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SCIENTIFIC EXCHANGE ASSIGNMENT TO JAPAN
A REVIEW AND EVALUATION

J. L. Daniel

April 1968

AEC RESEARCH &
DEVELOPMENT REPORT

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SCIENTIFIC EXCHANGE ASSIGNMENT TO JAPAN
A REVIEW AND EVALUATION

By

J. L. Daniel

Materials Research Section
Materials Department

April 1968

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SCIENTIFIC EXCHANGE ASSIGNMENT TO JAPAN
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J. L. Daniel

PREFACE

Although the information contained in this report is not new, it is presented here in a single document for the first time. Management and scientists particularly interested in the progress of my assignment in Japan, especially Dr. W. E. Roake (Battelle-Northwest) and Mr. J. M. Simmons (U.S. Atomic Energy Commission), were aware of the nature and course of events in my work on an almost day-to-day basis. Several individual oral reports, conferences and discussions pertaining to this assignment have been conducted since my return to the United States.

The first draft of this summary report was written shortly after my return, but I have delayed publication to allow my thoughts to become reoriented to American viewpoints before stating my conclusions. The fourth U.S.-Japan Information Exchange Meeting on Ceramic Nuclear Fuels has been conducted since my return and I find the direct personnel exchange aspects of the program to be of greater value than ever.

The opinions and conclusions expressed throughout this report are based on my own observations and experiences during my residence in Japan and on my many contacts with Japanese scientists and engineers before and since this assignment. I hope that the next American scientists to work in the Japanese laboratories will find this review useful in preparing for an assignment which can be highly rewarding to the scientific community, American international relations, and to the scientists' personal and professional lives.

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SCIENTIFIC EXCHANGE ASSIGNMENT TO JAPAN
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SUMMARY

The Wells-Haginoya agreement between the United States and Japan provides for scientific personnel exchanges in the field of ceramic nuclear fuels. The author, accompanied by his family, was the first U.S. participant to be assigned to a Japanese laboratory, September 1965 to September 1966. As a Visiting Chief Research Scientist for Mitsubishi Atomic Power Industries near Tokyo, he directed a new research program on high stress deformation and bonding mechanisms of UO_2 . In addition, he participated in numerous Japanese company, government laboratory, and professional activities; presented several talks and papers, and took part in two major international conferences. Daily personal contacts with a large number of Japanese citizens in all walks of life provided continuous opportunities for professional and cultural exchanges.

Satisfactory arrangements were achieved for personal life as Americans in Japan. The ability of all family members to accept prevailing customs and conditions was essential, along with a specific attempt to become an integral part of the community during residence there. A broad range of cultural activities was available, and participation in local events was frequent. Living costs for Americans generally were higher than in the United States.

Continuation of exchange assignments of U.S. scientists to Japan is highly recommended. Japan is by far the best "window" the U.S. has into all Asia, and at the same time is an outstanding example to Asians of the accomplishments of

sincere East-West cooperation. Japan still is not a large contributor to basic atomic energy developments. However, her ability to provide strong detail support in research, the rapid and continuing growth of her technology in recent years, her urgent goal of becoming a self-sufficient nation contributing on an equal basis to the rest of the world, and her steadily increasing influence on Asian and world-wide policies, all make cultivation of U.S.-Japan atomic energy relationships especially important to both nations.

It is suggested that the next U.S. exchange scientist be assigned to a Japanese government laboratory. While conditions imposed by rural living will be more difficult, greater freedom of information exchange throughout all of Japan's public and private atomic energy programs will result. A short concentrated study of Japanese language in preparation for a two-year assignment, and authorized use of American government supply sources and social facilities in Japan, is also recommended.

BACKGROUND FOR THE EXCHANGE ASSIGNMENT

A general agreement for exchange of information and personnel in the area of ceramic nuclear fuels was established between Japan and the United States in 1962 by Mr. A. Wells, U.S. Atomic Energy Commission, and Mr. T. Haginoya, Atomic Energy Bureau (AEB) of Japan. Working details of the exchange program were further developed by Mr. Y. Ihara, Japan AEB, Mr. J. M. Simmons, USAEC, and Dr. W. E. Roake, Battelle-Northwest (BNW), liaison scientist for the U.S.-Japan Exchange. The first Information Exchange Meeting on Ceramic Nuclear Fuels took place at Tokaimura, Japan, in May 1963. Since that time, three more exchange conferences have occurred at 18-month intervals: at Richland, Washington, USA, in 1964 and 1967, and at Tokai in 1966. Between meetings, an active information exchange program has been maintained by means of newsletters from each country. In addition, several Japanese scientists have spent varying periods of time in United States laboratories as part of the personnel

exchange aspects of the program. Mr. Simmons proposed in October 1964 that I become the first U.S. scientist to work in Japan on this program and, on September 2, 1965, my year of residence began. In the intervening 10-months' period, official arrangements were made and a working agreement developed between Battelle, Mitsubishi Atomic Power Industries (my resident employer in Japan), the U.S. government, and the Japanese government. The final formal agreement, completed during my residence in Japan, was delayed by discussions required to effect patent agreements and resolve some points of Japanese patent law.

The stated purpose of this exchange assignment was to plan, initiate and conduct a cooperative research program of mutual interest to both the Japanese and U.S. laboratories, working closely with recognized Japanese ceramic fuels scientists in the private laboratories of the Mitsubishi Atomic Power Industries (MAPI), at Ohmiya City near Tokyo. During this period, I was to become familiar with Japanese research techniques, and endeavor to pass on as much of my own American research philosophy, technique and knowledge as possible to the Japanese. I was also to assist whenever possible in obtaining information pertinent to their programs from their U.S. counterparts. It also was my intention to participate as fully as possible in Japanese scientific activities, including local and international conferences, visits to Japanese national and private laboratories, and discussions with manufacturers and experts in my own particular field of interest, electron microscopy.

BUSINESS ARRANGEMENTS AND RESEARCH FACILITIES

The Mitsubishi Laboratory in which I worked is located approximately 20 miles north of Tokyo, requiring a commuting time of 1-1/2 to 2 hours each way by subway and trains from my home in Tokyo. Under terms of the exchange assignment, I remained a Battelle employee. As "Visiting Chief Research Scientist," however, I was subject to the employment regulations of MAPI and reported directly to the manager of the Solid State and Materials Research Section, Dr. Shuichiro Takahashi. Dr. Takahashi is well recognized as one of the two or three most able, dynamic, and far-sighted individuals in Japanese atomic energy research today. I shared an office with him and two or three of his top-line researchers, including Mr. B. Ishii, a very competent scientist and electron microscopist who was assigned to work with me.

Mr. Ishii and his technician provided me with full-time research and engineering assistance. Service laboratories in the Mitsubishi Metal Mining Company research complex in Ohmiya also were available. In Japanese laboratories, the engineers and scientists perform many of the jobs involved in a research program which, in the United States, would be turned over to such specialists as machinists, X-ray technicians, micrographers, and photo lab technicians. Mr. Ishii insisted that he be allowed to do these jobs for me.

The laboratory equipment was adequate but not elaborate. For example, the electron microscope was an early high resolution model, but MAPI management very willingly allowed me to update the microscope as far as possible, and without hesitation provided essential equipment and facilities for that purpose. The high energy impaction machine used initially was at Nagasaki, a day's travel away, but later a similar machine was installed at the Mitsubishi Laboratory in Ohmiya.

Library facilities were available, both at MAPI and at Mitsubishi Metal Mining Laboratory, and copy and reference service could be obtained from the Japanese Diet (national) Library in Tokyo. The biggest handicap was in obtaining back issues of English language reference materials. A good supply of current books and journals is received from the United States fairly quickly, and some USAEC publications and documents are received. However, journals dating back a few years, particularly those published during and just after the war, are either completely missing or difficult to obtain because of short supply. Therefore, background literature searches were not easily achieved in English. The Japanese are avid readers of technical literature and generally are well acquainted with the current status of any problem with which they are involved.

It is a common practice in Japan for the employer to provide or pay for many of the personal daily needs of employees. Some of the standard employee benefits which I received included free or reduced-rate commuter tickets on public transportation, reimbursement for any travel within the city of Tokyo on company affairs, use of the company store and medical services as required, and assistance in straightening out income tax problems which I encountered. The MAPI Laboratory management also provided personal assistance whenever it was needed in our daily life in Japan. Upon both our arrival and departure, Mitsubishi provided transportation and laborers to assist in moving our household belongings. They provided car and driver for our use during initial house hunting, and many other incidental services such as printing of address labels and house map, cashing of checks, and occasional guide and interpreter service.

Substantial credit for success in this assignment must be especially accorded Dr. Takahashi for his helpful responses to my many requests, Mr. Ishii for his sympathetic understanding and research skills, and all levels of management, research, and supporting personnel of MAPI for their continuous efforts to fulfill my research and personal requirements.

RESEARCH AND TECHNICAL ACTIVITIES

Professional activities during the year covered a broad range. Although conduct of a research program at MAPI was my primary responsibility, attendance at several international and local technical conferences, preparation and presentation of talks and papers, daily discussions with MAPI management and scientists, and visits to various Japanese laboratories comprised a significant part of my work. A summary of these professional activities is given in Appendix A.

RESEARCH PROGRAMS

Selection of the major research program for my year in Japan was made in consultation with Dr. Takahashi of MAPI and Dr. Roake of BNW soon after my arrival in Japan. The program comprised a basic study of UO_2 particle deformation and bonding mechanisms under conditions of high stress such as occur in swaging, pressing and high energy rate impaction processes. Specifically included were 1) study of the bonding mechanisms occurring in high energy rate impaction of UO_2 in relation to more common fabrication processes such as sintering or swaging, 2) study of diffusion characteristics between materials of various compositions during impaction, 3) evaluation of the effects of annealing and impaction temperatures, and 4) identification of significant impaction variables, especially as related to the previous aspects of the problem. The program was particularly suitable because of the considerable interest in investigation and application of rapid high pressure fabrication techniques in both MAPI and Battelle laboratories. At

MAPI, hot swage and high temperature hydrostatic pressing techniques had been examined earlier, and several laboratories in the Mitsubishi industries were strongly interested in possible applications of high energy rate impaction methods for both atomic energy purposes and general fabrication of heavy industry products. The only impaction machine available to Mitsubishi was located at the Heavy Industries laboratory at Nagasaki, and two major trips there were made by MAPI personnel and myself for impaction experiments. Later in the year, Dr. Takahashi managed to borrow a similar impaction machine from the Japanese manufacturing representative for installation in our laboratories at Ohmiya.

The experimental program was based to a large extent on micrographic study of impaction products, along with use of other analytical techniques. The Japanese, accustomed to (and particularly adept at) obtaining maximum amounts of information from a minimum amount of experimenting, were particularly interested in adopting my somewhat broader American experimental approach for this program. Combining the Japanese and American philosophies, we managed to obtain a considerable amount of information within the limited time of my assignment. A summary report of this research program appears in Appendix F.

A second research program involved the application of dynamic reflection electron microscopy techniques to several MAPI research programs. Instrumentation was obtained and methods established similar to those which I had already developed in the United States, including a high temperature microscope device. Similarly, a continuous electron gun bias for control of image intensity (developed at Battelle-Northwest) was installed in the MAPI microscope. Since highly skilled instrument makers such as those employed at Battelle-Northwest were not available in the MAPI laboratories, assistance and

fabrication of the intricate parts needed for the electron microscope attachments were obtained from the Japan Electron Optics Laboratory Company. Reflection electron microscopy techniques were demonstrated and applied to some of our high energy impaction research specimens. However, the old model electron microscope at MAPI was not well designed for reflection techniques and, although various modifications of the instrument were made, high quality reflection micrographs could not be achieved.

I participated frequently in discussions of MAPI research programs not related to my own work, and occasionally was able to contribute to their progress. I was requested not to discuss some specific programs with personnel outside MAPI, and I generally avoided such information altogether when possible. My proficiency in the Japanese language was very limited, so technical discussions in the laboratory were frequently conducted in English for my benefit. However, prolonged conversation in English imposed a severe strain on most Japanese participants.

My initial investigation into the feasibility of formal study to learn Japanese adequately for business purposes led me to conclude that my limited time of one year in Japan would be better spent in scientific pursuits, in as much as most of my professional contacts were with men who spoke English passably and who could understand my English rather well. Mr. Ishii improved his English in daily work with me to the point where he was able to pass a government-sponsored English language examination. I soon learned of the numerous pitfalls in translating from American expressions to Japanese thought, became adept in understanding Japanese-spoken English, and in turn learned to communicate in terms that would not be misunderstood. Even so, discussions of philosophical interpretations of scientific experiments proved difficult, primarily because shades of

meaning can be accurately translated from one language to another only by skilled and experienced persons. For an assignment of 2 years or longer, facility with the Japanese language would be well worth the time and effort required.

BUSINESS TRIPS

My association with MAPI allowed me access to many of the wide-spread Mitsubishi interests, both for information exchange purposes and as a guest speaker. My visits to other parts of the company took me to Mitsubishi Steel in Tokyo, and to Mitsubishi Heavy Industries and Mitsubishi Electrical Industries in Nagasaki. Informal discussions also were conducted with company representatives of Asahi Glass and Mitsubishi Chemical Companies during their visits to our laboratories.

A major trip was made to Nagasaki in company with Dr. S. Takahashi, my direct manager at MAPI. The first objective of this trip was to participate in the high energy rate impaction of our second series of UO_2 specimens, comprising a large portion of the experimental work on my research program at MAPI. At the Heavy Industries Laboratory, high energy rate impaction is being used for experimental fabrication of turbine buckets, propellor blades, and other small parts for their large ship-building industry.

A second purpose of the trip was to visit several of the major Nagasaki components of the Mitsubishi group, among them the Heavy Industries and Ship Yard, the Steel Industries, and their associated laboratories. The tour of the ship yard was an impressive revelation of Japanese abilities. The equipment and techniques are obvious contributors to the Japanese position as major world shipbuilders. Similarly, the visit to the Steel Industry laboratories was highly impressive. The

nearby Electrical Industries establishment was not visited, but all three of these components are closely cooperating in producing Mitsubishi products of diverse nature in the Nagasaki area.

The third objective of this trip was the presentation of technical lectures to the Mitsubishi Heavy Industries and Mitsubishi Steel Industries laboratory personnel. On both occasions I discussed high energy rate impaction methods in general and dynamic electron microscopy methods in more detail. These lectures were in English with the intermittent assistance of an interpreter, although most of the personnel attending these lectures understood sufficient English to follow the gist of my comments. My use of the BNW movies, entitled "Current Methods of Plutonium Fuel Element Fabrication" and "Electron Microscopy of UO_2 - Tungsten Cermets", assisted considerably in Japanese understanding of the subject matter. A similar lecture was given later at Mitsubishi Steel's Tokyo laboratory.

The fourth objective was to learn more about Japanese geography and history, both current and ancient. In traveling to Nagasaki, Dr. Takahashi and I drove a rented car across the island of Kyushu, visiting the active volcano, Mount Aso, and other areas of thermal activity enroute. In Nagasaki, we visited several observation points and areas of historical interest. A few hundred years ago, Nagasaki was the only open port in Japan and the main outlet for commerce with Europe, especially with the Dutch traders. Much evidence of European influence remains throughout Nagasaki, with probably the greatest concentration of Christian churches found in any part of Japan.

Several business trips were taken in the Tokyo area in connection with meetings and research conferences during the year. I was already well acquainted with several scientists and engineers of the Japan Electron Optics Laboratory Company (JEOL),

manufacturers of the electron microscopes with which I normally worked in the BNW laboratories. Since a close working relationship was enjoyed also between MAPI and the staff of JEOL, I made several lengthy technical visits to the JEOL facilities at Akishima near Tokyo, and was shown the one million volt electron microscope some months before it was introduced to the general public.

Although I was specifically assigned to work in the Mitsubishi Atomic Power Industries laboratory, it was well understood by the Japanese that I actually represented the United States Atomic Energy Commission and, therefore, would participate in discussions and visits to all cooperating Japanese laboratories, both private and federal. However, since inter-laboratory competition in Japan is extremely strong and information exchange between private domestic laboratories is almost nil, the managers of some private Japanese atomic energy laboratories were somewhat hesitant to invite me to their facilities and to discuss their programs. However, some visits were made, often as a result of close friendships with members of other laboratories whom I had met previously in Japan and during their visits to Richland on scientific assignments. The reluctance to exchange information was not apparent in the government laboratories of the Japan Atomic Energy Research Institute (JAERI) and Atomic Fuel Corporation (AFC). In fact, research personnel had been assigned from MAPI and other companies to those government laboratories in a consulting or advisory position for several months during the period I was in Japan. Through those men, and by occasional visits, I was able to follow some of the work being conducted in Japanese government laboratories, and to relay information about related work in progress in the United States.

MEETINGS AND INTERNATIONAL CONFERENCES

I presented papers at two major international conferences in Japan. The first, the International Fracture Conference, occurred in September 1965 at Sendai in northern Honshu,

a week after my arrival in Japan. This meeting was the first international conference on this subject, and my paper, co-authored with S. Takahashi, reported observations from both Battelle-Northwest and MAPI regarding plasticity and flow of uranium dioxide.

The second international meeting, in Kyoto in August 1966, was the Sixth International Congress on Electron Microscopy. I presented two papers at this well attended meeting, and displayed micrographs from Battelle-Northwest. Of particular interest were the discussions and demonstrations of (1) the first "commercial" one million volt electron microscopes, and (2) the first commercial scanning electron microscopes, specifically designed for high magnification topographical examinations with great improvement over reflection electron microscopy.

Since my knowledge of the Japanese language was extremely limited, attendance at Japanese national scientific meetings was of marginal value. However, I presented two papers in English to the spring, 1966 meeting of the Atomic Energy Society of Japan in Tokyo. These papers, based on work conducted at MAPI and on my previous work at Battelle-Northwest, were well received by the Japanese audience.

I attended a meeting conducted in Tokyo in March 1966 by the Belgian government for the purpose of obtaining international research contracts for various Belgian industries. Representatives of the major Japanese industries were invited, and the Crown Prince of Belgium presided at some sessions.

In addition to these conferences, I attended meetings at Tokai-mura on three occasions. Tokai-mura, 150 miles northeast of Tokyo, is the location of the main facilities for JAERI and AFC (now part of the Power Reactor and Nuclear Fuel Development Corporation). I first visited AFC in September 1965, shortly

after my arrival in Japan, to participate in the U.S.-Japan discussions at the opening of the new Plutonium Fuels Laboratory. This meeting was also attended by Dr. Roake of BNW, Mr. James Sako of RL-AEC, and others from the United States, as well as by Japanese laboratory management and other personnel. Dr. Nakamura and others of AFC described the processes, facilities, and goals of the new Plutonium Laboratory, and American participants commented briefly on plutonium technology. Meeting participants also toured the facilities. Later that week, during the IAEA meetings conducted in Tokyo, Dr. Glen Seaborg also visited the new AFC laboratories in company of Mr. Sako and other USAEC officials.

I next visited the Tokai area for the Third Information Exchange Meeting on Ceramic Nuclear Fuels, conducted by AFC in the same Plutonium Laboratory building. Seven other U.S. representatives and a large delegation of Japanese scientists attended. This conference has been reported in previous documents by the participants. I presented papers based on both my BNW and MAPI work, and participated in several of the laboratory and facility tours. My association with MAPI put me in the unique position of representing both Japanese and American scientists, and I found it a distinct advantage in interpreting the significance of the meeting program and events.

A personal meeting was conducted at Tokai during the summer of 1966 to discuss the latest research activities at AFC with Dr. Nakamura, Mr. Koizumi, Mr. Uchikoshi, and others of that laboratory. On this occasion, Dr. Nakamura also brought me up to date on the philosophy of his laboratory operations and discussed in some detail the qualifications of the next exchange scientists whom he would like to have assigned from the United States. These discussions are summarized in the concluding section of this report.

PUBLICATIONS

The editors of Nihon-Genshiryoku-Gakkai Shi (Journal of the Atomic Energy Society of Japan) invited me to submit a paper. I elected to write "Comments on the Nuclear Ceramic Fuels Information Exchange Program," in order to present an American viewpoint of our approach to long-range major research. Several significant differences between American and Asian research approaches, each with merits and disadvantages, were discussed in the paper. Dr. Takahashi, recognizing my intent, circulated the paper widely among MAPI management. Fearing that it would not gain enough attention if it appeared only in English, he and two or three of his staff put considerable time into translating the paper for publication. The Japanese and English versions as published are reproduced in Appendix E.

Other publications during the year were the two papers included in the Proceedings of the International Congress on Electron Microscopy in Kyoto in August 1966.

PERSONAL CONTACTS

We came into close day-to-day contact with a large number of Japanese officials, managers, government representatives, and people in all walks of life. Nearly always we received very friendly receptions and expressions of sincere concern for our personal welfare. Appendix B lists some of our closest contacts at the upper and middle management level.

MAPI

Frequent discussions were conducted during the year with MAPI management, ranging from the Managing Director, Mr. Ishida, to all company levels. Generally, these managers were interested in my own areas of research, and at the same time were eager to describe the operating philosophies and long-range goals of the company. Since a small business recession occurred during the twelve months of my stay in Japan, economics as a whole were a

major concern to management and long-range goals were being carefully scrutinized. Mitsubishi continues to maintain a strong position in Japanese industry, including atomic energy, and has established an outstanding long-range research and development program which will assure a prominent position in the rapidly expanding atomic energy field. The Toshiba-Hitachi combination, with General Electric Company cooperation, has been more outwardly productive in commercial atomic energy programs to date.

USAEC

I met several times with the U.S. Atomic Energy Commission scientific representatives and their assistants. During the first few weeks, Dr. Peter Morris was the scientific representative, but early in November he returned to the United States to take another assignment with the Commission. The assistant representative, Mr. Dean Cooper, conducted the activities thereafter until March 1966, when Mr. J. W. McCool arrived to head up the office. My discussions with these men centered primarily on information which each of us obtained in the course of our work in Japan, and observations regarding Japanese progress in atomic energy development work.

My official contacts with the USAEC in Tokyo were minimal. While I was participating in an AEC-sponsored program, I was considered by the AEC not as a direct USAEC representative but as a Battelle employee assigned to Mitsubishi. However, the Japanese government considered us to be U.S. Government representatives although we were accorded none of the privileges of U.S. Embassy employees. This put us in a rather awkward middle ground at times, since the responsibility for satisfying some of our official needs was not well defined. Dr. Morris, Mr. Cooper, and Mr. McCool, and their families, however, were personally very helpful in assisting us on these occasions when Japanese and American government red tape urgently needed to be untangled or cut.

UNITED STATES VISITORS

Several business associates from the United States visited Tokyo during this period. The identities of these visitors and their purposes in Japan are described in the following paragraphs.

Dr. E. W. Rebol, USAEC, spent a large part of a day at the MAPI laboratories discussing questions of United States fuel supplies, shipment casks, and related problems. Later he was entertained at a MAPI dinner party which I also attended.

Dr. W. E. Roake visited early in September 1965, in connection with the Tokai Plutonium Laboratory opening, and again in April 1966, while attending the U.S.-Japan Exchange Meeting. With Dr. Roake at the Exchange Meeting were five other visiting U.S. scientists.

Mr. Howard Clukey, General Electric Company, San Jose, visited in connection with Toshiba-General Electric business, and in preparation for construction of a new reactor in a joint project of these two companies.

Dr. Ersel Evans from General Electric, Vallecitos Laboratory, visited the Plutonium Laboratory at Tokai, and later conducted an information meeting in Tokyo, which I attended with research and management personnel from MAPI, Toshiba and AFC.

Mr. Edward Wessel, Metallurgical Engineer from Westinghouse Research and Development Center, attended the Sendai Fracture Conference. He subsequently visited the MAPI laboratories in connection with the long-standing informal business relationship which exists between Westinghouse and Mitsubishi.

Mr. Colin Caldwell, NUMEC, spent several weeks at AFC when the new Plutonium Laboratory went on the line. He then visited several Japanese laboratories, including MAPI. In addition to his engineering skills, he made a very favorable impression on the Japanese public by promoting one-legged skiing as a rehabilitation sport for amputees.

Numerous other American and foreign visitors also passed through the laboratories while I was there, emphasizing the vastly increased accessibility of Japanese scientific work compared to 1963, when Dr. Roake, Mr. Simmons, and the U.S. delegates to the exchange conference were the first foreign scientists admitted to some of these same laboratories.

PERSONAL LIVING ARRANGEMENTS

HOUSING AND DAILY LIFE

From discussions with Japanese and American friends, we concluded that Tokyo was the optimum location for our home. Reasonable transportation was available from there two hours north to my office in the suburb of Ohmiya, and 1-1/2 hours to the American School in Chofu west of Tokyo. Travel anywhere within greater Tokyo generally presents no problems. Taxis are abundant and cheap, and subways and commuter trains radiate to all parts of the city on very frequent schedules. However, circuitous routing is often required because there are no direct trains or highways between most suburbs, and travel conditions are often extremely congested. Rail transportation along major routes all around the country is consistently good, however. A private or rented car is essential for travel outside of the city anywhere off the beaten path, but definitely is not worth the effort in the badly-overcrowded city traffic.

School buses for the American School in Japan also circulate widely throughout Tokyo. The American School is located in new

facilities on a corner of the campus of International Christian University in Chofu. Very high standards in American curricula are maintained, and the school takes advantage of its Japanese location by emphasizing far eastern studies and Japanese geography and history. While all classes are conducted in the English language, students from some 30 countries make up the student body of 1,000, from kindergarten through twelfth grade. At least two other English-language schools are located in Tokyo, but the normal waiting list then was about one year long and their curricula did not meet the age span requirements of our children.

Another factor in selecting Tokyo as our residence was the availability of suitable housing there. The American moving to Japan experiences a major change in living conditions and costs. Western-style houses are scattered throughout the large cities, but rentals are always expensive, and they must be found by a house-by-house search, generally using the services of several English-speaking real estate agents. In addition, several large Western-style apartment buildings have been completed recently in Tokyo. These apartments, while expensive to rent also, reduce the need for tenant attention to heating problems, water supply, telephone service, and the many other aspects of daily life which periodically lead to minor crises in the lives of foreigners in Japan. The apartments generally are small and not well suited to Americans with small children.

It is normal to pay at least \$500 per month for house or apartment rental in Tokyo, another \$100-\$150 monthly for utilities, heat, and telephone, and a \$100 fee for new telephone installations. Other common American-style services are proportionally high. "Key money" is often charged by

Japanese realtors and landlords as a fee simply for the privilege of obtaining a rental contract. The key money, usually not refundable, generally amounts to the equivalent of from two or three months' to a year's rent. All these costs are for facilities considered minimal in the United States. Outside the cities, rental rates are substantially lower, but Western-style housing is rarely available.

We quickly learned that most American business men in Japan have a Tokyo office of their home company to assist in making necessary living arrangements. However, as a Battelle-Northwest employee, a "visiting scientist" for Mitsubishi, and an unofficial representative of the U.S. government, we were largely dependent upon our own resources in negotiating for housing, schooling and other necessary arrangements. Considerable help came initially from Dr. and Mrs. Peter Morris (USAEC Scientific Representative), Mr. and Mrs. Dean Cooper (assistant to Dr. Morris), and members of the Tokyo Union Church whom we met soon after arrival in Japan. In addition, the Mitsubishi Company supplied us frequently with cars, drivers, interpreters, and lists of possible (or impossible!) accommodations for us to inspect. A continuous search for about four weeks (a short period by Tokyo standards) finally yielded a suitable house at Roppongi, near the geographic center of Tokyo itself. While the house was modest by U.S. standards, it was considered highly desirable in Tokyo, particularly because of its convenient location and generous sized yard, a rarity in Tokyo. We were successful also in finally negotiating, through our real estate agent "nakagai" ("go-between"), a rental of only \$500 per month plus heat and utilities and without any "key money" requirements. A two-year lease was obtained to allow for any unexpected extensions of my assignment there, with the privilege of termination by myself with one month's notice at any time.

Procuring day-to-day living supplies comprises another problem. Even in Tokyo, clothing to fit American sizes and builds is difficult to find, especially for medium-to-large size Americans, and the best solution generally is in tailor-made clothes or imports from U.S. mail-order houses. Good quality food is abundant in the cities, particularly fresh Japanese fruits, vegetables and fish, but many Western-style foods are difficult to find even in the city, and impossible elsewhere. Familiar drugs and cosmetics are available in import drug stores and in some of the city "super markets," but imported products cost twice as much as in the United States.

Despite the language difference, the American in Tokyo soon finds that he is able to communicate reasonably well in English if he is patient, if he learns a little basic Japanese to go along with his English, and if he patronizes merchants or service centers where English is commonly encountered. However, the help of an interpreter is essential for some purposes, for example, in dealing with repair men, electrical, telephone, and gas suppliers, or in other situations where a fair amount of give and take discussion is required. For this reason, most American families hire some domestic help, usually either part-time or live-in maid service. We found it more satisfactory to have a young Japanese student interpreter live in our home. She was able to practice her English and learn American customs and idioms in her daily life with us and, in turn, supplied interpreter's services, explanations of Japanese customs, and daily assistance essential for the life of a foreigner in Japan.

In summary, the American moving to Tokyo or to other cities in Japan can expect to live in reasonable comfort if he is willing to make adjustments and allowances for his location. The total cost of living for Americans is high;

Appendix C lists those major "beyond normal" expenditures incurred in our own case. In addition to the high cost of housing itself, Americans should be prepared to spend about 25 to 50% more than would be required for the necessities of life in the United States, to meet very high personal income tax rates, and to pay tuition at any English-language schools. Outside the cities, the supply of American "necessities" is severely limited, and the American family living in rural areas must make many additional adjustments in its normal way of life. In addition, a working knowledge of the Japanese language is virtually a necessity when living outside the city to avoid the endless frustrations of being unable to communicate at will.

VACATIONS AND HOLIDAYS

Since Tokyo is the hub of Japan we took advantage of most weekends to explore the city, nearby countryside, religious and cultural activities, and local points of historical interest. In addition, we visited several other parts of Honshu (the main Japanese island) and I toured Kyushu on a business trip. Our main cultural travels beyond Tokyo are listed in Appendix D.

The main Japanese holiday is the New Year's weekend, comprising several days of celebration and ritual. On January 1, all Japanese visit a shrine; in our case it was the Meiji Shrine in Tokyo, where we were in the company of thousands of Japanese paying homage to the Shinto religion. January 2 is traditionally a time to visit close friends and family, and we were invited into Dr. Takahashi's home for a major feast and celebration in company with some of our other Japanese friends. Foreigners rarely have the opportunity to visit private Japanese homes. We were privileged to visit others also on several occasions, but this particular invitation was a special honor for us.

During a week-long vacation in April 1966, we drove from Tokyo to Kyoto by way of the mountains and along the famous Tokaido Highway. This is a very famous route along which many of the most interesting sites related to Japanese old world history are located. Our itinerary also included visits to some of the modern aspects of Japan, including the pearling industry at Ise. Our guide in Kyoto was Mr. Toraji Nishijima of the Toshiba Company, who made it his personal responsibility during our entire time in Japan to see that we learned as much about Japanese philosophy and personal life as possible. In his words, this was as important a part of our exchange assignment as the technical aspects and he was extremely helpful in interpreting the basic ideas behind many of the most famous areas in Japan.

We climbed Mount Fuji in July 1966, staying overnight in a crude hut high on the mountainside in order to watch the sunrise from there in recommended Japanese fashion. Our Japanese friends told us that "everyone should climb Mount Fuji once in his lifetime, but only a fool climbs twice".

During our final weeks in Japan, while attending the International Electron Microscopy Conference in Kyoto, we visited nearby Nara and local points of interest in Kyoto. Mr. Ishii, also attending that conference, was our guide and interpreter.

CONCLUSIONS

JAPANESE ATTITUDES IN GENERAL

It is appropriate here to point out some of the general goals and philosophies which are strongly influencing Japanese thinking and direction of progress, particularly in scientific research and atomic energy programs. Perhaps dominating all

else in Japan is the urgent national goal of becoming entirely self-sufficient in as many areas as possible, as quickly as possible, despite a serious shortage of raw materials and lack of experience in commercial applications of atomic energy. These same material shortages dictate the necessity for developing new energy facilities as soon as possible to meet the increasing requirements for electrical power and yet avoid increasing imports of oil or other fuels for this purpose. One of the most promising means of greater self-sufficiency in reactor fuels is in the utilization of the plutonium produced in their present and future reactors. Admittedly this plutonium output is still low. However the reactors now under construction or in the planning stages will provide more and more plutonium which the Japanese feel can assist them to achieve self-sufficient reactor fueling.

Two directions which utilization of plutonium can take are, (1) recycling into thermal reactors, and (2) fueling for fast breeder reactors. It might seem that recycling for thermal reactors is the more practical approach since Japan will have many thermal reactors on the line, and the plutonium recycle concept is relatively firmly established although not widely utilized. However, there are other factors involved. One is the opportunity for Japan to become a real contributor in the newly developing field of fast reactors. Another is the promise of fast breeders to eventually provide some relief for Japan's nuclear fuel shortage, thus assisting toward increased self-sufficiency. While the Japanese realize the practical advantages of utilizing development work already done around the world, by heritage they are highly sensitive about receiving more than they are contributing to the international fund of knowledge, and are bending strong efforts toward establishing a research

program in which they can pull their own weight. Therefore, the fast reactor route is being pursued very strongly in Japan with plans for a test facility and a prototype reactor in the relatively near future. The fast reactor facilities are official national goals in the government's long-range research programs, and a large portion of government funds are being diverted in that direction.

Japanese industry, however, does not share the same attitude toward plutonium utilization, simply because of the economics of the problem. Industrial research men agree upon the need to utilize plutonium, but they consider its use as fuel too expensive for commercial utilization now. Four new privately financed uranium fuel preparation plants are planned or under construction in Japan; none of these is being considered for future expansion to include a mixed plutonium-uranium fuel fabrication facility. When asked about this apparent anomaly, management points out that the costs and risks of going into the plutonium handling business are vastly greater than they feel is warranted at the present stage of atomic energy development in Japan. However, some private laboratories are developing limited capability and interest in plutonium technology through extended personnel assignments to the government's Plutonium Fuel Development Laboratory.

Therefore, it appears that the government must still play the leading role in plutonium fuels development. The existing plutonium-handling plant in Japan is too small for practical reactor fueling, and another production facility is planned. However, it may be some time before plutonium utilization can be achieved entirely from domestic sources.

The Japanese are handicapped in all of this work by their relative inexperience in conducting major original research and development programs within restrictive time limitations

imposed by urgent needs. Since that kind of approach is needed for new major undertakings in atomic energy research and development, it seems likely that for the present the Japanese will continue to provide strong detail support in research and development, while adapting established principles and developments to their own specific requirements. New, unique research and development will emerge in the future as they develop increased abilities for faster, independent progress.

BENEFITS OF THE EXCHANGE PROGRAM

The most obvious result of my assignment was the establishment of a new and continuing research program, a summary of which is given in Appendix F of this report. Since high energy rate impaction had been shown to be useful elsewhere, Japanese laboratory management was strongly interested in investing the year in a detailed basic study of the mechanism of impaction bonding. Applied aspects of the impaction process had been examined in the United States, but the basic factors beyond those influencing immediate production quality had never been studied seriously. This difference in research interest is indicative of the relative approaches to research often observed in Japanese and American laboratories. My contribution to the program was primarily in providing the originality, foresight, and leadership needed in imaginative research planning. My Japanese co-workers gave continuous cooperation in planning the program details, invested considerable time, energy and patience in carrying out the program, and provided data from related research also in progress in their laboratories. During the year, the basic program became well established and significant initial results were achieved. Work on the program is continuing in both Japan and the United States.

A second major benefit from this assignment was to provide an observation post in Japan for early awareness of new work, and

evaluation of quality and direction of existing programs of research. During my year there, it became apparent that many of the influential persons in Japanese atomic energy research had recognized the need to establish a sound, long-range direction for atomic energy development in Japan. On occasion, some of these men sought my suggestions and inquired about related United States experience. Thus we had the opportunity both to explain American policy and programs, and suggest appropriate directions for Japanese policy and research.

The exchange definitely operates in both directions. Japan is exerting particular efforts to become self-sufficient in the atomic industry by seeking means to alleviate scarcity of high quality fuel materials, by expanding technical and engineering capabilities, and by making substantial investments in commercial reactor facilities. In solving these problems, they are engaging in more and more high quality original research pertinent to the international atomic energy effort. My position allowed me to observe and participate in some of the Japanese research programs first hand, and to continuously exchange the information gained directly and rapidly with the American laboratories where it could be utilized or factored into current programs. The ceramic fuel information exchange newsletters between Japan and the United States provide a similar exchange of information periodically, but are relatively infrequent and include mainly reports of work which is relatively well established. Speculative results or work in very early stages are seldom reported.

Current business agreements in atomic energy between companies in the United States and Japan are another step in the same direction, but information gained in those industrial exchanges is closely held within the industrial group. The

scientific representative for the USAEC in Japan performs some information exchange functions, but his information generally is obtained through more formal Japanese channels, and is necessarily slower in getting back to the operating U.S. laboratories where it can be utilized.

A less tangible return from the personnel exchange is the direct encouragement given to Japanese-United States technological relationships. Many of the results will not be immediately apparent. However, the American assignments provide an opportunity for Japan to impart information on an equal basis with the United States, thus allowing the Japanese to satisfy an important point of honor by maintaining full two-way participation in the information exchange. Optimum utilization of the unique Japanese skills of patient research and ingenious technology can be achieved, while actively showing evidence of U.S. willingness to cooperate in fact rather than simply on paper.

Finally, the exchange experience provides U.S. participants the opportunity to gain a deeper understanding of Japanese thinking. This depth of understanding, unobtainable by any means other than living with the Japanese, is essential if we in the United States are to cooperate effectively with the Asian people in their economic and cultural development. Certainly Japan is our best window into all Asia. At the same time, she is the outstanding example to Asians of what can be accomplished by sincere East-West cooperation. Maintenance of this relationship becomes even more important as Japanese influence on Asian and world-wide policy steadily increases. Full understanding by Americans of the accomplishments of the Japanese since the war, and of their influential role in raising the living standards of everyone in the Far East, is a significant step in actively maintaining this spirit of exchange and cooperation.

RECOMMENDATIONS FOR FUTURE ASSIGNMENTS

It is definitely recommended that the exchange assignments of U.S. scientists for study of ceramic nuclear fuels in Japan be continued. The Japanese have much to offer in particular research skills and fresh viewpoints, and the exchange offers an opportunity for individual scientists to conduct work from a new approach. In addition, the program promotes individual understanding and appreciation of accomplishments and working conditions on an international level. Perhaps most important, the exchange establishes a continuous rapport between the laboratories and citizens of Japan and the United States to a degree impossible to accomplish simply by conversations across the table at periodic conferences.

My exchange assignment was to the Mitsubishi Atomic Power Laboratories, one of the strong progressive private industrial research concerns in Japan. For the first exchange assignment, this was an ideal arrangement, since Mitsubishi is recognized as a leader in establishing new policies in Japan, and Dr. Takahashi is well known and respected for his opinions and leadership in the atomic energy industry.

The next assignments would better be to a Japanese government laboratory for several reasons. First, some of the private industrial atomic energy laboratories in Japan have become associated with American companies and are now conducting their own internal exchanges of American scientists and engineers in connection with the joint commercial projects they have underway. The government laboratories on the other hand, do not have that kind of opportunity for international exchange, and generally are visited only briefly by foreign visitors rather than resident scientists. Important long-range programs are in progress in the government laboratories, and exchange scientist participation would be of particular value to both countries.

Another advantage of association with a government laboratory is the increased access to the private industrial laboratories in Japan as a "visiting government consultant." In my assignment with Mitsubishi I became regarded, in some respects, as a Mitsubishi employee and therefore did not always have easy communication with personnel of competitive laboratories. My handicap was minimized by long-standing friendships with scientists from the other companies, but affiliation with a government laboratory would afford easier access for the exchange scientist, without requiring previous acquaintance with laboratory management or personnel.

The most appropriate Japanese laboratories are at Tokai-mura, namely, the Japan Atomic Energy Research Institute for basic studies, and laboratories of the government's newly established Power Reactor and Nuclear Fuel Development Corporation for applied research and development on plutonium and uranium ceramic fuels. At the government laboratories located at Takasaki (isotopes research) and at Chiba (medical studies of radiation effects), little or no work is conducted on ceramic fuels. In terms of present Japanese interests and world-wide trends, the most valuable exchange scientist would be a plutonium-fuels expert, and more specifically a fast-reactor fuels oriented person. Such a scientist would have the advantage of maximum cooperation and support from the Japanese laboratories and, at the same time, could conduct a research program of direct major interest to the United States.

Assignment to the major Japanese government laboratories is not without its difficulties, however, primarily from the standpoint of personnel living conditions. All these laboratories are located in rural communities, two hours or more from Tokyo or any other major city. Living conditions are correspondingly rural, although houses, apartments, and schools

have been established for foreigners in some areas by General Electric or the British government to satisfy their own requirements in previous industrial assignments. Japanese homes are uninsulated and frequently almost unheated, are very small by American standards, and generally lack the basic American necessities of plumbing, water supply, and other features. Rural schools are either entirely Japanese or are limited to elementary schools operated largely for local employees of a company such as General Electric. The alternative is boarding school at Tokyo or Kobe, some distance away. Therefore, it would be most desirable for the scientist assigned to Tokai to have only children of pre-school age or old enough to board away from home.

The exchange assignment should last about two years. A few months are required to become firmly acclimated to the new environment, and thereafter the research program can proceed rapidly if the laboratory personnel are completely cooperative and willing to follow American ways of fast action. However, the value of an extended assignment is closely related to the effectiveness of communications. Much information is gained through normal day-to-day contacts, of course, but it is unreasonable to expect the Japanese scientists to speak English continuously for the American's benefit. It is highly desirable for this reason that any person assigned to Japan for more than a year either have some Japanese language skills before moving to Japan, or that he (and his wife) attend an intensive course of study to master basic conversational Japanese immediately on arrival in Japan. A full time course of approximately three months would be adequate, since continuous exposure to the language thereafter would lead to rapid improvement in the use of basic Japanese in ordinary daily conversations. The increased communication skills would easily compensate for the three-month delay in starting a research program.

Another handicap which the American in this assignment faces is that of being in a position "betwixt and between" in personal, social, and business relationships with the English speaking community there. The Japanese government considers the scientist to be sponsored by the United States government despite his employment by a private American company and, because he is considered to be on official government business, he is not required to register as an alien. However, the United States government considers the assignee to be an employee of private industry. We had none of the social or supply privileges of the American Embassy or access to military base facilities. Since our home company had no Tokyo office, we had none of the basic social or supply conveniences commonly provided for foreign employees and embassy personnel in this part of the world. I strongly recommend that anyone receiving this assignment in the future be authorized to obtain membership in the American Club or comparable social organization in Tokyo, and that he be authorized to use such American government supply facilities as the post-exchanges on the nearby air bases. This latter provision is particularly essential for an assignment exceeding one year, since clothing, home furnishings, and many other basic items simply are not available in usable size, style, or quality in the open Japanese market

In my discussions with Dr. Yasuji Nakamura of the Atomic Fuel Corporation at Tokai before leaving Japan, he stated that his laboratory expected to offer several benefits to any U.S. exchange scientist assigned to his laboratory. At that time, he expected that a small Western-style house and a car could be provided, and that an English-language elementary school would be available. The Japanese laboratory also was reportedly prepared at that time to pay a part of the salary of the individual assigned there. Details of such arrangements should be clearly established directly with the Japanese government and laboratory personnel before arrival of the scientist involved.

Finally, it is strongly recommended that the new assignee and his family receive detailed briefings before leaving the United States. These discussions should be conducted by both local employer and by representatives of government offices who may have an interest in the assignment in Japan, and should provide as much background as possible on the individuals and laboratory with whom he will be working.

APPENDICES

APPENDIX A

SUMMARY OF PROFESSIONAL ACTIVITIES IN JAPAN (1965-1966)RESEARCH PROGRAM

- A. Conducted the first U.S. personnel exchange in the U.S.-Japan Ceramic Fuels Information Exchange program. Developed close working and information exchange relationships with many members of the Japanese atomic energy industry. Obtained detailed information on Japanese programs, techniques and philosophy. Instructed several Japanese scientists in the use of Battelle and other American methods.
- B. Conducted new program of basic investigation into high stress deformation and bonding mechanisms, especially the fundamental behavior during pneumatic impaction of ceramic materials. Revealed some distinctive features of impaction behavior, especially as related to effects on individual particles, crystals and interfaces.

PAPERS AND TECHNICAL MEETINGS

- A. "Fracture of Uranium Dioxide" (Coauthored with S. Takahashi)
Presented at the International Conference on Fracture, Sendai, Japan, September 13-16, 1965.
- B. "Material Forming by High Energy-Rate Impaction"
Prepared for presentation to MAPI management by S. Takahashi, December 23, 1965.
- C. "High Temperature Behavior of UO_2 -W Cermets During Cine Electron Microscopy"
- D. "Microplasticity and Fracture of Single Crystal UO_2 "
(Coauthored with S. Takahashi)
Papers C and D presented at the Annual Meeting of the Atomic Energy Society of Japan, March 30 to April 2, 1966, Tokyo, Japan
- E. "Basic Studies on High Pressure Impaction Forming of UO_2 and UO_2 - Sm_2O_3 " (Coauthored with B. Ishii and S. Takahashi)

- F. "Fracture, Micro-Plasticity and Hardness of Uranium Dioxide"
(Coauthored with S. Takahashi, Y. Honda, S. Nagata and K. Maruya)

Papers E and F presented at the Third U.S.-Japan Ceramic Fuels Information Exchange Conference, Tokai-mura, Japan, April 19-22, 1966.

- G. "Dynamic Microscopy of Ceramic Nuclear Fuels"

- H. "Microstructure of UO_2 Compacted by High Pressure Techniques"
(Coauthored with S. Takahashi, B. Ishii, N. Asami and H. Uchikoshi)

Papers G and H presented at the Sixth International Congress for Electron Microscopy, August 28 to September 4, 1966, Kyoto, Japan.

- I. "Ceramics Research, Electron Microscopy and High Energy-Rate Impaction at BNW and Other USAEC Laboratories"

Presented on approximately six occasions to Mitsubishi technical personnel in Tokyo, Ohmiya and Nagasaki, Japan.

OTHER PROFESSIONAL VISITS AND CONSULTATIONS

- A. Atomic Fuel Corporation, Tokai-mura; September 1965; August 1966.
- B. Mitsubishi Steel Manufacturing Company, Nagasaki and Tokyo; February 1966.
- C. Mitsubishi Heavy Industries, Nagasaki; February 1966.
- D. Japan Electron Optics Laboratory (Nihon Denshi), Akishima, Tokyo; periodically.
- E. Sumitomo Electric Industry, Ltd., Kumatori, Sennagun, Osaka; August 1966.

PUBLICATIONS

- A. "Comments on the Nuclear Ceramic Fuels Information Exchange Program" (Invited paper)
Journal of the Atomic Energy Society of Japan, 8, No. 5
(May 1966).

B. "Dynamic Microscopy of Ceramic Nuclear Fuels"

C. "Microstructure of UO_2 Compacted by High Pressure Techniques"
(Coauthored with S. Takahasi, B. Ishii, N. Asami, and
H. Uchikosi)

Papers B and C published in "Electron Microscopy 1966"
edited by R. Uyeda, Maruzen Company, Ltd., Tokyo, 1966;
Vol. I.

DISPLAY

Dynamic Microscopy of Ceramic Nuclear Fuels:

- Oxidation of PuO_{2-x}
- Vaporization from UO_2 -W Cermet
- Recrystallization of W Bi-crystal

(Micrograph displays at the Sixth International Congress for
Electron Microscopy, August 28 to September 4, 1966, Kyoto,
Japan)

APPENDIX B

SELECTED LIST OF MANAGEMENT CONTACTS IN JAPANMITSUBISHI GROUP

Mitsubishi Atomic Power Industries, Inc.

Mr. Saburo Seno	President
Mr. Kyuchi Ishida	Managing Director
Mr. Masatoshi Yokosuka	Member of the Directors' Board and General Manager
Mr. Kazumu Sugimoto	Deputy Director, Engineering and Research Laboratory
Dr. Shuichiro Takahashi	Manager, Solid State Physics and Advanced Material Section

Mitsubishi Steel Manufacturing Company

Mr. Mitsuo Kitahara	Managing Director
Mr. Masao Nakatsukasa	Director, Manager of Development Department
Mr. Yoshihira Tsuji	Assistant Manager of Development Department
Mr. Yoshuhiko Eda	Director and General Manager, Nagasaki Steel Works
Mr. Katsumi Shibuya	Manager, Production Engineering Department, Nagasaki Steel Works

Mitsubishi Metal Mining Company, Ltd.

Mr. Akira Masuda	Manager, Central Research Laboratory
Dr. Ryoitiro Sato	Chief Research Engineer, Central Research Laboratory

OTHER INDUSTRY

Dr. Kenji Kazato	President, Japan Electron Optics Laboratory Company, Ltd., Tokyo
Mr. A. Ashinuma	Chief, Technical Divisions, JEOL.

JAPANESE GOVERNMENT

Dr. Eiichi Takeda

Commissioner, Japan Atomic
Energy Commission, and
Director, Research Laboratory
of Nuclear Reactor, Tokyo
Institute of Technology

Mr. Tohru Haginoya

Chief, Nuclear Fuel Section,
Atomic Energy Bureau

JAPANESE ATOMIC ENERGY LABS

Dr. Y. Nakamura

Manager, Plutonium Fuels
Laboratory, Atomic Fuels
Corporation, Tokai-mura

Dr. T. Amanuma

Atomic Fuels Corporation,
Tokai-mura

APPENDIX C

APPROXIMATE REIMBURSIBLE COSTS FOR ONE-YEAR ASSIGNMENT

Transportation - Round Trip	\$3,000	(5 persons)
Transportation - Round Trip	2,400	(1500 lbs. household goods)
Arrival & Pre-Departure Hotel Expenses	3,000	(Approximately six weeks total)
Rent (Housing in Japan)	5,500	(\$500/month)
Cost-of-Living Adder	2,000	(\$170/month)
Japanese Income Taxes	3,500	(Municipal and National)
School Tuition	2,400	(Three children/year)
Misc. (Trips, mailings, etc.)	<u>600</u>	
	\$22,400	

APPENDIX D

CULTURAL TRAVEL (BEYOND TWO HOURS FROM TOKYO)

Nikko and Environs (north of Tokyo)	- November 1965 and June 1966
Yonezawa (Northern Honshu)	- December 1965
Beppu to Nagasaki via Mount Aso (Kyushu)	- February 1966
Tokyo to Kyoto via Tokaido Road and Ise (south and west from Tokyo)	- April 1966
Mount Fuji (Summit) and Fuji Lakes Area	- July 1966
Kyoto and Nara (west from Tokyo)	- August 1966

APPENDIX E

JAPANESE/ENGLISH INVITED PUBLICATION

"Comments on the
NUCLEAR CERAMIC FUELS INFORMATION EXCHANGE PROGRAM
of Japan and the United States"
(Journal of the Atomic Energy Society of Japan, 8, 282-4, 1966)

談 話 室

セラミック核燃料に関する
日米情報交換プログラムについてのコメント三菱原子力工業(株)研究所
客員主任研究員 J.L. ダニエル*

私は「セラミック核燃料に関する日米情報交換計画」(アメリカ原子力委員会 AT(45-1)-1830 契約のもとに行なわれている)の一環として、第1回目のアメリカ政府原子力委員会(U.S.AEC)派遣科学者として日本の原子力研究機関で1年間研究を行なうようになったことを光榮に思っている。この計画はU.S.AECのA.Wells氏と当時在米日本大使館員の萩野谷徹氏(訳者註・現在原子力局核燃料課長)との申合せにもとずいて開始され、その後当時原子力局核燃料課長の伊原義徳氏とU.S.AECのJ.M. Simmons氏の努力で、1963年5月東海村で、「第1回日米協力専門家会議」が開催された。この計画の目的は、核燃料に関する問題について、国際水準での自由な討議をかわし、両国が核エネルギー(訳者註・人的ならびに物的)資源をより速く、より効果的に、かつ、より経済的に開発せしめることにある。全体としてこの計画は、その目的にふさわしい成果をあげており、日本での当所における協力研究で、私は、専門分野において非常に鼓舞されており、また個人としても満足している。

日米両国はこの計画を成功させるために、それぞれの国の持つ独自の力を發揮して貢献してきた。日本の科学者が基礎研究、応用研究およびエンジニアリングの分野で相当の技術を有していることは以前から認められている。私が特に興味をもって

の応用の分野では指導的地位にある。アメリカは原子力に関して長い研究経験をもち、U.S.AECの大部分の研究施設は、協同研究として日本の科学者にも利用されている。日本の科学者の英語の能力は、当初に予想されたよりも意思の疎通を容易なものにしており、去る4月19~21日の3日間、東海村で開催された「第3回日米協力専門家会議」も首尾よく成功裡に終わった。

この計画が確立され、円滑に運営されている現在、私達は、急速に進歩しつつある科学の世界において、その科学的卓越性を維持するために、いかなるものが必要であるかを考えなければならない。おそらく最も必要とするものは、**能動的かつ豊かな想像力**であり、それはしっかりした基礎技術、大胆な計画および正しい価値観を伴っていないといけない。想像力は新しいアイデアを生み出す鍵であり、研究やエンジニアリングについての潜在的な可能性を可視の世界に引き出すために必要な精神上的“顕微鏡”である。これらの**新しい見方は**、主として現在の人類の既知の知識の上に築かれたものである以上、それを成就させるためには、その方針を示す大胆な計画を必要とする。結果の究極の価値と、その結果に到達するまでに要する費用との均衡がとられて初めて、正しい価値判断がなされたことになる。しかし、リーダーシップというものは、直面する障害を乗り越えてアイデアと計画とを将来に向けて打ち立てて行く人に与えられるものであろう。また、非常に重要なことは、自ら進んで責任を引き受け決定を下す

ことであり、その決定は迅速かつ明確な方向と目的をもって下さなければならない。今日の研究は時々刻々移行している。それで、たとえ興味あるものであっても、それがわき道であれば、そのすべてを探究する時間も金もないことがしばしばある。もしも私達が一歩先んじて前進しようとするならば、一般に個々の問題を(その問題についてすべての知識を得る以前は)、完全に研究することは不可能であろう。また、ただ単にわれわれの研究がの研究と異なるものであろうという理由だけで、重要度の低いテーマを行なう余暇はない。(訳者追記)——つまり欲求によってのみプログラムの多様さをエンジョイするようなぜいたくは許されない。その代わり私達は、重点を置くべき最も重要な領域を選択して、枝葉の問題点は私達の背後にある人々によって研究されていくことも認めなければならない。確かに選択をあやまることも、また、重要な面を見落す危険もある。この危険がかえってより一層刺激的な、かつ価値あるものになっていることが数多くの重要な実績が示している。

最後に、研究は必要欠くべからざるものであると同時に、費用のかかるものであることは今日の科学界において、自明の事実であろう。金銭の面では、国家や会社は他のものより一歩先んじているためには、いや単に遅れをとらないためにさえ、実効ある、かつ一貫した投資を覚悟しなければならない。また、個々の研究者は本人自ら強い個人的**動機**(incentives)をもたなければならない。たとえ、その動機が研究者自身の金銭的利得、専門分野での評価欲、あるいは個人的な満足である場合でも、民間企業および公益事業の研究が、結局は個々の科学者の手によって行なわれざるをえないのであるから、個人的動機は必要欠くべからざるものであろう。

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このようなもの(Characteristics)のすべてを結び付ける共通の絆はコミュニケーションである。すなわち、隣りの研究所から、遠くは海外の国々まで、どこであろうが共通の関心をもつ人々の間で、アイディアや考えや基礎知識を交換することである。急速な進歩は、無駄な重複をさけるために研究協力を必要とし、基本的には研究“協力”とは“コミュニケーション”であろう。

コミュニケーションは現代生活のあらゆる面で主要な要素となっている。しかし、異なる言語が用いられる場合、単に言葉を訳すだけでは重大な誤解をひきおこす。文化の相違によって、ある国では普通の文章であるものを、他の国では耳なれぬ不適当な言葉になるかもしれない。また直訳はある国の正確な言葉や文章が、他の国の言葉では冗長な要領を得ないものとなる場合がある。私達は言葉だけを翻訳するのではなく、アイディアの全体を翻訳する必要がある。それは、私達が主題についての健全な基礎的理解とお互いの見地を理解しようとする強い願望を合わ

せ持つ場合にのみ達成できる。幸いにも、私達科学界のものにとってはコミュニケーションの多くは“世界共通語”すなわち数字、方程式、顕微鏡写真、化学反応等を通じて行なわれる。しかしこれらの表現は、しばしば基礎的理解が築かれている証拠となるものである。基本的なアイディアの討論になると、また誤解の危険性を含む古いもとの言葉に逆戻りしなければならなくなる。進歩は良識ある人々の忍耐強い相互理解への努力によってもたらされるものであろう。

今日の科学者は、国際会議に出席したり、簡単に世界を廻ることを普通のことと考えている。しかし短い交際はしているが、異なる国民性と文化を持ち、技術的教育を受けた経験豊かな人々が、席を同じくして互いにその理念や技術的能力や短所を真に知るに十分なだけ、長時間共同で仕事をする機会をはかなか持てない。「日米間のセラミック核燃料に関する情報交換計画」はこれらのコミュニケーションに関する問題を克服する非常に意義ある一段階であ

り、日米両国が、原子力の分野における研究協力推進のために、私達すべてのものにとってかくも重要である分野を選んだことは全く喜ばしいことである。

(中川 群、高橋修一郎、他共訳)

(訳者後記)本文はダニエル博士自身「このような文章を日本語することは困難であるから原文のみの方がよい」といっておられますが、学会からの要請で和訳した。なるべく原文に忠実にし、また数名が翻訳作業にあった。しかし、翻訳は必ずしも充分といかぬので“参考”程度にして、読者の方々はできるだけ以下の“原文”を読んでいただければ幸いである。

なお、ダニエル博士は U.S. AEC の費用で私達のところで働いておられるが、勤務態度で逆に教えられるところが多くある。彼自身、研究上ではいうまでもなく、人間的にも第一線の人物であり、この短いコメントは日米研究協力に関するコメントであるが、同時に、開発にたずさわる研究者あるいはエンジニアの「心得帳」に、また研究マネジメントの参考にもなるかと思う。

(1966年5月16日 高橋修一郎 記)

Comments on the
NUCLEAR CERAMIC FUELS INFORMATION
EXCHANGE PROGRAM
of Japan and the United States*

Dr. J.L. DANIEL**

It is my privilege to be the first United States scientist to conduct a year of research in a Japanese atomic energy laboratory, as part of the Japan-United States information exchange program in ceramic nuclear fuels. This exchange program is the result of an arrangement established by Mr. A. Wells, USAEC, and Mr. T. Haginoya, AEB, who was at that time the Second Secretary of the Embassy of Japan, Washington, D.C., U.S.A. Information exchange meetings were begun at Tokaimura in May, 1963, as a result of further planning by Mr. Y. Ihara, AEB, and Mr. J.M. Simmons, USAEC.

The purpose of the exchange program is to encourage free discussion of atomic energy fuel problems on an international level, and to enable each country to develop its nuclear energy resources more quickly, efficiently and economically. The program as a whole has been rewarding, and my associations here in Japan have been professionally stimulating and personally satisfying.

Each country has contributed from its own particular strengths to make the program successful. The considerable skill of Japan's scientists in basic and applied research and engineering has long been recognized. In the field of parti-

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cular interest to me, they have repeatedly demonstrated their strength and leadership in applied electron microscopy. The United States has brought a long research experience in atomic energy, and has made major AEC research facilities available to Japanese scientists for cooperative studies. The abilities of Japanese scientists to use the English language has made communication less difficult than originally expected, and the Third International Exchange Conference has just been concluded successfully at Tokaimura, April 19~21, 1966.

Now that the program is well established and working smoothly, we should consider what characteristics are necessary for each of us to maintain scientific excellence in the fast-moving scientific world of today. Perhaps the most essential is an active, fertile imagination, combined with sound basic skills, bold planning, and a good sense of values. Imagination is the key to new ideas, the mental "microscope" needed to bring the exciting potentials of research and engineering into view. Built mainly on the world's present state of knowledge, these new views demand bold planning to chart a course to achieve success. A sound sense of values provides the balance between the ultimate worth of the results and the cost of reaching them, but the leadership goes to him who is willing to ignore immediate obstacles and project his ideas and plans far into the future.

Highly important, too, is a willingness to accept responsibilities and to make decisions rapidly, flexibly, but with definite direction and purpose. Today's research moves quickly. Too often there is not time nor means to explore all the interesting sideroads. If we are to move ahead, we cannot often enjoy the luxury of "total" answers or of programs inspired only by a desire to be different. Instead, we must choose the most significant areas for emphasis, and allow the side issues to be explored by those who follow behind us. Obviously, there is a risk of making a wrong choice, or of overlooking a valuable facet. The more frequent important achievements, however, make that risk all the more exciting and worthwhile.

Finally, it is a simple fact of scientific life today that research is both essential and expensive. In terms of money, it means that countries and companies must invest substantially and consistently in order to stay ahead, or even just to remain abreast of contemporaries. The individ-

ual researcher must have his own strong personal incentives, also. Whether they be financial gain, professional recognition or personal satisfaction, they must be there, for the individual scientists are ultimately the real leaders, both in private industry and in public service.

The common thread which unites all of these characteristics is communication: the exchange of ideas, thoughts and basic knowledge among men of common interests, whether in adjacent laboratories or widely scattered countries. Rapid progress requires cooperation in research to avoid wasteful duplication, and "cooperation" is basically "communication".

Communication is a key factor in nearly every phase of modern life. But when different languages are involved, translating words alone can lead to serious misunderstandings. Cultural differences may transform a phrase common in one country into rude, inappropriate words in a second tongue. In other cases strict translation can make exact words and phrases of one language appear interminably evasive and inconclusive in another language. Obviously, we need to translate not just words but rather whole ideas; and that can be achieved only if we combine a sound basic understanding of the subject matter with a strong desire to understand each other's viewpoint. Fortunately for us in the scientific world, much of our communication is in terms of "universal languages" - numbers, equations, micrographs, chemical reactions. But these expressions are often just the evidence on which basic knowledge is built. When it comes to discussion of fundamental ideas, we must fall back on the same old languages, with the same hazards of misunderstanding. Progress demands patient attempts at understanding among men of good will.

The scientist of today considers it natural to attend international conferences, and to travel easily around the world. But in spite of these brief contacts, technically trained and experienced people of different nationalities and cultures rarely have an opportunity to work side by side long enough to gain a real insight into each other's philosophies, skills, and shortcomings. The nuclear ceramic fuels exchange program between the United States and Japan is a most significant step in overcoming these problems of communication. It is especially encouraging that our two nations have chosen to promote and strengthen cooperation in the field of atomic energy, a field of such great importance to all of us.

APPENDIX F

SUMMARY

PRIMARY RESEARCH PROGRAMDEFORMATION AND BONDING MECHANISMS OF UO_2
DURING PNEUMATIC IMPACTION

J. L. Daniel,* B. Ishii,** and S. Takahashi**

The use of pneumatic impaction for fabricating ceramic nuclear fuel materials is of wide interest, but present understanding of the basic mechanisms involved is inadequate. The purpose of this research program is to:

- Identify significant variables affecting high energy rate impaction behavior;
- Determine diffusion characteristics under impaction conditions;
- Evaluate the effects of impaction pressure and post-impaction annealing on basic properties;
- Determine the predominant bonding mechanisms; and
- Compare impaction behavior and products with those obtained by more conventional methods.

Earlier observations by many workers showed that two of the important factors in high energy rate impaction are plasticity or fracture characteristics, and chemical content of the source material. In addition, the final product may be affected by crystal orientation, physical and chemical condition of adjacent crystal phases, and the type of pressure-transmitting medium used.

Single crystal cubes, 3 mm on each edge, were carefully positioned with controlled orientations in small stainless steel cans, using Al_2O_3 or other ceramic powder as the supporting matrix. After evacuation and sealing, the specimen cans were

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impacted at 1100 °C using 20 to 30 k-bars pressure applied for approximately 0.1 sec. Most of the UO_2 specimens were wrapped in molybdenum foil or enclosed in a small covered graphite crucible to prevent direct contact with matrix powder. A 2-mm thick tracer layer of UO_2 powder was included with the Al_2O_3 matrix in several cans to study flow of the matrix powder during impaction. A few additional experiments were conducted using impaction cans containing only small single-crystal particles. Impactions were conducted on a Dynapak machine, Model 1220-D. A schematic summary of the experiments is shown in Figures 1, 2, and 3, pages F-8, F-9 and F-10.

After impaction, the steel cans and alumina matrices were removed by machining or sawing. Radiography of the impacted specimen cans to determine crystal positions allowed recovery of most specimen cubes with a minimum of damage.

Postimpaction study included evaluation of:

- Effectiveness of bonding;
- Diffusion and reaction at interfaces;
- Extent and character of crystal fracturing;
- Micro-structure and hardness changes;
- Crystallographic strain, distortion, slip, reorientation, twinning, etc.;
- Physical movement of specimens within cans;
- Flow and densification characteristics of the matrix.

Tentative conclusions reached thus far are:

1. Extensive plastic deformation of UO_2 single crystals occurs during impaction at 1100 °C, with only slight-to-moderate fracturing. The resulting crystals closely conformed to the applied pressure distribution within the impaction can. For example, in a specimen with a specially shaped lower die, the single crystal particles clearly showed the distribution of shear stress and low pressure areas existing during the impaction process. Larger single crystal cubes

showed marked deformation in lateral directions, and marked flattening without much fracturing of the original cubes. No relationship between the ultimate distortion shapes and the orientation of the original crystallographic axes was apparent.

2. In the single crystals, both simple slip and deformation twinning occur as indicated by fine striations and wide bands on the polished specimen surfaces. The twinning apparently resulted from the impaction shock. Twinning of this kind generally does not occur in a continuously stressed face-centered-cubic crystal structure. The twinning was tentatively confirmed by both optical microscopy and X-ray diffraction studies of several impacted crystal cubes.
3. Pressure differentials existed in the powder matrix within the impaction can in vertical and horizontal directions sufficient to both compress and distort single crystals axially, and to cause transverse movement of specimen components. Pressure differences apparently occur sequentially. For example, a green powder cube was shifted transversely with minimum damage and independently of an adjacent single crystal while both cubes were enclosed in a molybdenum foil wrap. The quasi-hydrostatic pressure surrounding both specimens within the matrix was apparently sufficient to hold even green-pressed pellets together while they were subjected to pressure differentials within the can during the brief impaction period.
4. A steep internal gradient was suggested both by the appearance of dislocation etch pits within crystal cubes and by the deformation of particles comprising green-pressed pellets. Examination of single crystal pairs by optical and electron microscopy revealed fringes of etch pits around the external surfaces of the cube pairs, but almost none of the etch pits were present on the crystal surfaces at the cube-pair interface. These etch pits extended from

the surface to a depth of about 50 microns, approximately the same distance as for the dislocation etch pits surrounding hardness indentations on single crystal UO_2 surfaces. In other specimens in which the molybdenum foil wrap was bonded tightly to the crystal cube surfaces, the UO_2 fractured within a layer adjacent to the molybdenum wrap to a depth of about 50 microns, similar to the width of the etch pits fringe in the non-bonded UO_2 . Other UO_2 crystals were noticeably flattened when situated between the impaction punch and horizontal face of a large single crystal "anvil." The same types of material, when located between vertical faces of UO_2 crystals, showed negligible flattening or distortion. Pressure apparently was transmitted non-uniformly to the intercrystal areas. The etch pit fringe was observed also in several of the single crystal particles comprising the specimen in which non-uniform pressure distribution was deliberately introduced.

5. Lattice deformation in the single crystals occurs as shown by X-ray diffraction studies. Deformation appeared to be related to the particle size and to the depth of strain in large crystal pieces. More crystal strain apparently was retained in the interior of impacted specimens than on the surfaces. Annealing of these specimens at 1000 °C for 2 hr produced a marked decrease in strain. Some of the crystal planes shown initially by Laue and surface diffraction patterns disappeared after annealing.
6. The matrix powder and powder specimens behave initially as nonviscous fluids during impaction, flowing freely along pressure gradients, and penetrating minute spaces, voids, cracks, and unprotected cube interfaces. For example, wafers of green UO_2 between the opposing faces of a single cube pair were largely extruded from between the cubes to bond firmly to one of the exterior crystal surfaces.

The matrix powder achieved a uniformly high density, usually greater than 95% of theoretical density, even when starting from a tap density of only 40 or 50%. No appreciable density variation within the matrix could be detected after impaction.

7. Bulk movement of powders and pieces, aside from that introduced by gross pressure differentials, was mainly parallel to the impaction direction. No turbulence, mixing, or tumbling appeared to have taken place. Tracer experiments showed that the matrix powder moved primarily as a bulk body during compaction, although some drag occurred along the can walls. Transverse pressure seemed to occur secondarily, that is, after the powder densification was largely completed by the vertical pressure movement.
8. The quality of bonding between individual single crystals of UO_2 ($\text{O/U} = 2.00$) in these experiments was generally poor. Qualitatively, the bonding between surfaces of any of the powder compact components was found to be better than the bond involving any single crystal surface. One exception was the good bond produced between the $\text{UO}_{2.08}/20\% \text{Sm}_2\text{O}_3$ green pellet and any second component, including the single crystals. The bond quality appears to be influenced by excess oxygen, and by an oxide additive. The bond is probably strongly influenced by particle size, surface condition, and the localized surface pressure distribution and direction. The poor bond between single crystal cubes may be due to the relatively low pressure per unit area, compared to that between small particles in which virtually point-to-point contact exists at the beginning of the impaction action. Bonds appeared to be better between two crystals positioned with one atop the other (that is, interface normal to the impaction pressure direction) than the bond between crystals side by side.

9. Although the two additive materials studied (ThO_2 and Sm_2O_3) apparently improved bond quality, electron microprobe analysis revealed no diffusion of either samaria or thorium from the mixed oxide cubes into green UO_2 powder or single crystal UO_2 cubes. It is possible that the bond was influenced to a depth of less than 0.001 mm (the limit of electron microprobe resolution), that oxygen was the active component in bond promotion, or that surface conditions may have played the more significant role in the observed bond improvement.
10. Interparticle bonding in green pellets was influenced both by oxide composition and by the additive component. The best interparticle bonding appeared to occur in the U_3O_8 specimen which had been heated at 1100 °C in rough vacuum in the standard preimpaction procedure, probably resulting in a composition of $\sim\text{UO}_{2.15}$ at the time of impaction. Although the $\text{UO}_{2.00}$ powder nominally produced equally good bonding, it had been previously high-fired in hydrogen to achieve the low oxygen content and therefore probably had experienced some grain growth in that earlier step.
11. The crystallographic orientation of single crystals and their location within the pressure can during impaction apparently had only minor effects on crystal or specimen behavior. Instead, several other factors appeared to be much more influential. These factors include the presence of adjacent components such as other single crystal particles, the particle size of the specimen itself, and the pressure gradient or pressure distribution during the brief period of impaction.
12. High energy rate impaction and bonding appeared to occur in two closely related stages: (1) Deformation and densification of individual particles leading to close conformation of component surfaces, an intimate contact between adjacent particles, and exclusion of interface

porosity; and (2) bonding of adjacent particles induced by the close surface contact resulting from the previous plastic deformation. The exact nature of the bond, although still undetermined, is known to be influenced by excess oxygen, impurity content and temperature. However, these influences may act on plasticity as well as on the actual bonding mechanism. Deformation, although apparently necessary for a strong ultimate bond, is not sufficient by itself, since such conditions as chemical composition of surfaces must be optimum also. On the other hand, while bonding may occur between points of contact without any preliminary plastic deformation, the ultimate strength of the piece will be severely limited by the extent of the bond and the total area in intimately bonded contact.

In the continuing research on this mechanism, several questions should be studied by specific experiments. Of particular interest are the roles of temperature, impaction pressure and rate, particle surface condition, and bulk composition.

Neg 0662706-2

FIGURE 1. Pneumatic Impaction, Series A, 20 K-Bars (285,000 psi)

Neg 0662706-3

FIGURE 2. Pneumatic Impactation, Series B, 20 K-Bars (285,000 psi)

Neg 0662706-1

FIGURE 3. Pneumatic Impaction, Series B, 30 K-Bars (425,000 psi)

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