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Memories and Reflections on a Career
As a Scientist-Engineer in Research, Management, Teaching and Editing
By John B. "Jack" Wachtman, 2009

"Self expression is the need of my soul" - Archie the Cockroach
By Don Marquis

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PREAMBLE

My working career fell into three nearly equal periods plus a shorter finale as an editor. I came directly from graduate school and began work at the National Bureau of Standards (NBS) in August 1951. At NBS I began as a scientist and then moved toward less personal technical work and progressively toward more managerial responsibility. This progression happened as I became a Section Chief, then a Division Chief, and finally a Center Director. At my managerial peak I was responsible for about 300 people. I took early retirement from NBS at age 55 in February 1983 to accept a chaired professorship at Rutgers University where I stayed though December 1995. After leaving NBS, I spent 13 years as a professor including 5 years as a Center Director at Rutgers University. Finally, I then spent about 4 years part-time completing a 12-year job as the technical editor of a major scientific journal in my field, the Journal of the American Ceramic Society. My professional career ended in 2000 after 49 working years including the final 4 years part time.

I am basing this memoir partly on memory and partly on my personal records. Also, there are four volumes of generally excellent history of NBS – see the references at the end. These volumes are written primarily at the level of broad decisions and actions although they do present examples of some of the work of selected people. They do not seek to give a personal sense of what it was like to be a research scientist or middle level administrator during the tumultuous times through which NBS has passed. My career at NBS was shaped by major trends that affected NBS. Some general understanding of these trends is needed as a context for this memoir. Even though this is a personal account, it is also necessarily to some extent an account of the times and their effect on NBS.

I want this memoir not only to reflect my personal experiences and reactions but also to show how circumstances can combine with personal ability and aspirations to shape a career in research, management, teaching and editing. Most of us are very much shaped by the job opportunities available in our time. In my case, my job and its requirements were affected by rapid advances in science and technology in the last half century and the great effect these had on my employers and on the requirements for my jobs.

Another major theme running through this memoir is how the culture of a person's peer group affects one's life and even character. I believe that the culture of Carnegie Mellon University, The National Bureau of Standards, and Rutgers University was one of excellence and integrity in technical work. I want to develop this theme and pay tribute to the people who maintained and passed on high standards.

PUBLIC SCHOOL AND UNIVERSITY

Before taking up my NBS period I want to say something about influences in my earlier life that helped me to measure up to the demanding environment of NBS. The most important influence on my life was my parents, of course. I was fortunate in having a mother and father who taught, and showed by example, responsibility, organization and hard work. My father also influenced me to become seriously interested in science and engineering. He might have had such a career, but never got beyond high school. His influence certainly helped me to a personal awakening in my middle teens to mathematics and physics.

The public school system in South Carolina in the 1930s and 1940s had only eleven grades instead of twelve as was normal in the North. I was a bright boy, or so my parents thought, but not especially studious although I loved to read. Somewhere in my early teens I was greatly influenced by the discovery of geometry, algebra and physics. I managed some how, it must have been with my parents' aid, to get college-level texts on these subjects in order to study them on my own.

I want to pay tribute to my public school teachers whom I remember with affection and respect. I wish I had thought to go back and thank them early in my life. By the time I had matured enough to return and do it many of them were dead.

I wanted to go to college but my parents certainly could not send me while supporting my brother and sister who were three and twelve years younger than I. I asked my high school principal about any scholarship possibilities. He said that he received notices of scholarships but doubted that I would be able to compete. However, he gave me the notices and I filed for several. I took examinations monitored by the high school staff and was offered three scholarships.

My time at Carnegie Tech was perhaps the highlight of my life. I loved the intellectual life and companionship of the students. The curriculum was designed to give scientists and engineers some degree of liberal arts education to the extent that this was possible. The real focus for us, however, was the rigorous study of science, engineering, and mathematics. We had quizzes and were given problems to solve. The Biblical injunction, "Be ye doers of the word, and not hearers only, deceiving your own selves" was quoted at the head of an extensive problem set in one of the texts. I learned that verbal facility, although valuable, was no substitute for being able to work out numerical answers to quantitative problems.

I thought that the faculty at Carnegie Tech was excellent. I remember a trio of physics professors (Mitchener, Prine and Leivo), a Chemistry professor (John Warner) and a trio of mathematics professors (Rosenbach, Whitman and Moskovitz) who were outstanding and enthusiastic with freshmen. They were demanding and had frequent quizzes. I remember one unfortunate student who somehow misused Avogadro's number and calculated a mass of reaction products larger than the mass of the earth. As I progressed, I took courses from many excellent physicists at Carnegie, including Frederick Seitz, author of "The Modern Theory of Solids."

I had a group of good student friends at Carnegie. They included Hans Weinberger (who became a professor of mathematics at U. Minnesota), Paul Zweifel (later professor of physics at Virginia Polytechnic), Ray Sedney, Jim Woodford (a straight A average Electrical Engineer), Edgar Pearlstein (later a professor at U. Nebraska), Rolf Winter and Robert Siegel (both later professors at William and Mary). I also knew John Nash, a math student who later was awarded the Nobel Prize in Economics for work begun at Carnegie. I have what is, I believe, a unique distinction in world history by being the only person ever to be bitten in the back by a future Nobel Prize winner. It came about as a result of some student horseplay between Nash, Weinberger and Zweifel. As the culmination of a series of practical jokes, Nash "mined" the room that Weinberger and I shared with small amounts of a wet powder that he prepared in the chemistry lab that dried to become explosive. For days we would get small and harmless explosions as we inserted a key, opened a drawer, and so on. In response, Weinberger and Zweifel built a glass apparatus that they used to blow copious amounts of cigarette smoke (which Nash hated) under his door. Enraged, Nash pursued the two of them into our room and sought to smash the apparatus. I grabbed the apparatus and tried to keep it away from him while they held his arms. He lunged forward, dragging them, and bit me in the back. Fortunately I was wearing a coat and he did not break the skin. We treated the whole thing as a joke. Perhaps it helped to prepare me for the backbiting that sometimes goes on in life.

AN AGENCY UNDER PRESSURE

NBS was no stranger to trouble and having to adapt to radically changing demands. I worked with people who had experienced being reduced to half-time employment combined with full-time unofficial working hours for periods during the depression of the 1930s. That era was followed by a great staff expansion during the wartime years as NBS was called upon to do work in support of WW II, then the Korean War, and then the Cold War.

As a bench scientist at NBS taking up work in 1951, I was initially unaware of this agency's continuing turbulent history. I became vaguely aware that there was major trouble at the top levels of NBS. The trouble was already growing when I joined NBS. As I progressed in my career I learned more and was more affected by a continuing problem at the heart of the NBS existence and function. What is the proper mission of NBS and how should it be carried out?

This question came to a dramatic focus beginning in 1948 with trouble over a battery additive. Allen V. Astin, a much respected NBS Director, was fired in March 1953 because of political pressure from the maker of a product that claimed to extend battery life. The scientific community supported the Director and eventually he was justified and restored to office in August 1953. But the incident caused lasting changes and a reorientation of NBS away from regulatory testing and toward measurements, standards and vital data.

A commission investigated the problem and recommended a change in NBS role with less emphasis on protecting the public from predatory and false claims and more emphasis on measurements, standards, and data. I am not trying to describe this situation in detail. The subject is well described in the official NBS history: “Measures for Progress” and following volumes. Rather I am concerned with the long-term impact of the crisis and change on staff, such as myself, as the NBS leadership sought to find, execute and defend its changing role. I believe that it is true to say that every subsequent Director of NBS has had to struggle with the question of the NBS mission and how to sell it in the budget process.

I was influenced by the hiring of promising scientists to lead the changes needed. I was especially affected by two brilliant and high-principled men, Alan Franklin and Elio Passaglia, who taught me much and became friends for life. Alan became my Division Chief when Dr. Insley retired. I worked under Dr. Astin as Director for many years with layers of management between me and him. I never knew Astin well, but did have some personal contact with him and developed an immense respect and admiration for him. He had high standards and expected good performance at all levels. He was decisive, but remained calm and courteous through very stressful times. He left a stronger NBS and a grateful staff when he retired. I was fortunate through most of my career to have good immediate and next higher level supervisors. These people taught me a great deal and I remain grateful to them.

I believe that every Director in my experience, with the possible exception of one short-term Director, strongly believed in the necessity of a base of excellent science at NBS and sought to promote science there as best he or she could. I shall take up in a later section the attempts of Directors to install a new management system to help the Director’s office deal with the problem of justifying NBS funding and science as a component of doing the NBS job. Science at NBS was never strongly sellable to the Department of Commerce and higher levels in the budget process. Science at NBS was generally regarded at such levels as a handmaiden in support of the justifiable mission elements of NBS, not as an end in itself. The National Science Foundation, not the National Bureau of Standards, was the primary government agency charged with promoting science in the national interest. When, after I left, NBS was reorganized by Congressional action, it was renamed “The National Institutes of Standards and Technology” not “The National Institutes of Science and Technology” as many at high levels in NBS would have preferred. My point here is that the question of defending NBS in the budget process was throughout my career there a constant concern of top NBS management and that the effect was felt at all levels down to the individual bench scientist or engineer. I will say more about the conditions affecting NBS and the management changes that later happened. But I want to turn now to my initial research program.

MY PERSONAL RESEARCH WORK AT NBS

I came to NBS directly from Carnegie Institute of Technology (now Carnegie Melon University) with a B. S. and M. S. in physics. I began work under Roman Geller, Chief of the Porcelain and Pottery Section, and his boss, Herbert Insley, Chief of the Inorganic Materials. Both were capable men and real gentlemen. I almost always respected and liked my supervisors at NBS and became personal friends with most of them.

I was hired on an Air Force contract to do research on mechanical properties of ceramics, especially at high temperatures. This was my introduction to the work environment and sources of funding at NBS. I learned that in addition to direct Congressional funding through the Department of Commerce, NBS did contract work for other government agencies. In my part of NBS the externally-funded work at times reached as high as 40% of all the support. So I became immediately accustomed to writing quarterly reports to the sponsor and, of course, to doing work to report upon. This situation forced a high degree of self-direction and self-reliance that was characteristic of much of the research-level staff at NBS.

My work began with studies of the deformability of oxide ceramics at high temperatures because of Air Force and other defense interests in using oxide ceramics for load-bearing roles in engines and other high temperature applications. When loaded rapidly these materials failed in a brittle manner even at elevated temperatures. I found that single crystals of aluminum oxide (sapphire) at temperatures above about half their melting point could undergo considerable plastic deformation before failure. However, this was true only when time was allowed for deformation under load to begin; an induction period was required. In contrast, polycrystalline aluminum oxide showed little plasticity and a considerable fall in strength above about half their melting temperature. I spent several years working on the crystallography of deformation; the crystal structure of sapphire caused great anisotropy in deformation. This in turn affected the plasticity, and plastic effects in causing failure. These results attracted interest outside NBS and work was taken up in other labs. Over decades, a considerable fundamental understanding with practical applications was developed by researchers in many laboratories. Indeed, work on mechanical properties, including temperature effects, on new, complex ceramics and temperature effects continues to this day.

Elastic deformation was also important technically so I measured the temperature dependence of strength and elastic moduli of a considerable number of polycrystalline materials from room temperature to the high temperatures at which plastic effects became dominant. It was apparent that directional effects in single crystal grains were causing internal stress concentrations leading to failure under certain conditions. Crystallographic effects in causing local internal stresses in polycrystalline ceramics led me into an interest in the orientation-dependent elastic deformation of oxide ceramic crystals and I measured the elastic constants of a series of important high temperature oxide single crystals including Al_2O_3, MgO, TiO_2, UO_2, and ThO_2 single crystals.

Most of my work was experimental. But I tried to interpret the results in terms of applicable theories and sometimes tried to develop empirical equations and/or to extend theory. Two examples involve temperature dependence of physical properties. I tried to adapt the Einstein theory of specific heats to describe the temperature dependence of elastic moduli from cryogenic to high temperatures. I published a partly theoretical equation in the Physical Review that gave a very accurate fit to such data for single crystal aluminum oxide. (ET) Thermal stresses could be important so that I became concerned with the anisotropy of thermal expansion and measured the single crystal thermal expansion of aluminum oxide single crystals from cryogenic to high temperatures.
I adapted a theoretical equation and used it to accurately fit my data on thermal expansion over the measurement range and to predict the values at higher temperatures. These fitted and extended data have remained in use. Two examples of my attempt to contribute to theory in explaining experiment are given below in my thesis work.

I had to learn and apply various experimental measurement techniques at low and elevated temperatures. These included techniques for doing strength, creep, elastic moduli by resonance techniques, elastic constants by ultrasonic techniques, and accurate dimensional changes by interferometric techniques. Fortunately members of the excellent NBS staff gave me indispensable help.

WORKING WHILE FINISHING MY Ph. D. DEGREE

I had hoped and planned to finish my Ph. D. in physics before leaving Carnegie Tech. I did pass my qualifying exam and begin work on a thesis, but my thesis advisor decided to move to the University of Illinois. At about that time my father had a stroke that incapacitated him, leaving my mother and younger brother and my father needing financial help. I was in no position to responsibly continue in graduate school and so took a job fortunately offered by NBS. Handling that job and my family responsibilities took all my time for several years before I was able to enroll part-time in the NBS-graduate school at the University of Maryland. I am grateful to Hertzfeld, to NBS, and to U. MD. NBS not only offered some on-site evening courses; it allowed me to shift the hours of my full-time work so that I was able to take courses at the U. of MD in College Park. Several other NBS staff members were also working for their doctorates at U. MD. I formed a close friendship with one, Robert “Bob” Parker, and we learned to study by teaching each other.

I knew that a good career in research in physics essentially demanded finishing the Ph. D. degree. Fortunately, NBS allowed me to shift my working hours. Even more fortunately, Dr. Charles Herzfeld, Chief of the NBS Heat Division, was also an adjunct professor at U. MD. Through him I was able to offer some of my continuing work done at NBS as a thesis. It was almost entirely self-directed work and was subsequently published by me in the Physical Review as a single-author paper – my 13th refereed publication as it turned out.(MER) In this paper I developed a theory describing how motion of point defects, vacancies and interstitial atoms, could cause temperature and frequency changes in dynamic mechanical and electrical properties. I applied this theory successfully to ThO_2. Over the years this paper has been frequently referenced and summarized in a textbook. I am also rather proud of this essentially single-handed and self-directed research effort. It took me ten years to get my Ph. D. in physics in 1962 after coming to NBS in 1951.

H. Steffen Peiser, an expert NBS crystallographer, subsequently collaborated with me to extend this work. We published a series of papers describing how applied uniform stress or electric field could reduce the crystal symmetry. (RC and subsequent papers.) We systematically worked out the conditions under which some crystal symmetry would remain and what that symmetry would be. This work was an intellectual pleasure to carry out. I believe that it is fundamental and that the results, being essentially mathematical, will stand indefinitely. Peiser became a friend for life and went on to a distinguished career in the NBS Director's Office as head of International Relations.

THE NBS RESEARCH PAPER REVIEW SYSTEM

I want next to take up several aspects of NBS that shaped my career. Prominent among these was the NBS publication review system. When I wrote my first paper I found out how carefully NBS reviews its technical papers before their publication. Before a paper could be submitted for publication it had to undergo two levels of review. First, someone within one's own division reviewed the paper. When it was revised to pass muster with him or her, it could then be sent on to a Bureau-level reviewer selected by the Editorial Review Board. I was initially taken aback at the rigor or the review, but quickly came to regard it as both beneficial to me and necessary to insure the quality of the NBS publications. I became a strong admirer and supporter of the system and served many times as reviewer myself. I still think that this is a good system and is indicative of the high quality standard sought by the National Bureau of Standards in all its work.

I feel that I learned much from the NBS review system. Most importantly, it taught me to think clearly about my work and to organize my thoughts. It taught me to use statistical design and analysis techniques to get the most from data and estimate their precision. It taught me to seek and listen to critical advice. It taught me much about quality and integrity in research and work in general. Perhaps it seems trite to emphasize such basic qualities of good thought and good work. The real learning process came from being surrounded by people who practiced these qualities. Seeing how they acted in practice was worth far more than any statement of ideals.

More directly, the review system helped me as a technical writer. No one is likely to consider me to be a creative or stylish writer, but I like to think that I am not bad at expository writing. I learned to write primarily in short, declarative sentences and not to abuse the use of pronouns. I learned to analyze my subject and plan my writing accordingly. I learned to write logically and tersely and stick to the point. Above all, I learned that one should base conclusions on evidence and present the evidence when possible. The review process taught one both ways – as author and as reviewer.

THE NBS TECHNICAL STAFF

A major joy of working at NBS was the contact with and learning from the generally excellent staff members. Throughout my career, the NBS management strove constantly to hire the best available people. These people were generally willing to take time to talk with me and generously share their expertise.

RECOGNITION

Every scientist wants to be recognized and valued by his community of peers. Reputation gained through reviewed publications is the primary method for those whose jobs allow them to publish. I was very fortunate in being at an agency that not only allowed but valued quality, peer-reviewed publications. Like many scientists I collected a variety of honors from various organizations including the National Bureau of Standards. Among the most meaningful to me were election to the National Academy of Engineering in 1976 and election to the International Academy of Ceramics, Faenze, Italy, in 1988. I also value the recognition indicated by becoming President of two national technical organizations: The American Ceramic Society, and the Federation of Materials Societies.

BUILDING A LARGER PROGRAM AND LEARNING TO BE A MANAGER

My work was favorably viewed by my immediate supervisors who saw that the field of mechanical properties of inorganic materials was of growing importance. They also saw it as a field in which it was appropriate for NBS to have a significant program. So they gave me support in building a larger program and eventually running a section – The Physical Properties Section - one of the fundamental managerial units of the NBS as it was then constituted. As I managed this section I began to deal with the job of handling people, including recruiting, directing, evaluating and living within financial limits. I will later discuss management from the point of view of a higher level of management.

I had the great good fortune to hire Sheldon Wiederhorn, a young chemical engineer, who was outstanding in research and who became a world-class scientist in his field. Hiring "Shelly" was perhaps the best thing that I did at NBS. His work and growing reputation took the Section far beyond my start and made it a magnet for young researchers. An early and outstanding addition was Anthony Evans, who went on eventually to double professorships at UC Berkeley and Princeton University. I remember struggling with the forms to get him a visa to allow us to hire him. Other section members who made international reputations included Brian Lawn, Stephen Freiman, Edwin Fuller, Robert Cook and Grady White. Another valued colleague at NBS was Dick Lam who worked with me for a time. He took a careful look at the prospects of a career in research versus a career in business and elected the latter. He has been very successful and remains a valued friend and correspondent and a shrewd observer of humanity. I also formed a lifetime friendship with Gordon Burley, an x-ray crystallographer, who saw the importance of materials for energy well before the oil embargo and who transferred to the Nuclear Regulatory Commission. He went on to become an expert on reactor safety and plutonium and completed his career at the Environmental Protection Agency.

MANAGING THE INORGANIC MATERIALS DIVISION

In 1968 I began a ten-year period as Chief of the Inorganic Materials Division. This division comprised the Physical Properties Section, the Inorganic Chemistry Section, the Crystal Chemistry Section, and the Crystallography Section, the Glass Section, and (later) the Solid State Physics Section. The Physical Properties Section was discussed above.

The Inorganic Chemistry section had a core of excellent people including Thomas Coyle, Frederick Brinkman, Rolf Johannesen, and Joseph Ritter. They mostly did work on molecular chemistry as opposed to solid state chemistry One example will indicate the quality of their work. Joseph Ritter and collaborators were among the first to demonstrate laser isotope enrichment; in addition to publishing, they received two patents.

The Crystal Chemistry Section under H. Steffen Peiser (later under Robert Roth) had a crystal growing program under William Brower and a phase equilibria program under Robert Roth. The latter provided data on regions of stability of various high-temperature compounds and their phases. This was work of both fundamental and practical importance to any industry producing materials by high-temperature processing. Roth was a prodigiously productive international star in his field. The American Ceramic Society established a fellowship in this section to evaluate and compile reliable data on phase stability. The series of books that resulted is to this day a continuing and unique world source on high temperature solid-liquid state chemistry.

The Glass Section under Wolfgang Haller did important work on fundamental aspects of the amorphous (vitreous) state of materials. He was a man of exacting standards in his work and he taught me much about glass and the vitreous state in general. Haller did basic work on several aspects of how processing affects the structure of glass. The Section also developed special apparatus to measure viscosity accurately at high temperatures over a range of high viscosities; it provided measurement techniques and data of fundamental and practical value to glass processing. It also developed apparatus to produce research quality glasses of a wide variety of compositions. This facility supplied a variety of special glasses as standard reference materials for composition and viscosity.

The Crystallography Section under Howard McMurdie (later under Stanley Block) was a center of work on x-ray diffraction studies of crystalline components of polycrystalline inorganic materials. They had two important programs on standard data for use in analysis of crystalline phases in solids that continue to this day as fundamental world-class analytical tools; they essentially provide the x-ray "fingerprints" of phases that can be used to identify them in complex mixtures. These were the crystal data and the powder data programs. The Joint Committee on Chemical Analysis by Powder Diffraction Methods (consisting of members from the American Society for Testing and Materials (ASTM), The American Crystallographic Association, and the Institute of Physics, see UI 252) established a continuing fellowship on the latter. The results are used in any laboratory doing x-ray phase analysis of crystalline mixtures.

The Solid State Section under Hans Frederikse had expertise in semiconductor physics and included a number of excellent scientists including Arnold Kahn, a theorist, Albert Feldman, an optical expert, Richard Forman, a spectroscopist, and William Hosler, an excellent experimentalist. Hans Frederikse was widely recognized for his research on the properties of semiconductors that led to a new understanding of electronic band structure, or the energy range of electrons. It is interesting to note that in the 1987 Nobel Prize winners in physics J. Georg Bednorz and K. Alexander Miller said that Dr. Frederikse's studies on the possible existence of superconductiviey in strontium titinate helped lead to their discovery of high temperature superconductiviey.

The Crystallography Section was also home to some important work on the stability of phases at very high pressures. Alvin Van Valkenberg pioneered the use of diamonds as pressure vessels that allowed optical inspection. Charles Weir adapted the technique by using a pair of diamonds to form a Bridgeman anvil pressure apparatus with a small pressure cell. This allowed material under very high pressures to be studied optically and with x-rays. But the pressures in the cell were not well known, being uncertain by perhaps 30%. (UI, p. 357, RNN, p 287). So the cell was used primarily for qualitative work. It was realized that an accurate method of measuring pressure would make the diamond anvil cell a unique instrument for high pressure studies. This possibility intrigued me and I wondered if some form of spectroscopy could be used to measure pressure. I made a start with the idea of using nuclear magnetic resonance but the sample required was larger than the cell volume. I next considered the sharp ruby fluorescence lines used in ruby lasers. With this in mind I got a laser spectroscopy expert from the Solid State Physics Section, Richard Forman, together at lunch with Stanley Block and Gasper Piermarini and suggested the idea. They took it up, working with a visiting scientist, J. Dean Barnett, and it proved to be successful. A flood of data resulted and they justly became world famous. To this day the diamond anvil cell with the ruby pressure scale and x-ray diffraction remains an indispensable tool for very high pressure materials studies.

The energy crisis of 1973 drove interest in coal and in alternative forms of energy generation. That year Sam Schneider and I wrote a "…summary of U. S. needs for more efficient and cleaner power generation from coal, followed by a description of the hostile environments existing in high-temperature gas turbines, magnetohydrodynamic power generators and coal gasifiers. The need for data and test methods was reviewed, and known materials properties were summarized." , p. RNN 419) We obtained support from the Department of the Interior Office of Coal Research and the Division did a series of measurements of properties of materials under energy conversion conditions. This type of study and work was driven by the need to support new national needs in an appropriate manner. The entire NBS was under pressure to respond to changing technologies and the need for appropriate NBS work on measurement methods, standards, and accurate data.

AN AGENCY CHANGING WITH ADVANCING SCIENCE AND TECHNOLOGY

The explosive advance of science and technology in the United States following WW II also drove great change at the National Bureau of Standards. The development of new, high-technology industries and the growth of great industrial research and development laboratories caused changes in the role of NBS services in measurement methods, data and standards to meet the needs of technology, industry, and commerce. NBS developed the concept of the National Measurements System and sought to find its place as the underpinning of accurate measurements for science, technology and quality control in evolving manufacturing and measurements standards for commerce involving new materials and devices. As time went on, increasing concern with health, air pollution, water pollution, recycling, occupational health and safety, consumer safety, and other public concerns drove the need for new work and new organizational structures at NBS. In addition, the continuing Cold War struggle drew NBS into a range of supporting services for defense. In time this extended to needs for the space program. The 1973 oil crisis resulting OPEC focused attention on all aspects of energy supply and use and drove new government roles, including the founding of what eventually became the Department of Energy, and new needs for appropriate NBS services.

TRENDS IN CERAMICS AND MATERIALS SCIENCE

As Chief of the Inorganic Materials Division, I was affected by the changing nature of needs for NBS services relating to the role of this class of materials in the U. S. technology, the U. S. economy, and in society in general. This division had grown up with the growth of the U. S. Ceramics and Glass Industry which included traditional ceramic products such as china, electrical porcelain, glass of many kinds. However, a whole new world of important technical ceramics was being born as I began my career. As I was given broader responsibility at NBS, I was increasingly drawn into evaluating the role that NBS might play in support of this growing and vital field of specialized materials.

A CHANGING PROFESSIONAL SOCIETY

Because of the interdisciplinary nature of materials and the variety of technical people involved, I have been a member of some eight national professional societies. My degrees are in physics and I have been a member of the American Physical Society (and eventually a fellow) since about 1950. I have published in the Physical Review. But my principal professional association has been with the American Ceramic Society (ACerS) although I attended other society meetings as well. When I joined ACerS in 1955 it was beginning major growth and change as the field of ceramics moved from low technology materials increasingly to high technology materials and merged into the field of materials science and engineering. Modern, high-technology “ceramics” go far beyond traditional ceramics and are more essential to modern products than most people know. A short list would include optical materials of many types, reinforcing and insulating fibers of many types, sensors for many applications, hard and soft magnetic ceramics, high temperature structural materials, cutting tools, wear resistant parts, filters of many kinds, body implants, exhaust clean up filters, and so on. One cannot watch a TV, hear a radio or recording, use a cellular telephone, drive a car, use a GPS, or have a CAT scan or an MRI without using some form of modern ceramic materials. A more extended summary of ceramic applications covers 23 pages. (CI, p. 10-32)

As ceramics rapidly grew in variety and technology, the American Ceramic Society began a long progression. It went from relatively empirical technology toward technology based on increasingly sophisticated science. Its traditional membership, primarily of ceramic engineers, became increasingly infiltrated by chemists, physicists, mineralogists, crystallographers, electrical engineers, chemical engineers, metallurgists, polymer scientists, and other disciplines. Three Executive Directors managed the society through these sweeping changes: Frank Reid, Arthur Friedburg, and Paul Holbrook. I became a lifetime friend to each of them and still enjoy frequent correspondence with Paul Holbrook.

As many industries moved more into high technology ceramics, they increasingly sent scientists and engineers from their research laboratories to meetings of the American Ceramic Society. This made the meetings very interesting and offered me a window into industrial practices and needs. During my career I profited greatly from attending technical society meetings of other societies also. Some of this profit came from hearing the formal papers; even more came from individual personal conversations. I found it easy to talk to people about their work. I was genuinely interested and willing to listen to people and respect them even when I disagreed with them. I formed many friendships that have lasted a lifetime. I will say more about the Society later in this memoir.

SERVICE AT THE CONGRSSIONAL OFFICE OF TECHNOLOGY ASSESSMENT (OTA)

The oil embargo of 1973 and the resulting general national concern with energy supply and use caused NBS to make a serious attempt to conserve energy and to consider its research program in the light of energy use and needs. I chaired a committee that looked into the problem and reported the results of our study to the NBS Director. This made me interested in legislation that affected the materials aspect of the energy problem. Through Gordon Research Conferences I made a friendship with a leading member of the Congressional Research Service, Franklin P. Huddle. Continuing contact with him made me aware of the new Congressional Office of Technology Assessment and its interest in materials. As a result, I applied for and received a Commerce Science Fellowship with assignment to this agency for 9 months beginning in 1974. This Office insisted that I stay until they hired a successor and I wound up spending 18 months on Capitol Hill. It was exhilarating, challenging and exhausting. I went through a forced learning process and made lasting friendships. I had the privilege of working directly with the Director of OTA, former congressman Emilio Q. Daddario who impressed me as a sincere and able man. We did a series of studies and produced a major report on materials in relation to energy. I was, however, glad to return to NBS. We also did studies on strategic materials and stockpiling, and on recycling.

MENTORS

Throughout my progression from bench scientist to Section Chief to Division Chief to Center Director I had many mentors. I can mention only some of the most important. Early mentors included Alan Franklin and Irl Schoonover. Probably the most important of all was John Hoffman, Center Director and then Laboratory Director. He was an amazingly versatile virtuoso of science and management – doing both almost to the end of his life. Perhaps his most well known of many contributions was his theory of chain folding of polymers. A Nobel laureate, Paul Flory, opposed this theory when it was first published, but eventually accepted it. Hoffman was my immediate supervisor for about ten years and I became a lifelong friend, seeing him socially until his death long after we both had left NBS. Almost as important to me were Hoffman's deputies, Howard Sorrows and then Emanuel Horowitz. Howard went on to manage the newly created Program Office under the NBS Director. I learned much about practical management from him, including his injunction to "Breathe in oxygen and give off carbon dioxide" in dealing with personnel. Emanuel Horowitz was another amazing combination of a superb chief of staff and scientist. His staff work load would have been more than enough for most people, but somehow he simultaneously developed a personal program on biomaterials. He left in 1980, three years before I did, and we had somewhat parallel subsequent academic careers. As a professor in the Department of Materials Science and Engineering and Director of the Center for Materials Science and Engineering and Director of the Center for Materials Science at Johns Hopkins University, he fostered an advanced materials research program and promoted interest in biomaterials. He continues to be active in retirement as a leader of related national standards committees. My two deputies as a Center Director, first Elio Passaglia and then Darrell Reneker, taught me a great deal also. Passaglia was perhaps the finest logician that I have known. He had the ability to isolate a problem from emotional factors and to think rigorously through the problem and possible solutions. Elio also summed up the role of a line manager under the Roberts system by saying, "When you dance on a hot stove, you can't stop." Reneker was not only a fine polymer scientist, but also an excellent pragmatic manager. He went on to a fine academic career at the University of Akron after leaving NBS. I also took courses and got valuable advice over many years from Charles Hertzfeld, Hans Frederikse, Larry Bennet, and Hans Oser of NBS.

I received some important mentoring during my 18 months at the Congressional Office of Technology Assessment. The OTA materials program was strongly influenced by Franklin P. Huddle of the Congressional Research Service. Huddle was perhaps the most able summarizer of complex material that I have ever known. He could listen to a full day of papers and discussion, including an evening session, and give an accurate summary of the essential content early the next morning. He wrote fluently and voluminously. I learned from many of the staff and consultants at OTA, but I want to mention two consultants in particular who taught me much about the minerals industry. James Boyd had been President of the Copper Range Company of Upper Michigan and chaired the 1973 study “Materials Needs and the Environment Today and Tomorrow.” Simon Strauss was a minerals economist and corporate executive. Between them they gave me a practical perspective on raw materials that undergird the whole of materials science and technology that I would never have gotten from reading alone.

MANAGING THE INSTITUTE FOR MATERIALS RESEARCH

In 1978 NBS was reorganized again. My supervisors, John Hoffman and his deputy Emanuel Horowitz, moved up to head the National Measurement Laboratory. I became Director of the Center for Materials Science under them. I respected them and was happy to continue working under them. I have had a lifelong friendship with both and I had the honor of delivering a eulogy at Hoffman’s funeral. I had the great good fortune to have Elio Passaglia as my deputy in the Center. The units in the Center were the Chemical Stability and Corrosion Division under Thomas Coyle, the Fracture and Deformation Division under Sheldon Wiederhorn, the Polymer Science and Standards Division under Ronald Eby, the Metal Science and Standards Division under William Ruff, the Ceramics, Glass and Solid State Science Division under Hans Frederikse, and the Reactor Radiation Division, under Robert S. Carter. I felt that my background was compatible with this larger responsibility with the exception of the Reactor Radiation Division. Clearly, I had no technical competence in their area – the assignment was for organizational convenience. Carter and his excellent team of Jack Rush and Michael Rowe managed the Reactor Radiation Division including its unique national neutron facility. This Reactor later became a separate unit. The Institute also contained a theory unit. Two top quality theoretical physicists, Robb Thomson and John Cahn, pursued independent research and were available as advisors. I learned from them and rejoice in their continuing friendship.

Managing the Materials Science Center was a challenge. Much time was spent on developing proposals for new budget initiatives such as proposals for new programs on mechanical reliability, on composites, and on measurements for processing science.

THE TRADITIONAL NBS MANAGEMENT SYSTEM

In the following I am going to describe the obligations of line managers and make some criticism of the situation in which many line managers were placed by the Roberts management system. In this discussion of management there is an important distinction that needs to be made between describing the proper responsibilities of line managers, on the one hand, and criticism of the situation in which they were sometimes placed, on the other hand. Describing the proper obligations of line managers and resulting problems is one thing; criticism of higher management techniques that unnecessarily increase these problems is another. Line managers have many legitimate obligations. People who take line management positions are obligated to face and carry out these responsibilities. Such people have no legitimate complaint about these obligations. Accordingly, I believe that line managers have an obligation to recruit and nurture staff, to recognize (or originate) good programs, to support them, to terminate not-so-good programs, to operate within financial limitations, to take appropriate measures when funding is insufficient, and (of great importance) to do ones best for staff including listening to them, showing respect and fostering their self-respect. The description that I am going to give of the fundamental problems of line management is not a complaint or an attempt to argue for an exemption from these fundamental line management responsibilities. It is an attempt to say that such responsibilities should not be made unnecessarily difficult by higher management as I believe that they sometimes were under the Roberts management system that replaced the traditional management system in 1974.

The management system in operation when I came to NBS continued in effect for about two thirds of my time there. It was a line management system under which individual scientist and engineers reported to a Section Chief who in turn reported to a Division Chief under the Director's Office. Subsequently, divisions were grouped into sets reporting to Institutes. My division, the Inorganic Materials Division, then reported to the Institute for Materials Research Director who reported to the NBS Director.

Under this system major responsibilities rested with the Division Chiefs. They were responsible for finance and personnel as well as overall technical supervision of their Section Chiefs. It was at the Division level that good staff members were recruited, personnel were evaluated annually, and promotion recommendations were formally initiated. Section Chiefs and Division Chiefs made primary program choices and directed technical programs.

I liked this system. Of course there were sometimes differences of opinion, but there was a clear line of responsibility and one could get definite and responsible decisions.

A NEW NBS MANAGEMENT SYSTEM

My initial and much-admired Director, Allan Astin, relied to a considerable extent on his line managers as described above. A later Director, Richard Roberts who came from industry in 1972 for a short stay at NBS, introduced a different review system. As employed by him and his immediate successor as Director, Ernest Ambler, this new system consisted of a highly formalized public review before an Executive Board. The Roberts system emphasized salesmanship and presentation skills and used public pressure as a driving force.

The base review system was conducted yearly by the Director himself supported by a new staff organization in his office – the Program Office. Presumably this review system had two purposes: first, to assist the director in judging units and allocating resources; second, to assist him in submitting budgets to the Department of Commerce and in justifying the NBS program. Selected young staff members were given term appointments in this office. Each line manager directly under the Director and their immediate line subordinates gave a public talk on the work of their unit to the Director and his staff. These program presentations were evaluated by the program office staff and the results made public. In the cautious words of the official history, "…These took on the appearance of "screen tests," with as much emphasis on style as content…" (RNN, p. 347)

This management system had some theoretical advantages for the Director. However, its effect on the morale of the line managers depended strongly on the tone of the proceedings. Perhaps some Directors could have maintained a sense of community and shared purpose among their subordinate line managers. Like me, all the other line managers of people that I talked with in my years under the system disliked the way the review system was operated. It often seemed to be an exhausting and sometimes demeaning drill that, even when well done, did little to protect the line units from wrenching budget shifts and personnel firings.

I want to emphasize that the Program Office contained many good people as personnel rotated through. The Head of this Office, Howard Sorrows, was a senior technical man with an industrial background. I respected him and formed a friendship with him that continued for years after I left NBS. We communicated by email and he came to New Jersey for a social visit not long before he died. My dislike of the new management system was not directed at the Program Office staff; it was caused by the way that the system was used by the Director in my last NBS years.

I wondered how objective evaluation would judge the success of the new management system and whether it would continue essentially unchanged under later Directors after I left NBS. How much, if at all, did it improve the internal management of the NBS program over the older system of appointing good line managers and relying on them to operate under broad direction from the Director and his office? How much, if all, did it improve the Director's ability to "sell" NBS to the Department of Commerce, the White House and Congress? In the cautious closing words of the official history published in 2000 after further role and management changes, "…it remains to be seen whether the agency will retain the capability for fundamental work in physics and chemistry that characterized the first century of its existence – the capability that made it instantly successful in its new role." (RNN, p. 787)

Many line managers had a similar type of problem under the annual review system – how to present as new and exciting a program that was valuable but necessarily continuing and that changed only slowly and incrementally. Some examples in my own area will illustrate the problem. The phase diagrams program and the crystal data program are both described in the official history of NBS as highlights. (RNN, p. 384) Both these programs had industrial support including fellowships at NBS. Ernest Levin and Robert Roth produced many volumes of evaluated phase diagrams that remain the international standard for such data. Howard McMurdie had a long career in powder diffraction date and worked at NBS after retirement under support from the International Center for Diffraction data. The National Research Council visiting committee repeatedly endorsed both programs. We did studies of industrial and scientific use of both data bases and presented them during the annual program reviews. Yet the NBS program reviewers generally were more interested in new and exciting work rather than needed basic continuing programs. There was also a wear-out factor for the managers who had to defend the continuing programs yearly. This wear-out was both in their perceived value as well as any in themselves. Hearing the same continuing programs defended year after year must have bored the review team and perhaps tended to reduce the line manager's reputation.

One of the most troubling aspects for line managers was the recurring need for reductions in force. Each line unit was responsible for making its expenditures equal to its income. Typically this income was uncertain far into the fiscal year. The problem was somewhat alleviated when in 1976 the fiscal year was moved to begin on October 1 instead of July 1. But the problem persisted. Congress often did not finalize the NBS appropriation until well into the fall – sometimes into December. The income from other agency contract programs at NBS was also uncertain until late in the fiscal year. At some point in the year a line manager had to decide whether his unit's costs would exceed its income. If he or she estimated that it would not, action to reduce costs had to be taken. Most of the costs were personnel costs although some savings could be obtained by cutting travel and supplies. In some circumstances a reduction in work force was necessary. The manager had the task of deciding which lines of work to stop. In principle, this was a program decision; actually, the decision was also based on personnel evaluation. An unstated, but well understood rule for line managers, was summarized for me as, "Breath in oxygen, give off carbon dioxide." In other words, hire the best people and get rid of the least useful. Those people whose jobs were eliminated, and who were not yet qualified for retirement, had the option of setting off a bumping chain by displacing someone with less seniority whose job they were qualified to do. This was a line manager's job; it went with the territory and he or she had to do it. I did my best when the necessity arose. I always met personally with those whose jobs were eliminated and did what I could to show them personal respect and to do what I could to help them find other jobs.

The retirement system in effect in my time at NBS had considerable bearing on staff retention and needs brief mention. In essence, after 30 years of service one could voluntarily retire at age 55 or more. The pension amount would be less for retirement under age 65, but a reduced immediate pension would begin after 55 with the requisite 30 years. At age 50 with 20 years of service, one could elect to receive an immediate pension, calculated on years of service, if dismissed from government service by the closing of a program. People over 50, but under age 55, who wished to retire voluntarily were said to be wearing "golden handcuffs." They had to wait until age 55 for an immediate pension or forego any pension until age 65 if they retired earlier.

A terrible and ironic fate followed for Richard Roberts, the NBS director who introduced the new program review system. He had modeled it on a system used in his industrial lab. He stayed at NBS about three years and then went to the Energy Research and Development Administration and from there soon returned to a special assignment in the firm from which he came, General Electric. Apparently the management system there put great pressure on him. Working under this system was quite different from introducing it at NBS and supervising it. According to a story circulating privately, he was under the pressure of a deadline for a major report on the future of technology in his company and was driving himself night and day. His wife helped but finally insisted on going to sleep one night. He worked on alone all night to prepare himself to face a review of the sort that he imposed on NBS. In the morning, he went out to his car, doused himself with gasoline, and set himself on fire.

LEAVING THE NATIONAL BUREAU OF STANDARDS

I came to NBS gladly and I left it gladly. I wanted to go on to another job while I still had idealism, energy, and enough self-confidence to act decisively. I had a good situation for most of my NBS stay until the last several years when the base review and matrix management system became increasingly onerous for line managers including myself. My last two or three years as Director of the Materials Center were an experience in endurance. Matters reached a decisive point with the rejection of two major initiatives that the Materials Center proposed. These initiatives were on composite materials and measurements for materials processing. I began to think that the Materials Center would probably slowly shrink under the operation of the new management system in combination with the priorities of the Director's office.

Looking back from the perspective of December 2009, I believe that my assessment was correct. At its peak, excluding the Reactor Radiation Division, the Materials Science Center in the early 1980s had about 250 staff members. In 2009 the NIST web site lists about 150 employees for the Materials Science and Engineering Laboratory, the Center's new name. So it appears that the materials unit staff is now about 60 percent of its earlier size. I believe that the Directors who followed me were all excellent people. I very much respect their accomplishment in being able to keep what is, so far as I can tell, a high level of excellence despite the shrinkage.

It appeared to me in the early 1980s that it might be better for the Materials Center if some young and promising person who enjoyed the Director's unreserved confidence took over. Fortunately, there was a rising star in the Materials Science Center: Robert Mehrabian, the chief of the Metallurgy Division, who favorably impressed the Director. Mehrabian was able, energetic and ambitious. I gladly and voluntarily stepped aside into an advisory staff position in the last six months before I became 55 so that he could take over. I was wryly amused when he left NBS after only about a year in the Center Director Position. He mover to a series of higher positions including Dean of Engineering at UCSB, President of Carnegie Mellon University and President of Teledyne Storm Technologies. He was succeeded in the renamed Materials Science and Engineering Center Director by another excellent person, Lyle Schwartz from Northwestern University.

Scientists and line managers in mid-career who left NBS for more fulfilling jobs elsewhere were not uncommon – especially after the new management system became fully operational. Pedro De Macedo left our Glass Section to head a vitreous state program at Catholic University. Joseph Simmons left to build a glass research program at the University of Florida. I recall several examples of line managers leaving within a few years of my own retirement. James McNesby, Chief of the Physical Chemistry Division and later head of the Measures for Air Quality program, left to become head of the Chemistry Department of the University of Maryland. Ronald Eby, a good Polymer Division Chief, left to head a Polymer Research Center at the University of Akron. My own outstanding and admired direct supervisor, John Hoffman, left the job of Director of the National Measurements Laboratory, to head the Dow Macromolecular Research Center. His deputy, Emanuel Horowitz, an excellent polymer research chemist and a good friend, left to found and head a major university research program on materials and biomaterials at Johns Hopkins University– an emerging field of great importance to medicine. There were numerous other examples of prominent NBS retirements in mid-career; these are just the people close to me who left about the time that I did.

I thought that, although I might be turning into carbon dioxide at NBS, I could still be oxygen in different circumstances and I arranged for a tenured faculty position at Rutgers University as soon as I could leave NBS. I made certain to work for one full pay period beyond the point that I could retire under the 30/55 rule. I had become wary and wanted to be sure that I had irrefutable proof, a pay statement, of the timing of my retirement. I worked through the last Friday of February 1983 and drove to Rutgers University over the weekend. On Monday I took up the job of full professor and center director there. I had no intention, then or later, of retiring to play golf.

CAREER AFTER NBS

My life after leaving NBS was certainly shaped by my experience there. All of the concern with careful and accurate work, pertinence to applications, careful review, and personnel development that I developed at NBS continued to be fundamental to my second career of academic research, industrial relationships, teaching, authorship, and editorship.

My initial assignment at Rutgers University was as the first Director of the new Center for Ceramic Research jointly funded by the National Science Foundation, the State of New Jersey, and industrial firms. The Center was located in the Ceramics Department and I worked closely with its able Chair Malcolm McLaren. This Center was intended to be partly supported by industrial members who paid for their memberships. Malcolm and I, supported by some other faculty members, had an immediate and major membership recruiting job. We succeeded in establishing a viable and active Center that remains active to this day with 27 current paying industrial members. My NBS experience, including the relationships I had built with staff in many industrial firms during my years of outreach at NBS, was very important, indeed vital, to recruiting members and, perhaps even more important, holding them. It is interesting that the December 2009 issue of APS News features an article by Philip J. Wyatt titled “The Critical Need for Closer Ties Between Physics and Industry.” He argues that such ties are essential to maintaining our economic and technical leadership. I take some satisfaction in my role in helping to create an ongoing University-Industry mechanism that works toward this end.

The job of Center Director plus the normal duties of a faculty member at Rutgers University was one of the most demanding that I ever held. I visited many companies and gave talks in many venues. It turned out that many of the ideas which I had tried unsuccessfully to promote at the Director's level at NBS attracted industrial support. Six years of this task was exhausting. Fortunately, working with Malcolm McLaren, I was able to hire my own successor, Dale Niesz of the Battelle Columbus Laboratory. Helping to hire Dale Niesz was perhaps the best thing that I did at Rutgers. Niesz did an outstanding job.

At the same time as I acted as Center Director, I gradually took up teaching responsibilities. I originated and taught two courses intended for seniors and incoming graduate students. When I stepped down as Center Director, I was able to write books based partly on courses that I taught. These courses were Characterization Techniques for Ceramics and Mechanical Properties of Ceramics. Initially there was no fully suitable text; I taught directly from the research literature. My Characterization book has been left behind by the rapid progress in that field. My book "Mechanical Properties of Ceramics," published in 1996, has remained in use. It was revised by two of my Rutgers colleagues, Professors Roger Cannon and John Matthewson, and came out in a second edition in 2009 coauthored by the three of us. Both editions owe much to the still-continuing work of the group on mechanical properties that I initiated at NBS. This graduate level book, priced at $106, sold 500 copies in the first six months. This is a significant sale for such a specialized and expensive book. It is interesting that 400 of these sales were outside the U. S. and Canada. These figures suggest that mechanical properties of ceramics remain an active subject and that this revised book is still a respected basic reference. The sales also indicated that advanced technical work in this field is no longer dominated by the U. S.

As I turned the Center Director Job at Rutgers over to my successor in 1989, I took on the part-time job of overall technical editor for the publications of The American Ceramic Society (ACerS) and held it for 12 years. My principal focus among their publications was on the Journal of the American Ceramic Society which is their premier scientific publication. I had the job and the pleasure of working with many top scientists and engineers in building a part-paid and part volunteer system of rigorous peer review of papers. The recasting of the Journal and the review system depended critically on two excellent world-class scientists who became Journal editors, Arthur Heuer of Case-Western Reserve University and Robert Newnham of Pennsylvania State University. Based on such measures as citation index, this journal became the leading research publication on ceramics in the world. The number of papers by foreign authors published in our journal rose over 50 percent during my tenure. In my last years as editor we succeeded in putting the Journal online (JACerS) with a subscription system.

Going online with a technical journal was not a simple task; it was quite a challenge for a middle-sized technical society in the 1990s. A number of large societies had pioneered with one or more publications using special software for themselves and special readers that users had to purchase. This software tended to be rapidly outmoded requiring new investment. We at ACerS decided that we could not afford to follow that path and that we would have to work until at least two conditions were met. There needed to be a de facto standard browser/reader and there needed to be a large enough base of our readers equipped with this software. I was technical advisor for this effort but the real work was done by a team of Russell Jordan and Mark Mecklinborg under Executive Director Paul Holbrook. The Journal began going online in 1998 and the online version is now published through Wiley. Now JACerS ranks first in the entire field of ceramics science according to ISI's 2007 Impact Factor rating. About 70 percent of the papers are from foreign authors, especially the Chinese.

Another concluding act of my working years was the collection, part authoring, and editing of a book, "Ceramic Innovations in the 20^{th} Century." It was published by the American Ceramic Society in 1999 for the 100^{th} anniversary of the founding of the Society. All of this work could only be done with the support of Paul Holbrook, the Executive Director of the Society, who made good decisions and committed resources to the upgrading. His work greatly improved the Society and shaped it for the future.

I also became an Associate Editor of the "Annual Reviews of Materials Science" under the general editorship of Robert Huggins of Stanford University. This was a great way to learn new trends in the broad field of materials science.

During my final years at Rutgers I also had the pleasure of working with Steve Freiman (then chief of the Ceramics Division at NBS), Terri Baker, and Ronald Munroe in the first stages of developing a data base of evaluated properties of ceramics. They carried it on far beyond our joint beginning.

I participated on numerous advisory committees at the National Research Council under the National Academies. Assignments included some for defense (at various times on committees for the Army, Navy and Air Force), at national laboratories (including Los Alamos), and I served terms on the National Materials Advisory Board and as a Commissioner on the Commission for Sociotechnical Systems. This was interesting work and rewarding in friendships made and intellectual broadening. In this way I had a tangential contact with NBS in the following way. I deepened a friendship of many years with Arden Bement, a leading nuclear engineer. He was and is a man of great capability and intellect. He held a succession of increasingly higher positions and was clearly on the way to the top. Yet he still had time to talk with me. We both had a broad interest in the field of materials and where it was going. We exchanged papers on this subject.

I was very impressed with Bement's ability and leadership. He immediately stood out in any group because of his intellect, fluency, self confidence and friendly but firm manner. He could speak on his feet without staff preparation and was very much his own man. I was delighted when Bement was appointed Director of NBS and I hoped that he would remain for a long time. However, he was soon called to an even higher position – Director of the National Science Foundation. The era of short term NBS Directors that followed Ambler's directorship continued.

I have never thought that I was a great research scientist, or a great research manager, or a great college professor. This statement is not modest; it is just realistic. I knew a number of people who truly were outstanding and by comparison recognized my abilities and limitations. I think that I was competent in research, management, and teaching and I think that I was reasonably effective. I worked hard to be organized, decisive and as considerate of subordinates as circumstances allowed. I like to believe that my employers got good value from me and that my subordinates got respect and fairness. I tried.

EFFECT OF NBS AND RUTGERS ON MY LIFE AFTER RETIREMENT

The lessons learned at NBS carried over into my retirement life. I finally had time to read seriously and discuss seriously many issues of our times. I am particularly interested in energy and environment related issues. In 2003 I set up an Issues Discussion Group in Riderwood Village, my retirement home of 2900 people. The group was, in effect, a graduate-level study that might be titled, "Western Civilization: its Origins, Problems and Competitors." As I write in December 2009 it is still going strong and I remain a co-chair. I have tried to bring to this group the ideal of objective and thoughtful analysis of whatever problem is under consideration. That ideal owes much to my NBS experience.

I am also currently the leader of two other groups at Riderwood Village: The Unitarian Universalist faith group and the Riderwood Chapter of the Maryland Continuing Care Residents Association.

A CLOSING TRIBUTE

I want to conclude with a tribute to the institutions and people who did so much for me and my career. I was lucky to have a 49-year working career including 32 years at NBS and 13 at Rutgers U as well as 12 overlapping years as technical editor. My later years were possible in considerable part because of the skills and reputation I developed during the NBS years. I want to express sincere appreciation. But the tribute that I want to pay is to the basic character and national value of the scientific and technical community, especially NBS.

I feel a great respect for the core tradition of technical excellence, responsibility, integrity, and sense of national service that was characteristic of the NBS staff in general during my time there. From the closing section of the official history, "…a culture which believed that NIST [National Institutes of Standards and Technology] should provide direct practical assistance to industry where NBS was uniquely positioned to respond, with that assistance backed up by the fundamental research needed to provide a solid foundation." (RNN, p. 787) Based on later conversations, I believe that this tradition has continued – excellence and integrity still seem strong. It is not immediately evident why this is so. This culture was established by the first NBS Director and generally reinforced by subsequent long-term Directors. Since 1990 there have been nine NBS Directors or Acting Directors. None has stayed longer than three years. It is hard to see how any of them had time to define and sustain a culture of excellence. It appears that some basic factor, in addition to Directorial leadership, has kept alive the high quality of the technical work at NBS. I suspect that factor is the nature of science and the continuing NBS dedication to measurement – to reality. One cannot fool nature. One will eventually be caught by the scientific community if one tries. Integrity is the best policy. I suspect that the culture of the scientific staff of NBS has done much to maintain excellence and to support the top management. Long may it be the ideal of the working staff at NBS.

By Albert Schweitzer: “At times our own light goes out and is rekindled by a spark from another person. Each of us has cause to think with deep gratitude of those who have lit the flame within us.”

APPENDIX

John B. Wachtman’s work Chronology:
1951-1962 Physicist and Project Leader at NBS
1962-1968 Chief, Physical Properties Section (about10 people)
1968-1978 Chief, Inorganic Materials Division (about 90 people)
1974-1975 Special Assignment U. S. Congress, Offices of Technology Assessment, as Head, Materials Program
1978-1983 Director, Center for Material Science (about 300 people)
1983-1989 Director. Center for Ceramic Research, Rutgers University
and Sosman Chair in Ceramics, Rutgers University.
1988-2000 Overall technical Editor (part-time), American Ceramic Society

Publications
160 peer-reviewed papers.
2 textbooks. Part author and/or editor of about 15 books – 12 remain listed for sale on Amazon.com.

Honors:
Silver Medal, Department of Commerce, 1960
Gold Medal, Department of Commerce, 1971
Robert B. Sosman Lecturer on Ceramic Science, 1974
Samuel W. Stratton Award, National Bureau of Standards, 1975
Elected to National Academy of Engineering, 1976
Hobart N. Kraner Award in Ceramic Science, 1978
Edward Orton, Jr. Memorial Lecturer, 1981
John E. Dorn Memorial Lecturer in Material Science and Engineering, 1981
Elected to International Academy of Ceramics, 1988
Arthur L. Friedberg Memorial Lecturer, 1989

National Offices:
President, Federation of Materials Societies, 1975
President, American Ceramic Society, 1978-79

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Note: (RNN, p. 281 indicates page 281 of RNN and similarly.)

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UI = "A Unique Institution – The National Bureau of Standards 1950-1969. by Elio Passaglia with Karma A. Beal. 822 pp. Published by the National Bureau of Standards, U. S. Department of Commerce. 1999

CE = "A Century of Excellence in Measurements, Standards an Technology" by David Lide, CRC Press, 2002.

ET = "Experimental Temperature Dependence of Young's Modulus for Several Oxides" by J. W. Wachtman, Jr., W. E. Tefft, D. G. Lam, and C.S. Apstein, Phys. Rev. vol. 122, No. 6, 1754-1759, June 15, 1961.

MER = "Mechanical and Electrical Relaxation in ThO_2 Containing CaO" J. B. Wachtman, Jr. Phys Rev Vol 131, No. 2, 517-527, July 15, 1963.

RC = "Reduction of Crystallographic Point Groups to Subgroups by Homogeneous Stress" by H. S. Peiser and J. B. Wachtman, Jr. J. Research NBS A Vol 69A 309-324, 1965.

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MP = "Mechanical Properties of Ceramics," by John B. Wachtman, John Wiley & Sons. 1996. Second Edition by John B. Wachtman, W. Roger Cannon, and M. John Matthewson. 2009.

CI = Wachtman, John B., 1999: "Ceramic Innovations in the 20^{th} Century," by John B. Wachtman, the American Ceramic Society. 1999.

The director of NIST is a Presidential appointment and confirmed by the United States Senate. Fourteen persons have held the position (in addition to three acting directors who served temporarily). They are:

- Samuel W. Stratton, 1901-1922
- George K. Burgess, 1923-1932

- Lyman J. Briggs, 1932-1945
- Edward U. Condon, 1945-1951
- Allen V. Astin, 1951-1969
- Lewis M. Branscomb, 1969-1972
- Richard W. Roberts, 1973-1975
- Ernest Ambler, 1975-1989
- John W. Lyons, 1990-1993
- Arati Prabhakar, 1993-1997
- Raymond G. Kammer, 1997-2000
- Karen Brown (acting director), 2000-2001
- Arden L. Bement Jr., 2001-2004
- Hratch Semerjian (acting director), 2004-2005
- William Jeffrey, 2005-2007
- James Turner (acting director), 2007-2008
- Patrick Gallagher, acting 2008, confirmed 2009.