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.

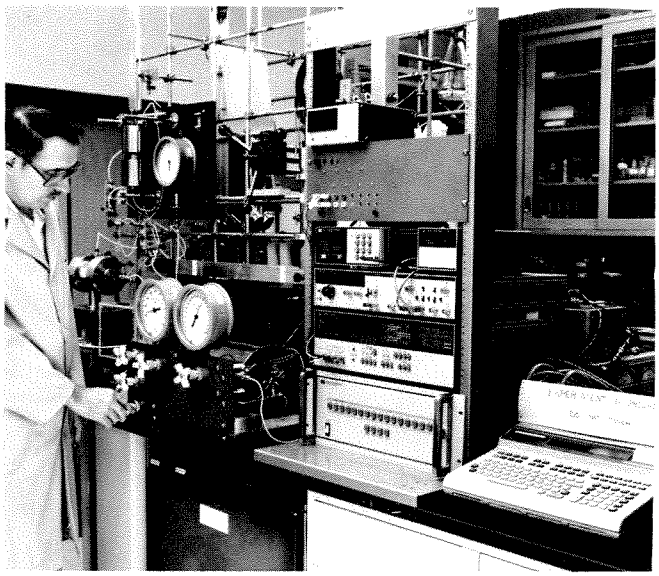
NOTES

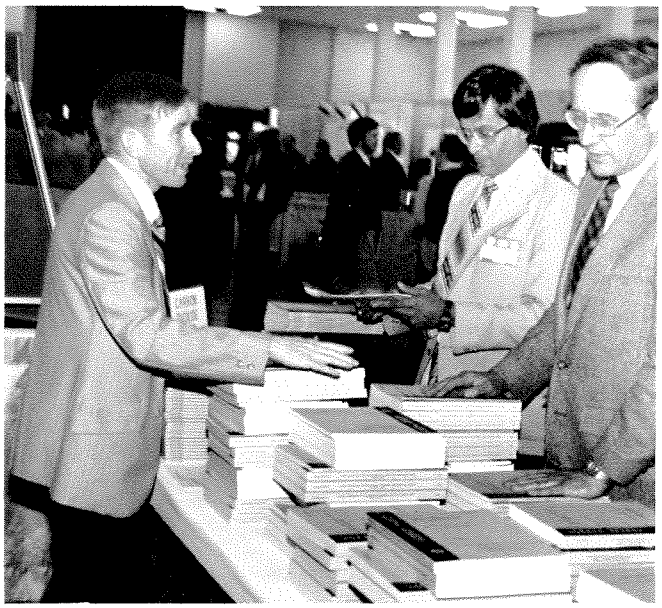
1. See Gerald D. Nash, *United States Oil Policy, 1890–1964* (Pittsburgh: University of Pittsburgh Press, 1968), pp. 180-208 and Crauford D. Goodwin (ed.), *Energy Policy in Perspective: Today's Problems, Yesterday's Solutions* (Washington, D. C.: The Brookings Institution, 1981), chapters 1-5.
2. Goodwin, *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

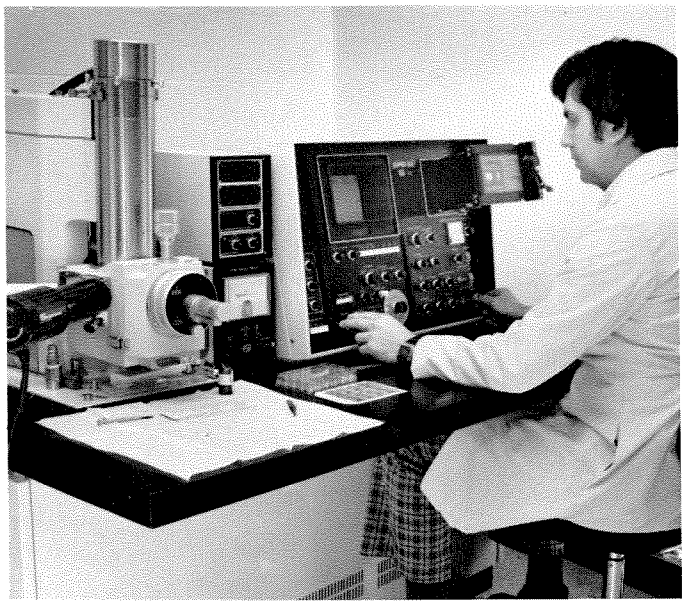
Government Liaison Committee, November 9, 1964, BETC Vault, Box 37, 1965–66, 826.322-826.65.

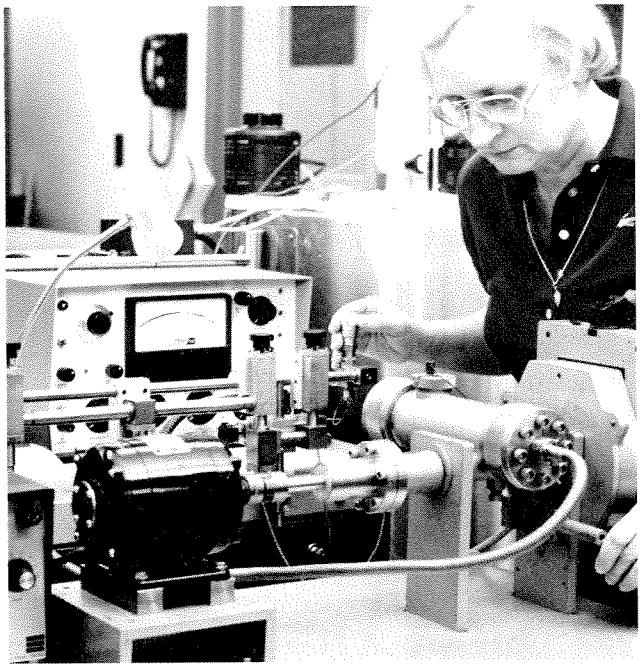
56. T. M. Geffen to J. S. Ball, November 23, 1965; C. Kenneth Eilerts to J. S. Ball, December 2, 1965; W. E. Eckard to J. S. Ball, December 4, 1965; R. T. Johansen to J. S. Ball, December 3, 1965; D. R. Douslin to J. S. Ball, December 3, 1965; R. W. Hurn to J. S. Ball, December 2, 1965; J. S. Ball to 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.