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ORNL FOREIGN TRIP REPORT

ORNL/FTR-3630

DATE: June 1, 1990

SUBJECT: Report of Foreign Travel of V. J. Tennery, Section Head, High Temperature Materials Section, Metals and Ceramics Division

TO: Alvin W. Trivelpiece

FROM: V. J. Tennery

PURPOSE: The traveler visited Japan to discuss research results on structural ceramics at the Government Industrial Research Institute, Nagoya; to review IEA research plans at the Japan Fine Ceramics Center, Nagoya; to tour the Kyocera ceramic manufacturing complex and the corporate research and development laboratory at Kokubu; to attend the annual meeting of the Japan Fine Ceramics Association (JFCA) and accept the International Prize for Mr. A. A. Chesnes of the U.S. Department of Energy in Tokyo; to visit staff of the Ministry of International Trade and Industry (MITI) and of the Agency of Industrial Science and Technology (AIST) in Tokyo; to make a technical presentation to JFCA and MITI staff on fracture analysis results from IEA Annex II research in Tokyo; and to visit the Mechanical Engineering Laboratory of the AIST at Tsukuba.

SITES VISITED:

05/18	Government Industrial Research Institute Nagoya, Japan	T. Ohji
05/18	Japan Fine Ceramics Center Nagoya, Japan	H. Awaji J. Tsubaki
05/21	Kyocera Central Research Laboratory and Structural Ceramics Production Facility Kokubu, Japan	Y. Hamano Y. Oishi M. Matsunaka
05/22	Japan Fine Ceramics Association Tokyo, Japan	T. Ito
05/23	MITI and AIST Tokyo, Japan	S. Nagamatsu T. Yamaura M. Sonai
05/23	Japan Fine Ceramics Association Tokyo, Japan	S. Iwata
05/24	Mechanical Engineering Laboratory AIST Tsukuba, Japan	Y. Uchiyama K. Matsuno

ABSTRACT: The traveler visited the Government Industrial Research Institute in Nagoya to review the status of tensile strength measurement techniques in Japan. Valuable discussions were held with the task leaders for Subtasks 5 and 6 of the IEA Annex II research in Japan at the Japan Fine Ceramics Center. It was determined that funding for the IEA research has not yet been appropriated by the Japanese government; however, this funding is expected to become available in the next two months. It was also determined that the industrial participants in the IEA research in Japan are expected to provide the majority of the funding.

It was determined from a visit to the Kyocera Central Research Laboratory and to the nearby structural ceramic production facility that this company has created highly robotized ceramic production lines, and that one of these lines is currently producing 6000 silicon nitride turbocharger rotors per month. This production level is scheduled to increase to 12,000 rotors per month in August. The current production line includes an automated slip casting unit capable of producing one green state rotor every 2 min. One part of this production line is a fully robotized machining and balancing facility, where rotors are machined and final balanced prior to joining to the metal shaft. Currently, 100% of the green state rotors are visually inspected, and 100% of the rotors are characterized using microfocus X-ray and ultrasonic analyses. The automated machining line was routinely achieving dimensions of ±0.003 mm (±0.0001 in.) in the shaft region of the rotors. In addition, I was told that 100% of the rotors are currently spin tested, but that this evaluation was done elsewhere. These rotors are being manufactured for a major Japanese automobile manufacturer who will be announcing a new turbocharged engine using these components within the next three weeks. The research laboratories at Kyocera are extremely well instrumented, including a Hitachi supercomputer and a broad range of instrumentation for characterizing the composition and properties of ceramic and metallic materials.

The annual meeting of the Japan Fine Ceramics Association included the presentation of several awards, including the International Prize. This year, only the third awardee was recognized for this award. The traveler accepted the prize for Mr. A. A. Chesnes of the USDOE. The award was made in recognition of Mr. Chesnes' long-term support of the use of advanced ceramics in both gas turbine and piston engines, and for his efforts to encourage cooperation in the area of structural ceramics between the United States and Japan.

Meetings with high level staff members of both MITI and AIST provided the traveler with a clear indication that the new 100-kW ceramic gas turbine program in Japan is about to be initiated, that the Japanese government clearly would like to cooperate with the United States in developing measurement standards for various properties of structural ceramics which are critical to their successful commercialization, and that the Japanese government would like to initiate a personnel exchange program with the United States in the area of materials and components of ceramic gas turbine engines.

ABSTRACT (CONT'D): The presentation made by the traveler to members of the JFCA, MITI, and AIST on some of the results obtained in Subtask 4 of IEA Annex II on fracture strength measurements of structural ceramics elicited considerable discussion as to what further work was required before reasonable international strength measuring standards might be available. The Japanese obviously feel that this need is fairly urgent and that lack of such standards is now a major impediment to successful commercialization of these materials in engines of various types. They are also concerned about the cost of establishing such standards in a time frame of one to three years.

The Mechanical Engineering Laboratory of the AIST at Tsukuba is conducting very interesting research on the operative mechanisms during machining of ceramics and metals, and has been studying how the machine tools should be modified to provide the ability to machine materials to much higher tolerances than now possible. Major studies have included determining how the stiffness of grinding machines can be increased while lowering the mass and controlling resonant frequencies of the machine plus techniques for measuring the dimensions of a workpiece to very high accuracy (±0.001 mm or better) while it is being machined. Considerable research has been done in this laboratory to determine the optimum type of diamond grinding wheels required for structural ceramics, particularly silicon nitride. These researchers have also developed a method for electrolytically dressing a grinding wheel while it is in use, and a videotape of the laboratory's projects showed one of these units and the narrator discussed the ability to grind ceramic materials to very high accuracy using this automatic dressing technique.

COMPREHENSIVE TRIP REPORT

Government Industrial Research Institute, Nagoya, Japan

Dr. Tasuki Ohji showed me his laboratory in which most of the ceramic tensile strength research in Japan has been conducted to date. He has developed a technique which employs hot grips (the load application to the specimen occurs inside the furnace) and the load is applied via circular pins oriented perpendicular to the flat ends of the specimen. I was shown a large number of specimens of silicon nitride ready for measurement, and these all had integral "flags" on them for use with a Zimmer light system for measuring specimen strain. The flags were located well beyond the end of the circular gage section of the specimen. Dr. Ohji told me that he felt that he could consistently measure strain with a reproducibility of about 10 µm, although when I asked about the stability of the system at high temperatures, he indicated that perhaps the actual measurable strain value may be higher than 10 µm. The gage section diameter was essentially 3 mm, the original thickness of the flat plate from which the specimens were machined. The gage sections were hand lapped with diamond to reduce surface damage. I was unable to obtain an answer to my question regarding the cost of these specimens, and I was told that one of the technicians at the GIRI had developed the method for making these specimens and that he has essentially made all of them to date.

Dr. Ohji's laboratory has an impressive array of mechanical test machines, including screw machines with both vacuum and air furnaces for both tensile and tensile strength type specimens, plus four dead load machines for use in determining creep properties. He currently has four test machines configured for tensile strength measurements in which the loading rate can be varied. When asked about the budget situation in his research area, he told me that the biggest problem is that they have rather generous funding for new instruments, but essentially no travel funds, and that therefore he even has difficulty visiting different laboratories in Japan. It is presently very difficult for him to obtain funds for foreign travel. Later in this trip, I received a copy of a new Japanese industrial standard for measurement of the tensile strength of high performance ceramics (JIS R 1606), and Dr. Ohji's gripping system is one of four methods cited in the standard. Dr. Ohji will be one of the major investigators in the federal laboratories conducting mechanical property measurements of structural ceramics as part of the new Japanese ceramic gas turbine (CGT) program. He told me that the effort on the already-in-place 300-kW program has been relatively modest, but the present plans call for much more effort on the new 100-kW CGT program which is targeted at vehicle propulsion.

In a discussion about the amount of funds budgeted for this research, I learned that for FY 1990 (started April 1, but no budget has yet been appropriated by the Japanese Diet), the GIRI at Nagoya has a total budgeted staff of 239 people and a total budget of about $17M. These laboratories are budgeted very similar to the U.S. laboratories having government employees in that the budget consists of a part which pays for the personnel and a second part which pays for discretionary research expenditures. It is therefore difficult to determine the exact budget for any given project without knowing the number of personnel assigned. With this in mind, the budget value for the energy conservation technology research, which includes Dr. Ohji's CGT-related research and an effort on recycling aluminum, has a discretionary budget of about $0.26M, with the budgets being about equal for the two different parts. Therefore, the non-personnel (salaries, insurance, and retirement) cost for this effort is about $0.13M for this fiscal year.

Japan Fine Ceramics Center, Nagoya, Japan

The Japan Fine Ceramics Center (JFCC) was constructed partly with government funds, but essentially all of the operating costs are to be provided by industrial companies. The JFCC is located in a very large new building and contains some very impressive equipment. For example, in the JFCC I saw a new JEOL 4000FX transmission electron microscope, two new scanning electron microscopes, a large number of presses, hot presses, a large isostatic press, and a large hot isostatic press. In addition, one laboratory contained about six surface and axial grinding machines equipped with diamond grinding wheels for ceramics. I visited the JFCC specifically to meet Dr. Awaji and Dr. Tsubaki, who are the designated task leaders in Japan for Subtasks 5 and 6, respectively, for the IEA Annex II research on structural ceramics. Dr. Awaji showed me two laboratories containing a large number of mechanical test machines, including a screw machine onto which they intend to install a set of Instron grips for use in the IEA research on tensile specimens. He told me that a total of five machines were being set up in this laboratory for conducting tensile strength measurements, with the one machine having the Instron grips. This machine will be used, in addition to other things, for measuring the five tensile specimens which we will exchange with them, plus others they may obtain from the other national participants. Dr. Awaji asked for the Weibull template which we used for flexural strength data in the earlier Subtask 4 research, and I agreed to provide it to him. We examined the computer with which he plans to do these analyses, and I confirmed that it does have U.S. DOS installed, and that therefore U.S. Lotus should run properly on the computer.

Dr. Tsubaki brought up the issue of problems in Japan with Subtask 6 on characterizing ceramic powders, in that their participating companies are quite upset about being told they must reveal their specimen preparation details and complete instrumental procedures before any of the measurements actually are conducted. I agreed to talk to Dr. Steve Hsu of the National Institute of Standards and Technology (NIST) about this problem. My impression was that the Japanese are not very happy with the present situation.

I was somewhat distressed to learn from Dr. Awaji that in Japan they intend to conduct the flexure strength studies using a flexure fixture having an outer span of 30 mm and an inner span of 10 mm rather than using the 40 mm by 20 mm span fixtures which will be used in the United States, the Federal Republic of Germany, and Sweden as part of the Subtask 5 research. I asked him if some of the measurements could be done on specimens using the 40 mm by 20 mm span fixtures, he said that he wasn't sure and would look into the matter. We then discussed specimen exchange within Subtask 5, and he said that they would like to exchange 10 flexure specimens and 5 tensile specimens, and I agreed that we would do so. I reiterated that our flexure specimens must be 50 mm long in order to provide enough specimen to extend beyond the outer loading pins.

Kyocera Central Research Laboratory and the Kagoshima Kokubu Plant, Kokubu, Japan

Originally, the itinerary had been planned to visit the main corporate facility of Kyocera located at Kyoto. During discussions in the United States between Dr. Y. Hamano, Senior Managing Director, Kyocera Corporation, and Mr. A. A. Chesnes of the USDOE, it was decided that it would be more fruitful for me to visit the main corporate research laboratory and the main structural ceramic manufacturing facility located in Kokubu, Japan. Therefore, I traveled to Kagoshima/Kokubu with Dr. Hamano and was provided with a very thorough orientation and tour of their facilities where all of the silicon nitride ceramics produced by Kyocera are made. This facility currently includes six semiconductor products plants, three electronic components plants, three industrial ceramic plants, plus two others which were unspecified, plus the central research laboratory, an athletic center, and a large dormitory facility for employees. This site currently has 4370 employees.

I was also given a presentation on the latest results of property measurements for Kyocera's new silicon nitride which is identified as SN 260. Considerable data, including SEM microstructural information, were provided. This information shows that SN 260 has a much more uniform microstructure than does SN 252. The latter material has been the best for high-temperature service which Kyocera produced until the development of the newer SN 260. The SN 260 is reported to have a flexural strength of about 550 MPa at 1400°C, whereas the SN 252 material would not support significant stress at this temperature. The current creep failure data presented to me showed no failures at a stress of 345 MPa at 1400°C.

The facilities at Kyocera were most impressive. First, the central research laboratory contained a large number of highly sophisticated instruments which are used for characterizing ceramic and other materials produced by the company. The bulk of Kyocera's business is electrical ceramics, and some of these are manufactured at this site. The company is one of the largest producers of ceramic packaging for large-scale integrated circuits in the world. I was shown a very large testing laboratory where these packages are routinely tested under a number of conditions necessary to certify them for electronic use. The research laboratory contained a transmission electron microscope (JEOL 2000FX); two scanning electron microscopes; an Auger spectrometer; an ESCA spectrometer, sophisticated X-ray spectrometers, including a 13-kW unit used for residual stress analysis; a high-temperature scanning calorimeter; a laser flash diffusivity system; a rather complete computer facility including six terminals all connected to a Hitachi supercomputer including the NASTRAN and CARES programs; and mechanical testing machines including eight creep machines for flexure or tension, four screw machines presently configured for flexure testing, with two now being reconfigured for tensile testing, and two cyclic fatigue machines. Other impressive instrumentation was present in the manufacturing R&D area. This included a cold spin test facility, which can reach about 100,000 rpm, and a hot spin test facility which has been used for AGT (U.S.) rotors in the past.

Second, I was shown several of the manufacturing areas, and was privileged to be shown the automated production line for silicon nitride turbocharger rotors. As noted earlier, Kyocera is currently manufacturing 6000 rotors per month, with a scheduled doubling of this production to start in August. The rotors, made of Kyocera's SN 250 silicon nitride, are produced in a highly automated production line using only a few people (except for inspection) and about six robots from the starting slip to the final green state rotor. Kyocera has decided that injection molding has too many problems for rotor manufacture and has developed a very fast slip casting process. They are capable of producing one rotor every 2 min, and I saw several produced by the special machine designed for this purpose. The green state rotors are all handled by robots, including weighing and initial dimensional checks. All data are entered instantly into a computer system, and each part is uniquely identified and tracked once it is cast. The green rotors are passed to an inspection station which includes about 10 inspectors who examine each part using optical microscopy and the computer display of the data for that part which was previously obtained by the measuring robots. The green rotors are then loaded onto furnace trays by robots and the parts sintered in high-pressure nitrogen. After sintering, the rotors are off-loaded from the furnace trays by robot and passed to a fully automated machining line. In this line, robots measure critical dimensions and the mass, and the computer determines if the rotor should be set aside or be given final machining. At least four robots were handling rotors by feeding them to various grinding machines, while several more were measuring various dimensions. This line prepares the rotors for joining to the metal shaft. I was not shown this joining operation. In several cases, I noted that a specified dimension was ±0.003 mm (±0.0001 in.), and I asked if the machines could routinely finish a dimension to this value and routinely measure to this accuracy. I was told that accuracy and precision checks were performed routinely on the machines and that drift was not a major problem at this control level. I was told that after the rotors are joined to the metal shaft, the rotors are balanced in an automated facility. I did not see this unit. I was told that cold spin testing of these rotors requires 200,000 rpm, and that this testing is done elsewhere.

I asked Dr. Hamano about their choice of silicon nitride powders, and he said that they currently use only powder from Ube Industries, but they are very concerned about having only one powder source. They presently are considering setting up a facility to produce their own powders.

I was also shown a large alumina producing plant and a facility where a very large hot isostatic press and several cold isostatic presses were located. Parts being removed from the cold isostatic presses which I saw frequently measured up to 20 cm in diameter and up to 60 cm long. The hot isostatic press has a capacity of up to 15 cm in diameter and up to about 40 cm length.

Finally, I was offered the opportunity to drive the Subaru automobile with a ceramic piston engine developed and built by Kyocera for MITI. Dr. Hamano told me that Kyocera invested much of its own funds to develop the engine, and that MITI only provided 100,000,000 ¥ (about $650K) for the project. The engine is a four-cylinder horizontal opposed diesel and has all silicon nitride pistons and valves as well as the hot plate, which is made of zirconia. The crankcase is conventional. The small sedan accelerated quite well in the short driving distance available for my test drive.

Japan Fine Ceramics Association, Tokyo, Japan

The annual meeting of the Japan Fine Ceramics Association was the occasion for the recognition of several contributors to the development and/or commercialization of fine ceramics. The author was present at the award ceremony to accept the International Prize for Mr. A. A. Chesnes, USDOE, for his support for use of structural ceramics in advanced engines, including gas turbines, and for his efforts to encourage international cooperation in this area by making the annual Contractor's Coordination Meeting in the United States available to the Japanese, his support for international cooperative research efforts in advanced ceramics through the IEA, and other similar activities. During this ceremony, Showa Denko K.K., Nippon Steel, Ube Industries, and Asahi Glass Company all received awards, but due to the fact that all discussion was in Japanese, I could not determine the nature of their activities which led to the awards.

Ministry of International Trade and Industry, Agency of Industrial Science and Technology, Tokyo, Japan

I was taken to the building in downtown Tokyo in which these two government agencies are located. First, I was introduced to Mr. M. Sonai who is Director, Fine Ceramics Office, MITI. He explained that his mission is to provide funding for various purposes to further the use and applications of fine ceramics in Japan. Next, I was taken to Mr. Nagamatsu's office. I judged that Mr. Sonai works for Mr. Nagamatsu. Mr. Nagamatsu visited ORNL last October as part of the IEA review of the Annex II project. Mr. Ito had previously told me that Mr. Nagamatsu was a particularly powerful person, because he has considerable control over the funding of the new ceramic gas turbine program in Japan and other programs involving advanced ceramic research and development. Mr. Nagamatsu said that we were going to have a short meeting with his supervisor, Mr. Tokio Yamaura, Deputy Director General for Technological Affairs in AIST. We then spent about 15 min in Mr. Yamaura's office. Mr. Yamaura told me that he hoped that Japan and the United States could cooperate in a number of ways in our efforts to utilize structural (fine) ceramics in advanced engines. He said that increasing environmental restrictions and anticipated increases in fuel costs are going to make it important for Japan to be able to utilize a number of fuels in vehicle engines and for them to operate so as to produce much lower emissions than present engines. They foresee that this can be done using new engines, such as the CGT. However, they fully realize that the cost for developing the required materials to the point where their automotive industry will adopt such engines will be very high, and they in Japan are interested in determining ways in which these costs might be shared with other countries, such as the United States. One area in which AIST sees a critical need is in standardization of property measurements. Mr. Yamaura told me that he thinks this must be done somehow with the participation of all interested countries as soon as possible. He feels that the IEA activity is an important first step. After leaving Mr. Yamaura's office, I asked Mr. Nagamatsu what magnitude of budget was included in Mr. Yamaura's responsibility. Mr. Nagamatsu told me that currently, Mr. Yamaura is responsible for 50 B¥ (about $333M) for the current fiscal year, including the new Moonlight project on CGTs. He also explained that contracts from AIST to industry for such programs as the CGT are handled by NEDO, the New Energy and Industrial Technology Development Organization which reports directly to MITI as does the AIST. I later briefly met Mr. Koichi Satoh, Director General, Energy Conversion and Storage Department, of NEDO, who is apparently closely involved with the CGT program in Japan. At the end of this discussion, Mr. Nagamatsu commented to me that it was unfortunate that very little government funds are available for international cooperative research such as the IEA Annex II, while approximately $5M have been appropriated for support of VAMAS activities in Japan. This situation requires very significant cost sharing by participating Japanese companies for the IEA project to succeed.

During our closing discussion, Mr. Nagamatsu said he would like to discuss an issue which he felt was very important. He then provided me a draft entitled, "Reciprocal Researcher Invitation Between U.S.A. and Japan," which described a proposed research exchange agreement which would cover personnel in each country spending approximately 30 days conducting research either on gas turbines or on gas turbine materials in laboratories in the other country. The host institute in Japan would be either an AIST research institute or a company in Japan participating in their CGT project. He is prepared to pay for the U.S. participant's travel expenses represented by economy class round-trip air fare and living expenses of 20,000 ¥ per day (about $130 per day) while the participant is in Japan. He told me that he has these funds available now. He asked if we could reciprocate on this cost. The proposed qualifications of the participants were particularly interesting. For those from Japan, it is proposed that the Japanese researcher be from a national laboratory or a university working in the field of CGT technology, while the proposed qualification of a U.S. researcher going to Japan as part of this program is only that they be a U.S. researcher in the field of CGT technology. It therefore appears that we are being offered much more latitude regarding the personnel which we could select compared to a more narrow restriction on Japanese personnel who would come to the United States.

Japan Fine Ceramics Association, Tokyo, Japan

My presentation on the analysis of fracture properties of structural ceramics resulting from the earlier Subtask 4 research in IEA Annex II was attended by about 30 people, including Mr. Nagamatsu and Mr. Sonai of MITI/AIST, along with many of the people from the federal laboratories and some from industrial laboratories who will be participating in Japan in the new Subtask 5 research on mechanical properties. This included Dr. Awaji from the JFCC, Dr. Ohji from GIRI-Nagoya, Mr. Uchiyama and Mr. Sasaki from the Mechanical Engineering Laboratory-AIST, and many others whom I could not specifically identify. Mr. Iwata of the JFCA provided a well-qualified interpreter which facilitated my presentation. Following my presentation, which lasted approximately 1.5 h, a question and answer period lasted about 10 min. Dr. Nagamatsu was most interested in how long we intended for the research to continue in both Subtasks 5 and 6, and I told him that present plans are for the research to be all completed by the end of calendar year 1991.

Mechanical Engineering Laboratory, AIST, Tsukuba, Japan

At my presentation in Tokyo, Mr. Uchiyama asked if he could come to Narita airport and discuss various subjects before my plane left for the United States the next day. We agreed to meet in the morning at the airport. When we found that I would have about 5 h available, he asked if I would like to visit their laboratory at Tsukuba. We agreed to this arrangement, and arrived at his laboratory about 10:30 a.m. I was introduced to Dr. Matsuno, who is Deputy Director-General of the Mechanical Engineering Laboratory, and he reviewed the status of various research projects. This laboratory has a staff of about 230 people, of which about 30% have doctorate degrees and about 25% have masters degrees. The laboratory conducts research which spans mechanical engineering and materials. For example, much research in the laboratory has been conducted on heat exchanger designs to improve heat transfer and considerable research has also been done on fabricating and evaluating various materials for heat exchangers and determining how these selections affect heat transfer. Considerable work has been done in this laboratory on Stirling engines and hydrogen-fueled engines as well as the hydride storage media for this engine. This laboratory will have a fairly significant role in the forthcoming 100-kW CGT, but I did not learn specific details. Dr. Matsuno told me that the Mechanical Engineering Laboratory is presently undergoing a mandated reduction in available positions of about 3% per year, and that this reduction is being handled through normal retirements.

APPENDIX A

ITINERARY

5/16-17/90	Travel to Osaka, Japan, from Oak Ridge, Tennessee
5/17/90	Travel from Osaka, Japan, to Nagoya, Japan
5/18/90	Government Industrial Research Institute Japan Fine Ceramics Center
5/18/90	Travel from Nagoya, Japan, to Kyoto, Japan
5/19-20/90	Weekend
5/21/90	Travel from Kyoto, Japan, to Kagoshima, Japan Kyocera Central Research Laboratory and Structural Ceramic Production Facility Travel from Kagoshima, Japan, to Tokyo, Japan
5/22/90	Annual meeting of Japan Fine Ceramics Association, Tokyo, Japan
5/23/90	Presented paper, "Cooperative International Structural Ceramics Research Program (International Energy Agency)," to the Japan Fine Ceramics Association, Tokyo, Japan
5/24/90	Travel from Tokyo, Japan, to Tsukuba, Japan Mechanical Engineering Laboratory, AIST, Tsukuba, Japan Travel from Tsukuba, Japan, to Tokyo, Japan Travel from Tokyo, Japan, to Oak Ridge, Tennessee

APPENDIX B

LITERATURE ACQUIRED

1. *Government Industrial Research Institute Nagoya*, brochure describing FY 1990 research projects.

2. T. Ohji, "Towards Routine Tensile Testing," *Int. J. High Technol. Ceram.* **4** (1988) 211-225.

3. Technical leader's summary for IEA Subtask 6, Ceramic Powder Characterization, April 22, 1990.

4. Research Plans for IEA Subtask 5 in Japan, May 15, 1990.

5. *Kyocera - On the Forefront of Technology*, brochure describing the Kyocera Corporation, including its various products.

6. *Outline of Kyocera Corporation, Kagoshima Kokubu Plant and Central Research Laboratory*, brochure describing the number of employees, the layout of various plant buildings, and the organization of the facility.

7. *Properties of SN 260*, brochure containing property data for the latest silicon nitride developed by Kyocera Corporation.

8. *A Synopsis JFCA*, a brochure describing the history of the Japan Fine Ceramics Association, its membership and purposes.

9. *FC Annual Report for Overseas Readers, Fine Ceramics for Future Creation, 1989*, the latest annual report brochure of the JFCA available. Includes description of some of the ongoing research projects.

10. *Fine Ceramics, Engineering Research Association for High Performance Ceramics*, brochure describing research program including several Japanese companies funded partially by the AIST to develop structural ceramics with sufficiently good properties that they can be considered as candidates for use in the CGT program.

11. Makato Sonai, "Promotion of the Fine Ceramics Industry," article containing analysis of budgets in Japan for number of ceramic related research projects supported by MITI/AIST.

12. *Testing Methods for Tensile Strength of High Performance Ceramics at Room and Elevated Temperature*, new Japanese industrial standard, JIS R 1606-1990, published by the Japanese Standards Association, 1-24, Akasaka 4-chome, Minato-ku, Tokyo, 107, Japan (in Japanese).

13. *Testing Methods for Fracture Toughness of High Performance Ceramics*, new Japanese industrial standard, JIS R 1607-1990, published by the Japanese Standards Association, 1-24, Akasaka 4-chome, Minato-ku, Tokyo, 107, Japan (in Japanese).

14. *AIST, Agency of Industrial Science and Technology*, brochure describing the FY 1989 programs and budgets of the AIST.

15. *Moonlight Project, Ceramic Gas Turbine*, brochure published by NEDO describing the 300-kW ceramic gas turbine program.

16. *The Moonlight Project, Developing New Technologies for Energy Conservation*, brochure published by MITI describing a number of energy conservation programs now under way in Japan. Brochure published in March 1989. New version is now in press.

17. *NEDO, New Energy and Industrial Technology Development Organization*, brochure describing a number of energy conservation and other energy-related projects sponsored by NEDO.

18. *Mechanical Engineering Laboratory of the AIST*, brochure describing research projects being conducted in the MEL during FY 1989.

19. *Tsukuba Science City*, brochure describing all of the government research institutes and laboratories located at Tsukuba.

APPENDIX C

DISTRIBUTION

1. J. J. Easton, Jr., Assistant Secretary for International Affairs and Energy Emergencies, IE-1, DOE, Washington
2. A. A. Chesnes, Acting Deputy Assistant Secretary for Transportation Technology, Conservation and Renewable Energy, DOE, Washington
3. J. M. Davis, Assistant Secretary, Conservation and Renewable Energy, DOE, Washington
4. D. J. Cook, Director, Safeguards and Security Division, DOE/ORO
5. J. A. Reafsnyder, Deputy Assistant Manager, Energy Research and Development, DOE/ORO

6-7. Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831

8. P. Angelini
9. B. R. Appleton
10. R. L. Beatty
11. P. F. Becher
12. T. M. Besmann
13. E. E. Bloom
14. R. A. Bradley
15. C. R. Brinkman
16. R. S. Carlsmith
17. D. F. Craig
18. M. K. Ferber
19. W. Fulkerson
20. C. R. Hubbard
21. M. A. Janney
22. D. R. Johnson
23. R. R. Judkins
24. A. J. Moorhead
25. M. A. Karnitz
26. E. L. Long, Jr.
27. T. A. Nolan
28. G. M. Slaughter
29. J. O. Stiegler

30-34. V. J. Tennery

35. T. N. Tiegs
36. A. W. Trivelpiece

37-38. Laboratory Records Department

39. Laboratory Records Department - RC
40. Laboratory Protection Division
41. ORNL Patent Section
42. ORNL Public Relations Office
43. M&C Records Office