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This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONR Tokyo,

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Distributed problem solving
Statistics
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Robustness
Statistical computing
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Scanning
Imaging
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Measuring

20. Abstract (cont.)

with certain reports also being contributed by visiting stateside scientist. Occasionally a regional scientist will be invited to submit an article covering his own work, considered to be of special interest.

CONTRIBUTORS

Educated at California Institute of Technology with a major in aeronautics, Dr. Theodore Y. Wu is currently interested in three areas of fluid mechanics: biophysical, geophysical, and naval hydrodynamics. He joined the faculty of Caltech in 1952, holding the position of Professor of Engineering Science since 1961. During this Fall Quarter of 1979 he was also a Russell Severance Springer Visiting Professor of Mechanical Engineering at the University of California at Berkeley.

Robert E. Stevenson is an oceanographic at the ONR Western Regional Office, resident at the Scripps Institution of Oceanography. He obtained a Ph.D. in marine geology in 1954 from the University of Southern California, and has held positions at Texas A&M University, Florida State University, and the Bureau of Commercial Fisheries. His current interests include coastal oceanography meteorology, and climatology as well as the application of spacecraft sensors to analyses of surface-layer oceanography.

Francis A. Richards recently returned to his position of Professor of Oceanography at the University of Washington after completing a two-year assignment with ONR Tokyo. Dr. Richards' research interests in chemical oceanography include analysis of seawater, plankton pigments, oxygen-deficient and sulfide-bearing environments in the ocean, and interrelationships among the branches of oceanography through chemistry.

Harley J. Walker is Boyd Professor in the Department of Geography and Anthropology at Louisiana State University. He just completed a nine-month visit as a Japan Foundation guest professor at Tsukuba University. Dr. Walker's interests lie in the areas of arctic hydrology, coastal morphology, and coastal defense systems.

Rudolph J. Marcus served 14 years at the ONR Western Regional Office in Pasadena before becoming Scientific Director of ONR Tokyo in March 1979. Special areas of concern during that time were photochemistry-photophysics and computer control of chemical experimentation. Dr. Marcus served as founding secretary of the American Chemical Society's Division of Computers in Chemistry (1974-79). His papers on photochemical energy conversion in the 1950s are still being cited.

Leon H. Fisher recently joined the staff of ONR Tokyo and is on leave from California State University, Hayward. He recently completed an eight-year assignment as Dean of Sciences at Hayward, where he is also Professor of Physics. Dr. Fisher has held professorships at New York University and at the University of Illinois, has led research groups at the Lockheed Palo Alto Research Laboratory and the General Telephone and Electronics Laboratory, and has been visiting professor at the University of California, Berkeley, the University of Washington, and the University of Southern California. His specialty is gaseous electronics, and his interests include ionization coefficients in gases, mechanism of electrical breakdown in gases, formation of negative ions, corona discharges, and plasma physics. Dr. Fisher has recently coauthored articles on contact potentials.

George Sandoz is Scientific Department head of the Office of Naval Research Branch Office, Chicago. He is a metallurgical engineer with many years of research experience at the Naval Research Laboratory. Dr. Sandoz's special interests are stress corrosion cracking, hydrogen embrittlement, corrosion fatigue, and fracture in steel and titanium alloys. He has also studied the notch ductility and graphitization kinetics of cast irons and protective coatings for refractory metals. His three-month assignment at ONR Tokyo in 1977 resulted in a monograph, "An Overview of Materials Science and Engineering in Japan."

D. Lynn Johnson received his Ph.D. in ceramic engineering in 1962 from the University of Utah. He worked at the U.S. Smelting, Refining, and Mining Company and joined the Department of Material Science and

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George Y. Onoda, Jr., is a professor in the Department of Materials Science and Engineering at the University of Florida. He received his Ph.D. in ceramics from the Massachusetts Institute of Technology in 1966. Dr. Onoda has worked at Aerojet General, Rockwell Corporation, and at IIT Research Institute. His current areas of interest are ceramic processing, glass technology, and surface chemistry.

Randall Davis is an assistant professor at the Massachusetts Institute of Technology where he currently holds an Esther and Harold Edgerton endowed chair. He received an undergraduate degree in physics from Dartmouth in 1970, graduating Phi Beta kappa and summa cum laude. In 1976 he received a Ph.D. from Stanford University where he specialized in artificial intelligence. Dr. Davis spent two further years at Stanford as a Chaim Weizmann postdoctoral scholar and in 1978 he went to M.I.T. His research interests are in the area of artificial intelligence, specializing in knowledge based-systems, problems of knowledge representation, and distributed problem solving.

Shelemyahu Zacks is professor of statistics at Virginia Polytechnic Institute and State University. He received his early education at The Hebrew University of Jerusalem and at the Technion, Haifa, and his Ph.D. from Columbia University followed by a postdoctoral research in statistics at Stanford University. He was chairman of the Department of Mathematics and Statistics at Case Western Reserve University from 1974 to 1979. His research interests range over the various fields of theoretical and applied statistics and probability.

Seikoh Sakiyama, Scientific Affairs Specialist of ONR Tokyo, has had considerable industrial experience in laboratory chemistry, electronic instrumentation, and quality control methodology. His interests include computer science, linguistics, and energy technology.

CONTENTS

COVER: An old house in Yanaka, Tokyo, drawn by Justin L. Bloom, Counselor for Scientific and Technological Affairs, American Embassy, Tokyo. The house is representative of those quickly disappearing old buildings in the Yanaka residential area of Tokyo. The drawing was done by pen and ink on paper and reduced to two-thirds of its original size by photo-offset lithography.

EDITOR'S NOTE

The brush painting (SUMI-E), which graced the cover of our October-December 1979 Issue, was done especially for the Bulletin by Mrs. Sarah Gruner, a member of the American Embassy, Tokyo, Community. The printer regrets that this painting, shown correctly here, was printed upside down by mistake. Our apologies are extended to Mrs. Gruner, together with our thanks for her contribution.

A GLIMPSE OF NAVAL HYDRODYNAMICS RESEARCH IN CHINA

Theodore Y. Wu

What is the field of fluid mechanics like in China today, and particularly research in naval hydrodynamics? A privileged opportunity of seeing a few glimpses of these and of seeing "the New China" at the same time, was cordially accorded by the Chinese hosts to a U.S. delegation, co-sponsored by the U.S. National Academy of Sciences, the Office of Naval Research, and the National Research Council. The delegation consisted of Professor George F. Carrier of Harvard University, the representative member of NAS who also served as the delegation leader; Mr. Ralph D. Cooper, Program Director, Fluid Dynamics Program, ONR; Mr. Lee M. Hunt, Executive Director, Naval Studies Board, NRC; and myself. In addition to visiting some Chinese centers of research in naval hydrodynamics, the delegation wished to discuss with the Chinese leaders the use of international forums for discussion and exchange of advanced research results in the field of fluid mechanics, in particular the future participation by Chinese in the continuing series of ONR Symposia on Naval Hydrodynamics. This was first communicated to Professor Zhou Pei-yuan (Chou Pei-yuan), the Caltech-graduated physicist who is now president of Peking University, vice-president of Chinese Academia Sinica (CAS), and acting chairman of the Scientific and Technological Association (STA) of the People's Republic of China. The detailed organization of our visit was delegated to the Chinese Society of Naval Architecture and Marine Engineering (CSNAME) as our primary host, with its deputy secretary general, He Zhi-gang (Dr. C. K. Ho) in charge. A superb program for a three-city tour was arranged, which took place October 7-13, 1979. With a charming classical concern for guests, Dr. He personally came from Beijing to Shanghai to meet us and to accompany us to the capital of China after our visits in Shanghai and Wuxi.

Somewhat earlier last spring, it happened that I also accepted invitations from Professor Chu Wu-hua, president of Shanghai Jiaotong University and from President Wang Heng of the Northwestern Polytechnical University in Xian, each asking me to take on a lecture series sometime in 1979. I felt fortunate that all these functions fit well into a single trip. Secretly I hoped that I could manage to have enough moments between these activities for visits with my relatives, some of whom I had not seen for thirty long years, and some younger ones whom I had not even met. With all these exciting events to look forward to, I set out from Pasadena, arriving in Shanghai in good time to join the Chinese hosts in welcoming the other three members of our delegation on Sunday, October 7, 1979.

CURRENT TRENDS OF PRC SCIENCE POLICY

Before proceeding with details, a prefatory note on current trends in science policy in the PRC, as I have learned them, may be of interest to help put in perspective what one sees in China. As is by now well known, the drastic changes in China's overall national plan and policy took place right after the sudden downfall of the "Gang of Four" (in October 1976), to whom have been attributed all the destructive deeds that occurred, at all levels, during the era (1966-76) of the Cultural Revolution (CR). The new policy directions can be summed up in the much popularized slogan of the "four modernizations," referring to the four categories of agriculture, industry, national defense, and science and technology, with the last being identified as the key to the modernization of the other three. This policy was apparently deliberated upon, and first enunciated, by the late Premier Chou En-lai in January 1975, but not until two years later was it concretely formulated at the 1978 National Science Conference (March 18-31) attended by over 6,000 delegates. From the conference have emerged, in sharp focus, many important decisions. (See, e.g., P. M. Perrolle: Trends in science policy in the People's Republic of China, 1977-78. Report, 1979, Committee on Scholarly Communication with the PRC.) These decisions are based on the principle that a major effort will be committed to promoting an integral

development of science and technology, and that higher education will be aimed at building up a strong scientific work force (target figure of 800,000 highly qualified professionals by 1985). Priorities would be set up for receiving funding, with more attention paid to nurturing basic research, which had been neglected in the past, while applied research would continue to play an important role. Further, scientists will have at least 5/6 of their working time for pursuing research, be more free to select problems in accordance with the national needs, and have their significant contributions recognized with material rewards. As a result, there is the sign of increasingly enhanced social standing of scientists, educators, and other professionals. They are now esteemed after having been denigrated, scorned, and for some, inhumanly treated by the "Gang of Four" over the long period of CR. Viewed against this background, one cannot help marvelling at the renewed vigor and high spirit let out so freely and unpretentiously by the intellectuals in their endeavors for the four-modernization movement.

Another point of interest is a brief sketch I have learned of the general structure by which scientific research and technological development is being governed and implemented in China today. At the national level, the policy steering, planning, and funding fall under the authority of the State Science and Technology Commission (SSTC), now headed by Vice-Premier Fang Yi. The actual work of research is carried out in four major branches of the institutional framework spreading throughout the nation; namely, (1) in the Academia Sinica, or Chinese Academy of Sciences (CAS)—together with the other three academies (of agricultural, medical, and social sciences), (2) in the various industrial ministries, (3) in a vast number of universities, and (4) in industrial factories of all sorts. Evidently the CAS plays the leading role in basic research, as can be suggested by the names of its many institutes (said to be over 80 at present) covering nearly every discipline in science. In addition to these institutes, the CAS also runs four important universities: The Chinese University of Science and Technology in Hefei, Anhui; Chekiang University in Hangzhou; and two more universities of science and technology, one in Harbin and the other in Chengdu. Professor Zhou Pei-yuan, known for his leadership in the CAS, STA, and many other capacities, is said to be influential in charting out medium-to-long-term plans for scientific research and manpower development, including the exchange scholar program with foreign nations.

Of China's industrial ministries, there are seven ministries of machinery (MM, called the First, Second, ... MM), each having a number of important research institutes. For instance, the China Ship Scientific Research Center (CSSRC) that we visited in Wuxi is under the Sixth MM (responsible for development of naval architecture and marine engineering), which also sets the priorities of the institute's research funding. While basic research may be given higher priorities under the new policy than before, the general research activities at these institutes are very likely problem-focused in nature. In addition to running these institutes, the MMs also directly administer a number of polytechnical universities in their respective fields of interest. As an example, Shanghai Jiaotung University, which we also visited, and Harbin Shipbuilding Engineering Institute are both under the auspices of the Sixth MM.

Universities as a group form the third major branch of the structure which supports scientific research. There are about 450 or more institutions of higher education (IHE), of which approximately 100 (a round figure we kept hearing about) are designated as key (in terms of comprehensiveness and completeness) universities. Many of these institutions went through a major process of "reorganization of institutes and departments" in the 1950s under the direction of the State Council, resulting in relocations of many institutes and departments in universities to different cities. A decade later, the IHEs were subjected to another round of severe regrouping during CR period, patterned more or less after the U.S.S.R. fashion. As told, there was, for a time in the CR years, no teaching at all in many IHEs, let alone research. But they are on the way of a brisk comeback, perhaps marching in so many various directions and at such different paces as to make an assessment of the present status difficult. Another complicating factor is that not all of the IHEs are under the same administration by the Ministry of Education (MOE) as related in the foregoing. Although there were reports stating that there is very little research activity on the university campuses, my own limited contact seems to indicate that this is no longer generally true. Several universities now have their own journals for publication by their own faculties. From the small number of volumes I have seen, there quite often can be found some sparkling thoughts backed up by expert handling in exploring them.

The fourth major sector of research work in China consists of industrial factories. Their vast number and

great diversity in nature makes it easy to understand why very little is known (outside of China) about this sector of research. It would be reasonable to assume that this class of research might be problem-stimulated and hence aimed at some practical solutions to the particular problems at hand. However, after talking with several engineers who are responsible for design, development, and production in factories, it became quite evident that they are very knowledgeable about outside literature, sharp at value judgment, and have their own fine ideas to pursue and test. It is nevertheless impossible to give a general picture.

With the above background information, we now return to report on the first city we visited.

DELEGATION VISIT TO SHANGHAI

Shanghai, now comprising 6,000 sq. km. and a total population of 11 million, is still a most lively industrial and commercial entrepot. Today, it accounts for one-eighth of China's total industrial product and one-third of China's foreign trade. It is only natural that Shanghai should become China's center of shipbuilding industry. The Jiangnan Shipyard, the best known before the advent of the People's Republic, must have multiplied manyfold, for it is now surrounded by clusters of satellite institutes like Shanghai Ship Design and Research Institute, Shanghai Naval Engineering Research Institute, Shanghai Ship and Shipping Research Institute, etc. There is also a large regional chapter of CSNAME, whose many leading members we were to see and to get better acquainted with during our stay there. At a seminar, I was happy to see again Dr. Yuan Sui-shen, deputy chief engineer of the Shanghai Ship Design and Research Institute, who was a member of the first Chinese delegation attending the 15th ITTC (International Towing Tank Conference) held in September 1978 in the Hague, where I first met him.

The seminar was staged for the "American friends," as we are termed, to perform in two groups (simultaneously in two rooms at the Science Conference Hall), one on hydrodynamics, attended by George Carrier and me, and the other on science and research management, in which Ralph Cooper and Lee Hunt took part. In our session, where Dr. Yuan presided in charming fashion, George Carrier gave a lecture on a tsunami study to a group of about 40-50 people. The problem has been stimulated by a fairly recent field observation which indicates that along narrow harbor in an island of Hawaii was found, from the tide-gauge record, to continue ringing for many days after a strong tsunami. The perplexing question is: why was the wave leakage from the harbor mouth so weak? Trying to answer this question, Carrier presented a systematic discussion on the fundamental sloshing-mode of oscillation of the water in a long straight channel with a horn-shaped opening to the sea and with the water deepening as the channel widens. So refreshingly different from the general practice of delivering a talk on polished work, Carrier chose on-going research, evidently of keen interest to him and his student, Claude Noiseux, to exemplify how an interesting problem is first spotted, and how to use physical insight to arrive at the best model that grasps all the essential elements of the problem. With the formulation in hand, Carrier elucidated the physical mechanism of geometric wave theory that every transversely inclined ray becomes increasingly more bent toward the channel wall, thus enhancing the "wave trapping" within the harbor. Mathematically, the analysis can be effected by a conformal mapping of the harbor plan-form into a simpler shape; this was explained and the final result was almost in sight. I was happy that the audience had an opportunity to see an analytical mind at work. The learning from such a process, rarely discernible in published papers and books, can never be overdone, for beginners and experts alike.

During the discussion period, I asked if there are documented records on tsunamis along the China Coast. The answer was a qualified yes, that there had been in recent decades some tsunamis reported, mostly along the southern part of the coast, and none terribly devastating. In conjecture, this was attributed to the geographical location of the islands of Japan, which perhaps served as a shelter for tsunamis from across the Pacific Ocean. It was suggested that such a historical record may cast light on this hypothetical contention.

To my regret I could not attend the parallel session in which Ralph Cooper and Lee Hunt made presentations. But I soon learned that their audience valued most highly their contributions to that session. They succeeded in giving the audience a clear picture about planning and managing scientific research programs on a grand scale as it is practiced and advanced in the U.S. This subject is being greatly emphasized in China today, especially the management of scientists and technological workers as a national human resource.

CHINA SHIP SCIENTIFIC RESEARCH CENTER (CSSRC) IN WUXI

After a relaxing train ride of about two hours that took us in dusk through the heartland of bounty (popularly dubbed the countryside of fish-and-rice) on the south bank of the fertile Yangtze delta, we arrived in Wuxi. A good-sized welcoming party met us at the station; we were swished through the city, now after dark but still bustling, in a caravan of cars to the new Hubin Hotel located in the charming Li-yuan Garden right on the lake side of Taihu.

Our program for the day started with a visit to CSSRC, located a short distance (about 6 km) south of the hotel, at the foot of a rocky hill. We were picked up at 8 a.m. and driven along the scenic road by the lake. Typical of the Chinese, all members of the hosting team were waiting in front of the administration building for our arrival, and always followed by a moment of polite and sincere insistence as to who should stand where for snapshots. We were then ushered into the reception room where we had a half-hour briefing led by the Center's new director, Professor Ku Mao-hsiang. (Prior to this appointment Professor Ku was teaching at the Harbin Shipbuilding Engineering Institute. He was a member of the Chinese delegation that attended the 15th ITTC Conference in the Hague, where I first met him.) The warm, casual, and sincere hospitality of Professor Ku and his entire staff made our two-day visit in Wuxi both scientifically beneficial and socially pleasurable.

The center was established (in the early 1960s) for ship hydrodynamics, ship motion, and structure research. It now has about ten major facilities for various experiments and studies. A brief description of some of them can be given as follows:

- Towing tank–474 m long, 7 m water depth, 14 m wide in the middle portion (175 m long) and 7.5 m wide in the remaining parts. Equipped with two carriages, one weighing 12 tons for testing surface ship models over a speed-range of 0.5-20 m/s, and the other of 20 tons for testing submerged bodies over the 0.5-15 m/s range, with speed-control accuracy of ±0.1%. It has a paddle-type wavemaker for generating regular waves of wavelength 3-16 m. This facility has been in service since 1965.

- Cavitation tunnel–variable pressure tunnel built in 1973 for propeller model tests in a 3.2-m-long working section of 0.8 m diameter, over a speed range of 3-20 m/s, corresponding to a minimum bare cavitation number of 0.15. It has a resorber composed of two vertical limbs (each extending to the depth of 32 m in the rock foundation) joined by a 27-m-long horizontal limb. The air content can be varied and controlled by deaeration.

- Seakeeping basin–a rectangular shaped basin, 69 m long by 46 m wide by 4 m deep, built in 1971 for testing ship models, marine vehicles, and other structures in regular or irregular waves that can be produced by pneumatic-type wavemakers on two adjacent sides of the basin. Equipped with a steel bridge (rotatable up to 45° from its centerline) and a carriage having a maximum speed of 4 m/s. Models of length 2.5-3.5 m, having three or six degrees of freedom, can be tested in self-propelling or in towing mode.

- Rotating arm basin–circular basin 48 m in diameter and 4.5 m in water depth, built in 1968 for testing hydrodynamic characteristics and maneuverability of various models (2-4 m long) in tow by a rotating arm up to a top speed of 1 rad/s.

- Low-speed wind tunnel–a single-return wind tunnel built in 1970 for measuring hydrodynamic characteristics of submerged bodies in an 8.5 m-long working section, with an octagonal cross section of 3 m inscribing diameter, up to a maximum wind speed of 93 m/s.

In addition, the center has facilities for testing ship structure, material properties, structural vibration, and impact dynamics as well as other supporting laboratories. These facilities were seen to be well kept in operational condition, except for the rotating arm basin as its central pedestal was in the midst of reconstruction and modification. On the whole, these facilities have been designed and constructed by the local people, who, in

turn, have made good use of them by investigating problems of current professional interest and producing significant results, as their contributions to the last 15th ITTC Conference can attest. On both accounts we can detect a sense of self pride. Their present data acquisition and processing system, we were told, is slow and tedious, and its updating is an urgent goal.

At one time, our conversation touched on the nearby earthquake which occurred last May, with epicenter at Li-yang (about 80 km WWS of Wuxi) and a magnitude of about 5.8 on the Richter scale. This immediately prompted a tale relating to the history of the center, which I thought may be of interest to my earthquake engineering colleagues. In selecting the site of the center, the present one was chosen, in slight favor over Shanghai (where the ground may be subject to slow subsidence), primarily on account of its immense rock foundation, although it would, and did, cost extra in digging holes for laying the water tunnel resorbers (and the summer here is notoriously hot). This foresight has been reaffirmed by the 1979 Li-yang earthquake as every window pane at the center stood intact, in proud contrast to many broken ones in Shanghai.

In the afternoon there was a seminar-like session, attended by about 50 people, at which several CSSRC staff members presented some research findings. Professor Ku served as chairman and also translated the Chinese presentations into English. Four papers were presented: all with expanded abstracts and figures showing plotted results handed out in advance:

1. vertical impact of a disk on a compressible fluid surface (by Chen Chiu-si);
2. theoretical and experimental investigations of drag reduction by means of ejecting polymer at high Reynolds numbers (Wang Xi-liang and Xia Chang-sheng);
3. an experimental study of cavitating performance characteristics of propeller series for high speed ships (Chu Heng-shuen);
4. optimization of hydrofoil craft control system (Wang Zhen).

This turned out to be a very informative meeting, since it provided us with an opportunity to see the scope of their activities, to discover that they are very familiar with the current literature and up-to-date advances, and further to obtain a feeling about the prevailing attitude of Chinese scientists toward handling research problems. As a few noticeable features, I might mention that paper 1 extends the classical case of pure water to a study of the more useful practical situation when a liquid has some gas bubbles, finding that a small content of gas bubbles can result in a large reduction and a longer transient time of the impact force. Such results will undoubtedly lead to a new view about the liquid impact problem. Paper 2 also combines studies on drag reduction for the simple geometries of a flat plate and axisymmetric bodies with practical considerations on propeller performance. Paper 3 presented an effort-taking determination of the specific criteria of various types of propeller cavitation, such as tip-vortex cavitation, back-sheet cavitation, front-face cavitation and fully developed cavitation.

In the morning of October 10, it was our turn to perform. The general topics covered in Shanghai were adapted to give a new performance for the Wuxi audience. I was spared this time because it was known I would return later that month for a second visit by myself. This part of the meeting was followed by a long period reserved for a special discussion session in which our hosts were ready to bring up numerous questions, mostly very general and broad in scope. For example: what is the present state-of-knowledge about ship propeller noise, cavitation noise, turbulent boundary-layer noise? What are the best experimental techniques for these studies? How does one solve the unsteady cavity flow problems and investigate the underlying viscous effects? Are there any numerical methods available? It seems that scientific researchers everywhere are very much alike in their anxiety to solve difficult problems, and our Chinese counterparts do not appear to be any different or to be much more pragmatically inclined. Nevertheless, I must say that we had an interesting general discussion on these subjects.

SHANGHAI JIAOTONG UNIVERSITY (CHIAO TUNG UNIVERSITY)

The university, founded in 1896 as Nanyang College and named Chiao Tung University since 1921, is one of

China's oldest and foremost technological universities. Prior to the advent of the People's Republic, it had three colleges: science, engineering, and business administration. The university has since undergone great changes and development. Numerous reorganizations and readjustments have been made after 1949 in meeting the needs of rational distribution of disciplines. There are now four Jiaotong universities, the other three being called the Northern, Xian, and Southwestern, respectively, not all under the same administration. Today, Shanghai Jiaotong University, or "Jiao-da" as popularly known, has become a polytechnic university of science and engineering with thirteen departments (naval architecture, marine engineering, electrical engineering and computer science, electronic engineering, material science and engineering, mechanical engineering, precision instruments, applied mathematics, applied physics, engineering mechanics, applied chemistry, industrial administration, and technical foreign languages). The last six departments have all been established after 1977. Related to the teaching program are five research centers (naval architecture and ocean engineering, marine engineering, electronic engineering and computer science, material science, and mechanics). In addition, there are a number of training factories where students acquire industrial experience for design and manufacturing of various products. The curricular and extracurricular planning seems to have centered around naval architecture and marine engineering, but the newly established departments in applied sciences all point to the trend of development being in line with the national policy mentioned earlier.

The student enrollment has been climbing steadily to the current figure of 5,500 (projected to 12,000 by 1985). The number of teaching staff is about 1,600, of which 150 are professors and associate professors, some 820 lecturers, and the rest are just called teachers. Since 1949, the university has produced more than 25,000 students. As early as the fifties, there were eleven graduates and faculty members who had received the honored title of Academician of the Chinese Academia Sinica. In the 1978 National Science Conference, the university won 33 awards of "important scientific research achievements." In emphasizing the university as an advanced institution, Vice-Premier Wang Chen of the State Council has, in recent years, acted also as chairman of the University Council, assisted by Vice-Chairman Teng Shu-chu.

In the morning of October 11 we were picked up early for a visit to the Shangai Jiaotong University (SJU). There, we first had a general briefing by Vice-Chairman Teng of the University council and Vice-president Zhang Shou. This was followed by a tour to the SJU Ship Hydrodynamics Laboratory. The Laboratory, established since 1958, has two major facilities, a ship model towing tank and a cavitation tunnel.

- Ship model towing tank–110 m long, 6 m wide, 3.5 m deep (up to 3 m in water depth), used since 1958 for model resistance experiments, openwater propeller, ship motion, and performance tests in calm water and in waves. Equipped with a towing carriage (supplied by Kempf & Remmers of Hamburg) of 6-ton weight for a speed range of 0.04-6 m/s and a plunger-type wave maker for generating regular waves up to length of 6 m. The rails require periodic vertical adjustment because of the rather poor subsoil of the site. We were given a ride on the carriage to observe a typical ship resistance test.

- Cavitation tunnel–built by the Kiangnan Shipyard in Shanghai, has a 2-m-long test section, a cross-sectional diameter of 0.6 m, in a closed loop with 10-m-long horizontal limbs and 11-m-long vertical limbs. It is used primarily for propeller tests in uniform and nonuniform streams, also for experimental investigations of hydrofoils, slender bodies, cavitation erosion, and cavitation noise. With propeller models of maximum diameter 0.3 m, the tunnel can be operated up to the maximum water velocity of 15 m/s, giving a minimum cavitation number of 0.15. Unlike the CSSRC tunnel, this one has no resorber, but performs satisfactorily with a deaerator.

The laboratory, headed by Professor He Yousheng, has been admitted by the 15th ITTC as a new member organization of the conference. It is a dedicated member organization, systematically carrying out various recommended experimental tasks using the standard models adopted by the conference. The results obtained in this primary program have provided, on the one hand, a comparative evaluation of the facility performance and the experimental techniques versus those in practice elsewhere, and on the other, a needed experience to pursue the central problems of current interest such as the scaling of cavitation, propeller model tests, ship model resistance and motion, etc. In research and development work, there seems to exist a close collaboration between

this laboratory, CSSRC, and the Shanghai Ship Design and Research Institute, all three being the only member organizations of the ITTC in China.

MY LECTURE TOUR

After the delegation tour ended with a two-day visit to Beijing, I returned to Shanghai Jiaotong University to deliver a three-week short course on selected topics of fluid mechanics, including fundamental principles, water waves, cavity and wake flows, and low-Reynolds-number problems. During this period, I visited once more the CSSRC in Wuxi, and Changzhou, my native town, which is now popularly known as China's model city of light industry. After that, I went on to Xian, the ancient capital of China, for a week's visit to the Northwestern Polytechnical University, where I also gave three seminar talks. My lecture on microorganism locomotion and ciliary propulsion in mammalian bodies here (and earlier at the Science Conference Hall in Shanghai) seemed to have stimulated some new interest. I later heard, to my delight, that several groups saw great importance in this subject and would like to work on it. Between these activities, I also had a memorable visit to Xian Jiaotong University. It is therefore appropriate that I give a brief description of these two universities.

NORTHWESTERN POLYTECHNICAL UNIVERSITY (NPU)

The university is a polytechnical university of aeronautical science and technology, and one of the key universities in China. It was established in 1957 by combining the previous Northwestern Institute of Technology and the Xian Institute of Aeronautics. The latter, previously-named East China Institute of Aeronautics, was originally formed by taking over the three aeronautics departments in Shanghai Jiaotong University, Zhejiang (Chekiang) University, and Nanjing (Nanking) University. In 1970, NPU was further enlarged by absorbing the department of aeronautics in the Harbin Institute of Engineering. The present enrollment is about 4,200 undergraduate and 200 graduate students. The teaching faculty has more than 900 professors, associate professors, and lecturers, and about 300 teachers, so that the student-to-faculty ratio is about the same as for other universities in China. In running the university, President Wang Heng stresses the principle of equal opportunity for all, with special attention to those areas that need extra help. His endeavor is ably assisted by several vice presidents, Professor Wang Peisheng (provost), Professor Ji Wenmei (academic program), and Professor Luo Shijun (research).

I was shown several laboratories, which appeared to be quite well equipped for general teaching and research purposes. In the Hydrodynamics Laboratory, there are a launching tank (6 m × 4 m × 3.5 m (high)) for testing the launching of slender bodies and a hydro-acoustic tank for studies of underwater acoustics. A water tunnel, designed to provide a maximum flow velocity of 18 m/s (corresponding cavitation number down to 0.15), in a test section 4 m in length, was still under construction. The Aerodynamics Laboratory has several wind tunnels. A low-speed, open wind tunnel with flow up to 45 m/s was being used in an experimental study of the flow separation from a slender body at yaw (up to 25°). A transonic wind tunnel, with a working section of 30 cm × 10 cm for the Mach number range $0.6 < M < 1.5$ and a supersonic tunnel (30 cm × 30 cm for M up to 4.5), both being fed by eight common storage tanks of 8-atmosphere capacity, can be operated twice an hour, each time for a duration of two minutes. Professor Luo has led a group study of transonic potential flow past an airplane using a finite-difference computation method; their results were found in good agreement with experiment. They were also studying transonic flows of a multi-component fluid within a turbine with jet injections and chemical reactions.

XIAN JIAOTONG UNIVERSITY (XJU)

This new campus of Jiaotong University was established in 1956, when many departments and their teaching faculty and students were moved from Shanghai to Xian and subsequently made independent. It is a comprehensive university of science and engineering and a key university directly under the Ministry of Education. The university now consists of eight departments (mathematics, mechanics, mechanical engineering and material science, power machinery engineering, electrical engineering, information and control, electronic engineering, basic courses) and six research institutes (metal properties, system engineering, mechanical

engineering, engineering thermophysics, electrical engineering, computer science). In addition, it has over 40 teaching laboratories and three training factories. The library has a collection of nearly one million volumes.

At present, there are over 4,000 students enrolled in a four-year undergraduate program and about a hundred graduate students undertaking a two-to-four-year advanced program. The number of teaching faculty is about 1,400 and of those, 140 are professors and associate professors. The university, like NPU and many other universities in China, publishes its own quarterly journal which reports new research results obtained by the faculty members and students.

COMMITTEE FOR COORDINATION OF JOINT PROSPECTING FOR MINERAL RESOURCES IN SOUTH PACIFIC OFFSHORE AREAS SUVA, FIJI (CCOP/SOPAC)

Robert E. Stevenson

The Fiji Islands may seem to be an unusual place for a growing, broadly-based program in marine sciences, but, because of the strength of the economy, the long competence of the Fiji Geological Survey, and their support of the University of the South Pacific, the Fijians are outstanding hosts for the small, but growing program sponsored by the United Nations Development Program.

The Committee for Coordination of Joint Prospecting for Mineral Resources in the South Pacific (CCOP/SOPAC) is an intergovernmental body established under sponsorship of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). Its primary function is to promote the investigation of the mineral potentials, including petroleum, of the shelves, platforms, and ocean floor in the South Pacific Region. At the present time, the member governments of the committee are: Cook Islands, Fiji, Kiribata (pronounced Keribash and formerly the Gilbert Islands), New Hebrides (soon to have a new name), New Zealand, Papua, New Guinea, Solomon Islands, Tonga, and Samoa.

When seepages of crude oil were discovered in Tonga (1968), interest was aroused in the South Pacific concerning the potential for hydrocarbon reservoirs. At the same time, the possibility of workable detrital heavy mineral deposits in the offshore areas was addressed. About this time, the growing potential of manganese nodules as a major mineral source was gaining favor. It became obvious, therefore, that there was a need to promote and coordinate offshore mineral prospecting in the South Pacific.

The Fiji government led the efforts. After support was given by other South Pacific countries, a preparatory meeting was held in July 1971 to arrange the establishment of a new body with the assistance of ESCAFE (ESCAP's predecessor). Subsequently, the first session of CCOP/SOPAC was held in Suva, Fiji, in November 1972. From that time on, sessions were held in member nations, on a rotating basis, and the largest, in 1979, was once again convened in Suva.

In 1974, a technical secretariat was set up in Suva to coordinate mineral prospecting carried out in the offshore areas of member nations. Dr. Loren W. Kroenke, on leave from the University of Hawaii, was the first project manager. Dr. A. J. Halunen, Jr., also from the Univeristy of Hawaii, succeeded Dr. Kroenke. He has a small staff (varying from two to four), headed by Dr. James V. Eade, on leave from the New Zealand Oceanographic Institute, Wellington. (Dr. Eade returned to the New Zealand position in January 1980.)

Since 1975, CCOP/SOPAC has supported its own prospecting program at sea for six months each year. Research vessels are either chartered from, or furnished by, institutions from the member countries. As the program grew, continued support was established through UNDF for the long-term project: "Investigation of Mineral Potential of the South Pacific." Help for this effort outside the UN channels continues to come from various groups in Australia, France, New Zealand, Japan, and the United States.

Although the technical staff of CCOP/SOPAC, now housed in buildings of the Mineral Resource Department in Suva, has always been small (it will increase by five this spring with a new manager), the symposia and the research reports they have sponsored have been excellent. A good example is the symposium held 18-21 September 1979 in Suva on "Petroleum Potential in Island Arcs, Small Ocean Basins, Submerged Margins, and

Related Areas in the South Pacific." Forty scientific papers were presented to an audience of well over 150 participants, a number stimulated, no doubt, by the recent determination of the sizable oil potential on the shallow shelf north of Vite Leon, Fiji.

Participants came from France, Philippines, Australia, Thailand, Jamaica, New Zealand, Japan, Canada, and the United States, plus, of course, all of the member countries of CCOP/SOPAC. In the case of scientific presentations, the greatest number of papers were given by visitors from the United States. Of interest, too, were the reports given by geophysicists from private industry such as Chevron, Pacific Energy and Minerals, Japan Petroleum Exploration, Svein GeCo (Norway), Paltech Pty (Australia), and Katwell Drilling (Philippines). Although most of these were on the petroleum potential in various regions, the industry scientists also entered into the basic science discussions by presenting papers on "Oscillations of the Melanesian (Island) Arc" (by Ian Deighton of Paltech), and on the "Geotectonic Setting of Fiji" (Jonathan Stoen of Pacific Energy).

For the most part, however, the research papers of substance were given by scientists from academic institutions–mainly from the U.S. Subjects covered included:

- "Paleomagnetic Indications of Island Arc Rotation" (David Faley, University of Sydney),
- "Fore-arc Tectonics" (Don Hussong, Univeristy of Hawaii),
- "Magnetic Anomalies (of the Southwest)" (Alexander Malahoff, National Ocean Survey, NOAA),
- "Mariana Tectonics" (Cary Mrozowski, Columbia University)
- "Heat Flow in Shallow Seas" (S. Uyeda, University of Tokyo), and
- "Emerged Reef Terraces, Central New Hebrides" (C. Jounnic, ORSTOM, Port Villa, New Hebrides).

This symposium, in September 1979, though one of many, pointed out the increased sophistication of the program under CCOP/SOPAC leadership. One can follow the growth nicely by the South Pacific Marine Geological Notes that are published by the technical secretariat of CCOP/SOPAC and ESCAP. From the first issue in 1975, a discussion of Oil Prospecting in Tonga, to the 9th note in the series in April 1979 (Mineral Resources off New Zealand), the expanding involvement by scientists in the member nations has been clear. Furthermore, the project managers have never lost sight of the prime purpose of the organization: the offshore economic potential of the South Pacific. Consequently, studies have addressed manganese nodules, shallow water bauxite deposits, oil potential of the Solomon Islands, and the gold-bearing sediments off Guadalcanal. These efforts, along with more basic determinations of structures revealed by "Reflection Profiles across the Tonga Arc" and the "Marine Geology of the Eastern Coral Sea," have given the personnel of CCOP/SOPAC and the member nations a well-deserved credibility in the geophysical community. As a result, more and more scientists are being drawn to the area to conduct research, and Suva clearly has become the center of marine science amongst the island nations of the South Pacific, excluding, of course, New Zealand.

MARINE SCIENCE ACTIVITIES IN TAIWAN

Francis A. Richards

My visits to the Institute of Oceanography of the National Taiwan University and Academia Sinica were arranged by Professor Tsu-Chang Hung, who is on the faculties of both institutions and a marine chemist. He is a former student of Professor Ken Sugawara at Nagoya University, and received his Ph.D. (chemistry) from the University of Minnesota. He and Professor Jong-Chin Su were the moving forces behind the Colloquium on Aquatic Environment in Pacific Region held in August, 1978, at Academia Sinica, which was reported in an earlier issue of *Scientific Bulletin* (Volume 3, No. 4). Warm friendships were developed at that time, but our hosts were very busy people and had little time for discussions not closely related to the colloquium. On my visit in September, 1979, Professors Hung and Su organized briefings for me at both Academia Sinica and the Institute of Oceanography.

At both Academia Sinica and the Institute of Oceanography, it was apparent that their research activities are predominantly aimed at the solution of practical problems–ecological problems and the problems arising from conflicts between population growth, industrial development, and preservation of the environment. As a small country hard pressed to feed a large population and to develop a foreign market for wholesome and marketable food products, basic studies of problems of pollution, sanitation, and productivity are being addressed at both Academia Sinica and the Institute of Oceanography.

ACADEMIA SINICA

At Academia Sinica, the emphasis on aquatic problems is focused on SCOPE, the National Scientific Committee on Problems of Environment; SCOPE is sponsored by ICSU, the International Council of Scientific Unions, and is the principal organization for international cooperation in studies of the protection of the environment. The Taiwanese have embarked wholeheartedly on the SCOPE program, and much of the work described in this report is related to SCOPE activities.

SCOPE has been in existence since 1972 and followed the activities of the International Biological Program (IBP), in which Academia Sinica participated for about five years. However, the entry of Taiwan into the IBP was rather late for the Taiwanese to participate very actively, although they were able to get a good idea of the functions of IBP, which stood them in good stead for participating fully in the activities of SCOPE. So, when SCOPE was established, Taiwan was able to launch several projects simultaneously, including general research on biogeochemical cycles; participation in the so-called mussel watch; toxic substances in the environment; biogeochemical cycles in tropical and subtropical ecosystems, and ecological effects of fire (admittedly not a topic of marine research!).

In addition to research projects, SCOPE provides advice to other agencies planning programs of research on the environment and has the responsibility for collecting and disseminating environmental data. SCOPE has also assumed the responsibility for initiating a major program for assessing water quality in the sea near the sites of nuclear power plants and for monitoring the water quality after the plants are built. Taiwan is building two nuclear power plants with two reactors each, in the northern part of the island; one-half of the first plant has been in operation since 1977. Fuel was loaded into the second plant in 1978, which will probably be licensed for commercial operation in 1980. Another plant for the southern tip of the island is planned.

Both the president of Academia Sinica and the chairman of the Atomic Energy Commission (A.E.C.) are deeply concerned about the ecological effects of the nuclear power plants, and a program of seaweed surveys, to begin three years before the opening of the southern plant, is jointly funded by the power company and the A.E.C. Initially, the program was planned to survey, and then to monitor, biological parameters, but economic factors, such as commercial fishery resources, have been added to the program. However, the fuel crisis has delayed the construction of the plant; scientifically this may be fortunate, because it has been concluded that three years are not enough time for a satisfactory baseline study–five or ten years would be more appropriate.

The baseline studies for the southern coast of the island were interrupted by a large oil spill from a tanker in February, 1977. This was turned to a scientific advantage by making a thorough survey of the effects of the spill and comparisons with the baseline conditions that had already been made. The nuclear power plant site presents potential biological problems. The cooling water will be discharged into a bay rich in coral reefs, and the effects of the increased temperature and the circulation of the warmed water is unknown. The oceanographic details of the bay, particularly the current pattern, are being studied in a cooperative program with the Institute of Oceanography of National Taiwan University.

Academia Sinica is involved with a variety of problems concerning the introduction of sewage, toxic elements and substances, wastes from agricultural practices, etc., into the rivers and the sea. Investigations have shown that, although the agricultural use of DDT in temperate climates presents serious hazards in the ecology, the dangers to the ecosystems of the tropics and subtropics is much less; biodegradation has been shown to be quite rapid in Taiwan.

The heavy metal levels in Taiwanese waters are generally much less than in U.S. waters, presumably because of the high rate of runoff in Taiwan. Arsenic is an exception, occurring naturally at high levels in Taiwan, levels that may lead to "block foot disease" in humans using water from deep wells; this has not been definitely established and the disease may be caused by various alkaloids.

A variety of industrial wastes are introduced into rivers emptying along the west coast of the island, and SCOPE oversees the research and monitoring activities on these rivers by other institutions in Taiwan. For example, a joint venture is proposed with a British petrochemical company to produce methacrylate. The synthesis uses large quantities of sulfuric acid, and it has been proposed to barge the waste material 10 km offshore and there disperse it in seawater. Although similar dumping into the North Sea was licensed by the British, SCOPE would not agree to such dumping (off the southwest coast), particularly because of the uncertainty about the effects on aquaculture. Initial results of studies, to see if the effects would be comparable to those in the North Sea, indicate that the practice may be acceptable, but long-range effects must be monitored.

A cooperative project for studying the nitrogen cycle in paddy soil is being carried out with Washington State University in Pullman, Washington. The objective is to determine nitrogen availability in paddy soils; lack of precise information has probably resulted in the wasting of much nitrogen fertilizer. Paddy soils become anoxic; rice plants can exist under such conditions because they have a system for transporting oxygen, formed photosynthetically in the leaves, down to the roots. However, bacterial processes in anoxic environments result in the reduction of nitrate and nitrite to free nitrogen and its consequent loss as a fertilizer. The first year of the study was concerned with how the nitrogen cycle is affected by the presence of rice residues. The project should last three to five years and is the only one of its kind in tropical or subtropical environments. Dumping of industrial, agricultural, and domestic wastes introduces both river pollution and stressed environments at ocean outfalls. Chin-Ti Li has begun a survey of the Taiwanese river systems–of which there are 121. Most of them flow into the sea along the west coast; the water quality varies from good to highly degraded, and the quality varies from time to time and from place to place. Of 36 rivers surveyed, only six were not polluted in some way. In many, the dissolved oxygen content is near or at zero for extended periods during the dry season. A comprehensive program of sampling the river basins and the industrial waste waters is under way.

Raw domestic sewage is generally disposed of through ocean outfalls. Seawater quality criteria have been established, but no such criteria have been set for effluents, and a working group has been established to do so.

Dr. F. C. Hung, who is also on the faculty of the Institute of Oceanography, National Taiwan University, is studying the ocean currents around the island and the effects of the physical and chemical oceanography on aquaculture, especially along the southern half of the west coast. Cultured organisms include oysters, prawns, fish, and the seaweed *Gracilaria* sp. Much of the aquaculture is carried out in brackish water, and some in ponds on lands reclaimed from the sea, which are highly suitable because of the high salinity of the soil. The ponds usually support a mixed aquaculture of milkfish, prawns, and *Gracilaria.*

The Taiwan government is sponsoring extensive research on aquaculture. The projects include basic research on species composition of populations, food chain studies, and studies of environmental factors. Important species include fish, abalone, and lobsters.

Dr. Hung, Dr. Su, and Jen-Leih Wu, also of Academia Sinica, are involved in the international mussel watch program. This program is aimed at worldwide pollution monitoring by the systematic sampling and analysis of mussel populations. Mussels were selected because of their practically ubiquitous occurrence and their proclivity for taking up various pollutants.

In Taiwan, the mussel watch is one of the activities of SCOPE. The program involves sampling and identification of the mussels followed by their analyses of heavy metals, radionuclides, hydrocarbons, and halogenated hydrocarbons. The first year's work concentrated on a sampling program. Samples must be collected from many places and should include healthy and unhealthy specimens of different ages and of both sexes. During the first year, three major sites, supposedly highly productive ones, were selected for sampling. Additional sites will be added later in the three-year program. A somewhat surprising early result of the mussel watch in Taiwan is the uniformly low heavy metal content of the animals, which Dr. Su attributes to their rapid growth rates and consequent short time to accumulate the metals.

The various institutes of Academia Sinica publish *Bulletins*, in either English or Chinese with abstracts in the other language. Some of the institutes issue *Annual Research Reports* in both languages.

The activities of SCOPE include several public service and educational projects. They arrange occasional broadcasts of panel discussions on environmental problems in Taiwan. They also have arranged for special activities during the World Environment days of 1978 and 1979; this included sponsoring the issue of special World Environment Day postage stamps and a children's poster contest, for which SCOPE provided prize money. SCOPE is now organizing a seminar on ecotoxicological problems in the Indo-Pacific Region, proposed to be held in Taipei in March, 1981. Inquiries regarding the seminar should be addressed to Dr. Jong-Chin Su, Institute of Zoology, Academia Sinica, Taipei, Taiwan 115.

Academia Sinica is beautifully sited in a southern suburb of Taipei, and the campus boasts modern, attractive, and well-kept buildings. Although my contacts were limited to the institutes of zoology and chemistry through their activities in SCOPE, I got the impression that the academy is a center of high-quality scholarship and learning, carrying on the ancient Chinese tradition of respect for learning and knowledge.

INSTITUTE OF OCEANOGRAPHY
NATIONAL TAIWAN UNIVERSITY

There are close ties between Academia Sinica and the Institute of Oceanography, maintained by common interests in the aquatic environment and cooperative research projects, by joint appointments of faculty members, and by shared laboratory equipment. Dr. Hung is a member of both faculties, and he and Dr. Su work very closely together on matters of concern to SCOPE.

The institute was formed in 1968 to teach, and to conduct research in, physical oceanography, marine chemistry, marine geology and geophysics, marine biology, and fishery biology. The institute offers masters'

degrees in marine biology and fisheries and will offer the doctor's degree in 1980. In 1979, there were over 40 students in the M. S. program. Both basic and applied research projects are undertaken. The budget from the National Science Council is in the neighborhood of U.S. $500,000, but more and more research is being funded by contracts from such organizations as the power company, the petroleum company, and the harbor administration. Basic research areas include:

- salinity-temperature-depth and wave studies around Taiwan;
- marine chemistry and pollution; the geology and geophysics of the Philippine Sea and areas adjacent to Taiwan;
- studies of marine sedimentation, geochemistry, paleontology, and hydrocarbon distribution of the region;
- the biology of coral reefs around southern Taiwan; and
- basic studies of tuna and demersal fisheries.

The institute has a faculty of 24 and a staff of around 41; the director is Professor Ju-Chin Chen, a geochemist. The institute is housed in an adequate and well-maintained building on the main campus of the university. The building houses a library, a number of laboratories, seminar and research rooms, and administrative offices.

MARINE BIOLOGY AND FISHERIES

Since 1970, Professor Hsi-Chiang Liu has been conducting a study of the population dynamics of the demersal fish resources of Taiwan; the main fishing grounds and regions of study are the East China, Yellow, and South China Seas and waters north of Australia. A preliminary estimate of the standing stocks and maximum sustainable catches for north Australian waters has been completed. Stock assessments are continuing, based largely on catch statistics from commercial fish landings. Mathematical modelling analysis of fluctuation and prediction of demersal fish resources is being developed. The work is in cooperation with the Taiwan Fisheries Research Institute, which operates a fisheries research vessel.

Professor Rong-Tszong Yang is concerned with the investigation of tuna fish resources and studies of the biology of coral reefs in Nanwan Bay at the southern tip of Taiwan. The Taiwanese tuna fishery earns about U.S. $20 million a year, mostly from albacore (sea chicken). The United States produces only 20-30% of its tuna demands, importing most of the remainder from Japan and Taiwan, Taiwan furnishing about one-half of the imports. The major fishery is on the high seas, but there is an important inshore fishery. In order to manage and improve this fishery, data are collected from local fishing operations to study size composition, sex ratio, gonad maturity, stomach contents, growth, morphometric characteristics, electrophoretic patterns of serum protein and muscle extracts, migration, distribution, and stock structure of the yellowfin and skipjack tunas around Taiwan. Summaries of the catch-effort data, including the high-sea longline fishery, are compiled, computer-processed, and published each year.

The coral reefs of Nanwan Bay are the most beautiful in Taiwan, but the bay is to be used to discharge cooling water from a proposed nuclear power plant. The power company has asked for a general survey of the bay to help preserve the biology. Bioassay studies of the effects of temperature on corals have been computed and published. A monitoring program designed to follow any changes in species composition and diversity indices of the population has been initiated.

One program in marine biology is associated with the development of OTEC (ocean thermal energy conversion). Major problems to be solved before OTEC becomes practical are fouling by marine organisms and corrosion of heat exchangers and piping. Biofouling is probably initiated by the formation of films on a surface by microbiological growth. Little is known of the physical and chemical properties of these films, but studies of them are being undertaken by W. L. Jeng. The emphasis will be on the properties of the film and their effects on subsequent settlement of organisms on, and corrosion of, the surfaces.

CHEMICAL OCEANOGRAPHY, GEOCHEMISTRY, AND POLLUTION

Dr. T.-C. Hung has a primary interest in the relationships between chlorophyll a concentrations and particulate and dissolved organic carbon in the seawater around Taiwan. This is closely related to the SCOPE study of the biogeochemical cycle of carbon. Hung is also concerned with marine pollution problems, of which Taiwan has many. The immediate objective of his program is to determine the distributions of heavy metals, hydrocarbons, phenolic compounds, nitrate, nitrite, phosphate and silicate in seawater, organisms, sediments, and interstitial waters around the island. No less important is to understand the effects of pollution on micro- and macro-organisms and entire ecosystems. Some of the projects carried out since 1971 include:

1. Studies of the pollution of Keelung Harbor.
2. Studies of the pollution of the coastal areas around Keelung. Garbage from Keelung city is dumped into the sea and the study included the effects of the practice on the ecosystem.
3. Similar studies of Kaohsiung Harbor. Kaohsiung is the second largest city in Taiwan and is an industrial center. Its position on the southwest coast is near the most important site for aquaculture.
4. Studies of the pollution of the shellfish cultivation areas of the west coast.
5. Pollution studies of the Linyuan coastal area. The study was concerned with petrochemical discharges in the area. The observations include the mineral composition of the sediments and suspended particles, heavy metals (Cd, Co, Cr, Cu, Mn, Ni, Pb, Zn, Fe_2O_3); suspended material and transparency; biological and chemical oxygen demands; nitrite, nitrate, phosphate, chlorphyll a primary production, assimilation numbers, sulfide concentrations; phenolic compounds; total oil; mercury, arsenic, copper, chromium, zinc, cobalt, and maganese in the water; total and fecal coliforms, zooplankton and phytoplankton counts.
6. The water pollution part of a pilot plant pollution control project.
7. Studies of the coastal environment near the Ta-Tu Chi (river) and its estuary. This is an important clam and oyster culture area. The study was carried out as part of the Sino-American Scientific Cooperative Program between the Institute of Oceanography, NTU, and the Institute of Marine Science, University of Alaska; Dr. D. C. Burrell of the latter organization has cooperated on the project.

PHYSICAL OCEANOGRAPHY AND OCEAN ENGINEERING

The institute has long been engaged in studying the physical oceanography of the waters around Taiwan. Much of the effort is now directed toward environmental studies for OTEC under the direction of Professor Nai-Kuang Liang. The effect of the Kuroshio on the waters around Taiwan is such that the mean sea-surface temperature east of the island is about 2°C higher than west of the island in the Taiwan Strait. In addition, the northeast monsoon winds and typhoons have an enhanced effect on the waves in the strait, making measurements in the strait difficult and costly. A project is underway to measure these waves using a self-contained wave meter and a submerged buoy system. Four such meters in the central part of the strait and a similar array across the southern part of the strait are proposed.

The eastern coast of the island has a more benign wave regime, warmer surface water, and a sharply steepening topography, making the east coast the site of choice for OTEC power development. Tides are being measured, using gauges imported from England, on the east coast and on Tal Tung and Lutau islands, and salinity-temperature-depth sections connecting these points are being collected. Currents near Lutao Island are being monitored, using an array of Aanderaa current meters. The studies are being funded by the Harbor Bureau and the power company.

An interesting part of the project has been the initial development of artificial upwelling induced by ocean currents. An apparatus consisting of several horizontal Venturi-type contraction and expansion tubes is planned for pumping water to near the sea surface from depths of 200-300 meters. Laboratory experiments have indicated that the system is sufficiently promising to warrant further development. The theory and experiment were described by Liang, and others in *Ocean Engineering*, 5, 83-94 (1978). The laboratory model was tested in the tow tank of the Institute of Naval Architecture. Field trials have been carried out with a one-half-meter diameter Venturi tube. A pilot plant model has been assembled on shore and floated to sea; problems were

encountered because only small fishing boats were available. Plans are being made to use the institute's research vessel for the project.

The development of artificial upwelling would be a contribution not only to the OTEC program, but, also, it should be useful in elevating cooler nutrient-rich water into the surface areas where cooling waters from nuclear power plants are being introduced.

MARINE GEOLOGY AND GEOPHYSICS

The major objective of the marine geophysics program is to define and relate the major tectonic elements that have formed the present structures of Taiwan. These elements include the surrounding continental shelf, the Ryukyu and Philippine island arcs and trenches, and the Philippine and South China seas.

Dr. C. T. Shyu is working on the magnetic and gravity anomalies around Taiwan. Although the institute has no gravimeter, data are available from previous geophysical cruises in the area. Shyu is interested in geothermal processes, which he has studied in the Imperial Valley, U.S., and in Turkey, and wants to build up a heat-flow system for the institute so that he can apply his model of heat-flow to areas around Taiwan and in the Philippine Sea.

Associate Professor M. P. Chen, a graduate of Texas A & M University, is a specialist in nannofossils and is studying the distribution of coccolithophores in the sediments of the Taiwan offshore area. The principal objective is to understand the pattern of dispersion of suspended materials discharged by the rivers. To do this, he determines the ratio of redeposited nannofossils to total nannofossils in the sediments. The study is intended to aid in understanding the fate of material introduced by the rivers, which becomes more and more important as pollution increases. Nannofossils are good fossils for reconstructing stratography; and to help evaluate the distributions off Taiwan, Chen has made a study of sedimentation rates in the Philippine Sea, a nearby example of a stable region.

Other sedimentological studies of the Okinawa trench include size and carbonate distribution determinations aimed at understanding the paleoenvironment. The size and carbonate contents differ in the nearshore, Kuroshio, and pelagic parts of the trench, with less than 5% carbonates in the nearshore area, 5-10% under the Kuroshio, and up to 42% in the pelagic sediments, which are high in coccoliths and foraminifera.

Other geological studies, sponsored by the China Petroleum Corporation, are being conducted in Shinchu Strait, a possible site for oil drilling. Various properties of the sediments, including shear strength, clay mineral content, and the water content, are determined on both piston and box core samples.

Studies of the oxygen-18 to oxygen-16 ratios in foraminifera and coccoliths for the determination of paleotemperatures in the south China Sea are proposed. A mass-ratio spectrometer is being purchased to use in this study and in studies of geothermal waters in Taiwan.

Associate Professor W. L. Jeng is working on the marine geochemistry, specifically the hdyrocarbons, of the sediments of the Taiwan Straits. He is investigating the distribution of normal alkanes in the region, and determining their CPI, carbon preference index, to establish the contribution of organic matter from land. In land plants, normal alkanes containing 25, 27, 29, and 31 carbon chains predominate. The index is formulated

$$CPI = \frac{1}{2}\left(\frac{C_{25} + C_{27} + C_{29} + C_{31}}{C_{24} + C_{26} + C_{28} + C_{30}} + \frac{C_{25} + C_{27} + C_{29} + C_{31}}{C_{26} + C_{28} + C_{30} + C_{32}}\right).$$

Values of the CPI of 3-6 are observed in estuaries, and values of 1.7-2 in the Taiwan strait indicate that the terrigenous contribution to the sediment is not very great.

The director of the institute, Professor Ju-Chin Chen, is studying the distribution of heavy metals in sediments and volcanic rock off the islands of Luta and Lantsu. He is also studying basaltic rocks from the Philippine Sea supplied by the Deep Sea Drilling Project (DSDP).

LABORATORY EQUIPMENT

The institute has a large variety of good equipment for analysis of samples. Included are:

1. Perkin-Elmer 703 atomic absorption spectrophotometer with tubes for the determination of Zn, Cu, Pb, Cr, Fe, Mg, Mn, Al, Co, Cd, Si, Ti, Zr, Ga, Au, Ag, Ni, Na, and K. It is used primarily for analyses of sediments and interstitial water.
2. Shimadzu gas chromatograph with flame ionization detector, used for hydrocarbon determinations. There is also access to a gas chromatograph equipped with flame ionization and thermal conductivity detectors in Academia Sinica and to one in the laboratory of Dr. Y. L. Chen, at the Institute of Agricultural Chemistry, NTU, equipped with an electron capture detector. The latter is used for determination of PCBs (polychlorinated biphenyls).
3. Anodic stripping voltammetry for the determination of lead, copper, and cadmium in seawater.
4. Three Australian-made induction salinometers, two used on their research vessel and one used in the laboratory.
5. A model MPS50L Shimadzu multipurpose-recording spectrophotometer, good in the range 200-2500 nanometers. It is used for determining phenolic compounds and for analyzing nutrients. A fluorometer can be attached to it for chlorophyll determination, as can a Wang data processor.
6. Perkin-Elmer Coleman 50 cold-vapor mercury analyzer.
7. Viscometer.
8. Insonorator, used to break up phytoplankton for pigment analyses.
9. Oceanography International total-organic carbon analyzer for total and dissolved organic carbon.
10. Nuclear-Chicago gas-flow radiation counter for determining primary productivity by the carbon-14 method.

RESEARCH VESSEL *CHIU LIEN*

The *Chiu Lien* is a former USN tug converted to accommodate 26 crew members and 15 scientists for extended cruises. She has three laboratories, one for electronics, one for chemistry, and one for physics and biology. Length is 143 feet; beam, 33 feet; displacement, 900 tons; and speed, 12.5 knots. Equipment includes a seismic reflection profiling system with air-gun and sparker sound sources, magnetometer, satellite navigation, salinity-temperature-depth (STD) system, salino-thermograph, deep-sea and hydrographic winches, geomagnetic electrokinetograph (GEK), precision depth reader (PDR), fish finder, pyrheliometer, submarine photometer, bottom camera with stroboscopic light, salinometer, and various water, bottom, and plankton samples. Because of the bad weather during the northeast monsoon in winter and typhoon season in summer, the ship can be operated only about 120 days a year.

PUBLICATIONS

The institute publishes *Acta Oceanographica Taiwanica, Science Reports of the National Taiwan University* in English. No. 9 was published in February, 1979, in commemoration of the retirement of Professor Tsu-You Chu. There is also a *Special Publications of the Institute of Oceanography* series. These are generally reports of special projects, contain substantial data reports, and may be in either Chinese or English.

FACULTY

Prof. (emeritus) Tsu-You Chu	Physical Oceanography
Prof. Ju-Chin Chen, Director	Marine Geochemistry
Prof. Rong-Tszung Yang	Fishery Biology

Prof. Hsi-Chiang Liu	Fishery Biology
Prof. Young-Meng Chiang	Marine Botany
Prof. Tsu-Chang Hung	Marine Chemistry
Prof. Nai-Kuang Liang	Physical Oceanography
Adjunct Prof. L. W. Tang	Coastal Engineering
Adjunct Prof. Kun-Hsiung Chang	Marine Botany
Adjunct Prof. M. T. Hsu	Physical Oceanography
Adjunct Prof. Y. S. Pan	Geophysics
Adjunct Prof. I. C. Liao	Marine Biology
Associate Prof. M. P. Chen	Geophysics
Associate Prof. W. L. Jeng	Marine Geochemistry
Associate Prof. K. L. Feng	Physical Oceanography
Adjunct Associate Prof. C. C. Liu	Geophysical Prospecting
Adjunct Associate Prof. N. C. Yao	Physical Oceanography
Dr. C. T. Shyu	Marine Geophysics

RESERVOIRS FROM THE SEA: HONG KONG'S ANSWER TO ITS WATER SUPPLY DEMANDS

H. J. Walker

"With its enormous population growth, more and more of Hong Kong's shoreline is being lost to development of various kinds . . ." This statement by Francis A. Richards in his article "Marine Sciences in Hong Kong" (*Scientific Bulletin*, Vol. 4, No. 3) is relevant to Hong Kong's water supply in at least two ways. First, Hong Kong's rapidly expanding population places continually increasing demands on its water supply system, demands that are acerbated by the Colony's industrial, commercial, and residential development. Second, given Hong Kong's position, size, shape, relief, and subsurface rock types, engineers charged with meeting water supply needs have turned to the creation of "reservoirs from the sea." Of course, such reservoirs can be formed only at the expense of coastal bays, straits, estuaries, and their shorelines.

BACKGROUND

POPULATION

Hong Kong, with a land area of only 1,052 km^2, today is one of the most densely populated places on earth. Such has not always been the case. It is mountainous, has relatively little fertile land and water, and was described in 1841—the year it became a British Colony—as "a barren island with hardly a house upon it." However, it did have a good harbor and, almost from the beginning, became a focal point along the coast of China for trade. Although Hong Kong (the Colony) consisted, in 1841, of only Hong Kong (the Island), the Colony enlarged in 1860 by addition of another small island and the Kowloon Peninsula. In 1898, the Colony expanded again through the leasing of part of the mainland and some 234 islands for 99 years, a lease that is approaching its termination.

The population of Hong Kong began to grow almost as soon as it was established. It increased from a population of about 1500 in 1841 to over 300,000 (96% Chinese) within 10 years. Rapid growth was typical although occasional reversals occurred from time to time. For example, World War II and occupation by the Japanese brought a population decline as Chinese residents fled. However, after the Armistice, many of those same Chinese returned, usually with friends and relatives in tow. The return rate was so rapid that the population increased from an estimated 600,000 in August, 1945, to more than 2,300,000 by the end of 1950. Growth continued and today the population is very nearly 5,000,000; about 98% are Chinese.

Such rapid population changes place serious strains on educational and health services, housing, communications, transportation, and public works and utilities, not the least important of which is water supply.

NATURE: A RESTRICTING FACTOR

Hong Kong, located at the edge of an eroding mountain chain in coastal China, consists of 237 islands and islets and a small, serrated portion of mainland (Fig. 1). This combination results in an exceptionally long and highly varied coastline and detached areas of limited flatland. It is composed primarily of folded and metamorphosed volcanic and sedimentary rocks, the crystalline nature of which limits quantities of water. Further, the lack of any sizable rivers or lakes means that natural surface storage is also minimal.

Despite the fact that Colony lies within the tropics, rainfall is highly seasonal and somewhat erratic.

Although the average of 2,250 mm/year is quite high, about 80% of it is concentrated between May and September. June, with an average of 457 mm, has the highest total. About half of the annual rainfall occurs with tropical cyclones, many of which cause severe flooding and loss of water, water that might otherwise be captured and become part of Hong Kong's water supply. High variability has resulted in chronic water shortages, which, in turn, have frequently necessitated water rationing. It is generally considered that rationing has to be initiated when the annual rainfall drops below 1500 mm.

WATER SUPPLY

A BRIEF HISTORY

By 1851 (only ten years after becoming a colony) Hong Kong had already begun its long uphill battle over water. In that year, five wells were dug--wells that were satisfactory only when there was sufficient rainfall to maintain a high water-table. Unreliability led to the construction of Hong Kong' first reservoir in 1859, a reservoir that was capable of holding about 8000 m^3 of water. Unfortunately, the poorly constructed dam collapsed six years later. A replacement reservoir, with 33 times the capacity, was constructed in 1871. By 1941, when the colony reached its 100th anniversary, another 12 reservoirs had been built, increasing total capacity to about 25 million m^3.

Although most of these reservoirs were located on the island of Hong Kong, they were small and could not meet the island's demand. In 1931, cross-harbor submarine pipelines were laid between Kowloon and Hong Kong in order to alleviate the water problem by providing service directly from the mainland. After World War II, reservoir construction was renewed, utilizing watersheds on the other large islands (such as Lantau) and in the mountainous parts of the New Territories. Such construction rapidly utilized all of the feasible high-level storage basins.

A MULTITUDE OF SOURCES

Whereas high-level surface storage has been the mainstay of the water supply in Hong Kong during most of its history, it seldom has been able to meet demand. Thus, Hong Kong has attempted and utilized several other means of coping with the problem. One procedure is the use of sea water for such functions as toilet flushing, fire fighting, and street washing. During the three years from 1976-78, an average of 75×10^6 m^3 of salt water (equal to about 16% of the total) was used. Another partial solution has been the purchase of fresh water from China. In 1960 an agreement was worked out with the Chinese government for water to be piped from the Sham Chun Reservoir. A large pipeline from the reservoir (Fig. 1) now carries water to Hong Kong. In 1978, 144×10^6 m^3 of water was piped from China. China has also furnished water, by barge and tanker, on at least three occasions. During the drought years of 1903, 1930, and 1964, water was brought from the Pearl River estuary. In 1964, much of S.E. Asia suffered a severe drought. The supply by pipeline from the Sham Chun Reservoir was inadequate and nearly all reservoirs in the Colony were dry. During that water year, consumption was very restricted (Fig. 2)--not one day with a full supply. Nearly 10×10^6 m^3 was shipped by tanker from the Pearl River.

Hong Kong, as mentioned above, uses salt water directly for various purposes. However, it was not until 1975 that it began the conversion of salt water to fresh water. Although the first land-based desalination plant was constructed in Egypt by the British in 1912, and although Hong Kong has a generous quantity of salt water around its lengthly shore, it was not until 1971 that the Government decided to build a large-scale desalter. Desalination had been considered before, both prior to and after the war, but had never been implemented because of cost. In fact, in 1965, the Hydraulics Research Station, Wallingford, England, had made a model study of the effect the dumping of hot water from a desalination plant would have on circulation in Victoria Harbor (Fig. 1).

The plant was constructed at Lok On Pai (Fig. 1), a point located on the Pearl River side of the New Territories. The fresh water from the Pearl River, especially during the rainy season, extends sufficiently far into

the South China Sea to reduce the salinity of coastal waters along this part of the mainland. The desalter, a multi-stage flash type, is capable of producing 181,000 m^3/day of fresh water. It replaced the 114,000 m^3/day desalter in Kuwait as the world's largest. The fresh water produced in Hong Kong's desalter is chemically treated and pumped into the Tai Lam Chung reservoir located about 3 km from the plant. At the dedication ceremony in 1974, the Governor of Hong Kong stated that "It is an immense relief to have this new source of supply, equal to about one-fifth of fully daily consumption, which is independent of rainfall." The desalination plant, considered as an auxiliary source, is operated only during times of unfavorable reservoir storage. In June 1978, it ceased operation and according to the "Hong Kong 1979" yearbook, "planned maintenance commenced and detailed feasibility studies into 'mothballing' the plant were in hand."

RESERVOIRS FROM THE SEA

Late in the 1950s, while Hong Kong's Public Work's Department was examining possible ways of increasing supply, "the idea of converting sea inlets into fresh-water reservoirs by damming the inlet, pumping out the sea, and replacing it with fresh water" was proposed. Once proposed, possible sites were selected and consulting engineers began their investigation. The first of these "reservoirs from the sea" to be constructed in Hong Kong (and in the world, for that matter), was at Plover Cove (Fig. 1). Because it was such a demanding undertaking, engineering contracts over the eight-year construction period were handled by French, Swedish, Japanese, and local Hong Kong firms. The work force was even more international; it also included Americans, Australians, Dutch, Germans, and Norwegians. Model tests were conducted at the Hydraulics Research Laboratory in England, in the early 1960s, in order to find a practical way of closing the dam, to determine the velocity patterns that would occur at various stages of closure, and to examine the dropshafts that would lead water from the small catchment basins scattered throughout the drainage area to the large reservoir.

Work, which began in November 1960, was not completed until December 1968, although the first water from the reservoir was furnished the supply system in 1967. The conversion of Plover Cove inlet into a reservoir required construction of a main dam, two subsidiary dams, and a spillway. In the construction, the large quantity of sand and stone used was quarried from several sites. One of the two largest "borrow" areas became the site for the Chinese University of Hong Kong (see the Richards article). Early in 1967, the dam was closed and the sea water trapped behind it pumped out. Impounding of fresh water was begun in June. Within four months the reservoir had almost 50×10^6 m^3 of water. The reservoir, when filled to capacity, is 5½ km long, has an area of 12.1 km^2, and will hold 233×10^6 m^3 of water, an amount that was triple Hong Kong's water storage capacity at the time.

Plover Cove proved so successful that the Public Work Department's engineers decided to emulate what they called "the world's first attempt to carve a freshwater reservoir out of the sea," by constructing another, even larger, reservoir. This time, instead of enclosing a bay, they selected the strait that separated High Island from the mainland (Fig. 3). Construction was somewhat different than in the case of Plover Cove, mainly because of the sedimentary history of the strait. Riverine and marine sediments had accumulated to depths up to 45 m in the strait, sediments that had to be removed before dam construction. Two cofferdams were needed at each end of the strait—one to keep channel water in, the other to keep seawater out, during construction of the main dams. Three of these cofferdams were considered as temporary. The fourth, the eastern seaside cofferdam, was constructed for permanency. After its service as a barrier for the sea during the main dam construction period, it was retained to serve as a buffer from the high seas that are generated by tropical cyclones in the South China Sea. Its seaward face is covered with nearly 7,000 armor units of the dolos variety. Shaped like and H with one arm twisted through 90 degrees, each dolos weighs 25 metric tons. The inside of the dam is armored by concrete "Svee" blocks which protect the inside of the dam in the event waves overtop the structure.

Although the main dams are not so spectacular in appearance as the east cofferdam, they required more than three times as much rock fill. Rising 66 m above sea level, these dams provide a basin that is 5.6 km long and has an area of 6.9 km^2. Although about three-fourths full at the time I visited in September, 1979, its projected capacity is 278×10^6 m^3.

CONCLUSIONS

To date in Hong Kong, over 25 km of seashore is now submerged beneath fresh water in two reservoirs–Plover Cove and High Island. It should be kept in mind, however, that the main change has been the exchange of one type of interface for another–from land and seawater, with its special energy and biologic systems, to land and fresh water, with quite different systems. Indeed, the fresh-water shoreline is longer by at least one-half than the original coastline. The new shoreline has a major potential as a recreational area, although at present access is restricted.

These reservoirs from the sea are but one way in which Hong Kong has modified its coastline, an implication that follows from Richards' statement quoted above. Lack of suitable building land has led to the filling or partial filling of a number of bays such as those at Sha Tin, Tuen Mun, and Tsuen Wan (the straight shoreline resulting from fill at these three locations can be seen even on the small scale map of Fig. 1). Such fill has provided space for industry, commerce, residential buildings, airport runways, recreation facilities including race tracks, and many others. In all, over the years, Hong Kong has reclaimed about 40 km^2 of its coastal waters, nearly half (i.e., 19 km^2) of which is occupied now by fresh water in its two major reservoirs.

With the completion of the High Island Reservoir, Hong Kong now has storage capacity of nearly 600×10^6 m^3 of fresh water, an amount considered to be adequate well into the 1980s. Nonetheless, the members of the Water Supplies Department are continuing their investigations into other possible sources such as alternative desalting processes, development of new catchment areas in the more remote areas of the colony, the recycling of waste water, and the addition of other reservoirs from the sea.

It was predicted in 1977, at the first United Nations Conference on Water, that water shortage will replace energy at the top of the world's crisis table by the year 2000. If such should prove to be the case, the knowledge gained in Hong Kong in meeting ever-increasing water demands will prove to be of value to the engineers in other countries. Certainly the conversion of bays into fresh water reservoirs is feasible at many locations around the world. Indeed, in England it has been discussed frequently during the last two decades as a viable solution to some of its own water-supply problems; it has yet to be implemented, however.

ACKNOWLEDGMENTS AND SUGGESTED READING

During a four-day visit to Hong Kong in September, 1979, Dr. C. L. So, a physical geographer at the University of Hong Kong, who is a specialist on the coastline of Hong Kong, was my host. We spent three days in the field examing much of the shoreline of the island of Hong Kong and of the mainland portion of the New Territories. On one day, Dr. Lai Hon-Wah, a hydraulic engineer, took Dr. So and myself on a tour of the High Island Reservoir and its catchment basin. Included were discussions with some of the Colony's engineers and the Reservoir's maintenance personnel.

The Water Supplies Department has produced, and the Government Printer, Hong Kong, has issued, a series of relatively detailed and well-executed booklets on their various water projects. Three of those pertinent to anyone interested in Hong Kong and its water supply are entitled *Plover Cove*, *Lok On Pai Desalting Plant*, and *High Island*. In addition, an informative and reasonable priced ($18.00 Hong Kong or about $3.50 U.S.) book is *Hong Kong 1979*. It has 301 pages with many full-page color photos and can be obtained from the Government Publications Centre, GPO Building, Connaught Place, Hong Kong.

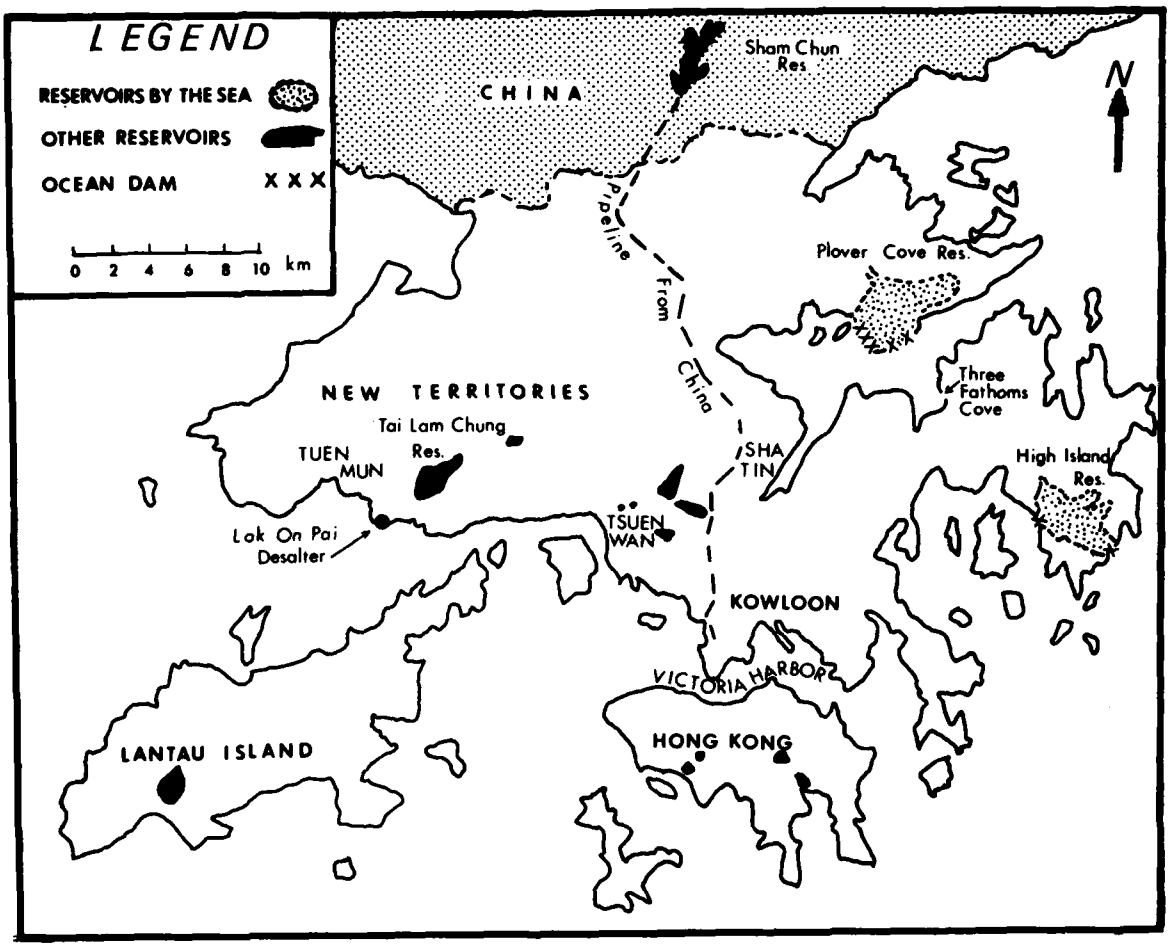

Figure 1. Map of Hong Kong showing the major water systems.

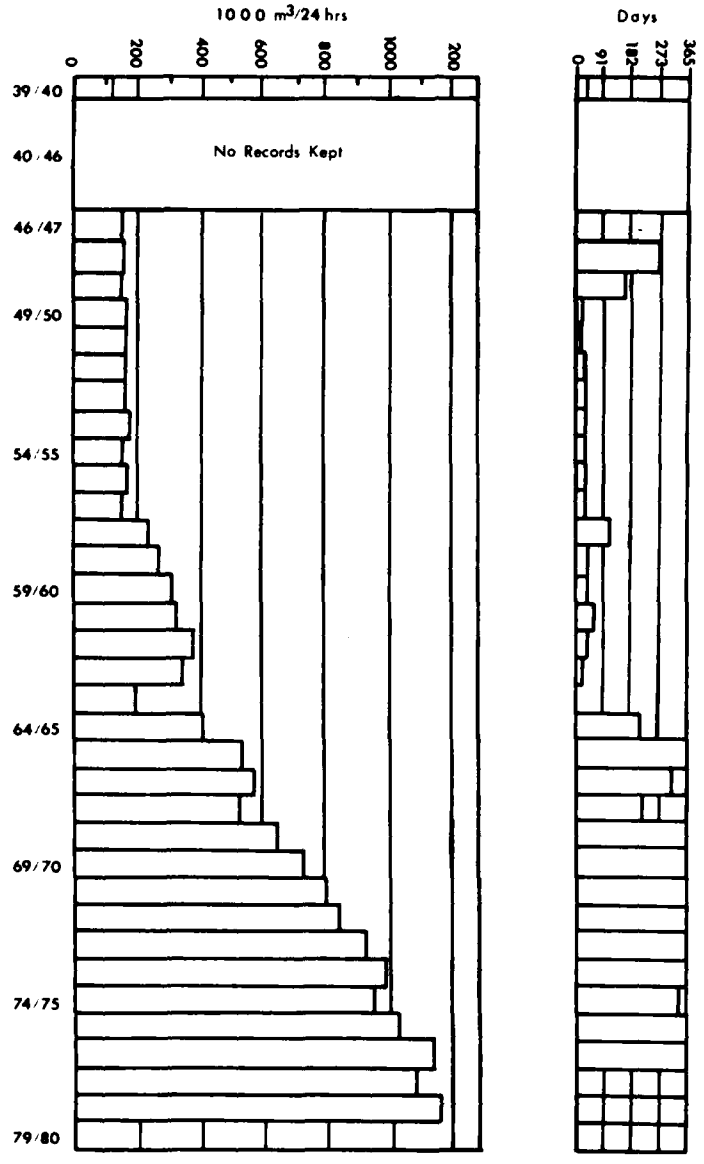

Figure 2

Mean daily consumption of water in Hong Kong by water years (1 April–31 March). Note the low value of the water year 63-64.

Days of full supply of water by water year. No data available for water years 77-78 to present.

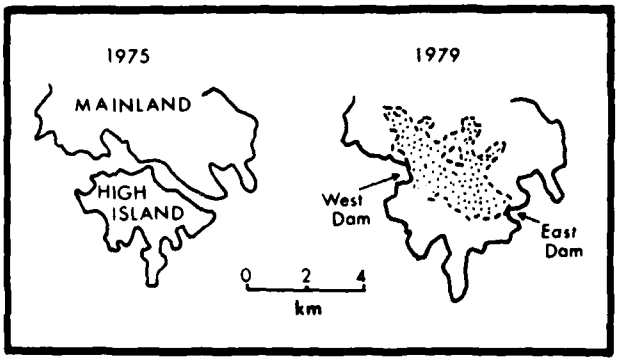

Figure 3. The shorelines of the High Island area before and after construction of the High Island "Reservoir from the Sea."

NORDENSKIÖLD AND SCIENCE IN JAPAN

H. J. Walker

On Monday, 19 November 1979, a number of distinguished scientists and laypeople assembled at the Tokyo Geographical Society Building in Shinjuku-ku, Tokyo. The occasion was the opening session of the centenial celebration of A. E. Nordenskiöld's transit of the Northeast Passage. The reader can hardly be faulted if he asks why Japan celebrated an expedition that was conducted under Swedish auspices 100 years ago? The relationship between this voyage and Japan is not generally known and its important to Japanese science appears to be little appreciated.

Despite the fact that Japan has a very long history, it was not until the Meiji restoration of 1868 that it began to modernize. Thus, the new era was only 11 years old when Nordenskiöld visited Japan following 12 months in the Arctic. Things Western had already begun to be introduced and accepted, a new educational system had been inaugurated in 1872, and scientific endeavors were beginning to receive encouragement from forward-looking politicians. However, and not surprisingly so, progress along such lines was slow. Cultural heritage made acceptance difficult and much reluctance still remained–reluctance that probably was more the result of a fear of change, and of something new and different, than for any other reasons.

NORDENSKIÖLD: HIS VOYAGE AND VISIT TO JAPAN

A. E. Nordenskiöld, born in Finland in 1832, studied mineralogy, chemistry, and physics at the University of Helsinki. In 1857, he moved to Stockholm and within a year began a period of exploration and research in the Arctic that spanned 25 years. Expeditions took him to Spitsbergen and Greenland and involved such diverse types of research as an investigation of the flattening of the poles and the advantage of sled dogs over Lapland reindeer in polar work. However, his most noteworthy endeavors were devoted to the problem of the opening up the Northeast Passage. Unlike most scientists in the middle of the 19th Century, Nordenskiöld believed that the passage could be used as a regular trade route. Despite this conviction, he proceeded with caution and made two reconnoitering trips as far as the Yenisei River before attacking the entire route.

Nordenskiöld, with 30 crew members, sailed from Tromsö, Sweden, on 21 July 1878 in the steamship "Vega." Although hampered some by fog, he made good time and had a relatively easy voyage until reaching within about 200 km of Bering Strait. Stopped by ice in late September, the crew wintered over. Time was not wasted, however, because Nordenskiöld continued scientific observations throughout the period of confinement.

The ice began to break up in mid-July, 1879, and the voyage was renewed under steam on 18 July. Two days later, the ship sailed between "Old and New Worlds" and achieved the passage that had been attempted many times during the previous 300 years, but without success. The significance of the event is reflected in Nordenskiöld's statement that the passage was achieved "... without the sacrifice of a single human life, without sickness among those who took part in the undertaking, without the slightest damage to the vessel, and under circumstances which show that the same thing may be done again in most, perhaps in all, years in the course of a few weeks."

Nordenskiöld reached Yokohama on 2 September 1879 and immediately telegraphed the King of Sweden, Oscar II, about the successful transit. The news spread rapidly and when he returned to Sweden in February 1880, he was awarded the title of Baron.

Nordenskiöld's visit was an opportune one from the standpoint of Japanese science. Scientific societies, which did not exist prior to the Meiji restoration, began to be formed. One of the earliest, if not the first, is the Tokyo Geographical Society (TGS). It was founded in March, 1879, at the time Nordenskiold was wintering over north of Siberia. Most of the approximately 100 original members of the TGS were influential politicians and wealthy merchants; only a few were scholars. It was on 25 August that the Society first learned of Nordenskiöld's success and that it was to be a welcoming body.

Nordenskiöld was the first distinguished scientist to visit Japan in the new era; he was well received and attracted much attention. The Society, in cooperation with the Asiatic Society of Japan and the Germanic Asiatic Society, held a reception on 15 September, a reception that was attended by over 130 people. Two Japanese princes and the Japanese Ministers of Finance, Foreign Affairs, and Navy, attended, as did a number of foreigners, including some from the United States and Russia. Nordenskiold wrote that "Several Japanese ladies, dressed in European style, took part in the entertainment." Every guest was presented a fan with a map of the course of the "Vega" drawn on it. In Nordenskiöld's address of thanks, he urged the Prince to mount an expedition under the Society's auspices to reverse his track and be the first to sail the Northeast Passage in a westerly direction. The attempt, however, was not made. A few days later Prince Kitashirakawa, president of the TGS, presented Nordenskiöld with a large (9.5 cm in diameter) gold medallion.

Nordenskiöld visited many cities such as Kobe, Kyoto, and Nagasaki, in addition to Yokohama and Tokyo. He used much of his nearly two months in Japan in the collection of prints, maps, atlases, and books. He wrote that he concentrated on those that "were printed before the opening of the ports to Europeans." They numbered more than 6000 items and are now housed in the Royal Library in Stockholm. Nordenskiold's collection—which includes items from his other stops as well (Shanghai for example)—served as the basis for his two famous historical atlases. Before his departure from Nagasaki for China, he was given a "grand parting feast, at which speeches were spoken in Japanese, Chinese, English, French, German, Italian, Dutch, Russian, Danish, and Swedish, a proof of the mixture of nationalities which prevailed there, . . ." Returning to Sweden via the Suez Canal, he became the first to circumnavigate Eurasia.

ONE HUNDRED YEARS LATER: A SYMPOSIUM

The "Japanese-Swedish Joint Symposium for the Centennial Celebration of Nordenskiöld's Expedition in the Arctic" was held 19-24 November 1979 in Tokyo, under the sponsorship of the TGS, the Association of Japanese Geographers (AJG), and the Swedish Society for Anthropology and Geography. The Symposium was a multi-faceted affair and included commemoration addresses, scientific lectures, popular speeches, motion pictures, an excursion to Hokkaido, and an exhibition. The delegation from Sweden was a distinguished group of arctic specialists. Professor Gunnar Hoppe, resident, Royal Swedish Academy of Sciences, headed a group that included Professor Valter Schytt, member of the Swedish Natural Research Council, and Professor Erik Bylund, Umeå University.

The opening session, attended by an estimated 75 invited guests, was devoted to welcoming addresses by Professor Seitaro Tsuboi, president, TGS; the Honorable Bengt Odevall, Ambassador, Royal Swedish Embassy; and Professor Kiyoo Wadati, president, Japan Academy of Sciences. Commemoration lectures were given by Taiji Yazawa and Valter Schytt. Yazawa, president of the AJG, noted that it was probably the impetus given the then newly-founded TGS by Nordenskiold that was mainly responsible for its being able to also celebrate its own centennial.

The scientific portion of the celebration included eight lectures, four each by Swedes and Japanese. Gunnar Hoppe, who is also chairman of the Swedish Remote Sensing Committee, provided information about remote sensing in high latitudes. He noted that, in Sweden, priority in remote sensing research is given to oil spill surveillance, sea ice mapping, vegetation mapping, and analysis of effluents from industrial smokestacks. All of these types of remote sensing research are of significance to the Japanese, although the value of their use in sea

ice mapping in Japan proper is limited to Northern Hokkaido. Remote sensing is also of great value to those Japanese who are working in Antarctic waters.

Professor Seiiti Kinosita (Hokkaido University) reported on his studies of those landforms typical of the permafrost regions of Yakutia (Siberia) and the North Slope (Alaska). Although distinct forms are not developing in Japan today, he noted that Hokkaido does have fossil permafrost and related surface forms.

Two lectures were given about arctic peoples. One was by Professor Bylund on the Lapps; the other by Assistant Professor Tsuyoshi Fujimoto (University of Tokyo) on the "Pre-Ainu and the Satsumon Culture." The report on the Lapps was mainly ethnographic; that on the pre-Ainu archaeologic.

During the public session, the lectures were of the popular variety. Included was one by Professor Yoshio Yoshida, Japanese National Institute of Polar Research, who discussed the polar research of Dr. Schytt. Two movies were also shown: one about Antarctica, the other on the handicrafts of the Lapps.

One of the highlights of the celebration was the exhibition held at the TGS on 19-20 November. On display were many priceless items brought from Sweden, including atlases, maps, manuscripts, and the fan and medallion that had been presented Nordenskiöld 100 years ago.

SIGNIFICANCE AND RELEVANCE

There is little doubt but that Nordenskiöld's visit in 1879 was a major stimulus in Japan's first steps toward the development of a modern outlook. The visit not only influenced politicians, businessmen, and scholars but, also, it attracted the attention of laypeople. It provided the first concrete chance for the Japanese to deal with a highly respected scientist with world-wide acclaim and, despite much trepidation, they came through with appropriate and appreciated actions.

Although this first venture at high-level scientific contact did not lead the Japanese to attempt a reverse voyage as Nordenskiöld proposed, it did prompt Japanese science to send representatives to foreign meetings. Also, it has been responsible for some scientific cooperation between Sweden and Japan, cooperation that has been strengthened in recent years. According to one account, this strengthening has come about as the "time-distance between Japan and Sweden has shortened and as the knowledge of geography and mineralogy, Nordenskiöld's main fields of study, has developed." Examples of recent developments are: 1) establishment of The Japanese Institute for Social Studies on Sweden, an Institute that publishes a *Bulletin* which is now in its 12th year, and 2) frequent visits by Swedish scientists at the invitation of the TGS. These visitors, who present lectures around Japan, have included the likes of Professor Åke Sundborg, the famous alluvial morphologist of the University of Uppsala, three years ago.

Although there is no way in which the centennial celebration of Nordenskiöld's visit to Japan can have the impact on science the original visit had, it will serve to further strengthen contacts between the scientists of the two countries.

UNIVERSITY OF GUAM

Rudolph J. Marcus

The University of Guam is the only baccalaureate level institution in the Territory of Guam and the surrounding Trust Territory of the Pacific. The latter covers a wide reach of island chains, including the Marianas, Carolines, and the Marshall Islands. Because of the vast area covered, the political and social changes occurring in the islands, and their strategic value, there is a large amount of field work which is being done by faculty and students. Some of this research is supported by grants, and some field work is being done on a contract basis.

The University of Guam is fully accredited and has over 2000 undergraduates. Master's degrees are offered in biology, which also has the largest number of science majors, and in the Marine Laboratory. In the sciences, there are departments of biology, mathematics, and chemistry and physics. The latter graduates about three majors a year, most of whom find professional employment locally. Employers include the Territorial Crime Laboratory, Water Resources Board, and various environmental control agencies, a list which is familiar from chemistry employment in Asian countries reported on in the previous issue of the *Bulletin*.

There are some faculty members who do publishable research, whether it is supported or not. Dr. Oscer Levand of the Chemistry and Physics Department is examining nitrogen fixation in *Leuceana leucocephala*, a forage plant which lines the roads on Guam and is locally known as "tangan-tangan." Levand's work began with the observation that ground water, where tangan-tangan is grown, is rich in nitrates. In an earlier publication, Levand reported the isolation of asperuloside, as well as caproic and caprylic acids, from the fruit of *Morinda citrifolia*, a tree called "noni" in Hawaii and "lada" in Guam.

Dr. Daniel B. Matlack of the Biology Department is doing chlorine analyses in the part-per-million range, using the LD_{50} of several organisms as indicator. Dr. Douglas R. Smith is a bryologist who has described extensively the mosses of Micronesia. Like many other faculty members, Smith is interested in energy conversion and has measured wind velocities at the top of Mt. Jummulong-Menglo in order to examine its suitability as a site for a wind-generated power installation. Sustained wind velocities there are in excess of 10 mph, 67% of the time.

MARINE LABORATORY

The Marine Laboratory has seven faculty members and five support personnel, who are housed in a two-story building at the shoreline of Pago Bay. It has no ships of its own, but has two boats with outboard motors and uses Government or Navy ships occasionally. As mentioned previously, the Laboratory offers the M.S. Degree. The directorship of the Laboratory rotates; the current director is Dr. Charles H. Birkeland, who has his Ph.D. from the University of Washington and is interested in community ecology and species interactions. As a result of my visit, he has been put in touch with Continental American researchers having similar interests in the same geographical area.

Mr. Richard H. Randall, the only faculty member with an M.S. degree from the University of Guam, is an expert on coral ecology and taxonomy; his laboratory is lined floor-to-ceiling with coral samples. His M.S. thesis dealt with local reef corals before, during, and after the crown-of-thorns starfish (*Acanthaster planei*) predation. His current opinion is that crown-of-thorns infestation is a cyclic phenomenon which cannot be controlled because the starfish reproductive cycle occurs at depths not accessible by diving. Because of his intimate knowledge of coral reef ecology, Randall has done a lot of site surveys for dredging, docks, outfalls, etc. His

latest project is an "Atlas of the Reefs and Beaches of Guam," published with Dr. Lucius G. Eldiedge in 1976 and available from the authors. A similar atlas has been prepared by these authors for Saipan, under sponsorship of the Commonwealth of Northern Marianas (the name under which Saipan, Rota, and Tinian, now part of the Trust Territory of the Pacific, will become an incorporated territory of the United States in 1981).

Other staff members of the Marine Laboratory and their specialties are:

– Dr. Steven S. Ameshury	Ichtothyology, population biology
– Dr. James A. Marsh, Jr.	Primary productivity, energy and nutrient flow
– Dr. Stephen G. Nelson	Aquaculture, energetics
– Dr. Gerrat J. Vermeij	Marine biogeography and evolution.

The Marine Laboratory publishes a journal, *Micronesica*, contributions to which are mainly from off-island authors and are refereed by off-island reviewers. A list of individual publications, technical reports, environmental reports, miscellaneous reports, and M.S. thesis is available from the laboratory.

OCEAN THERMAL ENERGY CONVERSION

Two interesting projects in the Marine Laboratory are concerned with possible siting of an ocean thermal energy conversion (OTEC) demonstration plant in Guam. Both are carried out under the direction of Dr. Lucius G. Eldedge, whose interests are invertebrate biogeography and taxonomy. Several staff members and students are assisting Dr. Eldredge in this work.

The thermal energy used in OTEC is the temperature difference between the warm surface and the cold bottom waters. The conversion device is a turbine driven by a working fluid having a low energy of vaporization, such as ammonia, freon, or propane. The working fluid is expanded and drives the turbine at the high temperatures of the surface water, and is condensed at the low temperature of the bottom water. The thermodynamic efficiency is proportional to the temperature difference between top and bottom waters; the actual efficiency depends on the temperature gradient because construction and operation costs will increase considerably with the depth and horizontal distance of the pump intake for the cold bottom water.

In a project sponsored by the Guam Energy Office, a number of parameters were measured repeatedly over the course of year near Glass Breakwater, the entrance to Apra Harbor. These included temperature, reactive phosphorus, nitrite, nitrate, dissolved oxygen, salinity, pH, and total alkalinity. The results are published in Technical Report No. 53, issued in July 1979 by the Marine Laboratory. The following average temperature differences were found:

GUAM			HAWAII*		
Depth	T, °F	Distance from shore, ft.	Depth	T, °F	Distance from shore, ft.
1500	37.1	3300	–	–	–
2000	39.4	4224	2000	36	5280
2500	41.1	–	–	–	–
3000	42.2	5808	–	–	–

*The Hawaii values are for Ke-ahohe Point and are quoted in the Guam report; the original reference containing them, The Natural Energy Laboratory of Hawaii annual report for 1977, has not been examined.

A temperature difference of 35° is considered to be favorable for an OTEC site. The favorable temperature gradient occurs near an existing generating plant at the Guam site, thus providing a convenient electric power distribution network. The westward flow of the North Pacific Equational Current assures that prevailing currents will carry cool water effluents away from the proposed project site.

An interesting product of an OTEC plant in Guam would be the large-scale movement of deeper-water nutrients to the surface. This could be of considerable value to aquaculture or fisheries in a tropical area where surface waters are deficient in nutrients and hence productivity and fishing are poor.

Dr. Eldredge is also doing an ecological census of the project site. This might serve by a baseline study, against which environmental effects of an OTEC plant could be determined.

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POLYMERIC SUBSTITUTE FOR EYE FLUIDS

Rudolph J. Marcus

Some interesting cooperative work has resulted in a polymeric material which, in animal tests, has been shown to be a safe substitute for the vitreous body of animal eyes. The institutions engaged in this work are the Nihon Tenganyaku Kenkyusho or Japanese Eye Lotion Laboratory of Nagoya, the Nara Prefectural Medical School, and the Research Institute for Polymers and Textiles, originally of Yokohama but now located at Tsukuba. Complete addresses are given at the end of this article.

The material itself is a polyvinyl alcohol (PVA) hydrogel which was prepared as follows. A 7% aqueous solution of PVA, having an average polymerization degree of 2,000 and a saponification number of about 100, was sealed in glass amples under vacuum and was irradiated by 0.6 mr gamma rays. After irradiation, the soluble PVA was extracted, and the remaining crosslinked material was a transparent fluid gel. This gel was brought to equilibrium swelling with physiological saline. The swelling ratio was 115 (1 gram PVA: 115 grams hydrogel). The hydrogel was then sterilized by heating in an autoclave before use.

In a number of tests, 0.1-1 ml of vitreous was extracted from albino rabbit eyes and replaced by an equal or smaller amount of swelled synthetic hydrogel. The gel seemed to merge well with the vitreous since no visual interface was formed between them. This is shown in a color photograph in which the bottom of the eye can be seen clearly and without deformation. The substitution of the swelled synthetic hydrogel caused a temporary increase in the interocular tension, which returned to normal within two months after the substitution in a majority of the samples. Electroretinograms appeared normal and no histological abnormalities were observed in cornea, lens, or the vitreous.

While the infrared spectra of the synthetic hydrogel and the natural vitreous show some differences, these differences disappear when a second sample is extracted at an unspecified period of time after the replacement of some of the vitreous by the synthetic material. In the minds of the inventors, this shows that the natural material and the synthetic material mix smoothly, confirming the conclusion stated above about the absence of an optical boundary.

It might be pointed out that problems of replacement of the vitreous arise not only in some diseases, but also after certain delicate eye operations. Obviously the Nitten Eye Laboratory hopes that this material will also be suitable as a carrier for certain eye medications. Indeed, trials with pilocarpin hydrocloride, a miotic, have shown its usefulness in this respect.

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ELECTROSTATIC PRECIPITATION RESEARCH IN JAPAN

Leon H. Fisher

INTRODUCTION

Electrostatic precipitation and the Cottrell process are two terms used almost interchangeably to designate a process which is widely used in industry to remove suspended particles, fumes, and mists from flowing gases. At the present time, the most widespread use of the process in the United States is, by far, the removal of fly ash from coal-burning electric power plants. This is not the case in Japan at present.

In an electrostatic precipitator, a corona discharge is produced in the flowing gas by a d.c. high voltage. Electrons and/or gaseous ions produced in the corona discharge attach themselves to the suspended particles, fumes, and mist in the flowing gas. These charged suspended particles are then deposited on either the blunt conductor of the corona discharge, either a pipe or plates, or on one of two parallel electrodes beyond the corona region between which there is a d.c. field but no corona. Particles of about 10-micron diameter and less are brought near to the electrodes by turbulent flow of the gas, enter a laminar flow region near the electrodes, and reach the electrode by means of the electrical forces acting on them. Particles of much larger diameter than 10 microns are brought to the collecting electrode by means of the electrical forces acting on them, since their drift velocities due to the electric field are larger than the turbulent velocities. Particles having diameters between 10 and 50 microns are acted on by turbulent forces and electrical forces throughout the volume of the gas. The gas, now essentially devoid of particulates, is then expelled into the atmosphere. (Gaseous pollutants such as SO_2 are not removed by the electrostatic precipitation process.)

If the corona discharge is both charger and collector of the dust particles, the device is known as a Cottrell or single-stage precipitator. In the single-stage precipitator, one may have either a corona wire surrounded by a concentric cylindrical collector, or a series of parallel corona wires between parallel plates. Single-stage precipitators are almost always used for industrial applications, and most precipitators in Japan are of this type. If collection of dust occurs in a corona-free region, after charging in a corona region, the device is known as a two-stage precipitator. Two-stage precipitators are used for cleaning air in buildings, where it is desired to limit the production of oxides of nitrogen and ozone.

Although, at the present time, the prevention of air pollution from industrial stacks is the largest motivating factor in the use of electrostatic precipitators, recovery of valuable dusts and fumes such as copper, lead, and zinc oxides is also an important application.

The precipitation of fog in a small jar containing a charged pointed conductor was described in 1824 by M. Hohlfeld Sir Oliver Lodge discovered the effect independently in the mid-eighteen eighties. This led to an attempt to apply the method commercially to the precipitation of lead oxide fume arising from a lead smelter. Two steam-driven Wimshurst machines of five feet diameter were used to produce the high voltage for the corona. These experiments failed because (1) lead oxide fume particles are very small, and small particles accept only small charges, leading to small electrical forces on the particles; (2) the Wimshurst machines were unable to produce large enough corona currents in any case; and (3) lead oxide fume, when deposited on an electrode, leads to very high resistivity layers. Thus Lodge's method was applied with an inadequate high voltage source to one of the most difficult materials to precipitate.

The first successful industrial application of electrostatic precipitation was carried out in the United States in

1906, and the United States has continued to be a leader in the field. Considerable amounts of work are now being carried out on electrostatic precipitation in such countries as Japan, Australia, West Germany, England, and Sweden.

Frederick Cottrell (1877-1948) began work on the electrostatic precipitation of suspended particles from gases in 1906 on a laboratory scale at the University of California, Berkeley, where he was a member of the faculty of the Department of Chemistry. (Most of the early pioneers in the industrial application of electrostatic precipitation were chemists.) This work was motivated by the practical needs of industry and not by any academic or scientific questions begging to be answered. (Until recently, all work on electrostatic precipitation was carried out in industry. Now some universities like Stanford have research programs in this field. When H. J. White, who had been Director of Research for the Research Corporation for three decades, was invited to speak on electrostatic precipitation at Stanford University in 1979, he opened his lecture with the comment "If anyone had told me ten years ago that I would be giving a seminar at Stanford University on electrostatic precipitation, I would not have believed him.") Cottrell's principal contribution to electrostatic precipitation was the introduction of the high-voltage transformer, together with the synchronous-mechanical rectifier, as a source of high voltage and high voltage current. This may seem difficult for us to accept as a great step forward, but such devices were just then becoming available. The high voltage transformers available at that time were capable of giving voltages only as high as 10 or 15 kV; modern industrial electrostatic precipitators usually use 30 to 100 kV, but recently voltages as high as 200 kV have been employed. Cottrell also made the important discovery that negative corona is much more efficient than positive corona in charging particles; today, essentially all industrial electrostatic precipitators use negative corona.

Cottrell installed three precipitators industrially, and they were successful. His first two installations were used to precipitate sulfuric acid mist and the third installation precipitated about eight tons of lead and zinc oxide fume a day from a smelter. Notice that lead oxide fume is the material which Lodge's method could not precipitate.

In 1910, W. A. Schmidt, a former student of Cottrell's and a person who made important pioneering advances in electrostatic precipitation, installed an electrostatic precipitator which collected almost 100 tons a day of lime and clay dusts from cement kilns. The application of electrostatic precipitation to the collection of fly ash, its most extensive use in the United States today, did not start until the use of pulverized coal began in 1923, long after Cottrell had left the field.

Cottrell's first patent on electrostatic precipitation came in 1908. Idealistically, he turned his patents over in 1912 to a non-profit corporation, the Research Corporation, which Cottrell helped establish for this purpose. It was Cottrell's idea that the Research Corporation use its income for the support of the research of young and relatively unknown but promising univeristy faculty members. It was also his idea that the Research Corporation assist faculty members in the obtaining of patents on their work. The Corporation would receive some (or all, if the originator of the patent so desired) of the benefits of the patents. This came about, and in this way, the Research Corporation came to play an enormous role in the support of scientific research in the United States long before there was any appreciable involvement of the government in the support of research. Among the many projects supported by the Research Corporation were the cyclotron, the van de Graaff generator, the synthesis of vitamin B_1, and the irradiation of milk with vitamin D. Support is given to an investigator directly. A check is sent to the head of the institution in one lump sum at the beginning of the research and it is to be used at the complete discretion of the principal investigator with no strings attached. The Research Corporation only requests a summary of the work performed. Perhaps it would not be amiss for me to acknowledge the invaluable assistance that the Research Corporation gave me in supporting my research work at the beginning of my career.

Cottrell did not stay involved in electrostatic precipitation work very long and left the field, and the University of California, Berkeley, in 1911, although he published some review papers in the field after this date. He subsequently received support from the Research Corporation for some other research ideas. Ironically, there

came a time when the Corporation turned down his requests for support because his proposed work was not judged to be sufficiently promising.

NATURE OF ELECTROSTATIC PRECIPITATION OR COTTRELL PROCESS

The nature of the electrostatic precipitation or Cottrell process is now described in more detail. As mentioned in the introduction, electrostatic precipitation is a process in which suspended particles in flowing gases are charged by forming a corona discharge in the gas, and then are removed from the gas by a combination of turbulent action of the gas on the particles and by electrical forces. To produce a corona discharge, one needs one or more sharp or fine wire electrodes of one polarity tied together electrically, and one or more blunt electrodes of the other polarity. A non-uniform electric field is thus produced in the space between the sharp and blunt electrodes. If a gas is present, a sufficiently high potential difference between the sharp, or small radii, electrodes and the blunt electrodes causes a corona discharge. A corona discharge may be characterized as a self-sustaining discharge; it requires no external ionization to maintain it as do the very small currents that flow below the onset of corona. Corona may also be characterized as a partial breakdown of the gas, because at corona onset the current increases markedly, and light can be seen to be emanating from the region around the fine wires. Corona currents in small laboratory installations may be in the microampere range whereas, with industrial electrostatic precipitators, corona currents range from about 0.1 to 5 amperes. The large corona currents in operating precipitators are possible because of the large electrode areas. Corona currents in electrostatic precipitators with modern voltage sources are determined and limited by the gas and electrode geometry and not by the external power supplies, as was the case in the early use of Wimshurst machines in electrostatic precipitation. With modern voltage supplies, a corona discharge in an industrial electrostatic precipitator does not involve any appreciable lowering of the applied potential difference across the electrodes.

Corona discharges constitute a mechanism of power loss from high voltage transmission lines; they cause buzzing sounds and produce radio interference. During electrical storms, corona discharges appear on masts of ships, on edges of airplane propellers and wingtips, and on other sharp points, even fingers. In the above examples, the location of the "blunt" conductor is usually a charged cloud. When corona discharges are observed in nature, they are referred to as St. Elmo's fire. The Geiger counter is an application of the corona discharge.

Increasing the voltage across the electrodes, once corona has set in, further increases the intensity of the light, corona current, and the ionization about the wire. However, with sufficient increase in voltage, the corona transforms itself into a complete electrical breakdown of the gap with enormous currents flowing. Precipitous lowering of the potential difference between the electrodes occurs because the voltage supply cannot maintain the enormous currents capable of being conducted by the completely broken down gas region. After sparking, the power supply recovers and a high potential difference is once again applied across the electrodes. In ordinary gases, in the absence of dust in the gas and on the electrodes, the voltage at which a transition from corona to breakdown occurs is quite sharp. However, in the "dirty" and complicated conditions of electrostatic precipitation, no such sharp voltage transition exists. For the most efficient charging of the suspended particles, the corona current should be as large as possible. In the single stage precipitator or Cottrell type precipitator, sparks are allowed to occur. It is found that sparks, if not too frequent, do not interfere with the collection process. The higher voltage applied actually helps the efficiency. However, excessive sparking in the single stage precipitator is not conducive to efficient particle collection and should be avoided. It is also interesting to note that in the Cottrell type precipitator, Cottrell discovered that unfiltered unidirectional voltage was better than filtered d.c. voltage for the precipitator performance. In the two stage precipitator, lower voltages are used with no sparking, and in such arrangements, the d.c. is filtered and smoothed.

If corona onset is at 10 kV, breakdown may occur in the neighborhood of 40 kV. It is generally considered that there is no corona region in uniform fields and that complete breakdown occurs without corona ever appearing. For all practical pruposes, this statement is true, although there are some exceptions.

As has already been mentioned, there is great advantage in using negative polarity in electrostatic precipitators for the sharp or wire electrodes, and this is generally the case in practice. Cottrell showed that

much higher voltages and much larger corona currents are possible with negative than with positive polarity on the fine electrode. This makes the negative corona a much more efficient mechanism for electrostatic precipitation than the positive corona. All ionization in the gas occurs by electron bombardment of gas molecules, and at least one electron must be present to start the discharge. Such stray electrons are always present. Such an electron creates many electrons in what is known as an electron avalanche. Electron avalanches, together with secondary emission from the cathode by either photons or positive ions, in conjunction with space charge effects lead to a corona discharge. The only region where electrons have high enough energy to ionize gas molecules is in the high electric field region around the sharp or wire electrode. Most of the ionization in the corona discharge occurs in the immediate neighborhood of the small electrodes. Thus, if the polarity of the small electrodes is negative, any positive ions formed as the result of electron ionizing collisions are collected by the small negative electrodes without traversing any appreciable part of the interelectrode volume and without charging any appreciable fraction of the particles suspended in the flowing gas. However, the electrons (or in many cases electrons and/or negative ions in gases where electrons attach to form negative ions) must traverse the entire interelectrode separation before being intercepted by the blunt anodes. Thus, although at any place that electrons and positive ions are formed, they are created at the same rate, there are no positive ions anywhere in the gas volume except immediately around the wire where they are formed. There is a negative charge density over most of the gas volume. This is an example of a general principle that in low current discharges such as in ionization chambers, Townsend discharges, and in certain parts of relatively high current discharges such as corona, electrical neutrality does not exist, either locally or if integrated over the entire gas volume. Only in the body of plasmas is charge neutrality satisfied; in plasma sheaths, electrical neutrality does not exist.

Thus, in a negative corona discharge, the electrons or/and negative ions have an opportunity to attach themselves to the suspended dust particles. The electrons or/and negative ions are driven onto the suspended particles by two factors, a diffusive motion due to the random motion of the negative charges and an electrical force due to the distortion of the electric field in the neighborhood of the suspended particle. Those who have been tortured in electricity and magnetism courses by hiving to calculate the potential distribution and electric field surrounding a dielectric sphere or a conducting sphere when placed in an external electric field will be pleased to learn that the calculation has some very practical use. The field charging process is more important for particles larger than about 0.5 microns and the diffusion process is more important for particles smaller than about 0.2 microns. Both processes are important for particles between 0.2 and 0.5 microns.

It is desirable that as large a charge as possible be deposited on each particle; this is a problem which is still being worked on and which is getting a good deal of attention in Japan. Most suspended particles are charged to some extent even without benefit of corona, but only to a small fraction of the maximum possible charge. For example, under ideal conditions, a one-micron suspended particle may receive as many as several hundred electronic charges in a conventional corona discharge. The maximum charge depends on a number of factors, the charging field, the size and shape of the particle, and whether the particle is a conductor or insulator. If it is an insulator, the maximum charge depends on the dielectric constant. These negatively charged suspended particles acquire a drift velocity in the electric field. This drift velocity is superimposed on a turbulent gas velocity as well as being carried along by the overall forward motion of the gas. The drift velocities of particles ten microns and below in diameter are small compared to these gas velocities in industrial precipitators. Particles having diameters of 50 microns have drift velocities comparable to the gas velocities. Thus we can consider that the motion of the gas strongly dominates and affects the majority of the particles to be collected. Near the collecting electrodes, there is a narrow laminar boundary layer of perhaps a few millimeters thickness. If the turbulent flow brings charged particles of about 10 microns or less into the laminar boundary layer, then the drift velocity imparted to such particles will cause them to reach the anode and be collected. Thus the positive electrodes can collect these small charged particles in somewhat the same way that fly paper would trap flies blown by a wind against the fly paper. Larger particles are also collected because of their large drift velocity, independent of the turbulent motion of the gas. The particles then lose their charge but stick to the electrode. The electrodes on which dust has been collected are "rapped" (hit mechanically or vibrated) from time to time, and the precipitated material falls into hoppers with some reentrainment of dust particles (reintroduction of collected particles into the gas stream).

If one asks precipitator scientists whether turbulence is good or bad for electrostatic precipitation, the answer is always that it is bad. And yet the fine particles are transported to the collecting electrode by turbulent forces. This would seem to be an unresolved question, in my opinion.

Incidentally, one should point out that the electron and negative ion drift velocities are much larger than the turbulent and overall gas velocities. Thus, although we consider that the motion of the particles is dominated by the gas velocities, the particles are stationary as far as the charging by electrons and negative ions is concerned.

The precipitator associated with a 600 Megawatt coal-fired electric power plant may collect 800 tons/day of fly ash. Perhaps as much as 0.1% of the output power must be expended in operating the corona discharge of the precipitator for such a power plant. Perhaps a few hundredths of a percent of the current transported is associated with the deposition of the particles. The rest of the current is carried by negative ions and electrons everywhere except at the cathode, where most of the current is carried by positive ions.

One of the persistent problems of the electrostatic precipitation process is the fact that the material collected on the electrodes may have low conductivity. If this is the case, as material deposits on the collecting electrodes, the layers become more and more insulating with a number of effects coming into play, all deleterious to the collection process. These effects are classified under the term back corona, and is a complicated phenomenon even to describe. Back corona is generally considered to be initiated by some type of electrical breakdown of the insulating dust layer on the collecting electrode. It occurs when the resistivity of the dust exceeds a critical value of about 5×10^{10} Ω cm. A discharge may also occur on the surface of the deposited material, or a discharge may proceed out into the middle of the gas, or in some cases may cause sparkover between the corona electrode and the dust layer. These effects produce ionizaiton of the gas with positive and negative charges available for interaction with the already negatively charged particles. Since the negatively charged particles are already maximally charged, the newly produced positive ions tend to be collected by the particles, reducing the negative charge on the particles, and thus reducing the electric force on the particles. Thus collection of particles is hampered. Furthermore, the presence of back corona may concentrate the corona on localized areas of the wire thus impeding particle charging. What essentially happens in back corona is that negative charges, electrons, negative ions, and negatively charged particles, on being deposited on an insulating anode, cannot transmit their charges through the insulating layer to the external circuit. This leads to a large increase of the potential difference across, and of the electric field in, the insulating dust layer at the expense of the potential difference across, and the electric field in, the gas between the electrodes. This must be the case since the potential difference between the electrodes is the applied potential regardless of whether or not there is a dust layer. The electric field in the gas is everywhere reduced by the presence of negative charges on the dust surface, as it is increased everywhere in the dust layer. The dust layer breaks down, and the subsequent discharges follow in ways that are not too clearly understood.

The first paper on the program of the first Gaseous Electronics Conference, held at the Brookhaven National Laboratory in 1948, was given by H. J. White, probably the world's best known worker presently active in electrostatic precipitation; the title of his paper was "Characteristics and Fundamentals of the Back Corona Discharge." It was the first time I had ever heard the term, back corona. The problem of back corona is still being worked on 32 years later and, as we shall see, Japanese workers are actively engaged on this problem. The problem has become more urgent of solution with the growing use of low sulfur coal in electric power plants.

Conditioning of precipitator gases to avoid back corona, that is, adding material which makes the dust conducting, is a technique which has been used since the pioneer days of electrostatic precipitation. The materials added include water spray, SO_3, and Na_2O. It is a technique not much used in Japan. The lack of enthusiasm in Japan for gas conditioning arises from a number of factors. If water is used, the gas temperature may be reduced and the lift from the stack will be lowered. Furthermore, people will see condensed fog emanating and this gives rise to complaints. Furthermore, it is difficult to choose suitable conditioning agents. SO_3 is being used successfully in fly ash-collecting precipitators, and NH_3 is widely used at present in oil-burning power plants to neutralize sulfuric acid, since heavy oil is high in sulfur. Furthermore, it is feared in Japan that some additives may be carcinogenic. Most conditioning agents are supplied without specifying contents because

of commercial secrecy. The validity of the technique for reducing back corona in precipitators used in copper smelting has recently been brought into question by E. Potter of Australia, although it has been used for many decades.

The resistivity of dust particles often decreases with increasing temperature. Precipitators in which the flowing gases are hot, higher than 300°C, are called hot or hot-side precipitators. Above this temperature, the resistivities of materials such as fly ash become less than the critical resistivity, and so back corona may be avoided by using hot-side precipitators. They do have some disadvantages. Nevertheless, starting in 1965 they have been used more and more in the United States where there are now about 100 such installations. However, there are only one or two in operation in Japan. Furthermore, their use in Japan is not to solve the back corona problem, but to remove the fly ash from the gas before the gas enters a catalyzer to remove NO and NO_2. The catalyzer operates at elevated temperatures and the catalyzer should not be contaminated by fly ash.

It would be very desirable, if possible, to be able to use purely electrical means to solve the back corona problem. Pulsed voltages on the corona, tri-electrode electrostatic precipitators (a configuration where a third electrode is placed between the corona wire and the dust collecting electrode with openings for current to flow through the gas from the wire to the collecting electrode), and novel methods for charging the dust particles (the Boxer-Charger) are being vigorously investigated in Japan as means of overcoming the problems of back corona.

One might ask why it is that the kind of breakdown called back corona is so deleterious and that an ordinary spark a second causes no problems in electrostatic precipitation. The answer is that the corona currents in the case of sparking to a conducting dust layer recover very quickly to their normal value; with back corona, the corona currents are often drastically concentrated in localized regions on the wire and efficient charging of dust particles is not possible. Furthermore, in back corona, there is a constant discharge at the dust layer which tends to reduce the negative charge on the particles already charged and which are in the neighborhood of the insulating layer.

Despite such problems as back corona, electric precipitation has no rival for the collection of fine particulates. The power required is small compared to mechanical methods because the force is exerted on the charged particles and not on the gas as a whole. This is true even though only a minute part of the expended corona power is used to deposit the particles. Most of the charge transferred, and most of the energy, is expended in transferring unattached electrons and ions. Mechanical methods, in any case, do not work for small particles. Some gases that have to be cleaned are hot; mechanical methods cannot handle gases at elevated temperatures.

Conventional research work on corona discharges and on spark breakdown involves gases without particles and employs electrodes which are conducting and stay conducting. Such studies are complicated enough. The problem of corona discharges and spark breakdown in the presence of dust particles and insulating layers on electrodes is even more complicated. Workers in conventional corona and spark discharges should approach the problems of back corona and precipitator physics with humility.

BACKGROUND FOR INTEREST IN ELECTROSTATIC PRECIPITATION RESEARCH IN JAPAN

Interest in electrostatic precipitation in Japan started in earnest in 1970 when basic legislation was enacted for Environmental Pollution Control of Air, Water, Noise,[1] Soil, and Vibration. Japan now has very stringent requirements on these matters and they are enforced. The need for stringent requirements is obvious if one considers that a population half that of the United States lives in a country which has only 1/25 the area of the United States, and that 80% of that small area is uninhabitable because of its mountainous terrain. Air pollution in Japan results from automobiles, power plants, steel manufacturing, cement plants, and many other sources.

[1] It is interesting to note that in Tokyo, and in some other parts of Japan, large visible digital readouts of noise levels are in evidence. The levels are given in phons and one can see the instantaneous fluctuation in noise levels.

The environmental standard for particulates in Japan for ambient air, i.e., the portion of the air to which the general public has access, is 100 micrograms per cubic meter averaged over 24 hours and 200 micrograms per cubic meter averaged over 1 hour. (The national primary ambient air quality standards for particulate matter in the U.S., as of July 1, 1975, are that the concentration averaged over 24 hours not exceed 260 micrograms per cubic meter more than once a year and that the annual geometric mean be no greater than 75 micrograms per cubic meter.) The emission standards in Japan for the exits of industrial stacks vary from 0.05 to 0.4 grams per cubic meter, according to the kind and size of the process and also according to the geographical location of the plant. However, a target has been set for emission levels at stacks of 0.05 grams per cubic meter; this is extremely stringent and reduces emission to an almost invisible level. As a result of these new regulations, smog in Japan is much less severe in intensity than it was. In particular, the smog which was so oppressive in Tokyo just five years ago has been reduced substantially.

Much effort has gone into work on electrostatic precipitators in the last six or seven years, both in Japan and elsewhere. Precipitators have been very much improved. For example, collection efficiencies for fly ash by electrostatic precipitators averaged about 99% in 1970 and currently are averaging about 99.8%. This is a tremendous improvement, especially when one realizes that incremental improvement in efficiency is difficult. Japan has been a pioneer in the manufacture of the wide-spacing type of electrostatic precipitators (WESP), with duct spacing going up to about twice the previous distance, namely, up to 60 cm. The development of WESP represents one of the most important developments in the last ten years in electrostatic precipitation. The collection efficiency has remained unchanged, providing voltages are increased. Such precipitators are more economical than the ones with ordinary spacings and have many advantages. Over 160 such precipitators have been built in Japan. Maintaining and improving efficiencies of electrostatic precipitators with high reliability under varying and capricious conditions, and developing designs that can be extended to larger and larger plants, is the task faced by workers in this field. Low installation and low maintenance costs as well as low power costs are vital goals to achieve. It is reasonable to say that the manufacture of precipitators is not a matter of mass production. Each precipitator must be custom designed for the purpose for which it will be used.

The number of precipitators in Japan has increased from about 300 in 1970 to about 1000 at the present time. (By 1970, about 4,100 electrostatic precipitators had been installed in the U.S.)

Electrostatic precipitators are now used in Japan for:

1. oil-burning electric power generators,
2. steam generators in chemical plants,
3. cement rotary kilns,
4. driers in cement plants,
5. sinter machines in the steel industry,
6. glass furnaces,
7. basic oxygen furnaces in the steel industry,
8. coke ovens, and
9. coal-fired electric power generators.

In a number of the above, back corona is a serious problem. For example back corona is a very severe problem in iron ore sintering plants and in basic oxygen furnaces in the steel industry. It is a problem, but not such a severe one, in cement plants.

It is interesting to note that although there are about 1300 fly ash-collecting electrostatic precipitators in the U.S., there are perhaps only four or five in Japan. In terms of percentages, this means that about 32% of the total number of precipitators in the U.S. are dedicated to fly ash collection, but about 75% of the total volume of gas treated in precipitators is in fly ash precipitators. The reason for this startling discrepancy in fly ash precipitation facilities between Japan and the United States is that in 1967, Japan decided to generate electric power by oil rather than by coal. Thus, from 1967 to 1977, although generation of electric power doubled in Japan, the amount of coal used for power generation decreased by a factor of five. In 1975, only 3.7% of the

total electric power generated in Japan was by coal-fired power generators. In the United States, about half of the electric power generated is from coal-fired generators. This is the reason that there are so many more fly ash collecting precipitators in the U.S. than in Japan. However, the use of coal in Japan for electric power generation is now increasing because of the high cost of oil. No more oil burning power plants will be constructed, and plans are being made to use oil and coal as a combined fuel. Thus, precipitators for collecting fly ash will be constructed in the future. Furthermore, the Nippon Steel Corporation, one of the world's largest steel manufacturers, is converting its blast furnaces from oil to coal and states that, by the end of 1980, it should have cut its oil consumption by 30 percent.

The use of pulverized coal leads to an enormous amount of fly ash suspended in the stack gases, perhaps about ten percent of the weight of the coal. Japan has been obtaining its coal for coal-fired electric generators almost wholly from within Japan. Thus, in 1977 only 0.3% of the coal used for this purpose was imported. However, as coal use increases, Japan is obtaining more and more coal from Australia and the United States. Japanese coal is very high sulfur coal and gives no trouble as far as back corona goes because of the low resistivity of the fly ash in the presence of SO_2. However, the use of high sulfur coal gives rise to terrible SO_2 emissions which are not in any way handled or managed by the electrostatic precipitation process. Australian coal and western coal from the United States, both of which Japan is importing, are low sulfur coals. Although low sulfur coal is good for limiting the production of SO_2, it leads to serious operating problems for electrostatic precipitators because of the high resistivity of fly ash in the absence of SO_2.

The electrostatic precipitators used in Japan are manufactured in Japan. Some of the manufacturers are:

1. Mitsubishi Heavy Industries (licensed by Lurgi Company of West Germany),
2. Sumitomo Heavy Industries (licensed by Western Precipitation, a company originally founded by Cottrell in 1907),
3. Sumitomo Metal and Mining Co., Ltd. (this company manufactures WESP and has licensed Buell-Envirotech for this purpose),
4. Nippon Kai Heavy Industries Co., Ltd.,
5. Hitachi Plant Engineering and Construction Co., Ltd.,
6. Nippon Steel Corporation,
7. Onoda Engineering Co., Ltd.,
8. Chiyoda Plant Engineering and Construction Corporation,
9. Nihon Cement Manufacturing Co., Ltd.,
10. Toyo Engineering Corporation (licensed by Lodge-Cottrell of England),
11. Gadelius Co. of Kobe (a Swedish company operating under a license from SF, Svenska Flaktfabriken),
12. Kawasaki Heavy Industries (has just started precipitator manufacturing under a license from Research Cottrell).
13. Nippon Kokan (is manufacturing precipitators for waste disposal boilers), and
14. Furukawa Mining Co. (is manufacturing precipitators for metal and mining industries.

An arrangement between Mitsubishi and Research Cottrell for manufacturing precipitators has very recently expired. Koyo Iron Works and Construction Co., Ltd. has just stopped manufacturing precipitators. At the present time, the market is almost saturated. However, manufacturers are waiting for another expansion in the market.

One may finally note that two electrostatic precipitators of what is known as the tri-electrode type have been installed in Japan. One of these is at the Nagoya Nippon Steel Corporation in the Nagoya district. Tri-electrode type precipitators will be described to some extent later in this paper.

THE MATRIX UNDER WHICH ELECTROSTATIC PRECIPITATION RESEARCH IS CARRIED OUT IN JAPAN

Support for electrostatic precipitation research in Japanese universities is supplied by the Ministry of

Education, and by contracts with university groups from industry. In addition, research work is being carried out in industry. We will discuss the support given by the Ministry of Education to universities.

Electrostatic precipitation research is being supported by the Ministry of Education under a "General Research Program" as well as within the framework of a complicated framework of a mission-oriented "Special Research Project." The "General Research Program" support for electrostatic precipitation is funded under the category carrying the largest sums of money and the largest support per investigator for non-mission-oriented work. The Ministry of Education is thus expressing its feeling that such basic work in the field is of great importance.

The support for electrostatic precipitation under the mission-oriented "Special Research Project" is embedded in a complex organizational structure. This "Special Research Project" has the following four components:

1. Environmental Science,
2. Cancer,
3. Natural Disasters, and
4. Energy (to be started in 1980).

Dr. K. Muto, Professor Emeritus of the University of Tokyo, is the director for the Environmental Science component of the above "Special Research Project" for the whole country. Under the Environmental Science component there are several groups, one of which is Dynamics of the Environment. Under Dynamics of the Environment is an activity known as Identification and Behavior of Man Made Pollutants.

The activity Identification and Behavior of Man Made Pollutants is under the direction of Dr. S. Masuda, Professor of Electrical Engineering at the Hongo campus of the University of Tokyo. There are seven different areas of investigation being carried out under Identification and Behavior of Man Made Pollutants. They are:

1. Electrostatic Precipitation, headed by Professor Masuda,
2. Bag Filter Studies, headed by Professor K. Iinoya, Department of Chemical Engineering, Kyoto University,
3. Surface Chemistry Catalytic Reactions Producing Cancer Causing Materials, headed by Professor H. Tominaga, Department of Synthetic Chemistry, University of Tokyo,
4. Health Effects of Particulates, headed by Dr. M. Tsuzuki, Professor of Surgery, University of Tokyo,
5. Urban Engineering, headed by Professor I. Hayakawa, Department of Environmental Engineering, Tokyo Institute of Technology,
6. Particulate Emission from Diesel Engines, headed jointly by Professor T. Sato, Department of Mechanical Engineering, Keio University, and
7. Particulate Emission from Heated Tires and Brake Shoes, headed by Professor T. Shirai, Department of Applied Chemistry, Keio University.

A second mission-oriented "Special Project" entitled Technical Control of Pollutants is to start in 1980 under the direction of professor R. Toei, Department of Chemical Engineering, Kyoto University. The work of this "Special Project" will be roughly equivalent to Dynamics of the Environment, mentioned above. This special project has already been organized, but has not yet been implemented. It is scheduled to start in 1980. One of the components under this "Special Project" will be Electrical Means for Particulate Control and is to be headed by Professor Masuda. Its work will be divided up into three activities:

1. Electrostatic precipitator research will be carried out on especially troublesome phenomena such as back discharge, entrainment (the removal of deposits from the collector electrode by the effect of gas flow on the material already deposited as well as the redeposition of already deposited material in the gas stream due to the rappping process), and turbulence (gas flows in industrial precipitators are always turbulent). This work will be headed by Professor Masuda.

2. Research will be carried out on the production and exploitation of charged water droplets to entrap submicron dust particles. This work will be headed by Professor M. Hara, Department of Electrical Engineering, Kyushu University.

3. Research will be carried out on the charging and driving of insecticides by electric fields to raise the efficiency of deposition. This work is to be headed by Professor K. Asano, Department of Electrical Engineering, Yamagata University.

Professor T. Adachi of Yamaguchi University is a supporting member for all of the above groups on all electrical aspects of electrostatic precipitation, such as computer solutions of Poisson's equation.

The Ministry of Education supplies the funds for equipment and supplies for the above work but not for salaries. Salaries must be obtained from fellowship granting groups.

With the contributions of industry toward work in electrostatic precipitation in universities and the support of the Ministry of Education, great flexibility exists in how the work is carried out. All of the activities are interdisciplinary and informal meetings of research workers from all over Japan are held frequently to exchange information and to report progress. Such meetings are required and generously supported by the Ministry of Education for this field as for others supported by the Ministry.

ACTIVITIES OF THE INSTITUTE OF ELECTROSTATICS JAPAN

Another manifestation of interest in electrostatic precipitation and electrostatic phenomena in general was the founding three years ago of the Institute of Electrostatics Japan. The Institute has a membership of some six or seven hundred, issues a journal quarterly, and holds a meeting annually. The symbol of the Institute is Gilbert's versorium, the first instrument that was used to measure electrostatic effects. It appears on all publications of the Institute. It is a metal arrow balanced on pivot and free to rotate. William Gilbert (1544-1603) was the first person who clearly distinguished electric from magnetic effects. The president of the Institute is Dr. S. Masuda, already mentioned above as being Professor of Electrical Engineering at the University of Tokyo. Dr. Masuda is the leading investigator in the electrostatic precipitation field in Japan. The address of the Institute is c/o Business Center for Academic Societies Japan, 2-4-16 Yayoi, Bunkyo-ku, Tokyo, 113.

The name of the journal issued by the Institute is *Proceedings of the Institute of Electrostatics Japan.* One half of the journal is devoted to review articles and the other half to original papers. The November 1979 issue consists of 66 pages with a preface, three review papers, four contributed papers, one letter, and a section labelled "Book Reviews." The journal is in Japanese, although there is an English index as well as English abstracts of the contributed papers. To give an idea of the contents of the journal we list the titles of the papers in this particular issue and give a summary of the one contributed paper involving electrostatic precipitation processes. The single letter also involves electrostatic precipitation processes, but its contents will be discussed in another place in this paper.

The preface is "On an Academic Society as It Ought to Be," T. Hasumi, Chairman of the Board of Trustees, Tokyo Electrical University.

The review articles are:

1. "Integrated Circuit Destruction Caused by Electrostatic Charge and Its Protection," M. Noyori, Semiconductor Research Laboratory, Matsushita Electric Inductrial Co., Ltd.,

2. "Electrostatic Problems in Electronics Industries," A. Fujie, 1st Engineering Department, Electron Sales Division, Nippon Electric Co., Ltd., and

3. "Handling Considerations for CMOS IC; Electrostatic Charge and Latch Up," H. Sakurai and Y.

Kawahara, Industrial IC/LSI Application Engineering Section, Semiconductor Division, Toshiba Corporation, and H. Kohima, Semiconductor Quality Assurance Department, Toshiba Corporation.

The contributed papers are:

1. "Specific Charge and Size of Water Drops Dripping from Conductors under High D.C. Voltage," M. Hara, S. Ishibe, and M. Akazaki, Kyushu University,

2. "Ionic Charging of a Very High Resistivity Spherical Particle," S. Masuda, University of Yokyo,

3. "Equivalent Energy of Discharges from Electrically Charged Plastic Sheets," S. Fujioka, Y. Fujii, K. Nakatsuka, Research Department, Osaka Works, Sumitomo Chemical Co., Ltd., and S. Masuda, University of Tokyo, and

4. Static Charge Reducer by Pseudo Ring Series of Many Body Frictional Electrification," N. Murasaki, K. Fujibayashi, M. Matsui, Tokyo Agriculture and Technology University, and Y. Yamano, Tsuruga Nylon Factory, Toyo Spinning Co., Ltd.

The letter is "Functional Devices in Applied Electrostatics and Boxer-Charger," by S. Masuda, University of Tokyo.

It is useful to summarize Professor Masuda's contributed paper "Ionic Charging of a Very High Resistivity Spherical Particle." The quantity of charge imparted to a spherical insulating particle in an electric field in a corona discharge by ion bombardment due to electric field effects (and not diffusion) has up to now been estimated by an equation derived in 1932 by Pauthenier and Moreau-Hanot and which is now known as Pauthenier's equation. In the derivation of this equation, the electrical field around the sphere is calculated by the superposition of two fields: (1) the externally applied field distorted by the presence of the perfectly insulating particle, and (2) an electric field resulting from the charge already collected by the particle, and which charge is assumed to distribute itself uniformly on its surface. On this picture, the particle continues to pick up charge until the external field distorted by the dielectric superimposed on the Coulomb field of the charge already on the sphere gives a zero electrical force driving charges onto the sphere. However, Masuda points out that the two assumptions of perfect insulator and complete surface conductance are contradictory. He says that the only justification for such contradictory assumptions is the possibility that the particle rotates during the charging process because of the turbulent flow of the gas. The paper makes a rigorous calculation of the time-dependent charging process without assuming uniform distribution of the charge over the particle surface. The results show that the saturation charge is considerably smaller than that calcualted by Pauthenier's equation. For instance, only 35% of Pauthenier's charge limit is given to particles with dielectric equal to two. If the dielectric constant of the particle is large, not much deviation occurs from Pauthenier's equation, since perfect conductivity corresponds to an infinite value of dielectric constant. On the other hand, when the dielectric constant is close to unity, a local concentration of charge on the upstream side of the particle occurs, which concentrates the electric field in that region and hampers further charging. Masuda carried out experiments to check these calculations. The experiments were carried out with spheres of steel, nylon (dielectric constant about 8), and teflon (dielectric constant about 2), all with 3-mm diameter. (For particles of this size, charging by the electric field mode predominates over the charging by diffusive motion of ions.) A high frequency discharge was used to provide a uniform plane ion source. Ions were drawn into the charging zone by applying a rectangular pulse voltage between the plasma source and an electrode parallel to it, the sphere being in this region. A grid was used to suppress ions of one polarity; thus unipolar charging occurred. Each sphere was suspended by a small nylon thread and charges were measured for different pulse widths. Good agreement with the present calculations were obtained within the limit of error of the experiment.

The "Book Review" section is a guide for beginners in the study of electrification and electrets. The section lists books in each of these two subjects, many of them not recent, along with some titles of journal articles and titles of some conference proceedings.

The Institute has held two meetings, one in 1978 and the other in October, 1979. Two publications cover the proceedings of each meeting. One is "Electrostatics Japan-19XX," which contains the abstracts in English of the papers presented at the meeting. The other publication covering the meeting is entitled "Electrostatic Association Conference Proceedings '79" (or '78) and gives a detailed account of the papers in Japanese. The 1979 meeting consisted of 54 papers, whereas the 1978 meeting consisted of 40 papers. Over half of the papers presented at the 1979 meeting were concerned with electrostatic precipitators and with the basic processes important to electrostatic precipitation. As will be seen, a number of papers on electrostatic precipitation had joint authorships from educational and industrial institutions, indicating a close relationship between these two kinds of organizations in this field. This kind of cooperation between universities and industry is not widespread in Japan. Papers on electrostatic precipitation were contributed by twelve educational institutions, four industrial organizations, one prefectural, and one government organization.

Some of the papers presented at the 1979 meeting which involved electrostatic precipitators and basic processes of electrostatic precipitation are now summarized, for the most part briefly, as a mechanism for giving the reader some idea as to what research problems are considered important by Japanese workers. In some cases, slight liberties with the English of the titles have been taken, for clarity's sake. Some parenthetical expository comments are occasionally inserted.

1. "Effect of Ultrasonic Sound on Collection of Smoke in an Electrostatic Precipitator," T. Nakane, T. Otsuka and K. Seya, Nihon University. An experiment is described in which smoke particles are collected in a model electrostatic precipitator in the presence of a high intensity ultrasonic source of frequency 20 kHz. It was found that the presence of the ultrasonic source improves the collection efficiency markedly. These authors have presented similar results in a paper, "Ultrasonic Assistance in Reducing Smog with Electrostatic Precipitation," at the Acoustical Society of America in 1978, and in a paper presented at an international ultrasonic meeting in 1979.

2. "Limiting of Electrostatic Precipitator Current by Means of Pulsed High Voltage," M. Yamaguchi, T. Miyashita, K. Ootsuka, Hitachi Research Laboratory, Hitachi Ltd., and H. Yamada, Hitachi Plant Engineering and Construction Co., Ltd. A pulsed high voltage of variable repetition rate, pulse width, and height was used to limit the discharge current in an electrostatic precipitator to less than the leakage current in the deposited dust layer in order to overcome difficulty in precipitating high resistivity dusts.

3. "Effectiveness of TEA on Electrostatic Precipitator Performance," K. Ootsuka and T. Yukitake, Hitachi Research Laboratory. Fly ash and triethylamine $N(C_2H_5)_3$, added to the flue gas from an oil fired test boiler, results in an increased corona current when passed through a model electrostatic precipitator, whereas fly ash and monoethanolamine, $NH_2(CH_2)OH$, decreases the corona current. (The addition of triethylamine was suggested by E. Potter of CSIRO, Australia.)

4. "Characteristics of Tri-Electrode Precipitator (TEP)," M. Ogihara, A. Shibuya, Ishikawajima-Harima Heavy Industries Co., Ltd., I. Hattori, Technological University of Nagaoka, and Y. Tabata, Research Institute of Industrial Safety, Ministry of Labor. This and the next paper involve what is known as the tri-electrode precipitator (TEP). Much work is going on in Japan on the TEP. The TEP is, as the name implies, a three electrode system. In addition to the corona wire electrode and the collecting electrode, there is a third electrode with openings which partially surrounds the corona wire. A d.c. voltage between the third electrode and the collecting electrode produces the collection field, and a d.c. or pulsed voltage is applied between the corona wire and the third electrode for producing the corona discharge. The hope is that this arrangement may lead to reduced problems with back discharge. This paper points out that the collection mechanism of TEP has not been investigated to any appreciable extent. Experiments are described on the current-voltage characteristics and on the collection efficiency of a model TEP in the temperature range from room temperature up to 400°C. Expressions for the current to the dust collecting plate and of collection efficiency in terms of the applied potentials are given.

5. "Back Discharge of the Tri-Electrode Electrostatic Precipitator (TEP)," S. Masuda, University of Tokyo, and S. Obata, Research Institute, Ishikawajima-Harima Heavy Industries Co., Ltd. In previous papers, these authors have reported that the back discharge of a TEP behaves quite differently from that of the conventional electrostatic precipitator. The expected collection performance can only be maintained if the electric field strength between the dust collecting electrode and the third electrode (which is between the corona wire and the collecting electrode) is kept below a certain critical level. Above this field strength, severe impairment of performance starts to occur. In some cases, a surface glow associated with back corona covers the entire surface of the dust collection electrode, not only the restricted region facing the corona discharge, but also the region of the dust collecting electrode which does not optically see the corona wire. The entire surface of the third electrode facing the dust collecting electrode is also covered with a glow. Thus, once the back discharge forms on the part of the dust collecting electrode facing the corona wire, the discharge propagates along the surface of the dust collecting electrode where no electrons or ions from the corona discharge impinge. This lateral propagation sets in when the magnitude of the electric field between dust collector electrode and the third electrode exceeds about 5 kV/cm in air at NTP, and is extinguished at a slightly lower field strength. The authors previously found that back discharges on the dust collecting electrode may also form in the shape of filamentary discharges, in which case a filamentary discharge also occurs in the gas volume between the dust collecting electrode and the third electrode. These phenomena depend very strongly on whether the third electrode, as well as the conventional dust collecting electrode, is covered with dust. The present paper reports that, when high resistivity dust covers both the third electrode and the dust collecting electrode: (1) the filamentary discharge does not bridge the electrodes; (2) the current pulse width associated with the filamentary discharge is much shorter, about 100 ns, than when the filamentary discharge bridges the gap; (3) there is a large d.c. component in the current wave form associated with the discharge; (4) the range of the electric field strength at which a filamentary discharge proceeds into the gas becomes wider and the critical field strength under which such a discharge no longer occurs becomes lower (about 3.5 kV/cm at N.T.P.); and (5) the average current density is higher.

   (The use of pulsed voltages for corona production in the TEP has been found to reduce the occurrence of the propagation of back corona along the dust collecting electrode. Professor Masuda believes that as more and more low sulfur coal is burned in Japan, the TEP with a pulsed mode for corona production will become more and more necessary.

   Both of the TEP's now operating in Japan are operating in the d.c. modes for producing corona because the resistivity of the material being deposited is not too high. However, with the pulsed mode, one can save energy. Only about one-fifth of the power is necessary in the pulsed mode compared to d.c.)

6. "Vanishing Temperature of Back Corona with High Resistivity Fly Ash in Hot-side Precipitation," N. Tachibana, Mitsubishi Heavy Industries, Ltd., Kobe Shipyard and Engine Works, and Y. Matsumoto and N. Sakamoto, Mitsubishi Heavy Industries, Ltd. and Takasago Technical Institute.

   (Hot-side precipitators have already been mentioned; they are precipitators that operate with gases above 300°C. They have long been used for precipitation of cement kiln dust. In about 1965, they began to be used in the U.S. in electric power plants burning low sulfur coal. As stated earlier, at these elevated temperatures fly ash is sufficiently conducting so as not to have back corona form. They have other advantages, but have some serious disadvantages. As stated, only one or two hot-side precipitators are in operation in Japan, and the motivation for them is not to reduce the resistivity of the dust but to remove the dust before the gas enters a catalyzer for removing NO and NO_2 (Denox). As stated earlier, it would seem that Japan is opting for other methods than the use of hot-side precipitators to solve the back corona problem.

   Thus, as the temperature of the gas in an electrostatic precipitator is increased, a temperature is

reached at which back corona vanishes; alternatively, as the temperature of the gas is decreased, a temperature is reached at which back corona appears. The temperature is the "vanishing temperature.")

Laboratory measurements were made of the temperature at which back corona disappears with high resistivity fly ashes of different species. It was found that the vanishing temperature for fly ashes from various low sulfur coals depends on the coal species and scatters over a considerably wide temperature range. The average ash resistivity at the vanishing temperature lies in a narrow range, independent of ash species. The vanishing temperature changes little with gas pressure or with the wave form of the power source.

7. "Detection of Back Discharge," S. Masuda and Y. Nonogaki, University of Tokyo. Methods for detecting back discharges in electrostatic precipitators were described. The current signal from a glow mode back discharge was continuous, although its light signal consisted of pulses. Filamentary modes of back discharge occurred as a sequence of discharges and provided pulsed signals of current and light. The filamentary mode could also be detected by antenna.

8. "Effects of Ripples in Voltage Waveform on Back Discharge," A. Iijima, Origin Electric Co., Ltd. and S. Masuda, University of Tokyo. The effects of ripples in the applied voltage on back discharge was investigated. The back discharge was produced by covering the inner surface of a duct electrode with a glass plate having holes of 0.05 cm diameter. With a negative wire, a filamentary surface discharge appears when the applied voltage has a minimum value, and a filamentary discharge occurs in the volume when the voltage has a peak value. No back corona appears in the time interval just after the peak and just before the voltage minimum. In the case of a positive wire, the back corona is only of the glow mode. A large increase occurs in the light emitted at the time just before the peak and just before the minimum voltages.

9. "Measurement of Electric Field Strength Within a Dust Layer," K. Fujibayashi, K. Nishizawa, M. Matsui, and N. Murasaki, Tokyo University of Agriculture and Technology. A biased probe was used to measure the current density and electric field strength within a layer of fly ash. The value of electric field strength measured with the probe gave the same value as did resistivity measurements, within experimental error. It is concluded that it is possible to use the biased probe to measure field strengths within dust layers.

10. "Corona Induced Vibration Mode of Discharge Wire in an Electrostatic Precipitator," M. Kawasaki, M. Takazyo, Nishinippon Institute of Technology, and T. Adachi, Yamaguchi University. Corona-induced vibration of a discharge wire in an electrostatic precipitator can produce undesirable results by lowering sparking voltage or breaking of the discharge wire. In this paper, the vibration modes of a discharge wire in a steady state were investigated. It was found that the vibration mode is mainly a circular motion round the axis of tension. The frequency is the natural frequency of the discharge wire and is independent of applied voltage. The amplitude increases when the applied voltage is increased above the vibration onset voltage.

11. "Observation of Moving Particles in a Model Electrostatic Precipitator by Means of a Laser Doppler Velocimeter," Y. Kawase, K. Tedjojuwono and T. Asakura, Hokkaido University. A laser Doppler velocimeter with high spatial resolution and high accuracy was used to measure the velocity of dust particles in a model electrostatic precipitator. The precipitator consisted of a 0.3 mm-diameter corona wire between two parallel electrodes, separated by about 3 cm. A differential-type laser Doppler velocimeter was used. The beam from a He-Ne laser was split into two parallel beams and recombined at the focal plane of a lens, the focal plane being within the electrostatic precipitator. An interference pattern is formed at the focal plane. The light scattered by moving particles in the probing area is gathered by a microscope system onto a photomultiplier used as a photodetector. The output signal from the photomultiplier is analyzed by a wave-period measuring system from which the velocity and fluctuations of velocity of moving particles are determined. The observations were restricted to laminar

flow, a condition which does not apply in an operating industrial precipitator. Spectacular diagrams are presented showing the magnitude and direction (obtained by making two observations at different angles) of the velocity of the particles, with parts of the volume showing nothing since they have been cleared of particles by electrostatic precipitation. The positive and negative corona were studied, with the positive corona giving stable and well behaved flows, whereas the negative corona gives unstable velocity flows. This laboratory is developing laser methods for a variety of types of measurements, including blood flow.

(It may be of interest to note that Professor Asakura is heavily involved in a graduate school in Indonesia which has been established through a joint effort by Japan and Indonesia. It is the first graduate school in Indonesia and was established 2 1/2 years ago with the support of the Japan Society for the Promotion of Science. Both the master degree and the doctorate are offered, but only in a limited field, namely opto-electronics and laser applications. The graduate school is in Jakarta at the University of Indonesia. Japan sends faculty members to the graduate school. About 20 Japanese faculty members are involved and they spend about one month there per visit. The lectures are given in English. Lectures are also given by Indonesian professors from all over Indonesia. About twenty students are enrolled in the master's program and three in the doctor's program. The first graduation ceremonies are to be held soon. Professor Asakura is very active in the administration of this endeavor, as evidenced by the fact that he goes to Indonesia about ten times a year in connection with this graduate school. Anyone wishing to know more about this activity may write to Professor Asakura at Research Institute of Applied Electricity, Hokkaido University, Sapporo, Hokkaido, Japan, 060)

12. "Motion of Small Charged Particles inside an Electrostatic Precipitator," S. Masuda, Y. Kanno, K. Akutsu, University of Tokyo, and M. Ko, Seoul National University, and T. Nakane, Nihon University. The motion of small charged particles inside an electrostatic precipitator was studied by means of a laser Doppler velocimeter for the case of turbulent motion. It was observed that a turbulent zone is likely to develop along the discharge wire. The components of the velocities inside the turbulent zone have large fluctuations compared to their mean values.

13. "Welding Fume Collector Using Corona Discharge," T. Yukitake, K. Ootsuka, Hitachi Research Laboratory, Hitachi, Ltd., and Y. Ookuma, Taga Works, Hitachi, Ltd. A new type of welding fume collector was developed in which the fumes are charged by a corona and then the charged particles are captured by a filter. The welding fumes have been collected with an efficiency of greater than 99% and with the new type of welding fume collector, the life of the filter is prolonged ten times that of the usual filter collector.

14. "Application of Boxer Charger to Electrostatic Precipitators," S. Masuda, H. Nakatani, University of Tokyo and A. Mizuno, Ishikawajima-Harima Heavy Industries Co., Ltd. The application of the Boxer Charger was developed by Professor Masuda and his group at the University of Tokyo. It is a novel charging method which promises to charge particles to very high values. It consists of two plane parallel narrow plasma sources which are widely separated and which are capable of being turned on and off separately. When one is on, the other is off. When either one is on, negative ions are drawn from it into the space between the two plasma sources and dust particles suspended in gases flowing between the two plasma sources are charged negatively. The electric field between the two plasma sources is then reversed and simultaneously the plasma source which was operating is turned off, while the second plasma source is turned on. Now negative ions are drawn from the second plasma source to charge the very same particles. Professor Masuda and his co-authors state that the particles are so heavy that they do not move appreciably toward either of the ion sources between voltage reversals and thus the particles are not collected in the Boxer Charger. This might seem difficult to understand if turbulence is the prime mover of the particles. But Professor Masuda feels that the Boxer Charger section is so short, that the particles are indeed through the Boxer Charger before any mass motion of the particles due to turbulence occurs. What Professor Musuda calls the "classical" Boxer Charger used 20 kHz for the plasma and 60 Hz for the reversal field; the "modern" Boxer Charger uses nanosecond pulses for the

plasma with a reversal field close to 60 Hz. The authors state that the Boxer Charger provides ion current densities an order of magnitude higher than those obtainable by the usual corona discharges. It is being proposed as an adjunct to the Cottrell precipitator. The Boxer Charger would be used before the particle laden gas enters the corona region of the precipitator. Since the particles will already have been highly charged before entering the corona region, corona currents for charging need not be so large, and hence the problem of back corona in the corona section, due to the heavy deposition of negative charges on the dust layer would be reduced. (One should remember that most of the charge causing back corona is not due to charged particles but to electrons and negative ions.) This would allow the corona in the precipitator to either operate at lower voltages than usual, or in a pulsed mode. Thus it is claimed that the Boxer Charger can charge extremely high resistivity dust effectively, and have it deposited in the corona section, without any problems associated with back discharge.

The Boxer Charger is still under development and has not yet been installed in an industrial precipitator. Professor Masuda told me that if a Boxer Charger is used ahead of a precipitator, the emission level at the exit of the precipitator stack is halved, and if pulsed corona is used in the precipitator as well, the emission is halved again. Thus it is expected that with the use of the Boxer Charger in conjunction with a pulsed corona in a precipitator, the exit emission will be about 25% of what it would otherwise be. Work, jointly sponsored by the Electric Power Development Co. and the Japanese government, is underway to implement these ideas. It is hoped that the Boxer Charger will be available in one or two years for coal-fired power plant precipitators. Eventually, one might expect the Boxer Charger to be used in conjunction with pulsed corona in tri-electrode type precipitators.

15. "Classification of Charged Particles by Using Quadrupole Fields," S. Masuda and M. Washizu, University of Tokyo. This paper describes an attempt to impart a given amount of charge to a number of spherical silicon droplets of 140 μm diameter. The charging was carried out by means of the "Boxer Charger" (see Paper 14) and then the particles were fed into a two-dimensional electrostatic quadrupole system. Both the ratio of charge to mass and charge of individual particles were measured. The quadrupole spectrometer gave the charge to mass ratio and the charge was measured by a Millikan oil drop method. The results show that the charge and mass of the particles produced were uniform.

The Boxer Charger is being used for a number of other purposes. I was shown a demonstration of the Boxer Charger acting as a dust monitoring device. Dust of a certain size and nature is swept through the Boxer Charger and the charges are deposited in a Faraday cage. The current measures the dust flow directly.

16. "Electrical Measurement of Submicrometer-Dust Size Distribution with Mobility Analyzer," K. Fujibayashi and N. Murasaki, Tokyo University of Agriculture and Technology. A disk type mobility analyzer was used to determine the size distribution of submicrometer dusts. Smoke particles were charged by negative corona and allowed to enter a gap whose electrodes were those of the mobility analyzer.

17. "Generation of Ozone and NO_x from Heated Corona Wires," S. Masuda, K. Akutsu and M. Ishida, University of Tokyo. The generation of ozone and oxides of nitrogen from heated positive and negative corona wires were studied with a special interest in the health problems of electrostatic precipitators that are used for air cleaning purposes (two-stage precipitators). Ozone generation form the corona wires can be greatly reduced by heating the wires. In the case of a negative corona wire, the ozone concentration was reduced at 270°C by 80% from the ambient case for the same corona current and it became zero at around 500°C. In the positive wire corona, ozone generation is about an order of magnitude lower than for negative wire corona. (This is one of the reasons that precipitators for air cleaning purposes usually have positive polarity for the corona wire.) However, heating of corona wires causes the generation of oxides of nitrogen (primarily NO^2) at the same time. In the case of a negative corona wire, the concentration of nitrogen oxides remain at very low levels up to a wire temperature of about 300°C, above which, however, it increases sharply with increasing temperature. In the case of the

positive corona wire, a slow rise of oxides of nitrogen concentration with wire temperature begins to occur at room temperature, and it becomes saturated at a low concentration level above about 300°C. It is concluded that an optimum temperature of corona wires exists at which the concentrations of both ozone and oxides of nitrogen can be kept at low levels and the corona current does not become excessively high. This temperature was around 350°C for the conditions of this paper.

ELECTROSTATIC PRECIPITATION RESEARCH AT THE UNIVERSITY OF TOKYO

Dr. S. Masuda, Professor of Electrical Engineering, University of Tokyo, has a large and well equipped laboratory in which all phases of electrostatic precipitation and electrostatics in general are actively studied. Dr. Masuda has had a long history of work in this field. His interest in electrostatic precipitation actually dates back to 1953, when he was an undergraduate. He was sent for field work to a cement plant in Kyushu to work on a motor for a rotary cement kiln. Peasants were attacking the plant because of the noxious emissions from the plant, even though a precipitator was operating. Masuda discovered that the synchronous rectifier was out of phase, and that the high voltage lead was shorted to the collecting electrode. In a month or so, Masuda rectified the operation. He is now devoting himself completely to the art and science of electrostatic precipitation.

The published papers, papers presented at conferences, and a summary of the year's progress in the laboratory are bound annually in a volume entitled "Research on Electrostatic Precipitation and Applied Electrostatics-1978 (for example)-Masuda Laboratory." Anyone wishing to obtain such reports should write to Professor S. Masuda, Department of Electrical Engineering, University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, Japan 113).

The 1979 volume is unfortunately not available at the time this article is going to press. The 1978 volume will be summarized and some of the work carried out in 1979 will be given.

The 1978 volume contains 24 entries and comprises 202 pages. These entries are:

1. "Back Discharge Phenomena in Electrostatic Precipitators," S. Masuda, Proceedings of the International Symposium on Transfer and Utilization of Particulate Control Technology–sponsored by EPA, July 24-28, 1978 in Denver.

2. "Flashover Measurements of Back Discharge," S. Masuda and A. Mizuno, Journal of Electrostatics, *4*, 215 (1978).

3. "Novel Electrode Construction for Pulse Charging," S. Masuda, same reference as Paper 1.

4. "Electrostatic Precipitators in Japanese Steel Industries," S. Masuda, same reference as Paper 1.

5. "Electrical Principles of Precipitation," Proceedings of the CSIRO Conference on Electrostatic Precipitation, August 21-24, 1978, Leura, New South Wales, Australia.

6. "Effects of Gas Composition on Sparking Characteristics of Back Discharge–A Preliminary Study," S. Masuda, A. Mizuno and M. Akimoto, same reference as Paper 5.

7. "BOXER CHARGER–A Novel Charging Device for High Resistivity Powders," S. Masuda, M. Washizu, A. Mizuno and K. Akutsu, same reference as Paper 5.

8. "BOXER CHARGER–A Novel Charging Device for High Resistivity Powders," S. Masuda, M. Washizu, A. Mizuno, and K. Akutsu, Proceedings of the IEEE/IAS Annual Meeting, October, 1978, Toronto.

9. "A Pulse Voltage Source for Electrostatic Precipitators," S. Masuda, S. Obata and J. Hirai, same reference as Paper 8.

10. "Maximum Charge of a Spherical Particle Imparted by Pulse Charging," S. Masuda and A. Mizuno, Proceedings of the 1978 International Workshop on Electric Charges in Dielectrics, October, 1978, Kyoto.

11. "Corona Charging of a Spherical Particle Having an Extremely High Resistivity," S. Masuda and M. Washizu, same reference as Paper 10.

12. "Statistical Design and Its Application to Efficiency Guarantee for Electrostatic Precipitators," S. Masuda, K. Fujibayashi and T. Ogata, Electrical Engineering in Japan, *93*, (1973), translated from Denki Gakkai Ronbunshi, *93A*, 329 (1973).

13. "Improvement of Particle-Charging Efficiency via Hermstein Glow Corona," S. Masuda and M. Niioka, Electrical Engineering in Japan, *95*, (1975), translated from Denki Gakkai Ronbunshi, *95B*, 423 (1975).

14. "Theoretical Characteristics of Double- and Triple-Array Electric Curtains of Standing Wave Type," M. Aoyama and S. Masuda, Electrical Engineering in Japan, *95*, (1975), translated from Denki Gakkai Ronbunshi, *95A*, 505 (1975).

15. "Hybrid-Type Electrostatic Precipitators," S. Masuda, S. Ago, T. Itoh, H. Saito and N. Furuya, Electrical Engineering in Japan, *96*, (1976), translated from Denki Gakkai Ronbunshi, *96B*, 90 (1976).

16. "Calculation of Fluid Field by Substitute-Charge Method," S. Masua and Y. Matsumoto, Electrical Engineering in Japan, *96*, (1976), translated from Denki Gakkai Ronbunshi, *96A*, 1 (1976).

17. "Apparatus for Electrostatic Powder Coating Utilizing BOXER CHARGER," S. Masuda and K. Akutsu, Proceedings of the 1978 Annual Conference of the Institute of Electrostatics Japan, 1978.

18. "Effect of Ambient Pressure on Charge Retention By Particles," T. Oda, M. Kosaka and S. Masuda, same reference as for Paper 17.

19. "Study on Velocity Distribution in ES-Type Electrostatic After Collecting Device Using a Laser Doppler Anemometer," S. Masuda, K. Akutsu and T. Nakane, same reference as for Paper 17.

20. "Maximum Charge of a Spherical Conducting Particle Imparted by Pulse Charging," S. Masuda and A. Mizuno, same reference as for Paper 17.

21. "Effect of Ripple in Voltage on Corona V-I Characteristics and Particle Charge," A. Iizima and S. Masuda, same reference as for Paper 17.

22. "Back Discharge Phenomena in Tri-Electrode Type Electrostatic Precipitator–Its Lateral Propagation," S. Masuda and S. Obata, same reference as for Paper 17.

23. "BOXER-CHARGER–A Novel Charging Device," S. Masuda, M. Washizu, A. Mizuno and K. Akutsu, same reference as for Paper 17, and

24. "Reaction Enhancing Effect of Auxiliary Electric Field on Electron Beam Gas Cleaning Process," S. Masuda, M. Hirano, K. Akutsu, M. Washino and O. Tokunaga, same reference as for Paper 17.

Professor Masuda considers that the following activities of the laboratory in 1978 were the most significant:

1. Understanding the back discharge, especially the effects of alkaline components and nitrogen oxides having low ionization potentials, as well as the effects of the thickness of the dust layer, and the investigation of the lateral propagation of the back discharge in the tri-electrode system.

2. The development and study of the "Boxer Charger" particle charger. According to Professor Masuda, this charger will not only be used in electrostatic precipitators, but will also be used in electrostatic powder coating, and DT-pellet fabrication for thermonuclear fusion work.

3. Motion of sub-micron particles inside an electrostatic precipitator under the influence of turbulent gas flow and the ionic wind.

4. Development of a fuel injector for laser-fusion and for a Tokamak type fusion chamber where the fabrication of a deuterium-tritium ice pellet and its movement into the chamber are the points of interest. This is to be accomplished using techniques of particle charging and control, including the "Boxer Charger."

5. Enhancement of denitrization and desulfurization of combustion gas by high energy electron beams.

Some of the papers emanating from the Masuda Laboratory in 1979 were:

1. "Lateral Propagation of Back Discharge," S. Masuda and S. Obata, Proceedings of the 1979 EPA-Symposium on Transfer and Utilization of Particulate Control Technology, July, Denver.

2. "Present Status of Wide-Spacing Type Precipitator in Japan," S. Masuda, same reference as Paper 1.

3. "Electrostatic Method of Particle Control as Applied to D-T Pellet Injector," S. Masuda, Journal of the Faculty of Engineering of the University of Tokyo A17.

4. "Application of Boxer Charger in Electrostatic Precipitators," S. Masuda, A. Mizuno, and H. Nakatani, 1979 IEEE paper.

5. "Effects of Gas Composition on Sparking Characteristics of Back Discharge-Preliminary Study," S. Masuda, A. Mizuno and M. Akimoto, Journal of Electrostatics, *6*, 333 (1979).

6. "Ionic Charging of a Very High Resistivity Spherical Particle," S. Maduda and M. Washizu, Journal of Electrostatics, *6*, 57 (1979).

7. "Lateral Propagation of Back-Discharge in a Tri-Electrode System," S. Masuda, S. Obata and Y. Ogura, The Institute of Physics Conference Series No. 48, 1979.

8. "Motion of Small Charged Particles Inside an Electrostatic Precipitator," S. Mauda, K. Akutsu and Y. Kanno, 1979 IEEE publication, and

9. "Generation of NO_x from Heated Corona Wires," S. Masuda, K. Akutsu and M. Ishida, 1979 IEEE publication.

Although a very large fraction of the authors of the above papers are from the University of Tokyo, a very few are from other universities and a few are from industry.

Professor Masuda considers that the most important equipment in his laboratory at present includes:

1. an image intensifier,
2. an image converter camera,
3. back discharge monitors,
4. special antenna for detecting back discharge,
5. special probe for measuring positive and negative ions in gases,

6. laser Doppler apparatus, and
7. frequency tracker.

The Masuda laboratory consists of a group of workers varying in size from ten to twenty. It is a well equipped, active organization reporting its results not only in Japanese meetings and journals, but also at international conferences and in foreign journals.

As a final comment, it may be pointed out that Professor Masuda has developed an electrostatic precipitator to be used in keeping the air in automobiles clean. It is a gas circulating system in which the gas in the car is passed through a series of corona discharges from points, and then passed through a set of collector electrodes made of plastic and coated with conducting material. This is thus a two-stage precipitator. Every six months, the light plastic collecting electrodes are discarded and replaced. The air also passes through activated charcoal and ultraviolet light. Finally, the clear air is passed over a needle corona discharge to add negative ions to the air to keep people "cheerful." Professor Masuda only developed the precipitator part of the device. The device is on the market and is being sold by a huge Japanese corporation.

I wish to express my appreciation to Professor S. Masuda for the meetings with him and for helpful conversations.

Appendix I

Mailing Addresses of Principal Investigators Mentioned in This Report

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SOME ELECTROSTATIC PRECIPITATION AND ANTIPRECIPITATION RESEARCH IN AUSTRALIA

Leon H. Fisher

Dr. Edmund Potter, Chief Research Scientist, Division of Process Technology, Commonwealth Scientific and Industrial Research Organization (North Ryde, New South Wales, Australia, 2113), spent a number of months in 1979 at the Masuda Laboratory at the University of Tokyo (see previous article) under the auspices of the Japan Society for the Promotion of Science. Dr. Potter is a leading worker in electrostatic precipitation in Australia. I attended a seminar, "Research Activities on Electrostatic Precipitation of Low Sulfur Coal Fly Ash," given by Dr. Potter at the University of Tokyo in December, 1979, and this paper is a report on that seminar. The seminar was attended by about 20 Japanese workers in the electrostatic precipitation field; they came from universities as well as from industry.

Despite the announced title, the first part of Dr. Potter's talk was not concerned with disposition of fly ash, but with the electrostatic deposition of mercury atoms in a mixture of air, SO_2 and SO_3. Dr. Potter reported that 50% of mercury atoms can be removed from a gas by electrostatic precipitation. The questions arose as to whether the remainder of the mercury could be removed in the same way. The efficiency of particle collection increases with increasing voltage from corona onset until somewhat beyond flashover. Dr. Potter found that the efficiency of mercury atom collection is quite high at the onset of corona, where the efficiency of particle collection is quite low. However, he found that, at the higher voltages, where the particle collection efficiency is quite high, the mercury collection efficiency is quite low. Thus the hope that the same electrostatic precipitator could collect mercury atoms and particles at the same time has not been realized.

Dr. Potter ascribes the declining efficiency of mercury atom collection with increasing voltage to the bombardment of the plate by ions. The material precipitating on the plate is not mercury, but a red oxide of mercury. Such results are obtained at ordinary temperatures as well as at 400°C, which is above the boiling point of mercury.

Dr. Masuda stated that the deposition of unwanted gaseous atoms and molecules is an entirely new application of electrostatic precipitation. Thus, these experiments should give food for thought to gaseous electronics scientists. When asked if a procedure of changing the voltage from low to high and back again to low, in a step pulse fashion, would possibly precipitate both particles and mercury, Dr. Potter stated that such a procedure had not been tried.

Dr. Potter then spoke about the problem of back corona from the point of view of the material on the collecting plate, and discussed the surface chemistry of fly ash. On the collector he finds successive layers of CaO, $CaSO_4$, and then H_2SO_4. Potter accepts the phenomenon of surface conduction for this deposit at room temperature, and thinks that surlfuric acid is the surface conductor by means of which the corona current passes through the dust layer at such temperatures. He stated that the passage of electricity through the sulfuric acid must involve the decomposition of water, and that the decomposition produces H_2 and O_2; hence H_2O is essential to the conduction of electricity through the dust layer at room temperature. Fly ash contains about 8% H_2O, but sometimes particles in industry do not contain H_2O, and then one has to add water.

Dr. Potter then discussed the resistivity of the layers. He pointed out that these electrolytic layers are non-ohmic, and that their resistivity goes down as the voltage goes up. Thus precipitators have a built-in defense against back corona. However, the acid layer is unstable at elevated temperatures. Thus, above 300°C, the

temperature above which electrostatic precipitators are said to be hot-side precipitators, the fly ash does not carry current by means of surface conduction, but by volume conduction. This volume conduction is by means of the electrolysis of a solid, rather than of a liquid. The fly ash deposit is a glass, and ionic migration occurs in the glass itself. The motion involves Na^+, K^+, and Li^+. These ions are able to move, and by means of them, charge transfer occurs. This process of conduction through glass by Na^+ has been demonstrated by Bickelhaupt of the Southern Research Institute in Birmingham to occur even below 350°C.

Dr. Masuda, who had just come back from a short visit to the United States, said that he had met with Bickelhaupt and Oglesby, also of Southern Research Institute, and was told that some industrial hot-side precipitators have given difficulty. They may work satisfactorily for a month or so, and then fail because of the depletion of Na^+. Dr. Potter thinks that the movement of Na^+ is not adequate to explain these failures because of the minute currents carried in precipitators. Instead, Dr. Potter suggested that the inability of hot-side precipitation deposits to conduct is due to the fact that lime is a bad conductor and that there are problems if there are enough non-conducting particles covering the plate.

Dr. Masuda's explanation of the decline of hot-side conductivity is that $Ca(OH)_2$ is fairly conducting, but that after several days or so, it becomes more and more solid. It was discovered from microscopic examination that $CaCO_3$ was developing. This has a high resistivity and acts as cement which combines particles together. There is some time delay before conduction decay occurs. The conductivity stays up for a day or two, and then becomes lower and lower.

Dr. Masuda asked if Na_2CO_3 should be added to coal to make the deposits conducting. Dr. Potter replied that when it was first suggested that Na be added to hot-side precipitators, he immediately thought it would be unacceptable because of the risk of corrosion. Australian coals are low in both Na and Cl, and are thus wanted by coal technologists. Australian coal is also very low in sulfur. Dr. Masuda asked where Na_2CO_3 should be put if used. Dr. Potter stated that, if Na_2CO_3 were used, it should be injected after the boiler at 1000°C. Dr. Masuda pointed out that the concept of adding Na_2CO_3 had often been suggested, to which Dr. Potter replied that this was bad from the boiler point of view. Apparently combustion engineers will not allow precipitator engineers to add sodium.

A discussion of smelters, with emphasis on the Cu smelting industry then followed. Dr. Potter pointed out that Cu_2S and CuS plus O_2 yield large quantities of SO_2 and Cu. The products contain about 5 to 7% SO_2. One also gets large quantities of copper and copper compounds, as well as Fe_3O_4, FeS, and iron-copper-sulfide compounds. The big problem is to control the SO_2 emission. In the copper smelting industry, electrostatic precipitators are used to precipitate Cu, and the industry is making money by doing this. No high resistivity problems exist; rather, they can have problems with low resistivity. He stated that the smelting reaction time takes 20 minutes, and that during the process the character of both the gas and particles change. Sometimes the resistivity becomes very low, less than 10^4 Ω cm. Under these conditions, the precipitator does not work effectively.

One of the methods used to solve this problem is the addition of H_2SO_4. This was first done by Rathburn, who added the sulfuric acid to obtain uniform resistivity throughout the 20 minutes of smelting. Dr. Potter found this strange because SO_2 and H_2O are already present. Rathburn's practice remained unquestioned until 1974, when Dr. Potter tested it on a full scale, despite the fact that it was feared that the precipitator would act poorly without H_2SO_4. He found that the addition of H_2SO_4 actually decreased the average performance of the precipitator over the 20 minutes of smelting time. Dr. Potter plotted a curve of the efficiency with and without adding H_2SO_4. The operation is always less efficient with H_2SO_4 added, regardless of the voltage. According to Dr. Potter, the addition of H_2SO_4 reduces the mechanical, and not the electrostatic, efficiency. He feels that H_2SO_4 makes the particles more "slippery."

Another topic discussed by Dr. Potter was "Antiprecipitation" or "Electrodispersion." There are only four papers on this effect in the literature. Consider a vertical glass cylinder, capable of being pumped out, into which two high voltage leads, suitably insulated, are inserted. One of these leads enters vertically at the top of the

cylinder, and the other enters horizontally at the bottom of the cylinder through the lateral surface. If Al_2O_3 is placed in the bottom of the container, the application of about 10 Kv potential difference between the two electrodes causes the alumina to disperse. A cloud of alumina is formed, with the effect depending on the magnitude of the potential difference. If gas passes through the cylinder while the potential difference is applied, dusty gas leaves the cylinder.

Dr. Potter has also studied this effect with copper particles, In this case, he used a horizontal glass cylinder with two electrodes entering one end of the cylinder. One of the electrodes was at the bottom, and the other at the top of the arrangement. Copper particles were then placed at the bottom of the horizontal cylinder. On the application of a potential difference between the electrodes and with appropriate pressures, less than 10^{-5} Torr and greater than 10^{-3} Torr, but not in between, the entire tube gets cloudy.

The phenomenon of antiprecipitation or electrodispersion has been studied very little. Dr. Potter states that microamperes of current flow, and that the current is carried by the moving particles. No corona discharge is necessary to observe the effects. When the voltage is applied in the case of copper, the mean free path of the copper particles is perhaps a centimeter or so. The particles collide and charge is transferred from one particle to the other. When the density of copper particles is very high, the transfer of charge is inefficient. Each particle moves up and down, with the conduction going on in this oscillating fashion. A charged particle transfers its charge, then falls, gets charged again, and then moves up again, etc. He stated that the process can also be carried out in liquids, and has studied the effect in perchlorethylene. The particles move more slowly in liquids than in gases.

METALS RESEARCH IN JAPAN

George Sandoz

(Editor's Note: Dr. Sandoz is the author of an ONR Tokyo Scientific Monograph, "An Overview of Materials Science and Engineering in Japan." The monograph describes research activities on the islands of Honshu and Kyushu, which Sandoz visited in the period January-April 1977. Copies of the monograph are available from ONR Tokyo.

The first three of four institutions described in this article are located on the island of Hokkaido. The materials research described here thus supplements Dr. Sandoz's monograph and should be read in conjunction with it.)

HOKKAIDO UNIVERSITY

Hokkaido University began as an agricultural school in 1872, later became an extension of Tohoku Imperial University in Sendai, and finally, in 1918, became a separate university, Hokkaido Imperial University. The university is principally located in Sapporo. The Faculty of Engineering was established in 1924, and the Faculty of Science in 1930. There are also several research institutes, such as the Institute for Low Temperature Science (1941), Institute for Catalysis (1943), Institute of Applied Electricity (1950), and the Metals Research Institute.

ELECTROCHEMISTRY LABORATORY

The principal host during this visit on 1-3 December, 1979, was Professor Norio Sato of the Electrochemistry Laboratory, Engineering Science Division, Faculty of Engineering. Professor Sato specializes in physical chemistry, electrochemistry, and corrosion science. A listing of Sato's associates and the titles of research studies underway currently is given in Table 1. Sato was also, of course, very active in the JIMIS-2 symposium on hydrogen effects in metals on 26-29 November, 1979, described elsewhere in this issue of the *Bulletin.*

Sato and his group have been particularly active in studying the nature of anodic barrier (passivating) oxide films on various metals in various solutions. For example, the anodic films on iron in phosphate and borate solutions have been studied ellipsometrically at pH levels from 1.8 to 11.5. In neutral solutions, the passive film consists of an inner oxide barrier layer and an outer hydroxide deposit layer. The barrier layer thickness is dependent on potential but the outer deposit layer depends on solution composition and is not dependent on potential. In acid solutions, the outer deposit layer dissolves and only the barrier layer remains stable. In subsequent work, Sato and Noda estimated the diffusion coefficients and activation energies for moving ions and concluded that the ionic current is probably carried by oxygen ions rather than iron ions in the barrier oxide film. This work was carried out in the passive potential region in acidic phosphate solutions.

In a collaborative research project supported by the Japan Society for the Promotion of Science and the National Science Foundation, Sato and Seo worked with ONR contractors J. B. Lumsden and R. W. Staehle of Ohio State University to determine the compositional depth profile of anodic films on iron in neutral solutions (boric acid-sodium borate at pH 8.4). Auger analyses coupled sequentially with sputtering techniques were used. The outer layer of the anodic films was found to contain significant levels of boron, suggesting that the outer

TABLE I

Electrochemistry Laboratory, Engineering Science Division
Faculty of Engineering, Hokkaido University

STAFF

Professor:	Norio SATO
Associate Prof.:	Masahiro SEO
Assistants:	Masao SAKASHITA
	Toshiaki OHTSUKA
Secretary	Chie MIURA
Graduates:	Sakae FUJITA
	Hitoshi MURAYAMA
	Yoshihisa MATSUMURA
Res. Fellow:	Yūji SERA
Undergraduates:	Satoshi OGI
	Tadashi SAKON
	Minoru MASUDA
	Nobutoshi ONO
	Kazuhiko OKAMURA
	Norio MITSUI

RESEARCH SUBJECTS

1. Applied electrochemistry and corrosion science.	(Prof. Sato)
2. Surface-analysis and physical chemistry of metals and alloys.	(Seo)
3. Electrochemistry on hydrous metal oxide membranes.	(Sakashita)
4. Ellipsometry of surface oxide films on metals.	(Ohtsuka)
5. Anodic oxide film on lead in sulfuric acid solution.	(Fujita)
6. Corrosion behavior and hydrogen permeability of steels in solutions containing H_2S.	(Murayama)
7. Corrosion resistivity and surface composition of iron-base binary alloys.	(Matsumura)
8. Electrochemical study of high nickel alloys in hot concentrated caustic solutions.	(Sera)
9. Anodic dissolution of iron and nickel by means of rotating ring-disc electrode technique.	(Ogi)
10. Semiconductor-electrode characteristics and composition of anodic oxide film on Ta.	(Sakon)
11. Ellipsometry of anodic oxide film on Ti.	(Masuda)
12. Crevice corrosion of Al alloys in sodium chloride solution.	(Ono)
13. Depth composition profiles of surface oxide films on iron-base alloys.	(Okamura)
14. Effects of light illumination on acid-dissolution reaction of copper oxides.	(Mitsui)

layer is formed by anodic oxidation of ferrous ion dissolved from the iron during initial passivation. However, the inner layer contained no boron, suggesting that the inner layer is formed directly by anodic oxidation of metallic iron.

The participation of various ions in the formation and passivation performance of the oxide anodic layer has been a continuing interest. In-depth profiles of anodic films on Fe-Ni alloys in neutral solutions have been obtained, again using Auger analyses and ion sputtering. Nickel accumulates at the oxide-substrate interface and leaves the film, depending on pH and anodic potential. The observation is explained as preferential dissolution and oxidation of the iron, coupled with preferential deposition of the nickel.

Similar studies on Fe-5Mo alloys show that, in sodium borate-boric acid solution, boron is present in the outer layer of the passive films on Fe-5Mo alloys and in the outer layer of the passive films formed on pure iron, but no molybdenum can be seen in the outer layer of the passive films. The inner layer of passive film on Fe-5Mo alloys is only half the thickness of the inner layer on pure iron, but the thickness does increase linearly

with increasing anodic potential. The presence of molybdenum in the inner layer apparently produces a barrier layer with high resistivity to ionic conduction.

Other studies involve the presence of chromium, tungsten, and cobalt on the outer hydrous oxide deposit or precipitate film. Sato currently seems to feel that the hydrous oxide deposit consists of an anion-selective layer in the metal side and a cation-selective layer on the solution side, and that there is therefore a rectification of ion movement regarding ionic current in the anodic direction. The hydrous iron, nickel, and chromium oxide membranes are inherently anion-selective in monovalent electrolyte solutions, but become cation-selective in the presence of some multivalent ions which enter the membranes from the solution and form a negative fixed charge. Therefore, the hydrous oxide deposit may be bipolarized, with an intrinsic anion-selective inner layer on the metal side and a cation-selective outer layer on the solution side, formed by absorption of multivalent ions. Anodic potential imposed, therefore, assists hydrogen ions in the membrane to migrate through the cation-selective outer layer into the solution, but the movement of metal ions adjacent to the metal surface is impeded by the anion-selective inner layer. Eventually, a dehydrated protective oxide film may be produced.

In solutions containing chloride ions, Sato proposes that the corrosion of iron covered with a hydrous ferric oxide precipitate film is accelerated by the enrichment of chloride ion under the film, which then may decrease the local pH and introduce a positive diffusion potential in the film. The adsorption of molybdenum oxide ions on the oxide changes the ion-selectivity of the precipitate film from being anion-selective to cation-selective in solutions containing NaCl and KCl. The cation-selectivity of the film may inhibit corrosion of the iron by promoting the diffusion of hydrogen ions out of the film.

Further details on the above may be seen in:

- Transactions of the Iron and Steel Institute of Japan, *19*, 504 (1979).
- Electrochimica Acta, *222*, 839 (1977).
- Denki Kagaku, *44* (6), 395 (1976); idem *45* (12), 744 (1977).
- Transactions of the Japan Institute of Metals, *20*, 501 (1979).
- Zeitschrift fur Physikalishe Chemie, Neue Folge, Bd. 98, 275 (1975).
- Corrosion, *35* (8), 351 (1979).
- Corrosion Science, *17*, 209 and 473 (1979); idem *18*, 577 (1978).
  Journal of the Electrochemical Society, *123* (8), 1197 (1976); idem *125* (11), 1135 (1978).

METALS RESEARCH INSTITUTE

Professor Taro Takeyama heads the Metals Research Institute, which pursues basic and applied research on the science of metals. His closest associates are K. Nishida and T. Shibata. The subjects of current interest are hydrogen embrittlement and stress corrosion of iron and iron base alloys, titanium and stainless steels, void formation from irradiation in metals and alloys, and pit generation in high nickel alloys. Many of these interests derive from practical interests in the construction of nuclear reactors.

The void formation studies on Cu-Fe and Cu-Ni alloys indicate that precipitates produced during irradiation, or aging prior to irradiation, interact with interstitial atoms to produce vacancies. In the Cu-Ni alloys, the density of dislocations increases with Cu concentration. Details of this work are described in:

- Eighth International Congress on Electron Microscopy, Canberra, *1*, 608 (1974).
- Journal of the Physical Society of Japan, *38*, 1783 (1975).
- Proceedings of the Fifth International Conference on High Voltage Microscopy, 571 (1977).
- Ninth International Congress on Electron Microscopy, Toronto, *1*, 380 (1978).
- Proceedings of the Fifth International Conference on Positron Annihilation, Japan, 9A-V-6, 249 (1979).

The studies of pitting and localized corrosion have included the analysis of passive films on 18-8 stainless steel using ESCA. The films formed in 1N H_2SO_4 and at various potentials, have shown peaks in ESCA spectra

of oxygen, carbon, chromium, and iron, but nickel spectra were weak. There was a substantial enrichment in chromium in the passive film compared to the polished surface. No enrichment of nickel was observed.

Pit generation in Inconel 600 and Inconel 800 in 3.5% NaCl solution is apparently a combination of several stochastic processes. The pretreatment potential before pit generation is related to the transition probability of each process, and this affects the pitting potential. This work is described in Nature, *260* (5549), 315 (1976), and Corrosion, *33* (7), (1977).

Shibata has examined active sites and micro-pits in the passive film of 304 stainless steel and found that chloride attack, as identified by platinum decoration, depends on the potential of film formation. Active sites on anodically-activated surfaces are evenly distributed and number 1.5×10^{10} per square centimeter. A heterogeneous distribution is seen on the surface covered by the passive film of both anodically-activated and micro-pitted surfaces; the number varies with potential. Shibata has also produced an interesting work on the application of high-speed elongation techniques to stress corrosion cracking of Fe-Ni-Cr alloys, a collaborative work of Shibata with ONR contractor R. Staehle of the University of Minnesota, formerly of Ohio State University. The transient current during high-speed elongation of passive metal was measured. The necessary condition for crack propagation (in hot magnesium chloride solution) was seen as the combined action of high dissolution rate of the metal at the crack tip combined with a low anodic reaction at the crack walls because of film formation. The data in the paper seem to bear out this model, cited in the Proceedings of Fifth International Congress on Metallic Corrosion, 487 (1974).

The work of Takeyama and Takahashi on the formation of microcracks, voids, and blisters in iron, steel, and Fe-Ni alloys centers on microscopic observations. Hydrogen may dissolve in these metals interstitially and segregate at lattice defects, at the interfaces of inclusions, or at the site of foreign atoms. The hydrogen may form a gaseous phase at these locations also, and produce voids, microcracks, and blisters. The microvoids, and microcracks, which are formed by cathodic charging (in the absence of stress), were indeed observed to form at tangled dislocations, grain boundaries, and precipitate interfaces, as shown in the Ninth International Congress on Electron Microscopy, Toronto, *1*, 602 (1978); and the paper delivered by Takeyama at JIMIS-2 on Hydrogen in Metals (proceedings available through Japan Institute of Metals, Sendai).

DEPARTMENT OF METALLURGICAL ENGINEERING

Professor Watanabe of the Department of Metallurgical Engineering is studying toughness and plasticity problems in the intermetallic compounds Ni_3Al, NiAl, CoAl, and Nb_3Al, which are potentially useful heat-resisting materials. Currently, he is growing crystals of the Nb_3Al-Ni_3Al eutectic and measuring expansion coefficients between room temperature and 1500°C, with the goal of reducing the concentration of vacancies at higher temperatures (vacancies reduce toughness).

The effects of particle bombardment on these compounds are also under study. The particles are electrons and neutrons, and next year ion radiation effects will be studied. Also of current interest is the coating of type 316 stainless steel by the co-chemical vapor deposition of Ti and Zr to form a compound. These compounds are intended to prevent flaking of the stainless steel under particle bombardment.

Hydrides of magnesium are also being studied. Magnesium hydrides are good for hydrogen storage, and do not crack, but the formation and dishcarge takes place at excessively high temperatures.

Other studies, over some years, have been on interdiffusion, work hardening rates and mechanisms, and precipitate interactions. Also, solid solution hardening has been an interest, particularly as related to computer simulation and statistical analyses. The alloys studied are in the Al-Zn, Al-Mg, Al-Si, Al-Cu, Cu-Al, and Cu-Fe systems.

Watanabe and his colleagues have published widely. Representative papers in the areas of recent study may be found in:

- Memoirs of Faculty of Engineering, Hokkaido University, *XV* (1), 19 (January 1979)
- Transaction of the Japan Institute of Metals, *12*, 147 (1971); idem *12* (6), 379 (1971); idem *13*, 278 (1972); idem *19*, 53 (1978); idem *20* (3), 126 (1979)
- Acta Metallurgica, *21*, 1033 (1973).

HIGH TEMPERATURE METAL CHEMISTRY LABORATORY

Professor K. Nishida and Dr. T. Narita of the High Temperature Metal Chemistry Laboratory were contacted only briefly, so no detailed account of their work can be given. However, they are working in the important area of the oxidation and sulfidation reactions with metal alloys and the control of the reactions by diffusion coatings. Papers have been written dealing with the reaction of sulfur vapor with Fe-Al alloys, chromium, Fe-Cr alloys, pure iron, and Fe-Ni alloys. Examples are in:

- Transactions of the iron and Steel institute of Japan, *10*, 421 (1970); idem *12*, 422 (1972)
- Corrosion Science, *13*, 759 (1973)
- Oxidation of Metals, *6* (3), 157 and 181 (1973)
- Transactions of the Japan Institute of Metals, *14* (6), 447, (1973); idem *15* (5), 314 (1974)
- Proceedings of the Fifth International Congress on Metallic Corrosion, 719 (1974)
- Denki Kagaku, *43* (3), 443 (1975); idem *44* (3), 159 (1976)

ANALYTICAL CHEMISTRY LABORATORY

Brief discussions with Professor M. Nagayama of the Analytical Chemistry Laboratory brought out his interest in anodic oxidation and cathodic deposition of metals, photoelectron spectroscopy of metal surfaces, and the chemistry of metallic ions in acqueous solutions. One current investigation is on the possibility of errors in the argon ion sputtering-Auger analysis method of determining composition of films as a function of thickness. There may be a selective removal of the surface material which could result in an erroneous analysis.

The visit to Hokkaido University was very rewarding. Their expertise in corrosion and related science is probably unsurpassed. A number of foreign postgraduates are attracted to do advanced study there, and this includes at least one from the United States (Professor Al Fromhold from Auburn University).

THE "MIT" OF JAPAN, MURORAN INSTITUTE OF TECHNOLOGY

The Muroran Institute of Technology blends well into the scenic hills and mountains which surround Muroran. On this occasion, I spoke with Professor H. Sugawara and Assistant Professor T. Misawa of the Metal Chemistry Laboratory. This group or "Koza" is engaged principally in studies of various aspects of metal corrosion (stress corrosion cracking, corrosion fatigue, hydrogen, embrittlement, and the electrochemistry of metals and alloys). Studies of the capacity of metals for the storage of hydrogen are also conducted. Specific subject areas are described below:

ELECTROCHEMISTRY OF Fe-25Cr STAINLESS STEELS

Of interest are the effects of molybdenum on the anodic polarization and pitting corrosion of Fe-25Cr alloys aged (embrittled) at 475°C for up to 5000 hours. Variations in chromium concentration have been another variable studied. The anodic polarization was measured in 1N H_2SO_4 and the pitting corrosion in 0.1M NaCl solution. Polarization curve characteristics signal the development of two phases during aging. The critical pitting potential shifts to active values with increased aging time.

According to Sugawara, the sensitivity of 18% chromium steels to intergranular corrosion is related to the proportions of alpha and gamma phases and the concentration of carbon in each; thus, the chromium depletion theory of sensitization is supported.

Tests of SUS 304 stainless steel have shown that repeated melting by electron beam heating produces a steel more susceptible to general corrosion in boiling 5% H_2SO_4, but less susceptible to intergranular corrosion following a sensitizaiton heat treatment. The general corrosion is accounted for by a loss of copper and the decreased integranular corrosion susceptibility to decarburization during electron beam melting. Further details are given in:

- Boshoku Gijutsu, *25*, 671-687 (1976); idem *27*, 15-21 (1978)
- Journal of the Japan Institute of Metals, *38*, (1), 22-28 (1974); idem *40* (10), 89-96 (1976); idem *40* (6), 551-558 (1976).

STRESS CORROSION CRACKING AND HYDROGEN EMBRITTLEMENT

One study under way is the stress corrosion cracking (SSC) and hydrogen embrittlement (HE) of Inconel 600 and Incoloy 800 in acid solutions of the type $HCl:HNO_3:CH_3COOH:H_2O$: in the ratio 2:1:1:36 at 50°C for two, 12 and 24 hours. Constant strain rate (0.05 mm per minute) testing is done with potentiostatic control to "stimulate" the corrosion reaction.

Another study aims to determine the role of lattice defects introduced by plastic deformation on SCC of austenitic stainless steels in H_2SO_4-NaCl solutions. Apparently the occurrence of strain-induced martensite, and martensite produced by sub-zero treatment, increases susceptibility to SCC. Interestingly, hydrogen-induced martensite has a similar effect. Increasing concentrations of nickel decrease the susceptibility to SCC, probably by increasing the stacking fault energy and thereby inhibiting the formation of martensite by plastic strain.

This work is partially described in:

- Journal of the Japan Institute of Metals, *42* (9), 850-857 (1978); idem *43* (3), 216-222 (1979); idem *43* (8), 720-727 (1979)
- Corrosion, *35* (10), 456-560 (1979).

CORROSION FATIGUE (CF)

There are several areas of study as described below:

a) Corrosion fatigue crack propagation in Inconel 600 and Incoloy 800 in pure water and in 50% NaOH solution at 85°C is of interest. The pure water contains 15 ppm oxygen and testing is at 1 cpm. Variables studied are the solution annealed or sensitized heat treatment and nickel content. Crack growth rates are measured versus ΔK. Fracture surfaces are subsequently examined by SEM.

Crack growth rates in the "pure" water have been found greater than in air. Larger fatigue striation spacings were observed in the water. It is suggested that some active dissolution on the fresh metal surfaces at the plastically deformed metal at the crack tip accounts for the wider striations and thereby the observed increase in fatigue crack growth rate.

Interestingly, the so-called sensitizing heat treatment at 650°C reduced fatigue crack growth rate in both alloys. This is the reverse of observations on type 304 stainless steel. Increasing nickel content further decreases fatigue crack growth rate.

In the 50% NaCl solution, the effects of potential on corrosion fatigue crack growth rates of the Inconel 600 alloy have been observed. Fracture surfaces have also been examined. The results have shown that fatigue crack growth rate (FCGR) is affected by potential. FCGR varies directly as: secondary passive region > corrosion potential > primary active region > primary passive region. Transgranular cracking prevails except at the secondary passive potential > (−0.04V vs SCE), where a maximum FCGR is observed and cracking is intergranular.

b) Corrosion fatigue and stress corrosion cracking of alpha brass in ammoniacal solutions under constant strain rate as a function of pH are under study. Both CF and SCC have been found to be sensitive to pH. Minimum fatigue life and fastest fatigue crack growth rate are seen in neutral tarnishing solutions, pH 6.5 – 7.0. Examination of fracture surfaces has shown intergranular cracking in neutral and acidic solutions, transgranular cracking in the alkaline solutions. The conclusion is that the tarnish film is not essential to cracking by fatigue in the acid range and that the intergranular propagation may reflect local dissolution at boundaries.

c) Misawa and others have studied fatigue crack propagation in low alloy (0.5Cr-0.5Mo-0.25V) steel in deaerated distilled water. The rates of fatigue crack growth were compared with rates in dry argon. Compact tension specimens containing pre-fatigue cracks were used. Crack growth rates were greater in distilled water than in argon, and the rates in water increased as temperature increased from 25°C to 65°C. The fatigue crack growth rate is therefore thermally activated. The fatigue crack growth rate has an activation energy, however, which is independent of crack tip stress intensity factor.

The fatigue crack growth rates relate to the proportion of intergranular versus transgranular crack path, which indicates dependence on alternating stress intensity factor. Similarly the relative crack growth rates due solely to the environmental effects were stress-intensity dependent.

d) Misawa and others have also studied the effects of bulk solution pH on fatigue crack propagation rates and fatigue strength of an S15C steel (0.15C). The solution was aerated HCl-NaCl-NaOH-water adjusted to give constant ionic strength of 0.5 and to give pH values between 0.5 and 13.7.

In the fatigue strength tests, the results show a steady decrease in fatigue strength with decrease of pH below 4.0, and a marked increase in fatigue strength with pH value over 13. In the midrange of pH, a maximum in strength was observed at pH 5-6 and a local minimum at pH 9-10. The latter minimum coincided with pit formation.

In the fatigue crack propagation rate studies, using precracked specimens, crack growth rates increased with pH values up to 11.2. In the higher pH range of 5.0 to 11.2, some effects of wedging by the formation of solid corrosion products in the crack were observed. Thus, the tests on fatigue life and on crack growth rate show essentially similar effects.

e) A recent interest is the study of cathodic charging effects on fatigue crack propagation rates in austenitic stainless steels (types 304 L, 316 and 310 S). This interest follows from consideration that liquid hydrogen will be stored in stainless steel containers as hydrogen energy systems develop. There will be, therefore, periodic thermal cycling of the stainless steel between about 20°K and 300°K as the tanks are filled and emptied.

The cathodic charging experiments at room temperature are intended to provide needed preliminary data at minimum cost. Compact tension specimens are used in a 1N H_2SO_4 solution. The specimens are tested at an R value of 0.1 and at 1.1 cycles/min. The poisons CS_2 and P are used to promote hydrogen entry.

The results so far suggest that increases in the nickel equivalent improves fatigue crack growth rate resistance. The so-called nickel equivalent is calculated from the total composition. Such calculations show the nickel equivalent of 304 L as 24.7, of 316 as 29.6, and of 310 S as 37.7. Cathodic charging increases fatigue crack growth rates at all nickel equivalents and increasing alternating stress intensity does likewise. Charging with a poison added to the 1N H_2SO_4 solution increases fatigue crack growth rates somewhat for the given amperage (70 mA/cm^2).

Further details on these subjects may be seen in:

- Boshoku Gijutsu, *25*, 493-497 (1976)
- Journal of the Japan Society of Materials Science, *26* (281), 172-178 (1977)

- Corrosion Science, *16*, 805-818 (1976); idem *18*, 199-226 (1978)
- Journal of the Japan Soceity of Materials Science, *43* (3), 249-257 (1979); idem *43* (10), 958-966 (1979).

METAL HYDRIDES AS HYDROGEN AND HEAT STORAGE MATERIAL

Studies are underway on the hydride formation characteristic of $LaNi_4Fe$, $LaNi_4Cr$, FeTi, and Ca - Ni alloys. One study involves accoustic emission signals during hydrogen absorption cracking in $LaNi_4Fe$ alloy. One paper describing details is in the Journal of the Japan Institute of Metals, *43* (2), 106-110 (1978).

In the past, Sugawara has studied electrochemical behavior in copper alloys. These have been published in Corrosion Science *7*, 513-523, (1967); and in the Science Reports of the Research Institutes, Tohoku University, *A18* (2), 86-104 (1966). Misawa has also described the atmospheric corrosion of iron and steel in Corrosion Science, *14*, 131-149 and 279-289 (1974).

In summary, the Metal Chemistry Laboratory at the MIT of Japan seems to be a small but highly productive unit, contributing most effectively to the solutions of problems in corrosion and related areas.

JAPAN STEEL WORKS, LTD.

The Japan Steel Works, Ltd., and its research laboratory were visited 4-5 December, 1979. Japan Steel Works is an independent company originally established in 1907 in collaboration with British interests (Armstrong-Vickers). The company specializes in large steel forgings and castings, a variety of steel plates, and industrial machinery. The company has historically engaged in heavy armaments production, and also has pursued other interests since the second world war, except for a small ordnance effort for the Japan Defense Agency. There are large efforts at present in making pressure vessels, heavy forgings, castings, plates, and reactor vessels for nuclear power plants.

In addition to the plant in Muroran, the company has operations in Hiroshima, Kashima (north of Tokyo), Yokohama, and Tokyo. The head office is in Tokyo, where the research and development planning office also is located. This is the coordination center for research and development for the entire company. The Materials Research Laboratory and the Research laboratory in Muroran specialize in large-scale forgings, ingots, pressure vessels for oil refineries and petrochemical plants, and components for nuclear power plants. Research in machinery and construction is conducted at the plants in Hiroshima, Yokohama, and Tokyo.

The Muroran plant covers 259 acres and employs some 3500 people. Several interesting capabilities were highlighted during the tour. Six 120-ton electric air furnaces and seven vacuum degassing pits combine to provide the capacity for the 570-ton (1,254 million lb) degassed ingots. A large four-high reversing rolling mill provides the capability for the 110-ton (240,000 lb) plates up to 5.15 meters (203 inches) wide and 350 mm (14 inches) thick. Disks up to 5.15 meters in diameter can be fabricated also. Bending presses of capability to 6000-ton and 10,000-ton hydraulic forging presses permit the fabrication of such products as heads for reactor pressure vessels, steam generators, and pressurizers. These components can also be machined or welded after being formed. Complementing all the melting and fabrication capabilities are fully adequate heat treatment, hydrostatic testing, and destructive and non-destructive testing facilities (including radiographic, x-ray, betatron, Linac, ultrasonic, magnetic, etc., equipment). A private wharf is equipped with two 600-ton cranes, so that 1200-ton (2.64 million lb) components may be loaded on ships.

Typical finished products are generator rotor forgings of 400-500 tons (1,100,000 lb), roll mill housing castings to 400 tons (990,000 lb), and flanges for nuclear reactors to 1000 mm (393 inches).

In all critical manufacturing capabilities, Japan Steel Works has been certified by both the American Society for Mechanical Engineers (ASME) and Technischer Überwachungs-Verein of Germany.

The research laboratory employs about 120 people, of whom 35 are professional. The activities are divided about equally between development of new or improved products and problem solving. The current general manager is Dr. J. Watanabe. The laboratory performs studies in the areas of melting and solidification, mechanical properties, welding, plasticity, heat treatment, corrosion, and chemical analysis.

One area of outstanding progress for JSW, and in particular the research laboratory, is the higher strength large rotor forgings through improved melting practice, involving the use of vaccum pit and ladle degassing equipment. This reduces segregation of impurities, particularly as revealed by sulfur prints, and minimizes the effects of temper embrittlement. An ingenious internal pressure burst test (JIB) has been designed to evaluate the strength within large forgings in different critical directions. The test specimen is essentially a hollow cylinder, and this cylinder is loaded internally by hydraulic pressure to the point of burst. Loads, strains at burst, the macro-fracture mode, and the fractographic fracture mode as observed by SEM are elements considered in evaluating serviceability of the forging. The same test specimen can be used to obtain fatigue data.

Precracked round compact tension specimens (RCT) are also used to evaluate fracture toughness and fatigue crack growth rates. The round specimens are useful because small center cores cut from the large forging can be used. In addition to fatigue crack growth rate data, measurements of J_{IC} can be made.

In addition to the large rotor forging investigations, studies are continuing on the following:

1. Mill rolls–rolling contract tests and thermal shock tests on 1 and 2% Cr-Mo steels illustrate the importance of hardness on roller life and thermal shock resistance.

2. Nuclear forgings–the mechanical properties across the thickness of PWRPV vessels have been determined and related to structure and levels of carbon, phosphorus, and sulfur.

3. Tests of stainless steel (347) have related grain size and location across the thickness to intergranular corrosion and cracking after bending.

4. It has been shown that the metallurgical structure and yield strength across the 500-mm thickness (with depth from the surface) of Cr-Mo-V cast turbine cylinder casings is much improved by quenching in water.

5. Temperature–K_c data have been obtained on controlled rolled steels containing about 0.1 C, 0.40 Si, 1.3 Mn, 0.01 P, 0.3 Ni, 0.15 Cr, 0.18 Al, 0.18 Cu, 0.06 Nb, and 0.02 Ti. Thickness and directionality effects were also determined.

6. Effects of cooling rate from the austenitizing temperature on the microstructure or notch toughness and the effects of compositional variations on susceptibility to temper embrittlement of 2.25 Cr-l Mo steels have been studied.

7. Concentration profiles across dendrites in Cr-Mo-Mn steels have been studied, using the electron microprobe x-ray analyzer and the benefits of vacuum melting demonstrated.

8. Studies of creep crack propagation in Cr-Mo-V steel at 550°C have been made.

9. Rather extensive studies have developed a stainless steel weld, overlay-PZ welding process for lining vessels. The process uses stainless steel strip 150 mm wide.

10. The effects of hydrogen at 250 Kg/cm^2 at 550°C on 1.25 Cr-l Mo steel for pressure vessels have been studied. Creep rupture curves illustrate deleterious effects of the high-pressure hydrogen and this has been correlated with microstructural effects.

11. Chemical analysis research has developed a demand-control computer center for rapid analyses from a number of furnaces during melting operations. This permits extremely easy adjustments of composition before the melt is poured.

In private discussions, metallurgist Y. Murakami described an investigation on problems of hydrogen-induced cracking in weld overlaid tube sheet for nuclear reactor vessels. The overlay is 309 and 347 stainless steel.

Weld joints of ferritic metal and austenitic metal are usually resistant to cold cracking because of high-hydrogen solubility, low-hydrogen diffusion rate in the weld metal, and a large capacity for relaxation of weld-induced strain. Thus the usual requirements for hydrogen cold cracking are not ordinarily met. These requirements are:

1. Presence of hydrogen
2. Stress over yield strength; ϵ_p = 0.5 percent
3. Temperature below 250°C (H trapping occurs)
4. VPHN $\geqslant$ 240; segregated areas VPHN 350-400

In the case of large weldments of nuclear pressure vessel components, however, there is much greater constraint during welding, and the possibility of cracking must be anticipated. Some real-life cases of such cracking have been encountered, hence, the investigation by JSW. This investigation indicated that hydrogen may diffuse out of the austenite into the base metal and cause cold cracking. The specific conditions required are as follows:

1. 3 to 4 ppm hydrogen diffuses from the weld metal into the heat-affected zone (HAZ).

2. The base metal must be susceptible to hydrogen embrittlement; this embrittlement may appear with as little as 1.5 ppm hydrogen.

3. Segregated areas in the base metal, which are difficult to avoid in large forgings, are the most susceptible to hydrogen embrittlement.

4. Residual stress may be more than 50 kg/mm^2, a value which exceeds the static fatigue limit (K_{IH}) of the base metal.

Prevention of the cracking is possible by minimizing the hydrogen concentration in the HAZ and by avoiding low temperatures during the cooling process following welding. Hence, preheat is applied during application of the first and secondlayers, and post heat and soaking are used following welding. It is also desirable to select base metal with a minimum of segregates. The use of steel melted by the vacuum carbon deoxidation process (VCD), as contrasted to the use of Si-Al killed steel, results in reduced segregation and lowers hydrogen embrittlement susceptibility of the HAZ.

Mr. T. Ohashi, also a metallurgist in the research laboratory, discussed concern for hydrogen cracking of generator-retaining rings operating in hydrogen gas. These rings, of Mn-Cr austenitic steel, are reported to have developed cracks which caused two accidents. A typical analysis is 0.5 C, 19 Mn, 5.7 Cr, 0.2 V, and 0.15 N. The steel is electroslag melted and cold expanded at 100-150°C; hence, the rings are highly anisotropic.

The laboratory is testing, in distilled water and in 3.5% NaCl solutions, cantilever beam specimens of these rings cut from various positions to determine K_{Iscc} values. This testing procedure is intended to assess the susceptibility to hydrogen atmosphere effects; tests in hydrogen gas are avoided at this time as being too slow. Results to date are as follows:

Direction	K_{Ic} ($Kg/m^3/2$)	K_{Iscc} Distilled Water	K_{Iscc} Saltwater
CL	350–400	240	140
LC		100	55

Bolt-tension type specimens are also being used in H_2S environments, but only the LC direction specimens have performed satisfactorily.

The susceptibility of 18 MN-5Cr alloys to stress corrosion in saltwater has been seen previously in German submarines (see Spiedel, Corrosion, *2*, (5), (1976).

Metallurgist Y. Murakami described a study of hydrogen embrittlement of temper-embrittled 2.25 Cr-lMo steel. The investigation has sought to determine whether there is a synergistic effect between hydrogen embrittlement and temper embrittlement. The results to date do indicate a marked effect of temper embrittlement in increasing hydrogen embrittlement susceptibility. Current efforts aim at determining the mechanisms of the interaction and also to determine countermeasures. This is an important study, for the results indicate that temper embrittlement affects hydrogen embrittlement (k_{IH} declines) at much lower transition temperatures than it does fracture toughness (K_{Ic}).

The personnel in the research laboratory are actively engaged in committee work and in round-robin testing for international societies. For example, round-robin K_{Iscc} tests on AISI 4340 are being conducted in cooperation with ASTM (American Society for Testing Materials) Committee E 24.04. Both cantilever beam and ITWOL specimens are being used, tested for 1000 and 4000 hours, respectively. Similar round-robin tests are being conducted with the Japan Academic Society (GAKUSHIN) on a 150 Kg/mm^2 UTS steel from Nippon Steel Company.

The investigations on hydrogen attack of Cr-Mo steel weldments (to test the validity of existing Nelson curves), temper embrittlement and hydrogen embrittlement, and hydrogen embrittlement of the bond structure between stainless steel overlay weld metal and the base metal are being done in cooperation with task groups of the Subcommittee on Hydrogen Embrittlement of the Materials Division of the Japan Pressure Vessel Research Council. Some eight steel manufacturers, ten vessel fabricators, and one research institute compose the subcommittee membership.

A list of the people visited at JSW follows:

Mr. H. Tsukada	Manager, Atomic Energy Department, Muroran Plant
Mr. K. Suzuki	Deputy Manager, Atomic Energy Department
Mr. J. Ishizaka	Castings and Forgings Group
Dr. K. Ohnishi	Manager, Research Laboratory
Dr. S. Sawada	Manager, Research Laboratory
Mr. R. Chiba	Metallurgist, Research Laboratory
Mr. Y. Murakami	Metallurgist, Research Laboratory
Dr. Y. Yoshino	Metallurgist, Research Laboratory
Mr. T. Ohhashi	Metallurgist, Research Laboratory
Mr. T. Tanaka	Metallurgist, Research Laboratory.

KOGAKUIN UNIVERSITY

Kogakuin University was established in Tsukiji, Tokyo, in 1887, as the first private training school for engineering. The founder was Mr. Koki Watanabe, then president of Tokyo Imperial University and later Minister of Education. The four-year curriculum was established in 1949, masters degree programs were begun in 1964, and the doctorate was first offered in 1966.

The philosophy of the education offered encourages the development of fundamental knowledge and habits of thought, study and analysis rather than "the cramming of knowledge." It is hoped that such engineers will be able to develop and adapt to new technology long after graduation.

The departments are mechanical engineering, industrial engineering and management, applied chemistry, chemical engineering, electrical engineering, electronic engineering, and a surprisingly large department in architecture. This latter department perhaps reflects the superb architecture in the tall new buildings in Shinjuku wherein the university is nestled. Graduate school majors are, incidentally, limited to mechanical engineering, applied chemistry, electrical engineering, and architecture. The number of students is about 6000.

Professor Ouchida of the Mechanical Engineering Department, recently retired from Hitachi, Ltd., is at present just getting settled into his new environment but is beginning some interesting research. As might be expected, there is some carry-over from his previous work at Hitachi. Specifically, he has continued his interest in problems with corrosion and fretting fatigue of shrink-fit components, such as led to the catastrophic turbine failure at Hinkley Point A in the United Kingdom in 1969. Ouchida is, therefore, studying the fatigue in various environments of rotating shafts upon which various bosses have been shrunk fit. The shafts and bosses are various combinations of carbon steel and austenitic 304 stainless steel. The environments are air, water, and saltwater.

It is interesting that, in air with both shaft and boss of carbon steel, the fatigue crack begins well within the boss, at the terminus of an approximately 1-mm fretting corrosion band. In water and saltwater, however, the cracking commences at the first exposed junction of shaft and boss, or even along the free shaft in the case of saltwater.

When the shaft is made of austenitic 304 stainless and the boss is of carbon steel, cracking begins, and continues, well down the shaft which is covered by the boss, an area seemingly unlikely to show environmental effects. However, Ouchida points out that the lower modulus of the austenitic shaft may result in larger deflections, which may promote fretting corrosion at the interface of the two different steels in contact. This equates perhaps to a type of crevice corrosion. Ouchida appeared to be pleased when the techniques of checking buried sites for pH, developed at the Naval Research Laboratory some years ago, were described. This technique, notably due to B. F. Brown, involves rapid cooling in liquid nitrogen, cooled specimen fracture, and the final application of suitable pH indicators as the newly-exposed fracture surfaces begin to thaw.

Brief interviews were held also with other faculty members at Kogakuin University as they were introduced by Ouchida. Hiroshi Matsuda, a lecturer in the mechanical engineering department, described work on the stress analysis of adhesive scarf joints by the finite element method (Proceedings of the 22nd Japan Congress on Materials Research, Society of Materials Science, Japan, Kyoto, 342 (March 1979)). This study of adhesive scarf joints takes into account the state of stress in both the adhesive and adherends for the design of such joints subject to tension. The specific effects of differences in Young's modulus between the adhesive layer and the adherends were a major consideration.

Dr. Yuji Kimura is a lecturer in chemical engineering, although his background is strongly mechanical as his previous studies at Keio University in Yokohama reflect. Kimura cited two different interests. One was a study in the changes in residual stress resulting from slip band accumulation in low-carbon steel after so-called rapid heat treating. Micro-structural changes were observed through an optical microscope during fatigue loading. The findings were that, below the 0.2% yield stress, residual stress relief is a reflection of plastic deformation in retained ferrite slip bands. If stress amplitude exceeds the yield strength, plastic deformation occurs in all of the structures including the martensite. Further details may be found in Bulletin of the Japan Scoeity of Mechanical Engineers, *15* (89), 1309 (1972).

Kimura is also interested in the statistical limits of fatigue life and of fatigue crack growth rate. One recent paper, "A Statistical Interpretation of Fatigue Limit on the Basis of the Extreme Theory," Engineering Fracture Mechanics, *12*, 317 (1979), is perhaps the best source of a detailed account of the first area.

The second area which Kimura discussed is of greater interest to the writer. This is a study of the statistical fluctuation of fatigue crack growth rate associated with the microstructure. The work, therefore, is of concern to the Naval Research Laboratory's investigators (T. Crooker, G. Yoder, and L. Cooley) working in this general area. Kimura et al, in fact, appear to have reached conclusions similar to the NRL investigators, using different material (steel) and a different analytical approach (statistics and computer simulation). Certainly the grain size dependence of fatigue crack growth rate is involved in both investigations. Kimura's work was reported in the 1976 Joint Japan-US Seminar on Strength and Structure of Solid Materials.

HYDROGEN IN METALS

George Sandoz

The Second Japan Institute of Metals International Symposium (JIMIS-2) on "Hydrogen in Metals" was held 26-29 November, 1979, at Minakami Spa, Japan. Although JIM organized the symposium, it was supported internationally by a number of other societies from the United States (*American Institute of Mining*, Metallurgical and Petroleum Engineers, and American Society for Metals), Canada, Germany, United Kingdom, and France. The International Advisory Committee included H. Birnbaum, R. A. Oriani, and R. H. Wiswall from the United States as well as technical leaders from France, Canada, United Kingdom, Poland, and the U.S.S.R. The organizing committee was chaired by the famous Taira Suzuki of the University of Tokyo. Suzuki also presented the opening address, following the welcome by T. Fuwa, president of JIM.

The 1979 International Symposium on Hydrogen in Metals in Japan is but one of a series organized annually by JIM in cooperation with overseas technical societies. In 1980, the Fourth International Conference on Titanium will be held and, in 1981, the Fourth International Conference on Rapidly Quenched Metals.

Since the proceedings are promised by 31 March, 1980, no attempt will be made here to review the papers presented in any detail. Many of the papers were not heard in any case, because either double or triple sessions were held at all times, except for a few invited general lectures. These general lectures were:

- Hydrogen Diffusion in BCC Metals-Low Temperature Effects by ONR contractor H. K. Birnbaum, University of Illinois at Urbana-Champaign
- The Partial Molar Volume of Hydrogen in Ferrous Metals and Hydrogen Damage by J. O'M Bockris, Texas A&M University
- Hydrogen Embrittlement in Hydride Forming Metals by T. Suzuki, Science University of Tokyo
- Metal-Hydrogen in Energy Conversion Systems by G. Alefeld, Technische Universität München.

The sessions on "State and Structure of Hydrogen Atoms in Metals," and on the "Nature, Structure, and Hydrogen Applications of Hydrides" were not attended (by the writer) and so will not be discussed. Sessions on the "Adsorption, Dissolution, and Diffusion of Hydrogen Atoms and Related Phenomena" were also largely missed.

With respect to several sessions on hydrogen embrittlement, a number of papers were heard relating to new developments concerning the embrittlement of steels; slip-induced crack formation; microcrack formation following hydrogen aggregation; and, in general, the effects of hydrogen on steels as related to composition, structure and deformation processes, and sequences. Fractographic evidence was cited heavily.

It appears now to be well established that hydrogen movement in a metal, notably in steel, nickel, titanium, and perhaps aluminum, is greatly accelerated by the movement of dislocations as occurs during deformation, general or local. Of course hydrogen also moves by diffusion when an appropriate potential exists. Embrittlement occurs as hydrogen accumulates at traps (defects or impurities) or apparent embrittlement is observed resulting from the promotion of plastic instability along slip lines, therefore promoting void formation. Of course, a third embrittlement mechanism is the formation of brittle hydrides under conditions which promote crack growth.

Where blistering is observed, it has been shown that the effects of inclusion shape is important, and hence the effects of additions of titanium and rare earth metals are significant. The nature of the traps—whether

reversible or irreversible—can be important, as studies by I. M. Bernstein of Carnegie-Mellon University have shown. Irreversible traps always act as sinks and are therefore beneficial to the extent that saturation takes place. Reversible traps act as both sinks and sources of hydrogen and they may be beneficial or not, depending on the alloy, the stress, and the mechanical constraint.

In this connection, the location, species, and amounts of impurities such as the metalloids can be critical, especially in determining the transgranular or intergranular mode of crack propagation. The concentrations of elements such as Mn, Si, and Al, in turn, affect the tendency for intergranular embrittlement through their influence on the metalloid concentration at the grain boundaries. This important work is being carried out by C. J. McMahon, Jr., at the University of Pennsylvania, in collaboration with scientists at Nippon Steel Corporation in Japan with NSF support.

Gaseous hydrogen, as well as aqueous environments which produce stress corrosion cracking, increase the rate of crack growth, depending on the pressure or on the potential. ONR contractor R. P. Wei of Lehigh University showed that the hydrogen-metal interface or surface reaction is the rate-determining process for hydrogen-assisted crack growth in high-strength steels. R. O. Ritchie (M.I.T.) showed that hydrogen reduces the near-threshold crack growth resistance and the threshold ΔK_0 for fatigue in 2-1/4 Cr–1 Mo steel.

Although stress-corrosion cracking almost certainly involves hydrogen embrittlement, the process may be more complex than is generally supposed. Hydrogen must be absorbed and there must be movement of the hydrogen to the reaction site with the lattice. Protective films must be destroyed for this to take place. Scully (University of Leeds) suggests that active path (dissolution) and hydrogen embrittlement mechanisms may operate simultaneously or alternately. The application of cathodic potential, which produces hydrogen, may not promote stress corrosion cracking if, at the same time, the repassivation process is accelerated. The latter occurs in titanium by making the crack tip region more alkaline.

Similar considerations have been highlighted by ONR contractors A. W. Thompson and I. M. Bernstein of Carnegie-Mellon University. They also are thinking in terms of the mutual participation of hydrogen embrittlement and dissolution processes, in aluminum alloys and stainless steel, but also point out the need for further work if important gaps in present knowledge are to be overcome.

There was considerable discussion on the problems of hydrogen-induced cracking in line-pipe steels carrying crude oil or gas contaminated with hydrogen sulfide. No spectacular findings were reported, but there was consideration of some effects of sulfide and insoluble nitride impurities on the nucleation of blisters. Some attempts to develop new simplified tests to evaluate materials in these environments were also described. One of these is the slow extension rate testing (SERT) test developed by Nippon Steel Corporation.

The famous N. Sato of Hokkaido University discussed hydrogen sulfide-catalyzed hydrogen absorption in pure iron and concluded that the ratio of hydrogen absorption rate to the recombination rate of absorbed hydrogen (Tafel reaction) increases with increasing hydrogen sulfide concentration. The proton discharge rate is independent of hydrogen sulfide concentration. Sato also found that the ratio of the hydrogen permeation current to the total cathodic proton discharge decreases with increasing pH.

Abstracts of papers given at this meeting are available at this office and specific ones can be sent to those who request them.

Proceedings of JIMIS-2 may be purchased for 12,000 yen (approximately $55) from:

The Japan Institute of Metals
Aramaki-Aoba
Sendai, Miyagi 980

The conference papers were grouped into the following categories:

- State and structure of hydrogen atoms in metals
- Effects of hydrogen on physical and chemical properties of metals
- Hydrogen embrittlement
- Adsorption, dissolution and diffusion of hydrogen atoms and the related phenomena
- Effect of hydrogen on mechanical properties of metallic materials
- Nature, structure and hydrogen storage application of hydrides
- Effect of hydrogen on the process of welding
- Role of hydrogen in stress corrosion cracking and corrosion.

INTERNATIONAL SYMPOSIUM ON CERAMIC PROCESSING, HAKONE

D. Lynn Johnson and George Y. Onoda, Jr.

An international symposium on "Factors in Densification and Sintering of Oxide and Non-oxide Ceramics" was held in Hakone on October 3-6, 1978. This was the first international symposium in ceramics science in Japan. Approximately 125 scientists and engineers attended the symposium, of which around 25 were from foreign countries. Those countries represented were United States, France, United Kingdom, W. Germany, Yugoslavia, People's Republic of China, and Japan. Noteworthy was the presence of a five-member delegation from the People's Republic of China, the first to appear at an international ceramics meeting in many years. The chairman and secretary of the symposium were President S. Saito and Professor S. Somiya, respectively, of the Tokyo Institute of Technology.

To all concerned, the symposium was considered a success. The foreign scientists had a unique opportunity to become informed on the details of Japanese work, since half of the 50 papers presented were from Japan, with some Japanese being exposed to a body of international persons in the field for the first time. Nearly all of the Japanese papers came from schools or national laboratories. The fact that only two papers came from industry reflects the reluctance of Japanese companies to discuss their research work in public.

Judging from the number of papers presented, the largest amount of work in sintering and densification is being carried out at NIRIM (the National Institute for Research in Inorganic Materials at Ibaraki) and at the Tokyo Institute of Technology. Other contributions came from University of Tokyo, Keio University, Mie University, Osaka University, the National Industrial Research Institute of Kyushu, the Ibaraki Electrical Communication Laboratory, Toshiba Corporation, and Asahi Glass Corporation.

Japan's interests in refractory, high-strength ceramic materials were readily apparent. These materials have potential value as various components in gas turbine engines, turbochargers, and power generators. More than 50% of the papers were related to silicon carbide, silicon nitride, and oxynitrides, three of the primary candidates for these applications. Most of the remaining papers were on various oxides such as alumina, titania and titanates, yttria, lanthanum chromite, and zirconia. A few papers were primarily of a theoretical nature, relating to compaction, sintering, densification, and grain growth.

The following discussions of papers presented at the symposium are grouped according to material, since this basically was how the program was organized. The last group discussed are those papers of a more general nature.

SILICON CARBIDE

The pressureless sintering of silicon carbide was discussed in three papers, with two involving the use of β powder and one involving α powder. H. Suzuki (Tokyo Institute of Technology) discussed the effects of boron and carbon as densification aids for β powder prepared from the reaction of carbon black with silicon monoxide. Mixtures of boron and carbon dopants were more effective than either alone, confirming earlier findings. From a study of grain boundary diffusion kinetics, Suzuki postulated that densification is controlled by diffusion in a grain boundary phase that formed as a result of the dopants. Y. Murata and R. Smoak (Carborundum Company) determined the role of BN, BP, and B_4C in a singering α-SiC. They observed that maximum densification occurred when these additives were present in a concentration equal to their solubility limit at the sintering temperature. S. Prochazka (General Electric Company) examined atmospheric effects in sintering β-SiC. In vacuum, some silicon evolves, leaving a carbon surface layer. Silicon vapor promotes coarsening and strongly

inhibits densification. Nitrogen inhibits densification, but in a reversible manner such that pumping out the nitrogen results in increased densification rate. Carbon monoxide irreversibly inhibits densification because the boron sintering aid is oxidized and volatilizes away.

The high-temperature properties of sintered α-SiC were discussed by J. Coppola and R. Smoak (Carborundum Company). The rate and activation energy for oxidation are less than literature values for sintered SiC. A stress-dependent, slow crack growth was observed at high temperature for a 98% theoretical density body sintered with B_4C and carbon.

The impregnation of reaction-bonded SiC by chemical vapor deposition, using methylchlorosilane, was studied by E. Fitzer (University Karlsruhe, W. Germany). The strength, creep resistance, and oxidation resistance were improved by impregnation. The CVD technique was also used to make SiC composites reinforced with SiC and C fibers. A flexure strength and Young's modulus of 1000 MN/m^2 and 450 $\times$ 10^3 MN/cm^2, respectively, could be achieved in the fiber direction.

SILICON NITRIDE

In the powder preparation area, K. Kijima (NIRIM) described a method involving chemical vapor deposition, in which silane and ammonia were reacted above an induction-heated graphite susceptor. High rates were obtained with nitrogen and hydrogen admixed with the reacting gases. The resulting powder was amorphous to x-rays with a BET surface area of 46 m^2/g; it contained 15.5 wt.% oxygen.

A review of the problems in sintering silicon nitride was presented by P. Popper (British Ceramic Research Association). He discussed reaction bonding, hot-pressing, pressureless sintering under high nitrogen pressures, and hot isostatic pressing. Popper suggested that an attractive method of obtaining high density with a minimum of deleterious grain boundary phases would be to start with a fine silicon powder to which Y_2O_3 has been added, reaction-sinter this up to 1400°C, and then sinter in high nitrogen pressure up to 1800°C. This could lead to high density and high strength.

There were several papers on sintering of Si_3N_4 in high nitrogen pressure. The results of using $BeSiN_2$ or Be_3N_2 were reviewed by C. Greskovich and S. Prochazka (General Electric Company). Sintered material with densities over 90% could be obtained. They observed that minor amounts of impurities such as FeO and CaO, added to high purity Si_3N_4 powder, greatly increase the sinterability but also increase the oxidation rate and the degradation of strength at high temperatures. The use of either MgO or lanthanide oxides (Ln_2O_3, La_2O_3, CeO_2, SmO_2) was discussed by M. Mitomo (NIRIM). With MgO, densities greater than 95% were obtained at 1800°C with 10 atm N_2. With lanthana additions, maximum densities (> 90%) were obtained at 2000°C and 40 atm N_2. The grain boundary phase was believed to react with Si_3N_4 and crystallize.

Hot pressing is at present the most successful method for fabricating Si_3N_4. K. Komeya reported on spin-test studies of prototype single blades at room and elevated temperatures. The blades were made by hot-pressing. Blades were successfully tested at 70,000 rpm with a temperature of 1200°C. The model blades were not of air foil shape. A metal foil or metal plating was used to cushion the root of the blade against the rotor material. Further tests were conducted at 60,000 rpm and 1150°C without the metal foil or blading, with success. Komeya expressed optimism at the success of the ceramic turbine.

Concerned with the problem of scale-up, K. Nishida, M. Komatsu, T. Ochiai, and A. Tsuge, (Toshiba Corporation) investigated the hot-pressing of silicon nitride articles with higher volume production techniques. Their material was Si_3N_4 with Y_2O_3 and Al_2O_3 additives. They heat-treated the powder to crystallize the additives, and then hot-pressed. They found that increasing the thickness of the specimen from 4 mm to 40 mm resulted in a greatly increased scatter in the strength data, a lower average strength, nonuniform second-phase distribution, and nonuniform crystallization, with crystallization being less at the interior than at the surface. To attempt to avoid these difficulties, they heat-treated the powder, then molded and hot-pressed. They observed reduced scatter in the strength, and an improvement in the average strength.

A unique approach for hot-pressing Si_3N_4 was reported by A. Tsuge, K. Komeya, H. Inoue, H. Hashimoto, and M. Komatsu (Toshiba Corporation). Powder mixtures of Si_3N_4, containing 5 wt.% Y_2O_3 and 2 wt.% Al_2O_3, were formed and then presintered at 1750°C in nitrogen to crystallize the glassy second phase. In the pre-firing process, two different microstructures resulted, a skeleton structure and rod-like structure. The pre-fired specimens were then hot-pressed with boron nitride powder as a pressure transfer medium at 1780°C and 49-59 MPa. The skeleton structure densified slowly while the rod-like structure densified in about two hours. The hot-pressed density decreased as the degree of crystallization increased, indicating that a liquid-phase is necessary for good densification. The influences of devitrification were considered in a paper by P. C. Martinego, A. Giachello, and P. Buri (Fiat S.p.A., Italy), presented by P. Popper (British Ceramic Research Association). They added 8% Y_2O_3 and 1% MgO to Si_3N_4, and observed a room-temperature strength of 600 MPa after pressureless sintering. Using DTA and dilatometry, they observed that crystallization of the grain boundary vitreous phase could be achieved at 1100°C in five hours after sintering. The high-temperature strength of the devitrified material was superior to that of the as-sintered material.

M. Kawai and H. Abe (Asahi Glass Corporation) described experiments in which hot-pressed Si_3N_4 was ground to varying degrees of roughness and tested at various temperatures. The flexural strength remained constant until a critical surface roughness was reached, typically 1 μm, above which the strength was degraded. In specimens which had been precracked with a Knoop indenter, the falloff did not occur until 20 μm surface roughness. They also observed that the strength was initially increased at intermediate oxidation times and then fell at higher oxidation times. Their findings are in agreement with results reported by others.

Professor T. K. Wu (Tsinghua University, Beijing) indicated that hot-pressed silicon nitride is being used for cutting tools and also for the rotor tip seals for rotary engines in China. He also indicated that reaction sintering with pure powder and nitrogen was being studied, as well as pressureless wintering with Y and Al additives.

OXYNITRIDE MATERIALS

Systems with Si, Al, O, and N were the subject of several papers. In particular, interest was focused on the β-Sialon phase. G. Petzow, S. Boskovic, and L. Gauckler (Max Planck Institut fur Metallforschung, Germany), and T. Y. Tien (University of Michigan) studied the sintering of $Si_2Al_4O_4N_4$, which can be formed from mixtures of Si_3N_4, AlN, and SiO_2, or of Si_3N_4, AlN, and Al_2O_3. The sintering kinetics of these two formulations are quite different, although the final composition is the same. They observed swelling and weight loss with the composition containing SiO_2, whereas the material containing Al_2O_3 showed less weight loss and good densification. A transient liquid phase forms which causes densification and then disappears as equilibrium is approached. Strength of this material is 315 MPa, and it has very good creep resistance and oxidation resistance. Thermal shock resistance is not very favorable, but can be improved by incorporating a slight amount of glassy phase. Turbochargers made of this material are being tested. T. Y. Tien (University of Michigan) discussed phase equilibria in Si_3N_4-metal oxide systems. He pointed out that the X_1 phase melts at 1710°C and that there is no liquid at 1650°C and lower in properly formulated Sialon materials. He then posed the question as to why these materials lose strength at temperatures much lower than these. His conclusion was that the materials developed thus far do not represent equilibrium conditions, which means that lower melting materials still exist in the grain boundaries. M. Mitomo, N. Kuramoto, and H. Suzuki, (NIRIM, Tokuyama Soda Company, Ltd., and Tokyo Institute of Technology, respectively), investigating the formation of single-phase β-Sialon, also observed nonequilibrium conditions, but, by the proper balancing of compositions, were able to obtain fully dense single-phase β-Sialon with very little evidence of a grain boundary phase. The reactive hot-pressing of β-Sialon was discussed by M. Kuwabara (Kyushu Institute of Technology), M. Benn, F. L. Riley, and R. L. Brook (University of Leeds, U.K.) They used various formulations of Si_3N_4, Al_2O_3, and AlN powders, both in and adjacent to the β'-Sialon phase field. They observed that increasing the Al_2O_3 content increased the densification rate and also the amount of glassy phase. S. Umebayashi and K. Kobayashi (National Industrial Research Institute of Kyushu) prepared Sialon by a reaction process between silicious sand and Al in an N_2 atmosphere. They milled 200 mesh aluminum with sand until the aluminum particle size was about 9 μm, and then used thermogravimetric analysis to study the reaction of this mixture in nitrogen atmospheres. At temperatures above

500°C, aluminum nitride formed, while silicon nitride formed above 1100°C. Under the proper conditions, the reacted product could be densified by hot-pressing.

The Si–Al–Y–O–N system was investigated by H. Tanaka, Y. Hasegawa, and Y. Inomata (NIRIM). Phase relations near the N-phase $Y_3AlSi_2O_7N_2$ were studied. It was concluded that the N-phase was a solubility limit of $YSiO_2N$ to yttrium silicate. J. T. Smith (GTE Laboratories, Inc.) discussed a study of Si_3N_4 and Y_2O_3 compositions with Al_2O_3 densification additives. High surface area Si_3N_4 powder, containing 1.75% oxygen, was thoroughly milled with Si_3N_4 milling media with Y_2O_3 and Al_2O_3 as additives. These were sintered in nitrogen with a final grain size less than 5 μm and sometimes less than 3 μm. Strengths were in the range of 700 MPa at 1000°C, dropping off to about 100 MPa at 1400°C. Without Al_2O_3, the strength was less at lower temperatures, but was degraded less at high temperatures and actually had higher strength at 1400°C. Oxidation of the Si_3N_4–Y_2O_3–Al_2O_3, containing less than 13% Y_2O_3, was very slow.

OXIDES

A number of papers indicated that aluminum oxide continues to be a material of research interest. D. H. Taylor and J. P. Roberts (University of Sheffield, U.K.) investigated the rapid sintering of alumina by a refined method of shadow measurements. They utilized a uniform 4046Å light beam. The light beam passed the ends of the sample and the ends of a reference sample of the same material; the intensity of light which passed was dependent upon the length of the specimen. The transmitted light passed through narrow-band pass filters to photodetectors. The sensitivity of the system was 5 μm in length of the specimen. The specimen was heated in a vitreous carbon specimen holder and susceptor by induction heating, and could be heated from 1200°C to 1950°C in 30 seconds. They determined that the morphology of the powder was far more important than dopants for rapid sintering. Y. Ishitobi, M. Shimada, and M. Koizumi (Osaka University) started with various low-temperature polymorphs of alumina, determined the high-pressure phase diagram for the various forms of alumina, and investigated "Reactive Pressure Sintering of Alumina." They concluded that α-alumina sintered by rearrangement, grain growth, and densification, while η-alumina first transforms to α and then undergoes grain growth and densification, and θ-alumina undergoes grain growth and densification, then transformation, and continuing grain growth, and densification. The latter gave discontinuous grain growth, while the η-alumina showed no appreciable grain growth. The changes in pore structure in the sintering processes of Al_2O_3 was considered by K. Asaga, M. Daimon, R. Kondo, and K. Hamano (Tokyo Institute of Technology). They prepared powders by plasma spheroidization and calcination of various precursors, and studied the surface area, pore size, and pore size distributions using Kr adsorption, mercury porosimetry, and microscopic examination. The pore sizes of fine powders increased with sintering, while that of the larger plasma spheroidized powder shrank. Other observations were consistent with previous sintering studies as well. Y. Ping Tsui and D. L. Johnson (Northwestern University) doped alumina simultaneously with TiO_2 and Fe_2O_3, and studied the influence of TiO_2 and Fe_2O_3 on the sintering of Al_2O_3. They observed that both TiO_2 and Fe_2O_3 enhanced sintering at higher concentrations, and explained their results in terms of cation Frenkel defects in alumina with Ti^{+4} creating cation vacancies and Fe^{+2} creating cation interstitials.

Other studies on primary oxides involved NiO, Y_2O_3, TiO_2, ZrO_2, and Fe_2O_3, with emphasis on the role of dopants. The defect structure and oxygen diffusion of undoped and doped polycrystalline NiO was discussed by S. Shirasaki, Y. Moriyoshi, and H. Haneda (NIRIM). An exchange experiment was used to measure oxygen diffusion coefficients in undoped, and Li_2O- and Al_2O_3-doped, polycrystalline NiO. The high-temperatue activation energy for Al_2O_3-doped material was 133 kcal/mole, while the low-temperature value was 44.4 kcal/mole. Other doping and atmosphere effects were considered by various authors. K. Uematsu, R. M. Cannon, M. Yan, and H. Bowen (MIT) investigated theoretical and experimental microstructure evolution controlled by dopants and pores at grain boundaries. As the initial volume fraction of porosity increases, the ratio of the maximum grain size to the mean grain size also increases. They discussed the role of solutes and pores in reducing grain boundary mobility and grain growth, and presented data for $MgAl_2O_4$, which show a large change in mobility with stoichiometry near the stoichiometric composition. T. Inukai and K. Koga (Ibaraki Electrical Communication Laboratory) considered the effect of dopants on hot-pressing Y_2O_3 ceramics using AlF_3, MgF_2, and Eu_2O_3 dopants in the range between 0.02 and 0.1 wt.%. Hot-pressings were carried out in a argon-nitrogen

atmosphere at temperatures between 1170° and 1700°C. Mean grain sizes for specimens prepared below 1400°C were 0.3 to 0.6 μm, irrespective of the dopant species, and were smaller than those of undoped material. In order to understand mass transport in TiO_2 as induced by capillary forces, T. Kato, K. Matsukawa, K. Kitazawa, and K. Fueki (University of Tokyo) studied the effect of nonstoichiometry on the sinusoidal profile decay of rutile. Using a variety of wavelengths of sinusoidal surfaces, they concluded that volume diffusion controls the sinusoid smoothing. The apparent diffusion coefficient calculated from the smoothing kinetics is essentially independent of oxygen partial pressure from 10^{-12} to 1 atm. Therefore, the defect concentration is extrinsically controlled (probably by impurities). Y. Moriyoshi, O. Maruyama, and S. Shirasaki (NIRIM) examined the grain growth in zinc oxide. The diffusion coefficients obtained from grain growth measurements were found to agree well with that of oxygen volume diffusion in zinc oxide.

T. Nomura and T. Yamaguchi (Keio University) considered the relationship of the character of raw ferrite powders to sintering behavior. They investigated the sintering of Fe_2O_3 powders of various states of agglomeration, and varying milling times. In harmony with other similar investigations, they found that the sintering behavior is closely correlated with the properties of grain compacts, primarily affected by the state of agglomeration and the nature of the agglomerates in the powder. A. M. Anthony (C.N.R.S., France) considered the sintering of dense zirconia ceramics and composites. Stabilized zirconia sintered at about 2000°C for three days at a porosity of about 5% without open pores. Porous zirconia was infiltrated with $LaCrO_3$ to prepare a composite of lower electrical resistivity for use as heating elements.

Multicomponent oxides were discussed in several papers. T. Sata, M. Yoshimura, K. Kuribayashi, and K. Matsumoto (Tokyo Institute of Technology) examined the effect of surface sintering on vaporization rate of multicomponent oxides. Incongruently vaporizing compounds such as $LaCrO_3$ develop a layer of the low-vapor pressure constituent (in this case, La_2O_3). Subsequent vaporization rates depend upon the degree to which this remnant layer sinters and seals the surface. In the above case, the La_2O_3 layer does not sinter, and subsequent vaporization proceeds via linear kinetics. For Ca-stabilized ZrO_2 and $MgAl_2O_4$, on the other hand, the remaining oxide layer sinters and diffusion controlled kinetics obtain. D. Kolar and Z. Stadler (Institute of J. Stefan, Yugoslavia) discussed sintering in a multicomponent system. They showed that the relative fired density of $BaTiO_3$–$SrTiO_3$ powder mixtures showed a minimum at the 50-50 composition. The chemical potential difference between the powder particles gives rise to Kirkendall porosity. Model experiments in which spheres are sintered to planes showed irregular necks similar to those observed by other workers in other heterogeneous systems.

The preparation of glasses without melting was discussed by K. Kamiya and S. Sakka (Mie University). From solid compacts of metal alkoxides, they were able to form glasses of Al_2O_3–SiO_2, TiO_2–SiO_2, ZrO_2–SiO_2, and MgO–SiO_2 which cannot be formed by melting since they crystallize. The alkoxides could be hydrolyzed to increase the viscosity, drawn into fibers, and then heated to pyrolyze and convert to glass fibers. Under suitable conditions they hydrolyzed SiO_2 would form polymer chains which made fiber drawing possible. Pyrolysis of pure SiO_2 fibers at 1000°C gave infrared absorption and x-ray patterns similar to fused quartz.

CARBON

Two papers were presented on the densification of carbon. S. Kimura, S. Kasuya, and E. Yasuda, (Tokyo Institute of Technology) discussed the densification of carbon fiber/carbon composites. They used non-graphitized fibers (50% by volume) with various polymeric carbon sources as matrix. These were pyrolyzed and heat-treated to temperatures as high as 2800°C. The maximum modulus of rupture observed was in the range of 320 MPa. Strength was a strong function of the open porosity, decreasing with increasing porosity. The behavior of boron on sintering and densification of carbon was presented by K. Kobayashi, T. Hagio, and K. Miyazaki (National Industrial Research Institute of Kyushu). Whereas, in normal practice, pitch binder is used as a bonding agent in the manufacture of graphite materials, they found that additions of B_2O_3 or B_4C permitted densification of graphite powder under hot-pressing at 20 to 40 MPa, with relative density of 95% and bend strengths up to about 150 MPa. Some boron was lost during the hot-pressing.

HIGH PRESSURE AND HYDROTHERMAL STUDIES

High-pressure sintering studies at the Tokyo Institute of Technology (TIT) were reported by President Shinroku Saito in the paper "Polycrystalline Compacts of Superhard Substances; High Dense Form of Boron Nitride and Related Materials," and by A. Sawaoka, K. Kondo, N. Hashimoto, and S. Saito in "Very High Pressure Sintering of Covalent Materials." President Saito outlined the history of high pressure research at TIT, describing the piston, belt, and cubic anvil presses with which diamond and high-pressure polymorphs of boron nitride have been synthesized. He also described a two-stage light gas gun in which a piston is propelled by an explosive charge to compress helium or hydrogen. At pre-selected pressures, a disc ruptures and the compressed gas accelerates a projectile to velocities up to 15 km/s. The projectile impacts the specimen in a die contained within momentum traps to prevent scattering of the specimens. By this means they were able to transform graphite-type BN to the wurtzite and zinc blende structures. This material can subsequently be sintered in the cubic anvil press to a dense material with a Vickers hardness number of 7600 kg/mm^2, and a compressive strength of 5.88 GPa (850 ksi).

Sawaoka et al. reported that, even at high pressures, conventional powders of Si_3N_4, SiC, and B_4C cannot be pressed above 95-97% of theoretical density at 1500/1600°C and 50 kb for 15 minutes. However, when the raw powder was mixed with copped powders, pressed to zero porosity, shocked at a half megabar using an explosive technique, leached in HCl + HNO_3, and dried, they could be pressed to 99% of theoretical density at about 1300°C. Nonporous Si_3N_4 was obtained at 1400°C and 50 kb for 15 minutes.

The hydrothermal reaction sintering of Cr_2O_3 and iron oxide was considered by S. Somiya, S. Hirano, M. Yoshimura, S. Itoh, and H. Kanai (Tokyo Institute of Technology). Chromium or iron metal was oxidized under hydrothermal conditions. Pure dense CrO_3 was obtained above 850°C under 98 MPa for three hours.

GENERAL PAPERS

An interesting result in the sintering of monodispersed amorphous silica particles was reported by T. Shimohira, A. Makishima, K. Kotani and M. Wakakuwa (NIRIM). They found that monodispersed amorphous silica spheres of from 0.1 to 0.6 μm diameter, prepared by hydrolysis of tetraethylsilicate, sintered readily only if they were randomly packed or possessed a nonuniform size distribution. Face-centered cubic packings, which were prepared by sedimentation, resisted densification because no rearrangement is possible.

H. Palmour and M. L. Huckabee (North Carolina State University) reviewed their work on rate-controlled sintering, in which the densification rate is the independent variable in a sintering schedule, with the temperature adjusted to provide a predetermined sintering rate program as a function of time. The effectiveness of a three-stage density-time profile, having an initial rapid linear densification rate to 0.75 density, a second slower linear rate to 0.85 density, and progressively slower, log decreasing rate to final density, was described. Finer grain size and more uniform microstructure are obtained compared with conventional methods.

The thermodynamics and mechanism of sintering were discussed by J. Pask (University of California). The importance of reduction of interfacial energy in the system, non-equilibrium dihedral angles, energy imbalances, curvature, anisotropy of grain boundaries, effectiveness of additives in reducing the anisotropy, and local mass transport phenomena were discussed.

A movie of sintering observed by high-temperature scanning electron microscopy was presented by J. Pask for D. N. K. Wang, D. J. Miller, and the late R. M. Fulrath (University of California). It should be noted that Professor Fulrath was undoubtedly the most beloved foreign ceramist among the Japanese, as a result of his many contributions in developing relations between the U.S. and Japan.

The mechanics of stress and green density variations within ceramic compacts was discussed by G. Onoda and F. Urban (University of Florida). The previous work was assessed, and the importance of determining the constitutive equations for compaction was stressed.

TOKYO INSTITUTE OF TECHNOLOGY

Part of the ceramics research at TIT is carried out in the Laboratory of Engineering Materials. The laboratory has six professors, nine associate professors, and 17 associates. Considerable ceramic research emphasis evolves around ultra-high pressure studies (Saito and Sawaoka), hydrothermal studies (Somiya), refractories (Sata), microstructure and properties (Kimura), sintering and grain growth (Hamano), minerals (Iwai), and electrical and magnetic properties (Nakamura). In the department of inorganic materials of the institute, work is ongoing on cement chemistry (Kondo and Daimon), glass (Yamane), analysis (Kato), clay (Osaka), and crystal chemistry (Udagawa).

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Abstracts of papers given at this meeting are available at this office and specific ones can be sent to those who request them.

Proceedings of the International symposium on "Factors in Densification and Sintering of Oxide and Non-oxide Ceramics" may be purxhased for 7,000 yen (approximately $29) from:

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Appendix I

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REPORT ON THE 6TH INTERNATIONAL JOINT CONFERENCE ON ARTIFICIAL INTELLIGENCE

Randall Davis

The International Joint Conference on Artificial Intelligence is held every other year and represents a major gathering of researchers in artificial intelligence (AI).

This year's conference was held in Tokyo, August 20-23, 1979. It was attended by over 600 people, roughly 450 from the host country of Japan, 100 from the United States, and 50 from another 20 countries in Europe and around the world.

The conference ran for four and one-half days, and except during several invited lectures, there were five or six parallel sessions. Some 230 technical papers were presented, covering a dozen different areas of interest, including machine vision, knowledge representation, natural-language understanding, problem solving, robotics, etc. Panel reviews and invited talks offered in-depth discussions of a number of other topics. The conference language was English, but to ease the language barrier, simultaneous translations were given during the invited lectures. A book exhibit, movie festival, photographic display of robotics in Japan, and a number of interesting live demonstrations of programs rounded out the conference.

Judging solely by the number of sessions devoted to a topic and the number of papers presented about that topic, some of the leading areas of current interest are vision, natural language, and applied AI, with problem solving, program synthesis and understanding, and learning as topics of additional interest.

Research in machine vision is concerned wi. t giving a computer the ability to "see," generally by digitizing the output of a television camera, and then having the system interpret the collection of intensity values as objects on the scene. The papers presented dealt with a range of topics including basic issues .e region and edge detection, shape, shading, and texture, as well as more advanced issues like object detection, motion detection, and image analysis.

Work on natural language attempts to make it possible for computers to understand "human" languages like English, rather than formal (programming) languages like LISP or FORTRAN. There were sessions devoted to basic issues such as parsing and semantics, and sessions which dealt with somewhat more abstract issues such as question-answering, dialogue, and discourse.

Work on applications of AI covered a wide range of topics. It included efforts on programs that were intended to function as consultants for difficult problems in geology, biology, medicine, and algebraic manipulation. The geology system attempts to aid in the location and detection of ore deposits. In algebraic manipulation, the MACSYMA program is a large and complex system that has been widely used for a relatively long time. At the conference, a report was presented on the use of a consultant program which helps the naive MACSYMA user. As a result, we have one program guiding the user in the appropriate application of a second program.

(Footnote: Perhaps the best brief definition of AI comes from considering some problems–like diagnosing a disease, proving a theorem, proposing a possible new theorem, or designing a building–complex enough that, if the person can solve the problem, we are likely to say that the person is intelligent. AI is that branch of computer science which attempts to create programs capable of solving those same difficult problems.)

Again comparing primarily on the basis of the number of sessions and total number of papers presented, interest in automated theorem proving seems to have declined in recent years. This year only a single session was devoted specifically to theorem proving, with a second session dealing with methods of deduction.

One cannot, of course, read too strongly into these trends, in part because geography plays an important role. Travel to Japan is very expensive; this no doubt influenced attendance at the conference and the selection of candidate papers.

This year's sessions were devoted to two topics which had not appeared in the previous years. One of these dealt with a field which has only recently come to be widely recognized: cognitive psychology. Very roughly, cognitive psychology is the study of issues which lie in the intersection of AI and psychology. Researchers working in this field are attempting to understand intelligence, both the human and artificial varieties, and to make use of insights about either one to help them with the other. That is, insights about human mechanisms of intelligence may lead to suggestions about building artificially intelligent systems and vice versa.

The second newly-organized session this year presented papers on distributed AI. Distributed AI tries to see how some of the standard paradigms of AI might be implemented on a collection of cooperating processors rather than on a single processor. The central issue appears to be to insure cooperation among processors when each processor is given some degree of autonomy. The work here focusses on what it is that systems might say to one another in order to effect cooperation, rather than how to get the messages back and forth.

Two sessions on architectures for AI dealt with interesting issues of both hardware and software architectures. The current interest in hardware architecture seems to be strongly focussed around the notion of LISP machines--that is, a computer whose basic machine language-level operations are the primitives of a high-level language, LISP. With the recent advances in semiconductor technology and the increasing ease with which new chips can be designed, it becomes plausible to explore new and more sophisticated architectures for machines. One general direction for this exploration has been to implement the primitives of high-level languages more directly in the hardware of the machine itself. This offers great advantages with respect to speed and efficiency of execution of programs written in that language. Since LISP is a widely used language for AI research, the emphasis has naturlaly fallen on the development of LISP machines.

In the session emphasizing the architecture of problem-solving systems, the emphasis seemed to be on exploring parallel architectures. That is, given a system with a large common memory and many processors to work with, how might one employ those processors in order to solve problems more quickly?

Four panel discussions at the conference dealt with topics of technical, historical, and social interest. Randall Davis of M.I.T. chaired a session dealing with uncertainty, which confronted the problem of reasoning in the face of inexact and incomplete information, and of reasoning in the presence of inexact inference rules. These problems appear to be ubiquitous in AI and a large number of different ad hoc techniques have been developed to confront them. Unfortunately, no really good theory exists on how to reason in the presence of uncertainty. The members of the panel gave their views on the nature of the problem, the unresolved issues remaining, the characteristics of a good solution to the problem, and their opinions on the current emphasis on numeric schemes for dealing with uncertainty.

Ed Feigenbaum of Stanford University chaired a fascinating panel on the history of AI research, focussing in particular on the period from 1956 to 1961. Panel sessions on the history of AI are a delightful two-year-old "tradition" of the IJCAI conferences. The field is unique in being so young and, as a result, in having so many of its "founding fathers" still around to describe origins of some of the important ideas in the field. In this year's session, in addition to Ed Feigenbaum, the panel had Saul Amarel (Rutgers University), John McCarthy (Stanford University), and Herbert A. Simon (Carnegie-Mellon University) describing their experiences and their opinions of the important developments of that period.

A panel on the industrial applications of robotics dealt with the potential utility of robotics in industry. The

panel attempted to explore the progress made over the past five years, and examined the reasons why current industrial applications seem not very far advanced over those of several years ago. It also examined what kinds of approaches should be taken to solve current problems and tried to look forward to see what the potential applications of robotics will be in the future.

The fourth panel dealt with the application of language-processing systems. As mentioned, natural-language understanding is an active and important area of AI research. This panel focussed on the prospects for practical application of natural-language understanding. It pointed out that many interesting advances have been made in the field, but, as yet, all existing systems are still primarily experimental. The panel attempted to deal with such questions as: What are the major obstacles to the realization of practical natural-language processing systems? What will be the promising areas of application in the next few years? And finally, what approaches should be taken to insure that these predictions will be satisfied?

Seven invited lectures provided a forum for a number of AI researchers to present their current ideas and suggestions for future directions. Herb Simon of Carnegie-Mellon University spoke about the importance of models of scientific discovery and their possible applications to AI. He talked, in particular, about the work of Lenat on the AM program and the work by Langley on rediscovering basic physics.

Professor Eiichi Goto of the University of Tokyo described the Flats machine, a machine for numerical, symbolic, and associative computing. It is specially designed to be particularly efficient when running numerical and algebraic programs. It has a number of interesting features, including variable precision arithmetic, overflow free arithmetic, associative computation based on content-addressed tables, and a range of hashing hardware and tag mechanisms.

Barbara J. Grosz of SRI International gave an overview of current issues in natural-language communication. She described a range of capabilities that a system would have to have in order to carry out natural-language communication and then evaluated current systems in this light. She pointed out the importance of both language, specific and general, common-sense reasoning capabilities, and the ability to represent and reason about beliefs, goals, and plans.

Alan Bundy of Edinburgh University described the MECCO system, which deals with problem solving in mechanics (e.g., simple pulley and weight problems of elementary statics and dynamics). The emphasis of this research has been on the use of "meta-level" inference (i.e., "knowledge about knowledge") as a problem-solving tool. He described its use in dealing with both the natural-language and common-sense reasoning tasks that arise. Professor Kunikatsu Takase of the Electrotechnical Laboratory in Japan spoke on the skill of an intelligent robot. His talk reviewed the development of the intelligent robot and separated what he called skills from high-level intelligence. Skills include the ability to control and monitor motion and force, and can be represented as virtual mechanisms programmed in software.

Harold Cohen of the University of California at San Diego gave a fascinating and unusual talk entitled "What is an Image?". He described a system he built, called AARON, a program which attempts to model some aspects of image-making behavior. Image making is viewed as a rule-based activity in which certain rules represent various low-level thought processes of design. The program is currently functional and generates a large set of "freehand" drawings. Professor Cohen discussed the theoretical basis for the program and speculated on the nature of creative behavior. This highly unusual combination of art and artificial intelligence offered a fascinating view into the world of art for what was, of course, primarily a scientific audience.

Finally, Earl D. Sacerdoti of SRI International spoke on the topic of problem-solving tactics. He described the basic strategies of automatic problem-solving and focussed on a variety of tactics which might be used to improve their efficiency. He attempted to provide some perspective on, and a structure for the existing set of tactics, and suggested new directions for problem-solving research. Some of the basic strategies included means-ends analysis and backtracking, while tactics included hierarchical planning, hierarchical plan repair, debugging, and constraint satisfaction.

The prestigious Computers and Thought Award went to Professor David Marr of M.I.T. this year. The Computers and Thought lecture was entitled "Visual Information Processing: The Structure and Creation of Visual Representation." The talk dealt with the basic question of what the problems are that the brain solves in order to allow us to see. The talk argued that vision is the construction of efficient symbolic descriptions from the images of the world. The important aspect of vision was seen to be the choice of representations for the different kinds of information in the visual scene. The talk supplied a framework for the different kinds of information in the visual scene and a three-step process for extracting shape information from images. Unfortunately, due to illness, Professor Marr could not present the talk in person; it was presented for him by his colleague, Shimon Ullman.

The distinguished service award of the International Joint Conference on AI was presented to Dr. Bernard Meltzer, formerly of Edinburgh University. Dr. Meltzer gave a talk entitled "Some Speculations on Language" which attempted to broaden the typical perspective taken on natural language. He suggested that communication is not the main function of language and suggested instead that natural language constitutes only a part of the total "language" of an organism.

As the final act of the conference, a site was chosen for IJCAI-81. The meeting will be held in August, 1981, in Vancouver, British Columbia.

Sessions of the conference were as follows:

Vision: image analysis
Natural language processing
Theorem proving
Data bases
Distributed AI
Program understanding
Poster session: vision
Problem-solving issues
History of AI
Vision: shape and shading
Natural Language: dialog & discourse
Vision: texture
Vision: object detection
Applied AI: medicine
Architectures for AI
Reasoning models
Natural language: semantics
Induction and learning
Poster session: applied AI
Planning
Applied AI
Program synthesis
Inexact reasoning
Robotics
Deductive methods
Cognitive psychology
Vision: region and edge detection
Poster session: expert systems & data bases
Games
Induction and learning
Representation
Natural language: question-answering
Natural language: parsing
Vision: motion
Paradigms for knowledge-based systems
Natural language

This proceedings and previous ones are available as follows:

IJCAI-79, Tokyo, Japan, 20-24 Autust 1979. 2 vols.
Copies available for $25.00, payment in advance, book rate; add: $5 for 1st class--U.S., Canada, Mexico; $20 air parcel post elsewhere. Calif. residents and sales tax. Make check payable to IJCAI-79.
Order from: IJCAI-79
Computer Science Dept.
Stanford University
Stanford, CA 94305 USA

IJCAI-77, Cambridge, Massachusetts, USA, 22-25 August 1977. 2 vols, 1005 pp.

Copies available for $25.00, payment in advance, book rate; add: $4 for 1st class–U.S., Canada, Mexico; $20 air parcel post elsewhere. Make checks payable to IJCAI-77.

Order from: IJCAI-77
Department of Computer Science
Carnegie-Mellon University
Pittsburgh, PA 15213 USA

IJCAI-75, Tbilisi, Georgia, USSR, 3-8 September 1975.

2 vols, 944 pp. Copies available for $17.50, payment in advance, book rate; add: $5 for 1st class–U.S., Canada, Mexico; $15 air parcel post Europe, South America; $19 Africa, Asia, Australia, USSR. Make checks payable to IJCAI-75.

Order from: IJCAI-75
MIT-AI Laboratory
545 Technology Square
Cambridge, MA 02139 USA

IJCAI-73, Stanford, California, USA, 20-23 August 1973.

1 vol., 703 pp. Copies available for $15.00, payment in advance, book rate. Make checks payable to SRI International.

Order from: Artificial Intelligence Center, J2044
SRI International
Menlo Park, CA 94025 USA

Advance Papers, Second International Joint Conference on Artificial Intelligence. London, England, UK, 1-3 September 1971. 1 vol., 697 pp. Full size copies available for $85.70; cloth covers, $10.00 extra. Microfilm copies, 35 mm positive, $42.90. Order number OP 65449.

Order from: University Microfilms International
P.O. Box 1467
Ann Arbor, MI 48106 USA
or
University Microfilms International Limited
18 Bedford Row
London, WCIR 4EJ, England UK

Proceedings of the International Conference on Artificial Intelligence, Washington, D.C., USA, 7-9 May 1969. 1 vol., 175 pp.

Full size copies available for $87.50; cloth covers, $10.00 extra
Order number 2004394.

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THE 42ND SESSION OF THE INTERNATIONAL STATISTICAL INSTITUTE, MANILA, PHILIPPINES

Shelemyahu Zacks

INTRODUCTION

The forty-second session of the International Statistical Institute (ISI) was held in Manila, Philippines, 4-15 December, 1979. The ISI meets in full assembly every two years in a different country. The previous session was in New Delhi, India, in December 1977. The next three biennial sessions are scheduled to take place in Buenos Aires, Argentina; Madrid, Spain; and The Hague, Netherlands.

The ISI is a closed international association of statisticians who are elected by peer members on the basis of their academic, applied research, or administrative achievements in the various fields of statistics. Most of the members are professional senior statisticians working in governmental agencies, in agencies of the United Nations, and at universities. Election of new members is performed by a special membership committee every two years from a pool of names petitioned by members. This election is approved by the general assembly of the delegates convening at the biennial sessions. The number of new members elected is restricted by a quota alloted to each country. In addition to the main body of the ISI, there are three professional sections: the International Association of Survey Statisticians (IASS), the International Association of Statistical Computing (IASC), and the Bernoulli Society. The latter consists mainly of mathematical statisticians. Membership in the affiliated sections of the ISI does not require peer election. Many elected members of the ISI are members also of some of the affiliated sections. There are, however, members of the sections who are not elected members of the ISI. The general assembly elects at its biennial meeting a governing bureau and its committees, which function for a period of two years. In addition, there is a permanent small administrative office in The Hague.

Close to 340 members and non-members from all over the world attended the Manila session. In addition, over 100 local persons, mostly government employees, participated in the various scientific and methodological meetings. The meetings took place at the new international convention center on the shore of Manila Bay. The facilities are glamorous, elaborate, and convenient; they are administered by the ministry of tourism. The 42nd Session of the ISI was officially held under the auspices of the government of the Philippines.

MAIN PROBLEMS AND FUTURE DIRECTIONS OF THE ISI

Long deliberations in the Manila meetings were held on three problem areas facing the ISI, namely: integration of the statistical profession; education and training of statisticians; and future directions of the Institute. A brief summary of the problems and the recommendations in each one of these areas is provided.

INTEGRATION OF STATISTICS

A Committee on the Integration of Statistics was set up in Warsaw meeting in 1975 to study the possible gaps between various categories of statisticians around the world and to recommend means and ways to bridge these gaps. The committee was chaired by Professor J. Durbin (United Kingdom, 1978-79) and by Dr. J. W. Duncan (United States, 1976-77), and consisted of members from Spain, Syria, United States, Czechoslovakia, Poland, Japan, Argentina, Brazil, India, Philippines, France, Israel, and Uganda. The Committee based its findings and recommendations on extensive research of the literature, a questionnaire to members of the ISI, and

informal communications. The findings were presented to the assembly of the ISI in a special printed report which was accepted and approved without much criticism. The main points featured in the report are:

1. It is natural and expected to find a high degree of fragmentation in the profession of statistics, due to the wide range of activities to which statistical analysis is applied. The growing specialization in the various fields of theoretical and applied statistics create barriers between statisticians. In particular, there is a growing gap between statisticians at the universities and those in government and industry. Although this gap is not uniform, and there are many examples of a high level of cooperation between theoreticians and practitioners of statistics, the problem in some sectors becomes very acute, especially in underdeveloped countries.

2. Deficiencies were found in statistical education. In particular, there is a tendency, at many universities, to place an undue emphasis on purely mathematical theory at the expense of applications. There was also some criticism of the statistics journals which do not require enough indication of the relevance of the published theoretical studies to the real world. There is also little or no training at the universities of practices in government statistics.

3. The Committee suggested several proposals for the reduction of the gaps between various fields of statistics. The main suggestions are:
   a. Education at universities should emphasize real-life applications. Junior statisticians at universities should be encouraged to be involved in consulting and practical work.
   b. Statistical journals should provide more space for survey and expository papers. Greater prominence should be given to papers in applied statistics.
   c. The ISI should regard the integration of statistics among its major objectives.
   d. The Committee on Training and Education should review curricula in statistics and recommend balanced education and training programs.
   e. Future biennial sessions of the ISI should include several meetings on improving communication and integration within the profession.

STATISTICAL EDUCATION

The Committee on Statistical Education was chaired by Dr. J. Gani (Australia). It consisted of four task forces:

1. Task force on education at the secondary school level.
2. Task force on international conferences.
3. Task force on coordination of training centers.
4. Advisory task force.

The main achievements of these task forces are respectively:

1. A journal, *Teaching Statistics*, was launched last year, to disseminate information on the nature of statistical practices and problems to the secondary school level.

2. An international conference on statistical education is planned for August 8-13, 1982, in Sheffield, England. The objective of the conference is to discuss ways of improving the teaching of statistics.

3. A meeting of the members of this task force was held in Rabat, Morocco, for the purpose of coordinating training centers which are affiliated with the ISI. At the present time, an almanac is being compiled which lists all training centers which have an international character.

4. Media have been developed for exchange of information on the education of statisticians, with an emphasis on computer-assisted instruction.

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FUTURE DIRECTIONS OF THE ISI

The Committee on Future Directions, under the able leadership of J. W. Duncan (United States), submitted over 85 specific recommendations with the aim of moving the ISI into a position of leadership throughout the world. These recommendations included specific steps designed to deal with the follwoing issues:

1. The academy concept for the ISI mission.
2. The integration of the profession and improving the communication with subject matter fields.
3. Regional search committees to increase participation from all parts of the world.
4. Organized program of research and development.
5. Education and training.
6. Regional programs of the affiliated sections.
7. The relationship with national statistical societies.

All the recommendations of the various committees were positively received by the General Assembly of the ISI, which voted to delegate to the newly elected bureau the authority to study the various recommendations and appoint appropriate implementation committees or task forces.

THE SCIENTIFIC PROGRAM

The scientific meetings spanned 29 scheduled sessions of invited talks and 25 sessions of contributed papers. In addition a few poster sessions were also held. The scientific sessions were sponsored by the various sections of the ISI. The invited and contributed papers will appear in the Proceedings of the 42nd Session. The invited lecture sessions can be grouped into the subject areas.

1. Probabilities of Catastrophes
   The session of probabilities of catastrophes was organized by J. Gani (Australia) and featured three lectures. The first talk by P. Todorosic (Canada) described an interesting modeling of extreme value processes for exceedances for the analysis and prediction of floods. The second lecture by H. Bohman (Sweden) discussed an insurance model for large risks with low claims. The third lecture by A. J. Miller (Australia) presented an interesting study on the risk of collision between ships and bridges.

2. General State Space Markov Processes
   The session on General State Markov chains was organized by K. B. Athreya (India). It featured a survey lecture by D. Revuz (France) on limit theorems for Markov chains and processes, an interesting discussion by R. I. Tweedie (Australia), and two contributed papers. The first paper was by L. Billard and M. R. Meshkani (U.S.) on an empirical Bayes estimator for finite Markov chains. The second contributed paper was given by T. W. Anderson (U.S.) on some relations between Markov chains and vector autoregressive processes.

3. Time Series Analysis
   The session on time series analysis was organized by D. R. Brillinger (Canada) and contained three stimulating lectures. The first was by H. Akaike (Japan) on construction of composite time series; the second lecture was by M. Rosenblatt (U.S.) on linearity and non-linearity in time series. The third lecture was given by G. C. Tiao (U.S.) on analysis and modeling of multiple time series. The three lectures were then discussed by T. W. Anderson (U.S.), M. Huzii (Japan), and M. B. Priestly (U.K.).

4. Analysis of Categorical Data
   This session was organized by S. E. Fienberg (U.S.) and included three talks on various aspects of the logistic (log-linear) models for analyzing categorical data. Dr. S. J. Press (U.S.) presented a very interesting multivariate generalization of the log-linear model and its application to empirical data on agricultural survey in the Philippines. Dr. P. McCullagh (U.K.) discussed the merits of a logistic model for analyzing ordinal data. He showed that, for his data, the double-logarithmic (extreme value) model explains the

phenomenon better than the logistic model. The third paper by A. J. Anderson (U.K.) on robust inference using logistic models provided a very promising elaboration of the Cox model.

5. Robustness

The session on robustness was organized by F. R. Hampel (Switzerland). Professor Hampel presented a general introduction to the subject and the main approaches and problem areas. A paper on robust and bounded-influence regression was given by R. E. Welsch (U.S.). He showed the applicability of the method of weighted robust regressions to the analysis of economic data on money papers. Dr. Hampel then presented the paper of B. B. Mandelbrot (France) and M. Taqqu (U.S.) on robust analysis where the data is subject to serial correlation. The papers were followed by interesting discussions of Professors P. Switzer (U.S.) and D. R. Cox (U.S.).

6. Statistical Computing

The area of scientific computing encompassed four sessions of invited talks. These were:

a. Tutorial session on statistical computing;
b. Simulation and optimization;
c. Calculators, personal mini-computers and computers in statistical computing; and
d. Technical information exchange on statistical software.

The organizers of these sessions were, respectively, D. Andrews (Canada), P. A. Lewis (U.S.), J. H. Maindonald (New Zealand) and I. Francis (New Zealand). The sessions were quite informative and interesting, but very specialized.

7. Data-Base Systems

Statistical data-base systems form a most important field of specialization, especially for governmental statistics. There were three sessions on this subject:

a. Statistical Data Base Systems;
b. Techniques for the Processing or Analysis of Large Data Sets;
c. Policies and Procedures for Acquisition and Management of Computer Facilities for Statistical Computing.

The organizers of these sessions were: S. Nordbotten (Norway), I. Francis (New Zealand) and A. M. Farrag (Egypt).

8. Environmental Statistics

This is a rapidly growing field of interesting statistical modeling in the areas of ecology, environmental protection of air and water, forestry and wildlife research, etc. The following sessions were held:

a. Definition and Measurement in Environmental Statistics; and
b. Statistical Ecology.

The organizers of these sessions were Professors K. J. Walton (U.K.) and G. P. Patil (India).

9. Statistics in Geology

There was only one session on statistics in the earth sciences. This session was organized by P. Switzer (U.S.) and contained three lectures and a discussion. The lectures were by J. F. Huntington and N. I. Fisher (Australia) on the identification of structural domains from geological orientation data; by W. Skala (Germany) on geostatistical analysis by exploration of marine deposits; and by N. Gressie (Australia) on variogram estimation by robust regression techniques.

10. Sampling Surveys

The sessions on the theory and applications of sampling survey methods generally occupy a large portion of the scientific meetings of the biennial ISI sessions. A large number of the ISI elected members are survey statisticians. The following sessions on sampling survey took place at the Manila meetings:

a. Rotation and other Resampling Schemes;
b. Incomplete Data;
c. Market Intelligence Surveys;
d. Surveys in Developing Countries;
e. Sampling for Consumer Price Indexes;
f Analysis of World Fertility Survey Data.

The organizers of these sessions were: I. P. David (Philippines), W. G. Madow (U.S.), S. Tulya-Muhika (Uganda), M. N. Murthy (India), B. A. Boyes (U.S.), and V. C. Chidambaram (India).

INTERNATIONAL MEETINGS IN THE FAR EAST

1980–1983

compiled by Seikoh Sakiyama

It is intended to update and augment this list in future issues of the Scientific Bulletin. The assistance of Dr. T. D. C. Grace, Australian Embassy, Tokyo, and Dr. M. J. McNamara, New Zealand Embassy, Tokyo, in supplying a listing of meetings in their countries is deeply appreciated.

1980

Date	Title	Site	For information, contact
April 7-10	International Conference and Exhibition on Liquefied Natural Gas	Kyoto, Japan	Dr. Y. Shibazaki The Japan Gas Association 38, Shiba-Kotohira-cho Minato-ku, Tokyo 105
April 7-11	International Conference on Plasma Physics 1980–Joint Conference of Fourth Kiev International Conference on Plasma Theory and Fourth International Congress on Waves and Instabilities in Plasmas	Nagoya, Japan	Prof. Yoshi H. Ichikawa, Secretary General, ICPP–1980 Institute of Plasma Physics, Nagoya University Furocho, Chigusa-ku, Nagoya 464
April 19-May 8	International Marine Biological Workshop	Hong Kong	Dr. B. S. Morton University of Hong Kong Pokfulam Road, Hong Kong
April 29-30	Ninth BMR Symposium 1980	Canberra, Australia	Mrs. E. E. Young, Bureau of Mineral Resources, PO Box 378, Canberra City, ACT, 2601
May 7-9	International Conference on Structural Foundations on Rock, 1980	Sydney, Australia	The Institution of Engineers, Australia 11 National Circuit, Barton, ACT 2600
May 12-14	Australian Physiological and Pharmacological Society	Brisbane, Australia	Dr. S. R. O'Donnell, Dept Physiology, Uni Queensland, St. Lucia, Qld., 4067
May 12-14	4th National Conference of the Australia Plant Pathology Society	Perth, Australia	Dr. G. D. McLean, Department of Agriculture, Jarrah Rd., South Perth, WA, 6151
May 12-16	Australia-NZ Geomechanics Conferference	Wellington, New Zealand	Victoria University, Wellington

1980–Continued

Date	Title	Site	For information, contact
May 12-16	Australian Biochemical Society Annual Meeting	Melbourne, Australia	Dr. H. C. Robinson, Biochemistry Dept., Monash University, Clayton Vic., 3168
May 12-16	Fifteenth Congress of the Australian and New Zealand Association for the Advancement of Science (ANZAAS)	Adelaide, Australia	Executive Secretary, ANZAAS, 157 Gloucester Street, Sydney, NSW, 2000
May 12-16	Combined International Meeting of the Royal Colleges of Physicians, Surgeons and Paediatricians	Sydney, Australia	RACP, 145 Macquarie Street, Sydney, NSW, 2000
May 19-22	4th International Conference on Titanium	Kyoto, Japan	The Japan Institute of Metals Aramaki Aoba, Sendai 980
May 12-23	Second International Archaean Symposium	Nedlands, W.A. Australia	Dr. J. A. Hallberg, CSIRO Div. of Mineralogy, Private Bag P.O., Wembley, W.A. 6014
May 20-30	Australian Society for Microbiology and the New Zealand Microbiological Society	Dunedin, New Zealand	Australian Society for Microbiology, 191 Royal Pde, Parkville, Vic., 3052 Australia
May 21-30	FAO Indo-Pacific Fishery Commission (IPFC) 19th Session	Kyoto, Japan	Mr. Koji Imamura, Research Division, Fisheries Agency, 1-2, Kasumigaseki, Chiyoda-ku, Tokyo 100
May 26-28	Second Australian Energy Conference	Melbourne, Australia	Dr. D. R. Warren, ARL, GPO Box 4331, Melbourne 3001
May 29	9th International Ceramic Fibers Meeting	Kyoto, Japan	Mr. Hiroshi Kanamura, Kyoto Gaijin Ryoko Center, Kinki Nihon Tourist Co., Ltd., Kyoto Hotel, Nakakyo-Ku, Kyoto 604
May (Tentative)	Annual Conference Australasian Institute of Mining & Metallurgy	(Undecided) New Zealand	Mr. L. S. Jones, New Zealand Branch Australian Institute of Mining and Metallurgy, Box 6342 TE ARO, Wellington
May (Tentative)	Twenty-eighth International Congress of Physiology	(Undecided) Australia	Australian Academy of Science, P.O. Box 216, Civic Square, A.C.T. 2608
May (Tentative)	28th International Congress of Physiology	(Undecided) Australia	Assistant Secretary, Aust. Academy of Science, P.O. Box 216, Civic Square, A.C.T. 2608

1980—Continued

Date	Title	Site	For information, contact
June 1-3	The 8th International Conference on Oral Biology	Tokyo, Japan	Association of Oral Hygiene, 1-38-6, Komagome, Toshima-ku, Tokyo 171
June 5-8	Congress of the International Association for Dental Research	Osaka, Japan	Prof. Y. Kawamura, Dental School, Osaka University, 32, Joan-cho, Kita-ku, Osaka 530
June 9-10	Implantology and Biomaterials in Stomatology	Kyoto, Japan	Prof. H. Kawahara, Osaka Dental College, 1-47, Kyobashi, Higashi-ku, Osaka, 540
June 19-20	Regional Meeting for Burn Injuries in Japan	Sapporo, Japan	Prof. Junji Hamamoto M.D., Dept. of Plastic & Reconstructive Surgery, School of Medicine, Hokkaido University, Kita 14, Nishi 5, Kita-ku Sapporo 066
June 23-26	3rd World Hydrogen Energy Conference	Tokyo, Japan	Japan Convention Service, Inc., Nippon Press Center Bldg. 8F, 2-2-1, Uchisaiwai-cho, Chiyoda-ku, Tokyo 100
June 30-July 4	The Eighth International Liquid Crystal Conference	Kyoto, Japan	Prof. Shunsuke Kobayashi, Dept. of Electric Engineering, Faculty of Technology, Tokyo University of Agriculture and Technology, 2-24-16, Nakamachi, Koganei-shi, Tokyo 184
June 30-July 4	The Seventh International Congress on Catalysis	Tokyo, Japan	Prof. I. Yasumori, Dept. of Chemistry, Faculty of Science, Tokyo Institute of Technology, 2-12-1, Ookayama, Meguro-ku, Tokyo 152
July 7-11	10th IUPAC International Symposium on Carbohydrate Chemistry	Sydney, Australia	Australian Academy of Science, P.O. Box 783, Canberra, ACT 2601
July 9-16	Australian Acoustical Society "Acoustics in the 1980s"	Sydney, Australia	The Australian Acoustical Society, Tenth ICA Executive Committee, The Science Centre, 35 Clarence Street, Sydney, NSW, 2000
July 19-20	ICA—1980 Associated Acoustics Conference	Auckland, New Zealand	ICA—1980 Associated Conference, P.O. Box 1181, Auckland
July 20	10th International Conference on Acoustics	(Undecided) New Zealand	Dr. C. Balachandron, New Zealand Acoustic Society, D.S.I.R. Private Bag Lower Hutt

Date	Title	Site	For information, contact
July 20-August 2	The 2nd International Symposia on Biology and Management of Mangroves and Tropical Shallow Water Communities	Port Moresby, Madang, Papua, New Guinea	The Western Society of Naturalists, Prof. David H. Montgomery, Biological Sciences Department, California Polytechnic State University, San Luis Obispo, California 93407 USA
July 22-25	IAU (International Astronomical Union) Symposium No. 93 "Fundamental Problem in the Theory of Stellar Evolution"	Kyoto, Japan	Prof. D. Sugimoto, Dept. of Earth, Science and Astronomy, University of Tokyo, 3-8-1, Komaba, Meguro-ku Tokyo 153
July 22-29	Vth International Symposium on Biological Control of Weeds	Brisbane, Qld. Australia	CSIRO Div. of Entomology, Private Bag 3, Indooroopilly, QLD. 4068
August 3-9	XVI International Congress of Entomology	Kyoto, Japan	Kyoto International Conference Hall, Takara-ike, Sakyo-ku, Kyoto 606
August 18-22	7th Australasian Hydraulics and Fluid Mechanics Conference	Brisbane, Australia	The Institution of Engineers, Australia, 11 National Circuit, Barton, ACT, 2600
August 18-22	5th Australian Electrochemistry Conference	Perth, Australia	Professor A. J. Parker, Murdoch University, Murdoch, WA, 6153
August 18-22	4th International Conference on Production Engineering	Tokyo, Japan	The Japan Society of Precision Engineering, Seramikkusu Bldg., 2-22-17, Hyakunin-cho, Shinjuku-ku, Tokyo 160
August 24-31	The 21st Congress of International Association of Theoretical and Applied Limnology	Kyoto, Japan	Assistant Prof. T. Miura, c/o Otsu Hydrobiological Station, Kyoto University, Shimosaka-Honmachie, Otsu 520-01
August 25-28	First Asian Seminar on Health and Medical Sociology	Tokyo, Japan	Prof. Mikio Yamamoto, Department of Health, School of Medicine, 1-11-2, Kaga, Itabashi-ku, Tokyo 173
August 25-29	8th Asian Congress of Pharmaceutical Sciences of the Federation of Asian Pharmaceutical Associations	Kyoto, Japan	Japan Pharmaceutical Association, 2-12-15-701, Shibuya, Shibuya-ku, Tokyo 150 Headquarters: The Federation of Asian Pharmaceutical Associations (FAPA), Hizon Bldg., 29 Quezon Bd., Quezon City, Philippines
August 25-29	12th Australian Spectroscopy Conference	Sydney, Australia	Australian Academy of Science, P.O. Box 783, Canberra City, ACT, 2601

1980—Continued

Date	Title	Site	For information, contact
August 25-29	4th National Congress, Australian Institute of Physics	Melbourne, Australia	Dr. R. J. Fleming, Dept. of Physics, Monash University, Clayton, Vic., 3052
August 25-29	Symposium on the Mangrove Environment in Asia	Kuala Lumpur, Malaysia	Prof. Ahmad Nawai, Deputy Vice-Chancellor, University of Malaya, Talipon 54361, SMA 1, Kuala Lumpur, Malaysia
August 25-31	International Conference Manufacturing Engineering	Melbourne, Australia	The Institution of Engineers, Australia, 11 National Circuit, Barton, ACT, 2600
August 25-September 1	The 10th International Cartographic Conference and the 6th General Assembly of the International Cartographic Association	Tokyo, Japan	Mr. K. Nishimura, Japan Map Center, Kudan Pompian Building, 8-8, 4-chome, Kudan-Minami, Chiyoda-ku, Tokyo 102
August 28-30	WHO/SPEC Official Meeting on Technical Co-operation in Pharmaceutical Supplies	Auckland, New Zealand	NZ Health Department, Wellington
August31-September 5	General Assembly, the 15th International Geographical Union, and the 24th International Geographical Congress	Tokyo, Japan	Prof. S. Yamamoto, Rissho University, 16-2-4, Ohsaki, Shinagawa-ku, Tokyo 141
August/September (Tentative)	16th Meeting of the Scientific Committee for Antarctic Research (SCAR)	Queenstown, New Zealand	Royal Society of New Zealand, Box 12249, Wellington
September 1-5	15th International Conference on the Physics of Semiconductors	Kyoto, Japan	Assistant Prof. K. Kamimura, Dept. of Physics, Faulty of Science, University of Tokyo, 1-3-7, Hongo, Bunkyo-ku, Tokyo 113
September 15-19	4th Asian Symposium on Medical Plants and Spices	Bangkok, Thailand	Dr. Vichai Reutrakul, Department of Chemistry, Faculty of Science, Mahidol University, Rama VI Road, Bangkok 4
September 21-28	XXXI Congress of the International Astronautical Federation	Tokyo, Japan	Secretariat, XXXI Congress of the International Astronautical Federation, World Trade Center Bldg., P.O. Box No. 12, Hamamatsu-cho 2-4-1, Minato-ku, Tokyo 105

1980—Continued

Date	Title	Site	For information, contact
September 22-25	Eighth International Conference of Occupational Health in the Chemical Industry	Tokyo, Japan	Prof. N. Takemura, Jikei University, School of Medicine, Minato-ku, Tokyo 105
September 24-27	The 4th International Conference on Magnetic Bubbles (ICMB)	Tokyo, Japan	Prof. H. Kobayashi, Department of Applied Physics, School of Science & Engineering, Waseda University, 3-4-1, Okubo, Shinjuku-ku, Tokyo 160
September 28-October 2	Symposium 1980 I.A.H.R. (International Association for Hydraulic Research), Section for Hydraulic Machinery Equipment and Cavitation	Tokyo, Japan	Prof. Dr. Masaaki Shirakura, Faculty of Engineering, University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo 113
September 29-October 3	The 3rd International Conference on Ferrites	Kyoto, Japan	Prof. M. Sugimoto, Dept. of Electronics, Faculty of Engineering, Saitama University, 255, Shimo-Ohkubo, Urawa, Saitama 338
September 29-October 4	International Conference on Steel Rolling (The Science and Technology of Flat-rolled Products)	Tokyo, Japan	The Iron and Steel Institute of Japan Keidanren Kaikan, 1-9-4, Ohtemachi, Chioyoda-ku, Tokyo 100
September 29-October 4	The 3rd World Conference on Medical Informatics (MEDINFO 80)	Tokyo, Japan	MEDINFO 80 Organizing Committee, c/o MEDIS-DC, Hongo P.O. Box 40, Bunkyo-ku, Tokyo 113-91
September 30-October 4	The 8th International Conference on Computative Linguistic (COLING 80)	Tokyo, Japan	Prof. Makoto Nagao, Department of Electronics Engineering, Faculty of Engineering, Kyoto University, Yoshida-Honcho, Sakyo-ku, Kyoto 606
October 1-3	The 10th International Symposium on Fault-Tolerant Computing	Kyoto, Japan	G. S. Mr. Shoji Watanabe, Kokusai Denshin Denwa Co., Ltd., 2-3-2, Nishi-Shinjuku, Shinjuku-ku, Tokyo 160
October 6-9	The 8th World Computer Congress I.F.I.P. (The International Federation for Information Processing) Congress '80	Tokyo, Japan	Information Processing Society of Japan, Kikai Shinko Kaikan, 3-5-8, Shiba-Koen, Minato-ku, Tokyo 105
October 6-10	Thirteenth Symposium on Naval Hydrodynamics	Tokyo, Japan	Prof. Takao Inui, Department of Naval Architecture, Faculty of Engineering, University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo 113

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Date	Title	Site	For information, contact
October 8-14	The 12th CODATA General Assembly and the 7th International *CODATA Conference*	Kyoto, Japan	Prof. T. Shimanouchi, College of Science, Tsukuba University, Saiki, Sakura-mura, Niihari-gun, Ibaraki 300-31
October 12-17	10th World Congress on Metal Finishing (INTERFINISH '80)	Kyoto, Japan	The Metal Finishing Society of Japan, Kyodo Bldg., 2 Kanda-Iwamoto-cho Chiyoda-ku, Tokyo 101
October 13-15	1980 International Electrical Research Exchange (IERE) Annual Meeting	Tokyo, Japan	The Japan IERE Council, Central Research Institute of Electric Power Industry, Ohtemachi Bldg., 1-6-1, Ohtemachi, Chiyoda-ku, Tokyo 100
October 13-17	The 6th International Symposium on the Transport of Dangerous Goods by Sea and Inland Waterways	Tokyo, Japan	Japan Marine Surveyors and Sworn Measurer's Association, Kaiji Bldg. 1-9-7, Hatchobori, Chuo-ku, Tokyo 104
October 13-17	Electric Energy Conference	Sydney, Australia	The Institution of Engineers, Australia, 11 National Circuit, Barton ACT, 2600
October 14-17	8th World Computer Congress (International Federation for Information Processing)	Melbourne, Vic. Australia	8th World Computer Congress, P.O. Box 880G, Melbourne, Vic. 3001 (Mr. A. W. Goldsworthy, State Govt. Insurance Office (Qld.), Box 1453 G.P.O., Brisbane, QLD. 4001)
October 26-31	The 3rd International Meeting on Radiation Processing	Tokyo, Japan	Research Corporation Section, Administration Division, Takasaki Radiation Chemistry Research Establishment Japan Atomic Energy Research Institute, 1233 Watanukicho, Takasaki-shi Gumma 370-12
October 27-29	International Conference on Welding Research in the 1980's	Osaka, Japan	International Conference Committee Welding Research Institute, Osaka University, Yamada-Kami, Suita, Osaka 565
October (Tentative)	RACI Cereal Chemistry Div. 30th Annual Conference	Melbourne, Australia	Dr. R. A. Orth, Aust. Wheat Board G.P.O. Box 4562, Melbourne, Vic. 3001
October (Tentative)	Fifth International Conference of Endocrinology	Sydney, Australia	Prof. Brian Hudson, University of Melbourne, Parkville, Vic. 2052

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Date	Title	Site	For information, contact
November 3-7	Second Asia and Oceania Congress of Nuclear Medicine	Manila, Philippines	Dr. Flora M. Pascasio, Second AOCNM P.O. Box EA53, Ermita, Manila
November 4-6	Hydrology and Water Resources Symposium	Adelaide, Australia	The Institution of Engineers, Australia 11 National Circuit, Barton, ACT 2600
November 10-14	Magneto Hydrodynamic Congress	Adelaide, Australia	The Institution of Engineers, Australia 11 National Circuit, Barton, ACT 2600
November 10-21	Xth International Conference on Lighthouses and Other Aids to Navigation	Tokyo, Japan	Navigation Aid Dept., Maritime Safety Agency, 2-1-3, Kasumigaseki, Chiyoda-ku, Tokyo 100
November 11	The First World Congress of International Society of Esophageal Diseases	Tokyo, Japan	Dr. K. Nakayama, Director, Nakayama Cancer Institute, 6-7-19, Ginza Chuo-ku, Tokyo 104
November 18-20	Microprocessors Conference	Sydney, Australia	The Institution of Engineers, Australia 11 National Circuit, Barton, ACT 2600
November 24-28	1st International Conference on Technology for Development	Canberra, Australia	The Institution of Engineers, Australia 11 National Circuit, Barton, ACT 2600
November (Tentative)	Geothermal Seminar	Rotorua, New Zealand	NZ Foreign Affairs, Ext. Aid Div. Wellington
December 1-5	4th International Symposium on Nitrogen Fixation	Canberra, Australia	Dr. A. H. Gibson, CSIRO Div. of Plant Industry, Box 1600, Canberra, ACT 2601
December 4-5	Lubrication Conference	Melbourne, Australia	The Institution of Engineers, Australia 11 National Circuit, Barton, ACT 2600

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January 25-31	International Symposium on Erosion and Sediment Transport in Pacific Rim Steeplands	Canterbury, New Zealand	Royal Society of New Zealand, Box 12249, Wellington
January 31-February 4	Conference on Large Earthquakes	Napier, New Zealand	Royal Society of New Zealand, Box 12249, Wellington
Februay 11-18	International Conference on Soils with Variable Charge	Massey, New Zealand	Royal Society of New Zealand, Box 12249, Wellington

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Date	Title	Site	For information, contact
March (Tentative)	Ecotoxicological Problems in the Indo-Pacific Region	Taipei, Taiwan	Dr. Jong-Chin Su, Institute of Zoology Academia Sinica, Taipei 115
April 13-17	International Telecommunications Conference	(Undecided) New Zealand	NZ Post Office, Wellington
April 26-May 1	1st Asian and Pacific Chemistry Congress	Singapore, Republic of Singapore	The Congress Secretary, 1st Aspac Congress, Singapore Professional Center, 129B Block 23 Ontram Park Singapore 0316, Republic of Singapore
May 11-15	4th International Conference on Trace Metabolism in Man & Animals (TEMA)	Perth, Australia	Australian Academy of Science, P.O. Box 783, Canberra City, ACT, 2601
May 11-15	Australian Biochemical Society Annual Meeting	Adelaide, Australia	Dr. H. C. Robinson, Dept. Biochemistry, Monash University, Clayton, Vic. 3168
May 16-22	The 12th IAPH (International Association of Ports and Harbors) Conference	Nagoya, Japan	Nagoya Port Authority, 1-8-21 Irifune, Minato-ku, Nagoya 455
May 23-30	The 12th Conference of the International Association of Ports and Harbors	Nagoya, Japan	Nagoya Port Authority, 1-8-21 Irifune, Minato-ku, Nagoya 455
May (Tentative)	34th Annual Metals Congress	Sydney, Australia	Undecided
May (Tentative)	Electric Energy Manufacturing Conference	(Undecided) Australia	The Institution of Engineers, Australia 11 National Circuit, Barton, ACT 2600
July 19-24	8th International Congress of Pharmacology—IUPHAR—	Tokyo, Japan	The Japanese Pharmacological Society Gatsukai Center Bldg. 4F., 2-4-16 Yayoi, Bunkyo-ku, Tokyo 113
July 27-August 1	The 4th International Congress of Biorheology	Tokyo, Japan	Japanese Society of Biorheology Physics Laboratory, Keio University 4-1-1, Hiyoshi, Kohoku-ku, Yokohama 223
August 10-14	International Congress of Pharmocology	Sydney, Australia	Australian Academy of Science, P.O. Box 783, Canberra City, ACT 2601

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Date	Title	Site	For information, contact
August 21-28	XIII International Botanical Congress	Sydney, N.S.W. Australia	Executive Secretary, Dr. W. J. Cram School of Biological Sciences, University of Sydney, N.S.W., 2006
August 24-26	Vth International Conference on Electrical Bio-impedance	Tokyo, Japan	Prof. K. Nakayama, Dept. of Electrical & Electronic Engineering, Sophia University, 7 Kioicho, Chiyoda-ku Tokyo 102
August 24-28	4th International Conference on Rapidly Quenched Metals	Sendai, Japan	The Japan Institute of Metals Aramaki Aoba, Sendai, Miyagi 980
August 24-28	International Federation of Automatic Control (IFAC) 8th Triennial World Congress	Kyoto, Japan	Prof. Y. Sawaragi, Dept. of Applied Mathematics and Physics, Faulty of Engineering, Kyoto University Yoshida-Honmachi, Sakyo-ku Kyoto 606
August (Tentative)	17th Annual Congress of the Australian and New Zealand College of Psychiatrists	Victoria, Australia	(Undecided)
September 1-5	9th ICAS-XXII CSI (9th International Conference on Atomic Spectroscopy and XXII Colloquium Spectroscopium Internationale)	Tokyo, Japan	The Japan Society for Analytical Chemistry, 9th ICAS-XXII CSI Gotanda-Sanhaitsu, 26-2, 1-chome Nishi-gotanda, Shinagawa-ku Tokyo 141
September 12-18	The 10th International Congress of Electroencephalography and Clinical Neurophysiology	Kyoto, Japan (Undecided)	International Conference Organizers Inc., Crescent Plaza 103, 2-4-6 Minami-Aoyama, Minato-ku, Tokyo 107
September 17-21	The 14th World Congress of International League against Epilepsy and the 13th Symposium of the International Bureau for Epilepsy	Kyoto, Japan	International Conference Organizers Inc., Crescent Plaza 103, 2-4-6 Minami-Aoyama, Minato-ku, Tokyo 107
September 20-23	1981 International Symposium on Gallium Arsenide and Related Compounds	Kanagawa, Japan	Prof. H. Yanai, Dept. of Electronic Engineering, University of Tokyo 7-3-1, Hongo, Bunkyo-ku, Tokyo 113
September 20-25	12th World Congress of Neurology	Kyoto, Japan	Simul International, Inc., No. 9 Kowa Bldg., 1-8-10, Akasaka Minato-ku, Tokyo 107
September 23-25	Australasian Society of Nephrology joint meeting with Cardiac Society	Brisbane, Australia	Dr. B. M. Saker, Renal Unit, Royal Perth Hospital, Perth, WA, 6000

Date	Title	Site	For information, contact
September (Tentative)	International Rock Mechanics Symposium on Weak Rock (Soft, Fractured and Weathered Rock)	Tokyo, Japan	Japan Society of Civil Engineers 1-chome, Yotsuya Shinjuku-ku, Tokyo 160
September/ October (Tentative)	International Union Conservation of Nature and Natural Resources	Christchurch, New Zealand	Lincoln College, Christchurch
October 4-7	4th Congress of International Society for Laser Surgery	Tokyo, Japan	Narong Nimsakul, M.D., Secretary General, 4th Congress of International Society for Laser Surgery, Department of Plastic Surgery, School of Medicine, Tokai University, Boseidai Isehara-shi, Kanagawa Pref. 259-11
October 7-9	11th International Symposium on Industrial Robots	Tokyo, Japan	Mr. Y. Komori, Secretary General Japan Industrial Robot Association 35-8, Shiba-koen, Minato-ku, Tokyo 105
Late October-Early November	FAI the 74th General Conference, 1981 (International Aeronautical Federation)	Tokyo, Japan	Japan Aeronautic Association 1-18-2, Shinbashi, Minato-ku, Tokyo 107
	1982		
May 10-15	General Meeting of the International Association of Geodesy	Tokyo, Japan	Assistant Prof. I. Nakagawa, Geophysical Institute, Faculty of Science Kyoto University, Oiwake-cho, Kita-Shirakawa, Sakyo-ku, Kyoto 606
May 23-28	16th International Congress of Dermatology (CID)	Tokyo, Japan	Japan Convention Services, Inc. Nippon Press Center 8F, 2-2-1 Uchisaiwai-cho, Chiyoda-ku, Tokyo 100
June (Tentative)	Twelfth International Conference of Biochemistry	Sydney, Australia	Prof. W. H. Elliot, Biochemistry Department, University of Adelaide Adelaide, S.A.5000
July 5-10	VI International Symposium on Solute–Solute–Solvent Interactions	Osaka, Japan	Prof. H. Ohtaki, Tokyo Institute of Technology at Nagatsuta, Department of Electronic Chemistry, Nagatsuta Midori-ku, Yokohama 227
Mid-July (Tentative)	The 5th International Congress of Plant Tissue	Yamanashi, Japan	Assistant Prof. A. Komamine, Dept. of Botany, Faculty of Science, University of Tokyo, 7-3-1, Hongo, Bunkyo-ku Tokyo 113

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Date	Title	Site	For information, contact
August 9-September 3	The 5th International Congress of Pesticide Chemistry, IUPAC	Kyoto, Japan	Rikagaku Kenkyusho, 2-1, Hirosawa Wako, Saitama 351
August 15-21	International Biochemical Congress	Perth, Australia	Australian Academy of Science and International Union of Biochemistry P.O. Box 783, Canberra, ACT 2601
August 22-27	Fourth International Conference on Organic Synthesis (IUPAC)	Tokyo, Japan	Prof. T. Mukaiyama, Department of Chemistry, Faculty of Science, University of Tokyo, 7-3-1, Hongo Bunkyo-ku, Tokyo 113
August (Tentative)	The Royal Australian Chemical Institute 7th National Convention	Canberra, Australia	Executive Secretary, RACI HQ 191 Royal Parade, Parkville, Vic. 3052
August (Tentative)	1982 International Conference on Solid State Devices	Tokyo, Japan	The Japan Society of Applied Physics Kikai-Shinko-Kaikan, 5-8, 3-chome Shibakoen, Minato-ku, Tokyo 105
August (Tentative)	International Biochemistry Congress	Perth, W.A. Australia	Australian Academy of Science, P.O. Box 783, Canberra City, ACT 2601
September 5-10	International Conference on Magnetism–1982 (ICM–1982)	Kyoto, Japan	Prof. J. Kanamori, Faculty of Science Osaka University, Toyonaka, Osaka Pref. 560
September 6-10	International Conference on Nuclear Physics in the Cyclotron Energy Region	Osaka, Japan	Prof. M. Kondo, Research Center for Nuclear Physics, Osaka University Yamada-kami, Suita-shi, Osaka Pref. 565
September (Tentative)	6th International Symposium on Contamination Control	Tokyo, Japan	Japan Air Cleaning Association 6-7-5, Soto-Kanda, Chiyoda-ku Tokyo 101
October 4-6	Third International Dental Congress on Modern Pain Control	Tokyo, Japan	Japan Convention Service, Inc. Nippon Press Center 8F., 2-2-1 Uchisaiwai-cho, Chiyoda-ku, Tokyo 100
Undecided	International Conference on Mass Spectroscopy	Hawaii, U.S.A.	Prof. T. Tsuchiya, Basic Science Lecture Room, Chiba Institute of Technology, 1-17-2, Tsudanuma Narashino, Chiba 275
Undecided	International Rehabilitation Medicine Association Fourth World Congress	Sydney, Australia	Prof. G. G. Burniston, Department of Rehabilitation Medicine, Prince Henry Hospital, Little Bay, N.S.W. 2036

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Date	Title	Site	For information, contact
May 10-12	Royal Australian College of Physicians ASM	Sydney, Australia	RACP, 145 Macquarie Street, Sydney NSW, 2000
May (Tentative)	52nd ANZAAS Conference	Perth, Australia	Dr. G. Chandler, University of Western Australia, Nedlands, W.A. 6009
August 1-7	International Association for Dental Research	Sydney, Australia	Mr. Scott Gotjamanos, Department of Pathology, Perth Medical Centre Verdon Street, Nedlands, W.A. 6009
August 17-24	Fourth International Congress of Plant Pathology	Melbourne, Australia	Mr. B. Price, Victorian Plant Research Institute, Department of Agriculture Victoria, Swan Street, Burnley, Vic. 3121
August 27-31	Twenty-fifth International Geographical Congress	Sydney, Australia	Australian Academy of Science, P.O. Box 783, Canberra City, ACT 2601
August 28-September 2	29th International Congress of Physiology	Sydney, Australia	Australian Academy of Science, P.O. Box 783, Canberra City, ACT 2601
August 28-September 3	The 3rd International Mycological Congress (IMC 3)	Tokyo, Japan	Prof. K. Tsubaki, Institute of Biological Sciences, The University of Tsukuba, Sakura-mura, Ibaraki Pref. 305
August 29-September 2	International Union of Physiological Sciences Congress	Sydney, Australia	Australian Academy of Science, P.O. Box 783, Canberra City, ACT 2601
August (Tentative)	International Solar Energy Congress	Perth, Australia	Mr. P. Driver, Honorary Secretary P.O. Box 123, Nedlands, W.A. 6009
October (Tentative)	71st FDI Annual World Dental Congress	(Tokyo), Japan (Tentative)	Japan Dental Association (Japanese Association for Dental Science) 4-1-20, Kudan-kita, Chiyoda-ku Tokyo 102
October (Tentative)	8th International Conference on Calcium Regulating Hormone	(Kobe), Japan (Tentative)	Prof. T. Fujita, 3rd Division, Dept. of Medicine, School of Medicine, Kobe University, 7-13, Kusunoki-cho Ikuta-ku, Kobe 650
October 29-November 3	71st FDI Annual World Dental Congress (Fédération Dentaire Internationale)	Tokyo, Japan	Japan Dental Association (Japanese Association for Dental Science) 4-1-20, Kudan-kita, Chiyoda-ku Tokyo 102
Undecided	Thirteenth International Congress of Chemotherapy	Melbourne, Australia	Dr. B. Stratford, St. Vincent's Hospital 59 Victoria Parade, Fitzroy, Vic. 3065

2ND MEETING OF WORLD FEDERATION FOR ULTRASOUND IN MEDICINE AND BIOLOGY 4TH WORLD CONGRESS ON ULTRASONICS IN MEDICINE

Rudolph J. Marcus

An international meeting on ultrasonics in medicine was held 22-27 July 1979 in Miyazaki, Japan. Although no one from ONR/Tokyo was at this meeting, the abstracts of papers given at this meeting are available at this office and specific ones can be sent to those who request them.

The following symposia:

Physics and engineering in clinical ultrasound
Real-time imaging for ultrasound diagnosis
Comparison of ultrasonic techniques with other approaches
Recent advances in ophthalmic ultrasound
How to use new techniques in echocardiography
Recent progress in abdominal echography
Biometric monitoring of pregnancy by ultrasound
Recent advances in urologic and nephrologic ultrasound
Application of ultrasound in intracranial circulation and pathology,

and panel discussions:

Signal processing for ultrasonotomogram
Problems in standardization of ophthalmic ultrasound
Size measurements of organs
Detection of shunt and regurgitation by ultrasound
Ischemic heart disease
Ultrasonic scanning and other diagnostic modalities for imaging of the pancreas
Ultrasonic diagnosis in infants and children
Screening use of ultrasound
Progress in ultrasound tissue characterization for detection of malignancy
Detection of breast cancer with ultrasound
Real-time imaging in routine obstetrical examination
Visualization of blood flow with ultrasound,

as well as contributed papers, were presented.

Space permits only the listing of symposium speakers, their addresses, and titles of their papers.

Name and Address	Title
– L. Pourcelot Service de Biophysique et Medecine Nucleaire CHU Bretonneau, 37044 Tours, Cedex, France	Vascular imaging

– D. Carpenter Ultrasonics Institute 5 Hickson Road Miller's Point Sydney, N.S.W. 2000 Australia	Multiple mode scanning linear array
– F. Dunn Bioacoustics Research Lab. University of Illinois Urbana, Illinois 61801 U.S.A.	Ultrasonic characterization of biological tissues
– M. Okujima 4-21-10-311, Nishi-Ooi Shinagawa-ku, Tokyo 140 Japan	Acoustic imaging using impulsive sound
– J. C. Somer Dept. of Biophysics University of Limburg P.O. Box 616 6200 MD Maastricht The Netherlands	Real-time ultrasonic imaging by phased array transducer
– P. S. Green Bioengineering Research Center SRI International 333 Ravenswood Ave. Menlo Park, CA 94025 U.S.A.	Advances in high resolution real-time imaging methods
– C. T. Lancee Erasmus University Rm. Ee 2302 P.O. Box 1738 300 DR Rotterdam The Netherlands	Real-time imaging: a 2-way approach
– D. O. Cosgrove Royal Marsden Hospital Downs Road, Sutton, Surrey U.K.	Comparison of electronic and mechanical scanners
– G. Baum Albert Einstein College of Medicine 1300 Morris Park Ave Bronx, New York 10461 U.S.A.	Advantages of ultrasound mammography

– S. Beppu National Cardiovascular Center 5-chome, Fujishirodai Suita 565 Japan	Image of the heart
– R. F. Heimburger Neurosurgery Office Room 139, Emerson Hall Indiana University Medical Center Indianapolis, Indiana 46233 U.S.A.	Comparison of ultrasound with X-ray diagnosis of brain pathology
– D. N. White Etherington Hall Queen's University Kingston, Ontario K7L 3N6 Canada	Ultrasonic techniques for the investigation of carotid and vertebral artery disease
– D. J. Coleman E. S. Harkness Eye Institute 635 West 165th Street New York, New York 10032 U.S.A.	Tissue characterization
– M. Massin 5 Villa Jocelyn 75116 Paris France	Ultrasound and ocular surgery
– H. Gernet Universitats-Augenklinik Westring 15, 4400 Munster F.R.G.	Echometry, correction of unilateral aphakia, and intraocular lens implants
– A. Bertenyi Pozsonyi ut 12 Budapest, H-1137 Hungary	A-mode ultrasound oculometry in retrolental fibroplasia
– P. Greguss Applied Biophysics Lab. Technical University Budapest Krusper u. 2 - 4 H-111 Budapest Hungary	What else could be done in ophthalmic ultrasound?
– S. Tane Dept. of Ophthalmology St. Marianna University School of Medicine 2095, Sugao, Takatsu-ku Kawasaki 213 Japan	Tomographic reconstruction of reflectivity images (recent advances in ophthalmic ultrasound)

– J. Poujol
Centre National d'Ophtalmologie des Quinze-Vingts
28, rue de Charenton
75012 Paris, France

Ultrasonographic measurement of choroidal thickness

– K. Machii
Center for Cardiovascular Disease
Mitsui Memorial Hospital
1, Kanda-Izumicho,
Chiyoda-ku, Tokyo 101
Japan

Ischemic heart disease

– D. Kalmanson
Service de Cardiologie
Foundation A. de Rothschild
25-29, Rue Manin
75019 Paris
France

Clinical use of echo-doppler velocimetry and spectral display for diagnosing acquired and congenital heart disease

– D. G. Gibson
Brompton Hospital
London SW 3 6HP
U.K.

Study of left vintricular function by echocardiography

– F. Weill
Serv. de radiologie A CHU
St. Jacques
25000 Besancon
France

Intrapancreatic canalar structures– ultrasonic patterns

– R. H. Picker
Dept. of Radiology
Royal North Shore Hosp.
St. Leonard 2065
Australia

Recent progress in abdominal ultrasound

– M. Fukuda
Dept. of Medicine
Cancer Research Institute
Sapporo Medical College
Minami 1-jo, Nishi 16-chome
Chuo-ku, Sapporo 060
Japan

Ultrasonic tissue characterization of hepatic and pancreatic malignancies by means of various pulse-echo ultrasound

– H. Lutz
Mediz. Univ. Klinik
Krankenhausstr. 12
D-8520 Erlangen
F.R.G.

Special diagnostic problems of the segmental chronic pancreatitis

– Y. Takehara Kanto Central Hospital 6-25-1, Kamiyoga Setagaya-ku, Tokyo 158 Japan	Clinical application of real-time imaging in digestive system
– R. C. Waag Diagnostic Radiology Box 648 University of Rochester Medical Center Rochester, New York 14642 U.S.A.	Digital processing of ultrasound images
– A. Kurjak Yubinkovac Sture 1 Zagreb, Yugoslavia	Ultrasonic, biometric, and dynamic assessment of small-for-dates babies
– S. D. Levi Hopital Universitaire Brugmann Service de Gynecologie-obstetrique Department d'Echographie Pice Van Gehuchten 4-1020 Bruxelles Belgium	Evaluation of a pregnancy screening for SFD detection by fetal echobrometry using centile distribution of 3 fetal diameters
– H. P. Robinson Professorial Unit Royal Women's Hospital Carlton, Victoria, 3053 Australia	Electronic measurement of fetal trunk area and volume–technique and clinical applications
– W. J. Garrett Royal Hospital for Women Paddington, 2021, Sydney Australia	The fetal umbilical vein–anatomic and functional relationships
– L. Dalla-Palma Director, Institute of radiology-university Ospedale Maggiore, Trieste Italy	Recent advances in nephrologic ultrasound
– T. Niijima Dept. of Urology University of Tokyo 7-3-1, Hongo, Bunkyo-ku Tokyo 113 Japan	Ultrasonic diagnosis of bladder cancer staging
– H. Watanabe Dept. of Urology Kyoto Prefectural Univ. of Medicine Kawaramachi-Hirokoji Kyoto 602 Japan	Recent advances in transrectal ultrasonotomography

– J. Kaneko
Kansai Rosai Hospital
1-69, 3-chome, Inabaso
Amagasaki 660
Japan

The diagnosis of the cerebral vascular disturbances with the ultrasonic doppler flowmeter

– S. Uematsu
398 Blalock
Johns Hopkins Hospital
601 North Broadway
Baltimore, Maryland 21205
U.S.A.

Pulsatile cerebral echo in diagnosis of brain death

– D. Gordon
2 Gooden Court
Harrow, Middlesex HAI 3PZ
U.K.

Doppler ultrasonic measurement of orbital circulation

– F. J. Fry
Ultrasound Research Labs of the Indianapolis Center for Advanced Research, Inc.
410 Beauty Avenue
Indianapolis, Indiana 46202
U.S.A.

Ultrasonic trans-skull visualization and interrogation of adult brain

– M. de Vlieger
Academic Hospital Rotterdam
Dijikzigt Dept. of Electro-Neurology
Dr. Molewaterplein 40
3015–GD, Rotterdam
The Netherlands

Limitations in clinical use of pulsatile echoencephalography

– Y. Tsutsumi
14-7, Yayoi 2-chome
Bunkyo-ku, Tokyo 113
Japan

Intraoperative application of doppler technique on intracranial aneurysms– clinical experiences and model experiments

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