrated major oil companies and small producers and between Mid-Continent producers and East Coast refiners, with the West Coast firms operating independently of the other regions. Furthermore, the struggle over control among the federal government, state governments, and the courts all combined to create a fluid situation in which the station could easily become an innocent victim of a conflict between powerful foes. The Bureau retained its Oklahoma orientation and remained reluctant to accept figures and data from refiners, although it cooperated somewhat more gladly with the crude oil producers. More importantly, the Bureau, following the lead of Congress in its passage of the legislation allowing the Interstate Oil Compact, the Connally Hot Oil Act, and the appropriation to conduct staff work for the IOCC, cautiously adapted to the new legislative environment by seeking to play a supportive role in the newly emerging system of production control.

Cooperation with the American Petroleum Institute

Formal cooperation between the American Petroleum Institute, the largest oil industry group, and the Bureau of Mines did not come about until 1937, despite the growth of the API as the leading organization of major refiners through the 1920s and the 1930s. And when a cooperative agreement was worked out in 1937, political difficulties surrounded it.

The agreement between the API and the Bureau to cooperate was worked out at a conference of the API held in early June 1937 at Colorado Springs. Within the API, technical committees of experts from different companies were formed to work on common problems. During the oil oversupply of the 1930s, the "Well-Spacing Committee" had emerged as a crucial group. Its task was to work out one technical basis for limiting production through specifying the distances between wells for optimum production. If some objective or scientific optimum could be established, then state authorities could justify prorationing rules limiting drilling on a technical basis, thereby convincing courts that such limitations, while having the effect of controlling production and reducing the surplus, were in accord with scientific principles of conservation. In order to determine optimum spacing for different fields, however, it was necessary to gather technical information about the saturation, oil content, and porosity of the sands in specific fields. At the conference, the twelve-member Well-Spacing Committee had to vote on the proposed API-Bureau agreement. The committee consisted of ten oil men, a representative of the University of California, and H. C. Miller from the Bureau's Washington office. Some of the corporate members were sympathetic to the Bartlesville station, including D. R. Knowlton of Phillips Petroleum and Carl Reistle, formerly of the station and now representing Humble Oil. Nevertheless, a majority of the committee voted down a blanket proposal by Knowlton to finance a study of well spacing to be done by the Bureau at the Bartlesville station. Miller reported that the political atmosphere of the times outweighed the personal considerations and alumni contacts which he had hoped to use:

> I learned after the morning session that one of the reasons for the majority vote against making a blanket appropriation was that some of the companies were so suspicious of what Congress may do that they hesitated to vote for such an appropriation to a Government Bureau.[37]

Miller noted that Hardison of Standard of Texas and Copley of California Standard voted against every motion in support of the Bureau even though they were his own close personal friends. He suspected they acted on orders from superiors in their companies.

The resulting agreement on a specific project to be funded by the API and carried on by the Bureau came only after Miller, working with T. V. Moore of Humble and Edgar Kraus of Atlantic Refining Company, developed two specific, interrelated proposals. The first was to work out a method for determining the fluid content of reservoirs; the second was to study subsurface pressures and work out tables of relationships between pressure gradients and fluid recovery. Miller hoped to set the projects up as two separate sets of experiments, each to be supported by a $6,000 grant from the API, but he warned the station that the API would be unlikely to approve more than a single grant for $6,000 to cover both projects. This is, indeed, what happened.[38]

In an exchange of correspondence throughout July 1937, Carl Young, Secretary of the API, and R. A. Cattell, at Bureau headquarters, worked out the specifics of cooperation. Six thousand dollars would be provided by the API for the Bartlesville station to work on the problem of finding a reliable technique for sampling fluid content of oil-producing sands. When coupled with a plan for spacing wells, the research could provide a technical basis for plans to limit production. "With these accomplished, the industry will have made constructive progress in its search for a solution of this problem, not only well spacing alone, but in working out a rational system for producing oil fields consistent with our present laws and regulations." In the parlance of the mid-1930s, "rational system" meant a legal means of holding down production to avoid the price-cutting that had led to the destruction of many companies.[39]

The API well-spacing committee sought to develop a method of obtaining a test sample of sand and rock from the bottom of wells that would allow the sample to be brought to the surface with its oil and gas content intact at strata pressure. Although existing core barrels allowed for the drilling of core material from the bottom of a well, the process of bringing it to the surface exposed it to water levels and to reduced pressures, during which the chance to obtain a precisely measurable sample of the oil and gas content would be lost. What was needed was a "pressure" core barrel which could hold a sample under the original pressure found at the bottom of the well. Miller, working with Berwald and D. B. Taliaferro from the Bartlesville station, met with Young and oil company representatives in Tulsa in September to discuss the precise work the station would undertake. Examining patent drawings of a core barrel designed by Granville A. Humason of the station, the API committee agreed that the barrel was a step in the right direction and reviewed the issue of how to dedicate to the public a patent for the proposed new invention. Miller explained that Bureau practice was for the individual inventor to apply for a patent on his device and to pay the patent fees; upon the granting of the patent, the inventor would then assign it to the public. Young suggested that the fees should come out of the API grant. The committee group doubted, however, that such a plan would lead to rapid development; rather, their view was that a monopoly on the pressure core barrel would be very difficult to establish, as several firms were already working on similar devices. In a memorandum to the committee, Miller noted, "I can see no other way out of this than to dedicate the patent to the government and let who will, manufacture the tool, giving all manufacturers an equal chance to bid on the construction of the trial models."[40]

The government sought to put on record the fact that any developments on the core barrel under the cooperative agreement would be *assigned*, not *voluntary*, work and therefore patentable for the government rather than by the individual researcher as his own project. In pursuit of this objective, John Finch, director of the Bureau of Mines, issued a formal order to Berwald to develop a device for the measurement of gas, oil, and water in a reservoir. "All employees engaged or assisting in this work," the order read, "are directed to exercise their inventive faculties towards the objectives of the study." This direct order would preclude someone later claiming the invention as an individual or personal by-product of his work at the station along the lines of the earlier patent opportunities opened to Reistle and Lindsly.[41]

Through the early months of 1938, Taliaferro and Berwald drafted a rough design of a core barrel, improving on Humason's design, to enable the core sample to retain its original pressure as it was brought to the surface. The rough plans were turned over to L. E. Garfield, a "core barrel engineer" at Hughes Tool Company, in May 1938 and, by July, Garfield had produced working drawings. Hughes Tool agreed to manufacture a model of the device for $1,500 and, by the end of 1938, the Bureau had approved the contract. Garfield told Taliaferro informally that the actual cost of developing the model was over $3,000. Hughes produced and field-tested a working model by May 1939. By November 1939, Berwald and Taliaferro learned that the Carter Oil Company was also working on a pressure core barrel, and a report on that device was made public at a Chicago meeting of the API. By May 1940, the API had purchased a Carter barrel and asked the Bureau to test it as well as the one developed by Hughes Tool.[42]

But, according to rumors that alumnus Reistle, who was serving on the Well-Spacing Committee of the API, picked up and passed on to the station concerning the Carter barrel, the Halliburton Company was actually slated to provide well-testing services using the Carter barrel, and this plan would supersede Bureau work on the device developed with Hughes' help.[43]

In any case, in the early months of 1942 war needs and concerns rendered the whole issue moot. The original need for the device had been to establish fluid content of wells and fields for the purpose of justifying *limits* on production; with the coming of the war and increased demand for petroleum, of course, the need for a pressure core barrel evaporated. Rumors from Reistle indicated that the Halliburton-Carter deal was "off for the duration of the war." With the increase in defense projects at the station, interest in the barrel declined, not to be revived until 1945 when its application to projects designed to increase, rather than limit, production made it once again a useful addition to the tool kit of the exploration companies.[44]

The aborted project demonstrated some limits on the station's ability to participate in the relatively fast-moving world of oil field technology and mechanical development. The time consumed in working out the politics of funding, getting the agreement signed, and issuing the proper orders to control the patent situation lasted from June 1937 through December 1937 and held back initial work. Then, in early 1938 it became clear that the rough design ideas of Berwald and Taliaferro could not be put together into a working model in the tool and machine shop at the station, and the project had to be farmed out to Hughes Tool, where supplementary financial and design help perfected the device.

Several other issues were raised in the discussions within the bureau and not satisfactorily resolved before the Carter core barrel superseded the Bureau barrel. Exactly what aspects of the device would be regarded as innovative and therefore subject to patent? Could the device be adapted for use with hard rock bits as well as sand bits? How would service charges for field use of the pressure core barrel be handled to offset development costs? Since the Bureau would consume parts, supplies, and other expenses in using the barrel to run tests on oil fields, charges would have to be collected, yet no arrangement existed for government charge for such testing service, even to cover the cost of worn bits.

In addition to these unresolved issues, larger policy issues severely restricted the potential for Bureau activity in this area. The API, for clearly political reasons, hesitated to involve a government bureau too deeply in schemes to limit production. Further, the API funds covered mechanical costs and travel expenses, but not salaries. Estimates of government salaries expended on the project ran as high as $10,000. In addition, Young at the API limited even expenditures of government money rather strictly, with the result that about $3,480 of the original $6,000 was used to pay expenses incurred by Hughes Tool Company. An estimated $10,000 in field test experiments, design time, and other expenses by the Bureau was paid directly by the government, with only some $1,434 in travel expenses by government employees paid by the API grant. Thus, this experiment in private aid to government research certainly did not ease the government financial load to an appreciable degree.[45] Despite these difficulties, however, Cattell and others at the Bureau believed the precedent of cooperation with the API was a valuable one. A Bureau report submitted to the API in May 1940 compared the cooperation with API not unfavorably to other cooperative projects, including work with the states of Oklahoma, Kansas, Illinois, and Michigan, as well as earlier work with the American Gas Association.

There is no doubt that the API project represented a significant effort on the part of the station to adapt to the pressures of the decade. Private oil producers were concerned with developing some technical justification for limiting production, and such justification required improved knowledge of subsurface conditions. Although the cooperation with API from 1937 through 1940 did not produce any significant results, it did demonstrate that cooperation was possible despite the political atmosphere, and it did show the capacity of Bureau personnel to "invent" a measuring device on order. The war prevented a full follow-up immediately; but cooperation with the API proved a valuable precedent for later work.

Conservation and Production Limitation at the Station

As is clear from the foregoing, over the decade of the 1930s, in several distinct ways, the Bureau and the Bartlesville station became drawn into policy matters surrounding production limitation. Associations and agencies attempted to utilize the Bureau's reputation for scientific objectivity to produce results that would justify limitation in the name of conservation, and provide a technocratic solution to the economic crisis plaguing the oil industry in a variety of ways:

- Reistle's work in East Texas, using pressure determinations to describe fields as a unit, together with Lindsly's work on temperature, served as a basis for demonstrating that different wells to the same reservoir could be treated as potential cooperators, rather than as natural competitors.
- Rawlins' work on gas reserves led to explanations that open-flow measurement was deceptive and that reserves were lower than they might appear to the public.
- Scott Turner, Director of the Bureau of Mines, suggested that the Bureau's fundamental work on the mechanics of gas pressure driving crude oil to the surface would lead to basic knowledge allowing for the conservation of energy in the form of pressure, and that such knowledge would, in the end, lead to rational production (that is, limited production).
- Reistle's and Lindsly's devices became widely used to enforce production limitation, to measure pressure and production declines, and to provide a technical basis for claims of conservation in fields where unitizing agreements were tested in court.
- On the urging of the IOCC, the Bureau demonstrated that excessively long storage of crude oil led to its deterioration. The implication of the study was that production ought to be limited to current needs in order to avoid waste through evaporation.
- Working with the API, the Bureau worked toward developing the pressure core barrel, a device which could help determine optimum well-spacing, needed to justify state-imposed prorationing.

With respect to production limitation agreements, judges in the mid-continent area were faced with a major dilemma. Not only did overproduction produce an economic crisis of unmanageable proportions, but that crisis soon escalated into a major confrontation in the political and judicial sphere. If the judges adhered to the old logic and treated all agreements to limit production as conspiracies in restraint of trade, then governors of the states would use force to close wells, presenting the courts with the difficulty of enforcing court orders against state-controlled troops and police forces. Thus, the courts were willing to listen to any sort of scientific justification for conservation to relieve the dilemma. It is precisely because the Bureau of Mines acted as an objective, independent, and scientific institution, with an unimpeachable record of concern for accuracy, that its devices and publications became so eagerly sought after in the period of the emergence of the state commissions and the IOCC.

By the period 1939–1941, the growing tempo of defense work not only reduced the Bureau's emphasis on the pressure core barrel, it changed the whole economic environment of the petroleum industry. Almost overnight, the industry moved from a demand to justify limiting production to a search for more, not less, oil. How to adapt the research at the station to the opportunities generated by defense and war priorities would itself be a difficult transition. Before the war clouds brought the conservation effort to an end, however, Cattell pondered the issues raised regarding patents by the contributions of Reistle, Lindsly, and Berwald.

Cattell wanted to avoid what he called patent "complexes," where an individual would unjustly try to get patents on his work; yet, at the same time, he saw a need for patents. If Bureau men developed something new, he believed, it should be made available to the public at minimal cost. The problem with simply publishing results, however, was that outside patent-scalpers would steal the idea and patent it. Some inventions should be patented—like orphans, Cattell argued, some would benefit from adoptive parents. Simple dedication to the public might prevent production by a manufacturer. There ought, in any case, to be some extra reward for invention. An expressed "shop-right" could be retained for the government use of any patented device. When conflict arose between the Bureau and the individual, however, the Bureau's interests ought to prevail.[46]

Despite the fact that Cattell explicitly examined the premises of the patent issue, he never questioned whether the government laboratory ought to be engaged in inventing devices to assist the industry. He took that as understood. Rather, the issue he raised and tried to solve was how best to encourage technical development and to get industry to adopt any devices that resulted.

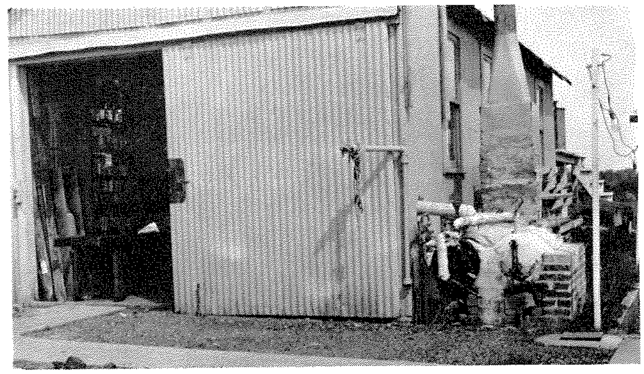
The war would not only change the economics of the oil industry; it would also gradually foster entirely different bases for government-industry cooperation. Cattell's analysis of the patent issues in the years before the war can be seen as an effort to come to grips with some of the practical dilemmas arising out of the effort to serve industry. Entirely separate procedures could be adopted when the overriding priority of national defense provided for joint efforts.

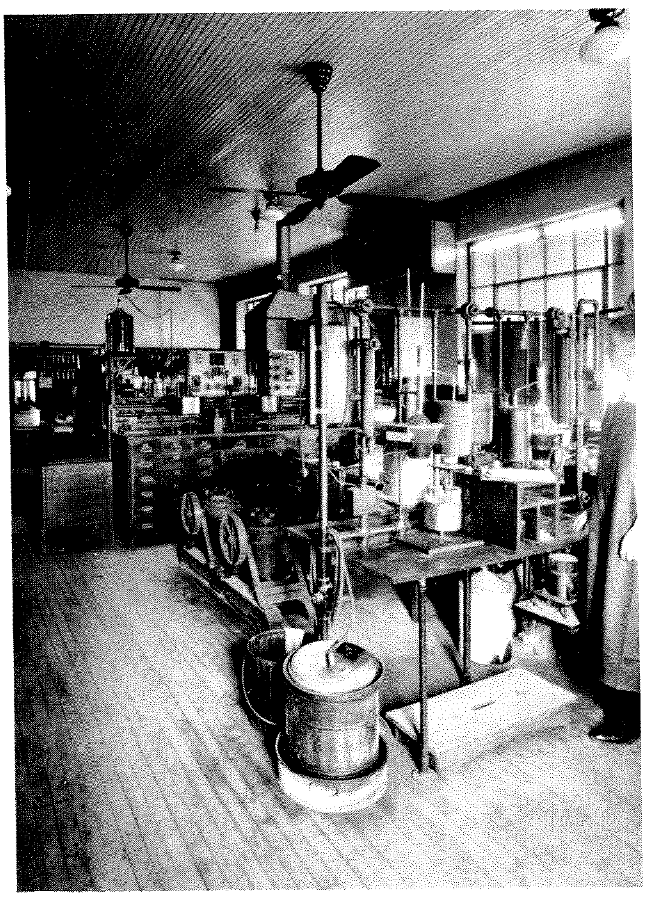
NOTES

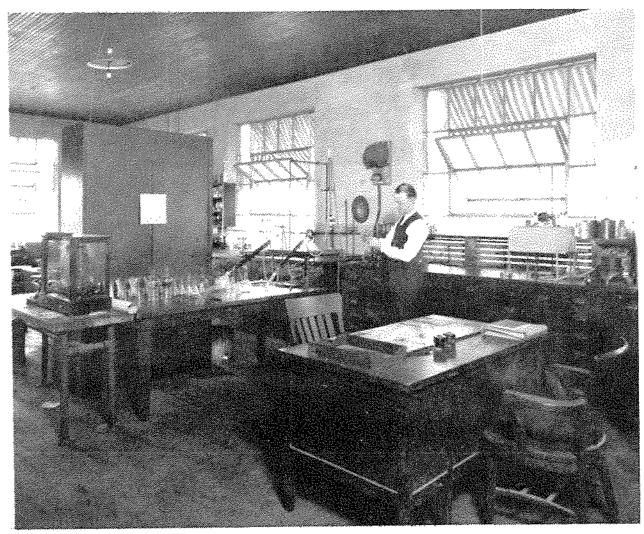
All box numbers cited are from the Bureau of Mines papers on deposit in the Fort Worth National Archives and Records Center, except where noted as retained at BETC.

1. Box 305242 (BETC)/101.1 History of the Bartlesville Station.
2. Schmidt to Cattell, March 12, 1936, Box 322232.
3. Schmidt to Cattell, Box 322345.
4. *Ibid.*
5. Schmidt to Cattell, December 3, 1937, Box 322235/Cattell File.
6. Box 224323/101.1 History of the Bartlesville Station.
7. Schmidt to Kraemer, October 1, 1937, Box 322235/Kraemer.
8. *Ibid.*
9. Box 224323/Organization of the Petroleum Division.
10. *Ibid.*
11. Smith to Fowler, August 21, 1935, Box 322235/Fowler.
12. Rawlins, "Gas Reserve Report," in Box 223318.
13. *Ibid.*
14. Box 224318/022.7 Natural Gas Section, AGA.
15. Cattell to Smith and Seibel, October 28, 1936, Box 224322/826, AGA.
16. Higgins to Berwald, March 15, 1937, Box 224320/0227, Natural Gas Section.
17. Rawlins to Heithecker, August 2, 1940, Box 224328/0227, AGA.
18. Report of Investigation #3493, May 1940.
19. Box 224328/022.7.
20. *American Gas Association Monthly,* June 1937.
21. Cattell to Smith, 1941, Box 224328/0227, AGA.
22. See Edwin T. Layton, *The Revolt of the Engineers: Social Responsibility and the American Engineering Movement* (Cleveland, 1971).
23. J. Stanley Clark, *The Oil Century* (University of Oklahoma, Norman, 1958), P. 237-8.
24. Turner to Cole, June 20, 1934, Box 224322 History of the Bartlesville Station.
25. Reistle to Fowler, October 31, 1931, Box 224316/017.41 Reistle.
26. Rawlins to Fowler, June 30, 1932, Box 224316/017.41 Rawlins.
27. Gas Reserve Report, Box 224318.
28. Cattell to Smith, March 24, 1934, Box 224316/019.22 Patents.
29. Miller to Smith, November 30, 1937, Box 224323/102 Organization of Petroleum Division, reporting on breakfast at which fifteen Bureau alumni, employees in private industry, met with four current Bureau employees at API Convention.
30. Grandone to Richardson, February 16, 1937, Box 224322/Fitts Pool.
31. Box 224319/460 Porosity Determination.
32. Fowler to Muscat, March 4, 1936, Box 224319/466.0 Porosity.
33. *Ibid.*
34. Schmidt to Cattell, August 1, 1938, Box 322235/Cattell.
35. Box 224320/Fuel Oil and Crude Oil Survey.
36. Box 224319/Gasoline and Motor Fuel Tests–Gasoline Survey.
37. Miller to Cattell, June 8, 1937, Box 224320.
38. *Ibid.*
39. Young to Cattell, August 1937, Box 224320.
40. Box 224322/019.22 Patent Office.

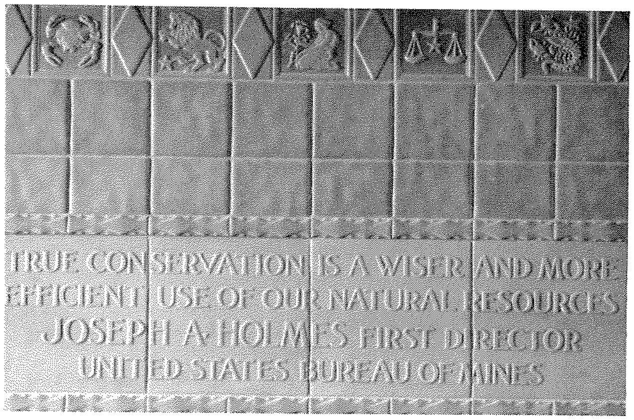
41. Finch to Berwald December 27, 1937, Box 224325/826, API.
42. Report of Investigation #3481; Memo to Committee Members, April 25, 1942, Box 224329/417 Spacing of Wells, API.
43. Taliaferro to Fowler, January 16, 1942, Box 224329/417 Spacing of Wells, API.
44. Heithecker to Fowler, May 18, 1942, Box 224329/417 Spacing of Wells, API.
45. Heithecker to Cattell, May 14, 1940, Box 224326/826 Contracts–API.
46. Cattell to Smith, 1941, Box 224329/Patents.







Work in the 1920s covered a range of subjects. Safety as exemplified by training in artificial respiration was important. A demonstration to a cable tool drilling crew in Osage County is shown (upper left). An experimental 10-gallon still (upper right) was used for assaying crude oil. The petroleum engineering laboratory in 1925 (lower left) was much different from present-day laboratories. The physical laboratory (lower right) was involved in development of a method to separate wax from crude oil.



Field Work

In accord with the motto over the fireplace in the library (upper left), research was taken to its place of application by mobile laboratories. A traveling water analysis laboratory is shown (upper right), and another laboratory truck is conducting experiments to determine the need for pressure maintenance by either gas or water injection. The more effective use of technology was the Bureau's way of promoting conservation.

Chapter 4

WORLD WAR II AND THE RESPONSE OF OIL TECHNOLOGY, 1941–1946

With the coming of war, the pendulum had begun to swing for both the American petroleum industry and the Bartlesville station. No longer faced with the problems of overproduction that had redefined conservation in the 1930s as an attack on "economic" as well as physical waste, oil men in both the private and public sectors now geared up to meet the unprecedented military demands for petroleum and its products. For the major integrated oil companies represented by the American Petroleum Institute (API), the war brought a reaffirmation of the benefits to be achieved through the associative state. Wartime cooperation with the Office of Petroleum Coordinator for National Defense, later the Petroleum Administration for War (PAW), resulted in tremendous growth and profits for the industry. Suspicious of Interior Secretary Harold Ickes' threats to make oil a public utility during the difficult years of the 1930s, oil executives now found the wartime petroleum czar and his many lieutenants who had come from industry to be helpful partners. Since there was business enough for all, and since economic prosperity was cloaked in a fervent patriotism, industry leaders resolved many of the existing divisions between independent and major, producer and refiner, Easterner and Westerner, as petroleum went to war.

This new environment also signaled a governmental policy change which had significant impact on the Bartlesville station. On the brink of war and facing all the uncertainties that entailed, the nation once again became concerned with the availability of petroleum supplies in both the near and longer term. On November 5, 1941, Interior Secretary Harold Ickes captured this mood in an address to the twenty-second annual meeting of the API in San Francisco. After first reviewing the problems of oil tanker shortages and voluntary conservation as part of the war preparedness program, the Secretary turned his attention to larger policy issues:

> Do not forget that petroleum is an exhaustible and irreplaceable natural resource. Not only does our commerce and our industry and our husbandry and our pleasure depend upon it, this war demonstrates that the possession of an abundance of petroleum and its products is a matter of life and death to a nation. And our own nation would be negligent of its duty, recreant to its trust, if it permitted any industry to waste such a valuable natural resource.[1]

This was most encouraging to Bureau of Mines technicians who had spent their entire careers working toward conservation practices in the oil fields. For over two decades, Bartlesville had led the way in many areas of conservation research, including the study and analysis of new fields, research into stimulative and secondary recovery technologies, rehabilitation of old wells, basic theoretical behavior of oil reserves, experimentation with drilling fluids, pressure core barrel testing, testing of high pressure gas wells, and a host of other related activities. Most of these "bread and butter" projects had been maintained throughout the 1930s and were in place when the war broke out. As Deputy Division Director Harry Fowler would later comment, the Bureau "not only was staffed with a key group of engineers and chemists capable of undertaking almost any work connected with the production, transportation, and refining of petroleum and natural gas, but one that during the preceding twenty-five years had accumulated a storehouse of information."[2]

Thus, one major theme of the World War II experience at Bartlesville was continuity. When America needed engineering expertise to insure the maximum utilization of oil and gas reserves, station personnel were there to take up the challenge, thereby justifying their role in keeping alive the light of conservation during a period of petroleum glut in the 1930s. But World War II also brought with it enormous change for a host of American institutions, and Bartlesville was no exception. Much of this change resulted from research projects undertaken with regard to two of the most important technological achievements of the war—the production of huge amounts of high octane aviation gasoline and the creation almost overnight of a vast synthetic rubber industry.

Bartlesville's initial war work centered on the aviation gasoline problem; station engineers assumed the tasks of identifying sources of crude oil, laboratory analysis of aviation fuel blends, and exploration of gas-condensate fields as sources of aviation fuel base stock. As these projects expanded, they became a major part of station work and highlighted the role of the petroleum chemistry and refining section. After the adoption of the Bernard Baruch committee report on synthetic rubber in 1942, the Bureau established a thermodynamics research section at Bartlesville to develop basic data on the conversion of butane and butene gases to butadiene, the basic component of general purpose synthetic rubber. Although by war's end this thermodynamics group had barely gotten underway, it symbolized a new direction for the station in the post-war era. By the mid-1950s, the Bartlesville thermodynamics laboratory had become a major center for the generation of basic data on hydrocarbons and sulfur and nitrogen compounds, and was known throughout the world. Coupled with the chemistry and refining work related to the aviation fuel program, this petroleum thermodynamics activity helped to move Bartlesville in the direction of a research center rather than an experiment station. Bartlesville did not abandon its traditional roles of fostering conservation practices in the oil and gas industries and providing practical engineering expertise to the Mid-Continent producer; but it did find that its functions had been expanded in important and far-reaching ways as a result of the World War II experience.

Mobilization for War

As soon as President Roosevelt declared a limited national emergency on September 8, 1939, after the Nazi invasion of Poland, Bureau of Mines engineers began to look for their place in war service. Yet despite high hopes, the early months of the preparedness program would prove frustrating, as many staff members felt that their expertise was going unrecognized and unused. They realized fully that much of their ongoing work had a direct bearing on the national goal of increased petroleum production and sought direction from Washington. Finally, in June 1940, Interior Secretary Ickes requested the director of the Bureau of Mines to provide specific information on a number of technical questions—including United States refining capacity, the overall aviation gasoline and fuel oil situation, and prospects for increased crude oil production. Cattell, who was Petroleum and Natural Gas Division chief—this was the same basic position he had held for the last two decades, although the name changed somewhat—outlined a national defense program for his unit in a memorandum to the director on July 5, 1940, and sent copies to the supervising engineers at each of the Division field headquarters. Cattell stressed that none of these projects were to be substituted for regular work, but that information should be gathered for Ickes on an informal basis.[3]

In September 1940, Cattell directed all Division engineers to review their ongoing projects and make recommendations as to changes in direction for the war effort. At a meeting of the Division subcommittee for production held in Bartlesville in October 1940, there was discussion of the overall situation. The committee decided to continue studies of oil-field water disposal related to waterflooding and research with drilling muds which would potentially save much steel for the war effort (primarily a San Francisco office assignment), and to reemphasize studies of fire hazards, evaporation losses, and corrosive effects of water as they impacted on petroleum transportation and storage. The committee decided that studies of natural gas hydrates, undertaken at Amarillo as a cooperative project with the American Gas Association (AGA) in the 1930s, should probably be deemphasized until the war was over.[4]

The first specifically defined war assignment for the Division grew out of a meeting between representatives of the Bureau of Mines and the Advisory Council of National Defense in September 1940. They agreed to conduct a survey of crude oil suitable for manufacturing aviation gasoline, a project which began a major Bartlesville effort in aviation gasoline work during the war. The study commenced in the fall of 1940 and, by early summer 1941, Bureau engineers had collected 250 individual crude samples which were forwarded to Bartlesville for analysis.[5]

More formal arrangements coincided with Roosevelt's appointment of Harold Ickes to the post of director of the new Office of Petroleum Coordinator on May 28, 1941. Bartlesville and other Division field offices had been functioning on an almost *ad hoc* basis with the Secretary, primarily providing statistics on numerous questions that had been asked on short notice. In August, a meeting between Cattell and Ralph J. Schilthius, representing Ickes, resulted in the drafting of an agenda of war problems that the Bureau production section could undertake. These included a study of the effects on production of the withdrawal of salt water from the East Texas field, an analysis of "distillate" (condensate) fields, and basic research into the rate of production and oil field drilling techniques as they affected the efficiency of oil field operations. The second of these projects, the study of condensate fields, would become a major Bartlesville wartime project.[6]

Further discussions in August with Wright Gary of the Petroleum Coordinator's office defined other Division assignments. Gary maintained that the number one national defense problem should be an extension of the crude oil survey for the manufacture of aviation gasoline to include a study of alkylate blends. These are high octane substances produced through specialized refinery processes, which, when blended with high quality base stocks and tetraethyl lead, produced 100-octane aviation gasoline. At this time, Bartlesville research was divided into three sections: a special technologic section, an oil and gas engineering section, and a chemistry and refining section. By the summer of 1941, the aviation gasoline blending studies had begun to take up virtually all the time of the expanded chemistry and refining section headed by senior chemist Harold Smith.[7]

These two research areas—the aviation gasoline study and investigation of the composition and reserves of reservoir fluids in gas condensate fields (which could become the source of aviation fuel components)—were designated by the Office of Petroleum Coordinator in 1941 as the two major war problems, and became the major focus of Bartlesville's early war research. Still, many on staff believed that the Petroleum Coordinator was not utilizing their talents sufficiently. Despite their long experience and the demonstrated relevance of their ongoing work in efficient oil and gas field management, they felt that Ickes' office and other defense agencies had failed to grasp the importance of this work in insuring a continuous, uninterrupted supply of oil for national defense.[8]

Even after Pearl Harbor, Cattell reported to his field engineers in February 1942 that "conditions in Washington remained uncertain."[9] Requested supplemental funds for the aviation gasoline study, gas condensate investigation, and already committed secondary recovery studies were still pending congressional action, and the Washington Division office as well as the field offices were becoming increasingly frustrated. In an effort to boost morale, Cattell wrote to the field:

> In spite of the uncertainties we have two very definite jobs in the petroleum field on which we can place emphasis. These are the two jobs requested by the Deputy Petroleum Coordinator, one relating to aviation gasoline blends and the other to condensate fields. We are held back because we lack equipment and funds for travel, supplies, and additional personnel. About all we can do to prevent this is to keep our plans with what we have available and throw as much as we can of our present facilities in the direction of these studies without putting ourselves in a position where we cannot supply information on other phases of our work if and when information concerning them is needed.[10]

Cattell also noted that "many of the boys feel that they could have contributed more to the war," but he reminded them that "having men on the job available for contingencies and emergencies is part of war."[11] In a larger sense, this had been the history of the Bartlesville station—being available with the proper technical expertise when the nation called.

Much of this frustration ended shortly thereafter, in an increased flurry of activity. Only ten days later, the Division received its first emergency funding authorization, and it embarked on a number of important research projects that called for exactly the expertise Bartlesville could provide. For several years, the regular annual appropriation for the Division's oil and gas research had remained constant at $260,000. These monies maintained and operated the main experiment station in Bartlesville; a second smaller station in Laramie, Wyoming; field offices in San Francisco and Dallas; supporting research at the Amarillo, Texas, helium plant; and a small headquarters staff in Washington. This appropriation had been augmented in 1941 by an additional grant from the Army Air Corps to fund the aviation gasoline survey. But if the Division was to make a major contribution to the war effort in 1942, increased funding was necessary.[12]

The Division's budget for fiscal year 1942 had originally been held at $260,000 but, after Pearl Harbor, an additional $66,000 came through for aviation fuel research. Annual appropriations then increased steadily in fiscal year 1943 ($368,000), 1944 ($553,380), and 1945 ($657,640). In addition, other special project funds flowed to the Division from various congressional deficiency appropriations acts. The Division hired new personnel and acquired needed equipment as it expanded to envelop war-related projects. At the height of its expansion in 1945, however, the total technical personnel of the Petroleum and Natural Gas Division amounted to only 147 individuals. Of this total, the largest concentration of technical staff was in Bartlesville, approximately seventy-five researchers. Because the station was spread relatively thin, many of the "bread and butter" projects carried on before the war, though continued in some form, had to be cut back.[13]

Aviation Gasoline Studies: The First Major War Problem

Knowledge of the technology of combustion in engines remained rather primitive in the early years of the twentieth century, and it was only during World War I that researchers discovered that high performance aircraft required special fuels. One of the first important Bureau of Mines projects in the area of petroleum refining had been research undertaken into the production of a synthetic aviation fuel for the military. Because of the cost of its manufacture, however, this approach died out after the war, and refiners primarily relied on the addition of benzol, natural (casing-head) gasoline, or cracked gasoline to straight-run product in order to obtain sufficient quality.[14]

Catalytic cracking, a technology developed in the 1930s, was also to have a major impact on the production of aviation base stock during World War II. First developed by French inventor Eugene Houdry, this process yielded a gasoline of much higher octane than that produced in conventional thermal cracking stills. Higher octane base stocks meant that smaller amounts of expensive additives were needed to obtain 100-octane quality. During the war, Houdry's fixed-bed catalytic units and the later-developed Jersey Standard fluid catalyst process played a vital role in Uncle Sam's aviation fuel program.[15]

In order to obtain the "fighting grade" 100-octane fuel demanded by the military, it was necessary to utilize all of the above processes and additives, many of them in conjunction with one another, and all enhanced with tetraethyl lead. Bartlesville engineers and chemists conducted a series of tests throughout 1941 on the various chemical properties of selected fuel samples, their relative merits as blended fuels, and the most efficient ways to produce them.[16] The goal of these studies was indicated in an October 1941 memorandum from Ralph Davies, Ickes' deputy. He defined the purpose as making "a series of tests to determine the effectiveness of various blends of alkylate, base stocks, isopentane and other materials. This will be of great assistance in immediate plans to utilize most efficiently the various components of 100 octane aviation gasoline."[17] This research represented a substantial expansion of work begun earlier by simply surveying and identifying crude oil fields and reserves which would yield the best base stocks.

This more sophisticated study of alkylate blends necessitated the addition of new equipment at Bartlesville. In addition to general equipment and personnel costs, the station required a supercharged test engine to test aviation blends. Bartlesville already possessed two variable, one-cylinder "bouncing pin" test engines which were perfectly adequate for evaluating the octane of automobile gasolines. These engines were used in conjunction with the national gasoline surveys begun in the 1930s as a cooperative project with the Cooperative Fuel Research (CFR) Committee. For evaluating aviation fuels, however, the anti-knock index alone was insufficient. Because they were used at high altitude in very high compression engines, vapor pressure, volatility, and other characteristics were crucial in assessing the quality of aviation fuels.[18]

As the alkylate blend program got underway in early 1942, there remained a fundamental question as to which source of base stocks should be given priority. The Coordinator's Office decided that those base stocks available to small refiners or used primarily by small refiners with alkylate would be first on the list. By serving the needs of the independent, Bartlesville was following its historical pattern of primary service to those smaller firms who had no research capability of their own.[19]

Since catalytic cracking units were not yet readily available to most refiners, another promising avenue of research was "superfractionation," to isolate the higher octane from the lower octane fractions in selected crudes, thereby obtaining a desirable base stock gasoline for 100-octane aviation. To conduct tests of this procedure, Bartlesville purchased a high temperature fractionating unit. By the fall of 1942, the lab had conducted preliminary studies of 17 samples, but a serious shortage of steel needed for the construction of commercial superfractionation facilities prompted the Petroleum Coordinator's Office to suspend this particular program.[20]

Two of Bartlesville's research sections—petroleum chemistry and refining, and efficient petroleum utilization—devoted their energies to the aviation fuel project. From 1942 through the end of the war, between thirty-five and forty professional chemists and engineers worked on refining problems. At the beginning of the war, station research centered on the quantitative side—how to obtain more aviation fuel; toward the end of the war, however, the qualitative issue of improving these fuels was prominent. The petroleum chemistry and refining section divided into five subprojects: (1) the processing of crudes and naphthas to provide test materials; (2) analysis of hydrocarbon mixtures and blending of high octane agents; (3) evaluation of samples by engine test; (4) testing for sulfur content, lead susceptibility, vapor pressure, and other relevant investigations; and (5) a technical reporting group responsible for making the results of all tests available to industry and government organizations. The efficient petroleum utilization section divided into four subprojects: (1) evaluation of crude oil to determine the content of aviation base stock; (2) evaluation of base stocks in blends with high octane agents; (3) upgrading of base stocks; and (4) analyses of base stocks for hydrocarbon content. A related aviation fuel project, which began in 1941 and continued for quite some time during the war, studied evaporation losses in the storage of high octane gasolines. Under the direction of Bartlesville engineer Grandone, this unit took careful measurement of the evaporation rates of different blends. These data proved valuable during the war in designing adequate storage and transportation facilities for such a volatile product.[21]

Bartlesville and Laramie teams evaluated an additional 65 samples of crude oils and condensates for aviation fuel in 1942, and continued to update this work with studies in 1943 and 1944. Related research released in 1942 and 1943 was critical for industry's use of desulfurization to increase the lead susceptibility of marginal base stocks in the manufacture of aviation gasoline.

An extremely important project related closely to the aviation fuel work was the survey of crude oils and refinery distillates as a source of toluene for the manufacture of TNT for military explosive devices. The Office of Petroleum Coordinator first requested the Bureau to conduct these surveys on May 9, 1942, and a report on them was submitted to the office on July 31 of that year. As toluene requirements became increasingly critical, additional requests came from Washington, and the Bureau supplied confidential data on toluene up through 1944. Both the Bartlesville and Laramie stations worked on the identification of sources of toluene and methylcyclohexane (which could be converted to toluene), issuing a report in April 1944 on 107 samples which they had analyzed. By the spring of 1944, there was sufficient toluene available for the munitions industry, and the Bureau of Mines redirected the toluene program to a study of the qualitative aspects of aviation fuel. Much of this work focused on superfractionation, and a total of three reports came out of these redirected studies in 1944 and 1945.[22]

The massive production of high octane aviation fuel for the military in World War II was one of the more important technological achievements of the conflict. British Foreign Secretary Lord Curzon's statement that the Allies had "floated to victory on a sea of oil" in World War I is often cited as an important measure of petroleum's growing importance in the twentieth century. Yet, if the Allied Powers had floated to victory in 1918, they had surely flown there in 1945 on the wings of 100-octane aviation fuel—an achievement that the United States Joint Chiefs of Staff termed "one of the great industrial accomplishments in warfare." In 1945, the Army Air Force alone consumed daily fourteen times the total volume of gasoline shipped to Europe for all purposes between 1914 and 1918.[23]

Bartlesville's contributions to aviation gasoline research were part of a much larger cooperative effort by business and government under PAW leadership. Industry, the Bureau of Mines, the National Bureau of Standards, the Cooperative Fuel Research Committee, and other organizations cooperated in the exchange of technical information, and private firms shared patent and licensing agreements under PAW auspices. At war's end, over 400 individual refineries were turning out the 87-, 91-, and "fighting grade" 100-octane aviation gasoline needed for the military forces.[24] Because of the need for hard data on the chemistry of base stocks and blends, there was a subtle but important change of focus in the personnel hired and the research agenda at Bartlesville. The aviation gasoline work pointed the station toward the direction of a research center involved with the basic chemistry of hydrocarbon compounds rather than its more traditional role of oil field production technology.

Gas-Condensate Studies: The Second Major War Problem

Because the liquids obtained in gas-condensate fields were of potential use as blends in aviation gasoline, the gas-condensate research complemented other Bartlesville research into aviation gasoline crude sources and high octane blends. With the deeper drilling of natural gas wells in the 1930s, producers frequently discovered a water-white or straw-colored liquid (then referred to as distillate) along with dry gas. Although similar to natural or casinghead gasoline that had been obtained from natural gas for a number of years, these condensates possessed chemical properties which made them even more valuable.[25]

Bartlesville engineers had pioneered in the study of these condensates in the 1930s through cooperative studies funded partly by the American Gas Association, and had conducted detailed studies of the flow characteristics, composition, and properties of fluids obtained from one of the wells in the East Texas field. Gas wells containing high ratios of liquid to gas received the designation of "combination wells."[26]

A preliminary war study in the fall of 1941 indicated that as many as 100 individual reservoirs of the condensate type might require investigation. To carry forward this work, however, additional funds would be required to supplement the Bartlesville operating budget. The only test equipment owned by the Bureau of Mines at the time was a cell for determining the phase relations of reservoir fluids (gas to liquid) developed at the Bartlesville station in the 1930s. The station submitted a proposal for a field study program under the direction of R. E. Heithecker and Ken Eilerts in December 1941. Targeted for immediate action in 1942, these field studies were planned to entail three separate stages. First, each reservoir designated by the Petroleum Coordinator would have an engineering study to provide a concise overall description of field conditions in order to estimate liquid and gas quantities. Second, Bartlesville engineers, with consent of the field operators, would conduct stabilization tests of the behavior, pressure, and temperature conditions in a given well at varying rates of flow. Finally they would analyze all hydrocarbon fluids coming from the well to generate data on the construction of cycling plants to produce liquids from wet gas.[27]

In February 1942, Heithecker made an exploratory trip to Texas and Louisiana. He met with many combination well operators, the Texas Railroad Commission, and the Conservation Department of the Louisiana Minerals Division, compiling a list of gas-condensate fields. In Bartlesville, Eilerts was preoccupied with assembling the intricate field-testing apparatus that would be needed to carry out the tests. Before Eilerts had completed the critical materials preparation, however, the Petroleum Coordinator's Office, on April 16, 1942, requested an immediate study of the Logansport-Joaquin combination field in Louisiana and Texas—a request prompted by growing shortages of critical materials for manufacturing aviation fuel. Heithecker's and Eilert's team submitted their report in July and quickly undertook studies of two additional Louisiana fields. Although these studies proved valuable, the Bartlesville group found themselves unable to meet the six-to-eight week time schedule that the Petroleum Coordinator had designated for each field. To expedite the work, Eilerts assembled a mobile field laboratory, and in January 1943, Cattell assigned the entire staff of the Dallas field office to condensate studies.[28]

Between June 1942 and April 1944, the Petroleum Coordinator's office received detailed reports on thirteen condensate fields, nine compiled by Bartlesville staff and four by the Dallas office.[29] In commenting on the value of these studies, Deputy PAW Director Davies wrote:

> Not only this office, but the entire natural gas and natural gasoline industry has benefited to a substantial degree by the availability of the Bureau's technical knowledge and skill at a time when the industry itself finds it extremely difficult to maintain adequate technical personnel.[30]

Davies, himself a former oil company executive, was referring primarily to the importance of condensate liquids for the aviation program; the sum total of Bureau research into combination wells, however, yielded data of much broader significance.

By 1944, approximately forty cycling plants existed to obtain condensate liquids found in these wells. The Bureau had also established the important conservation principle that the cycled dry gas reintroduced back into the well would not only provide future reserves of natural gas but, ultimately, by maintaining maximum well pressure, insure an increased long-term yield. Eilert's work, in particular, also confirmed that the best way to influence efficient exploitation of these fields was to unitize them—that is, to operate each as a cooperative pool—because keeping the number of actual drilled wells to a minimum through unitization would give the field a longer life. These conclusions, not particularly relevant to the original purpose of the condensate studies, nevertheless conformed to Bartlesville's previous experiences in conservation and well-spacing and were to have significant importance in the post-war era.[31]

In the midst of the war-emergency condensate studies, a related problem cropped up that soon commanded a great deal of the Bartlesville group's time. On September 4, 1942, Davies had requested that a complete engineering study be made of the Chickasha-Cement high pressure gas area in Oklahoma. Because of unprecedented demand for industrial use of natural gas, there was an alarming drop in closed-in pressure in the field and concern that it might soon become depleted. From December 1942 to June 1943, a Bartlesville team headed by Heithecker devoted its time exclusively to this project.[32]

The study became complicated when evidence appeared that oil migrating into the adjacent Medrano gas reserve threatened a great underground waste of gas. The Bartlesville engineering report resulted in a prorationing order by the Oklahoma Corporation Commission limiting production in the Medrano Sand of the West Cement field, issued on January 4, 1943, and amended on March 27, 1943. On July 9, 1943, Cattell directed that the West Cement study be terminated and Bartlesville's energies redirected to the gas-condensate studies. Tests of the West Cement field could reach no definitive conclusion as to the relationship between the oil and gas present. However, the importance of the knowledge gained in the West Cement study became appreciated in the post-war era as Bartlesville emerged as an important center for information on the determination of flow in high pressure gas wells and the development of allocation formulas for unitized gas operations.[33]

Thermodynamics Research

In August 1942, Harold Smith and Heithecker traveled from Bartlesville to Washington to review war work already undertaken and to discuss with both the Washington Division office and the Office of Petroleum Coordinator the focus of future projects. The two primary war problems at this point remained the same as before: the aviation blending project and the study of condensate fields, each under their respective direction. While in Washington, Smith, along with Cecil Ward and Harry Fowler of the Division office, met with Paul M. Raigordsky from the Office of Petroleum Coordinator. The purpose of the meeting was to discuss the establishment, within the Bureau of Mines, of a research team to investigate the direct conversion of butane to butadiene, the major component of general purpose synthetic rubber. This meeting turned out to be the genesis of the thermodynamics section at Bartlesville.[34]

At the outbreak of the war, there existed several processes for making synthetic rubber. DuPont's neoprene, for example, was an excellent product for certain specialized uses, but remained unsuitable for heavy-duty uses, such as in automobile tires. A more satisfactory product for heavy-duty use was Buna-S, a rubber manufactured from two organic ingredients, butadiene and styrene. The giant German chemical combine, I. G. Farbenindustrie, held the patents for the basic process, which it had developed in the 1930s. The United States rights were held by Standard Oil of New Jersey, a partner to Farben in several international cartel and licensing agreements. On June 28, 1940, after the fall of France to Hitler, President Roosevelt designated rubber as a strategic and critical material. Concerned about future rubber supplies as part of the war emergency, the federal government established a special subsidiary of the Reconstruction Finance Corporation, the Rubber Reserve Corporation, to address the rubber situation. Industry concluded the first agreements relating to technical information and patent rights with the Rubber Reserve Corporation on December 19, 1941, soon after Pearl Harbor. With the loss of critical natural rubber supplies after the Japanese conquest of Malaysia in early 1942, the situation became even more serious.[35]

A crucial technical question that faced policymakers was to determine the best and most efficient way to manufacture butadiene, the primary material needed for Buna-S. There were several ways to obtain butadiene from alcohol, most of which involved the dehydrogenation of ethanol. These processes had been developed in Europe, but in this country the Carbide and Carbon Chemicals Corporation owned patent rights to one of them. Additionally, there were three basic processes to manufacture butadiene from petroleum. The first of these relied on the original I. G. Farben patents and involved the dehydrogenation of butylene (butene) gas captured as a by-product of petroleum refining. The second was a similar dehydrogenation of butane and butene patented by the Houdry Process Corporation, the industry leader at that time in catalytic cracking technology. The third approach was a process developed by the Phillips Petroleum Company involving the dehydrogenation of butane obtained directly from natural gas.[36]

In February 1942, the Rubber Reserve Corporation issued a report recommending that 705,000 tons of Buna-S be produced with butadiene obtained from the Standard Oil (I. G. Farben) process. This sparked a great controversy which continued throughout 1942. Houdry, Phillips, and the alcohol lobby campaigned publicly and lobbied in Washington to change this decision—neither the first nor the last time that business competition and wartime cooperation came into conflict. Moreover, the debate was colored by the Standard Oil/I. G. Farben connections, and the Truman Senate Committee investigation in the spring of 1942 had given Standard a black eye for collaborating with the enemy in time of war. Congress passed the Rubber Supply Act in 1942, but FDR vetoed it on August 6 because of the continuing controversy among the advocates of different processes. He then appointed a special Blue Ribbon Committee, chaired by financier Bernard Baruch, to study the problem and make appropriate recommendations. The other committee members were Harvard president James B. Conant and MIT president Karl T. Compton.[37]

In its meeting with the Office of Petroleum Coordinator in August 1942, Bureau of Mines technologists described their proposed thermodynamics project as operating on a "fundamental" basis and "not a part of the so-called growth program of supplying immediate needs for rubber." As the Bureau began to stake out the groundwork for this research, the Baruch Committee submitted its report on September 16, 1942. Its conclusion basically endorsed the earlier Rubber Reserve Report with one exception. The largest amount of butadiene (283,000 tons per year) would be produced from the Standard Oil process, but smaller allotments were given to the alcohol, Phillips, and Houdry processes.[38]

Meanwhile, the Bureau of Mines had been assembling a formal proposal for supplemental funding to accomplish the thermodynamics work. On September 14, 1942, only two days prior to the formal announcement of the Baruch Report, they received a "green light" to go forward with a supplemental appropriations request of $50,000 to establish a laboratory at Bartlesville to pursue studies in petroleum thermodynamics.[39]

The literal meaning of the term "thermodynamics" is heat power or power developed from heat. The science of thermodynamics provides laws that govern the passage of energy from one system to another, the transformation of energy from one form to another, and the utilization of energy for useful work. Proper application of the first and second laws of thermodynamics allows one to analyze closely all transformations of energy and matter. For the chemist, thermodynamics data can provide, without costly experimentation, the amounts of given material that will be in both the initial and final stages of all chemical reactions. These scientific data, obtained in a research laboratory, are one of the necessary tools of the chemical engineer. In the 1920s and 1930s, researchers had only begun to apply the tool of thermodynamics, long used by the physical chemist, to organic chemistry. The Department of Chemistry at the University of California, Berkeley, became a major center for this research, and Professor G. N. Lewis of that department one of its foremost pioneers.[40]

There is nothing magic about the science of chemical thermodynamics. Indeed, the success of any thermodynamics analysis is critically dependent on the data underlying it. The numerical results of an analysis can only be accurate to the extent that the basic data are accurate. The central motivation of the Office of Petroleum Coordinator was to provide accurate data on the conversion of butane to butadiene. The Bartlesville laboratory was, therefore, to perform fundamental measurement tasks. The butane conversion process was one of those endorsed by the Baruch Report (Phillips process), and Bartlesville chemists had a long history of working on natural gas analysis. Once obtained, these fundamental data could then be utilized to make all butadiene conversions more efficient.[41]

In May 1943, the Bureau took a major step forward when it hired Dr. Hugh Martin Huffman from the California Institute of Technology to head the new thermodynamics section at Bartlesville. Huffman was a Ph.D. chemist, a former student of G. N. Lewis, and a respected researcher in the field of chemical thermodynamics. After coming to Bartlesville, he would pioneer in the development of instrumentation to measure the precise equilibrium of chemical reactions, and he later founded the prestigious annual Calorimetry Conference, which still continues today. Huffman visited Washington in early May, where he met not only with Bureau of Mines personnel but with chemists at the National Bureau of Standards. The main purpose of the meeting was to define a research agenda for Bartlesville that would avoid duplication with other ongoing projects. Among those with whom Huffman conferred was Dr. Frederick Rossini of the National Bureau of Standards, director of the American Petroleum Institute's Project 6 (an industry-funded basic research program on the fractionation, analysis, isolation, purification, and properties of petroleum hydrocarbons). Rossini was one of the leading chemical thermodynamicists in the country. Begun in 1927, this first cooperatively funded API research generated a mass of basic data which remains today a fundamental tool of the petroleum chemist and engineer. Included in these data are tables of the thermodynamics properties of various hydrocarbons. After discussing the Bartlesville program with the National Bureau of Standards people, Huffman then met with Dr. E. R. Gilliland of the Office of the Rubber Director to identify those areas of the rubber program where the Bartlesville work would be most helpful.[42]

The Division office had begun to make plans for staffing the new laboratory as early as February 1943. Now, with Huffman on board and funding approved, plans went forward in earnest. While in Washington, Huffman had also met with the Civil Service Commission, seeking qualified technical personnel, and had looked into ways to obtain the intricate instruments that he would require given the difficulties of the war priority situation.[43]

From the beginning of Huffman's arrival in Bartlesville, he signaled a new approach to research. He hired new men from the outside with the necessary degrees and experience in chemistry, and made clear his intention of publishing in leading national journals rather than Bureau of Mines publications—a fact that apparently irked some of the older staff, particularly Superintendent Smith, who had made the maintenance of Bureau scholarly standards his personal crusade for years. Huffman himself was only the second Ph.D. ever employed at the station and the only one on the staff at the time he was hired. One of the first men that Huffman himself hired was Donald R. Douslin, holder of an M.S. degree in chemistry from the University of Iowa, who came to the station from its Bartlesville neighbor, Phillips Petroleum. At Phillips, Douslin had worked on the firm's butadiene process, particularly the vapor-liquid equilibrium of related hydrocarbon systems. Other key men in Huffman's group included chemists J. W. Knowlton and Guy Waddington.[44]

Huffman's section concerned itself chiefly with the determination of specific heats—the heat necessary for phase changes, heats of combustion, and pressure-volume-temperature (PVT) data for many hydrocarbon compounds. Industry was heavily involved by this time in the crash program for synthetic rubber; but the Bartlesville team was only beginning to conduct basic research related to the equilibrium reactions involved in the butane-butadiene conversion. As had frequently happened in the past, the technology was in part preceding the science.[45]

The first several months of the thermodynamics work at Bartlesville were absorbed with obtaining and constructing new equipment, particularly apparatus for low temperature and combustion calorimetry, and progress was slow. Knowlton's job was to erect the combustion calorimeter and, by October 1943, he had tested it with calibrated samples from the National Bureau of Standards. Further experiments with sample hydrocarbons supplied by the American Petroleum Institute, however, indicated nagging flaws in the equipment and poor test results. The group finally decided that it had to operate the calorimeter at night so as to be immune from the vibrations caused by machinery and slamming doors. The first new experiments and data collection on two compounds, thus, did not occur until April 1944.[46]

In fact, thermodynamics data on butadiene reaction equilibrium turned out to be a very minor part of the synthetic rubber program during World War II. During 1943 and 1944, most of the butadiene produced in the United States was derived from alcohol (77 percent in 1943; 64 percent in 1944). This occurred because butylene gas, the refinery source for butene in the Standard Oil dehydrogenation process, was more critically needed to manufacture alkylates for aviation fuel. In 1945, however, butylene gas became available in sufficient quantity for petroleum-derived butadiene to constitute 61 percent of the total production figure.

The basic data developed by Huffman's thermodynamics laboratory, therefore, ultimately proved valuable.[47]

In late 1944 and early 1945, the laboratory turned out its first data on hydrocarbons. Aware that the immediacy had passed for the butane-butadiene work, Huffman began preliminary work to determine the heat of combustion of tetraethyl lead, a study with relevance at the time to the aviation gasoline program and all later studies of fuel technology. In 1945 his group broadened its inquiries to include thermodynamic studies of other basic hydrocarbon compounds, work very much in line with what other similar laboratories were doing.[48]

This group of well-trained researchers, possessing highly sophisticated equipment, was now ready to apply its skills to a range of related problems. They began a broad study of the specific heats of gases and explored other projects in discussions with the National Bureau of Standards and university laboratories conducting parts of the API basic studies. One forward-thinking project begun in 1945 centered on the study of the heats of combustion of jet-propulsion fuels. Although American technology was far behind the Germans in this field, there was great research interest in jet engines, and it was clear that they would be of post-war importance. One specific post-war outgrowth of the thermodynamics work was an 18-year Bartlesville station research program, cofounded by the American Petroleum Institute and beginning in 1948, on the sulfur compounds of petroleum. Later, an American Petroleum Institute project beginning in 1952 extended this effort to nitrogen compounds, a project which continued for twelve years.[49]

Although the actual thermodynamics research conducted at Bartlesville during the war had little impact on the synthetic rubber program, had it not been for the war emergency and the perceived need for these data, the section never would have been started—a fact of fundamental importance, because the establishment of this specialized research section had a profound effect on the future direction of the station. Combined with the sophisticated studies of aviation gasoline blends conducted by the refining and chemistry section during the war, this basic research thrust was significant in moving the station closer to the mode of the petroleum research center it later became.

Conservation and Secondary Recovery

The flurry of optimism that had appeared in 1941 following Ickes' references to the need for oil field conservation practice faded as the work at the station became almost exclusively dominated by the aviation fuel and gas-condensate studies early in the war. Commiserating with Schmidt, who had been lobbying for funding for a major Bartlesville study of secondary recovery in the Mid-Continent fields, Fowler wrote him in September 1942 that "we are now in the position of consultant to the OPC and in taking up any piece of work we must keep in mind that first things come first and the OPC, as far as we are concerned, is the organization to tell us what comes first."[50] Virtually all the Bartlesville supply and travel money remaining from fiscal year 1942 was earmarked for the aviation gasoline and condensate studies.

Fowler soon was able to provide some "happier" news, however. A supplemental appropriation for 1942 of $115,000 did contain a small amount for secondary recovery work—to Fowler this was an important, if belated, recognition of its importance. Of the total supplemental funds, $34,000 was designated for aviation fuels, $50,000 for the new thermodynamics lab, and $23,000 for condensate work. That left a mere $7,500 for a survey of Mid-Continent oil fields to recommend the application of practical secondary recovery operations and repair of wells, which Governors Armstrong of Oklahoma and Ratner of Kansas and Senator Capper of Kansas had requested in the spring of 1942.[51]

This dearth of secondary recovery work had troubled Schmidt and Superintendent Smith, who had been preparing their proposal to the new Oklahoma legislature and Governor-elect Robert S. Kerr for an increase in state appropriations for the 1943–1944 biennium. Much of the interest in secondary recovery emanated from an Interstate Oil Compact Commission (IOCC) report released in December 1942 showing that Oklahoma ranked second only to Pennsylvania in the total number of stripper wells. Schmidt also pointed out that the Bureau had last published something on marginal wells in 1937 and that "problems relating to marginal well operations and secondary recovery have been gradually shoved to the background so that within the past few years they were merely mentioned."[52]

To complicate matters further, the Bureau had provided substantial funds to investigate secondary recovery in Pennsylvania at the instigation of the Office of Petroleum Coordinator which, prompted by a shortage of Pennsylvania paraffinic oils valuable for high-grade lubricants, designated this as a war problem. In March 1942, the Bureau also opened a new Franklin, Pennsylvania, field office with staff spun off from Bartlesville, engineers C. J. Wilhelm and Sam S. Taylor. Cattell had assured Smith that, once war assignments had been covered, he would support a study of secondary recovery in Oklahoma and Kansas which he hoped would lead to future work in Oklahoma. "In this way," Cattell maintained, "we will be able to meet some of our obligations in Oklahoma along the lines of Armstrong's request, and, at the same time, will be able to do what the Bureau should do in assisting independent operators."[53]

Coinciding with the opening of the Franklin field office, Schmidt, then head of the secondary recovery section at Bartlesville, was promoted to the title of Assistant Supervising Engineer at Superintendent Smith's suggestion. This was apparently in part to provide recognition to Schmidt, who had been passed over as head of the Franklin office by Wilhelm, and to increase his salary. Records also indicate that Schmidt had been assuming more administrative responsibility from the aging Smith, particularly in negotiating a research agenda with Washington.[54]

Writing to Schmidt in December 1942, Fowler also sought to assure him that the Washington office would continue to push for support of secondary recovery projects. The 1944 fiscal year budget request contained a sum of $33,000 for such work, and the small supplemental appropriation of $7,500 mentioned above would be available soon after the convening of the 78th Congress in January. Fowler strongly supported secondary recovery, but conceded that "one of the difficulties is to be able to find the right people and tell the story in the right way to show that our work is a definite contribution to winning the war."[55]

Throughout the war, only a small group at Bartlesville worked on secondary recovery and related problems such as the disposal of oil field brines associated with waterflooding technology. Ben Taliaferro and David Logan published a history of Oklahoma waterflooding in 1942, and smaller studies of air and gas injection projects in Oklahoma were also written. One engineer conducted a preliminary study of stripper wells in Michigan, western Kansas, Arkansas, New Mexico, and Kentucky, and a group undertook a more detailed study of secondary recovery in the limestone formations of Illinois and Indiana. The focus of wartime secondary recovery work, however, was in the Franklin field office.[56]

Cooperative Research Projects

The emergence of cooperatively funded research in the 1930s represented one of the more significant institutional developments having a bearing on the future development of the Bartlesville station. In a general sense, of course, Bartlesville had always been engaged in cooperative funding, given the joint sponsorship with the Bartlesville Chamber of Commerce, private industry, the State of Oklahoma, and the federal government that had made the whole idea possible in 1918. Specific research projects funded jointly by outside groups from the private sector, however, represented an important new departure. As Bartlesville evolved into a more broadly defined research center in the post-war era, the cooperative model provided not only external funds to carry on research, but also an entree into the mainstream of state-of-the-art petroleum technology as perceived by industry.

To a great degree, World War II represented a hiatus from privately funded cooperative research as the pressing demands of PAW work forced many already contracted projects to the back burner. The most significant efforts brought together in the 1930s and extending into the war were: (1) API-sponsored pressure core barrel work; (2) AGA-sponsored studies of gas flow measurement, gas hydrates in transmission lines, and gas-condensate wells; and (3) the biennial motor gasoline surveys conducted in conjunction with the Cooperative Fuel Research (CFR) Committee, jointly funded by the API and the Society of Automotive Engineers (SAE) which came together during World War II to form the Coordinating Research Council. All three survived to a limited degree during the war and served as models for important cooperatively funded projects of the late 1940s and 1950s.

In 1937, as discussed in Chapter 3, the API had begun funding a joint project with Bartlesville to develop a pressure core barrel. This device could not only cut a core sample from a drilling formation but seal it at the same time, thus allowing detailed laboratory analysis of the core at its original rock pressure. The motivation for the project was to provide data for technically informed well-spacing regulations, and Bartlesville worked directly with the Institute's Well-Spacing Committee. The Hughes Tool Company constructed the barrel according to Bartlesville design, and it made its debut in 1939. Ultimately, its inventors, H. C. Miller, Taliaferro, and Berwald, received a patent (Serial No. 2,348,736, December 8, 1942).[57]

A conflict over priority, however, also previously discussed in Chapter 3, had developed between the API-Bureau design and a similar device patented by B. W. Sewall of the Carter Oil Company (Serial No. 2,216,912, October 8, 1940). This situation was complicated further when Sewall received a patent for a modified version of his core barrel on April 15, 1941 (Serial No. 2,238,609). Miller *et al.* raised a claim at this time that the new Sewall patent contained features found in their device, and filed a protest in 1942 on behalf of the public (i.e., the Bureau of Mines) and the API. In the interest of wartime cooperation, the Attorney General's office settled the controversy, and the official API history of petroleum engineering credits Carter and the Bureau of Mines jointly as having invented the pressure core barrel. This conflict, however, further clouded efforts to maintain testing programs with the pressure core barrel during the war.[58]

By 1942, the Carter barrel, which was commercially available, had become the one most commonly used by industry. In fact, Bartlesville engineers were testing the device for the API as part of their funding agreement. But in June 1942, the API had decided not to renew its annual $6,000 contribution for fiscal year 1943. A major factor in this decision was that the prorationing regulation needs demonstrated in the 1930s were no longer of immediate concern in the wartime petroleum economy. Schmidt wrote to Cattell in November 1942 requesting permission to use the core barrel in his secondary recovery studies of Oklahoma fields. Cattell, expressing both his own conservatism and an awareness of the sensitivities aroused by the patent disagreement, replied: "Personally, I do not feel that the Bureau has any right to go off on a new line of attack in the secondary recovery studies using the pressure core barrel without approval of the API committee." API approval did come (if not funding), and the barrel found some limited use in both secondary recovery and deep-well condensate studies during the war.[59]

One of the more fruitful associations that developed in the 1930s was a series of cooperative funding arrangements with the AGA to investigate a series of technical problems. The AGA made available a sum of $5,000 for fiscal year 1942 to carry forward ongoing work on the causes of freezing in natural gas pipelines in the form of hydrates, and studies of combination wells. Because of the wartime demands of the OPC, gas hydrate studies came under the rubric of special war problems. In October 1945, however, negotiations opened up again with the AGA to continue cooperative work into the post-war period. An agreement to study the storage of the natural gas in hydrate form was entered into on May 24, 1945, whereby the AGA Natural Gas Section would provide $15,900. This arrangement enabled the Bartlesville station to resume this amicable association and continue it into the post-war years.[60]

The National Motor Gasoline Surveys coordinated by Bartlesville commenced in the winter of 1935–1936 under a cooperative agreement between the Bureau of Mines and the CFR Committee. Further reports on the quality of gasoline marketed regionally appeared in subsequent summers and winters up to 1941. The Bureau suspended the survey during the winter of 1941–1942 and summer of 1942 because it was felt that the published data might possibly be of value to the enemy. It resumed in the winter of 1942–1943 and continued throughout the duration of the war. Chemist E. C. Lane authored the surveys until 1941, when they were taken over by chemist Oscar Blade, who continued this work until 1970.[61]

The survey took on particular importance in 1946, when the Civilian Production Administration needed estimates of tetraethyl lead for an anticipated peacetime boom. Although it required limited resources at Bartlesville, the National Motor Gasoline Survey was another important link between pre-war and post-war peacetime economies. As a neutral research organization, Bartlesville was the ideal clearinghouse for handling sensitive proprietary data provided by the major oil companies.[62]

Post-War Planning

In January 1945, the chief of the Bureau of Mines Fuels and Explosives Branch, Dr. A. C. Fieldner, requested the Petroleum and Natural Gas Division to formulate a post-war program of research. Cattell corresponded with his field offices and conducted discussions in Washington to determine a general program and tentative budget. With the end of the war now in sight, it would require a major administrative effort to coordinate the completion of Bartlesville's wartime work and begin to implement a program of future research.[63]

Superintendent Smith had by far outlasted his six predecessors, but was now in the twilight of his career. Cattell decided that Harry Fowler should move to Bartlesville to replace Smith as of February 13, 1945. Smith remained on staff at the station as a sort of "super editor," a task which he had really pioneered for himself over the years with his insistence on high writing and publishing standards. Smith retained his sense of humor in what must have been a delicate situation when he wrote Cattell on February 28: "This is only 16/28 of a monthly letter as during the first 12 days of February I was still Supervising Engineer." Demonstrating also that he was taking his new job very seriously indeed, Smith informed Cattell that he had already written a memorandum to Fowler outlining a "Program for Technical Writing" to be implemented at the station.[64]

As early as September 1944, a report by H. C. Miller and Fowler, entitled "War Work of the Production Section of the Petroleum and Natural Gas Division," had raised the theme of continuity to emphasize the importance of conservation studies in the post-war era. Although maintaining that the Bureau's traditional role had endured despite the disruptions of special war problems, they wrote that "there should be even less disruption in the adjustments from war to peace because the basic problems of the division always have pertained to the efficiency of oil recovery and better methods for making petroleum and its products easily available at reasonable cost—a desirable post-war objective."[65] The authors also compiled an agenda of research projects, many of which had been continued throughout the war on a limited scale.

Among the projects identified which had particular relevance for Bartlesville in the post-war era were several which related to the station's traditional role of oil field conservation practice. The wartime demand had added scores of wells to the stripper category, and it was clear that ongoing secondary recovery studies would be needed; but research in primary oil development was also relevant as new wells would most probably require deeper drilling and new methods of managing deep reservoirs. The exploitation of deep, high pressure reservoirs also opened up a broad field of research pertaining to the cycled dry gases that remained in reservoirs after removal of liquid fractions. This was already a Bartlesville speciality. The station could also fruitfully resume its pre-war work on the basic function of water in the production of oil by studying water-driven as opposed to gas-driven wells and the relationship of this basic research to secondary recovery. Experience had shown that further work was required on the measurement of the open-flow capacities of natural gas wells and methods of estimating both oil and gas reserves in order to achieve maximum efficiencies. There would be post-war need for pressure core barrel tests in determining well-spacing regulations and a demand for reactivating work on the formation of gas hydrates in gas transmission lines. Furthermore, World War II studies of high pressure, condensate-type reservoirs had highlighted the need for studies of corrosion in well-head fittings and other equipment.[66]

The 1944 report concluded with a restatement of the overall philosophy that had been hammered out over the years as the Bureau technicians walked the narrow line between basic and applied research, between the furthering of knowledge and proprietary interest:

> Individual companies and operators cannot be expected to prosecute extensive research of the kinds which the Bureau through long experience is best qualified to do with impartial benefit and without prejudice of property lines or viewpoint engendered by company application. In fact, the general problems on which the bureau will follow its course of coordinated research in the post-war period are of such types that usually company research organizations and commercial groups, as well as schools and colleges, are not in a position to undertake.[67]

Cattell visited Bartlesville in September 1945 for a three-day series of conferences with Superintendent Fowler and the members of each of the four technical sections: secondary recovery, petroleum production, petroleum chemistry and refining, and petroleum thermodynamics. Adjustment to peacetime conditions and evaluations of the assets represented in the research of the four groups headed the agenda. At Huffman's suggestion, there was a series of seminars presented by each section for the entire staff in order to encourage the exchange of ideas among different groups who might be working on related problems. For example, a chalk talk given by Harold Smith on the significance of studying pure compounds for finding better uses for petroleum meshed well with Don Douslin's seminar on PVT research into the thermodynamics of hydrocarbons and related compounds. Similarly, all engineers working on production-related projects were brought together to discuss such topics as the use of helium as a tracer gas and cycling and gas injection projects in primary fields.[68]

In addition to addressing its technical research agenda at the end of the war, Bartlesville also had to plan for the inevitable bureaucratic and political changes that were in the wind. With the formalization of the Petroleum Administration for War in December 1942, Harold Ickes had given assurances to oil company executives that regulation would come to an end with peace. Within a month of V-J day, the PAW had revoked almost three-quarters of the total of sixty recommendations, orders, and directives in place at war's end. Its staff, which had peaked at 1,438 employees, was down to 161 by December 31, 1945, and fifty-eight by April 1. A regulatory vacuum existed which, for the most part, pleased the private oil industry, but which also contained the potential for confusion and confrontation during the transition to peace.[69]

Fowler attended the winter meeting of the IOCC at Wichita in December 1945 and reported on some of these problems. There was generally favorable comment concerning Bureau technical reports, but Fowler was concerned about an IOCC move to create its own economics branch and make its own demand forecasts. There appeared to be a consensus within the IOCC that it should now take over the demand forecasts and other statistical work that the PAW had handled during the war. Fowler cautioned that "It is quite evident that a number of organizations have their eyes on the data files of the PAW, and apparently the Bureau may have to fight if it gets the material it wants. Or maybe I should say that the Bureau had better get 'high behind' before there is an act of Congress turning it over to somebody else."[70] These fears were not realized, but they indicated that another level of post-war planning was also necessary.

Also in December, Fowler met with officials of the Mid-Continent Oil and Gas Association, Independent Petroleum Association, and the refining editor of the *Oil and Gas Journal* to discuss post-war federal petroleum research, "a subject of primary interest to industry at that time."[71]

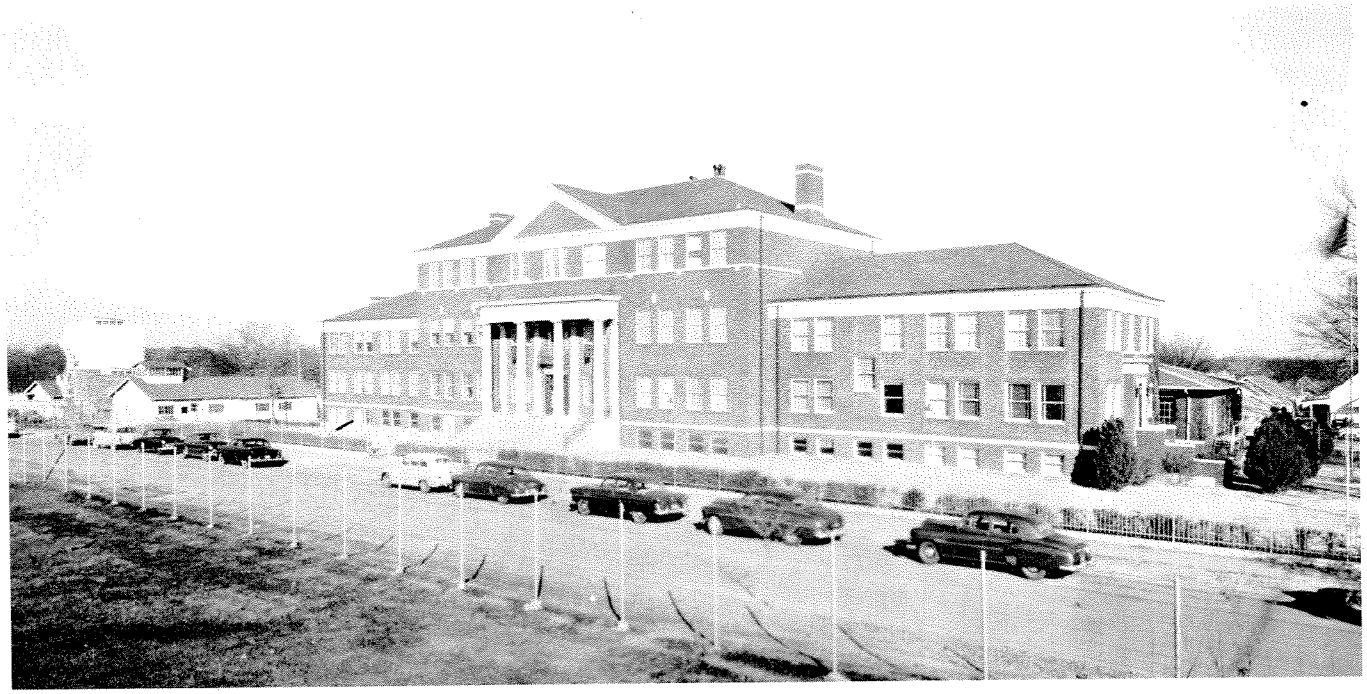
A central activity at Bartlesville during the first six months of 1946 was the compilation, revision, and editing of manuscripts and reports. Because of the extensive field work and testing that had been required during the war, and the quick turnaround demanded by the PAW for reports, station personnel had not had the time to produce the permanent Bureau publications that Smith had fostered during his long tenure. In his monthly letter of May 1946, Smith raised this issue directly with Cattell. Working from a list of Bureau publications from 1940 to 1946, Smith said he was shocked to note that "Not one bulletin or monograph was published in this period, and only three technical papers." He argued that, except for two important field reports, the other seventy-six listed represented "plenty of 'PUBLICITY' but little 'REPUTATION.'" Cattell responded with a general memorandum to all Supervising Engineers which echoed Smith's concerns but toned down the rhetoric.[72]

The immediate post-war years remained ones of consolidation. Part of this involved the completion of manuscripts and publication of data, but it also meant carving out a research agenda that could deal adequately with both the backlog problems that remained from the pre-war era and new sets of challenges presented in the future. Now that the wartime emergency had come to an end, could Bartlesville and the Bureau sustain the view that government-sponsored research had a continuing role to play in the modern American petroleum and natural gas industries?

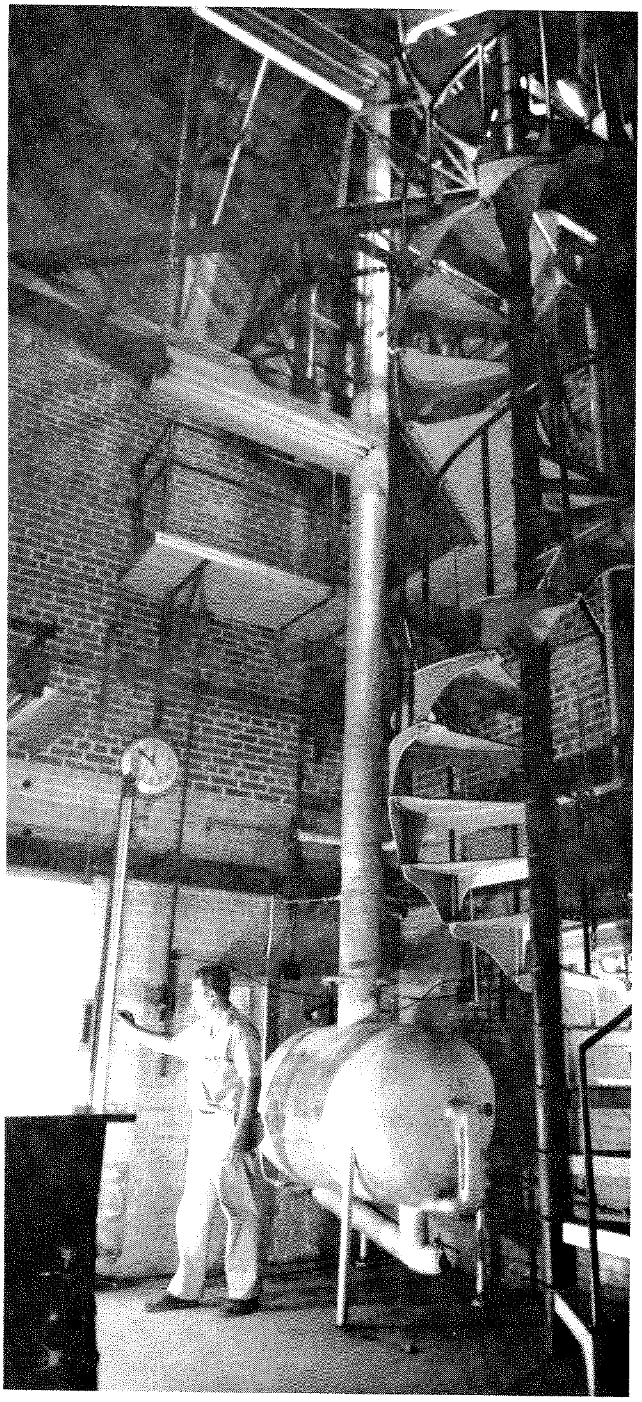
NOTES

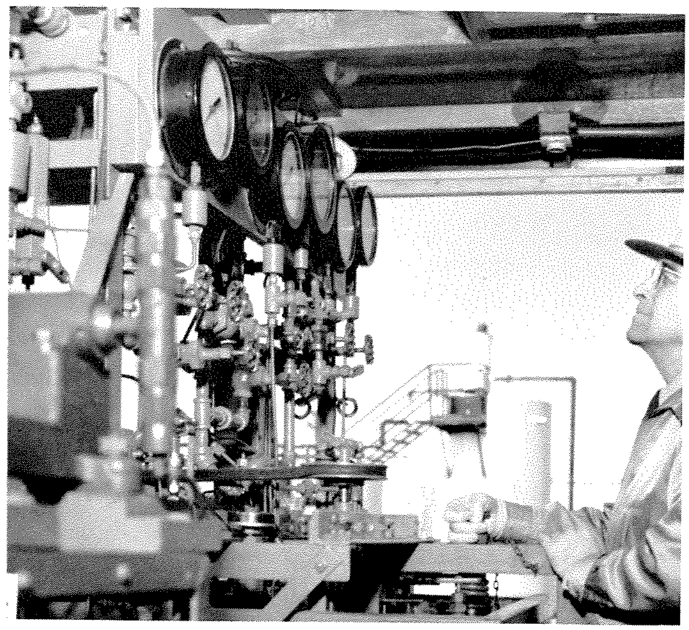
1. Address of the Hon. Harold L. Ickes before the 22nd annual meeting of the American Petroleum Institute, San Franciso, November 3–7, 1941, copy in RG 70, Box 224329, folder 022.1-API.
2. H. C. Miller and H. C. Fowler, "War Work of the Production Section of the Petroleum and Natural Gas Division, Bureau of Mines, Department of the Interior," Box 324908, pp. 2, 12.
3. *Ibid.*, pp. 19-21; Monthly Report, Petroleum and Natural Gas Division, June 1941, Box 224328, folder 017.4l–division reports.
4. Miller and Fowler, "War Work," p. 24; Ludwig Schmidt to R. A. Cattell, July 28, 1940, Box 322235.
5. Miller and Fowler, "War Work," pp. 25-28; Monthly Report, Petroleum and Natural Gas Division, June 1941.
6. Gerald Nash, *United States Oil Policy, 1890–1964*, (Pittsburgh, 1968), p. 160; Monthly Report, Petroleum and Natural Gas Division, December 1941, Box 224328, folder 017.41–division reports; Miller and Fowler, "War Work," pp. 29-30.
7. Monthly Reports, Petroleum and Natural Gas Division, August, September, 1941, Box 224328, folder 017.41.
8. Biennial Report, Petroleum and Natural Gas Division, FY 1942–43, Box 224332, folder 050, p. 75; Miller and Fowler, "War Work," pp. 30-31.
9. Miller and Fowler, "War Work," p. 33.
10. *Ibid.*
11. *Ibid.*
12. "History of Oil and Gas Investigations Appropriations Used on Special War Assignments" (Fiscal Years 1942–1945, inclusive), Box 324908.
13. *Ibid.*, Ernestine Adams, "History and Analysis of the Bureau of Mines' Petroleum and Natural Gas Division" (reprinted from *The Petroleum Engineer*, December 1948, January, February, March, 1949, pp. 1-2.
14. Matthew Van Winkle, *Aviation Gasoline Manufacture* (New York, 1944), pp. 3-9, 21-23; H. M. Smith, A. J. Kraemer, and H. M. Thorne, *Aviation Gasoline and its Component Hydrocarbons: Wartime Research (1940–45)*, Bureau of Mines Bulletin 497 (Washington, D.C., 1951), p. iv.; Harold F. Williamson, Ralph L. Andreano, Arnold R. Daum, and Gilbert G. Klose, *The American Petroleum Industry: The Age of Energy*, 1899–1959 (Evanston, IL, 1963), pp. 631-32; John W. Frey and H. Chandler Ide, *A History of the Petroleum Administration for War* (Washington).
15. Van Winkle, *Aviation Gasoline*, pp. 22-23; John T. Enos, Petroleum Progress and Profits (Cambridge, MA, 1962), pp. 131-150.
16. Monthly Reports, Petroleum and Natural Gas Division, December 1940 through December 1941, Box 224328, folder 017.41–division reports.
17. Memorandum, Harold M. Smith to N. A. C. Smith, November 3, 1941, Box 224330, folder 621; see also A. J. Kraemer to N. A. C. Smith, November 22, 1941, Box 224330, folder 621.
18. Harold M. Smith to N. A. C. Smith, December 1, 1941, Box 224330, folder 621; A. J. Kraemer to Harold M. Smith, January 15, 1942, Box 224330, folder 621; Wright W. Gary to Dr. Walter G. Whitman, NACA, February 2, 1942, Box 224330, folder 621.
19. A. J. Kraemer to Harold M. Smith, February 18, 1942, Box 224330, folder 621.
20. Van Winkle, Aviation Gasoline, pp. 69-70; W. L. Nelson, *Oil and Gas Journal* (January 1, 1942), p. 14; Harold Smith to A. J. Kraemer, February 18, 1942; L. S. Cannon, Continental Oil Company, to N. A. C. Smith, February 19, 1942, Box 2243301, folder 621; Monthly Report, Bartlesville Station, May, June, 1942, Box 224328, folder 017.4.
21. Annual Report, Bartlesville Station, 1943–1944, Box 224332, folder 050, pp. 18-20; Monthly Report, Bartlesville Station, April 1945, Box 2293321, folder 017.41; Monthly Report, Bartlesville Station, September 1941, March 1942, April 1942, Box 224328, folder 017.4.
22. Smith, Kraemer, and Thorne, *Aviation Gasoline*, pp. 1-3.
23. Frey and Ide, *PAW*, p. 288; Williamson et al., *Energy*, p. 748.
24. Biennial Report, Petroleum and Natural Gas Division, 1942–43, 1943–44, Box 224332, folder 050; Fifty Years of Petroleum Research (Bartlesville, OK, 1968), p. 41; Williamson et al., *Energy*, p. 789; Frey and Ide, *PAW*, pp. 199-202.
25. Theodore E. Swigart, "Handling Oil and Gas in the Field," History of Petroleum Engineering (New York, 1961), pp. 919-920; Miller and Fowler,"War Work," p. 43.
26. M. A. Schellhardt to Ellis A. Hall, Condon Petroleum Co., July 31, 1941, Box 224329, folder 460.2; C. K. Eilerts and M. A. Schellhardt, "Flow Characteristics, Composition, and Some Liquid-Phase Properties of Hydrocarbon Fluids from a Combination Well," Bureau of Mines Report of Investigation 3402, 1938; Miller and Fowler, "War Work," pp. 43-44.
27. Miller and Fowler, "War Work," pp. 45-49; R. E. Heithecker to R. A. Cattell, December 31, 1941, Box 224329, folder 460.2.
28. R. E. Heithecker to Harry C. Fowler, February 14, 1942, Box 224329, folder 460.2; Miller and Fowler, "War Work," pp. 54, 58.
29. Miller and Fowler, "War Work," p. 58.
30. *Ibid.*
31. *Ibid.*, pp. 58-60.
32. *Ibid.*, pp. 56, 61.
33. M. E. Schellhardt to R. E. Heithecker, March 15, 1943; Schellhardt to Harry C. Fowler, March 20, 1943, Box 224331, folder 017.41; Miller and Fowler, "War Work" pp. 61-63.
34. Monthly Report, Petroleum and Natural Gas Division, August 1942, Box 224330, folder 017.4.
35. G. S. Whitby, C. C. Davis, and R. F. Dunbrook (eds.), *Synthetic Rubber* (New York, 1954), p. 42; Henrietta M. Larson, Evelyn H. Knowlton, and Charles S. Popple, *New Horizons: History of the Standard Oil Company, 1927–1950* (New York, 1971), pp. 170-74.
36. Whitby et al., *Rubber*, pp. 56-70.
37. *Ibid.*, pp. 42-43; Larson et al., *New Horizons*, p. 508.

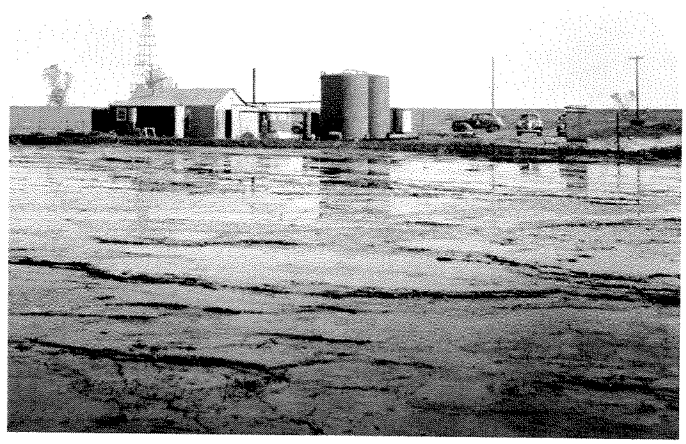
38. Monthly Report, Petroleum and Natural Gas Division, August 1942, Box 224330, folder 017.4; James B. Conant, Karl T. Compton, and Bernard M. Baruch, *Report to the Rubber Survey Committee* (Washington, D.C., 1942); U. S. Congress, House, *The Rubbber Situation, Message from the President of the United States*, September 10, 1942, 77 Cong., 2 sess., House Document No. 836.
39. H. C. Fowler to Ludwig Schmidt, September 15, 1942, Box 322235, folder, "H. C. Fowler."
40. Frederick D. Rossini, *Chemical Thermodynamics* (New York, 1950), pp. 1-2; J. M. Smith and H. C. Var Ness, *Introduction to Chemical Engineering Thermodynamics* (New York, 1975), pp. 1-9; George Sutton Parks and Hugh Martin Huffman, *The Free Energies of Some Organic Compounds* (New York, 1932), pp. 9-11; Donald R. Douslin, interviewed by Rodney Carlisle, Bartlesville, OK, October 7, 1980.
41. Van Ness, *Thermodynamics*, p. 2.
42. Monthly Report, Petroleum and Natural Gas Division, February, May 1943, Box 224330, folder 017.41; Douslin interview; Frederick D. Rossini, Beveridge J. Mair, and Anton J. Streiff, *Hydrocarbons from Petroleum* (API Project 6) (New York, 1953), pp. 1-3; Frederick D. Rossini, "Fifty Years of Thermodynamics and Thermochemistry," *Journal of Chemical Thermodynamics*, 8 (1976): 803-834.
43. Monthly Report, Petroleum and Natural Gas Division, February, June 1943, Box 224330, folder 017.41.
44. Douslin interview; Monthly Report, Bartlesville Station, July 1944, Box 224332, folder 017.41.
45. Douslin interview.
46. Monthly Letters, J. W. Knowlton, August 25, 1943; October 27, 1943; November 29, 1943; December 28, 1943; January 28, 1944; February 25, 1944; March 25, 1944; April 24, 1944; May 25, 1944; June 26, 1944, Box 224331, folder 017.41; Monthly Letters, Guy Waddington, May 24, 1944; April 24, 1944; March 25, 1944; Box 224331, folder 017.41.
47. Whitby et al., *Rubber*, pp. 102-103.
48. Monthly Report, Bartlesville Station, March, April 1945, Box 225332, folder 017.41; Monthly letters, Donald Douslin, January 26, 1945; February 24, 1945; March 26, 1945; April 25, 1945; May 24, 1945; June 23, 1945, Box 224332, folder 017.41.
49. Monthly Letters, Guy Waddington, April 25, May 24, June 23, 1945; Monthly Letter, J. W. Knowlton, June 25, 1945, Box 224332, folder 017.41.
50. H. C. Fowler to Ludwig Schmidt, September 15, 1942, Box 322235, folder "H. C. Fowler."
51. *Ibid.*
52. Ludwig Schmidt to R. A. Cattell and H. C. Fowler, December 16, 1942, Box 322235.
53. Biennial Report, Petroleum and Natural Gas Division, FY 1942–43, Box 224332, folder 050, p. 9; Monthly Report, Petroleum and Natural Gas Division, March 1942, Box 224328, folder 017.41; R. A. Cattell to N. A. C. Smith.
54. R. A. Cattell to N. A. C. Smith, March 18, 1942, Box 322235.
55. H. C. Fowler to Ludwig Schmidt, December 24, 1942, Box 322235.
56. Miller and Fowler, "War Work," pp. 76-77; D. B. Taliaferro and David M. Logan, "History of Water Flooding of Oil Sands in Oklahoma," Bureau of Mines Report of Investigation 3725 (November 1942); Monthly Report, Bartlesville Station, September 1944, Box 224332, folder 017.41.
57. Eugene G. L. Leonardon, "Logging, Sampling, and Testing," *Petroleum Engineering*, p. 501; R. R. Sayers, Director, Bureau of Mines, to Francis X. Shea, Assistant Attorney General, February 17, 1943, Box 224331, folder 019.22; Shea to Sayers, January 25, 1943, Box 224331, folder 019.22.
58. H. C. Fowler to H. C. Miller, January 29, 1943, Box 224331, folder 019.22; Fowler to C. A. Young, API, February 24, 1943, Box 224331, folder 019.22; Leonardon, "Logging," p. 501.
59. Biennial Report, Petroleum and Natural Gas Division, 1942–43, Box 224332, folder 050; R. A. Cattell to Ludwig Schmidt, November 3, 1942, Box 322235.
60. R. R. Sayers to E. A. Poe, AGA, July 14, 1941, Copy of Cooperative Agreement, July 1, 1941, Box 224330, folder 826AGA; H. D. Hancock, AGA, to Members of the Technical Research Committee, July 5, 1945, Box 224333, folder 022.7; Biennial Report, Petroleum and Natural Gas Division, 1942–43, Box 224332, folder 050, pp. 106-107.
61. O. C. Blade, "National Motor Gasoline Survey, Summer 1945," Box 224334, folder 632.1.
62. R. A. Cattell to Nielsen B. O'Rear, June 17, 1946, Box 224334, folder 632.1.
63. Monthly Report, Petroleum and Natural Gas Division, January 1945, Box 224332, folder 017-41.
64. N. A. C. Smith to H. C. Fowler, January 26, 1945, Box 224332, folder 017.41; Monthly Letter, N. A. C. Smith, February 28, 1945, Box 224332, folder 017.41.
65. Miller and Fowler, "War Work," p. 111.
66. *Ibid.*, pp. 111-129.
67. *Ibid.*, p. 129.
68. Monthly Report, Bartlesville Station, September 1945, Box 224333, folder 017.41.
69. "Somebody's Sweetheart Now," *Time* (December 14, 1942), p. 29; Frey and Ide, *PAW*, pp. 289-90.
70. H. C. Fowler to R. A. Cattell, December 18, 1945, Box 224333, folder 022.97.
71. Monthly Report, Bartlesville Station, December 1945, Box 224333, folder 017.41.
72. Monthly Report, Bartlesville Station, February, March, April, May, June, 1946, Box 224333, folder 017.41; Monthly Letter, N. A. C. Smith, May 29, 1946, Box 224333, folder 017.41; R. A. Cattell to Supervising Engineers, June 11, 1946, Box 224333, folder 017.41.



The office building, constructed in 1918, was enlarged to an administrative-laboratory building (upper picture) in 1937. This enlargement reflected the growth of the Station from 3 to the 58 people listed in the dedicatory booklet. A mobile laboratory is shown (lower) which was used to promote secondary recovery in the late 1940s and 1950s.







Three of the War programs at BETC involved analysis of aviation gasoline basestock, testing of condensate wells for production of basestock, and reclamation of old waste ponds for usable paraffin wax. The picture on the left shows a high-efficiency distillation column constructed for separation of crude oils analyzed for aviation base stock, and toluene for explosive manufacture. The top right picture shows C. K. Eilerts in a mobile laboratory checking the production of a field. The lower right picture shows the plant at El Dorado, Kansas for reclaiming wax from waste ponds.

Chapter 5

PETROLEUM RESEARCH UNDER SIEGE, 1946–1959

As government and industry abandoned wartime projects in the postwar period, the Bartlesville station faced severe problems of adjustment. H. C. Fowler, Superintendent in the decade and a half after the war, fought to rejustify every program and expenditure from year to year in the face of constant pressure to hold down budget and personnel. The search for "problems"—for viable research agenda items which would be both feasible and fundable—became extremely difficult. Budget ceilings, increased costs, the growth of private industrial and university laboratories that preempted whole research areas, all added to Fowler's difficulties. The outside pressures generated internal tensions; morale varied from group to group depending upon leadership, project funding, and personalities. Fowler attemped to build on the tried and true successes of the station, to preserve the best work and most distinguished divisions, and to foster a cautious search for new opportunities.

The economics of oil shaped and sometimes hampered Fowler's efforts. Imported oil from the Middle East undercut prices for American crude, forcing the Interstate Oil Compact Commission and state commissions to keep tight control on domestic production to prevent another low-price crisis like that of the early 1930s. As production in the once-flush fields of Kansas and Oklahoma declined, however, producers and commissions in those states explored means of increasing production through secondary recovery methods, especially forced injection of water. Therefore, despite the national tendency to hold down production, on a regional basis producers and commissions sought federal assistance in perfecting secondary recovery methods. Response to such opportunities had to be limited, for concern with already inflated government expenditures led the public and Congress to question a large role for government through the post-war years. Small increases in salary budget to allow for the cost of living might be acceptable; but programmatic expansion of the station to develop more waterflood expertise or other new programs was extremely difficult to "sell."

With the increased local interest in secondary methods of production brought on by the changes in oil economics, the Production division in particular faced a need to reexamine and rejustify its activities. But each of the other divisions or branches at Bartlesville also faced conditions which threatened their established purpose or function. The Chemistry and Refining branch, for example, had not dealt with refining processes since before World War II, and Superintendent Smith had recognized by the mid-thirties that refining work had become entirely proprietary. In World War II, the section under Harold Smith had done chemical evaluation of crude oil to enhance production of aviation gasoline, but the end of the war brought an end to such studies. The new thermodynamics laboratory had participated in the synthetic rubber project during the war, and the staff and equipment brought together by Huffman for determining the thermodynamic characteristics of hydrocarbon compounds, although in place, lacked a clear research agenda.

Given such conditions, it was a remarkable achievement that Fowler was able to maintain the station's activities. Sheer institutional survival required disruptive transitions and adjustments. Fowler also had to deal with increased internal friction and personality conflicts. Some of the younger staff saw Fowler's attempts to hold onto successful programs, individuals, and talent as mere adherence to tradition—the pursuit of routine for the sake of routine. Persistence paid off, however, and the decade and a half of rear-guard actions in defending funding and emphasizing past and current achievements gradually brought new monies and new projects to the station.

Financial Constraints

From the late 1940s through the early 1950s, Fowler viewed the budget itself as the most serious factor inhibiting his efforts. Federal appropriations for the center ranged between $329,000 and $498,000 per year for the period 1944–1949, and remained under $1 million per year until 1962, just before Fowler's retirement. The apparent doubling of budget over a decade and a half might appear a healthy increase, but in fact the rise in the budget was not steady, but fluctuated as advances were followed by cutbacks through the period. In the period following 1954, trust and working funds (that is, monies from cooperative agreements and contract work by the Bureau of Mines for other government agencies) regularly added over $100,000 to the station's budget. By the late 1950s, the amount from trust and working funds amounted to over $300,000 and was rising steadily. Much of that outside funding came to the station through the efforts of individuals who led the various research groups. As each group raised outside money, that funding could be used to demonstrate industry support, help justify the work of the group, and hence keep it included in the federal budget request as well. Yet the outside funding could sometimes result in a strong group finding its own share of the federal appropriation cut back or "nicked." Those branch chiefs who were good at "beating the bushes" for outside funding were quick to point out to Fowler that compensating cuts in their federal funds were most unfair, and he made an attempt to restrain such cuts.

The budget figures reveal that, in the long run, the station entered a transition period, changing from a laboratory almost entirely funded by, and responsive to, central direction from Washington into a facility working somewhat like a private laboratory—seeking grants and contracts to sustain its work. If the state contribution is omitted, trust and working funds as a percentage of the total station budget climbed from the range of 15–28 percent in the period before 1956 to a range of 30–37 percent in the period 1957–1962. For those branch chiefs who succeeded in raising funds, the reward was secure staffing, some new equipment, and more and more autonomy. By the end of Fowler's administration, the transition was complete, and the branches with the more aggressive leadership had developed the more extensive programs. Such a pattern also had disadvantages, in that the autonomy of the more independent groups worked against a demonstrable, single, coordinated program and left a legacy of internal divisions between the well-funded and the poorly funded for Fowler's successor.

Such a recapitulation of the change over an extended period makes the process sound smoother than was really the case. In fact, the growth of outside cooperative funding was erratic, as was the rise and fall of budgeted funding from year to year. Fowler faced a constant struggle, typical for many government agencies and bureaus, to justify the next year's funding and to stimulate projects that could bring in outside money, with no assurance that next year's federal or outside funding would even be up to the current year's level.

Conversely, when the Bureau succeeded in winning an increased appropriation, Fowler found it difficult to adjust the scale of activity upwards. As Fowler noted when the 1957 budget appeared likely to meet request levels, "if we would get all of the money that we estimated we could use in 1957, the step-up from the 1956 level would be so great that we couldn't meet the impact of the increased activity, particularly because of the dearth of qualified personnel."[1]

Despite Fowler's ritualistic complaints about budget limits, however, the station's budget and program grew under his direction, even taking into account the offsetting postwar inflation in supply, utility, and salary costs. The average hourly earnings of United States workers climbed from $1.00 per hour in 1945 to $2.00 per hour by 1957. The consumer price index, taking the period 1947–1949 as 100, had climbed twenty-six points by the end of the 1950s. In the face of low, but persistent, inflation, the apparent doubling of the Bartlesville station's budget between 1949 and 1959 still represented an average of 5 percent real growth per year.

More seriously limiting than the budget itself was the changed marketplace for new talent; in the year 1948–1949, a "sellers' market" developed, and younger men recently graduated from chemistry and engineering programs tended to be attracted to private industry. Fowler and his associates recognized the job marketplace as a major problem throughout the period of his directorship. The Production group, in designing its 1956 budget, noted: "The continuing difficulty of recruiting and retaining petroleum engineers and the inability of the Bureau to compete with the petroleum industry presents a serious problem in program completion. Recent advances in salary ceilings in the lower grades may partially alleviate this condition." The thermodynamics group faced a similar problem: "lack of sufficient funds for a fully adequate staff," as well as the perennial problem of inadequate funding for equipment. Fowler and his branch chiefs believed they could attract a first-class staff if they could get additional budget; funding, they said, was what hampered all efforts to meet program objectives.[2]

During the war years, a number of women had been hired at the station as chemists and researchers. But with a series of post-war reductions in force, most of these women were dismissed for lack of seniority. Cleo Rall, the wife of Bureau chemist Harry Rall, had earned an M.A. in chemistry prior to the war. With the departure of some Bureau technicians during the war, Mrs. Rall went to work at the station, supervising the routine analysis work in the Chemistry group. On the day after the Japanese surrender, she went into Smith's office to offer her resignation "to make way for the boys" who would be returning. Smith demurred, and she stayed on until 1953 before she retired for health reasons. But Cleo Rall was not typical, and there were few well-qualified women available to fill the openings for scientists and technicians. A number of less highly credentialed women who had worked through the war years were rather rapidly dismissed during post-war reductions in force.[3]

Fowler attempted, with no apparent success, to arrange the transfer of several women lab assistants to Laramie or to the oil shale experiment station at Rifle, Colorado. At Laramie, the response was particularly blunt: "We would rather have men. At present, the conditions under which we work are not very desirable for women workers and there are also certain other limitations." Despite Fowler's efforts to find jobs for loyal staff, therefore, the reductions in force fell more heavily on the recently hired women than on the long-term men employees.[4] As a consequence, by the late 1940s, the staff at the station tended to represent an older, largely male, pre-war generation of technicians with training only at the bachelor's degree level.

National Oil Policies

The conservatism and slow adjustment at the Bartlesville station during the 1950s stemmed, at least in part, from larger, deep-seated national factors. In Washington, the Bureau of Mines itself had become set in its ways. Since it dictated the control of manuscripts, funding ratios, and even the station's mission, this was bound to have a stifling effect on station operations and policy. But new interests on the part of petroleum producers represented by the Interstate Oil Compact Commission and regional associations, new concerns of refiners represented by the American Petroleum Institute (API), and new opportunities and problems brought on by the development of gas pipelines to which the American Gas Association (AGA) sought solutions meant that priorities set outside the government could possibly create new roles for the station if the station could adjust.

Throughout the period of Fowler's administration, however, the station's response to outside definitions of priorities remained ambivalent. On the one hand, such initiatives could provide funding and proof of the industrial utility of government research cooperation. On the other hand, Fowler and some of his staff feared that the increasing power of the private sector to set priorities and determine research agendas could represent an infringement on the station's independence. The government laboratory, if it worked too closely with the oil industry, would risk abdication of its role as an objective and neutral influence in petroleum technology. Fowler tried to steer a safe course between the alternatives of private sector support and private sector dictation of government's role.

In 1948, the Gavin Amendment expanded an appropriation for synthetic fuels research, originally set up in 1944, and authorized $1 million for research in methods of increasing recovery of conventional petroleum. Men at the station, in coordination with workers at other stations, prepared a set of proposed studies which would tap that source of federal funds and begin a detailed review of marginal wells in the Oklahoma area. Yet most of the synthetic fuels money went to Laramie and Rifle. Some individuals, particularly Boyd Guthrie and Dan Lankford, transferred to Rifle to work on synthetics.

Although the secondary recovery funding came through congressionally appropriated funds, the Bureau reported on work under the Gavin Amendment both to the government and to the Interstate Oil Compact Commission's Committee on Secondary Recovery. Recognizing the political influence of the oil compact states in securing the appropriation, Fowler presented a report in 1948 which was published in the Compact Commission's own *Quarterly Bulletin*. Through 1949, the Bureau continued to report to the Compact Commission on Gavin fund expenditures and plans, showing how engineering field studies in Oklahoma, Texas, Wyoming, California, and Pennsylvania related to the secondary recovery objectives of the funding. Specific projects at the Franklin, Pennsylvania, station, at the San Francisco Field Office, and at Bartlesville were also pertinent to the import of the Gavin funding.

Perhaps the most important result for Bartlesville of the Gavin Amendment was the organization of the Basic Production Research Group. This group laid the foundation for later work in enhanced oil recovery methods. Specific projects at Bartlesville that related to the secondary recovery interest in the 1950s included: locating abandoned wells through use of metal detectors, study of water-conditioning plants, study of the effect of dissolved gases on corrosion of metal, studies of rates and pressures of water injection, core and water analysis, and proposed uses of radioactive isotopes as tracers.[5]

Fowler also planned, with the funds provided in the act, further work on ideas for two tools under development by the Production group: a liquid level gauge and a well-bore caliper. The liquid level gauge would help determine the flow of water from water injection wells into productive sands; the caliper would determine the inside diameter of well cavities. This information might allow for more accurate determination of the flow and direction of water used. In 1952, the station filed for a government patent on the gauge. But the design of the well-bore caliper represented a "formidable" problem, as it had to be capable of being inserted through a 2-inch bore, then expanded to measure cavity diameters up to 36 inches to an accuracy of 1/4-inch, then collapsed for withdrawal through the tubing. The umbrella-rib-like design was to be ready for field tests in 1949. The project eventually led to a workable design, which was patented in 1956.[6]

By 1953, the Eisenhower administration cancelled the whole synthetic fuels program and the extra funding for secondary recovery work, due partly to industry pressure from integrated multinational firms and partly to the increased quantity and supply of crude oil coming in from Middle Eastern sources. The local rise of expectations and subsequent cutback was part of the much larger national debate over sources for petroleum fuels.[7]

In 1948, oil industry analysts recognized that the United States was at a turning point in its energy supplies. In 1947–1948, for the first time, the nation imported more petroleum than it exported. American-based independent oil producers sought a duty on foreign oil, a duty that the coal and oil shale states advocated be used to subsidize an extensive synthetic fuels industry, converting solid fossil fuels into liquid products. But the cost of imported oil, even with the addition of a duty, remained lower than American crude oil; oil imports continued to grow. Although not a "glut" of oil in the same sense as the East Texas boom of the early 1930s, the flood of foreign oil led to continued limits on domestic U.S. production.

Fowler expressed considerable doubt about oil shale as a source for synthetics, despite the national program for synthetic fuel research in the period 1944–1953. Bartlesville itself did not have a direct role in oil shale work, most of which was conducted at Bureau of Mines facilities at Rifle, Colorado, and at Laramie, Wyoming. Another facility at Louisiana, Missouri, studied processes for the hydrogenation of coal. When Ambrose, now a Bureau alumnus holding the position of president of Cities Service Oil Company, sought estimates of commercially available and recoverable oil shale, Fowler offered a critique of earlier Bureau of Mines estimates that some 300 billion barrels of oil from shale might be in reserve in Colorado, Utah, and Wyoming. Accounting for the need to leave supporting pillars standing in an underground mining program, and estimating a recovery rate of about 15 gallons of oil per ton of shale, Fowler thought that ultimately recoverable oil might amount to 200 billion barrels. Even when discussing such vast quantities, however, he retained a cautious and conservative tone. "Assuming that 75 percent of the shale can be mined, that satisfactory methods for retorting all of the mined shale can be developed," he thought the 200 billion barrel estimate "not unreasonable."[8]

Fowler obtained his information by sending queries to others in the Bureau who were working on various aspects of shale, including J. D. Lankford at the Rifle, Colorado, shale station, and Boyd Guthrie, head of the Rifle facility and regarded as the Bureau's leading shale expert. Both men had previously worked at Bartlesville.[9]

On the local level, Harold Smith became a minor advocate of synthetic fuels, while Fowler continued to indicate cautiously the limits of the resources. Smith became an instant expert on synthetic liquid fuels when he was invited to make a guest appearance at an "Information Please" session of the Natural Gasoline Association meeting in Ft. Worth in 1948. Although Smith was well known by the natural gasoline people, and was invited because of his contacts, he was not in fact a specialist in synthetic fuels. He worked furiously to build up his own knowledge to be able to handle the session, seeking help from R. M. Gooding in the Office of Synthetic Fuels at the Bureau of Mines headquarters in Washington, who supplied him with reports and data. At the time, retorted oil from shale cost $2.50 a barrel in raw material cost, not taking into consideration the actual cost of refinery construction. This price did not compete with the going rate of $1.75 per barrel for petroleum crude. Smith used Gooding's material, and the two jokingly noted that a bit of reading made one a "synthetic fuels expert" almost overnight.[9a]

On a national level, synthetic fuels and secondary oil recovery received only modest and short-lived support. But on a state and local level, in the mid-continent, interest in secondary recovery methods of increasing domestic oil production ran high. Policies laid down by state commissions tended to foster the development of marginal or stripper oil wells. In most states, those wells producing less than 10 barrels a day were not subject to limitation on the number of days per year allowed for production. For this reason, a marginal well of low production could be more desirable to a producing company than a more efficient, high-production well. Consequently, the mid-continent region saw a great growth in interest in secondary production of the older, marginal wells.

Of particular interest to Bartlesville in the immediate post-war period was the opening up of waterflood projects in Nowata County, Oklahoma, due east of Bartlesville, and in nearby counties due north in Kansas. Waterflood techniques had been discovered accidentally in Pennsylvania as a result of an illegal disposal of water into an oil well. As a means of increasing production, the method became popular in the 1920s as older wells lost pressure. By injecting water under pressure, oil could be forced to producing wells. Bureau of Mines investigators had studied the technique, and some producers experimented briefly with the methods in Oklahoma in 1930 and in Pennsylvania during the war, in cooperation with the Bureau's Franklin office. The great boom in domestic oil production in the 1930s decreased mid-continent interest in waterflooding, but when Oklahoma wells declined in the post-war years and state policies excluded the low production wells from proration, the technique became economically and technically viable. Secondary recovery remained of interest in the mid-continent region, and the Interstate Oil Compact Commission, which represented mid-continent oil regulatory commissions, monitored developments closely through the period.[10]

For a period of over a decade after World War II, the Bureau of Mines at Bartlesville hosted waterflood tours. Small independent producers, as well as petroleum production specialists from larger firms such as Phillips Petroleum, would gather for one or two auto caravan tours of waterflood projects per year. Kenneth Johnston, a petroleum engineer who had joined the station in 1942, arranged the details of the tours, charging $4.00 to each member of the group to offset the cost of the barbecue and beer that ended each tour. As many as 125 cars, escorted by the Oklahoma Highway Patrol, would carry 400 to 500 participants to a number of field projects. Printed handouts prepared by Johnston gave details of the various projects, and the tours served as a kind of "moving convention" of local producers, who used the opportunity to exchange information and to enjoy a social get-together.[11]

Comprehensive studies of projects to be toured were compiled as Reports of Investigation or Information Circulars and published for distribution to tour participants. Most of these were written by J. P. (Jack) Powell, J. L. (Les) Eakin, or Kenneth H. Johnston either alone or in collaboration. In addition to their technical content, a popular part of these reports was the detailed 3-dimensional drawings of each project prepared by Joe Lindley, Engineering Technician with the Bureau of Mines in Bartlesville.

These waterflood tours brought the station considerable regional notice and support through the late 1940s and the early 1950s. In fact, they were probably the single most important activity of the station in this period, at least when measured in terms of their public relations value among mid-continent oil producers. No other activity drew such measurable regional interest and attendance. In one sense, the tours represented a reversion to the demonstration style of operation characteristic of the early 1920s. But in another sense, they reflected also the effort to adapt to the changing economic factors confronted in the post-war decade.

In the mid-continent, smaller producing companies and regional associations of producers continued to request Bureau of Mines studies. And through the late 1940s and the 1950s, the station continued to produce field engineering studies of various oil-producing districts. As in the 1920s, the station gathered well information from producers, collected data on production rates and decline in production over time, and published reports. In 1947, in response to a request from the North Texas Oil and Gas Association, the station gathered data for a study of waterflood results in North Texas. In 1948, the station collected data on the Healdton field in Carter County, Oklahoma, one of the earliest major producing fields in the mid-continent region. In 1949, Wade Watkins of the station worked closely with the Kansas-Oklahoma Water-Flood Operators on questions of injection well spacing.[12]

The Bureau's traditional avoidance of areas of research in which the larger firms conducted competitive work had an increasingly limiting effect as the private research of the large firms expanded after World War II, even though Bartlesville continued to cooperate with local small producers and regional associations. Over and over, Fowler reminded others that their proposals came dangerously close to areas of private research. In 1956, for example, he warned against work in rock physics: I "feel that the Bureau should be very careful not to get into a field that is already preempted by industry and probably one in which industry can do a better job than the Bureau . . . I can see where the Bureau could spend a great deal of money in that area of research, and it might lead to proprietary questions and patent claims if the study were not watched closely." Similarly, he argued against proposals for work in offshore oil engineering, on the grounds that commercial specialists preempted the research. The highly technical problems, he feared, would constantly place the Bureau in the position of competing with proprietary developments.[13]

An incident which shed light on Fowler's style in handling relations between the Bartlesville station and industry on an extremely local level developed during this period. In 1949, the historian Carl C. Rister wrote *Oil! Titan of the Southwest,* naming as the first commercial oil well in Oklahoma, not the Nellie Johnston #1 drilled in 1897 in Bartlesville, but an entirely different location six years earlier than the Bartlesville well. The local Chamber of Commerce, representing local oil history pride, protested the work in its draft stages, and Rister finally included a statement that Nellie Johnston was "alleged to be the first commercial oil well in the state." The issue stayed alive, Fowler asked Cattell to keep the Bureau from getting involved. In 1953, a Bureau of Mines film, in its early stages, followed Rister's lead and referred to 1891 as the beginning of commercial production of oil in the state. Sensitive to the local pride involved, Cattell set about having the reference in the film removed. He did so, however, not by noting explicitly the potential political problem, but by developing a thorough and detailed scholarly analysis of the historical incidents of oil discovery in Oklahoma, which pointed out that the whole issue of first claims was fraught with ambiguity. Sending this document to the Bureau of Mines division chief in charge of the motion picture project was successful in getting the reference deleted. The fact that Fowler regarded the incident as potentially "embarrassing," rather than either an amusing critique on local pride or an opportunity for scholarly argumentation—as did Cattell—reflects the cautious and conservative style that Fowler brought to walking the tightrope of relations with the private sector.[14]

In another incident reflecting his style, Fowler reacted with considerable alarm to the fact that, in 1955, the API Mid-Continent District Study Committee on Core Analysis appointed an industry group to gather information and report on underground brines found in petroleum drilling. Both Fowler and Wade Watkins, petroleum engineer, perceived the API activity as an inroad into territory that had long been dominated by the Bureau; they felt it unlikely that the Institute and the Bureau could cooperate on a joint study. Fowler's reaction was to deemphasize future water studies at the station, to bring quickly to publication work pending on Oklahoma brines, and to coordinate future work without duplication of effort. "I think we should check carefully with the API to find out if there is to be an overlap in the other areas where we have been collecting . . . water samples and put our emphasis on water studies that industry is not in a position to do."[15]

On a national scale, the development of research facilities by integrated firms could only limit the role the government's laboratories might play. Industrial laboratories grew to dominate the research effort in petroleum. In the post-war years, extensive veterans' benefit programs swelled enrollments in colleges and universities, giving a boost to university research. The growing university facilities provided training and experience for industry technicians and scientists, replacing the modest part that Bartlesville had once played as a training ground.

Although private research might have a limiting effect on the station, it could also produce some benefits for the station's research program to the extent that the station could react with flexibility to industry initiatives. For example, when the API began its coordinated research project on sulfur compounds in petroleum due to increased marketing of sulfur-laden petroleum from U.S. fields and from abroad, which continued from 1948 through 1965, the laboratories at both Laramie and Bartlesville obtained small parts of it. Work at the Laramie station on the sulfur project included synthesis, purification, and determination of properties of sulfur compounds. Work at Bartlesville included determination of thermodynamics data of sulfur compounds, and separation, isolation, and identification of sulfur compounds in crude oils. Funding at Bartlesville varied for the two projects, totaling between $10,000 and $26,000 per year for the life of the projects. Related research on other aspects of the problem was carried on at university and private industrial laboratories. A similar effort, dealing with nitrogen compounds, continued from 1954 through 1966. Both projects allowed for Bartlesville to support work in its thermodynamics laboratory.[16]

In later years, the participation of the thermodynamics group in these two API projects was remembered with an ambivalent mixture of pride and embarrassment. On the positive side, the fact that the laboratory had Ph.D. chemists with the skill and equipment to produce technically excellent and accurate characterizations of compounds could be seen as a tribute to the national and international repute of the Bartlesville station. And the API funding over an 18-year period demonstrated that the station earned industry recognition and approval for its work from the major national industrial association in petroleum. Yet the repetitive nature of the work, and the fact that such studies were not innovative but simply the development of "handbook data" directed by an outside group, suggested to some that the station's top scientists were engaged, not in pure research, but in a sophisticated type of busywork, an elaborate exercise in routine, directed by outside administration. Such critics were not able to recognize the fact that handbook data were essential to the design of processes and equipment.

Bartlesville cooperated through 1951 and 1952 with the U.S. Geological Survey and the Petroleum Administration for Defense (PAD) in conducting a field survey of the Scurry Reef oil field in west Texas. In an effort with echoes from World War II research, the survey was taken on as part of the PAD reaction to increased demand during the Korean War. The engineering field study used data on reservoir fluid and reservoir rock obtained from cores to arrive at an estimate of the volume of oil originally in place in the reservoir. Such studies would help yield estimates of total U.S. reserves. Using techniques and principles developed by Ken Eilerts, the station submitted details of the prospective effects of repressurization, which could increase production of gasoline-rich fluids, even after cooperation with the Petroleum Administration for Defense came to an end in mid-1952.[17]

Throughout this period, Fowler developed and improved the procedures for obtaining new outside funding. Responding to developments in oil technology, a group or individual at Bartlesville would rapidly develop a proposal and attempt to sell it to an outside agency or association. If funded, the individuals who developed the proposal would see the project through to implementation. The process did not always work, but it provided a system of incentives that favored the more energetic and imaginative researchers. The economic adjustments of the post-war era created a host of opportunities in petroleum research. Although some of the men at Bartlesville responded, the net effect of the rapid changes in petroleum research, as noted earlier, especially the growth of industrial laboratories, was to diminish the station's proportionate importance.

The political atmosphere of the 1950s aggravated this trend by stressing the virtues of private enterprise and limited government expenditures. The vast growth of both private and university laboratories preempted areas of new technology. The massive increase in imported oil tended to retard interest in research into new methods of increasing production, with the exception of regional interest in waterflooding. In 1928, the Bureau had been at the center of petroleum research, particularly in studies of underground formations and in petroleum engineering; twenty-five years later, by the mid-1950s, that central locus of research had moved to the private sector, despite the station's newly added scientific capabilities. It seemed to Fowler and the Bartlesville researchers, despite their best efforts, that there was little they could do to regain the central place once held by the station.

Internal Stress and Achievement

At the same time that national trends reduced the importance of the station, local and internal problems exacerbated the difficulties of the post-war transition.

Fowler, a civil engineer with background in safety engineering who had worked at the Washington office, had been selected as Superintendent in 1946 over Harold Smith, an accomplished chemist who enjoyed a national reputation. Although both men, as professionals, were able to work together, increasing tension built up between them. In 1954, Smith was selected by the Bureau of Mines to be Director of "Region IV," which included Texas, Oklahoma, Arkansas, and Louisiana. The headquarters of the Bureau region was shifted from Amarillo, Texas, to Bartlesville to accommodate Smith, and he operated the regional office from the Post Office Federal Building, several blocks from the station. Although such a post would appear to put Smith in the line of authority over Fowler, Fowler continued to deal directly with the Petroleum and Natural Gas Division of the Bureau of Mines in Washington, providing Smith only with copies of selected memoranda.

Smith was put in charge of the region as part of an effort from headquarters to decentralize the Bureau and to make field facilities more responsive to local needs. But Fowler and Taliaferro (head of the Secondary Recovery Division at the station) preferred central to regional coordination and reminded Cattell at headquarters from time to time of a host of inefficiencies which sprang from funding a regional office. The strategy, claimed Taliaferro, "is contrary to the accepted good management practices followed by major oil companies," and resulted in duplication of work from region to region. Taliaferro also argued that funding a regional office took money away from research.

Consistent with this view, Fowler and Taliaferro supported the establishment of "steering committees," particularly in production, arguing that this would bring together researchers from various regions and avoid duplication. Although ostensibly designed to eliminate duplication of projects, the steering committee also had the clear effect of preventing regional directors like Smith from designing a regional, rather than a national, plan. By 1956–1957, it became clear that Smith would not win increased power as a result of decentralization. Indeed, Smith won very little support from Washington in the struggle. And by the late 1950s, the Regional office had become less important than the station Superintendent office, as Fowler continued to be able to work with Washington as if the Regional level did not exist.[18]

Fowler sometimes criticized technical "people," without naming Smith directly, who were promoted to administrative tasks. Furthermore, suggestions for administrative reform and research agendas advanced by Smith received severe and pointed critiques by Fowler and others at the station. In at least one case, plans for a conference advanced by Smith were thoroughly reviewed at the station and critical comments forwarded to headquarters.[19]

Other examples of more minor disagreement appeared between the two men. Smith developed a plan for keeping senators and congressmen from the region posted as to recent work of the station. He also worked to keep Bartlesville in the local papers. He prepared a detailed story on recent activities, for example, and had Taliaferro lend his name to it to have a local author as authority. In a report on the issue to Fowler, Smith recommended that a similar story be issued every three to four weeks and be sent to the local Bartlesville newspaper, the *Examiner Enterprise*. Fowler did not adopt the plan as set out by Smith.[20]

Other issues of personality, politics, and career path deepened, rather than ameliorated, a tendency toward stagnation at the station. Station scientists generally respected the thermodynamics section—headed first by Huffman during the war years then in turn by Guy Waddington, John P. McCullough and Don Douslin—as the elite of the laboratory. These men were Ph.D.s, dedicated to rather pure analytic problems, giving the group a style and manner that set it apart from much of the rest of the station. Although the two projects with API during the late 1940s and early 1950s provided the thermodynamics branch with a set of specific problems and a raison d'etre, the more academic and scientific (rather than practical and engineering) nature of the branch and its work, its established and repeated funding from API, and its consequent insulation from year-in and year-out struggles for outside funding, tended to keep it from developing the further industrial contacts and leads for new work that characterized the Production, Secondary Recovery, and Chemistry-and-Refining Divisions.

An undercurrent of tension through the period may have reflected the larger difference between the styles of those with training as scientists, particularly the chemists, and some of the petroleum technologists with training as engineers. The fact that Fowler, a civil engineer with little scientific background, supervised the work of accomplished scientists, some with training at the doctoral level, contributed to the undercurrents of disunity. All the staff recognized that loyalty to the station and to its leadership through the years of tight budget was necessary to survival. Yet when difficulties arose—such as reductions in force, division and use of scarce funds, assignment of staff to particular projects, or the acquisition of outside funding—the tensions would surface.

The division between scientist and technologist was not, of course, perfectly clear-cut. Since much of the scientific work of the station grew out of the need for technical solutions to practical problems, scientists suffered from the problems of technology: the demand for timely results for immediate needs. The work of Eilerts exemplified the dilemma of scientist-as-technologist.

Since 1936, Eilerts had been studying phase relationships in gas condensate wells, continuing to work towards the publication of a massive monograph. By the 1950s, he was in charge of an autonomous research group within the station to continue his work. The work reflected a sophisticated study of pressure-volume-temperature relationships of various gas condensate mixtures in different fields; but the fact that the project took over twenty years to finish limited the participation by Eilerts and his assistants in other problems and projects. He regarded a four-year project in the late 1940s dealing with the corrosion of oil well casings and tubing as a digression from his work on the monograph, for example, but he had to do it. So he fought to wrap up the shorter project quickly so that he could get back to his gas condensate work. His report on corrosion indicated that chrome alloys corroded far less than unalloyed steel, and the chromium alloys were widely adopted. Even on this short-range project, Eilerts was dissatisfied as a scientist, because the need for timely results prevented determination of the exact reasons for the better survival of chrome alloys under petroleum and gas contact.

Although others respected his long-term project, the extensive time involved in the gas condensate study and its probable irrelevance to market conditions when eventually published caused some resentment among his colleagues. Later, even Eilerts himself acknowledged that he had been too much of a perfectionist and that the project, when completed, attracted less attention than it might have if published some fifteen years earlier. When he began, the practice of pumping dry gas from wells which produced a mixture of wet and dry gas back into the underground formation had made economic sense, since the alternative to repressurization and underground storage was simply to release the dry gas and to flare it after removing the liquid fractions to refine into products.[21] But with the spreading construction of gathering and transmission gas pipelines in the post-war years, most dry gas produced in the field could be economically marketed, and was thus no longer available to repressurize the formation. Therefore, details of the liquid-vapor point of the mixtures of particular hydrocarbons present in various fields had far less practical significance when he finally published them in 1958 than they had earlier. Eilerts' scientific work was fifteen years too late for the market. He did not personally despair, however. On completion of the project in the late 1950s, Eilerts engaged in a program of computer applications to the study of underground formations, earned himself a masters degree in mathematics in 1963, and set off on a new course of research.[22]

In a sense, the pursuit of various projects by talented, well-trained, and powerful individuals like Harold Smith, Waddington, Douslin, and Eilerts tended to proceed in some isolation from one another and from the work of the rest of the station. Whether this development could have been offset by a more effective administrative style than that displayed by Fowler is, of course, a difficult question; but the answer may well be yes, at least to some degree. Many researchers at the station admired and respected Fowler as an administrator, and as a man of complete integrity. But the spirit of teamwork that had prevailed under the leadership of Nick Smith appeared to decline, and Bartlesville increasingly lacked the congeniality of joint ventures.

Efforts to Secure Outside Funding

Although the station suffered through readjustment, it remained active, generating a series of studies and reports, many of them useful and timely to the technological needs of the petroleum industry.

In 1955, the Production and Secondary Recovery groups at Bartlesville met with colleagues from Laramie and from other Bureau offices to plan priorities and research objectives. However, the meetings resulted largely in a program to eliminate duplication of work between the stations and resulted in recommendations for decreases, rather than increases, in budget and staffing. Even before the conference, Bartlesville's Watkins expressed his "firm belief" that the time was ripe for "an evaluation of the Bureau's petroleum-production research programs and for some action designed to eliminate duplication of effort and misdirected efforts (if any)."[23] The meeting became a platform attacking decentralization and the authority of regional directors like Smith to design local research agendas. The ideology of efficiency and reduction of waste, long the motto of the station, when applied to government itself, did not lead to new projects. Efficiency as a goal produced a constant pressure, even in project planning sessions, to reduce staff levels and budgets even further.

In particular, Watkins noted that, while Harold Smith had some excellent ideas for new projects, their implementation "would require much planning and considerable funds" as compared to more straightforward proposals on the study of oil field brines proposed from the station.[24] After the meeting, the Petroleum Production Steering Committee recommended that all funding remain at the same levels in the five various divisions working on production problems. Duplicate work would be ended, and the laboratory at the Dallas Field Office closed. Facing a fixed budget, the wisest way to increase availability of money was to eliminate duplication. According to Watkins, requests for expanded funding were simply not a reasonable alternative.[25] Furthermore, the steering committee saw a danger in the search for outside cooperative funding that might redirect a whole program. The committee recommended "that cooperative efforts (including grants of funds) be undertaken only when the work involved support work already in operation . . . thereby recognizing that grants of money as such should not influence the nature of our program."[26] Such caution about funding no doubt contributed to the rigidity of the station and its slow response to new opportunities.

Fowler and others at the station attributed some of the stagnation of the 1950s to the state of the art itself, rather than to their own administrative and policy decisions. Fowler believed that great scientific progress had been made during the war years, but that technological research had too often "gone to the well" of advances made under the pressures of the war. Put another way, progress had reached a plateau due to the working out of the technical consequences of wartime advances, and a new, massive stimulus was required. Such a view ignored the fact that a great many new opportunities for technical work came out of the contemporary oil economy, the problems and the technological issues of the decade.

The total staff did not react with caution and adherence to old patterns, however. Some of the new opportunities were noted, and some pursued by men at the station. Studies in diesel fuel, auto emissions, pipelines, secondary recovery and waterflood methodology, rocket fuel, and the use of radioactive tracers, together with long-range projects studying thermodynamic properties of sulfur compounds in petroleum and pressure-volume-temperature relations in condensate gas wells, all came out during the Fowler years.

In addition, some of the more enterprising staff members of the Bartlesville station began to get a few contracts to do research work for other government agencies, in effect, establishing a relationship with other branches of the federal government that resembled that of a private contracting firm to private clients.

One case which illustrates this particularly well is the career of Richard Hurn. Hurn had earned B.S. and M.S. degrees in mechanical engineering, and came to the station in 1948. Brought in because some of his graduate work had concentrated upon diesel fuels, he worked first in the Chemistry and Refining Branch, heading the engine laboratory that had been set up to test aviation fuels during the war. Hurn's work came in response to the greatly increased demand for diesel and for knowledge about diesel fuels, resulting from the conversion of railroads from steam to diesel engines, as well as from the growth of diesel engine use in the trucking industry. He developed a combustion chamber to study diesel processes, and worked on characterizing diesel fuels and issues related to stability and fuel compatibility. With respect to the latter, the problem was that unstable diesel fuels produced by cracking processes tended in storage to produce gums; incompatible cracked fuels, when mixed in storage, tended to lay down a sludge.

By 1951, Hurn completed the diesel work and turned his attention to problems of exhaust gases, not because of an internal policy decision of the station or the Bureau, but because of increased interest in smog by agencies outside the Bureau. In this regard, he violated the steering committee recommendation that outside funding not be allowed to shape programs. The constant volume combustion bomb that Hurn had developed to study diesel combustion gases could be used to study smog problems. Hurn raised outside money—not only accepting an increasing reliance on cooperative funds as a necessary part of getting research funding, but even welcoming the adjustment to priorities, set not by a Bureau committee, by the regional office, or by Washington, but by broader economic and political developments entirely outside of the federal government.

In the mid-1950s, Hurn, working in Harold Smith's group, made a minor administrative decision which reflected his approach and which ran head-on into the conservative strategies of Fowler. Hurn reasoned that the station should no longer participate in a regional exchange group set up during the war to verify local octane testing procedures. The practice was for samples of fuel tested by other private and university laboratories to be sent to the station. Test results of the octane level, when compared with other laboratories' results, would then determine whether standard testing engines at the station produced standard results. However, by the mid-1950s, the station's test engines were no longer used to determine octanes except for this special purpose, and Hurn sought to withdraw from the exchange group so that the engines would no longer have to be diverted from their main purpose of testing for smog.

When Fowler heard of Hurn's decision, he called Hurn in and asked him to explain the action. Hurn stated that there was no longer a need for such participation.

"But the exchange group is an institution here," said Fowler.

Hurn replied that he had not been hired to maintain an institution, but to do work. Since filling out the reports to the exchange group used resources and time better spent on productive work, he thought it perfectly logical to bring the participation to an end. Hurn later remarked that Fowler then became quite angry. Fowler believed Hurn had exceeded his authority and had diminished one hard-won and established method of receiving at least regional recognition. Hurn perceived Fowler's attitude as a case of institutional inertia—inertia which, Hurn believed, was precisely why the station no longer commanded the respect of the wider scientific and industrial community.[27]

Hurn continued to build contacts with individuals in industry, in local and state governments, and in federal agencies. Yet it was clear that men like Hurn, a self-confessed "maverick," were the exception, not the rule, at the station through the 1950s. He worked aggressively and with increasing success to find new research areas and outside funding. Few others at the center in the 1950s had his combination of abrasive independence of mind, energy, drive, and willingness to work closely with people in the regulatory agencies.

C. C. Ward, who succeeded Harold Smith as head of the Petroleum Chemistry and Refining section, also exercised some ingenuity in shopping around for funding sources. He worked to obtain $15,000 funding from the Western Petroleum Refiners Association in 1954 for the study of trace metals in petroleum, securing the placement of the project on the Association agenda in 1955. Trace metals such as vanadium, nickel, and iron reacted with catalysts in the cracking process, causing financial loss to refiners by ruining the catalytic crackers. Guy Waddington suggested in 1955 that the topic was "hot" and should be part of the program of the station.[28]

Ward also obtained funding from the Navy's Bureau of Ships to study the cause of diesel fuel instability. Following up on the earlier work by Hurn and Harold Smith on this topic, the section undertook to study oxidation of pure hydrocarbons at low temperatures and to develop methods to remove the most unstable hydrocarbon compounds from the fuels. In 1957, Ward worked to get the Bureau of Ships to extend the contract, particularly to study methods of removal of sulfur, nitrogen, and oxygen compounds which appeared most involved in the gum-forming process. Ward's modest budget of $12,000 to extend the work through 1958 at first appeared doomed by a lowered budget for research at the Navy's Bureau of Ships. In January 1958, however, Ward received word from his contacts in the Navy that the project would be supported.[29]

Always on the lookout for new money, Ward discussed with his Navy contacts potential Bartlesville work on "hypergolic" mixtures—the mix of oxygen and oxidizers used in missile fuels, keeping an eye on this possibly rich source of funding. However, no rocket work was forthcoming in 1958–1959.[30]

Ward's constant search for outside funding strengthened his branch, and by the end of the decade, the Chemistry and Refining section could anticipate continued expansion.

Ward, working as Hurn's supervisor, showed a style of administration and liaison that was considerably more diplomatic than Hurn's. Ward kept Fowler posted on all his contacts with outside sources, and worked closely with him on matters of budget. Ward's achievement of outside funding, rather than generating friction with Fowler, set a pattern of support that held promise of future growth. His style eventually, however, as will be discussed further in Chapter 6, led to friction with Hurn, who began to perceive him as too conservative.

A third example of funding ingenuity was R. Vincent Smith, a physical chemist with an M.A. from the University of Missouri at Columbia, who had joined the station in 1936, working first with Eilerts on phase relations of condensate gas. For a brief period in 1940–1941, he worked with M. A. Schellhardt and then continued with Eilerts through the war and early post-war years, co-authoring parts of Eilert's massive monograph. In 1949, he began work on projects of his own, concentrating on the issue of friction in gas pipelines. The rapid growth of pipelines for natural gas, crude oil, and for finished products like gasoline created a demand for studies of friction in pipelines and for principles that could lead to improved design. By 1954, he had completed work, under a continuing grant from the American Gas Association, which provided the basic calculations for construction of gas pipelines to determine optimum pipeline diameter and the spacing of compression stations. The AGA continued the funding, at least in part because Cattell at headquarters worked closely with Eddie Rawlins, Bartlesville alumnus, who served as chief engineer at Union Producing Company and as Chairman of the Gas Well Deliveries Subcommittee of the AGA. Vincent Smith's study provided a means of reducing to mathematical formulas the friction that slowed gas flow through pipelines. This work became widely cited and used in the pipeline expansion of the 1950s.[31]

Smith resigned from the Bureau in 1954 and went to work for the natural gas division of Phillips Petroleum, where he headed a team that produced technical and economic analysis of gas pipeline construction problems. As a physical chemist, Smith had gained experience in engineering issues in his twenty years at the station and then, like the technicians of the 1920s, transferred both his academic training and his rich field experience to the private sector. His work, like earlier projects in the 1930s, attracted the notice of a rapidly expanding sector of the petroleum business and provided basic nonproprietary data that were widely utilized, and, like that of Hurn and Ward, was eagerly accepted and funded by groups outside the Bureau of Mines.[32]

Technology Transfer

In several areas, Fowler did attempt to respond, in his own way, to new opportunities. In the parlance of a later generation, Bartlesville could facilitate "technology transfer," both from the government's own atomic energy program to the domestic oil industry and, in a broader sense, from the United States pool of technical know-how to the rest of the world—as petroleum fields developed in Latin America, the Middle East, and elsewhere. Fowler made efforts in both directions, with varying degress of success.

The burgeoning production of radioactive isotopes from the atomic energy program provided a new tool; isotopes could be used as tracers in the study of flow of fluids in underground formations. Although Taliaferro and Fowler hoped to adapt to the new developments spun off from the atomic energy program by developing both equipment and skills to use radioactive isotopes as tracers, and to construct a separate special laboratory for the purpose, inability to attract funding prevented the project from getting off the ground.[33]

Wade Watkins arranged for F. E. Armstrong, an electrical aide at the station, to take a special course in instrumentation for work with radioactive isotopes at the Oak Ridge Institute of Nuclear Studies in 1949. Watkins recommended Armstrong highly to Oak Ridge and worked for his admission to the study program. However, funding was so limited in fiscal years 1949–1950 that money could not be spared for the training or the whole development of an isotope-tracer program for petroleum use.[34]

The first isotope study at Bartlesville was not conducted, therefore, until 1952. It traced iodine-131 placed in the strata through a water injection well and measured its outflow through four surrounding producing wells. This method held the promise of establishing optimum spacing of injection and producing wells in varied strata conditions.[35] But the project was "hampered seriously" through 1954, according to Taliaferro, since only one physical chemist and one electronics engineer could be spared to work on it. Through 1954 and 1955, the station sought cooperative funding from the Atomic Energy Commission to aid in the project, but in vain.[36]

Overseas, the expansion of United States firms led to the need to train foreign nationals in United States petroleum technology, opening an opportunity for the station to provide a new service. By bringing foreign technicians to the station for an extended visit, the station could obtain the benefit of their services and, at the same time, assist the petroleum firms in developing an experienced cadre of foreign nationals who could work in overseas locations. The political advantages to United States firms could be considerable, in that such efforts would help respond to pressures in the overseas locations to staff firms with local people and to get some local economic benefits from exploitation of resources.

In 1951, the station accepted some twenty foreign technicians for study from Venezuela, Iran, France, Italy, Egypt, Mexico, Canada, Japan, Sweden, Uruguay, and Great Britain. Most were early in their careers, less than thirty years of age, and came under a variety of international exchange programs from both universities and industry. Similar groups came each year through the 1950s.[37]

Petroleum developments overseas produced another possible avenue for station service, that is, sending station personnel to foreign nations which had already nationalized their oil industries. On a government-to-government basis, the station could provide consultation, advice, and possibly on-site training. One of the first such opportunities for the station came in the early 1950s.

In the summer of 1952, Taliaferro visited Yugoslavia under United Nations auspices. The bureaucratic impediments to the trip were severe—he had to take a leave of absence without pay from the station and be placed on a temporary payroll of the Technical Assistance Administration of the United Nations. As a result of the move begun in 1948 to break off close relations with Moscow, Yugoslavia had requested U.N. assistance in ninety different technical areas as part of its move to modernize the nation without reliance upon Soviet technical experts.

Taliaferro spent most of his time at the Petroleum Institute in Zagreb and in oil fields in Croatia and Slavonia. He reported that the Yugoslavs' oil industry, developed by the Germans during World War II, was in considerable disarray with an odd assortment of equipment from Italy, Germany, Russia, France, and the United States.

Taliaferro offered comments and recommendations, particularly regarding equipment modernization. However, due to the language barrier, what Taliaferro himself saw as a relatively low level of importance attached to the advice in Yugoslavia, and the severely constrained resources of the Yugoslavs, the work seemed to have little lasting impact. Taliaferro's trip brought some local press attention to the station in Oklahoma, but it did not lead to an immediate follow-up program of work in foreign fields.[38]

Technology transfer included a variety of meetings and activities. The waterflood tours served to demonstrate new techniques to local producers. Annual meetings of the American Petroleum Institute advisory committees provided a forum for transfer of government research to the private sector. Through the 1950s, an annual Diesel Conference brought together diesel engine manufacturers and diesel fuel refiners for discussion of research. As with Huffman's Calorimetry Conference, an annual meeting of thermodynamicists, these regular meetings provided not only a channel for research to flow to industry, but also allowed contact and ideas for the renewal of projects and discussion of new private funding to the Bartlesville station. Concerted liaison with industry, thus, helped the station survive and even flourish in particular areas.

Survival Under Siege

By 1955, Fowler had developed an explicit style of response to the period's financial and structural limits and the new opportunities. He supported the concept that station superintendents, together with their branch chiefs and individual researchers, should initiate projects. He opposed the effort to set up a higher coordinating level under regional directors. He argued for the addition of a "writing engineer" to the staff who could help in the polishing of manuscripts, and he worked toward timely publication of results, attempting to maintain the tradition of excellence begun under Superintendent Smith.

When it came to outside funding, Fowler increasingly recognized the growing significance of outside cooperative funding from associations. At first he remained very cautious, warning that outside funding should not substitute for federal allotments but should, instead, make possible the "best use of the Federal allotments." Yet, over time, he developed a host of outside-funded projects. Fowler attempted to protect personnel from being laid off during funding cutbacks, worked to keep lively projects going, tried to avoid duplication of effort with other branches of the Bureau, and struggled to maintain the level of recognition and achievement built up by Smith through the 1930s and the war years.[39]

For those who lived through the period, the issue of why the station entered a time of alternation between stagnation and readjustment remains extremely hard to understand even in retrospect. Some veterans of the period tend to view the issues entirely in personality terms, attributing friction and morale problems to the individuals involved. And, on the small stage of the laboratory, personality conflicts and tensions were indeed real factors. But equally clearly, the station also faced limitations which, when viewed in perspective, stemmed from outside forces as well as from the traits and style of those in charge at the time.

Hurn's development of an air pollution program and the increased work in secondary recovery in response to local interest provided the station with continuing strength, attention, and some notable successes. Constant searches for new projects, some quite small, by Branch Chief Ward enlivened the work of the Chemistry group. Routine work on fuel surveys, which year-in and year-out summarized reports on octane testing provided by industry itself and on locally requested field surveys, together with the gradual and steady progress by Eilerts and the thermodynamics group, also kept the technical and industrial community informed that the Bureau of Mines station at Bartlesville was still at work.

By the end of the 1950s, the station had fully adjusted to change. Its work had found a place despite the tensions between major integrated multinational firms, with their increased reliance on imported oil, and the mid-continent producers who continued to rely on government research to aid in the development of secondary recovery methods. The internal tensions over personnel and budget had been weathered. Engineers and scientists had maintained an uneasy truce and continued to take pride in each other's major accomplishments. Restrained federal budgets had limited the station's growth, but the careful building of outside funding had set a pattern that could provide a means of continued growth. The siege had been difficult, but the station was ready to respond to new opportunities in research and technology which would come in the 1960s.

NOTES

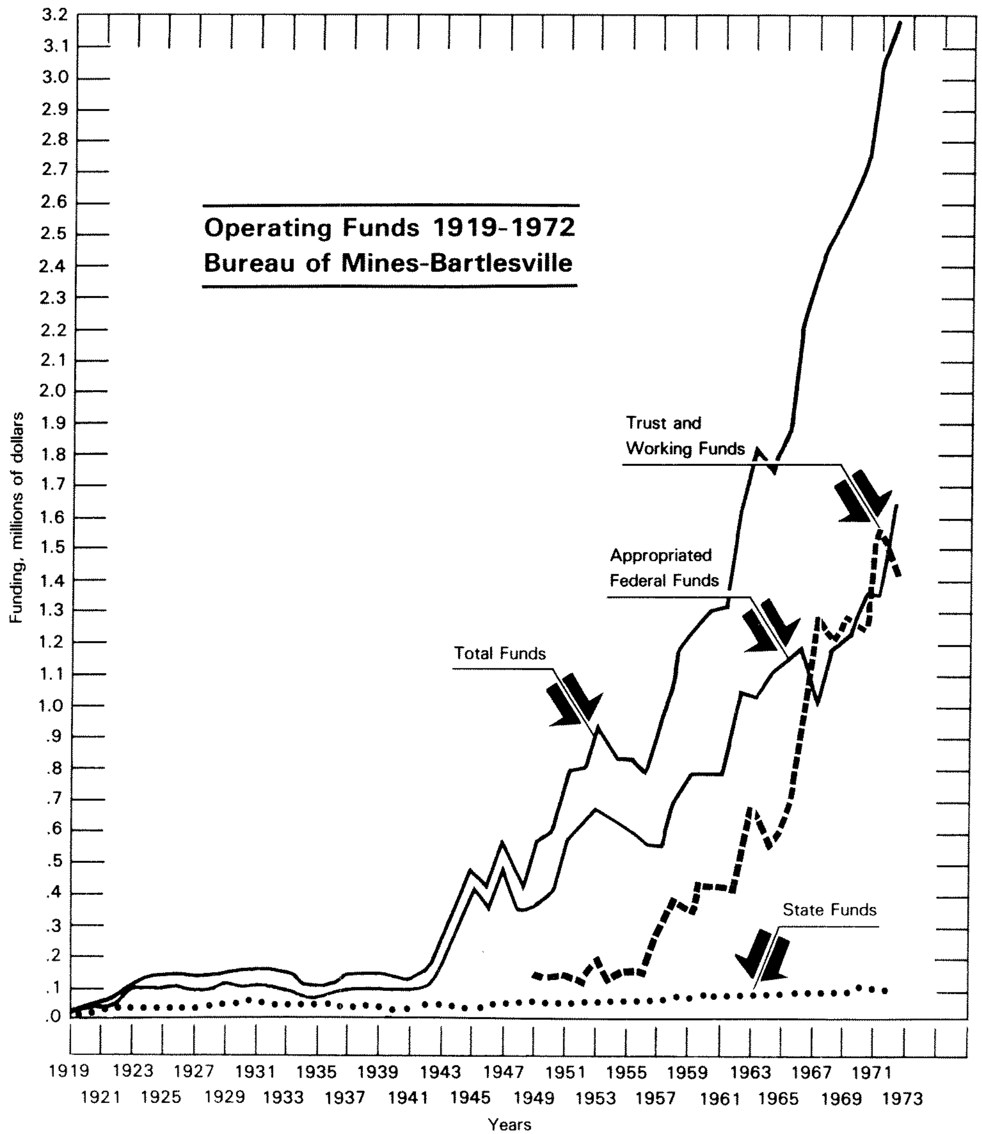
1. Fowler to R. F. Anderson, February 8, 1955, Box 324908/Project References.
2. Box 324908/Steering Committee-Production; Fowler to Anderson, August 18, 1949, Box 224340/050 Director's Annual Report.
3. Fowler to Rue, November 15, 1945, Box 224340/150. 2 Reductions in Force.
4. Rue to Fowler, November 28, 1945, Box 224340/150. 2 Reductions in Force.
5. Report to Advisory Committee on Secondary Recovery, Estes Park, Colorado, September 1, 1949, Box 324908/Work of the Station.
6. Fowler to Anderson, November 29, 1948, encl. proposal, Box 224338/621.3 Synthetic Fuels.
7. *Ibid.* Crauford D. Goodwin, "The Truman Administration:

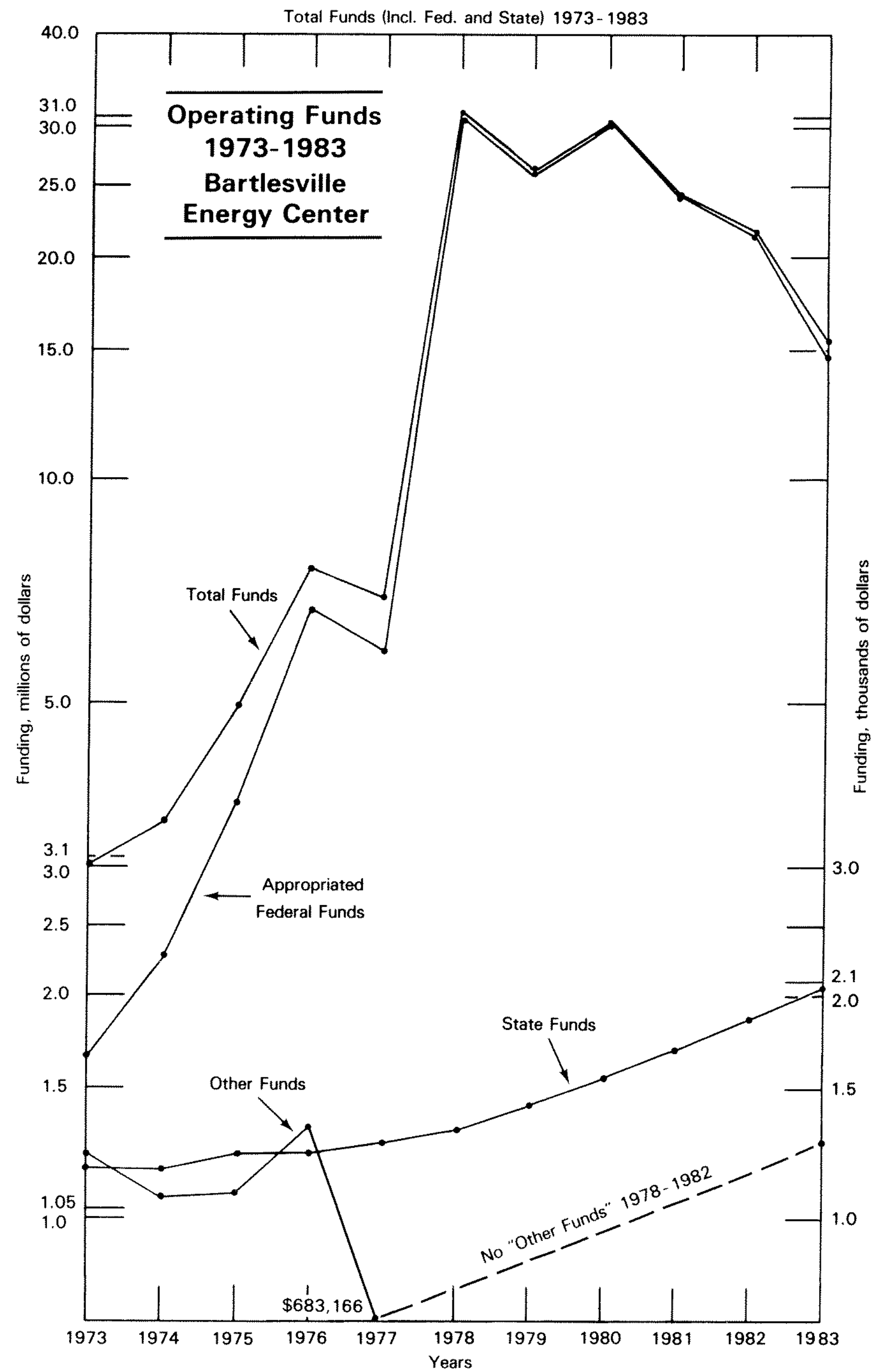
Toward a National Energy Policy," 1-62, and "Truman Administration Policies Toward Particular Fuels" (Petroleum), 63-129, (Synthetic Fuels), 146-166; William F. Barber, "The Eisenhower Energy Policy: Reluctant Intervention," 205-286; in *Today's Problems, Yesterday's Solutions* (The Brookings Institution, Washington, 1981).

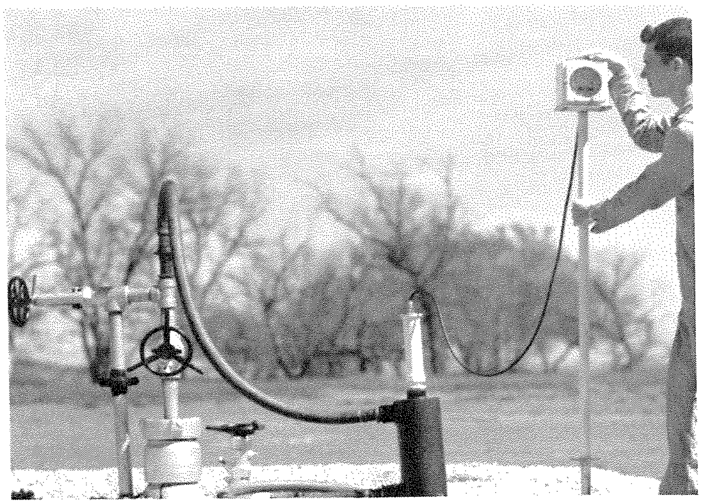
8. Ambrose to Fowler, November 21, 1947; Fowler to Ambrose, November 19, 1947, Box 224336/612.23 Shale Lab Work.
9. Fowler to Lankford, 1948, Box 224336/612.23 Shale Lab.

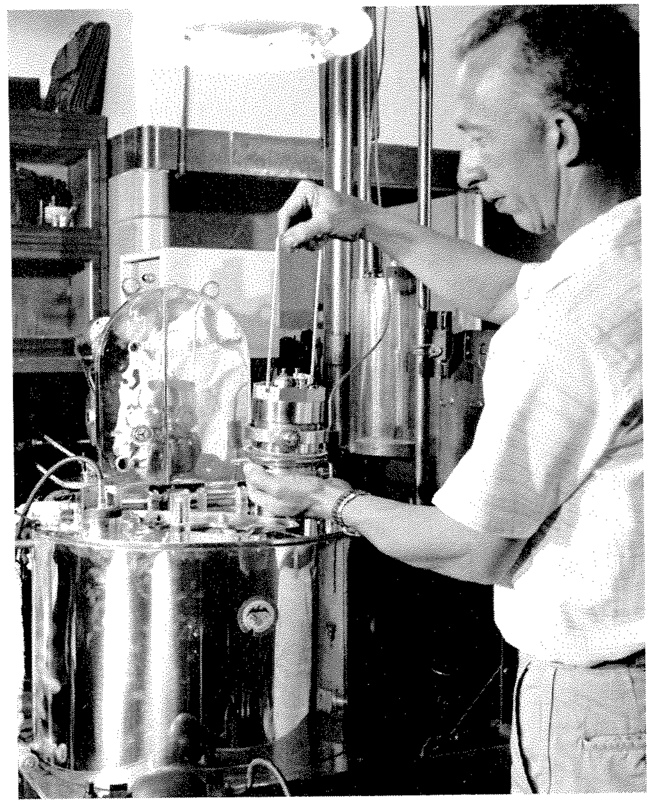
9a. Gooding to H. M. Smith, March 11, 1948, Box 22436/612.33 Shale Lab Work.

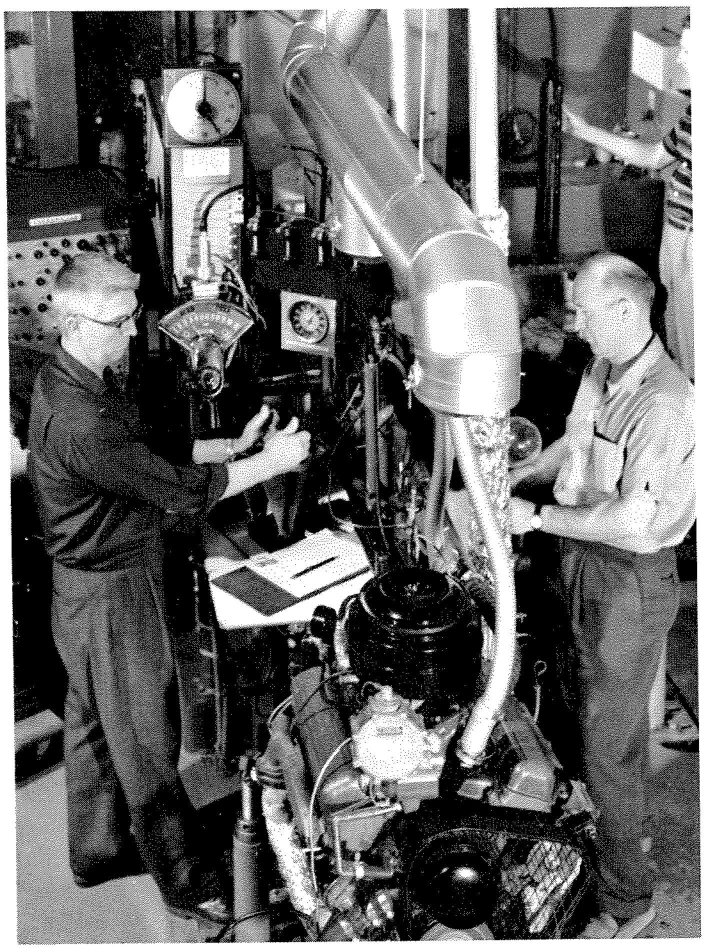
10. Box 224333/Reports, Fowler, June 1946.
11. Interview Carlisle-Kenneth Johnston.
12. Fowler to Cattell, November 7, 1947, and Guthrie to Cattell, October 30, 1947, Box 224335/831.15 Texas-Red River; Riggs to Producers, August 19, 1948, Box 224338/ 531.32 Healdton; Box 228338/831.194 SE Kansas-Bundred Oil Company Study.
13. Fowler to Cattell, February 3, 1956, Box 3249O8/Steering Committee-Production.
14. Cattell to Chief, Office of Mineral Reports, January 27, 1953, Box 224344/017.407 Cattell, RA; Fowler to Cattell, February 4, 1953, same folder.
15. Fowler to Smith, April 1, 1955, Box 324908/Project Reference.
16. Fowler to Anderson, August 18, 1949, Box 224340/050 Director's Annual Report.
17. Fowler Tech Report, July 1952, Box 224344/017.41 Bartlesville.
18. D. B. Taliaferro, "Recommendations on Improvements in the Work of the Division," Box 324908/Steering Committee.
19. Watkins to Smith via Fowler, March 25, 1955, Box 324908/ Project Reference.
20. Smith to Fowler, July 20, 1956, August 10, 1956, Box 324908.
21. Eilerts to Low, February 3, 1953, RG 70, FN NARS, Box 224344/019.121 Patents of Employees; interviews Carlisle-Burman, Carlisle-Eilerts.
22. Interview Carlisle-Eilerts.
23. Watkins to Taliaferro, February 28, 1955, Box 324908/ Project References.
24. *Ibid.*
25. Cattell to Fowler, January 20, 1956, Box 324308/Steering Committee.
26. C. J. Wilhelm to Cattell, February 16, 1956, Box 324908.
27. Interview Carlisle-Hurn.
28. Waddington to Fowler, January 24, 1955, Box 324908/ Project Reference.
29. Ward to Kelley, November 13, 1957, January 31, 1958, BETC Vault 826.85.
30. *Ibid.*
31. Interview Carlisle-R. V. Smith.
32. Cattell to Rawlins, April 13, 1951, Box 224342/Fowler Files. Monograph 7 "Back-Pressure Data on Natural-Gas Wells and Their Application to Production Practices"; Monograph 10—"Phase Relations of Gas-Condensate Fluids."
33. Taliaferro to Anderson, April 19, 1949, Box 224338/468 Tracer Studies.
34. Watkins to Overman, June 17, 1949, June 29, 1949, Box 224338/468 Tracer Studies.
35. Box 224344/017.41 Technical Report, September 1952.
36. Watkins to Taliaferro, February 28, 1955, Box 324908/ Project References.
37. *Bartlesville Record* Clipping, June 12, 1951, Box 324908/ Work of the Station.
38. Box 224344/017.407 Taliaferro's Yugoslavia Trip (1952).
39. Fowler to Smith, June 10, 1955, Box 324908/Project References.

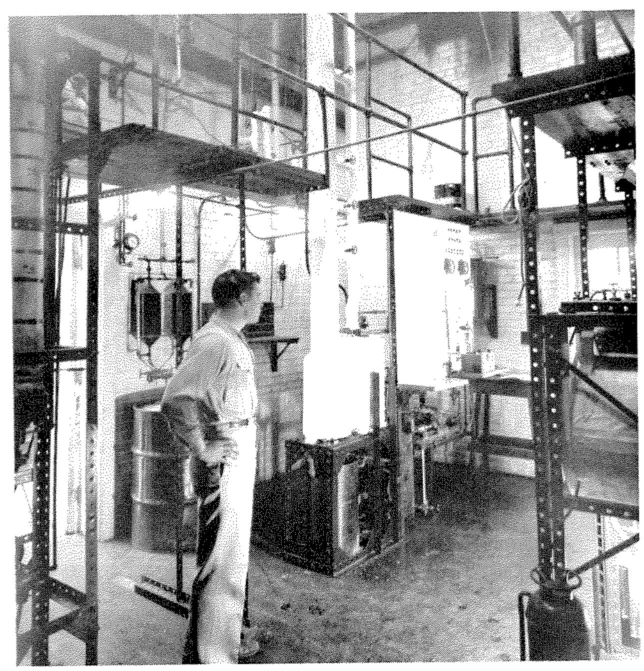

Operating Funds 1919-1972
Bureau of Mines-Bartlesville
Funding, millions of dollars
3.2
3.1
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
.0
Trust and
Working Funds
Appropriated
Federal Funds
Total Funds
State Funds
1919
1921
1923
1925
1927
1929
1931
1933
1935
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
Years


Total Funds (Incl. Fed. and State) 1973-1983
Operating Funds
1973-1983
Bartlesville
Energy Center
Funding, millions of dollars
40.0
31.0
30.0
25.0
20.0
15.0
10.0
5.0
3.1
3.0
2.5
2.0
1.5
1.05
1.0
Funding, thousands of dollars
3.0
2.1
2.0
1.5
1.0
Total Funds
Appropriated
Federal Funds
State Funds
Other Funds
No "Other Funds" 1978-1982
$683,166
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
Years



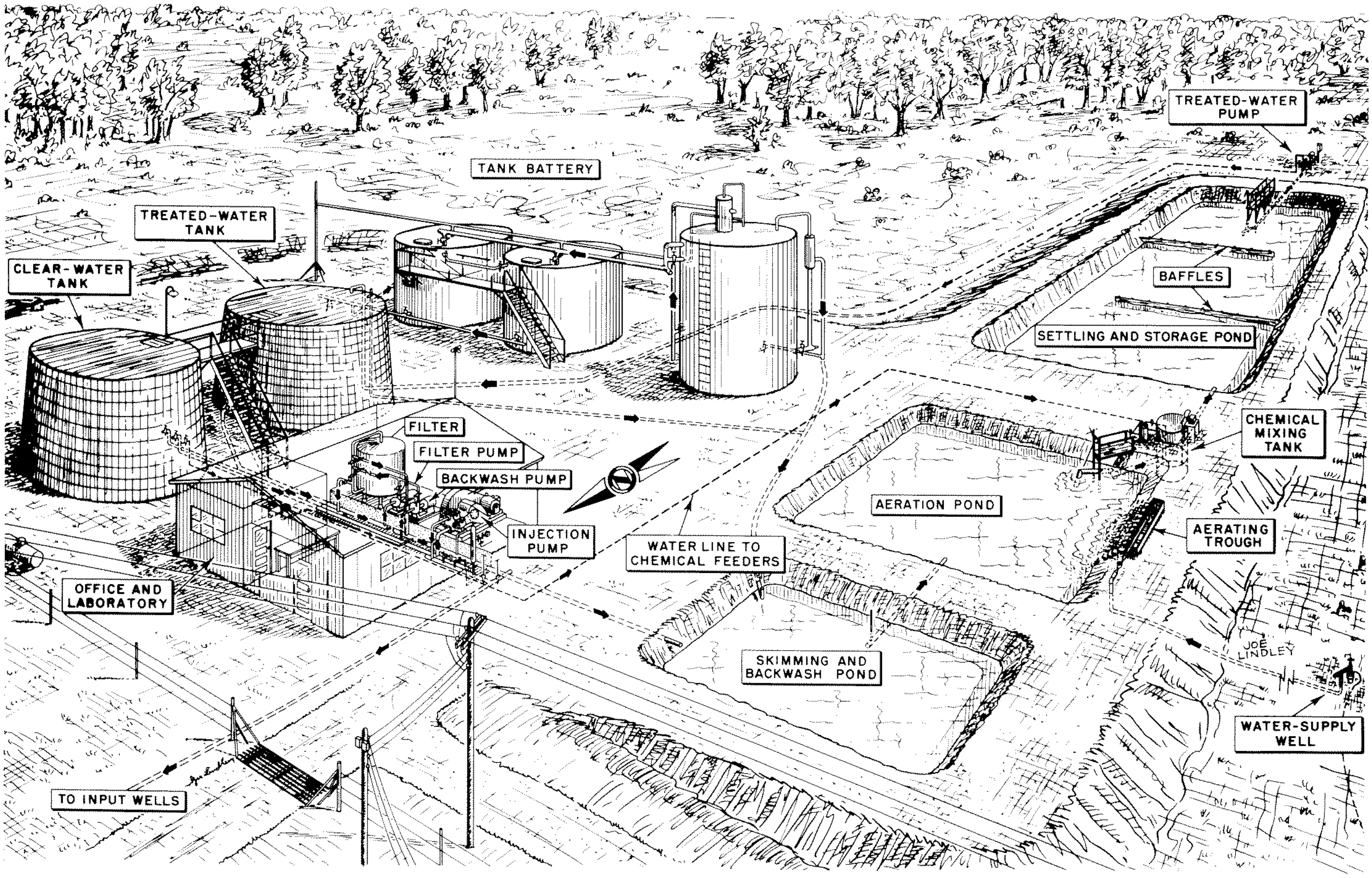


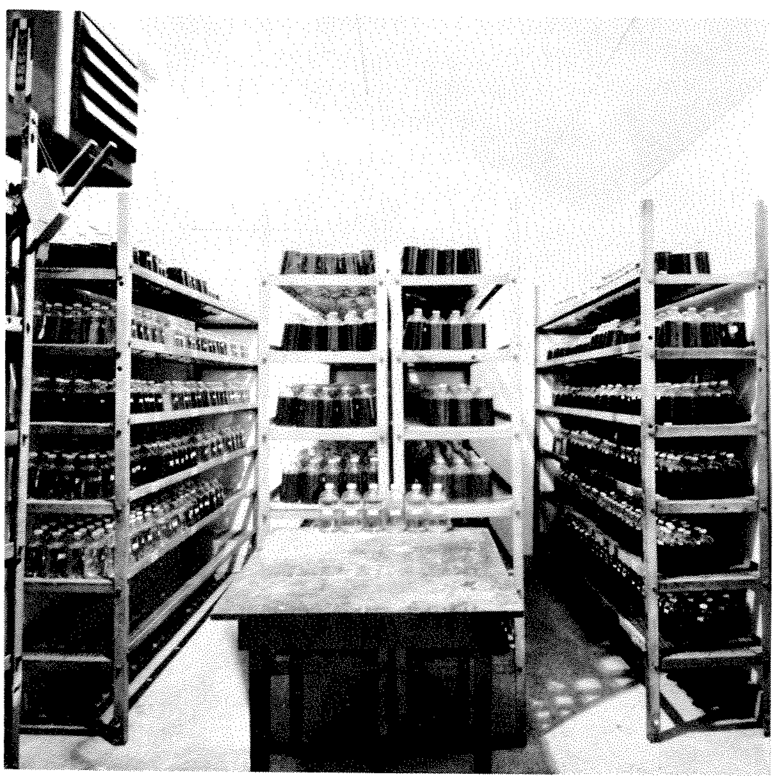




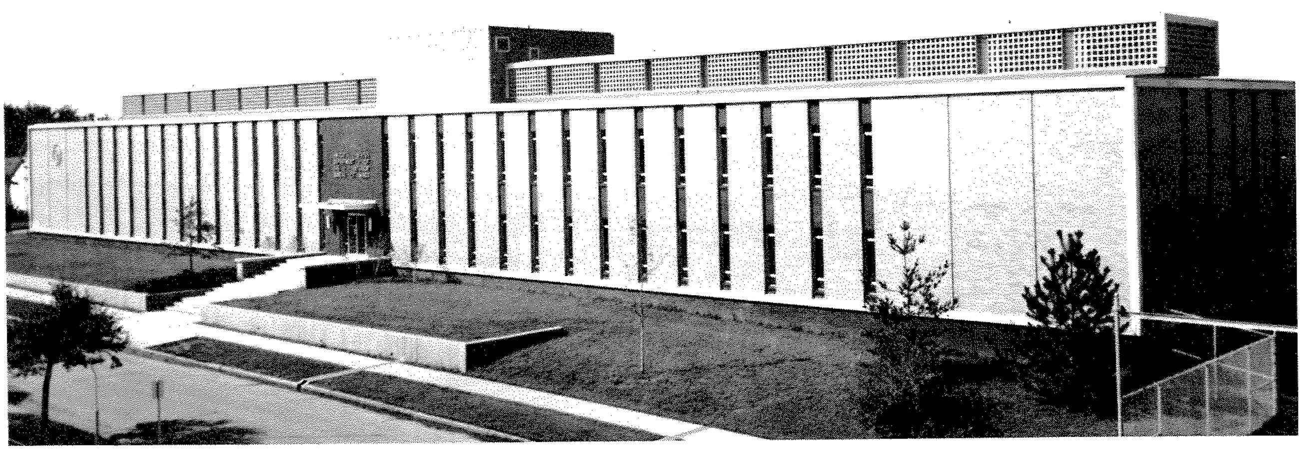
Evolving Research Frontiers

The 1950s brought a new set of problems to the Bartlesville Petroleum Research Center. Low-level radioactive tracers were injected (upper left) into oil-bearing formations by Engineer Bill Howell to determine the flow path. Heats of combustion of difficultly-combustible compounds were determined in a bomb developed at Bartlesville (upper right), operated by Chemist Bill Good. Growing interest in the smog problem and its connection with automobile exhaust prompted experiments to determine the mechanism (lower left). The importance of composition of crude oil to refiners required distilling many crude oils in order to analyze them (lower right).

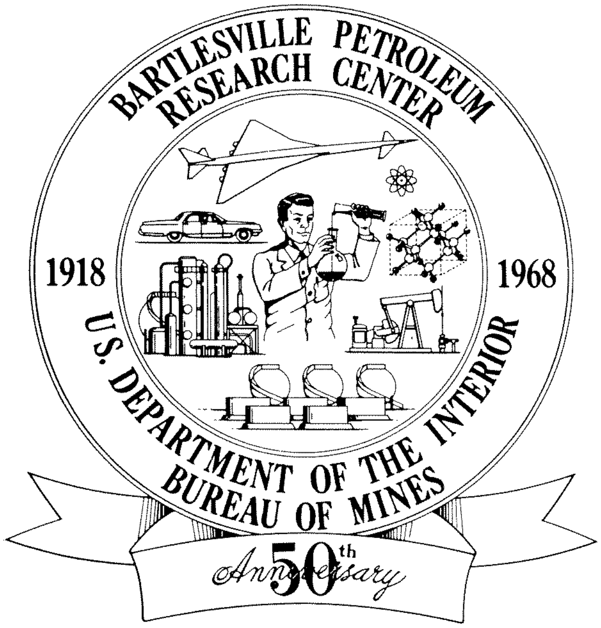


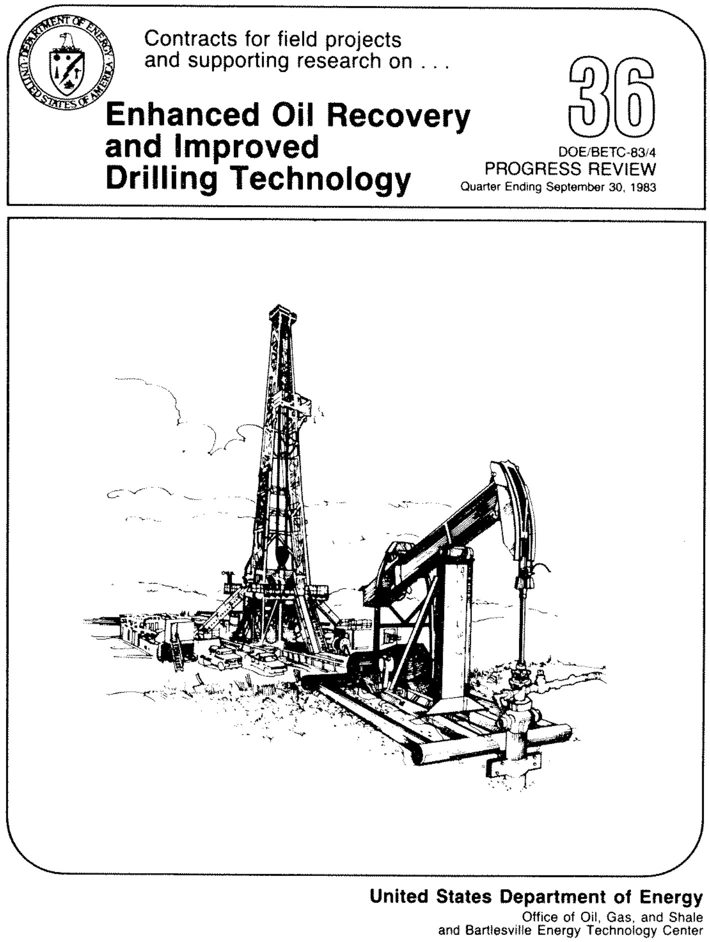


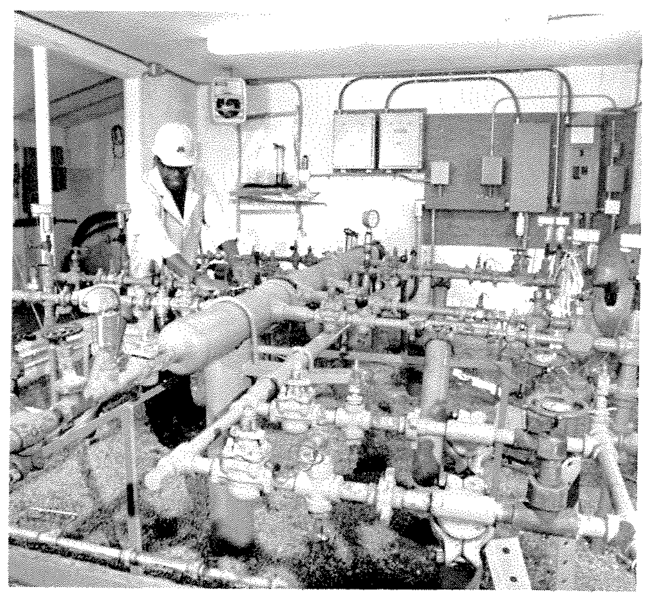
For the waterflood tours, a description of the projects to be visited was prepared ahead of time. One feature of these publications was a schematic (upper picture) of the waterflood prepared by Joe Lindley, BETC illustrator. Studies of the stability of petroleum products were carried out for the armed services over the period 1950–1980. One feature of these was the storage of samples of oil for a given time at elevated temperatures in the "hot room" (lower picture).



The increasing importance of secondary recovery in the 1950s was recognized in the waterflood tours in which groups of producers were taken to model operations by automobile caravans. The upper picture shows a group at a project in Anderson County, Kansas in 1953. Continued growth of the Center called for expansion of facilities and the Engineering and Physical Science Building (lower) was dedicated in 1963. By this time the Center had grown to 170 persons whose expertise covered many scientific areas affecting petroleum. The Fiftieth Anniversary celebration in 1968 brought special recognition to the Center.







Technology Transfer has been an important part of the program at BETC. The waterflood tours and associated meetings and publications were the main forum in the 1950s. In 1968, the Center celebrated its 50th Anniversary and the logo (upper left) was an important symbol of it. Starting in 1975, Progress Reviews on Enhanced Oil Recovery were published quarterly (upper right). A companion publication was *Liquid Fossil Fuels Technology*, published quarterly from 1980–1983. Shown in lower left is Editor Bill Linville checking quality of this publication. Another feature of technology transfer was field projects, and the control room in the Nowata Micellar-Polymer project is shown. Ray Jones is the technician (lower right).

Chapter 6

PETROLEUM SCIENCE AS A NATIONAL RESOURCE, 1959–1967

The immediate post-war years and the decade of the 1950s had indeed been difficult for the staff of the station. During this period, the station's survival as a center for petroleum research was itself a victory. President Harry Truman had advocated a stronger federal role in oil from 1946 through 1952, but an antagonistic industry and a largely uncooperative Congress had thwarted his efforts. The Eisenhower administration, in contrast, took a consciously more passive position consistent with both the chief executive's own philosophy and the general Republican desire to deemphasize an active federal policy role. The Kennedy-Johnson policies of the 1960s would prove to be somewhat different from either.[1] Although it is tempting to read into these years the origin of a national "energy policy," it is more realistic to view the 1960s as a transitional decade between the traditional fragmented fuel policies in which the Bureau of Mines played but one role, and the new policies of the 1970s, born in crisis and symbolized by the Energy Research and Development Administration (ERDA) and the Department of Energy (DOE).

Overview of the Period

Presidential candidate John F. Kennedy suggested a new political tone as early as April 1960 in a West Virginia address when he asserted that "we must immediately establish a National Fuels Policy—a policy which will take the vast, intricate, and often contradictory network of laws and regulations which govern the nation's fuel industry and weld them into a sound and logical whole."[2] Although the Kennedy and Johnson administrations did not achieve this goal, they made significant strides. Under the overall direction of Interior Secretary Stewart Udall, the Bureau of Mines began to direct its research efforts more toward a designated national policy agenda.

It should be noted in this connection that the Eisenhower administration had not been entirely devoid of progress toward the goal of a national fuels policy. The report of the Paley Commission, submitted in the final months of the Truman Presidency, had established at least an awareness at the highest levels of the growing depletion of America's energy resources. Officially known as the President's Materials Policy Commission and chaired by William S. Paley, this June 1951 report had warned that the nation was fast approaching a major change in its economic life. Eisenhower policies, as implemented, however, rather than heeding this plea for a federal response to this broad problem of declining energy independence, focused more on the protection of the particular markets of domestic producers of the key energy fuels. Implementation of import curbs on foreign petroleum aimed at aiding the independent oil man is the prime example of these policies. The net effect of these voluntary, and later mandatory, import restrictions was to accelerate the drilling and utilization of domestic oil supplies. Although Eisenhower failed to develop a true comprehensive energy policy, steps taken by his administration to further the advancement of science and technology in the United States would bring changes favorable to basic research in petroleum technology and thus indirectly assist developments at the Bartlesville station.[3]

The Soviet Union's launching of Sputnik I in 1957 sent shock waves throughout the scientific community which led to a new federal policy of support for basic and applied research. In the fall of 1957, Eisenhower created the new post of Special Assistant for Science and Technology and appointed a Science Advisory Committee in the executive branch. This group's influential report, *Strengthening American Science* (1958), resulted in the formation of the new Federal Council for Science and Technology. It was in this spirit that the Bureau of Mines changed the name of its experiment stations, thus giving birth in 1959 to the Bartlesville Petroleum Research Center. Concomitant with this change in name, Superintendent Fowler's title now became Research Director. The Bureau of Mines also undertook a comprehensive internal study of its research and publication procedures in 1959–60 and took administrative steps to strengthen both.[4]

The Bartlesville Petroleum Research Center similarly found itself focusing on research projects designed to respond to national priorities. As the center strengthened its external funding base with other governmental agencies, it maintained cooperative agreements and warm relationships with the American Petroleum Institute (API) and the private sector. Many of the tensions that had already developed in the 1950s, including disagreements over the nature of "basic" and "applied" research, tight budgeting of appropriated funds, and controversy over relations with private industry, remained nagging problems in the 1960s; but the overall atmosphere and sense of purpose at the center bore a greater resemblance to the war years rather than to the depressed malaise of the 1950s.

The new Physical Sciences and Engineering building at Bartlesville, dedicated in April 1963, was a tangible, if somewhat belated, representation of the federal government's commitment to petroleum research in the service of the nation. Soon after the dedication, Fowler retired as Research Director, to be succeeded by John S. Ball, a longtime member of the research staff at Laramie. Beginning with his appointment on June 10, 1963, Ball inaugurated a new era at the center. An excellent administrator with a proven personal record of research, Ball was also a man of vision. Aware that institutional inertia alone was insufficient to justify the research programs at Bartlesville, the new Director sought to mesh the center's work with changing national needs and priorities. Problems remained, and the center under Ball particularly found itself waging a fight for its fair share of appropriated funds. But the new Director was eminently qualified to lead Bartlesville during the challenging years of the 1960s.

Administrative Readjustments

When the Bureau of Mines had moved its Region IV office from Amarillo to Bartlesville in 1954, it reflected a larger policy change aimed at decentralizing activities and ensuring that research and technical programs responded to local needs. Harold Smith had become the new Regional Director, as noted in Chapter 5, and he soon came into conflict with Fowler over policy questions. Fowler's continued resistance to this new line of authority and his frequent bypassing of Smith in direct communication with the Washington office had not only rankled the Regional Director but, by the later 1950s, had caused a *de facto* erosion of Smith's authority. This situation only became formally resolved in early 1960, and not to Smith's satisfaction. As part of its internal study in 1959, the Bureau decided to make significant changes in its field organization. In a memorandum of January 22, 1960, Bureau Director Marling J. Ankeny announced that, as of February 1, all research and development functions would revert to the Headquarters Divisions of Minerals, Petroleum, and Bituminous Coal in Washington so that research "can be more effectively planned, programmed, supervised, and coordinated."[5] The regional offices remained in place, but their functions would now be exclusively administrative and financial. In effect, Washington had removed Harold Smith and all other Regional Directors from the technical aspects of the overall Bureau program. While acknowledging that field activities were widely dispersed geographically, Ankeny stated that "activities are necessarily oriented within a framework of broad national objectives. In these circumstances, a better supervisory atmosphere can be provided through central direction."[6]

To some extent, personality conflicts like those which existed between Fowler and Smith in Bartlesville may have contributed to this decision. More importantly, however, this policy shift reflected a wider movement in the wind in the 1960s—the emergence of a Bureau of Mines research program more closely linked with national policy. Smith was greatly disappointed by the decision, as were some at the center who had sided with him against Fowler. But since his first love was analytical chemistry, Smith chose to return to the center to reassume his title of Research Scientist and continue his work on a subject in which he had long expressed interest—studies of the basic geologic origins of petroleum. Heading his own small research section, Smith continued these studies throughout the 1960s.[7]

Another era came to an end on February 1, 1962, with the retirement of "Shorty" Cattell as Chief of the Division of Petroleum, Department of the Interior. He was succeeded by Carl C. Anderson, and in July 1962, J. Wade Watkins moved from Bartlesville to Washington to assist Anderson as Chief Petroleum Engineer. As one of his first administrative tasks, Anderson undertook a study aimed at recommending a new overall plan and statement of purpose for the Division. As part of the subtle policy shift in Washington, both the Bureau of the Budget and the Congress were eager to attach specific budget and time limitations to the goals of the Division. Anderson appointed a five-man committee to develop a goals statement chaired by John Ball, then on the staff at Laramie. Robert T. Johansen represented Bartlesville on the committee.[8]

The Division office charged Ball's group with developing goals for future work which "should be the direct outcome of work on assessing the petroleum position of the U. S.," a clear indication that the Kennedy administration sought to define a broader fuels policy.[9] The conclusions of the Ball committee are revealing in that their recommendations for immediate Division goals represented a new long-range planning approach. The first stated goal, to make an assessment of the United States petroleum position by 1970, demonstrated the desire to mesh the expertise of the Division with the broader concerns of energy depletion and future supply. The report then listed specific projects undertaken in the various centers, in each case targeting a time for completion of the study. Some of these were simply restatements of traditional Bartlesville research areas such as the improvement of well drilling and coring technology and increasing petroleum recovery by 50 percent, both goals to be achieved by 1975. Two items focused on oil shale activities at Laramie and Rifle—the evaluation of *in situ* techniques to be completed by 1970 and a compilation of data on the use of oil shale in conventional operations to be completed by 1975. Other Bartlesville projects highlighted were two in the thermodynamics area (data on oxygen compounds and a ten-year compilation of the physical properties of petroleum components and derivatives) and Dick Hurn's work to correlate the composition of fuels with their behavior in an engine, both to be completed by 1975. The committee targeted Harold Smith's study of the origin, migration, and composition of petroleum in a single geologic basin as they relate to the origins of petroleum for conclusion in 1972. A particularly forward-looking goal for 1975 involved research into fuel cells, a novel energy conversion device which has generated a great deal of interest in the early 1980s. Finally, the report included a generalized goal "to make use of our special skills and knowledge as they apply to related problems."[10]

John Ball's selection to chair the Committee on Goals indicated his growing status within the Division of Petroleum. Holding both a B.S. and M.S. in chemical engineering from Texas Technological College (now Texas Tech University at Lubbock) and a doctoral candidate at the University of Colorado, Ball had gone to work at Laramie in 1938 rather than completing his degree. Initially hired to analyze crude oil samples, he shifted to oil shale research in 1944 and became the key Laramie researcher on sulfur compounds and nitrogen compounds. In 1963, Ball went to Washington for a three-month management training program and was in line for a top job at the Division office, Laramie, or Bartlesville. Upon Fowler's retirement in April 1963, the Division named Ball his successor as Bartlesville Research Director.[11]

One of Ball's initial tasks was to implement a formal system of programming at Bartlesville to comply with the Petroleum Division's desire to establish the well-defined research agenda provided by the Committee on Goals. The new program format contained both a "Mission of Research Center" section and one on "Contributions to National Goals." Since in part the Division intended these program statements to "sell" the center's research activities on the Hill, each center or field office wrote them in nontechnical language intended for the layman.[12]

Further impetus for the adoption of formal programming had arisen out of congressional hearings in the spring of 1963, when a member of the House Subcommittee on Mines and Mining of the Committee on Interior and Insular Affairs had requested an assessment of the value of basic research conducted by the Bureau of Mines over the past ten years. The committee specifically requested information on the cost of projects that had been "unsuccessful." On June 10, 1963, the day that Ball formally became Research Director at Bartlesville, Representative Wayne N. Aspinall, Interior and Insular Affairs Committee chairman, wrote to Interior Secretary Udall requesting such a study.[13]

The Division required all field offices to submit a list of Bureau-financed research completed between July 1, 1952, and June 30, 1962, including estimates of the cost of each project. Upon receipt of these data, the Washington office then subdivided all projects into five categories, ranging from "failures" to those research efforts which already had proven commercial feasibility. Between these two extremes were three intermediate categories. Ranked next to failures were those which showed creditable evidence of economic feasibility but had no evidence of current exploitation. Next came those projects which had no commercial application but which had clearly "extended the horizon of human knowledge." Next came those which had not achieved their objectives but nevertheless had resulted in commercially valuable by-product findings. It was clear that the Committee placed highest priority on those projects which could demonstrate specific economic benefits.[14]

The House Committee request proved to have an effect beyond the original submission of data. On December 2, 1963, Bureau of Mines Director Ankeny announced a new experimental reporting program, in which all proposed projects would show a dollar value indicating 1) resulting new annual production of oil or gas, 2) the annual value of improvements in quality or quantity, 3) the capital expenditure for a new facility or addition to facilities resulting from such research, as appropriate. They would also provide clear statements of purpose, justification, and method. Subsequent program statements embraced this format.[15]

Aspinall's committee eventually published the results of the original ten-year study in January 1965. In a cover note circulated to his project coordinators with a copy of the document, Ball wrote "this might give you a shock to find out which projects have been considered failures by the W. O. [Washington Office]," and added that, "Aspinall is a bit demanding!" Of the approximately 578.3 million spent by the Bureau of Mines between 1952 and 1962, only $14,531,800 went toward petroleum research, while metallurgy and coal each received well over $30 million. This disparity in funding remained a constant sore within the Petroleum Division during the 1960s.[16]

In addition to dealing with administrative issues on the Bureau and Division levels, Ball encountered some internal Bartlesville problems soon after his arrival. As project leader of fuels combustion research at the center, Hurn (as noted in Chapter 5) had been steadily carving out an important niche for himself and his people. Originally hired to head up a group studying the combustion of diesel fuels, Hurn had soon recognized the opportunities available on the emissions side of fuel combustion research. By the mid-1960s, his aggressive leadership had obtained extensive outside funding from the API, the Public Health Service, and a small grant from the Atomic Energy Commission, and had established close liaison with smog officials in Los Angeles and Sacramento, California. His Bartlesville group was thus in a strong position to obtain a major share of the air pollution research that would become so crucial as a result of the new environmental awareness of the 1960s. Tension developed, however, between project leader Hurn and his immediate supervisor, Cecil Ward, head of the petroleum Chemistry and Refining group. Believing that Ward was "too conservative," Hurn wanted to obtain more autonomy for his air pollution work.[17]

Ball, generally concerned with bringing Bartlesville research closer to the "cutting edge" and impressed with Hurn's proven track record of bringing in outside money, acquiesced to his wishes and recommended a reorganization of the Chemistry and Refining group. He spun off Hurn's Fuels Combustion Research group as a new research section in the spring of 1964, Ward remaining head of the Chemistry and Refining section. With this move, Ball had achieved two key administrative goals. He rewarded a dissatisfied Hurn with advancement, and the center now possessed a higher profile research arm capable of responding to the growing national priority of air pollution studies.[18]

In early 1965, Ball again demonstrated his willingness to support reorganization plans proposed by his senior staff. When Ball arrived at Bartlesville, he found all oil production work combined into one unit, the Basic and Applied Production Research group. Fowler had effected this centralization as a result of personnel changes which had occurred in the late 1950s. Watkins headed this group until July 1962, when he left for the Washington office, and Fowler replaced him with Robert T. Johansen. Ball decided to once again split this group into two separate entities: a Basic Production Research group, to be headed by Johansen, and a Petroleum Engineering group, to be headed by W. E. Eckard, who came in from Morgantown. Johansen had been unhappy at the time, not only because he had aspirations to lead the larger section, but also on the intellectual grounds that it was a mistake to separate petroleum engineering studies from the application of physics and chemistry. In 1965, Johansen proposed a reorganization of his Basic Production group into four subdivisions: petroleum, brines, reservoir studies, and energy applications. The purpose of this plan was, in Johansen's words, "not just the shuffling of a few people, but rather the beginning of a new research program oriented around projects instead of people and instruments."[19]

Ball congratulated Johansen on his plan and indicated his support of the attempt to bring Bartlesville research closer to basic science. Indicating that he was aware of Johansen's disagreement with the 1963 split of his group from Eckard's, Ball acknowledged the limitations of petroleum engineering alone, and cited the need for research into understanding the scientific principles which underlay oil reservoir behavior. Stressing how personally challenging the work was to him, Ball hoped that Johansen and his associates would "see the possibilities inherent in this assignment."[20]

Response to National Priorities: BPRC Air Pollution Studies

Although Hurn's air pollution work had begun to establish some credibility in the 1950s, it really took off in the 1960s. The major source of funding for this research had come from the Public Health Service under authority of the Air Pollution Research and Technical Assistance Act of 1955. Public Health Service funding progressively increased from $135,000 in FY 1961 to $157,000 in 1962, $235,000 in 1963, $275,000 in 1964, and $289,000 in 1965. The Clean Air Act of 1963, one of the first significant pieces of environmental legislation to come out of the 1960s, authorized funds for the 1965 appropriation. The following year, 1966, saw Public Health Service funds increase to $325,000. Hurn's efforts to develop a first-rate air pollution research team in Bartlesville were now rewarded as national priorities altered in favor of a cleaner environment.[21]

Hurn conceived of his Fuels Combustion group as encompassing a number of related areas. Basic studies into the nature of vehicular pollution included the characteristics and photochemical reactivity of emissions as well as the mechanisms of air pollution reactions. Specific projects also investigated the effects of engine, fuel, and combustion system parameters, the composition of emissions from various auto exhaust conversion devices tested in the laboratory, and the particular pollution problems related to diesel engine exhausts. External funding of this research had allowed Hurn to accumulate expensive laboratory equipment and measuring devices essential to the performance of this work, and Bartlesville had one of the best-equipped air pollution facilities in the United States. As public awareness of air pollution increased, opportunities beckoned to develop the center's expertise further.[22]

The Clean Air Act of 1965, proposed by Senator Edmund Muskie of Maine, provided for the creation of a federal air pollution control laboratory. After introduction of the bill, a familiar pattern repeated itself as the Bartlesville Chamber of Commerce mobilized its forces to have the center designated as the laboratory. The Chamber produced a slick brochure for distribution in Congress highlighting the air pollution work at Bartlesville. Phillips Petroleum provided help in the artwork and general layout of the pamphlet. The Chamber also solicited favorable external evaluations of the Bartlesville air pollution work from independent outside experts. As it had done in the past and would again in the future, the Chamber exhibited unusual and dedicated loyalty to the center. Although they had to be scrupulous in refraining from direct involvement in the Chamber of Commerce lobbying effort, of course, both Hurn and Ball were fully apprised and supportive of the effort.[23]

When the bill became law, however, the decision to create a designated national air pollution laboratory remained unclear. The final version of the bill had simply given authority to the Secretary of Health, Education and Welfare (HEW) to establish such facilities as necessary rather than focusing on one centralized facility. Undaunted by this development, the Bartlesville Chamber of Commerce shifted its lobbying efforts to increasing the center's budget within the Interior Department so as to expand its air pollution research capability. This would place the center in a commanding position to obtain a major share of new monies made available by HEW. The Chamber enlisted the Oklahoma Senatorial delegation to spearhead the effort in Washington, which was, unfortunately, doomed to ultimate failure.[24]

Even though the desire of both Hurn and the Chamber to see a dramatic expansion of the Bartlesville center's air pollution studies did not come to fruition, the Fuels Combustion group remained sound, with continued support from HEW and additional funds from the Coordinating Research Council representing the private sector. Successful tests with a demonstration automobile at Bartlesville in 1966–67 led Interior Secretary Udall to announce on December 28, 1967, that the Bureau of Mines had "demonstrated conclusively" the technical feasibility of curbing air pollution from automobile exhausts with methods and equipment already available. Bureau of Mines Director Walter Hibbard added that the next phase of work, reducing evaporative emissions from the carburetor and gas tank, would be attained by early 1969. "When we have done that," Hibbard said, "we will have equipped a car with a complete system for emission control and we will have accomplished what we set out to do. Then, the project will be terminated." It should be noted that Bartlesville's demonstration car used exhaust manifold reactors to control emissions rather than the catalytic converter—the solution ultimately embraced in the mid-1970s. Although Hurn saw future potential in the catalytic conversion principle, he believed it was still in an early development stage; in any case, Bartlesville was not equipped to test converter systems. Nevertheless, the center's technical work on auto pollution provided the basic rationale for the more stringent emission standards imposed by the Environmental Protection Act of 1969.[25]

Hurn's Fuels Combustion group achieved prominence at the center as a result of its high public profile and success in obtaining external funds. Yet despite this success, Ball expressed some misgiving about research priorities in a memorandum written in August 1967 to Watkins, then Director of Petroleum Research at the Bureau in Washington. Ball was concerned that the new Petroleum Research Program statement had overplayed Bartlesville's air pollution work. He wrote that "Somehow, air pollution considerations have managed to become predominant over those of supplying adequate energy. I don't believe this should be done although I would not minimize the air pollution impact."[26] Unfortunately, Ball's concerns for the total long-term energy picture, as prescient as they were in 1967, still remained outside the mainstream of public or congressional concern in an era of still apparent plentiful energy. Air pollution was "in" and energy conservation was "out."

Solutions in Search of Problems: Nuclear Studies at BPRC

The air pollution studies represented a technological response to a perceived national need. Nuclear energy related programs at Bartlesville, in contrast, as elsewhere in the 1950s and 1960s, more often resembled attempts to find a need for the technology. Much has been written about the Atoms for Peace program initiated by the Eisenhower administration in the mid-1950s, and it is not necessary to elaborate on it here. The basic fact was that the massive crash program represented by World War II's Manhattan Project had resulted in the development of an explosive device. Whether the motivation for peaceful atomic energy was rooted in altruism, the need for a public relations mask for continued weapons development, or international prestige, the result was the same. After passage of the

Atomic Energy Act of 1954, laboratories and scientific research institutions across the country experimented increasingly with atomic energy under Atomic Energy Commission (AEC) license in order to explore the mysteries of this new science or, as in the case of Bartlesville, investigate relevant commercial applications.[27]

Initial Bartlesville atomic energy work began in the early 1950s, proposing to use radioactive isotopes as tracers to obtain information about underground fluids. Use of these tracers enabled researchers to ascertain important data on the flow characteristics and patterns of crude oils and brines. This work extended into the 1960s under joint funding from the Bureau and the Division of Isotope Development of the Atomic Energy Commission.[28]

By the mid-1960s, the use of radioactive tracers in petroleum secondary recovery operations had become somewhat routine and much of Bartlesville's pioneering work widely accepted. In waterflooding operations, for example, operators used tritiated water to delineate the progress of a particular project in a field. Although it appeared promising to use such tracers also to follow the movement of natural gas, a major obstacle existed with the potential contamination of the gas deposit itself. In 1965, the center entered into a cooperative agreement with the Pipeline Research Committee of the AGA to develop a low-level gas tracer system suitable for natural gas operations.[29]

This problem of the radioactive contamination of natural gas deposits was indirectly related to the most dramatic research project undertaken by center technologists in the 1960s, Project Gasbuggy. By detonating an underground nuclear device in nonproductive, low permeability reservoirs, scientists theorized that they could stimulate gas production. Gasbuggy and the related Project Bronco—a plan to use a nuclear explosion to facilitate *in situ* recovery of shale oil—were the core of the Plowshare Program sponsored jointly by the Atomic Energy Commission, Bureau of Mines, and the U.S. Geologic Survey. Gasbuggy was essentially a Bartlesville project; Project Bronco essentially a Laramie one.[30]

A major concern in the planning for Gasbuggy was the radioactive contamination of natural gas which they feared would migrate to the reservoir cavity following nuclear fracture. The Bartlesville research team consulted with Oak Ridge National Laboratory on this problem to explore various ways to remove contamination from the natural gas—including Atomic Energy Commission filters, cryogenic processes, and tritium-hydrogen exchange procedures. Some data on underground gas contamination were available from Project Shoal—a nuclear detonation in the fall of 1963 designed to test the nuclear fracturing of rock formations—but there remained still some uncertainty as to the exact extent of contamination to expect with Gasbuggy.[31]

On June 16, 1965, the Bureau and the Atomic Energy Commission announced that Gasbuggy would proceed in cooperation with the El Paso Natural Gas Company, using a site located in the San Juan Basin, Rio Arriba County, New Mexico. President Johnson's elimination of funds from the FY 1967 budget, however, temporarily halted the project in early 1966. After several more months of delay, the final go-ahead came for the test to take place on December 10, 1967. Contamination of gas supplies did not, in the event, prove to be the most relevant concern. Rather than opening up fractures and stimulating recovery, the intense heat of the Gasbuggy blast sealed the rock formations and actually prevented the production of gas.[32]

From 1962 through 1966, Atomic Energy Commission appropriations of $164,000 had funded the research, development, and planning for Gasbuggy at Bartlesville. The nuclear shot itself cost the Atomic Energy Commission an additional $1.5 million, although this was part of a broader underground testing program involving research other than Gasbuggy. The experiment had certainly not shown that nuclear devices could stimulate gas and oil recovery. In fact, it had shown that such an approach was simply not technically feasible.[33]

Mainstream Research

For the many on staff at the Bartlesville center who were not involved in Gasbuggy, the 1960's offered little in the way of glamorous research; nor could they readily connect their work to an emerging national need other than the historical mission of conservation and engineering efficiency. This was the case, for example, for much of the routine work that Ward's Chemistry and Refining section performed. The semiannual API gasoline surveys continued under the direction of Oscar Blade at Bartlesville, to which, over the years, the center had added aviation fuel, diesel oil, and burner fuel surveys. On several occasions in the 1960s, Blade had to make adjustments in the gasoline surveys as, for example, when marketing patterns or octane ratings changed and "in-between" grades appeared. For the most part, however, this work was fairly mundane. Beginning in 1960, Blade began to require that the data for the survey be submitted on IBM cards to facilitate their compilation.[34]

In addition to these API-funded fuel surveys conducted at Bartlesville and published by the Bureau, work also continued on diesel fuel stability under a cooperative agreement with the Bureau of Ships, U.S. Department of the Navy. There was particular interest in determining the cause of instability after extended storage of the fuels. A similar contract with the U.S.

Army Materiel Command funded Bartlesville studies of stability in motor gasolines in storage. Neither project was especially innovative; however, they did bring in a steady stream of working funds and served to maintain staff in Ward's group throughout the 1960s.[35]

Beginning in fiscal year 1964, Bartlesville obtained a $50,000 Air Force contract to conduct studies of thermal stability in jet fuels. As the speed of modern military jets increased and the frictional heat of the aircraft climbed, the fuel supply itself served as a coolant or "heat sink." Under this considerable heat, however, the fuel frequently deteriorated, especially at speeds of Mach 3 or higher, forming gums and other degradation products. Center work on this project proceeded up through fiscal year 1966. A broader and more heavily funded program also sponsored by the Air Force centered on the long-term study of the availability of aviation fuels, including jet fuel. This project resembled the aviation fuel work that the center had carried out during World War II, testing various crude oils to ascertain their value as potential suppliers of high octane aviation fuels.[36]

In a similar vein, both Johansen's Basic Production group and Eckard's Petroleum Engineering group carried forward several projects rooted in past work. These included a study of oil production in Oklahoma waterflood areas, the use of foaming agents in stimulating oil recovery, petroleum composition research, oil field brine and water studies, and the removal of waterblocks from gas-producing formations. Largely funded by appropriated funds, these projects represented both examples of traditional Bartlesville engineering expertise and a demonstration of the center's capabilities if and when oil and natural gas production again became a national priority.[37]

Additional cooperative work with state agencies also remained a continuing thread in Bartlesville work during the 1960s. This included a project with the Kansas State Board of Health, on brines associated with waterflood projects, and Ken Johnston's annual waterflood tours in conjunction with the Kansas-Oklahoma Waterflood Association. The center maintained its long-standing and amicable relationship with the State of Oklahoma, and the basic state appropriation increased, from what had been a steady $75,000, to over $82,000 in fiscal years 1966 and 1967.[38]

Other ongoing projects which lapped over into the 1960s included Eilert's computer modeling studies of the delivery capacity of gas wells, and Harold Smith's broadly defined work on the geologic formation of crude oil. Originally conceived by Smith and N. W. Bass of the U. S. Geologic Survey, this project had lain dormant from 1957 to 1960. Upon returning to Bartlesville from the Region IV office, Smith devoted most of his time to aspects of this research under the title of "A Chemical-Physical Approach to Finding and Producing Petroleum."[39]

In the final analysis, however, despite a great deal of rhetoric in Washington about a redefined role for federal petroleum technology, the center still justified much of its activity in terms of conservation and efficiency—a mission that had been central to the core of Bartlesville work since its initial funding in 1918.

Service to Government or Support for Industry?

The undeniable fact was that, by the 1960s, the locus of petroleum research in the United States had shifted dramatically away from the public sector since the early years when the Bartlesville Petroleum Experiment Station was well in the forefront of almost all areas of research. An administrator of vision, but above all a realist, Ball was acutely aware of this fundamental change.

While in Washington on a training assignment in 1965, Johansen received the assignment of drafting the new program statement for Bureau of Mines petroleum research. Headquarters sent the draft to Ball at Bartlesville and to the Directors and Chiefs at Laramie, San Francisco, and Morgantown. Emphasizing the traditional Bureau role in furthering conservation and eliminating waste, the statement also stressed the major role that the Petroleum Division played in a broad range of scientific and technological issues affecting both the petroleum industry and the national economy. Johansen's draft was an improvement in language and organization over previous program statements. Nevertheless, it continued to play an outdated tune by exaggerating the level of expenditure and involvement of the Bureau of Mines.[40]

In a memo to Watkins critical of the program statement, Ball expressed the view that, although it might be accurate in describing the coal and mineral industries, it no longer reflected the realities of the petroleum industry. Ball believed strongly in both Bartlesville's and the Division's role in a federal research effort, but maintained that the administrative leadership had to decide "whether we intend to hide behind the set of half-truths which this program statement gives or whether we wish to strike out on a new approach."[41]

The reality was that the sum total of Bureau of Mines research in the petroleum industry represented only about two percent of the total United States effort. In this new era, in which large private sector research and development laboratories dominated, Ball argued that the function of providing advice to government should supersede the historical mission of conservation. The Bartlesville Director suggested that "not only is there advice given concerning legislation, policy formation, and similar subjects, but active cooperation is engaged in with a number of governmental agencies whose missions impinge on the petroleum research activities of the Bureau." Ball also complained that the program statement focused too much on petroleum production problems (demonstrating Johansen's influence). Most importantly, however, Ball emphasized that the Petroleum Division's research role differed markedly from that of the Bureau's Coal and Minerals Divisions where "they are a preponderant force in the research effort and . . . expect little except support from the industry forces." The fact was that, unlike the petroleum area, there was no real private research program in these other industries. The major problem as Ball saw it, was that the coal men were taking over the Bureau of Mines.[42]

After receiving a memo on the program statement from Hurn, which largely concurred with his own views, Ball dashed off another memo to Watkins accompanied by an alternative version of the statement he had hurriedly drafted over the weekend. The central core of Ball's document was the statement that "The role of the Bureau has, therefore, changed from a major producer of research knowledge to a consulting role in furnishing research competence to governmental and other agencies." He then tacked on the obligatory boilerplate language about the historical mission of conservation, need for basic (e.g., nonproprietary) research, role of information dissemination, and service to the independent company.[43]

Ball won only a limited victory, as the final program statement issued in February 1966 dodged the fundamental issue that the Bartlesville Director had postulated. It did, however, tone down greatly many of the broad claims suggested in the original Johansen draft and offered a more realistic assessment of the federal role in petroleum research. Ball kept hammering away, and the following year was able to write Watkins concerning the 1967 program statement that "the draft of the petroleum research program statement seems to be evolving into a much different document than our justifications of yesteryear which contemplated helping the small producer. This is, I believe, a desirable trend because I think it shows our thinking maturing into a national viewpoint dedicated to the public interest rather than a regional viewpoint centered on helping private industry."[44]

A further indication of the Bureau of Mines' diminishing influence in the private sector was the fate of the annual "alumni" breakfast. Since the 1920s, as noted earlier, these events had been held at the annual API meeting and served as an important informal way to obtain industry input into the research programs of the Petroleum Division. Attendance had been dropping off for many years, however, as fewer Bureau alumni moved into the research units of the large companies. The 1964 breakfast reached a nadir when only four alumni and fourteen current Bureau personnel were present. When planning for the 1965 breakfast indicated that only three alumni, three active Bureau employees, and Assistant Interior Secretary Cordell Moore would attend, Bartlesville cancelled the event and never revived it.[45]

The API: An Evolving Relationship

The demise of the traditional "old boy" network evidenced by the end of the alumni breakfasts did not mean that contact and liaison with the API, the petroleum industry's most influential trade association, was dead. A major area of association remained the cooperative funding agreements which had developed with the API projects on sulfur compounds and nitrogen compounds. Bartlesville's share of these projects had averaged approximately $52,000 a year from 1960 to 1966, funding divided between Don Douslin's thermodynamics and Cecil Ward's chemistry and refining groups. On July 1, 1966, the API terminated four research projects with Bartlesville, but negotiated two new cooperative agreements. Under the first, Ward's group received $50,000 to conduct research on the characteristics of high-molecular weight compounds in petroleum (heavy ends). The API renewed this project for several years and it became an important link with the Institute. (Laramie, North Dakota State University, and Carnegie Institute of Technology carried out other phases of the same project.) Under the second, Douslin's thermodynamics group obtained $75,000 to investigate the thermodynamic properties of hydrocarbons and related substances. In addition, the API continued to fund the annual fuel surveys under Blade's direction at the rate of $9,500 a year.[46]

The API cooperative agreements were extremely important for two reasons. They provided valuable dollars to keep basic scientific research going, but they also provided a "seal of approval" to research at the center. The situation which had arisen with the Aspinall committee in 1962 demonstrated the necessity of continuing to convince the Congress of the commercial relevance of the Bartlesville research. Cooperative support from the API became an excellent way to legitimize this work.[47]

The API relationship could be a double-edged sword, however. Congressmen might be impressed with the compilation of thermodynamics tables as basic research, for example, but not everyone within the Bureau of Mines concurred with this judgment. In a memo to Ball in January 1967, Henry C. Allen, Jr., Assistant Director for Minerals Research, stated that "you prefer to classify the program [thermodynamics] as basic research. My feeling is that it exists primarily for data collection, and that it contributes little to new thermodynamics and lately, at least, to new methods of measurement." Here Allen was using "lately" in contrast to the early days of the laboratory under Huffman, when Bartlesville was clearly a pioneer in low temperature calorimetry and other thermodynamics techniques. This negative view of thermodynamics as "data collection" was strongly confirmed in a recent interview by the authors with Dr. Walter Hibbard, Jr., at that time Allen's boss as Director of the Bureau of Mines.[48]

Ball today partially dismissed these charges with the rebuttal that the critics were "coal men" who failed to appreciate the value of the thermodynamics work to the petroleum industry. For example, Elmer O. Mattocks, director of API's Division of Science and Technology, justified this work in 1966 by saying that "scientists using these tables can more precisely devise new refinery processes for new and better products from petroleum." Ball does admit, however, that even so the data collecting charge has some validity.[49]

The case of the thermodynamics laboratory provides some insight into the functioning of the Bartlesville center more generally during these years. Without funding from the API, the thermodynamics section would have undoubtedly ceased to exist in the 1960s. This need for survival prompted Douslin and the other members of the group to pursue funding actively and outline additional projects. Here, "institutional inertia" actually helped the unit continue to function. In order for any research group to remain viable, however, a critical mass of scientists and support personnel is essential. If the group atrophies and dies during lean times, there will be no expertise available when national priorities change for the better. The thermodynamics laboratory was a creature of the World War II synthetic rubber crisis in the same way that the Bartlesville center itself traces its origins to the conservation concerns of the World War I era. The question of whether or not the federal government needs to maintain an independent research arm to respond to similar emergencies remains of crucial relevance today.

There was another problem in the 1960s which Ball perceived as such—the increasing share of nonappropriated funds in the Bartlesville budget. In early 1966, the Bartlesville Director became alarmed when projections suggested that, by fiscal year 1967, contributed and working funds would surpass appropriated money from the Bureau of Mines budget. API money was, of course, only one part of the nonappropriated total—which included significant amounts from Health, Education and Welfare, the Atomic Energy Commission, the AGA, and the armed services among others. Ball noted that the last increase that went for real research program expenditures in the Bureau budget appropriated for Bartlesville had occurred in fiscal year 1950–51, and that pay increases and operating expenses in connection with the new building had accounted for increased internal appropriations at the center.[50]

Ball spoke with praise of the strong cooperative relationships that had grown between the center and the API, AGA, and the Coordinating Research Council. The advisory committees of these private industry groups had ensured that Bartlesville research was reasonable, logical, and not wasted. But, Ball added, "the question which comes to mind is whether even a good thing can be overdone." In appealing for an increase from government funds, the Director argued that "The contributions that the Center has made are important and well documented. In some respects it appears that this achievement has been made in spite of, rather than because of Bureau of Mines control."[51]

A good deal of ambivalence clearly existed concerning the virtues of cooperative funding, particularly with the API. This situation was further complicated when public statements by members of the Kennedy–Johnson administration critical of the oil industry threatened to endanger what had at least been a very pleasant and supportive relationship with the Institute. In July 1964, Assistant Secretary of the Interior John M. Kelly alienated many within the ranks of the API by addressing the National Petroleum Council on the need for a renewed research effort in the oil industry. Kelly called for a major study and analysis of domestic petroleum production, suggesting that "little in the way of real action to deal with the problem has been forthcoming from industry members."

Since early in 1962, Kelly had played a role in various Interior Department studies concerning the need for a broader fuels policy. In an earlier address before the API, for example, he had implied that government petroleum research had to increase because industry had not undertaken sufficient work. These attacks on the petroleum industry by a member of the administration served to drive a wedge between the Institute and all government agencies. In spite of the long history of cooperation between the industry and the Bureau of Mines personnel, the adversarial nature of these recent statements threatened the basic ground rules.[52]

The API reacted by sending a committee to Washington to tell their side of the story: how much proprietary research was actually taking place. Ball, the other field directors, and the Washington staff met with the API group. The meeting concluded on the note, according to Ball, that "industry knew much less about our work than we knew about theirs." It was decided to form a new API Government Liaison Committee which would visit the various Bureau field centers and learn first-hand about the federal program in petroleum technology.[53]

The first trip by the Liaison Committee to Bartlesville occurred on October 5–6, 1964. Headed by T. M.

Geffen of Pan American Petroleum (oil recovery), the group also consisted of C. W. Arnold of Humble (oil production research), G. Denison of California Standard (production refining), F. M. McDonal of Socony Mobil (geophysics, geochemistry, and well logging), and G. Rittenhouse of Shell Development (geology). Texaco's C. E. Moser, a process refining specialist, was unable to attend. Things got off to a shaky start, and Ball felt that the committee was "somewhat antagonistic." At the conclusion of the visit, however, the members seemed highly impressed with much of what they saw, and both sides concurred that increased communications should be given high priority. To a suggestion by Geffen that his committee function as a general advisory committee to make an annual survey of Bartlesville work and make recommendations as to its value, Ball replied that the committee had to recognize that the center had many obligations to other petroleum industry groups, conservation groups, and to political direction from Washington. It had been largely for these same reasons that Superintendent Smith had resisted the formation of a general industry advisory committee for the station as early as the 1920s.[54]

The bombshell came in January 1965. Geffen sent Ball and his counterparts at Laramie and Denver copies of the Liaison Committee's report, after he had forwarded it to the API and Interior Department. The report concluded that most of Bureau petroleum research was "basic in nature and of value generally to the petroleum industry and the public," but that "in no case did the committee, on the basis of a first visit, become aware of research areas that warrant appreciable expansion; nor does it appear that there are any new areas not now under study which the government laboratories should enter, for advantage to the public."[55]

The Bartlesville staff was understandably angry. After the second Liaison Committee visit, in October 1965, Chairman Geffen agreed to submit a draft of future reports to the centers so that they could respond and provide input prior to final submission to the API Central Committee and the Interior Department. Ball received his copy of the draft second report in November and circulated it among Bartlesville project leaders. A series of detailed memos from them to the Director enabled him to send Geffen a detailed critique which clarified and expanded areas of the report which his staff felt to be either in error or unfair.[56]

Both positive and negative things resulted from the API Liaison Study and reports. On the one hand, a favorable evaluation of petroleum chemistry and thermodynamics helped Ward's and Douslin's groups to obtain continued API funding. On the other hand, Eilerts was bitter about the criticism of his computer studies of gas well delivery capacity, and Eckard was skeptical about some of the positions taken by committee members on secondary recovery strategies. At one point Eckard even speculated as to whether or not certain statements made were "to throw us off the track." It remained for Hurn, always seemingly able to get to the heart of the issue, to articulate the greatest danger that lay in the API Liaison Committee experience: "The report may be seriously misleading if it is assumed by the reader that all projects are treated in like fashion. This assumption may or may not be made, but I venture that someone relatively uninformed (e.g., the New Director) will be either positively misled or woefully confused by the report." Hurn proved in this case to be disturbingly prophetic.[57]

The recently appointed new Director of the Bureau of Mines, Dr. Walter D. Hibbard, Jr., had come to government following a career with the General Electric Company. Apprehensive about potential policy changes and aware that the Director had little petroleum background, the Bartlesville staff looked with nervous anticipation to Hibbard's first visit to the center in March 1966. Accompanying Hibbard were J. B. Rosenbaum, the Acting Assistant Director for Minerals Research, and Petroleum Research Director Watkins. Ball prepared a thorough orientation program, which included a walking tour, visits to laboratories, and a conference discussion with himself and the project coordinators. Hibbard also met with community leaders, including the Bartlesville Chamber of Commerce, and addressed the meeting of the advisory committees for two API projects which were coincidentally meeting at Bartlesville.[58]

The new Bureau Director was well aware that the Bureau's petroleum research no longer enjoyed a central place in the industry due to the massive growth of research and development in the large companies since World War II. Moreover, he placed great importance on industry advisory committee recommendations. It is also clear that some of the negative aspects of the API Liaison Committee reports served to hinder Ball's attempts to obtain larger appropriations for the center. After Hibbard's visit to Bartlesville, in conformance with the Bureau Director's strong belief in advisory committee input, the API Government Liaison Committee planned a third visit to be held in September 1966.[59]

Research projects at Bartlesville had historically originated at the center. When approved by the project coordinator and the center Director, they would then be sent to Washington for approval. Hibbard initiated his administration with the statement that he was going to change all that. The difficulty lay, according to Ball's recollection, in that technical people tend to be very specialized and are not usually versatile enough to adapt to new circumstances. This made it impossible for Washington to be able to utilize technical personnel efficiently.[60]

There was little disagreement between Ball and Hibbard about the realities of petroleum research in 1967. Unlike the coal industry, the private sector was now clearly the dominant force in petroleum. What separated the two men was Ball's firm belief that the center had an important role to play in the development of long-range basic research and as an advisor to government as it sought to mold policy in the public interest.

Epilogue: "Fifty Years of Petroleum Research"

On December 7, 1967, John Ball wrote to his former Laramie colleague, O. C. Baptist, to congratulate him on his transfer to head the San Francisco Petroleum Research Office. In his letter, he stated that "efforts to make an impression with a small work force always require an uphill fight. As Avis says—it's necessary to try harder. In Bartlesville, we are in the shadow of the much larger Phillips Research Center, and it is difficult to shine very brightly. However, we are going to make a real effort with our Golden Anniversary celebration for 1968."[61]

The first item prepared for the center's fiftieth anniversary was a gold-covered booklet, *Fifty Years of Petroleum Research*, assembled hurriedly in the fall of 1967. The core of the publication consisted of a listing and description of fifty selected achievements in petroleum science and technology arranged in five topical groupings. Collectively, they highlighted a history of Bartlesville service from J. O. Lewis's 1917 studies of oil recovery to Project Gasbuggy, which detonated only weeks before the brochure was printed. Most of the statements of achievement had been prepared two years before for an internal Bureau of Mines study and merely had to be edited and collated. Also prominent in the booklet were a list of "alumni" of the station/center and awards which had been presented to personnel over the years. Bartlesville's first full-time editor (if we leave out Superintendent Smith), Bill Linville, assumed this job. Linville, an experienced technical writer and editor, had come to the center from the post of editor of engineering publications for Oklahoma State University.

The introduction to the anniversary booklet pays homage to the traditional verities—conservation and the application of scientific and engineering principles to the petroleum business. But it also reflects some of the realities of the 1960s which Ball had tried to assert during the first four years of his tenure. Among these were the extensive development of private industrial laboratories in the petroleum industry, the preeminent role of basic research in the Bureau of Mines program, and the newly perceived function of "interpreting petroleum technology to other government groups."[62]

A number of other celebratory activities took place during the fiftieth anniversary year; there was much to reflect on and a list of accomplishments of which to be proud. Perhaps the high point occurred at the industry luncheon held in Bartlesville on March 28, 1968. It was there, amid many leading representatives of the petroleum industry, that both API president Frank Ikard and Assistant Secretary of the Interior Cordell Moore delivered speeches highly complimentary of the contributions that the center had made throughout its history.[63] The first fifty years taken as a whole represented indeed a tremendous collective accomplishment. The next decade of its history would present more dramatic challenges still.

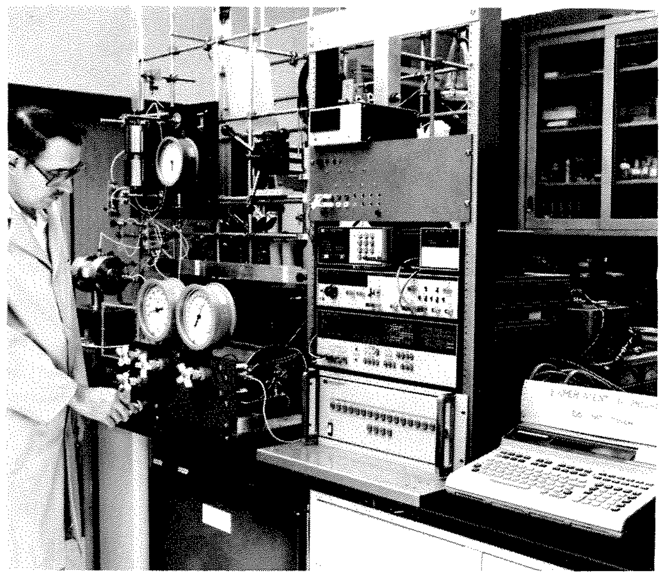
NOTES

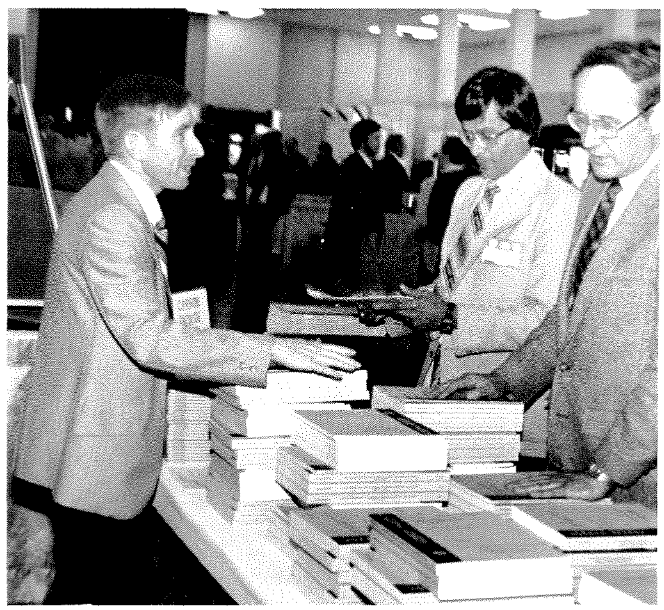
1. See Gerald D. Nash, *United States Oil Policy, 1890–1964* (Pittsburgh: University of Pittsburgh Press, 1968), pp. 180-208 and Crauford D. Goodwin (ed.), *Energy Policy in Perspective: Today's Problems, Yesterday's Solutions* (Washington, D. C.: The Brookings Institution, 1981), chapters 1-5.
2. Goodwin, *Energy Policy*, p. 288.
3. *Ibid.*, pp. 52-53, 205-206, 285-286.
4. *Ibid.*, pp. 339-340; R. M. Gooding, "Fifty Years of Petroleum Research and Service by the Bureau of Mines," unpublished manuscript, 1960, BETC, p. 185.
5. Marling J. Ankeny to Regional Directors, January 22, 1960, BETC Vault, Box 18, 1959–65, "Organization."
6. *Ibid.*
7. Memo, K. J. Hughes to J. Trevorrow et al., February 3, 1960, BETC Vault, Box 18, 1959–65, "Organization"; H. C. Fowler to Project Control Officer, Washington, March 20, 1963, BETC Vault, Box 27, 1964–65, 202.1-202.2.
8. H. C. Fowler to C. C. Anderson, February 1, 1962, BETC Vault, Box 18, 1959–65, "Organization"; Gooding, "Fifty Years," pp. 185-186; J. S. Ball to C. C. Anderson, December 21, 1962; J. S. Ball to G. U. Dinneen *et al.*, December 21, 1962, BETC Vault Box 27, 1964–65, 202.1-202.2.
9. Ball to Anderson, December 21, 1962.
10. *Ibid.*
11. John S. Ball, interviewed by Rodney Carlisle, Bartlesville, Oklahoma, January 20, 1982.
12. J. S. Ball to Wade Watkins, July 7, 1965, BETC Vault, Box 13, 1965–66, 47.51-050.2; "Program for Bartlesville P. R. C., January 1, 1966," BETC Vault, Box 35, 1966–67, 202.3.
13. *Review of Research by the Bureau of Mines*, Committee on Interior and Insular Affairs, House of Representatives (Washington, D.C.: U.S. Government Printing Office, 1965), 89 Cong., 1 sess.; C. C. Anderson to J. S. Ball, June 28, 1963, BETC Vault, Box 27, 1964–65, 202.1-202.2.
14. Anderson to Ball, *ibid.*
15. Marling J. Ankeny to Assistant Directors, December 2, 1963, BETC Vault, Box 27, 1964–65, 202.1-202.2; see "Program for BPRC, January 1, 1966," BETC Vault, Box 35, 1966–67, 202.3.
16. *Review of Research by the Bureau of Mines* (see note 13 above); J. S. Ball to Cecil Ward, R. W. Hurn et al., February 9, 1965, BETC Vault, Box 3, 1965–66, 08.4-022. 1; *Review of Research*, pp. 1-3.
17. Ball interview, January 20, 1982.

18. *Ibid.*, Memo, J. S. Ball to C. C. Anderson, March 30, 1964, BETC Vault, Box 181 1959–65, 101.3.
19. R. T. Johansen to H. C. Fowler, December 13, 1962, BETC Vault, Box 18, 1959–65, 101. 3; R. T. Johansen to J. Wade Watkins, February 3, 1965, BETC Vault, Box 18, 1959–65, 101.3.
20. J. S. Ball to R. T. Johansen, February 4, 1965, BETC Vault, Box 18, 1959–65, 101.3.
21. A. C. Stern to M. J. Ankeny, August 8, 1963, BETC Vault, Box 47, 1964–65, 826.15; "Contributed and Working Funds, BPRC, 1961–66," BETC Vault, Box 20, 1965–66, 180. 5-201; V. A. Mckenzie to Harry Perry, September 4, 1964, BETC Vault, Box 47, 1964–65, 826.95.
22. R. W. Hurn to Francis H. Woo, March 16, 1965, BETC Vault, Box 47, 1964–67, 826.95; R.W. Hurn to Jack Phillips, March 5, 1965, BETC Vault, Box 47, 1964–65, 826.95.
23. J. S. Ball to Wade Watkins, June 23, 1965; *Bartlesville, Oklahoma* (Bartlesville: Chamber of Commerce, 1965) ; C. E. Cummings to J. M. Houchin, June 23, 1965, BETC Vault, Box 4, 1965–66, 022.1-023.1.
24. J. S. Ball to Wade Watkins, December 15, 1965, BETC Vault, Box 39, 1965–66; Sen. Mike Monroney to Hon. Stewart L. Udall, January 3, 1966; Bartlesville Chamber of Commerce to Monroney, December 28, 1965; Sen. Fred Harris to Udall, January 17, 1966, BETC Vault, Box 39, 1965–66.
25. J. Wade Watkins to M. K. McLeod, January 3, 1966, BETC Vault, Box 57, 1966–67; "Contributed and Working Funds, 1961–1966"; Press Release, U. S. Department of the Interior, Office of the Secretary, December 18, 1967, BETC Vault, Box 26, 1967–68, "Public Relations" R. W. Hurn to H. D. Bowman, September 5, 1967, BETC Vault, Box 51, 1966–67, 602-605.
26. J. S. Ball to Wade Watkins, August 18, 1967, BETC Vault, Box 12, 1967–68, "Prog. Planning and Review."
27. See George T. Mazuzan and J. Samuel Walker, "Developing Nuclear Power in an Age of Energy Abundance, 1946–62," Papers Presented at the Conference on Energy in American History, Mountain Lake, Virginia, September 30–October 3, 1982 (Blacksburg, VA: Virginia Tech Center for the Study of Science in Society).
28. J. S. Ball to Acting Deputy Director, Bureau of Mines, December 13, 1963; "Accomplishments," BETC Vault, Box 27, 1964–65, 202.1-202.2; R. E. Jenkins and E. H. Koepf, "New Tools and Methods Improve Fluid Tracing," *Oil and Gas Journal* (April 1, 1963), pp. 102-104; "Contributed and Working Funds, 1961–1966."
29. Annual Progress Report to Pipeline Research Committee, AGA, October 1965, BETC Vault, Box 34, 1965–66, 552-603.
30. Charles H. Atkinson and Mitchell A. Lekas, "Atomic-Age Fracturing May Soon Open up Stubborn Reservoirs," *Oil and Gas Journal* (December 2, 1963), pp. 154-156; memo, J. Cordell Moore to Solicitor, February 1, 1967, BETC, Vault, Box 531, 1966–67.
31. A. D. Brownlow to J. S. Ball, June 2, 1965, BETC Vault, Box 2, PPE 1970; F. E. Armstrong to Participants, Shoal Experiment, November 5, 1963; A. Douglas Brownlow to M. A. Lekas, August 6, 1965, BETC Vault, PPE 1970.
32. J. S. Ball to David Rose, June 10, 1965, BETC Vault, Box 4, 1965–66, 022.1-023.1; Don C. Wood to Frederic H. Lahee, February 4, 1966, BETC Vault, Box 2, PPE 1970; Hon. Steward Udall to Dr. Glenn T. Seaborg, AEC, December 1, 1966, BETC Vault, Box 53, 1956–67, 825.1-826.1; *Fifty Years of Petroleum Research* (Bartlesville: U. S. Bureau of Mines, 1968), p. 22.
33. "Contributed and Working Funds" 1961–1966.
34. *Fifty Years*, p. 40; O. C. Blade to API Subcommittee on Fuel Surveys, March 15, 1961, BETC Vault, July 1, 1959–June 30, 1962, PC & R 16; C. C. Ward to R. M. Gooding, August 4, 1966, BETC Vault, Box 51, 1966–67, 602-605.1.
35. Memo, C. C. Kelley to C. C. Ward, August 18, 1961, BETC Vault, Box 46, 1964–65; "Contributed and Working Funds, 1961–1966"; "U. S. Bureau of Mines Field Work Order," January 18, 1967, Army Materiel Command, BETC Vault, Box 57, 1966–67.
36. W. V. Paxton to C. C. Ward, February 11, 1963, BETC Vault, Box 47, 1964–65; C. C. Anderson to Director, Bureau of Mines, August 20, 1963, BETC Vault, Box 36, 1964–65.
37. J. L. Eakin to R. T. Johansen, March, 13, 1963; R. T. Johansen to W. E. Eckard, January 18, 1965, BETC Vault, Box 27, 1964–65, 202.1-202.2; R. T. Johansen to J. Wade Watkins, April 2, 1965, BETC Vault, Box 33, 1965–66, 510.5-551.0; W. E. Eckard to S. M. Linger, AGA, September 29, 1965, BETC Vault, Box 36, 1965–66, 826.12-826.32; R. S. Sanford, Area IV Mineral Director, to Paul Zinner, August 4, 1964, BETC Vault, Box 6, 1964–65.
38. R. T. Johansen to Bruce F. Latta, June 14, 1963, BETC Vault, Box 45, 1964–65; K. H. Johnston to W. E. Eckard, October 27, 1966, BETC Vault, 1966–67, Box 48, 510.21-550; J. S. Ball to Hon. Ed Berrong, January 28, 1965, BETC Vault, "Cooperative Agreements, 1941–1965"; "Contributed and Working Funds, 1961–1966."
39. C. K. Eilerts to J. S. Ball, July 2, 1965, BETC Vault, Box 16, 1965–66, 080-110; C. C. Anderson to H. M. Smith, March 7, 1963; H. C. Fowler to Project Control Officer, Washington, March 20, 1963, BETC Vault, Box 27, 1964–65, 202.1-202.2.
40. C. J. Wilhelm to J. S. Ball, July 19, 1965, BETC Vault, Box 23, 1965–66.
41. J. S. Ball to Wade Watkins, August 6, 1965, BETC Vault, Box 23, 1965–66, "Prog. Statements."
42. *Ibid.*; Walter B. Hibbard, Jr., conversation with Rodney Carlisle and August W. Giebelhaus, Blacksburg, Virginia, October 1, 1982; John S. Ball, interviewed by Rodney Carlisle and August W. Giebelhaus, Bartlesville, Oklahoma, July 1982.
43. R. W. Hurn to J. S. Ball, August 9, 1965, BETC Vault, Box 23, 1965–66; J. S. Ball to Wade Watkins, August 9, 1965, BETC Vault, Box 23, 1965–66.
44. See "Petroleum Research Program Statement, February 1966," BETC Vault, Box 23, 1965–66, 202.3; J. S. Ball to Wade Watkins, August 18, 1967, BETC Vault, Box 12, 1967–68, "Prog. Statements."
45. J. S. Ball to Wade Watkins, September 28, 1964; Watkins to Ball, August 17, 1964, BETC Vault, Box 5, 1964–65; Watkins to Ball, November 1, 1965; C. C. Ward to Watkins, September 13, 1965, BETC Vault, Box 4, 1965–66, 022.1-023.1; Ball interview, January 20, 1982.
46. "Contributed and Working Funds, 1961–1966;" P. C. Caesar to API Advisory Committee on Refining and Products Research, April 1, 1965, BETC Vault, Box 36, 1965–66, 826.12-826. 32; J. S. Ball to Mervet M. Madkour, December 16, 1965, BETC Vault, Box 3, 1965–66, 08.4-22.1; API News Release, December 7, 1966; J. S. Ball to Michael Sinclair, *Industrial Research*, January 10, 1967, BETC Vault, Box 56, 1966–67, 826.32-826.37; "Contributed and Working Funds, 1961–1966."
47. Ball interview, January 20, 1982.
48. Harry C. Allen, Jr. to J. S. Ball, January 27, 1967, BETC Vault, Box 52, 1966–67, 605.3-706; Hibbard interview October 1, 1982.
49. Ball interviews July 1982; API News Release, December 1, 1966, BETC Vault, Box 56, 1966–67, 826.32-826.37.
50. J. S. Ball to Wade Watkins, January 11, 1966, BETC Vault, Box 20, 1965–66, 180.5-201.
51. *Ibid.*
52. U. S. Department of the Interior News Release, July 28, 1964, BETC Vault, Box 6, 1964–65; Goodwin, *Energy Policy*, pp. 341-346; J. S. Ball to C. C. Anderson, October 2, 1964, BETC Vault, Box 37, 1965–66, 826.322-826.65.
53. Ball to Anderson, *Ibid.*
54. *Ibid.*
55. T. M. Geffen to J. S. Ball, January 8, 1965; "Report of API

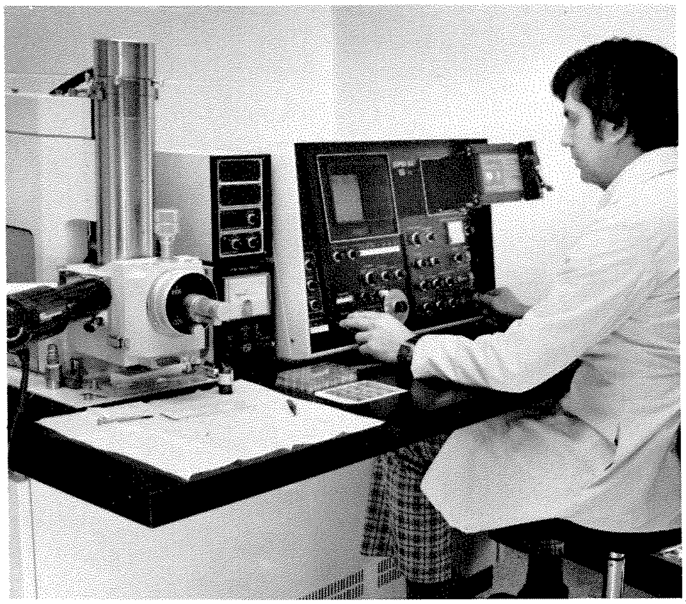
Government Liaison Committee, November 9, 1964, BETC Vault, Box 37, 1965–66, 826.322-826.65.

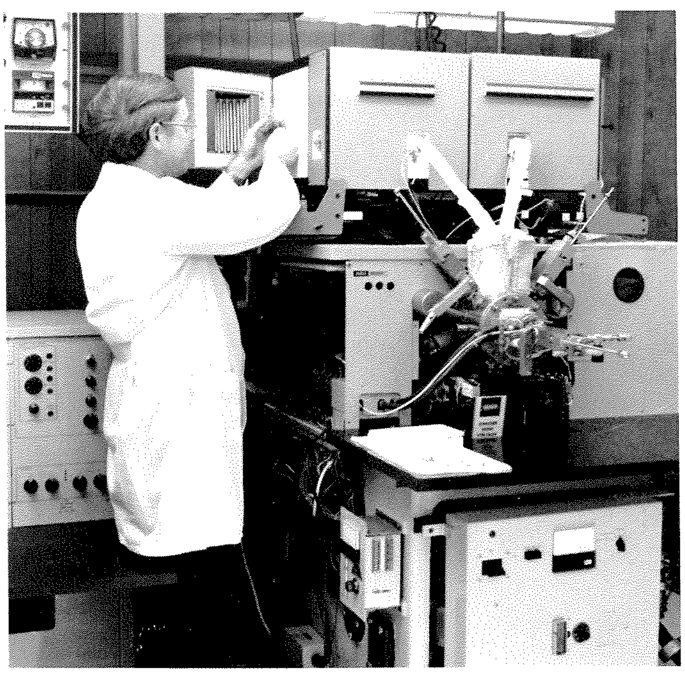
56. T. M. Geffen to J. S. Ball, November 23, 1965; C. Kenneth Eilerts to J. S. Ball, December 2, 1965; W. E. Eckard to J. S. Ball, December 4, 1965; R. T. Johansen to J. S. Ball, December 3, 1965; D. R. Douslin to J. S. Ball, December 3, 1965; R. W. Hurn to J. S. Ball, December 2, 1965; J. S. Ball to T. M. Geffen, December 13, 1965, BETC Vault, Box 37, 1965–68, 826.332-826.65.
57. Eilerts to Ball; Eckard to Ball; Hurn to Ball, *ibid*.
58. Hibbard conversation, October 1, 1982; memo, J. S. Ball to Project Coordinators, March 7, 1966, BETC Vault, Box 23, 1965–66; Monthly Report, Director of Petroleum Research, March 1966, BETC Vault, Box 14, 1965–66, 050.11.
59. Hibbard conversation; T. M. Geffen to J. S. Ball, April 13, 1966; J. S. Ball to Geffen, April 22, 1966, BETC Vault, Box 37, 1965–66, 826.322-826.65; J. Wade Watkins to Geffen, May 16, 1966, BETC Vault, Box 56, 1966–67.
60. Ball interview, January 20, 1982.
61. J. S. Ball to O. C. Baptist, December 7, 1967, BETC Vault, Box 26, 1967–68, "Public Relations."
62. *Fifty Years of Petroleum Research* (Bartlesville, 1968), pp. 1-2.
63. Communication, J. S. Ball to R. Carlisle, July 5, 1983.

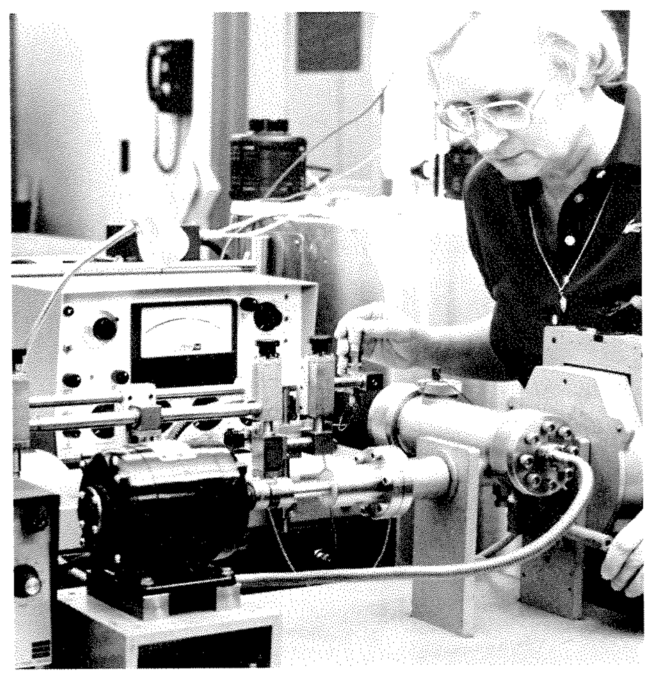




Upper left is a permeability apparatus designed to determine permeability at the pressures existing in the rock formation. Upper right is an automobile guided through a standard run by a mechanical controller to check exhaust emissions and efficiency of operation. Lower left is an X-ray apparatus which is used to measure the size of colloidal and micellar aggregates in crude oil. Lower right is one aspect of the technology transfer at BETC. It shows the distribution of publications from BETC at one of the major technical meetings.







The 1970s brought an oil shortage and an expanded recognition of the value of petroleum research. Responding to this attitude brought new equipment and new projects to the Center. Some of these are shown in the illustrations. Upper left is a scanning electron microscope used to analyze the surfaces of cores from oil wells with chemist Mike Crocker. Upper right, chemist Dennis Brinkman is using equipment for rerefining used lubricating oil. Lower left is a mass spectrometer combining the properties of gas chromatography with mass spectrometry to produce a powerful analytical tool. It is operated by chemist Gene Sturm. Lower right is an inclined plane vapor pressure gage designed and constructed at BETC. Chemist Ann Osborne is operating the instrument.

Chapter 7

GOVERNMENT ENERGY RESEARCH: EMERGING DEFINITIONS, 1968–1975

In the period 1968–1974, Ball continued the Bartlesville Petroleum Research Center's struggle for survival and self-definition. Some of Ball's difficulties were similar to those faced by Fowler two decades earlier in the post-war period. Shortage of funds, declining importance of government petroleum research, and the competitive job market, which made it hard to find and keep talented scientists, all hampered efforts to define a clear research agenda and stick to it.

Furthermore, older justifications for Bureau of Mines work in petroleum were no longer relevant. In the 1920s, the small government laboratory had assisted the petroleum industry by sponsoring research and technological development and by giving young technicians direct experience before they moved to careers in the private sector. As the industry developed its own research facilities, such small federal efforts could no longer make a significant impact.

By the 1960s, the public no longer viewed government and private sector as two parts of national system, working together for the common good. Rather, the public, government, and industry itself viewed bureaucrats and businessmen as opposing groups, a far cry from the cooperative mood of the 1920s or the 1940s. In the new view, almost any government assistance to private enterprise, no matter how modest or carefully structured, could seem a potential violation of ethics, a betrayal of trust.

As Ball managed the center through day-to-day crises and fought for dollars in this changed political climate, he and his colleagues tried explicitly to come to grips with their plight. Ball sought help from a variety of sources. He used history to show that the past achievements set precedents and patterns which offered a variety of potential lines of research for current and future work. In addition, he maintained outside sources of support, including continued cooperation with industrial associations and other government agencies requiring work in petroleum. Carefully staying within federal regulations regarding political activity, Ball and others at the center brought the center's plight to the attention of sympathetic congressmen, senators, and governors. In addition, Ball revived contact with the local Chamber of Commerce as a mechanism for political action.

Energy Research–An Opportunity for New Agendas

Following Presidential guidelines during the Nixon years, the Bureau of Mines began to emphasize energy research. Yet the new organizational emphasis on energy supply at first elevated those divisions and individuals in the Bureau of Mines whose backgrounds were in the coal industry. Rather than opening a new set of justifications for the center, the Washington concern with energy supply put the petroleum specialists at Bartlesville on the defensive. Ball argued forcefully that the patterns and approaches relevant to coal did not apply. The ensuing debate with Bureau of Mines headquarters provided an opportunity to develop a thorough-going self-examination and clarification of the center's function, its research agenda, and its place in the larger scope of federal research endeavors. The defense of the center by memorandum, conference and bureaucratic in-fighting consumed more and more of Ball's time as the struggle continued.

In 1971, the Bureau of Mines changed the designation of the center from a "petroleum" to an "energy" research center. And when the energy research activities of the federal government were consolidated in 1975 into the Energy Research and Development Administration (ERDA), the Bartlesville, Laramie, and Morgantown laboratories and the San Francisco office of the Bureau of Mines were transferred to the new agency.

The new Washington concern with energy supply in an overall sense did not, however, resolve pressing practical problems which had haunted the center since

1945. Exactly how would the talents and equipment of the center be utilized? What should be the center's relationship with the private sector? What particular research would be appropriate? Could a facility spending less than one percent of the nation's petroleum research budget (considering the massive private funding in industrial laboratories) realistically expect to have a leadership role, or even to make major contributions?

Ball and his staff worked to find new answers to these long-standing issues, as their holding actions against budget cuts required them to rethink thoroughly their own mission. But their lines of argument seemed to carry little weight with Bureau officials and with Congress. Their debates over the relationship of petroleum research to the total energy question, prior to the creation of the new Energy Research and Development Administration, laid a groundwork of arguments, vocabulary, and sophisticated policy positions that would be useful in the continued struggles over energy policy during the Ford, Carter, and Reagan administrations.

At the same time that Ball dealt with the larger policy questions surrounding the center's existence, he continued to manage the day-to-day business of the center. In particular, he struggled to tighten up the administration and internal budgeting practices of the center, to improve staff morale, to strengthen and develop outside cooperative agreements, and to ensure continued support for the work in emissions control which generated national recognition. The concept of nuclear explosive fracturing of gas and oil strata had held out promise for a few years of greater funding and a significant role, but the Atomic Energy Commission dismantled those projects rapidly in the period 1968–1970 due to technical problems of radioactive residue in the product and to the tendency of the underground blasts to fuse the strata rather than creating fissures and cracks. Coupled with the fact that the Atomic Energy Commission had set up an office of nonnuclear energy, the dismantling of Gasbuggy left a legacy of friction between the Bureau employees and those of the Atomic Energy laboratories—friction that was to hamper efforts to unite the two energy-related research agencies when the Energy Research and Development Administration was later planned and implemented.

Administration: Bureaucracy or Good Management?

The growth of the station and its increased reliance on outside funding through cooperative agreements and transfers of funds from other federal agencies required structuring of administrative systems at the center. As technologists and scientists, rather than managers, senior researchers at Bartlesville approached the need for more administrative work with ambivalence, some disdaining management techniques even as they practiced them.

Watkins, who had worked at Bartlesville in the production group, now served at Bureau headquarters as Director of Petroleum Research. In order to bring some coordination to the Bureau's petroleum work, Watkins issued a call for a conference of research directors and senior staff from the laboratories at Bartlesville, Laramie, and Morgantown, and from the San Francisco office, to be held in the spring of 1968. He circularized the centers for their ideas about the agenda for such a meeting, and Ball, in turn, asked his project coordinators and his administrative superintendent, Kenneth Hughes, to develop ideas for the proposed meeting.

Ball forwarded these ideas to Watkins. The staff believed the meeting would be a waste of time if devoted exclusively to discussing strictly administrative issues. Even Hughes, whose main responsibility had become mechanical, technical, and administrative services, shared this concern. He warned against dwelling on "the nuts and bolts of our operation," "our collective areas of weakness," and "how many copies of X proposals were sent to whom!" Rather, he hoped that the meeting would concentrate on the research being conducted, with each project coordinator discussing his areas: Hurn on Air Pollution, Douslin on Thermodynamics, Eckard on Petroleum Engineering, Johansen on Basic Production, Eilerts on Fluid Flow, and Ward on Processing and Utilization, with similar reports from the other centers.

The project coordinators agreed with Hughes: Johansen noted that the meeting should be "as short as practical" and that it should "stick to petroleum research problems." Eckard, even more skeptical, did not even think such a meeting should be held. Douslin suggested that the meeting be limited to 50 percent "administrative matters," and he hoped each project coordinator would be required "to review and interpret his research in light of long-term objectives." Hurn stated bluntly that the meeting should cover "technical research *only*; no administrative matter whatsoever." Ward, like Eckard and the others, thought such meetings a waste of time, with a ritualistic "commiseration" as the main function; if a meeting absolutely had to be held, he thought the project coordinators should not be required to attend.

Ball relayed the comments to Watkins, who had received similar comments from the other centers. In spite of the expressed views about administration, however, Watkins noted an undercurrent of ambivalence: "Some consensuses were expressed. The principal one was that such a meeting should be devoted to research, rather than administrative matters. This really is a hard one to analyze, because many of the examples of topics suggested for discussion fall into the category of research administration."[1] In the end, no agenda was needed. The proposed spring conference was cancelled due to the Poor People's March on Washington and the Washington riots following the assassination of Martin Luther King, Jr.

Ball, with his own background in petroleum chemistry and his experience at Laramie as a researcher, often felt uncomfortable about the administrative duties and behavior expected of research directors. In a sardonic, almost tongue-in-cheek "trip report" regarding dedication ceremonies for monuments at the helium facility in Amarillo, for example, Ball told Watkins that "unusual touches which added to the general interest included helium filled balloons at all events, the use of a helium filled balloon to pull the wrappings off of the Helium Monuments at the moment of dedication, the presence of Donny Anderson, the Green Bay Packer, to kick footballs filled with helium into the crowd as souvenirs." Ball's discomfort with the public relations efforts of Dr. Seibel at the Helium Research Center reflected his own, more formal attitude towards the Bureau's mission.[2]

All the project coordinators shared his ambivalence and disdain toward administrative duties. As scientists and technicians, they sought recognition from their peers in professional associations and from industry, but most of them did not thrive on publicity or on administrative power. Eilerts expressed this most explicitly when he argued against changing his own title from Research Scientist to Research Supervisor following a Bureau of Mines directive to that effect. "I have never sought to have large and increasing appropriations, many people to supervise, or numbers of publications . . . I want to continue on difficult assignments that can yield a novel, reliable, and potentially useful result if I succeed. I want associates enough and money enough to make efficient progress at those assignments and no more." Men with such values found it difficult to survive political and budgetary in-fighting.[3]

Within this general resistance to increasing bureaucratization, Ball and most of his project coordinators did work diligently to increase the efficiency of the center, to structure more formally the system of research, and to improve the center's publication output. Some of their methods reflected traditions of the center. The addition of Bill Linville as a "writing engineer" to improve the technical writing of the center, for example, was a conscious effort to fill the function once performed informally by Superintendent Smith. Linville, as Technical Writer–Editor, conducted workshops and seminars, inviting outside specialists to help in the in-house training. In addition to conducting his own course in Technical Report Writing, he brought in a variety of consultants to offer pointers on such topics as the writing of effective abstracts.[4] Ball also worked on the writing issue directly, issuing guidelines and clarifying the distinctions between papers given at conferences, reports to associations, and formal and informal talks.[5]

In day-to-day administration, Ball put in several new procedures to tighten up the working of the center. On details requiring action by all project coordinators, Ball issued regular, short, numbered memoranda, keeping the coordinators informed as to due dates for budgets and reports, visits by outside VIPs, news of awards and honors to staff members, arrangements for remodeling of facilities, and requests for standard information. Ball also developed a straightforward system of assessment against outside funds raised under cooperative agreements and transfers from other agencies, which allowed each project coordinator to know how much administrative cost for the center as a whole would be assessed against each outside fund. By forewarning his coordinators of forthcoming budget changes, Ball hoped to avoid unpleasant surprises and awkward shortfalls.[6]

Ken Hughes worked as Ball's assistant on administrative, budget, maintenance, and personnel matters. Hughes was able to determine for Ball those coordinators who over- or under-spent government appropriations or cooperative funding, to arrange for balancing transfers of funds inside, and to signal forthcoming problems. With funding coming from fifteen to eighteen outside agencies or associations, Hughes' assistance was vital.[7]

Further, Ball worked to keep the project coordinators informed of developments in Washington and to seek their involvement in policy discussions. Like it or not, the project coordinators learned about the political and policy battles surrounding the center; Ball sought and usually received their help and ideas. When Ball was called to Washington to meet with other research directors from the Bureau, he named a project coordinator, usually Johansen or Ward, to serve as protem research director of the center, and on his return he would give his senior staff a detailed report of the meeting. In order to involve the researchers who worked in the project coordinators' groups, Ball set up meetings with the members of each group to discuss finances and research progress. Through these meetings, even frontline researchers—the "bench men"—knew what was going on regarding the funding of their work.[8]

Ball then used the communication channels he had established to strengthen his hand in dealing with headquarters. He insisted that each project report emphasize at least one element of clear progress. As a scientist himself, Ball asked for such reports with a sympathetic understanding of the researcher's difficulties: "The pace of scientific research is slow enough so that it always becomes a problem as to when items should be reported. Nevertheless, even if progress was small, even slight positive results should be specifically noted so that Washington would gain no false impression of inaction."[9]

Despite Ball's efforts, the fundamental problems facing the center continued to plague him. Over the period 1962–1969, appropriated funds for Bartlesville increased by 11 percent, although not in regular increments. Yet out of those funds, the center was required to grant pay raises to all employees which averaged 35 percent. In 1967, when the station faced a reduction in force, Ball and his project coordinators scrambled to raise outside funds to offset the possible cutback. But dependence on nongovernmental funds entailed serious problems, especially since private groups would not build in inflationary increases from year to year.

Furthermore, some associations expected a minimal matching fund from the Bureau. If the Bureau contribution remained static and matching funds were required, a limit to the proportion of outside funding would very quickly be reached. In 1968–69, when the center achieved about 55 percent of its budget from non-Bureau sources, this natural limit of outside funding, given an inflexible federal appropriation, appeared to be reached. Ball recognized these limits but continued to fight for growth. Growth was essential, not for its own sake, but because the lab needed more staff and equipment to achieve any stability and to maintain its reputation for excellence. Ball complained to Bureau headquarters that the center remained inadequately equipped, partly because increases in budget had gone to preserve personnel rather than to modernize facilities. The center was simply not up to what Ball regarded as "critical mass"—that is, a budget and staff large enough to afford such basic needs as computer facilities, interchange of scientists with other laboratories, information services, and craftsmen for production and repair of equipment.[10]

Cooperative Funding: The Heyday

Ball also recognized that reliance on outside funding brought administrative headaches to the center. "We are particularly vulnerable," he noted in 1968, "because of the high percentage of contributed trust and working funds . . . No supplement to these funds is available to take care of the pay increase." And reliance on such money led to other difficulties. "Many of the working or trust funds," Ball wrote, "expire at various times during the fiscal year and no certainty of renewal is available until that time." Federal agencies that transferred funds to the Bureau for petroleum work received their final appropriation late in the fiscal year, keeping the final amount to be transferred uncertain. Past experience indicated that only about one-half of new funds under preliminary discussion from private sources ever materialized; yet that experience could not provide a firm guideline on which to base long-range planning. As scientists, Ball's staff could not bring themselves to ask regularly for 200 percent of needed money and expect to get 100 percent. The budget game might be played in that fashion in dozens of agencies, but Bartlesville persisted in asking for specific, needed equipment, supplies, and personnel using real, predictable costs.[11]

Ball tried to explain some of the difficulties to friends in industry. Specifically, a pay raise in fiscal year 1968 was difficult to cover. The government provided a supplemental appropriation for government budgeted funds. Yet cooperative funds from associations, such as API funding, would only be increased if the association would agree to do so. Without an increase, staff would have to be cut from the association-funded groups since the mandated pay raises had to be funded from somewhere. Federal budget cuts to the Atomic Energy Commission, the Air Force, and the Office of Saline Water led to slightly reduced transfers of funding from those agencies to the center. Ball tried to minimize the consequent expected 10 percent reduction in force by accepting retirements and resignations, and making some transfers of personnel to other facilities. Nevertheless, the staff cut claimed twenty-four positions. Ball asked his contacts at Shell Oil to use their influence with the API committees to work toward increased funding so that the API project work at the center would not have to be cut.[12]

The fact that private groups, by providing such money, could determine internal research agendas remained a sore point. When questioned by the Bureau of Mines on the degree to which non-Bureau funding determined the level of thermodynamics work, Ball admitted that thermodynamics research was planned in response to private funding. But Ball saw this in a positive light—in that private funding served to validate and insure the relevance of the research to national and international needs. Ball said he would "aim our work toward Bureau projects" if he could, but he doubted "if we can find groups working with sufficient sophistication to need thermodynamic data. However, I should point out that laboratories with the capability of our thermodynamics laboratory are 'rare birds' indeed (there are perhaps two in the free world) and that a concept of serving only Bureau of Mines research would reduce our benefit/cost ratio to an unacceptable level. Consequently we must base our assessment on an international service." The Bureau simply had to allow thermodynamics a wider field of clients to support the work if it was to continue.[13]

Private funding had become a case of the tail wagging the dog. Ball confessed to his colleague G. U. Dinneen, Director of the Laramie Center, that he and the Bartlesville staff had virtually given up trying to prepare programs based on the fiscal year. "We believe ourselves unable to write a fiscal year program and attempt to make ours for the calendar year. This is a reflection that our outside funding makes a bigger difference in our program than the appropriated funds."[14] Of course, for government planning purposes, Ball and Hughes still produced fiscal year plans despite the awkwardness of adjusting the two budgeting calendars. Through the late 1960s and early 1970s, this practice of keeping dual calendars was continued to keep both government and private sources satisfied.

In preparing the fiscal year 1972 funding, the center projected that more than 50 percent of its funding would still come from sources other than Bureau of Mines appropriations for petroleum research. Bureau funding for oil shale, mine safety, helium work, and coal research accounted for 22 percent of the proposed funding, with an additional 29 percent planned to come from other agencies and from cooperating associations:

Petroleum Research–Bureau	1,882,900	49%
Other Bureau Funds (coal, shale, etc.)	841,268	22%
Other Agency and Cooperating Groups	1,114,500	29%
Total Proposed for FY 1972	3,838,668[15]	100%

Ball summarized his thoughts about the advantages and disadvantages of the high level of outside funding that had developed for Watkins at Bureau of Mines headquarters in a clear-cut list of pros and cons. The arguments against outside funding, in his view, were that such funding prevented concentration on Bureau of Mines programs, could not be relied upon for renewal, did not provide for escalating costs due to inflation or for capital expenditures, and tended to divide the allegiance of the laboratory.

On the other side, outside funding permitted larger staff with a wider area of competence, provided new programs to enlarge areas of work, kept competent employees interested, and allowed for a larger laboratory (which, in turn, provided greater opportunities for personnel advancement, interdisciplinary consultation, and wider resources for problem solving). The competition for outside funding provided incentives for developing better proposals, and sometimes required a higher standard of performance than in-house programs. The reports from the center to other laboratories improved communication and transferred research know-how to the field. Finally, outside funding provided recognition and liaison from industry through advisory committees and monitors. Arguments in favor, thus, were quite compelling.

Ball also pointed out that some of the disadvantages of outside funding, particularly budget uncertainty, were not restricted to outside funding but applied also to internal Bureau funding. And in point of fact, the greatest single loss of funds during his tenure (the cut which had caused the center to search out greater outside funding) came in the sudden and unexpected cut of 1967 appropriated funds from the Bureau. With encouragement from the Director of the Bureau, Hibbard, the center raised its outside funding from 40 to 55 percent in that year. Hibbard expected to be able to restore and even raise the appropriated contribution to the center's work to match the outside funding. But Ball noted sadly that "this has not come to pass and our holding operation becomes more difficult each year."[16] Ball could argue in favor of outside funding when he was called upon to do so, but he remained well aware of the administrative and fiscal difficulties that it imposed.

When justifying high outside funding, of course, Ball stressed only the positive aspects of cooperative work. In explaining and justifying the high proportion of outside funds in the January 1, 1968, program statement,* the program stressed only the positive aspects of cooperation:

> "Advisory Committees bring new viewpoints into the planning and development of projects. Projects sponsored by industry often have access to information from company laboratories which constitutes a substantial contribution to the success of the research. Committees from industry associations can bring to the attention of government researchers the needs for information in specific fields. Most particularly, however, the association provides a means for disseminating the results of Bureau research to those who can most effectively use it in the interest of conservation."[17]

Such a presentation was not mere puffery. The high level of outside funding through this period did allow the center to survive, to maintain its reputation for professional work, and to disseminate the resulting information. Without the funds, the station would have shrunk to one-half its size, much too small for survival according to Ball's own calculations. Work with the API sustained several groups, including the continued crude oil and product surveys, the analytic work on the heavy ends of petroleum, basic thermodynamic work on petroleum hydrocarbons, and chemical analysis of compounds found in automotive and industrial exhausts. By 1974, for example, work on the "heavy end distillates" at Bartlesville had led to the preparation of some forty-five papers.[18]

Cooperation with other associations also continued and expanded. Funds from the AGA helped projects on oil and gas well stimulation by chemical explosives.

*Ball noted that "the ratio of direct to transferred funds is about 1:1." Actually, the proportion of outside money was slightly higher.

Individuals' membership and participation in associations also served to keep the station informed of developments and provide a degree of access to the business network, although they rarely yielded funding. Johnston and Eckard from the Bartlesville center and Watkins from Bureau headquarters, for example, attended meetings of the Independent Petroleum Association of America.[19] Johansen and Eckard served on the Secondary Recovery and Pressure Maintenance Committee and the Research Committee of the Interstate Oil Compact Commission.[20] Thus, despite increasing government-business tensions in the 1960s and 1970s, the center remained in relatively close contact with the private sector through business, professional, and cooperative work.

Specific cooperation with particular companies in exchange of information, equipment, and samples continued in much the same way as it had for decades. In particular, the center worked with DuPont, Shell, Sun Oil, and, of course, with nearby Phillips Petroleum on a range of specific projects. DuPont provided samples and information regarding its chemical explosives.[21] The center studied a Shell compound of sodium tripolyphosphate to improve oil well deliveries by its injection. Shell representatives came to the center for discussions of that project and received the obligatory tour of the facility. Ball and the staff believed that this and dozens of similar minor meetings and center tours through this period kept industry aware of the potential help and technical capacity at the center.[22]

More substantive cooperation in the tradition of demonstration projects went forward between Sun Oil's local DX Division and the center, with DX providing a gas well for testing with explosive fracturing methods to increase gas well deliveries. Costs were equally shared between the Bureau and Sun on a well in Osage county, convenient to the center. Publications produced under the agreement were cleared both by Sun and the Bureau.[23]

Cooperation of another kind continued with Phillips, as the researchers at the center used rental time on the Phillips IBM 360 computer. The rental of computer time presented a problem, since the rate charged by Phillips ($1,000 per hour) was higher than any other computer time charge paid by the government. Ball and Hughes worked up a justification for the expense, showing that savings on travel time to alternative facilities in Tulsa, as well as Phillips' cooperative work on debugging programs and in providing assistance at no charge, far outweighed the direct rental cost. And internally, Hughes and Ball noted that the Automatic Data Processing contract people in the General Services Administration (GSA) regional office who complained about the rate did not understand the issue. Hughes told Ball of the GSA complaint: "This is the tune they have sung for a long time; however switching cities will not help our service." Independent time-sharing consultants felt that the arrangement with Phillips was a bargain, and the center was able to keep the contract.[24]

Throughout the period, less formal, day-to-day community contact with former colleagues at Phillips and with other researchers there kept the two laboratories in touch. By 1970, however, the research facility at Phillips far outstripped the Bureau facility in staff, capital equipment, floor space, and budget. Indeed, the significance of the Bureau facility had so diminished that many local residents were no longer aware that Bartlesville was the site of the federal government's major petroleum research facility. The several thousand employees of Phillips and the company-town atmosphere served as a constant physical and psychological reminder to center staff of the minor part the center now represented in the total petroleum research effort of the nation.

Cooperation with government agencies ranged from small, older projects to large, new activities, and provided more funding and activity through this period than did cooperation even with the private sector. The cooperation with the State of Kansas over oil field brine disposal, which had continued on a small scale since 1935, came to an end in 1970; but the loss of that continuing project was quite minor, since funding of less than $1,000 per year had not even been fully expended in its last few years. By contrast, Hurn's budget from the Public Health Service (then the Health, Education and Welfare budget) and later, from the Environmental Protection Agency, represented the single largest infusion of outside money. Hurn's 1972 proposal included over $700,000 requested from EPA alone. Requests and transfers to other groups from Navy, Air Force, and the Water Quality Administration provided a few hundred thousand dollars through the period, while large transfers from Bureau work in mine safety, coal research, and oil shale fleshed out the budget on a larger scale. After the decline of the Gasbuggy work for the Atomic Energy Commission in 1967, the major large-scale, non-Bureau funded part of the Bartlesville program remained the auto emissions work of Hurn's group, to be discussed in more detail below.

Auto Emissions

Through the late 1960s, increasing media and public concern with the quality of the environment raised the issue of air pollution from local and regional forums to the national level. The 1965 Clean Air Act set national standards to be reached in auto emissions over the 1970s; the State of California set standards even in advance of the federal standards. Political agitation over the issue caused the petroleum and automotive industries to fear that public pressure might lead to either technically impossible standards or the pursuit of nonpetroleum fueled vehicles, such as electric-powered cars. A Department of Commerce task force in 1968 attracted wide publicity with its work on the feasibility of electric cars, for example, giving substance to the fears of the petroleum people.

In response to such pressures, in the period 1968–1970 the automotive and petroleum industries worked on several alternate solutions to the air pollution problem that would allow retaining the gasoline-driven internal combustion engine. Which path would eventually be taken depended on several factors, including the technical feasibility of alternate devices and systems, the commercial practicality of the choices, the ability to adjust control systems to established methods of producing fuel and producing automobiles, and on a range of political decisions made by state and federal governments.

Companies and industry groups experimented with several possible solutions: (a) a "reactor" to be installed in the exhaust system or manifold of new vehicles to burn hydrocarbons which otherwise would escape to the atmosphere; (b) lead-free gasoline of sufficient octane to meet popular desires for high-powered vehicles, which would be compatible with the reactors; and (c) systems of exhaust returns and crankcase ventilation which would provide for the condensation and reinjection into the fuel supply of gases containing unburned hydrocarbons. At Bartlesville, Hurn's group participated in government testing programs for all these systems; in addition, Ward's group participated in work on the development of standards for unleaded fuel.

On December 29, 1967, Secretary of the Interior Stewart Udall reported on HEW-funded tests conducted at Bartlesville of an experimental model of an exhaust reactor developed by DuPont. Under the 1965 Clean Air Act, the Department of Health, Education and Welfare had initial federal responsibility for evaluating emissions control systems. But much of the technical work for the Health, Education and Welfare testing was conducted with transferred funds through Bartlesville. In an indignant tone, Henry Ford II, Chairman of the Board of the Ford Motor Company, wrote to President Lyndon Johnson complaining of what he perceived as Udall's publicity-seeking announcement of the technical feasibility of the DuPont reactor. Specifically, Ford complained that it appeared that the Department of the Interior was wrongfully invading the area set aside for HEW jurisdiction. Ford noted that, despite "some difficulties" and "differences of opinion" between HEW and the manufacturers, an "effective working relationship" had been established. Udall's announcement, claimed Ford, raised the "specter that two separate arms of the Federal government may be vying to see which shall regulate our industry's technical efforts to reduce vehicle emissions."[26]

After checking with Udall, Johnson explained that the Bureau of Mines undertook technical work under cooperation with Health, Education and Welfare, and he assured Ford that HEW would continue to be the responsible agency for federal regulations under the Air Quality Act. No duplication would be permitted to exist. However, Interior's Bureau would conduct some of the research because "for more than half a century, the Department of Interior, through its Bureau of Mines, has been engaged in research on air pollution associated with the production, treatment and use of minerals and fuels."[27]

The publicity surrounding Udall's announcement of Hurn's work brought a flurry of inquiries and attention to the center. Hurn himself responded to inquiries from congressmen and state officials in Arizona and California, explaining that the testing of the reactor had only proven its technical feasibility, not its commercial application. More directly, Hurn wrote to technical people at the Ford Scientific Laboratory, explaining that the publicity had somewhat misrepresented his efforts. It was also Hurn's position that Udall released information about the reactor to reassure the public that smog reduction with internal combustion engines was quite possible, and that the electric car option advocated in the Department of Commerce studies need not be immediately pursued.[28]

In response to inquiries from California state and local officials as to the efficiency of the DuPont reactor, Hurn documented that the installed system yielded values of hydrocarbon emissions, carbon monoxide, and nitrogen oxides, and aldehydes that, in 1967, largely conformed to the California standard and met the planned 1970 national standards. Hurn warned, nevertheless, that optimism about the device should be tempered by the knowledge that its very high operating temperatures, in the range of 1500 to 1700 degrees F, created questions about the durability of the metals involved. With similar caution, he warned that "reference to technical success with the manifold reactor is to be interpreted only in the sense that at least one control approach is available; there may be others equally or preferably acceptable."[29]

Since tetraethyl lead would foul the reactors, a lead-free fuel had to be developed and marketed if reactors were to become commercially adopted. A special task force established by the API worked on the problem, and Hurn's group proposed a test experiment to run on several alternate no-lead fuels. However, as Hurn repeatedly explained in response to both public and technical inquiries, his laboratory did not "do developmental work on air pollution prototype devices." For such work, he referred questioners to the Department of Health, Education and Welfare's own National

Center for Air Pollution Control in Washington. The competence of the Bartlesville center lay more especially in "the analysis of combustion and mineral process gases as well as in the measurement of a wide gamut of related gas-borne contaminants."

As responsibility for emissions control was shifted to the Environmental Protection Agency, Hurn obtained funds from the new agency for his group to continue work. Cooperating with American Airlines and the EPA, Hurn arranged a project testing emissions from aircraft engines.[30] He continued to publish results and to give papers through this period, giving two papers focusing on fuels research at a 1970 conference of the American Society for Testing and Materials.[31]

1970 Efforts to Redefine the Center's Goal

Ball had remained dissatisfied with the underlying justification of the center's research listed every year in the statement of program. In January 1970, Ball suggested to Watkins, as Director of Petroleum Research at the Washington office, several major revisions in the program statement. In making his suggestion, Ball opened for discussion a fundamental issue which had troubled the center for decades but which had rarely received such frank and full airing. The existing program justification read as follows: "To develop new technology to increase efficiency and reduce the cost of finding, developing, producing, processing, transporting and utilizing the petroleum, natural gas, and oil-shale resources of the United States." Ball had serious objections to this statement and wanted to change "To develop new technology to increase the efficiency and reduce the cost" to language which emphasized a more proper, governmental role: "To promote the interests of the Government and the general public by the development and dissemination of technology."

Ball's recommendation was more far-reaching than might at first appear, and he was well aware that he was raising an issue fraught with political and ideological overtones. But he argued that several developments had outmoded the earlier approach of simply developing technology to increase the petroleum industry's efficiency.

First, he pointed out that the small budget of the Bureau of Mines was inadequate to affect significantly the total petroleum research picture. He estimated that the American petroleum industry spent about $500 million on research. The Bureau's total petroleum and oil shale research budget of less than $5 million raised the issue as to why the private sector could not simply take over all the research. He noted that there were at least fifteen private laboratories with far greater resources than those of the Bureau of Mines. Since all were profit-oriented and well aware of cost-benefit ratios, the private laboratories, with their superior reservoirs of skill, equipment, and resources, could readily take on any projects likely to increase efficiency in the industry. Ball was careful to recognize historical origins of the point of view of government assistance to industry, but he noted that the values which had gone into supporting government research in the decade 1910–1920 simply made little sense in the 1970s. The Bureau's original mission had been achieved, in that the private sector was now fully convinced of the value of and quite capable of conducting research that would modernize and make efficient transportation, production, refining, and other aspects of the industry.

As long as the Bureau continued to search for projects with "payout" defined as individual industry profit, Ball believed there was no reason to expect that the Bureau would find projects that the private sector would not be willing to take on. However, if the Bureau defined "payout" as a benefit to the entire industry or to the general public, then the laboratory's role might be useful. Further, if the government could accept low benefit-cost ratios, then industry might feel that the government should go ahead with the work in such areas as environmental improvement. In some particular cases, the cost of a research effort could be too high for a single company, even though the possible benefits might also be high; in those situations, the government might also have a role, as in the case of the Gasbuggy project. In short, under the older "efficiency justification," in the context of current industry research, the government research role was limited to three areas: projects broadly useful to industry, but not profitable to any single company; projects with too low an advantage to attract private sector work, as in environmental work; and projects, like nuclear work, that were so vastly expensive that private risk capital was hard to accumulate.

By adopting a more straightforward view that the work should benefit the government and the public, other more logical justifications were possible. Thus, the government might engage in research to benefit the environment without concern for cost-benefit analysis. Or the center could engage in research which would serve to interpret the complex technology to other government agencies concerned with regulation or prediction. Basic research and long-term research with no immediate or even foreseeable payout might be undertaken. Further, there would be unpredictable but very real benefits, such as benefits to science generally, information service to the general public, training service for individuals (including foreign nationals), and the spread of better technological practices through industrial associations, technical societies, and state governments.

Ball argued that the "government-and-people" orientation made sense, and in fact described what the center was actually doing. But the new definition of role could also open new areas. "If the program of Petroleum Research is built around the restated objective, a new emphasis would result. This emphasis would bring increased responsibility for us to take the initiative to inject ourselves into problems of current interest."

Ball solicited comments on his new "position paper" from his project coordinators and the project leaders who worked under them, and a lively debate ensued at the center through January 1970. Larman Heath of the Petroleum Engineering Research group liked the concept of protecting the public interest, and enthusiastically suggested a range of new projects which might be justified under the new program objective. Eilerts, however, warned that moving in the direction of "surveillance" of industry, rather than cooperation, would endanger the support from the business constituency that had been built up over the years. In particular, Eilerts suggested rephrasing changes in a way that would tend to reduce the implied criticism of industry (as if its interests were at odds with the public). He continued to view industry and the public as part of a single national entity, believing that the Bureau of Mines cooperative approach worked out in the 1920s and 1930s was appropriate.

Hurn, in contrast, agreed with Ball that the new description more closely conformed with what the center was in fact doing; Hurn's own concentration on emissions work did serve other government agencies and the interests of the public and placed emphasis on environmental concerns which industry had ignored until public pressure forced changes. Hurn worked closely with industry, but his work was in the political context of growing "environmentalism" which stressed the role of government as regulator of industry. Hurn agreed that the "cost-benefit game" was a poor guideline for work at the center.

Other researchers, like Johansen, agreed largely with Ball's new direction, merely suggesting some stylistic changes to give the statement more impact and readability. Ball incorporated some of the suggestions forwarded to him and made the presentation to Watkins in Washington.

On February 26, 1970, President Nixon announced a series of economy measures affecting a wide range of agencies and departments in the government, calculated to save $2 billion in government expenditures. As one small part of that effort, the petroleum research effort was to be redefined, according to the Presidential message, as follows: "Federal petroleum activities in the future will be limited to those research activities which are in the public interest, but which would not otherwise be funded by the petroleum industry. Research projects in the interest of the oil industry, which clearly could be financed by that industry, will no longer be paid for by the federal government."

Although Ball's rethinking of the center's mission happened to coincide nicely with the White House policy, in line with the new guidelines, the fiscal year 1971 Bartlesville budget was to be cut $300,000. As Ball noted in information provided to the local Chamber of Commerce, this cut came after severe cuts through the period 1967–1970 and on top of a longer period (1962–1967) in which appropriations were generally static in a period of increasing cost. The result had been a steady deterioration in the capability of the center to pursue petroleum research, even though in that same period new projects on air pollution research had expanded the competence of the facility in that regard.

Through May of 1970, Ball amplified his thoughts on the proposed new program statement, which would provide a mission in accord with his earlier ideas, and sent a fuller analysis of the Bartlesville research program and its necessary revision to Watkins, and through Watkins to W. L. Crentz, the Acting Assistant Director for Energy in the Bureau of Mines. Crentz's response appeared to miss several of the points that Ball had developed; but Ball believed, nevertheless, that he had stimulated a discussion which would help clarify the center's role. He felt that he had aroused the most "effective dialogue" in seven years of work with the exchange of correspondence with Watkins and Crentz over the question of policy direction.

Ball's basic point was that the center was "boxed in with a very narrow area of permissible work." Since the Bureau of the Budget would not fund research that industry itself could fund, only a residual area of public interest items and environmental subjects was left. Since pollution work was primarily undertaken by other agencies, the funding for emissions studies would never be direct. However, since the center had competence in the petroleum research area, it could provide assistance to the other agencies more directly involved. Furthermore, the suggestion of converting the petroleum research centers to "energy centers" raised some issues that Ball felt needed to be solved. Would each center diversify and take on a variety of kinds of energy research, or would Bartlesville continue to specialize in petroleum as an energy source? In any case, Ball wanted the Bureau to "place a stop under a badly eroding program." He argued strongly that the Bureau emphasize service to the public and to other agencies, and abandon the concept that "for a few thousand dollars" the center could have an effect on a "multimillion dollar industry." Ball patiently repeated to Crentz the differences between the structure of the petroleum industry and the coal industry, with which Crentz was more familiar.

The 1971 locally authored program for the center reflected the new language for which Ball had argued. But despite the articulation of the issues through an exchange of correspondence, Ball had received very little real policy direction from headquarters, and no fundamental change in the direction of the Bureau of Mines itself came out of the dialogue. The center staff may have clarified their own mission, from that of serving industry to a more conscious adaptation to the new politics of government-industry separation which had developed over the previous decades, but the change was seemingly lost on the headquarters personnel. The change of philosophy and adaptation to the new political environment, however, came just in time to help win local community and political support.

For example, Ball and his colleagues at the center used his new program in an appeal to the political forum in the form of a campaign mounted through the local Chamber of Commerce, which reached out to oil industry figures and state politicians. The Chamber mailed detailed materials regarding impending budget cuts to the Oklahoma congressional delegation. The materials described proposed cuts in budget from $1,353,000 to $1,053,000 (22 percent) and outlined the severe impact that such cuts would have on particular Bartlesville center research programs. The materials also outlined the direct impact of previous cuts of personnel and the loss of twenty-four positions in 1968 due to reductions in force combined with mandated increases in salaries for those who remained.

Budget cuts constituted a depressing tale and required a frank departure from the usual onward-and-upward tone of public relations material. The material prepared by Ball and Linville for the Chamber, and through the Chamber, for Congress, admitted the severe nature of the fiscal and morale problems openly. It was a sad story of unrepaired instrumentation, unmaintained buildings, sometimes overcrowded facilities, and no money to recruit younger scientists when staff retired. Instead, they noted, the center developed a staff "of advanced age whose training is obsolescent and whose average rating has crept up to an average level too high for the job being done." Morale declined from the repeated blows of 1967 budget reduction, the 1968–1969 reduction in force of twenty-four positions (from less than 200), and the proposed budget reduction of 1971. The most capable and youngest of the scientists and technicians looked for outside employment. Ball noted ruefully, for example, that of eleven petroleum engineers, two had taken outside employment in early 1970 and the others were looking for outside jobs. Despite all these difficulties, project coordinators had responded by raising outside monies and had conducted "a holding operation." But Ball and the rest were convinced, they said, that the 22 percent cut proposed in fiscal 1971 would destroy the center. Armed with such materials, the Oklahoma congressional delegation, led by Congressman Ed Edmondson, were able to prevent the cut in the 1971 budget.[32]

Crises Unresolved

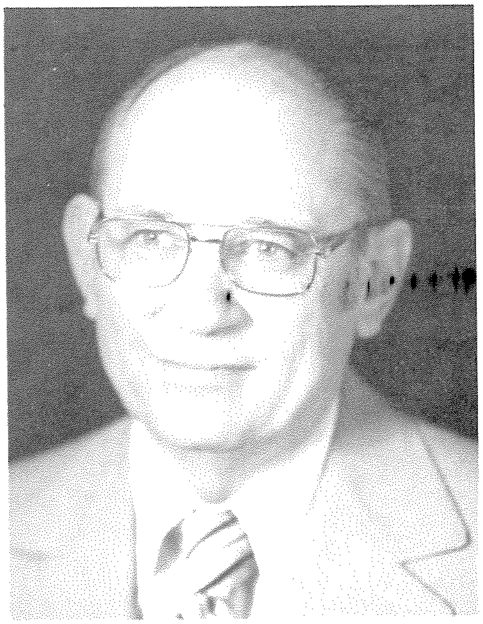
The budget crisis of 1970–1971 passed; however, Ball and his staff had found no permanent answer to the continuing need to justify the center and its research. At another level, concerns with America's total energy supply became a national priority during the Arabian oil producers' boycott of 1973–1974. Yet a concerted national response to the energy crisis was hampered by the virtual stalemate in government operations due to the Watergate scandal in 1974.

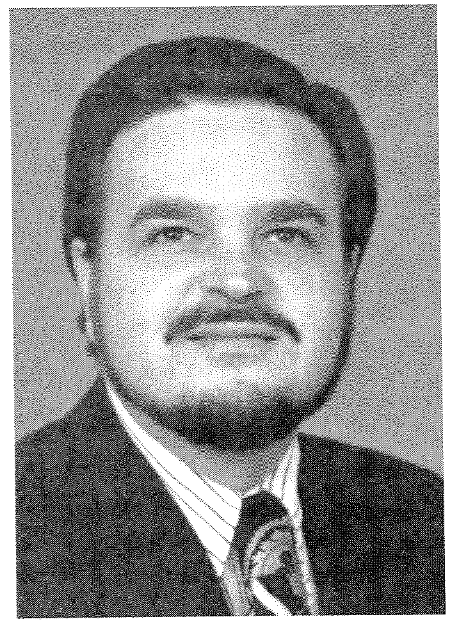
One proposal, which held promise for the future and reflected a successful case of bureaucratic and political in-fighting, was a set of plans for enhanced oil recovery or tertiary recovery, first put forward in the spring of 1973. The proposal went from Bartlesville through Crentz into the Bureau of Mines budget proposal put before Congress. Crentz supported the plans, and the idea received backing from Senator Bellman and the Oklahoma congressional delegation, who successfully fought off an attempt to have the work undertaken by the Atomic Energy Commission. After inclusion of funds in a supplemental budget appropriation in fiscal year 1974, funding on a regular basis began in fiscal year 1975. The first work on enhanced oil recovery under the proposal began in June 1974.

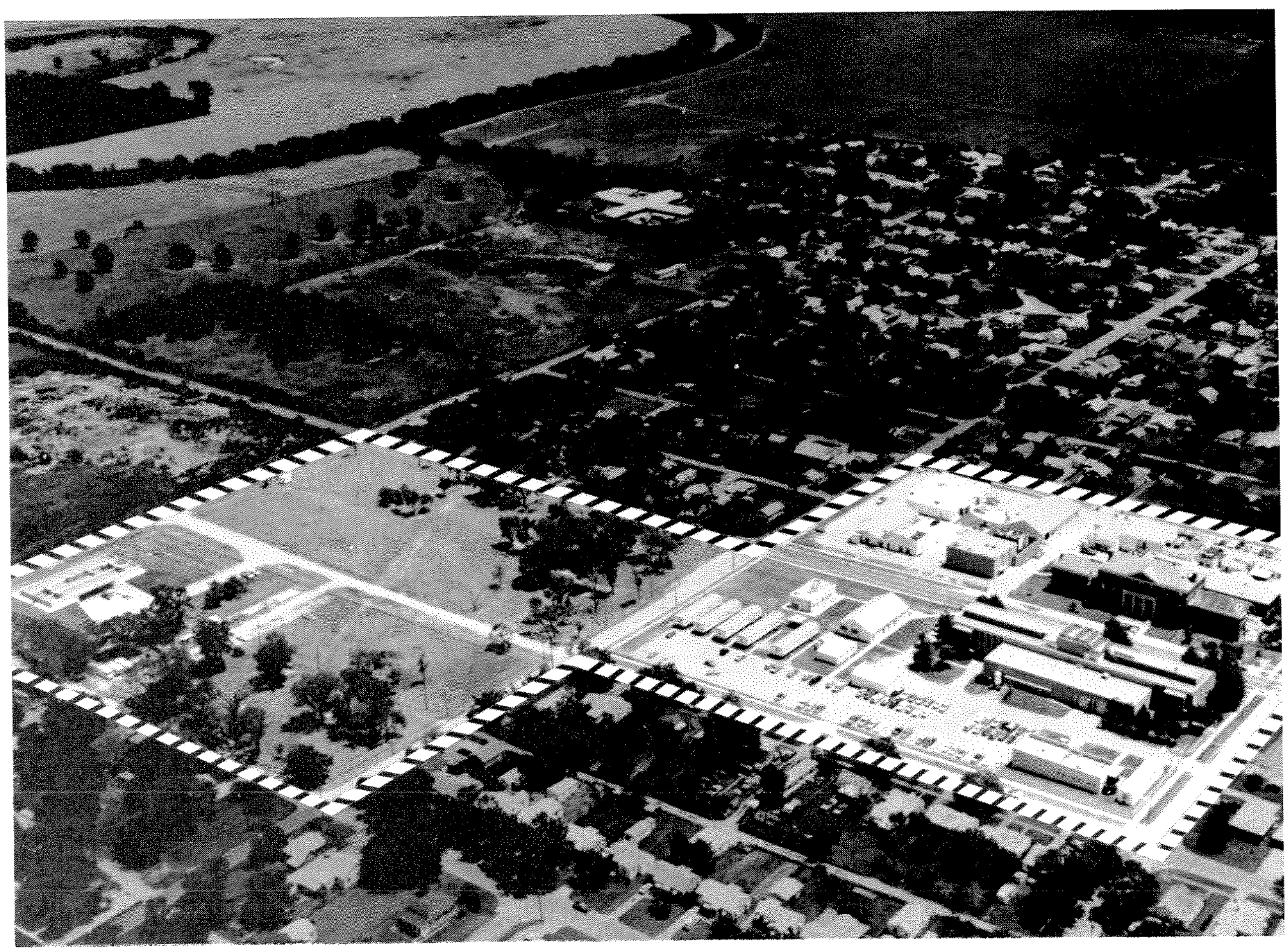
NOTES

1. Correspondence, March and April 1968, Hughes-Ball, Johansen-Ball, Eckard-Ball, Douslin-Ball, Hurn-Ball, Ward-Ball, Ball to Project Coordinators, Watkins-Ball, Ball-Watkins, BETC Vault, Box 5, 1967–68, Fuels Instruments to Meetings and Conferences.
2. Ball to Watkins, May 1968, BETC Vault, Box 7, 1967–68, Org-Monthly.
3. BETC Vault, Box 1, Administrative Management, FY 71.
4. Linville to D. P. Helander, May 7, 1968, BETC Vault, Box 27, 1967–68, Public Relations.
5. Ball to Project Coordinators, Box 7, 1967–68, Organization-Monthly Operations Reports, June 7, 1968.
6. Ball to Project Coordinators, Box 7, 1967–68, Organization-Monthly Operations Reports, June 19, 1968.
7. Hughes to Ball, September 18, 1968, BETC Vault, Box 3, 1968–69, Financial Management.
8. Ball to Project Coordinators, December 6, 1968, March 3, 1969, BETC Vault, Box 10, 1968–69.
9. Ball to Project Coordinators, June 10, 1969, Box 9, 1968–69, Organization and Administration.
10. Ball to Kostner, April 3, 1969, BETC Vault, Box 3, 1968–69.
11. Ball to Watkins, November 18, 1968, BETC Vault, Box 3, 1968–69, Financial Management.
12. Ball to Hinds, January 29, 1969, BETC Vault, Box 7, 1968–69.
13. Ball to Zinner, May 14, 1969, BETC Vault, Box 3, Finanical Management.

14. Ball to Dinneen, October 13, 1970, BETC Vault, FY 1971, Box 8, Proposals.
15. Ward to Crentz, March 26, 1961, BETC Vault, FY 1971, Box 8, Proposals.
16. Ball to Watkins, October 14, 1969, BETC Vault, Box 13, FY 1970, Property Management to Program Planning and Review.
17. Program for Bartlesville Petroleum Research Center, January 1, 1968, BETC Vault, Box 13, 1968–69.
18. Ball to Strauss, May 22, 1974, BETC Vault, Thompson Corr, Box 1; Summary of Program Changes and Achievements, 1967–68, BETC Vault, Box 2, 1968–69.
19. Ball to Taylor, October 10, 1968, BETC Vault, Box 1, 1968–69.
20. Ball to Watkins, March 18, 1969, BETC Vault, Box 2, 1968–69, Committees and Societies.
21. Eakin to Loving, February 15, 1968, BETC Vault, Box 4, Information Services, 1967–68.
22. Johansen to Ball, February 23, 1968, BETC Vault, Box 7, 1967–68, Organization–Monthly Operating Reports.
23. Livingston to Ball, September 25, 1968, BETC Vault, Box 4, Hughes Correspondence.
24. Hughes to Ball, June 6, 1969, BETC Vault, Box 1, FY 1970, Auto Data Proc-Bldgs & Grnds.
25. Ball to Watkins, June 10, 1970, BETC Vault, Box 4, 1970.
26. Ford to Johnson, January 12, 1968, BETC Vault, Box 5, 1967–68, Fuel Instruments to Meetings and Conferences.
27. Johnson to Ford, January 29, 1968, BETC Vault, Box 5, 1967–68, Fuel Instruments to Meetings and Conferences.
28. Hurn to Caupan, January 17, 1968, BETC Vault, Box 26, 1967–68, Public Relations.
29. Hurn to John Foran, January 18, 1968, BETC Vault, Box 26, 1967–68, Public Relations; Hurn to Pauline Koch, May 7, 1968, BETC Vault, Box 5, 1967-68, Fuels Instruments to Meetings and Conferences.
30. Hurn to Assistant Director for Energy, Bureau of Mines, June 28, 1971.
31. Ward to Ball, July 16, 1970, BETC Vault, Box 20, FY 1971, Reports and Stats.
32. "Future of the Bartlesville Petroleum Research Center," BETC Vault, FY 1971, 21, Reports and Statistics.







The BETC of the 1970s, directed by John S. Ball (1963–1978) (upper left) and Harry R. Johnson (1978–1982) (upper right), had grown both in area and stature. In sixty-five years, the Experiment Station of 1918 responded to industry needs and government policy changes, eventually becoming the National Institute for Petroleum and Energy Research in 1983. The lower picture shows the present extent of both land and buildings.

The Oklahoma Historical Society and the Oklahoma Petroleum Council cooperate in placing granite markers to commemorate important events in oil industry history. At left is the monument to Oklahoma's first waterflood (1931) near Nowata which was placed in 1973. Shown from the left are John S. Ball, then director of BETC, Kenneth Hughes, director of BETC Operations Division and R. C. "Chuck" Earlougher, a pioneer in waterflooding technology. At right is the marker describing the achievements of the Bartlesville Energy Technology Center which was placed in 1978. The marker states that BETC is the Nation's birthplace for petroleum technology.

Chapter 8

ERDA, DOE, AND FUTURE-ORIENTED ENERGY RESEARCH, 1976–1983

Ball remained director of the center through mid-1978, seeing the facility through two periods of energy research reorganization. In January 1975, the Bureau of Mines energy-research facilities, including the Laramie, Pittsburgh, Morgantown, and Bartlesville research centers and the San Francisco office, were merged into the Energy Research and Development Administration (ERDA). About 80 percent of the ERDA staff were former Atomic Energy Commission personnel, and many of the new agency's approaches and practices reflected the Atomic Energy agency's way of doing business.

Although short-lived, the two-year, nine-month existence of ERDA was a period of great advance for energy research in general. Yet, at the same time, a period of hectic reorganization of research administration in Washington and consequent disruption in the field facilities.[1] After the inauguration of Jimmy Carter in 1977, the administration worked to implement a campaign pledge to raise energy concerns to a cabinet-level issue by the creation of a new department.

October 1, 1977, saw creation of the Department of Energy (DOE), which combined the research and development programs of ERDA with a number of independent regulatory functions. The new DOE administration worked to put the various research programs, including those in "Fossil Energy" which would include "liquid fossil fuels" such as petroleum, on a coordinated and integrated basis.

In an effort to hold down the size of government, the Nixon, Ford, Carter, and Reagan administrations all imposed personnel ceilings. As always, federal managers sought to find ways around the restrictions. The solution of the Atomic Energy Commission had been the "GOCO" laboratory—a government-owned, contractor-operated facility operated by private personnel but financed by government. Similarly, the Washington offices of various bureaus and agencies brought contractors in to continue and expand their efforts. The cost would be politically acceptable, since Congress and the public would allow budget deficits as long as the "size" of government, measured in total number of employees, did not expand. Advocates of this procedure even argued, in the face of contradictory budget figures, that the private sector could do the job cheaper and still make a profit.

At Bartlesville, the highest personnel count was in 1968, although the highest funding was not achieved until ten years later. Contracting out to do various types of work enabled the center to meet the increasingly severe limitation on personnel. The procedure entailed a reduction in the amount of resident personnel with skills and knowledge, and more and more staff time monitoring contracts. As a consequence, of course, the staff had less time to do in-house assigned research or to take on outside cooperative-funded research.

Over the decade of the 1970s, contracting out work and reduced personnel resulted in attrition of the center's greatest asset—a group of highly qualified petroleum scientists and engineers available to tackle new problems. The impact of this process on morale was mixed. Many "bench-men" resented the new administrative, contract management tasks imposed on them; others seemed to thrive on the change.

Within the Atomic Energy Commission, the pattern of research decision and setting of research priorities had been vastly different from those of the Bureau of Mines. The national laboratories working on nuclear problems—including Los Alamos, Livermore, Argonne, Brookhaven, Oak Ridge, and Sandia—had operated on a massive scale. With nuclear research funded as part of the national defense, Congress and administrations since World War II had recognized that, in the area of nuclear technology, such research was extremely expensive. The mission of each laboratory was thus set as a matter of national policy. Although there were still struggles over budget, the priorities of projects were set within far more generous budget guidelines than the Bureau of Mines had ever dealt with.

By contrast, the government-owned, government-operated "energy technology centers"—shifted from the Bureau of Mines into ERDA and then into DOE—had fought annual budget fights alone, as if each were a small government bureau unto itself, with no nationally recognized defense mission. With only minimal political influence—consisting of one or two congressmen, one or two Senators, and sometimes a governor—and subject to the distant jurisdictional and budget struggles of Washington, for decades the centers had survived, sometimes barely, but had never flourished like the laboratories of "big science" such as Los Alamos, Argonne, and Brookhaven. Under the new ERDA and DOE arrangement, the centers, including Bartlesville, now faced the problem of competing for funding against the more powerful atomic energy laboratories in a changing and unclear administrative forum. Always subject to Washington decisions, the centers could only hope that ex-bureau personnel at ERDA headquarters would carry on their struggle.

Transitional Difficulties and Legacy of Assets

During the ERDA years, a series of developments exacerbated internal divisions at the center. Uncertainty about the future of the center continued, with hints that the AEC-dominated new agency would simply ignore the Bartlesville facility. The pattern which Ball and his division directors had established of seeking outside cooperative funding continued, but had brought with it severe internal complaints. Groups which had raised large amounts sometimes complained about Hughes and his implementation of a regularized system of an applied administrative 20 percent overhead to all funds. It seemed almost immoral to a scientist or engineer to see research funds diverted to necessary functions such as mowing grass, repainting, or other building maintenance. In addition, research funds raised by one group might be transferred from one group to another on orders from headquarters to support continuing personnel. Line researchers often saw such transfers and overhead as tantamount to theft, despite the fact that Ball, and Fowler before him, had worked diligently to keep the overhead rate low.

Hurn succeeded in raising the largest amounts of funding, often at odd moments in the fiscal year planning cycle. Ball, unlike Fowler, supported Hurn's work as one of the major assets of the facility. A few disgruntled researchers believed that Hurn was "out of control," operating as he saw fit and running his own division with an iron hand, threats, and fear of reprisals in the form of delayed promotions. Others, however, reported only restrained disagreements and procedures that were invariably perfectly honorable.[2]

Researchers and support personnel in all divisions, however, grumbled at the paucity of promotions. Several of the older employees were active in local politics, church groups, and civic organizations; some newer staff members who did not receive promotions wondered whether it was because they had failed to belong to the proper political movement, church, or men's organization. This is an unnecessary explanation, however, as the objective situation was such that Ball could make few promotions during the early 1970s.

Yet researchers did not entirely despair during the ERDA period. Under a major program, initiated at the center and supported in Washington, the center began to administer enhanced oil recovery projects in response to the energy crisis and petroleum shortage of the 1973–1974 embargo. The program, beginning in June 1974, opened major contracts in chemical flooding of oil fields already exhausted by waterflood techniques. The first of these cost-shared operations, using detergent-like compounds in a micellar-polymer process, entailed $5.4 million in government funding and $7.7 million eventually spent by the contractor, Cities Service Corporation. In 1975–1976, another micellar polymer project began between Phillips Petroleum and ERDA in the Burbank field, Osage County, close to Bartlesville. Another 1975 ERDA project, utilizing improved water flooding techniques, engaged Kewanee Oil Company which later merged with Gulf Exploration and Production Company at Shidler, Oklahoma, also near Bartlesville. Over the next years, new projects studying aspects of chemical and thermal enhanced oil recovery were added, using ERDA funds at a wide range of university laboratories and at oil fields all over the United States.[3]

Such cost-shared projects eventually absorbed, over the period 1974–1982, in excess of $96 million in government funding that was more than matched by private industrial outlays of over $130 million. For the most part, each project was "front-end funded," that is, the government share would be paid out in the first year of the project to assist in starting the project. These multimillion dollar amounts, paid from ERDA's and then DOE's contracting funds, showed up in the annual center budgets, raising the appearance of that budget to unprecedented scales.

Since the vast majority of the funding "passed through," however, the actual impact on the center was not of proportional fiscal benefit. Although the projects were funded generously, and although there were, by 1983, over twenty-five such projects, the administration—that is, the monitoring and evaluation of the projects' data and results—fell disproportionately on the staff at Bartlesville. Men and women hired as researchers were now cast increasingly in the role of administrators. Administrative responsibility consumed increasing staff hours, yet the center's total staff did not increase during the period of increased responsibility for monitoring enhanced oil recovery cost-shared contracts; rather, the total number of staff declined.[4]

The contracts for such cost-shared projects were placed from Bureau headquarters; however, Bartlesville researchers participated in the source evaluation boards and in project planning committees, as well as serving as technical project officers and research managers once the contracts were underway. In order to manage such large-scale contracts effectively, staff members with differing research backgrounds had to be assembled into management teams to oversee the various technical aspects of the cost-shared enhanced oil recovery projects. Ball gave Johansen the responsibility of setting up the teams. Johansen assembled matrix management groups that ranged in size between four and six, drawing on the skills of different types of technical people—chemists, petroleum engineers, production specialists, and reservoir analysts.

The enhanced oil recovery projects, from their inception, were viewed as a mixed blessing by the Bartlesville researchers. On the positive side, several benefits from the new contract management activity were clear. Those involved would work closely with colleagues in industry and in the universities and also travel to the field sites. As new locations developed under the system, more and more of the sites were further afield, with seven in California, two in Louisiana, two in West Virginia, and a scattering in other states. Field trips and professional exposure were fringe benefits for researchers engaged in matrix management.[5]

On the negative side, staff who were not involved tended to view the new responsibilities as detracting from the center's main research function. A few resented the removal of staff members from internal research projects to serve on Johansen's matrix management teams, as needed. Although this resentment could be interpreted by Ball and Johansen as "sour recycled grapes" on the part of those left out, in reality it reflected the complex of internal jealousies and bitterness that already existed, made worse by this infusion of contract management.

During the ERDA period, in-house and monitored research often brought results which attracted national attention. In October 1975, for example, ERDA announced an agreement with El Paso Natural Gas Company to increase natural gas production by massive hydraulic fracturing of the "tight" gas-bearing formations of the Green River Basin in Wyoming. This "western gas sands" or "tight formation" project attracted wide interest in the gas industry because hydraulic fracturing held out good chances of rather rapid pay-back in increased production. The principle was similar to earlier plans for nuclear-explosive fracturing, but would not entail the environmental problems associated with the nuclear approach. Under the project, to which ERDA initially contributed $596,000 and El Paso Natural Gas spent over $4.7 million, massive injection of polyemulsion fluid and sand proppant in the range of 200,000–500,000 gallons would force open gas-bearing formations to increase gas recovery. Like the enhanced oil recovery projects, it entailed a contract monitoring team from the Bartlesville center.[6]

Another such project was the development and testing of a process to recycle used engine oil, announced by the center in June 1977. Unlike earlier recycling processes, the Bartlesville method did not produce an "environmentally objectionable by-product" in the form of acid-rich sludge. Rather, the old oil was heated to drive off volatile hydrocarbons and water. A solvent removed carbon sludge. The clean oil could then be redistilled, and other additives to improve color and odor mixed to reformulate the oil. This "retread oil" met high engine performance tests, making it the first recycled lubricant in the United States to perform at or above new oil specifications.

Charles Thompson, Bartlesville's head of Chemistry and Refining, expected difficulties in marketing the final product of the process due to public resistance to any "used" oil, even if it was chemically identical to "new" oil. Yet the potential saving of petroleum in a time of crude oil shortage was enormous. Thompson estimated that 1.1 billion gallons of lubricating oil per year were used; of this amount of waste, 480 million gallons were burned as fuel oil, 90 million gallons were recycled by older, polluting processes, and 200 million gallons were used in road oil and asphalt. Some 340 million gallons simply vanished into the environment. With proper legislation, the Bartlesville process could convert the vanished gallons into a replacement for new products at the same time it was reducing pollution.[7]

Headquarters

If the offices of ERDA faced a mixture of new opportunities and confusion, dissension, and morale difficulties, the merger of Atomic Energy and Bureau of Mines administrations at ERDA headquarters could only be described as an organizational nightmare. In 1976, under ERDA, the Market Oriented Program Planning Study (MOPPS) task force was established to evaluate research priorities for the agency. At the very time that the Fossil Energy staff became absorbed in the MOPPS study, however, Congress approved the creation of the Department of Energy to absorb and replace ERDA. Few Fossil Energy staff members were present in the ERDA office to oversee the transition to the new agency, since most were involved in the MOPPS work. During the establishment of the Department of Energy (DOE) after October 1977, therefore, administrations constantly had to reshuffle personnel.[8]

George Fumich, a former West Virginia political figure, who had previously run the office of Coal Research in the Department of the Interior and had extensive political experience but no research experience, assumed direction of the new Fossil Energy unit within DOE. Fumich had been confirmed by the Senate; but his nominal superior, the acting Assistant Secretary for Energy Technology, had not. Fumich himself was then appointed Assistant Secretary at Senator Byrd's specific request, under which circumstances, of course, he was able to make crucial policy decisions with de facto near autonomy.

Within ERDA, Harry Johnson, working with Martin Adams and with Watkins, formerly of the Bartlesville center, had helped develop the rationale for the enhanced oil recovery program and had "sold it within the administration." The result was the first "real slug of money" to go into this area. After Fumich's appointment to head the Fossil Energy unit within the new DOE, Johnson went to the DOE Comptroller's office to establish what he later called a "think tank" Office of Financial Policy. Given the background of Johnson's success in promoting enhanced oil recovery and setting up the Office of Financial Policy, Fumich selected Johnson to replace Ball as Director of the Bartlesville center—holding the appointment open for Johnson, in fact, while he finished work on Commercial Task Force Studies already underway at DOE headquarters.[9]

It was during this transition period that the Department's policy of "decentralization" was put in place. Fossil Energy field offices had sought this change for years under the Bureau of Mines, as had the management of Energy Technology within ERDA. Both groups desired that research management be handled not in Washington but by the field offices. The nuclear national laboratories had in the past operated under such a decentralized plan, and the former Bureau of Mines Fossil Energy people welcomed the change.

A New Director—Harry Johnson

Harry Johnson had earned a B.S. degree in Petroleum Engineering at the University of Pittsburgh in 1960, and had served as a researcher at the Bureau of Mines Morgantown facility from 1960 to 1965. For the next ten years, he had worked at the Department of the Interior in Washington, D.C., in a variety of research management positions—putting him in a good position to participate in the transitional activity from ERDA to DOE. When he took on the directorship of the Bartlesville center in October 1978, he was charged with bringing the research capacity in the field into line with the law and policy statements of the new Department of Energy.

Johnson inherited a center which had already faced two recent administrative changes: Bureau of Mines to ERDA, 1975, and ERDA to DOE, 1977. Yet careers which had begun in the early post-war era were still in full swing. "Old-timers" now included men who had lived through the difficult Fowler years and the budget "crunches" of the 1960s, and who still had at least five or often ten years to serve before reaching retirement age.

Johnson was under a mandate, but had few powers to work with in carrying it out. He could bring only a limited number of new staff members in; given the staff configuration, retirements and resignations would only gradually open a few new slots. In order to accomplish a management reform from the "top down," therefore, Johnson would, for the most part, have the task of requiring long-term, experienced researchers—some senior to him in years of service—to change their methods, their lines of communication, their objectives, and their reporting procedures.

Johnson's approach was to bring to bear new philosophies of management: He used a "systems approach" on petroleum research and expected to plan research by the "critical path method," using "mission-oriented" and "management by objective" structures and planning tools. Skeptics saw the new language as rhetoric; supporters believed that specific, real changes would result from the new approach.

In the period before the creation of ERDA the budget of the center was in the range of $2–3 million per year. In the 1977, 1978, 1979, and 1980 fiscal years, it climbed to the range of $20–30 million per year. The vast bulk of the new funding was not spent directly at the center—in that it represented funding of outside "cost shared," or contracted out, projects with private firms and universities, largely in the area of enhanced oil recovery research and development initiated during the transition from Bureau of Mines to ERDA. The center's internal budget increased only slightly to over the $4 million per year range.

Senior Personnel—Shifts and Appointments

The appointments Johnson was able to make soon after he arrived at Bartlesville brought in staff members who had had prior experience at headquarters, including Bob Folstein, a chemical and nuclear engineer who had served with the Central Intelligence Agency from 1961 to 1976 and who managed the Fossil Energy Planning and Analysis Staff in Washington during the Department of Energy's first two years of existence; Barbara Barnett, who had a prior administrative career at the AEC and ERDA; attorney Ron Olson; and petroleum engineer Don Ward.

The autonomy of the research divisions which had grown up during Fowler's and Ball's administrations represented a potential barrier to unification. Johnson's first priority, therefore, was to implement a new "integrated" research plan. No longer could each research division at the center, now under DOE rules, acquire separate outside funding. Instead, the center would have to develop a coordinated single research program which explicitly met the policy lines, policy statements, and legal expectations of the enabling legislation.

Not surprisingly, Hurn disdained the management style and the Washington orientation of the new staff; and from their point of view, his persistence in proceeding on his own independent way was unworkable. His retirement came on February 19, 1980, however, and Johnson was able to bring in Ted dePalma, with over thirty years in petroleum industry experience, to replace him. Aside from Hurn, for the most part Johnson found great support among division directors. Charles Thompson of Petroleum Chemistry was "a tower of strength," Johnson later commented. He also found Bill Good of Thermodynamics to be extremely helpful in preparation of new documentation for the center. Johnson put Johansen, whom he found to be dynamic and a clear thinker, in charge of project management; he then combined Johansen's Production Division and the Resources Characterization group into a new division, Extraction, which he headed by new appointee Ward. On Thompson's retirement a little later, Johnson selected Bill Good to head the Processing Division. Thus reorganized, within two years the center had been reduced to three large research divisions, all headed by Johnson appointees: Extraction, headed by Ward; Processing, headed by Good; and Utilization, headed by dePalma.[10]

Johnson and certain of his new appointees—Folstein, Olson, Barbara Barnett in Administration, and Don Ward in Extraction—soon became regarded as the "Washington group" within the center, and their innovations and ideas were sometimes resisted by individual old-timers, particularly those who had been successful in working with Ball, as those of outsiders. But those who had felt bypassed under the Ball administration welcomed the new direction.

New Management Goals

Johnson convened a meeting in November 1978 to begin work on planning a systems approach to the research at the center which would yield a coordinated single research plan. Called the Liquid Fossil Fuel Planning Cycle, the systems approach applied at the center required researchers to view their own work as part of a larger system which as a whole produced results useful to other researchers. Beginning with exploration and moving through recovery, processing, refining, and utilization, this approach viewed petroleum as a fuel source subjected to a series of technological processes, taking it from its underground source through refineries to eventual energy production. Viewing the production of liquid fossil fuels in this systematic fashion made the connections between different research areas clear. For example, research work on one type of chemical enhanced recovery process might in fact be wasted if other technologists had already discovered in field tests that, for whatever reason, the particular chemical gave difficulty in refining. Certain sectors of the national or total petroleum research system (such as geology) were not represented at Bartlesville; but research on a good part of the whole petroleum process could be conducted at the center.

This application of a systems approach to the center's petroleum research struck some as an exercise in bureaucratic time-wasting. As staff members wrote up the planning cycle, however, several benefits became obvious. In February 1979, a draft report, based on two intensive planning conferences held in November 1978 and January 1979, explained the approach. The center staff placed their research in a national context, noting that about one-half of the energy used in the United States derived from liquid fuels. The flow of liquid fuels from discovery to use needed to be examined in three categories: extraction, processing, and utilization. Using this conceptual framework, the staff systematically studied technology objectives that would promote the orderly flow of liquid fuels into the national economy. The report described the research, summarized the state of the art, identified objectives, and described current research, future needs, and expected results.

Using this information base, the staff worked to "prioritize the options, select what is appropriate for Government involvement," and then decide who would undertake specific program elements. The program was not simply designed to reflect work underway or anticipated at Bartlesville; rather, it was constructed as a nationally applicable model for *all* liquid fuel cycle research.

Altogether, fifty staff members participated in the conferences, representing the core of the research professionals at the center. In addition, four outside consultants were brought in, including Ball, now working as a free-lance consultant.[11]

When Folstein arrived a few months after Johnson, one of his first assignments was to continue the planning work on the Liquid Fossil Fuel Cycle and related management issues. Folstein brought a mission-oriented approach from the Central Intelligence Agency and a critical path method to budget discussions.

Folstein supervised the issuance of the 1980 planning document, which extended the work of the 1979 document. The 1980 planning report took on a more definite and confident character, reflecting growing staff support for the whole process, Johnson's tactful work in bringing the staff together, and Folstein's mastery of this type of systems method. As the Department of Energy's "lead center" for petroleum research, the Bartlesville center claimed a major responsibility to make petroleum research responsive to the "national security" issue of petroleum production and efficiency. Consequently, the center declared in its plan, the Liquid Fossil Fuel Cycle concept developed by the center served as a "tool for planning and managing" its efforts in support of national objectives.

The March 1980 report asserted that the Liquid Fossil Fuel Cycle, by including the full spectrum, from characterization of the resource in the ground through combustion of the final fuel and handling of environmental effects, "forces management to confront the entire problem and to identify the critical needs of the system." The cycle included a work breakdown structure for each of the three major categories (extraction, processing, and utilization), which identified all the programmatic steps required to establish schedules and to set research priorities.

Although noting that the whole cycle could be used to describe industrial and university places in the research system, the center-authored study did not delineate the precise roles of these two groups. Rather, since "BETC [the center] occupies a strategic position as the major government agency dealing with liquid fuels on a total basis," it could exert influence on the cycle and "give primary assistance in reaching the President's goals." Prior work in enhanced oil recovery was used to illustrate the pivotal role the station could play.

The report indicated the mechanisms for impact of the research. The process of passing on information to potential users, or "Technology Transfer," would include meetings, publications, seminars, workshops, grants, contracts, and direct conversation and advice. Further, the center would encourage commercialization through demonstration and cost-shared projects.[12]

In each area of work, the report suggested "milestones" and scheduled research, including projects in recovering fuel from heavy oils, increasing natural gas productivity, enhanced oil recovery projects, characterization of resources, stimulated recovery methods, mining of tar sand, liquid processing, engines as energy conversion devices, and systems integration. Each unit or branch of the center could be seen as having a specific mission which itself was part of the larger mission; each group could find its place in the larger picture spelled out explicitly. In this fashion, everyone's job could be seen as related, through a specified structure, to a clearly stated national objective.

Reaction to New Management

The overall effect of the exercise in applying systems logic to the work at the center was difficult for staff members to assess. On the one hand, specific and real benefits began to accrue. From 1976–1980, national energy supply was indeed a matter of national priority. Reseachers in various separate areas now had explicit, written missions which related their work to that of others at the center and, in a logical manner, to the national energy goals of the Carter administration. As researchers accepted these premises, they could take pride in their connection to a coordinated effort to work on matters of crucial interest to the nation. Furthermore, Johnson, Folstein, and their staff hoped that the system would provide a real weapon in budget decisions in Washington, reached within the Department of Energy and in Congress. The clear, mission-oriented approach provided excellent planning language for dealing with the engineering and research managers at the Departmental level.

On the other hand, despite such apparent uses of the new planning document, many old-timers at the center remained skeptical that the change was basically cosmetic—new terminology simply stating ongoing activities in a more stylish fashion, designed to impress Washington bureaucrats. Budgets still had to be fought for, and the approach, some agreed, while bureaucratic and impressive-sounding, might prove too sophisticated for headquarters and Congress. Research could not be produced like an industrial product, in their view. Milestones were all well and good, but as science advanced into the unknown, it was simply impossible to predict *when* a particular breakthrough would occur.

Such resistance to the systems approach did not extend to all the center staff inherited from Bureau of Mines days, however. Some researchers, like Herb Carroll who headed "Resource Characterization," enthusiastically supported the new approach even though he understood some of his colleagues' resistance. Good, long in charge of the Thermodynamics Division as a separate unit, and now in charge of processing, saw both good and bad in the new approach. Hughes and his people consciously and deliberately adapted to Johnson's system, believing he had the authority and the right to "run his shop" in his own way.[13]

Johnson recognized that the new management initiatives met with varied reactions—ranging from sullen resistance to quiet cooperation through relatively enthusiastic and professional endorsement—and attempted to provide leadership which would increase cooperation. Continuing Ball's efforts at communication, he held regular weekly staff meetings with all division directors. In addition, special meetings would be convened to communicate new developments regarding budget and to deal with any problems that may have arisen. Briefings for visiting headquarters personnel and visiting outside experts, together with programmed seminars, also brought groups of staff together. Johnson developed a reputation for being open to criticism and discussion, and for not bearing grudges toward those who opposed him on matters of opinion or detail. And by late 1980 and early 1981, he had developed a coherent liquid fossil fuel program that received cheerful cooperation from a majority of the staff.

Johnson also made a concerted effort to catch up on overdue promotions. About thirty professionals who were performing tasks above their grade level received promotions between 1978 and 1982 (when he left the center), creating a solid reservoir of good will. In addition, special training and upgrading programs, labeled "upward mobility," advanced the careers of support personnel.

New Strengths and Developments

Thus, Johnson made a series of administrative changes which improved the nature of the work of the center. Under ERDA, administrative support contracts were allowed which would assist the center in its day-to-day operations. Although DOE rules cut back on the amount of regular operational work which could be contracted out, several tasks continued to be performed by outside contractors, including specifically the use of Ad-Tech services to operate a computer-based contract monitoring system, and the recruitment of Ball, now working as an independent consultant, to assist in the preparation of quarterly reports. Under Office of Management and Budget Circular A-76, those services which could be procured commercially at a lower cost to the government than through the direct employment of government workers were placed out on contract. Including such services as plumbing and electrical contract work, this "A-76" system allowed for the cutback of fourteen positions by 1982, without diminishing the quality of maintenance.[14]

Decentralization, or the management of research from the field rather than from headquarters, greatly increased the responsibilities of center staff during a period of steady or even declining resources. The management of cost-shared projects, university research, and other contracts absorbed the manpower of an estimated thirty staff members. Under these circumstances, the publication rate of center staff members declined, but this traditional measure of excellence had become supplemented with new criteria of recognition and professional influence. First, the quarterly reports on the enhanced oil recovery work circulated among over 6,000 professionals in production, discovery, consulting firms, and financial institutions. That fact alone became a measure of the recognition of the center. Second, the data accumulated in the enhanced oil recovery projects, combined with voluntary reports from firms using enhanced oil recovery methods under some 400 tax incentive-induced projects, were placed into an "E.O.R. Data Bank" which continues to grow. The use of this data bank, available to the public, also became a measure of the center's influence.[15] By the early 1980s, indeed, researchers at the center anticipated the widespread use of the data bank as eventually the price of crude oil would rise to the point of making these relatively expensive methods more widely competitive in the marketplace. The world oil glut developing in 1982–1983 set back that expectation, but interest and work on the data base by the National Petroleum Council served as still another form of industrial recognition.

In a number of ways, the pattern of industry-government relationship which emerged under Johnson resembled patterns created and developed under Smith and his predecessors during the 1930s and the 1920s. While industry remained reluctant to share proprietary information directly, out of fear that competitors would use the information to undercut or obtain an unfair advantage, or reluctance to open themselves to charges of collusion, the fact that a neutral government office could assemble and transmit industry data clearly has created a situation that stimulated oil technological information interchange. Just as the "peg model" in the lobby of the Ardmore hotel in 1922 could pool information to the advantage of all drillers, the computer models and data banks of the 1970s and 1980s opened the door to similar sharing of private research information through government auspices. While the alumni breakfasts of Smith's day were long forgotten by the research community, the holding of briefings and seminars and the constant flow of research interests from the industrial community to the center through a host of modern media, including the rich journal collection of the center's library, served to keep the center abreast of industry interests and needs.

Despite problems of morale, incipient factionalism, and resistance to "Washington" and its methods, and despite severe budget constraints now buried in the massive pass-through, cost-shared budget, the center made several major contributions through the period of Johnson's administration. In addition to further developing the enhanced oil recovery data base, the center conducted significant thermodynamics work on synthetic fuels derived from coal, developed projects on gas production, and took on the administration of a major international agreement with the state-owned Venezuelan petroleum research facility. The last merits further discussion.

In July 1980, representatives of the center, implementing a March 1980 general agreement regarding oil information exchange, met with representatives of the Venezuelan Ministry of Energy and Mines to work out details in the area of enhanced oil recovery. Amendments to the original agreement extended the period of work from the original eighteen months, and the cooperation continued into early 1983. In particular, the Venezuelan Ministry wanted to apply enhanced oil recovery methods to heavy oil deposits in the Orinoco Basin, whereas American applications of the technology seemed most needed in California. Under the agreement, teams of researchers from Venezuela came to Bartlesville for training and for exchange of information. Unlike earlier technology transfer projects, under this agreement research at Bartlesville was coordinated with research in Venezuela; the two sides operated as equivalent colleagues, rather than structuring the relationship as a one-way transfer of American know-how. The equal partners approach, Johnson believed, could serve as a model for future international research cooperation, particularly with Mexico and Canada. By June 1983, five technical reports resulting from this agreement had been published and distributed.[16]

The Election of 1980 and its Aftermath

One of the campaign pledges of Ronald Reagan in 1980 was to dismantle the Department of Energy. In response to widespread popular suspicion that the energy crisis of the mid-1970s was an artificial price increase generated by oil firms, the new administration reflected public reluctance to assist in the financing of oil industry research. Although the new administration did not succeed in dismantling the department, many senior positions remained unfilled, and budget requests for the department vastly cut back its earlier rapid growth. As personnel resigned or retired, the center simply shrank in staff size. In 1982, a severe cut was proposed in the Fossil Energy administrative budget. That budget, if implemented, would have cut out not only the Bartlesville center, but four of the five energy technology centers. Congress restored funding to keep the centers open in 1982–1983, but during that fiscal year, the Department of Energy worked to transfer the Laramie, Bartlesville, and Grand Forks facilities to private operation. As of this writing, transfer of the Bartlesville facility to a cooperative operation under the auspices of the IIT Research Institute was planned to go into effect in October 1983. Johnson resigned in July 1982, and the center remained directed by interim administrators, Ed Lievens and Gordon Dean, through September 1983, when the center was transferred to private operation.

The Johnson Years–The Morale Issue

Questions of morale had affected the Bartlesville research facility from its very beginnings. In the 1920s, the rapid turnover of key personnel, including the Superintendents of the station, had made continuity of research and the generation of published reports extremely difficult. Then Smith came, to operate the facility through a period of growing refinery technology, helplessly watching the station lose touch with that sector of the industry. The depression and the oil glut of the 1930s forced adaptation on the station, as did World War II. Under both Fowler and Ball, the facility faced recurrent budget and survival struggles.

Johnson's administrative group, although encountering some resistance to the "Washington crowd" by old-timers at the station, worked to implement new management systems and, at the same time, attempted to resolve some of the root causes for personal jealousies and bitterness within the center. "Morale" itself is an intangible quality, and its impact upon research might be regarded as too elusive for serious discussion. Yet, as Folstein noted in thinking back on the administration of the center, uncertainty and disruption had several offsetting effects. When faced with a possibility that the center would close, most researchers worked harder to bring pending projects to conclusion. Then, as they wrapped up projects and faced continued uncertainty during 1982, some continued to be diligent, assuming that a good personal record would assist them in career survival, either under a reconstituted center or in outside employment. A smaller group stopped work altogether, simply serving time until the change would be implemented. Still others were confused, trying to work but finding the uncertainty so disruptive and unsettling that their productivity declined.

For such reasons, a recurrent concern for the intangible quality of morale has been one of the themes of this work. In Johnson's tenure of office, it appeared that he won the loyalty and the cooperation of the vast majority of the researchers at the center within two years. In his third year, positive results began to accrue as the center coordinated its work and handled contract management, and as researchers exchanged detailed information from project to project, working to an extent as a single large team on various aspects of the Liquid Fossil Fuel Cycle. The election of 1980 and the subsequent uncertainty once again brought a crisis of morale to the center which would persist until the future status of the facility was clarified.

The larger issue—the role of the government in petroleum research—had haunted the facility since its first days as a Bureau of Mines experiment station. National politics brought constantly changing definitions of the government role. The Progressive model of an agricultural experiment station stimulating efficiency and safety methods yielded reluctantly to Herbert Hoover's Associative State form of cooperation between industry and government through structured advisory committees. The Progressive legacy remained intact through the New Deal, as the Bureau of Mines retained the confidence of industry figures even as the regulatory model of government agencies became prevalent. World War II converted the station into a minor adjunct to the war effort with defense-related synthetic rubber and aviation gasoline projects. The survival efforts of Fowler yielded a hybrid—a government laboratory increasingly dependent on private contract work. By the late 1960s, Ball took that model to its logical extreme, until over half the center's budget derived from sources outside regular appropriation. Yet Ball fought to bring the center into tune with national priorities, coming to grips with a government role in environmental and energy supply research. The systems approach of Johnson no sooner began to work than the center fell under the effort of the Reagan administration to divest the government of its decades-long accumulation of bureaus and agencies.

The role of the center had evolved, always in adjustment to political pressures. That evolution was not toward some abstractly ideal role for a petroleum laboratory. Rather, the facility, despite continuities of personnel, reputation, equipment, and the force of heritage, changed its role to accommodate politicians' decisions and their perceptions of petroleum supply.

Never large enough to do more than stimulate research and to make occasional contributions, the center had played a small but steady role in provoking lines of research, in setting a high standard of professionalism, and in keeping alive an unbiased and objective concern for efficient use. The motto of the Bureau of Mines remains above the fireplace in the main building of the Bartlesville center. "True conservation is a wiser and more effective use of our national resources." That Progressive faith in the gospel of efficiency has survived and will shape the future of the government's petroleum center.

NOTES

1. Jack M. Holl, *The United States Department of Energy: A History*, November 1982 (DOE/ES-0004), Washington, D.C., Department of Energy; Alice L. Buck, *A History of the Energy Research and Development Administration*, March 1982 (DOE/ES-0001), Washington, D.C., Department of Energy.
2. Interviews, Carlisle-Herb Carroll, April 26, 1983; Carlisle-Bill Good, April 26, 1983; Carlisle-Folstein, April 25, 1983.
3. Progress Review #26, *Enhanced Oil Recovery and Improved Drilling Technology*, Bartlesville Energy Technology Center.
4. Memorandum Folstein-Jan Mares, February 24, 1982, BETC Files-Folstein, subject: BETC Core Capability.
5. Progress Review #26, *Enhanced Oil Recovery and Improved Drilling Technology*, Bartlesville Energy Technology Center; interview Carlisle-Good, April 26, 1983.
6. *Examiner-Enterprise*, October 26, 1975.
7. *ERDA News*, June 27, 1977.
8. Interview Carlisle-Folstein, April 25, 1983.
9. Interview Carlisle-Johnson, April 22, 1983.
10. Interview Carlisle-Folstein, April 25, 1983.
11. *Planning Framework for Liquid Fossil Fuel Cycle*, "Draft For Second Review," February 2, 1979, Bartlesville Energy Technology Center.
12. *Planning Framework for Liquid Fossil Fuel Cycle*, March 7, 1980, Bartlesville Energy Technology Center.
13. Interview Carlisle-Good, April 26, 1983.
14. Memorandum Folstein-Jan Mares, February 24, 1982, BETC Files-Folstein, subject: BETC Core Capability; Interview Carlisle-Folstein, April 25, 1983.
15. Interview Carlisle-Folstein, April 25, 1983.
16. DOE News Release, 7/10/80, BETC Files-Public Relations.

APPENDIX I

BARTLESVILLE PERSONNEL
Partial Listing

This appendix shows personnel at Bartlesville who are mentioned in the text. The listing includes (if available) the year of beginning service, the field of work or administrative title, and the year of departure. It should be noted that many of these individuals had prior or later government service at other facilities or offices. This listing does not include all Bartlesville staff members, only those discussed in the text.

Personnel	Year begun	Field of work or title	Year left
A. W. Ambrose	1918	Superintendent	1920
F. E. Armstrong	1949	Electronics Engineer	1977
John S. Ball	1963	Research Director	1978
W. H. Barlow	1936	Associate Petroleum Engineer	1942
Barbara Barnett	1978	Special Assistant to Director	—
E. O. Bennett	1924	Technologist	1934
W. B. Berwald	1926	Senior Petroleum Engineer	1939
O. C. Blade	1926	Petroleum Chemist	1969
Dennis Brinkman	1976	Research Chemist	1983
Larry Burman	1944	Petroleum Research Engineer	1960
E. P. Campbell	1925	Superintendent	1925
Herb Carroll	1967	Petroleum Engineer	1983
R. A. Cattell	1921	Superintendent	1925
Alton Cook	1935	Petroleum Engineer	1969
Mike Crocker	1970	Research Chemist	1983
Thomas Curtin	1918	Field Agent	—
Ted dePalma	1980	Supervising General Engineer	1982
Gordon Dean	1982	Interim Administrator	1983
John Devine	1925	Associate Petroleum Engineer	1933
E. J. Dewees	1924	Natural Gas Research Engineer	1956
D. R. Douslin	1952	Physical Chemist	1976
D. B. Dow	—	—	—
H. N. Dunning	1951	Physical Chemist	1960
W. P. Dykema	1918	Superintendent	1920
J. L. Eakin	1949	Petroleum Engineer	1974
W. E. Eckard	1965	Petroleum Engineer	1970
C. K. Eilerts	1930	Physical Chemist	1973
R. L. Folstein	1979	Deputy Director/ Director	—
H. C. Fowler	1923 & 1944	Safety Engineer & Director	1928 & 1963

Personnel	Year begun	Field of work or title	Year left
W. D. Good	1952	Research Chemist	1983
Pete Grandone	1926	Petroleum Engineer	1956
Boyd Guthrie	1927	Refining Engineer	1944
L. J. Heath	1953	Petroleum Engineer	1979
R. E. Heithecker	1926	Senior Petroleum Engineer	1945
H. H. Hill	1920	Superintendent	1922
W. D. Howell	1958	Petroleum Engineer	1980
H. M. Huffman	1943	Physical Chemist	1950
K. J. Hughes	1943	Superintendent	1983
G. A. Humason	—	—	—
R. W. Hurn	1948	Mechanical Engineer	1980
R. T. Johansen	1951	Research Chemist	1981
Harry Johnson	1978	Director	1982
T. W. Johnson	1926	Natural Gas Engineer	1936
K. H. Johnston	1942	Petroleum Engineer	1972
Ray Jones	1963	Petroleum Engineering Technician	1983
M. J. Kirwan	1921	Superintendent	1929
J. W. Knowlton	1943	Physical Chemist	1948
E. C. Lane	1919	Assistant Petroleum Chemist	1942
F. W. Lane	1924	Petroleum Chemist	1928
J. D. Lankford	1942	Chemical Engineer	1944
J. O. Lewis	1917	Superintendent	1919
Ed Lievens	1982	Interim Administrator	1983
Joe Lindley	1948	Information Specialist	1983
B. E. Lindsly	1924	Senior Petroleum Engineer	1934
C. C. Linville	1967	Technical Information Officer	—
David Logan	—	—	—
John P. McCullough	1949	Supervisory Chemist	1963
R. O. Neal	—	Chemical Engineer	—
Ron Olson	1980	Attorney/Advisor	1983
Ann Osborne	1957	Research Chemist	1983
J. P. Powell	1947	Petroleum Research Engineer	1959
Cleo Rall	1943	Chemist	1953

(This table continued on next page.)

Personnel	Year begun	Field of work or title	Year left
H. T. Rall	1928	Research Chemist	1969
E. A. Rawlins	1925	Senior Petroleum Engineer	1936
C. E. Reistle	1930	Petroleum Engineer	1935
M. A. Schellhart	1930	Natural Gas Engineer	1944
Ludwig Schmidt	1921	Petroleum Engineer	1947
F. X. Schwarzenbek	—	—	—
D. W. Scott	1946	Research Chemist	1979
N. A. C. Smith	1925	Petroleum Chemist & Superintendent	1952
Harold M. Smith	1923	Petroleum Chemist	1967
R. V. Smith	1936	Physical Chemist	1954
Gene Smith	1969	Research Chemist	1983
T. E. Swigart	1914 & 1922	Chemical Engineer & Superintendent	1920 & 1923
D. B. Taliaferro	1928	Petroleum Engineer	1959
Sam S. Taylor	1929	Assistant Petroleum Engineer	1942
C. J. Thompson	1947	Research Chemist	1981
H. M. Thorne	1924 & 1933	Refining Engineer	1926 & 1935
E. M. Tignor	1938	Junior Natural Gas Engineer	1941
John Trevorrow	1925	Maintenance Engineer	1968
Guy Waddington	1943	Physical Chemist	1957
C. C. Ward	1935	Chemical Engineer	1974
D. C. Ward	1958 & 1979	Petroleum Engineer	1971 & 1983
J. Wade Watkins	1943	Petroleum Engineer	1962
C. J. Wilhelm	1929 & 1945	Petroleum Engineer	1942 & 1955
W. L. Williams	—	—	—
L. D. Wosk	1925	Asst. Natural Gas Engineer	1926
M. K. Youker	—	—	—

APPENDIX II

FUNDS - BARTLESVILLE ENERGY RESEARCH CENTER
FY 1919–1983

FY	Appr. Funds	Trust Funds	Working Funds	Total T&W	Total Fed. Funds	Oklahoma Funds 185	Oklahoma Funds 550	Total State Funds
1919	$ 25,000				$ 25,000			
1920	25,000				25,000		$12,500	$ 12,500
1921	35,000				35,000		12,500	12,500
1922	35,000				35,000		37,500	37,500
1923	95,000				95,000		37,500	37,500
1924	104,000				104,000		37,500	37,500
1925	104,000				104,000		37,500	37,500
1926	104,700				104,700		37,500	37,500
1927	96,908				96,908		37,500	37,500
1928	90,840				90,840		50,000	50,000
1929	111,500				111,500		50,000	50,000
1930	101,000				101,000		62,500	62,500
1931	102,000				102,000		62,500	62,500
1932	101,300				101,300		57,500	57,500
1933	94,600				94,600		57,500	57,500
1934	62,000				62,000		40,300	40,300
1935	64,000				64,000		40,300	40,300
1936	82,400				82,400		41,800	41,800
1937	109,424				109,424		41,800	41,800
1938	106,150				106,150		47,960	47,960
1939	107,380				107,380		47,960	47,960
1940	107,380				107,380		30,385	30,385
1941	103,260				103,260		30,385	30,385
1942	113,040				113,040		39,635	39,635
1943	191,303				191,303		39,635	39,635
1944	326,849 + 30,000 land purchase				326,849		39,635	39,635
1945	428,800				428,800		39,635	39,635
1946	369,435				369,435		50,405	50,405
1947	497,632				497,632		50,405	50,405
1948	354,500				354,500		60,230	60,230
1949	361,510			$ 143,116	504,626		60,230	60,230
1950	417,677			134,800	552,477		60,230	60,230
1951	578,529			153,550	732,079		60,230	60,230
1952	640,221			119,390	759,611		60,230	60,230
1953	670,357			191,904	862,261		60,230	60,230
1954	646,202			129,477	775,679		60,230	60,230
1955	618,330			152,893	771,223		60,230	60,230
1956	576,125			160,000	736,125		70,000	70,000
1957	559,448	$151,800	$ 160,130	311,930	871,378		70,000	70,000

(Table continues on next page.)

FY	Appr. Funds	Trust Funds	Working Funds	Total T & W	Total Fed. Funds	Oklahoma Funds 185	Oklahoma Funds 550	Total State Funds
1958	$ 708,580	$142,394	$ 235,000	$ 377,394	$1,085,974		$75,000	$ 75,000
1959	782,746	146,467	227,000	373,467	1,156,213*		75,000	75,000
1960	779,126	115,522	320,751	436,273	1,215,399	$12,500	75,000	87,500
1961	789,641	101,620	338,664	440,284	1,229,925	12,500	75,000	87,500
1962	1,050,220	89,521	374,950	464,471	1,514,691†	12,500	75,000	87,500
1963	1,040,620	93,275	593,000	686,275	1,726,895	12,500	75,000	87,500
1964	1,107,420	91,200	466,575	557,775	1,665,195	15,000	75,000	90,000
1965	1,140,000	93,450	542,780	636,230	1,776,230	15,000	75,000	90,000
1966	1,172,000	141,500	791,377	932,877	2,104,877	15,000	82,877	97,877
1967	1,007,125	422,268	852,390	1,274,658	2,281,783	15,000	82,838	97,838
1968	1,180,000	339,625	876,498	1,216,123	2,396,123	15,000	85,000	100,000
1969	1,225,000	422,822	841,305	1,264,127	2,489,127	15,000	86,530	101,530
1970	1,357,137	334,000	919,930	1,253,930	2,611,067	15,000	95,201	110,201
1971	1,365,000	306,193	1,246,961	1,553,154	2,918,154			114,536
1972	1,652,000	266,282	1,158,477	1,424,759	3,076,759			116,858
1973	1,666,521	n/a	n/a	1,220,063	2,886,584	n/a	n/a	116,858
1974	2,257,817	n/a	n/a	1,006,179	3,323,996	n/a	n/a	115,815
1975	3,652,405	n/a	n/a	1,070,054	4,873,577	n/a	n/a	122,917
1976	6,789,500	n/a	n/a	1,336,220	7,469,860	n/a	n/a	122,917
1977	5,897,078	n/a	n/a	683,166	6,850,244	n/a	n/a	125,957
1978	31,068,423	n/a	n/a	—	31,068,423	n/a	n/a	133,624
1979	26,000,000	n/a	n/a	—	26,000,000	n/a	n/a	144,421
1980	30,000,000	n/a	n/a	—	30,000,000	n/a	n/a	155,181
1981	24,130,000	n/a	n/a	—	24,130,000	n/a	n/a	170,061
1982	21,700,000	n/a	n/a	—	21,700,000	n/a	n/a	187,784
1983	14,005,000	n/a	n/a	1,264,000	15,269,000	n/a	n/a	208,507

*An additional $146,754 for plans & specs. New Bldg.

†$250,000 added building maintenance.

BIBLIOGRAPHICAL NOTE

The research for an institutional history necessarily engages the historian in a sequence of detective tasks, some enjoyable, some tedious. We began work with the document collection housed in the "vault" of the Bartlesville center. The vault was literally a concrete-lined, safe-door locked room about 8 feet by 12 feet, containing approximately 150 cubic feet of records, particularly rich through the period of the 1960s and early 1970s. Included were several photo albums and previously gathered "historical files," as well as the day-to-day divisional collections of correspondence, reports, memoranda, and financial records for the later period. Giebelhaus and Carlisle later returned to this collection, flagging and copying thousands of selected documents. If the document collection is preserved, future researchers would find rich sources for histories of certain research efforts, particularly the pollution control and enhanced recovery research.

Records from the period of Bureau of Mines administration of the center had been shipped to the National Archives and Records Service in Fort Worth, Texas, under records retention and disposal guidelines established by the Bureau. Some 35 cubic feet of these records were reviewed, with especially rich finds for the 1920s and 1930s. Again, future researchers may wish to track through our citations to these documents. Particular accession numbers which yielded excellent collections were:

Accession Number	Original FRC* Number	Years Documented
70-61-A-612	322232	1920s
	322255	
	322271-272	
68-A-200	326235-236	1960s
61-A-612	322281-282	1940s–1950s
	322250	1920s
	322235	1920s
65-A-855	224310-334	1920s–1930s

*Federal Records Center

The library at the center, under the direction of Vern Hutchinson, later Elizabeth Mohr, and, most recently, under Bill Linville, houses an excellent collection of petroleum-related publications. Of special use was the article reprint file, arranged by author, as well as the rich collection of journals, bibliographies, and Bureau of Mines reports and monographs.

In addition to extensive records at these sources and at the National Archives in Washington, D.C., the NARS records center in Suitland, Maryland, and the Hoover Presidential Library, the surviving group of "old timers" enhanced our understanding of the operation of the center. Present and former staffers interviewed for this study included:

John Ball	Harry Johnson
Barbara Barnett	Kenneth Johnston
Larry Burman	Bill Linville
Don Douslin	Elizabeth Mohr
Ken Eilerts	Cleo Rall
Robert Folstein	Harry Rall
Bill Good	R. V. Smith
Kenneth Hughes	C. C. Ward
Richard Hurn	J. Wade Watkins

These interviews verified details, gave us new leads to other questions, and offered varying points of view on a range of controversies and problems. The interviews also provided a sense of priorities as they evolved over the years and a wealth of anecdotes and insights that the historian can never gain from the documents alone. Yet, beyond these benefits, the most rewarding serendipity was the sense of the human story of the center—the intuitive knowledge of personality and character brought to us by each person interviewed. The authors hope that some sense of that personal side of the story has survived in the final work.

Secondary literature on petroleum is extensive and growing because of renewed interest in issues of energy supply and the politics of oil. However, few studies of the details of petroleum research have been written by the historian of technology; historians of oil policy have not focused on the impact of policy upon particular research settings, especially in the federal government

The following bibliography, while not definitive, provides a list of those works we consulted for this study, and would provide the reader with more general interests, a number of excellent introductions to the issues of petroleum technology, petroleum pricing, petroleum policy, and some of the larger issues in the history of technology and science.

BIBLIOGRAPHY

Adams, Ernestine, "History and Analysis of the Bureau of Mines' Petroleum and Natural Gas Division," *The Petroleum Engineer* (December 1948; January, February, March 1949).

Atkinson, Charles and Michael A. Lekos, "Atomic-Age Fracturing May Soon Open Up Stubborn Reservoirs," *Oil and Gas Journal* (December 2, 1963).

Ball, Max, *This Fascinating Oil Business.* Indianapolis, 1940.

Bartlesville Energy Research Center. *Sulfur Compounds in Crude Oil*, by H. J. Rall and others. Washington Bureau of Mines, 1972. TN 870.5. B35 1972.

Bartlesville Energy Technology Center. *Draft for Second Review of Planning Framework for Liquid Fossil Fuel Cycle.* February 2, 1979. (B.E.T.C. - U.S. Dept. of Energy, Bartlesville, Oklahoma).

Berle, Adolf A. and Gardiner C. Means, *The Modern Corporation and Private Property.* New York, MacMillan, 1933.

Borkin, Joseph, *The Crime and Punishment of I. G. Farben.* New York, 1978.

Borth, Christy, *Pioneers of Plenty: The Story of Chemurgy.* New York, 1935.

Boyd, T. A., "Pathfinding in Fuels and Engines," *Society of Automotive Engineering (SAE) Quarterly Transactions*, 4, 2 (April 1950), pp. 182-95.

Boyd, T. A., "Gasoline Went to War and the Part Chemistry Had In It," *Record of Chemical Progress* (II) (January/April 1947): 11.

Brandes, Stuart D., *American Welfare Capitalism, 1880–1940.* Chicago, 1970.

Buck, Alice L., *A History of the Energy Research and Development Administration.* (DOE/ES--0001) Dept. of Energy, Washington, D.C., March 1982.

Bureau of Mines Petroleum Research Center. *Fifty Year History.* 1968.

"Bureau of Mines Research Related to Petroleum," *The Mining Magazine* (October 1955).

Bureau of Mines [Staff Office of Renewal Program] *Potential Oil Recovery By Waterflood Reservoirs Being Produced by Primary Methods.* I.C. 8455. Washington, G.P.O., 1970.

Calvert, Monte A, *The Mechanical Engineer in America, 1830–1910.* Baltimore, 1967.

Cattell, R. A., *Petroleum and Natural Gas Research Program, Bureau of Mines Fiscal Year 1953.* Bureau of Mines Information Circular 7717, June 1955.

Chandler, Alfred D. Jr., *Strategy and Structure: Chapters in the History of the American Industrial Enterprise.* Cambridge, 1962.

Chandler, Alfred D. Jr., *The Visible Hand: The Managerial Revolution in American Business.* Cambridge, 1971.

Clark, J. Stanley, *The Oil Century: From the Drake Well to the Conservation Era.* Norman, 1958.

Cochran, Thomas C., *American Business in the Twentieth Century.* Cambridge, 1972.

Conant, James B., Karl T. Compton, and Bernard M. Baruch, *Report to the Rubber Survey Committee.* Washington, D.C., 1942.

De Chazeau, Melvin G. and Alfred E. Kahn, *Integration and Competition in the Petroleum Industry.* New Haven, 1955.

Eilerts, C. Kenneth, *Phase Relation of Gas-Condensate Fluids.* Monograph 10, Volume II, 1959. Bureau of Mines and American Gas Association.

Engler, Robert, *The Politics of Oil.* New York, 1961.

Engler, Robert, *The Brotherhood of Oil.* Chicago, 1977.

Enos, John L., "A Measure of the Rate of Technological Progress in the Petroleum Refining Industry," *Journal of Industrial Economics* (June 1958), pp. 180-93.

Enos, John Lawrence, *Petroleum Progress and Profits: A History of Process Innovation.* Cambridge, 1962.

Fortune. "Monsieur Houdry's Invention," *Fortune* (February 1939), 56-7 ff.

Foster, George, "An Examination of Process Innovation in Petroleum Refining," in *Technology Transfer*, pp. 165-174., ed. by H. Davidson, Marvin J. Cetran, and Joel D. Goldhas. Leiden, 1974.

Fowler, H. C., *Developments in the American Petroleum Industry, 1914-19: Exploration, Drilling, Production and Transportation.* Natural Resources Planning Board. August 1940.

Fowler, H. C., "Development of the American Petroleum Industry, 1914–1918: Exploration, Drilling, Production, and Transportation," Information Circular, Dept. of the Interior, Bureau of Mines, Washington, 1941.

Franks, Kenny A., *Early Oklahoma Oil.* College Station (Texas), 1981.

Frey, John W. and H. Chandler Ide, *A History of the Petroleum Administration for War.* Washington, D.C., 1946.

Gibb, G. S. and E. H. Knowlton, *History of Standard Oil Company [NJ] 1911-1927.* New York, 1956.

Giebelhaus, August W., *Business and Government in the Oil Industry: A Case Study of Sun Oil 1876–1945.* Greenwich, CT., 1980.

Goodwin, Crauford, *Energy Policy in Perspective - Today's Problems, Yesterday's Solutions.* The Brookings Institution, Washington, D.C., 1981.

Hawley, Ellis, "Herbert Hoover, the Commerce Secretariat and the Vision of an Associative State," *Journal of American History*, 61 (June 1974), pp. 116-40.

Hawley, Ellis, *The New Deal and the Problem of Monopoly.* Princeton, 1966.

Hilt, Luis, "Chronology of the Natural Gas Industry," *American Gas Journal*, Vol. 172, No. 5.

Holl, Jack M., *The United States Department of Energy: A History.* (DOE/ES-0004) Dept. of Energy, Washington, D.C. November 1982.

Hutchinson, V. Vern, *Selected List of Bureau of Mines Publications on Petroleum and Natural Gas, 1971–1975.* BETC/1C/75/2. Bartlesville Energy Research Center. September 1975.

Hutchinson, V. Vern, *Selected List of Publications on Petroleum and Natural Gas, ERDA-BuMines July 1, 1975–December 31, 1976.* BETC/1C/77/2. Bartlesville Energy Research Center, Energy Research and Development Administration. April 1977.

Hutchinson, V. Vern, *Selected List of Bureau of Mines Publications on Petroleum and Natural Gas, 1961–1970.* Supplement to

Information Circular 8240. IC8534 Bureau of Mines Information Circular/1972. U.S. Dept. of the Interior, Bureau of Mines, Washington, D.C., 1972.

Hutchinson, V. Vern, *Selected List of Bureau of Mines Publications on Petroleum and Natural Gas, 1910–1962*. Bureau of Mines Information Circular 8240. U.S. Dept. of the Interior, Bureau of Mines, 1964.

Ickes, Harold, *The Secret Diary of H. Ickes 1933–1936*. New York, 1953.

Ickes, Harold, *Fightin' Oil*. Repr. of the 1943 ed. [1976] New York, 1943; Westport, 1976.

Interstate Oil Compact Commission. *Oil and Gas Production: An Introductory Guide to Production Techniques and Conservation Methods*. Norman, 1951.

Johnson, Arthur Menzier, *Petroleum Pipelines and Public Policy, 1906–1959*. Cambridge, 1967.

Katz, Donald L., et al, *Handbook of Natural Gas Engineering*. New York, 1959.

Kelly, Patrick and Melvin Kranzberg, eds., *Technological Innovation: A Critical Review of Current Knowledge*. San Francisco, 1978.

Klose, Gilbert G., *The American Petroleum Industry: The Age of Energy, 1899–1959*. Evanston, 1963.

Kolko, Gabriel., *The Triumph of Conservation*. New York, 1963.

Kraemer, A. J., *Petroleum and Natural Gas Research, Bureau of Mines, Fiscal Years 1954–1955–1956*. Bureau of Mines Information Circular 7940. U. S. Dept. of the Interior, 1959.

Larson, Henrietta M. and K. W. Porter, *History of Humble Oil and Refining Co.* New York, 1959.

Larson, Henrietta M., E. H. Knowlton, C. J. Popple, *History of Standard Oil Company [NJ] 1927–1950*. New York, 1979.

Layton, Edwin T., *The Revolt of the Engineer: Social Responsibility and the American Engineering Profession*. Cleveland, 1971.

Leeston, Alfred M., John T. Crichton, John C. Jacobs, *The Dynamic Natural Gas Industry*. Norman, 1963.

Leffler, William L., *Petroleum Refining for the Non-Technical Person*. Tulsa, 1979.

Leonardon, Eugene G. L., "Logging, Sampling, and Testing," in *History of Petroleum Engineering*. New York, 1961.

Linville, Bill, Contracts for field projects and supporting research in Enhanced Oil Recovery and Improved Drilling Technology. DOE/BETC-80-2. Progress Review, Quarter Ending March 31, 1980.

McKnight, David Jr., *A Study of Patents on Petroleum Cracking*. Austin, 1938.

McLean, John G. and Robert W. Haigh, *The Growth of Integrated Oil Companies*. Boston, 1954.

Marx, Leo, *The Machine in the Garden*. New York, 1964.

Matthews, John Joseph, *Life and Death of an Oilman: the Career of E.W. Marland*. Norman, 1951.

Miller, Kenneth, *Miller's Oil and Gas*. Chicago, 1973.

Mohr, Elizabeth and Marjean L. Gudgel, *Bartlesville Energy Technology Center Publications. January 19, 1975–September 30, 1979*. BETC/1C-/79/1. Bartlesville Energy Technology Center, Department of Energy. April 1979.

Nash, Gerald, *United States Oil Policy, 1890–1964*. Pittsburgh, 1968.

Nordhauser, Norman, "Origins of Federal Oil Regulation in the 1920s," *Business History Review*, 47, 1 (Spring 1973), pp. 53-71.

Parks, George Sutton and Hugh Martin Huffman, *The Free Energies of Some Organic Compounds*. New York, 1932.

Pettengill, Samuel, *Hot Oil, The Problem of Petroleum*. Repr. of the 1935 ed. [1976].

Rister, Carl Coke, *Oil: Titan of the Southwest*. Norman, 1945.

Rossini, Frederick D., *Chemical Thermodynamics*. New York, 1975.

Rossini, Frederick, Beveridge Main, and Anton Streiff, *Hydrocarbons from Petroleum*. (API Project 6) New York, 1953.

Sampson, Anthony, *The Seven Sisters*. New York, 1975.

Scott, Otto J., *The Professional: A Biography of J. P. Saunders*. New York, 1976.

Shannon, C.W. and L.E. Trout, *Petroleum and Natural Gas in Oklahoma*. (1915, 1917) Oklahoma Geological Survey.

Solberg Carl, *Oil Power: The Rise and Imminent Fall of an American Empire*. New York, 1975.

Stoff, Michael, *Oil, War, and American Security*. New Haven, 1980.

Stotz, Louis, *History of the Gas Industry*. New York, 1938.

Swigart, Theodore E., "Handling Oil and Gas in the Field," *History of Petroleum Engineering*. New York, 1961.

Tompkins, Walker A., *Little Giant of Signal Hill*. Englewood Cliffs, 1964.

Uren, Lester C., *Petroleum Production Engineering*. New York, 1950.

Utton, Albert E., *National Petroleum Policy*. Albuquerque, 1970.

Van Winkle, Matthew, *Aviation Gasoline Manufacture*. New York, 1944.

Watkins, Myron W., *Oil Stabilization or Conservation*. New York, 1937.

Wertman, William T., E. Mingnor and S. Taylor, "Secondary Recovery Research, U. S. Bureau of Mines," *Producers Monthly*, Vol. 20, No. 5, March 1956), pp. 20-25.

Whitby, G. S., C. C. Davis, R. F. Dunbrook, eds., *Synthetic Rubber*. New York, 1954.

White, Gerald T., *Formative Years in the Far West* (Standard Oil of California). New York, 1962.

Williamson, Harold, et al, *The American Petroleum Industry: The Age of Energy, 1899–1959*. Evanston, 1963.

Wilson, Joan Hoff, *Herbert Hoover: Forgotten Progressive*. Boston, 1975.

Winner, Langdon, *Autonomous Technology: Technology-out-of-Control as a Theme in Political Thought*. Cambridge, 1977.

Zimmerman, Erich, *Conservation in the Production of Petroleum*. New Haven, 1957.