ORNL/FTR--3595

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ORNL
FOREIGN TRIP REPORT

ORNL/FTR-3595

DATE: April 19, 1990

SUBJECT: Report of Foreign Travel of Henry Jones
Program Manager, Gas-Cooled Reactor Program

TO: Alvin W. Trivelpiece

FROM: Henry Jones

PURPOSE:

(1) To present an invited paper at the "First JAERI Symposium on HTGR Technologies" in Tokyo, Japan, March 19-22, 1990.

(2) To visit the Japan Atomic Energy Research Institute (JAERI) research centers at Oarai and Tokai and the High-Temperature Test Reactor (HTTR) fuel manufacturing facilities of Nuclear Fuel Industries (NFI) at Tokai.

(3) To participate, in conjunction with the U.S. Department of Energy (US-DOE) sponsor, in coordinating committee discussions under the existing DOE/JAERI High-Temperature Gas-Cooled Reactor (HTGR) Collaboration Agreement. These discussions took place at Tokai and at JAERI headquarters in Tokyo.

SITES VISITED:

3/19-21	JAERI Symposium, Tokyo, Japan (See Appendix A for list of contacts)
3/22	JAERI Oarai Research Establishment, Oarai-Machi, Japan JAERI Tokai Research Establishment, Tokai-Mura, Japan Nuclear Fuel Industries, Ltd., Tokai-Mura, Japan
3/23	JAERI Headquarters, Tokyo, Japan

ABSTRACT:

The US-DOE was invited to attend the "First JAERI Symposium on HTGR Technologies" in Tokyo, Japan, to present papers and to chair a session. Mr. A. C. Millunzi, Director, Division of HTGRs, accepted for the US-DOE and submitted the following paper titles and authors to the conference organizers:

"Present Status and Future Program of HTGR in the USA," Millunzi, A. C. (US-DOE)
"Licensing Overview of the MHTGR," Millunzi, A. C. (US-DOE)
"Modular High-Temperature Gas-Cooled Reactor Design," Bramblett, G. C. (General Atomics)
"Research and Development Associated With Licensing of MHTGR," Jones, H. (ORNL)

The papers were accepted, and the three authors attended the symposium as a US-DOE team. The symposium program and pre-prints of the paper abstracts are attached to this report (Appendix B). Additional papers by U.S. authors from the utility industry will also be found in the program.

This traveler also visited JAERI research establishments, with specific tours and discussions relating to the Japan Materials Test Reactor (JMTR) and HTTR reactors, the Helium Engineering Demonstration Loop (HENDEL), and the Very-High-Temperature Reactor Criticals (VHTRC) assembly test facility. All are involved in research under the DOE/JAERI HTGR Collaboration Agreement. Also visited was the NFI fuel manufacturing facility, where fuel for the HTTR was being processed at the time of our visit. Samples of this fuel are to be irradiated later in ORNL's High Flux Isotope Reactor (HFIR).

Following these visits, there were a number of meetings with JAERI personnel responsible for work under the Collaboration Agreement. These meetings resulted in detailed Actions and Commitments (A & Cs) which will affect the near-term direction of the joint research programs. These have been communicated to the cognizant task managers at ORNL; and, when relevant, they have already been acted upon. They are attached to this report as Appendix C.

See Appendix D for a complete itinerary of this trip.

COMPREHENSIVE TRIP REPORT

The First JAERI Symposium on HTGR Technologies, Tokyo, Japan

The symposium was organized by JAERI to coincide with the imminent start of construction for their High-Temperature Test Reactor (HTTR). Since the subtitle of the program was "Design, Licensing Requirements, and Supporting Technologies," the symposium was not strongly oriented toward scientific papers. Therefore, papers presented generally reviewed the existing state of the art only and provided little new data.

Attendance at this meeting was by invitation and was predominantly from government, industry, and research institutions with individuals at relatively high management levels. The papers presented were, therefore, generally an overview of activities in the speakers' organization/country. The countries represented by individuals attending the symposium were Bangladesh, China (PRC), France, Federal Republic of Germany (FRG), Indonesia, Japan, Switzerland, and the U.S. In addition, Dr. J. Kupitz (Austria) attended as the representative of the International Atomic Energy Agency (IAEA). Attendance by representatives of Russia had been expected (with several papers to be presented), but they were unable to attend at the last minute.

In general, the theme of the meeting was to review where HTGR had come from and its prospects in today's world. The Japanese papers emphasized their optimism and their confidence in the next stage of the development of HTGR in their country, i.e., the construction and operation of the HTTR. They are in the final stages of the licensing process and have broken ground in anticipation of the start of construction in mid 1990. They continue to see advantages in the HTGR for high-temperature industrial processes, and the HTTR will provide the capability for testing the concept, validation of the design, and technology development, with essentially full-scale components. The reactor is a 50 MW(t) design with a targeted core outlet temperature of 1000°C. It is basically a small prototype for their Very-High-Temperature Reactor (VHTR) process heat reactor.

Papers from the other countries with prior HTGR experience were generally not so positive, since recent history is dominated by the premature closing of the only two operating HTGRs, Fort St. Vrain (FSV) in the U.S. and the Thorium High-Temperature Reactor (THTR) in the FRG. In spite of this, the four U.S. papers emphasized the ongoing plans to implement a second generation of modular HTGRs (MHTGRs) with specific and quantified goals of improved safety and reliability, the latter point (reliability) being a weakness that contributed to both premature closings. Papers from the FRG emphasized that ongoing programs for two specific types of HTGR continue, in spite of the recent premature closing of THTR. It was emphasized that the latter was influenced more by financial/political considerations than by technical ones.

Two papers from developing countries were presented and provided a new and interesting perspective. Both countries (Bangladesh and Indonesia) had conducted economic studies of specific applications of the HTGR within the broader constraints of their local economies. The conclusions of both were not favorable, with a strong implication that the HTGR technology would have to be much more mature (proven in operation?) before it could be considered in their environment. This is particularly noteworthy in view of the statements frequently heard, that the unique passive safety characteristics of the MHTGR make it particularly well suited for developing country applications. The Indonesian application was a very large one for improving the yield of heavy petroleum from their Duri oil fields. The paper did not reject the use of HTGR but leaned toward continued use of bootstrap oil burning for the time being with the implication that improvements in MHTGR technology maturity and overall economic competitiveness would be followed closely for future consideration.

My overall impression of this symposium was favorable. It was very well organized, and from the Japanese perspective, very timely because they are entering a new and important phase of their HTGR development. This, until now, has been progressing somewhat slowly and cautiously since 1969. Construction of HTTR represents an accelerating trend in their program. It also represents an opportunity for the US-DOE and ORNL to have access to an important source of data from this new phase, by continued implementation and support for the existing Collaboration Agreement. We must pay special attention to keeping up our side of the agreement in future years in order to have access to this important source of relevant but independent data.

Visits to the Oarai and Tokai Research Establishments

Relatively brief visits to specific JAERI facilities at these establishments were organized primarily to give participants in the symposium an opportunity for a brief overlook of the range of facilities available. Facility descriptions were provided for both establishments and are available in the ORNL Commercial MHTGR files. Specific facilities visited were the JMTR, the future site of HTTR, HENDEL, and the VHTRC critical experimental facility. All of these facilities are either involved in, or are of interest to, the technology development programs which are the subjects of specific Annexes to the Collaboration Agreement. For that reason, this traveler was asked by JAERI personnel to stay overnight at Tokai following the general tour of the establishment, and specific discussions were held regarding the work under Annex 2 (Fuel Development) and Annex 3 (Graphite Materials Technology). This discussion was continued the next day in Tokyo and is described under "Meetings at JAERI Headquarters." (JAERI personnel were T. Oku, M. Eto, and K. Fukuda.)

Visit to Nuclear Fuel Industries, Ltd.

This brief visit was also arranged for the symposium participants, but was noteworthy for the opportunity to see actual HTTR fuel batches in process. The entire process was demonstrated, including the final stage of pressing a fuel compact. This Japanese design is an annular shape, 26 mm outside diameter by 39 mm long, with an 8-mm hole. Triso-coated fuel particles are employed with a 60-micron kernel diameter. This configuration is slightly changed from that currently at ORNL for irradiation in HFIR, and we are being asked to submit a proposal to JAERI for changing to the new design in the HRB-22 capsule. Descriptions of the NFI facilities were provided and are in the ORNL Commercial MHTGR files.

Meetings at JAERI Headquarters, Tokyo

This meeting was arranged as a series of Coordinating Committee meetings to discuss progress and future direction under the existing Annexes 1 through 5 of the Collaboration Agreement, and to make preliminary plans for the next Steering Committee meeting. (Coordinating committees govern the work plans under each Annex, and the Steering Committee governs the activities under the entire agreement.)

Attendees:

USA: Andrew C. Millunzi, US-DOE (NE), Director, Division of HTGRs.
Milton A. Eaton, Sr. Rep., US-DOE, U.S. Embassy, Tokyo.
James L. Scott, US-DOE (NE) Technical Advisor in Japan, Tokyo
Henry Jones, Program Manager, Commercial MHTGR, ORNL.

JAPAN: Shinzo Saito, Director HTTR Project, JAERI
Motokuni Eto, Principal Research Engineer, JAERI
Hajime Nakajima, Manager, Materials Lab., JAERI
Tatsuo Oku, Head Materials Lab., JAERI
Masahide Suzuki, Materials Lab., JAERI

Annex 1: The subject of this annex is the irradiation of Japanese (Toshiba) fission chambers for HTGR service. The U.S. had originally agreed to arrange for this work to be carried out in FSV, but this is now impossible. An alternative of irradiation in HFIR has been proposed, but this will involve additional cost, since in FSV the neutrons would have been free of cost. JAERI would like to have an estimate of this cost, and DOE accepted two A & C items, one of which was delegated to ORNL and has already been completed. (See Appendix C for A & C lists.)

Annex 2: The subject is irradiation of JAERI fuel for HTTR by ORNL. This was to have been accomplished in capsule HRB-22 in HFIR. Due to the extended delay in HFIR restart, the original fuel supplied by JAERI is now obsolete; and they would like to replace it with their latest design. This will require dissassembly of the capsule and some modification of the internals due to small configuration changes in the new fuel. ORNL had already indicated that this would be feasible in principle, but had not yet performed a definitive estimate of cost. DOE, on behalf of ORNL, agreed to accept an A & C item committing to supplying that estimate by April 15. This estimate was subsequently prepared and sent to DOE by ORNL for transmittal to JAERI through their Washington office.

Annex 3: The subject is graphite materials technology development. This area has received frequent attention from the task managers from both countries and is making good progress. While a number of A & C items were generated by this meeting, they are of a relatively routine and detailed nature. Their handling at ORNL should be routine.

Annex 4: This annex is for exchange of metals technology development results. The proposed work scope has existed for some time, but implementation on the U.S. side has been slow due to funding limitations. There is continued (and enhanced) interest on the U.S. side, however. The purpose of this meeting was, therefore, to reiterate this interest and to make a proposal for a scope of data to be exchanged. JAERI accepted an A & C item to review the U.S. proposal and to respond during April. Their response has recently been received. The next action here will be to submit the proposed scope to the Steering Committee for approval.

A part of the enhanced interest in this annex is due to the U.S. studies on advanced MHTGR versions with higher core outlet temperatures. This has been the JAERI objective throughout their development. For that reason they probably have some very good data to share. For example, during this meeting they were very enthusiastic about progress on an alloy they have been developing for some time based on the metallurgical system Ni/Cr/W. They stated that this alloy was proving to be superior in all respects to their previously developed low Cobalt Hastelloy X, and they were expecting to use it in all the metal components in the hot end of the HTTR coolant loop.

Annex 5: This program has many elements and was recently the subject of a coordinating committee meeting in Washington (February 20, 1990) and at ORNL (February 21, 1990) which generated a number of A & Cs. (Ref. letter by A. C. Millunzi dated February 23, 1990.) Therefore, although some time was spent at this meeting on a discussion of possible new areas for cooperation, none were identified and there are no new A & C items.

Mr. Millunzi was particularly interested in whether JAERI wished to cooperate in development validation of analytical methods (and codes), but there was zero interest from JAERI. When pressed they basically said, "We are more interested in building our reactor." Furthermore, the HTTR is intended to demonstrate the technology experimentally.

Another item discussed was the possibility of joint programs in HENDEL and the Oarai Gas Loop. JAERI representatives were not encouraging. Their usage of these facilities is falling off; therefore, it is no longer cost effective to use them. They will be subordinate to HTTR in their budget/manpower planning, and there is serious consideration of dismantling both. They are open to outside use, but would have to charge enough to swing their own negative evaluation of the cost/benefit ratio for these facilities.

Steering Committee: Two A & Cs relating to the Steering Committee for the DOE/JAERI Collaboration Agreement were generated and agreed to by both parties at this meeting (see Appendix C). One is for JAERI to set a specific date for the next Steering Committee meeting (expected to be around June 1990 in Washington), and the other is for DOE to draft the text of an extension to the existing agreement. Both were due March 30, 1990.

APPENDIX A

LIST OF PERSONS CONTACTED

(FROM THE SYMPOSIUM ATTENDANCE LIST)

BANGLADESH	Choudhry Sazzadul Karim Principal Scientific Officer Nuclear Power & Energy Division Bangladesh Atomic Energy Commission
INDONESIA	Mursid Djokolelono Director, Centre for Nuclear Energy Studies National Atomic Energy Agency (BATAN)
	Himawan M. Samudro Professor of Mechancal Engineering Bandung Institute of Technology (BIT)
	Iyos Subki Deputy for Assessment of Nuclear Scince and Technology National Atomic Energy Agency
ITALY	Luigi F. Noviello Project Manager, Advanced Reactor Program ENEL
FRANCE	Daniel Bastien Coordinator for Gas Cooled Reactor Commission a L'Energie Atomique (CEA) Centre d'Etudes Nucleaires
	J. F. Veyrat Head of Department, CEA Centre d'Etudes Nucleaires de Grenoble
FRG	Erhard K. W. Arndt Project Manager HTR-500 Marketing of HTR's Gesellschaft fuer Hochtemperatur- reaktoren (HTR-GmbH)

Erwin Balthesen
Director,
Forschungszentrum Juelich GmbH
(KFA-PTH)

Herbert Diehl
Head, Division for Fossil Energy
and High Temperature Reactors
Fed.-Ministry for Research
and Technology

Horst W. Hassel
Vice President, CECCN
NUKEN GmbH

Norbert Kirch
Head of Project,
Forschungszentrum Juelich GmbH
HTA-Projekt

Rudolf Schulten
Member of Board, Thyssen Industries
Rheinisch-Westfaeliscre Technische
Hochschule-RWTH-Aachen

Isidor Armin Weisbrodt
Marketing and Sales manager
Gesellschaft fuer Hochtemperatur-
reaktoren (HTR-GmbH)

PRC

Wang Dazhong
Director,
Institute of Nuclear Energy Technology
(INET)
Tsinghua University

SWITZERLAND

Gerard Sarlos
General Manager,LASEN EPFL

UK	J. R. Askew Programme Director UKAEA Tecnology Harwell Laboratory
	N. W. Davies Thermal Reactor Collaboration Manager UKAEA Risley
USA	George C. Bramblett Director(Acting), MHTGR-NE Project General Atomics
	Harold L. Gotschall GCRA
	Henry Jones Program Manager, Commercial MHTGR Oak Ridge National Laboratory
	William E. Kessler Project Manager Consumers Power Co.
	Luther Daniel Mears General Manager Gas-Cooled Reactor Associates
	Andrew C. Millunzi Director, HTGR Division Office of Nuclear Energy (NE-451)

J. L. Scott
Advisor to DOE in Japan

Walter A. Simon
Director, Business Development
General Atomics

USSR

Anatoly Egorikov
The Ministry of Atomic Power
and Industry of the USSR

Vladislav Golovko
The Construction Bureau of
Machine Building

Igor Mosevitsky
I. V. Kurchatov Institute of
Atomic Energy

IAEA

Juergen Kupitz
Head, Section on
Nuclear Power Technology Development
International Atomic Energy Agency

<u>JAPAN</u>

安 成弘 Dr. An Shigehiro	Chairman of the RAHP
荒木 隆夫 Mr. Araki Takao	Toshiba Corporation
江森 敬樹 Mr. Emori Takaki	The Kansai Electric Power Co.,Inc.
深井 佑造 Mr. Fukai Yuzo	Toshiba Corporation
更田 豊治郎 Dr. Fuketa Toyojiro	Japan Atomic Energy Research Institute
早川 均 Mr. Hayakawa Hitoshi	Fuji Electric Co., Ltd.
林 喬雄 Dr. Hayashi Takao	The Japan Atomic Power Co.
井田 勝久 Mr. Ida Katsuhisa	Science and Technology Agency
井上 登代一 Mr. Inoue Toyokazu	Toshiba Corporation
板倉 哲郎 Dr. Itakura Tetsuro	The Japan Atomic Power Co.
伊東 光義 Mr. Itoh Mitsuyoshi	Ishikawajima-Harima Heavy Industries, Co.,Ltd.
祝迫 重明 Mr. Iwaisako Shigeaki	General Secretary of the RAHP

小嶋 正幸 Dr. Kojima Masayuki	FBEC
舞田 靖司 Mr. Maita Yasushi	Mitsubishi Heavy Industries, Ltd.
飯井 敏夫 Mr. Meshii Toshio	Mitsubishi Heavy Industries, Ltd.
村田 浩 Mr. Murata Hiroshi	Japan Atomic Industrial Forum, Inc.
中川 群 Mr. Nakagawa Gun	Mitsubishi Heavy Industries, Ltd.
中川 弘 Mr. Nakagawa Hiroshi	The Japan Atomic Power Co.
中野 秀男 Mr. Nakano Hideo	Fuji Electric Co., Ltd.
中尾 昇 Mr. Nakao Noboru	Hitachi, Ltd.
中山 勝馬 Mr. Nakayama Katsuma	The Japan Atomic Power Co.
緒方 謙二郎 Mr. Ogata Kenjiro	Science and Technology Agency
大野 哲雄 Mr. Ohno Tetsuo	Mitsubishi Atomic Power Industries, Inc.
太田 博 Mr. Ohta Hiroshi	Ministry of Foreign Affairs
斉藤 伸三 Dr. Saito Shinzo	Japan Atomic Energy Research Institute

佐野川 好母 Dr. Sanokawa Konomo	Japan Atomic Energy Research Institute
佐藤 貞 Mr. Satoh Sadamu	Tokyo Electric Power Co.
高橋 洋一 Dr. Takahashi Yoichi	Tokyo University
武田 充司 Dr. Takeda Atsushi	The Japan Atomic Power Co.
武井 満男 Prof. Takei Mitsuo	Nagoya Economics University
竹之下 正隆 Mr. Takenoshita Masataka	BABCOCK-HITACHI K.K.
武谷 清昭 Dr.Taketani Kiyoaki	Chuo Univ.
田中 好雄 Mr. Tanaka Yoshio	The Japan Atomic Power Co.
田中 義久 Mr. Tanaka Yoshihisa	Kawasaki Heavy Industries,Ltd.
谷口 富裕 Mr. Taniguchi Tomihiro	Agency of Natural Resource and Energy
Mrs. Taniguchi	
上田 隆 Mr. Ueda Takashi	The Japan Atomic Power Co.
内田 秀雄 Dr. Uchida Hideo	Nuclear Safety Commission
梅野 誠 Mr. Umeno Makoto	Mitsubishi Heavy Industries, Ltd.

占部 茂美 Mr. Urabe Shigemi	Ishikawajima-Harima Heavy Industries
若林 宏明 Dr. Wakabayashi Hiroaki	Tokyo Univ.
渡部 一徳 Mr. Watanabe Kazunori	GA Technologies Inc.
渡部 隆 Mr. Watanabe Takashi	Kawasaki Heavy Industries,Ltd.
山田 正夫 Mr. Yamada Masao	Fuji Electric Co.,Ltd.
米川 源人 Mr. Yonekawa Gento	Assistant Secretary of the RAHP

APPENDIX B

PROGRAM FOR

THE FIRST JAERI SYMPOSIUM ON HTGR TECHNOLOGIES

WITH

ABSTRACTS OF THE PAPERS

(The full Symposium Proceedings will also be available and will be filed in the Commercial MHTGR files when published.)

The 1st JAERI Symposium on HTGR Technologies

—— Design, Licensing Requirements and Supporting Technologies ——

March 19～20, 1990 at Toranomon Pastoral, Tokyo

Organized by The Japan Atomic Energy Research Institute
Supported by The Atomic Energy Society of Japan

Program

March 19 (Monday)

8:30～ 9:00			Registration
9:00～ 9:10			Opening Address — Ihara, Y. (JAERI)
9:10～10:40		**Session 1**	**Invited Lectures** Chairman: Ikuta, T. (JEERI)
	9:10～ 9:25		Perspectives on utilization of nuclear energy and HTGR in Japan — Mukaibo, T. (JAEC)
	9:25～ 9:40		International aspects of HTGR development — Kupitz, J. (IAEA)
	9:40～10:40		History, salient features and prospectives of HTGR — Schulten, R. (TH. Aachen)
	10:40～11:00		**Coffee Break**
11:00～18:00		**Session 2**	**Basic Strategy for Development of HTGR and Present Status of HTGR Design** Chairman: Kupitz, J
	11:00～11:20		Current status and future plan of HTGR in Japan — Ida, K. (STA)
	11:20～11:40		Present status and future program of HTGR in the USA — Millunzi, A. C. (DOE)
	11:40～12:00		Utility/User requirements for and assessment of the MHTGR Kessler, W. E. (CPC), Mears, D. (GCRA)
	12:00～12:30		Experience in development and operation of HTGR in Germany and its prospects Balthesen, E. (KFA), Diehl, H. (BMFT)
	12:30～14:00		**Lunch**

		Chairman: Kondo, T. (JAERI)
	14:00~14:20	Status of R&D works and possible HTGR applications in the USSR Mosevitsky, I. S. (KIAE)
	14:20~14:40	Present status and development strategy of the HTGR program in PRC Wang, D. (Tsinghua Univ.)
	14:40~15:00	Present status and future program of HTR-research and development in Switzerland Sarlos, G. (IGNT)
		Chairman: Egorikov, A. (MAPI)
	15:00~15:20	Technology, cost economics and other factors influencing selection of HTR in a developing country Karim, C. S. (BAEC)
	15:20~15:40	Progress on HTR application's study in Indonesia Subki, I., Djokolelono, M. (NAEA)
	15:40~16:00	Study of fission products redeposition by COMEDIE loop in the experimental SILOE reactor Veyrat, J. F., Bastien, E. (CEA)
	16:00~16:20	**Coffee Break**
		Chairman: Millunzi, A. C.
	16:20~16:45	Design and safety considerations in Japanese High-Temperature Engineering Test Reactor (HTTR) Saito, S. (JAERI)
	16:45~17:10	Modular High-Temperature Gas-Cooled Reactor design Bramblett, G. (GA)
	17:10~17:35	Design details of HTR-Module and HTR-500 Arndt, E. (HTR GmbH)
	17:35~18:00	Desigh features of VG-400 and VGM reactor plants Golovko, V. F. (CBMB)
18:00	**Adjourn**	
18:30~20:00	**Banquet** **Welcome Address**	Fuketa, T. (JAERI) Mishima, Y. (AESJ)

March 20 (Tuesday)

9:00~14:30	**Session 3**	**Licensing Safety Issues and Associated R&D of HTGR** Chairman: Dieh, H.
9:00~ 9:30		Key licensing safety issues and draft review results of HTTR — Ibe, Y. (STA)
9:30~10:00		Licensing overview of the MHTGR — Millunzi, A. C. (DOE)
10:00~10:30		Licensing safety issues and results of HTR-Module safety concept review by independent experts — Weisbrodt, I. A. (HTR GmbH)
10:30~10:50		**Coffee Break**
		Chairman: Wang, D.
10:50~11:30		Safety problems of HTGR, Licensing in the USSR and the allied research works — Mosevitsky, I. S. (KIAE)
11:30~12:00		Research and development related to licensing of HTTR — Yasuno, T. (JAERI)
12:00~13:30		**Lunch**
		Chairman: Sarlos, G.
13:30~14:00		Research & development associated with licensing of MHTGR — Jones, H. (ORNL)
14:00~14:30		Research and development requirements before and beyond licensing HTR-Module — Kirch, N. (KFA)
14:30~15:00		**Coffee Break**
15:00~17:00	**Session 4**	**Panel Discussion** —Future perspectives, public acceptance and international cooperation in HTGR— Chairman: Murata, H. (JAERI) Diehl, H. (BMFT) Millunzi, A. C. (DOE) Mosevitsky, I. S. (KIAE) An, S. (Tokai Univ.) Sanokawa, K. (JAERI) Kupitz, J. (IAEA)
17:00~17:10	**Closing Address**	Sato, K. (JAERI)

1-1 Perspectives on utilization of nuclear energy and HTGR in Japan

Takashi Mukaibo
JAEC
JAPAN

The generation of energy by nuclear fission has become an industry of a considerably large scale. In Japan, the nuclear power is generating about one third of electricity and about ten times more around the world.

However, there are still a lot of technologies to be developed for the nuclear power system.

The improvement of efficiency of the conversion of heat to electricity is one of them.

As a kind of heat engine, it is at least worth-while to raise the operating temperature to improve the efficiency of the use of heat. The development of HTGR is along this direction.

Following the countries which started nuclear power programs earlier, Japan started R&D on HTGR in 1969. At that time, it was aimed at using the high temperature for the reduction of iron ore. The R&D on HTGR itself was undertaken by JAERI and the steel industries organized a R&D group for the handling and use of gas of temperatures around 1,000°C.

After a couple years of study, it was concluded that the reduction of iron ore by high temperature gas was not realistic mainly from economical view point and the research of steel industries mentioned above was abondoned. However, at JAERI, they continued such basic and engineering studies on HTGR as those on nuclear fuel and other materials, instrumentation; physical and other studies related to the design of the nuclear reactor, with some reduction of speed of development.

In recent years the slow down of the development of HTGR abroad was reported but there are still expectations on HTGR for the supply of heat as well as electricity in many countries. On the other hand, the cogeneration system of supplying heat and electricity starting from high temperature gas has been developing in recent years in and outside of the country.

Thus, in the latest long term plan of developing nuclear power in Japan in 1987, it was suggested to construct a high temperature gas cooled engineering test reactor for the purpose of accelerating the HTGR project, utilizing the knowledges and data so far obtained in the JAERI project.

JAERI is going to start its construction this year. The details of the reactor and the R&D programs will be described by other speakers in this symposium.

1-2 International aspects of HTGR development

J. Kupitz
International Atomic Energy Agency

For about 30 years the HTGR has been under development in several countries, such as the Federal Republic of Germany, France, Japan, Switzerland, USSR, UK and USA. The technical feasibility and the advantages of this reactor line have not only been demonstrated by experimental results but also by the successful operation of a number of experimental and demonstration reactors.

While HTGRs have not yet been commercially developed on an large scale, their potential to provide, besides electricity, high temperature process steam and process heat for various industrial applications has been, together with high safety margins, the continuous incentive for further development. During the last decade particular attention has been paid to HTGR module type reactors, which have emerged in the Federal Republic of Germany, USA and USSR. The specific advantages of this concept have contributed to a strong, renewed international interest in the HTGR for electricity generation and process steam production. The successful construction and operation of the HTTR in Japan will provide for important data and experience still necessary for the HTGR to produce high temperature nuclear process heat.

1-3 History, salient features and prospectives of HTGR

R. Schulten
TH. Aachen
Federal Republic of Germany

The High Temperature Reactor belongs to the second generation of the use of nuclear power and presents new possibilities and characteristics: New, simplified safety technologies, the generation of process heat, combination loops with gas and steam turbines and the economical feasibility of small reactors.

During the last decades ceramic fuel elements with coated particles have been developed to applicability. In combination with helium as a coolant they allow temperatures of up to 1000°C while keeping the contamination of the primary loop to a minimum. This opens new areas of application for nuclear power exceeding the mere generation of electricity.

A new technology of nuclear safety has been discovered, which masters the dangers of all unintended changes in reactivity and core heatup due to decay heat. Even corrosion due to air or steam leaking into the primary loop can be avoided sufficiently. A new development of fuel elements with a coating of silicon carbide will avoid all possibilities of corrosion in a simple and transparent way. The objective is a security technology which is based only on the behavior and the properties of the fuel elements. The other components of the power plant should not have any function in the retainment of fission products. Any perceptible impact on the environment due to radioactivity can be ruled out in all cases. The new self driven safety concept simplifies the power plants by rendering certain components obsolete and by lowering the necessary standards for construction. This seems to be important for the acceptance and for the use of this technology in threshold and developing countries.

Nuclear power at high temperatures can help decrease the CO_2 problem because it makes the use of cogeneration more effective and can be used for oil drilling by steam injection. The High Temperature Reactor provides a future technology for the supply of heat for residential and industrial use and for the production of hydrogen or equivalent products from fossile fuels.

Due to the development of the fuel element and the SiC coating as a protection against air ingress into the primary loop the High Temperature Reactor can also be employed in a combination of a gas and steam turbine loop and thus increase its efficiency considerably.

Simplification of nuclear technology, mass production and the increase of efficiency provided by combination plants will improve the economic performance also for units with a rather low power output in the range of 200 to 500 MW_{el} e.g. by coupling several units.

2-1 Current status and future plan of HTGR in Japan

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A High Temperature Gas-Cooled Reactor (HTGR) has excellent characteristics such as producing heat at higher temperature, higher inherent safety and higher fuel burn up, and is considered as one of the most promising nuclear reactors to improve the economy and to extend the application of nuclear energy. Therefore, Japan has been involved since 1969 in R&D for a Multipurpose Very High Temperature Gas-Cooled Reactor(VHTR) in collaboration with associated organizations and institutions. In 1987, the Japanese Atomic Energy Commission (JAEC) issued the revision of Long-Term Program for Development and Utilization of Nuclear Energy, recommending that Japan should proceed with the development of more advanced new technologies for the future, in parallel with the existing nuclear system. Then, the Japan Atomic Energy Research Institute(JAERI) decided to construct the High Temperature Engineering Test Reactor(HTTR) instead of the experimental VHTR in order to establish and upgrade the technology basis for an HTGR, serving at the same time as a potential tool for new and innovative basic researches.

In order to establish and upgrade HTGR technology basis systematically and efficiently, and also to carry out innovative basic researches on high temperature technologies, Japan will carry out necessary R&D in cooperation with the JAERI, universities, national research institutes as well as industries. In addition, in order to promote the R&D on HTGR more efficiently, Japan will promote the existing international cooperation with the research organizations in foreign countries.

2-2 Present status and future program of the HTGR in USA

A. C. Millunzi
U.S. Department of Energy
United States of America

2-3 Utility/User requirements for and assessment of the modular high temperature gas-cooled reactor

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and
L. Daniel Mears, Harold L. Gotschall
Gas-Cooled Reactor Associates
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This paper describes the approach used by Gas-cooled Reactor Associates (GCRA) in developing Utility/User Requirements for the Modular High Temperature Gas-Cooled Reactor (MHTGR). As representatives of the U.S. utility/user industry, it is GCRA's goal that the MHTGR concept be established as an attractive nuclear option for safe, economic energy supply with limited ownership risks. Commercially deployed MHTGR systems should then compete favorably in a mixed-fuel economy with options using fossil, other nuclear and other non-fossial sources.

To achieve this goal, the design of the MHTGR plant must address the strains experienced by the U.S. industrial infrastructure during deployment of the first generation of nuclear plants. Indeed, it is GCRA's intent to utilize the characteristics of MHTGR technology for the development of a nuclear alternative that poses regulatory, financial and operational demands on the Owner/Operator that are, in aggregate, comparable to those encountered with non-nuclear options.

The dominant risks faced by U.S. owner/operators with current nuclear plants derive from their operational complexity and the degree of regulatory involvement in virtually all aspects of operations. The MHTGR's approach to passive safety provides the technical basis for dramatic simplification of overall plant licensing and operations and, thus the opportunity for reducing the risks of nuclear plant ownership.

The paper describes utility participation through GCRA in the MHTGR Program and the rationale for the selection of key requirements in the context of a business risk management philosophy. It also provides a summary assessment of the current design against key top level requirements.

2-4 Experience gained with high temperature reactors and their prospects

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and
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Experience in development and operation of HTR's in the Federal Republic of Germany has been derived from an extensive R+D-program for almost 3 decades and the construction and operation of the pilot plant AVR and the demonstration reactor THTR-300. In the beginning the program was embedded in the climate of general nuclear enthusiasm. Lateron the oil crisis in the 70'ies, the almost worldwide nuclear moratorium in terms of plant orders since the mid 70'ies and the increasing antinuclear movement in the last decade had major impacts on the program and, ultimately, prevented the technology from commercial introduction. Nevertheless, in '83 there was general consensus that the technology was mature enough to transfer program lead and responsibility from the public domain to the reactor industry.

The operation of AVR since '67 provided significant confidence in the technology. THTR construction since '71 suffered already from increasing requirements from the licensing procedures. After a very extensive testing program in the 3-years commissioning phase the plant was surrendered to the utilities in June '87. Prototypic technical failures and critical attitudes of the licensing authorities resulted in poor availability figures. Mainly economical aspects for further operation forced the parties involved to shut down the plant end of '88.

The experience from the operation of the plants confirmed the generally expected specific advantageous HTR-features like safety behaviour, fuel utilization, temperature potential, high efficiency etc., but also revealed technical deficiencies which require further development work.

On the basis of this experience new reactor concepts, the HTR-module and the HTR-500 were designed. They are based on new safety concepts which rely mainly on the proven quality and fission product retention capability of the fuel elements. The main task for the future is not only the proof of the specific safety behaviour of the HTR systems and components and the application of advanced materials and components, but much more the improvement of the economic features, an indispensable prerequisite to achieve market introduction at all. Intensified international cooperation could certainly facilitate the technology deployment.

2-5 Status of R&D works and possible HTGR applications in the USSR

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N.N. Ponomarev-Stepnoy, A.Ja. Stolyarevsky
Uion of Soviet Socialist Republics

Status of R & D works on HTGR in the USSR, features of completed projects and their concepts are considered. Purposes for construction the pilot plants VGM, problems of the experimental investigations and checks of the main design solution, being planned on this plant are discussed. Possible fields of application in the USSR of commercial plants with HTGR reactors, including power and process plants are analyzed.

2-6 Present status and development strategy of the HTGR program in PRC

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This paper summarizes the present status and main progress of chinese HTGR R&D program. It is being carried out in the INET and the relevant institutions and covered in the national high technology research and development program. Briefly introduces the technical features of the 10 MW HTR-Test Module which will be a joint project with Siemens-Interatom. KFA Juelich. Some preliminary results and prospects of HTGR application in the heavy oil recovery and petrochemical complex are also described. At last, this paper discusses the role and position of HTGR in the future energy system and its development strategy in China.

2-7 Present status and future program of HTR-research and development in Switzerland

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and
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ETHZ
Switzerland

Research, Development and Design of Gas-cooled Reactors has already a long and well accepted tradition in Switzerland. These activities began with the design and construction of an experimental gas-cooled power station of 30 MW by the Swiss industry in the early sixties.

However, it was soon recognised, that for a small country like Switzerland, nothing but the cooperation within international projects opens a field for successful activities in the domain of nuclear energy. Therefore Swiss industry restricted themselves to the development and the supply of reactor systems and components only.

Since the beginning of the german pebble-bed type high temperature reactor development, Swiss companies and institutions were participating at the R&D which led finally to the supply of components for the THTR.

The companies concerned and teh PSI agreed in 1979 to join as partners and established the "Swiss Community for the Development of Nuclear Technology" called IGNT. Partners of IGNT are ABB, Baden; Sulzer, Winterthur; B+G, Lausanne, EWI, Zürich; Colenco, Baden; and the PSI. IGNT represents and coordinates the activities of the partners.

As a consequence of this partnership, the members of IGNT engaged themselves in the development of the HTR-Technology in general and particularly in the design of the HTR-500. Another project which was pursued in Switzerland over the recent years, is the gas-cooled heating reactor, a small pebblebed HTR of 10-20 MW for district heating purposes.

Details of the activities of the Partners of IGNT are given and outlined.

Considering the present world-wide unsatisfacory situation in the nuclear area, we will be faced with the question "what are the driving forces justifying further research and development in the field of High Temperature Reactor Systems"?

Each machine or technical system has, within its technical utilisation and lifetime, a positive evolution and there is no plausible reason why this should not be the same for nuclear reactor systems also. Therefore there will always be necessary improvements in design and for safety, which call for generic activities in the field of research and development leading to new and/or advanced systems. This applies also for the HTR.

The demand of electricity is steadily increasing in Switzerland by about 2 to 3% per annum. This means that this demand will in any case call for new nuclear reactors to be built in the future. Therefore IGNT has signed new contracts for cooperation which Germany on the HTR-500 development and has ensured funding for future research by the governement.

2-8 Technology, cost economics and other factors of HTR as relevant to a developing country

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Growth of the consumption of commercial energy and of electricity all over the world was arrested following the energy crisis of the 70's. Endeavors to develop energy sector in the developing countries are still facing challenges due to uncertainties and constraints in supply, and of price of primary energy resources. The environmental effects of burning fossil fuels have further aggravated the concern as coal can no longer be considered as the most viable proposition in finding a solution to the problem. Under such circumstances the possible role of nuclear power in the future energy scenario of many developing countries have assumed a new dimension. Most of the reactors with proper reference and operating experience can not be considered appropriate for such countries in view of their smaller grid size and a weaker infrastructural base. In this context gas cooled reactors could be considered as a viable proposition. The paper elaborates the prospects and shortcoming of SMPR in general and HTR in particular in meeting the growing needs for electricity in developing countries.

The HTR is identified as one of the so called inherently safe technologies. This may be considered as an added advantage to the countries with comparatively weak infrastructural base. However this has to be weighed against the inadequacy in operating experience with such reactors. Some of the factors of passive cooling systems, which need further confirmation in facilitating decision-making, are presented in the paper.

The importance of capital cost of nuclear power plants with HTR in the process of decision making can hardly be over-emphasized. Some preliminary calculations of cost-economics under a set of conditions are given which will help in forming an idea about the cut-off point in capital cost.

So far as developing countries are concerned, the problem of financing is expected to remain as the main problem in implementing a nuclear power project, be it a SMPR or a larger plant. The trend in international financing of nuclear power projects in developing countries are far from being favorable. Some indicative suggestions toward solution of this problem, based on the cost economic calculations, are provided in this paper.

2-9 Progress on HTR application's study in Indonesia

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Study on the application of HTRs for the enhanced oil recovery in the Duri oil field (Sumatra, Indonesia) was performed in 1986/1987. The economic and technological advantages over crude burning option were identified. Crude oil prices, HTR capital costs, discount rates, company's income structure represented dominant parameters. Further sensitivity calculations on important economic parameters were obtained to reflect the condition of 1988.

This nuclear option was also incorporated in the energy planning study for the whole Indonesia using the MARKAL model, and resulted the conditions of its applicability. The scenarios chosen in this MARKAL study were high and low GDP growth rate, whereas the criteria chosen were the minimum cost with and without a predetermined policy of reduced domestic use of oil. In the high scenario the HTRs as well as the natural gas options could not compete against the low cost boilers with crude-oil fuel. But in the case of reduced domestic oil use the HTRs came out to supplement the crude-burning boilers starting in the sixth five year plan (1994 -1999), even earlier then the natural gas option.

The authors further discuss the industrial environment, in relation with the regional development, the possible local participation, as well as the plan to materialize the merits of this novel application.

2-10 Study of fission products redeposition by COMEDIE loop in the experimental SILOE reactor

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France

SILOE is a 35 MW MTR, pool type experimental reactor located in GRENOBLE (FRANCE) and operated by the French Commissariat à l'Energie Atomique.

Among many irradiation facilities, an in-pile helium, COMEDIE, loop has been installed to study the release, migration and deposition of fission products, from HTR fuel elements. This loop (70 bars, 800°C gas max. temperagure, 40 g/s flow) managed by the Experimental and Prototype Reactors Division, Physics and Experiments Department is able to conduct the following experiments.

- Study of the release of fission products by the fuel element; migration of fission products through the block to the gas.
- Deposition of fission products on well qualified tubes.
- Contamination and corrosion studies.

The loop itself includes:

- The fuel element section.
- The fission products deposition section with 3 clusters of tubes.

These two parts are in the pool of SILOE Reactor.

- The out-of-pile part with the blower, the heat exchanger, the heater, the filters, the purification stage, the control panels and the data acquisition systems.

Operating parameters, such as helium temperature, helium flow, helium chemical composition, etc. can be adjusted according to the program. The power of the fuel block can be varied and transient experiments are feasible.

A modification of the loop, to do in situ blow down tests to study fission products lift off, is now in progress.

To complete the loop, fission gas analysis is done continuously in the Fission Products Analysis Laboratory specially equipped for this task, and Post Irradiation Examinations are operated in the High Activity Laboratory, both located close to the Reactor, and managed by the Fuel Behaviour Study Dpt.

COMEDIE will be used till to 1993 for a program of irradiations under a contract with DOE/USA, managed by MMES/ORNL/USA with the collaboration of GA/USA.

COMEDIE installations and the CEA know how in the HTR irradiations field give a high capacity support for HTR Studies.

2-11 Design and safety considerations in the Japanese High Temperature Engineering Test Reactor (HTTR)

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Japan

The HTTR is a high temperature gas cooled test reactor with thermal output of 30MW and maximum reactor outlet coolant temperature of 950°C, aiming at establishing and upgrading the technology basis for advanced HTGRs and performing various innovative high temperature basic researches.

This paper describes the design of the HTTR specifically focussing on design considerations for achievement of 950°C outlet gas temperature and safety considerations in the design. The paper also describes briefly safety evaluation of the HTTR and its construction schedule.

The HTTR is the first HTGR in Japan and will be the first HTGR in the world which provides high temperature gas higher than 800°C outside the reactor vessel. Therefore, various considerations were taken in the design to achieve reactor outlet coolant temperature of 950°C in the HTTR.

Due considerations were made how to minimize the maximum fuel temperature, how to reduce the coolant flow rate ineffective to cool the fuel, how to minimize thermal and irradiation stresses of graphite block, how to resolve the problems relevant to high temperature and high pressure in the primary cooling system design, and so on.

Several important safety considerations for fuels, reactor shut-down system, back-up reactor cooling system, multiple barriers against FP release, etc., were also adopted in the design of the HTTR.

These elaborate considerations in the design of the HTTR together with extensive research and development make it possible to produce and take out very high temperature helium gas up to 950°C outside the reactor vessel in the HTTR.

The safety review of the HTTR by the government is presently underway. Construction is scheduled to start in 1990 and first criticality is expected in 1995.

2-12 Modular high temperature gas-cooled reactor design

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The Modular High-Temperature Gas-cooled Reactor (MHTGR) is an advanced power plant concept which has been under development since 1984. The design utilizes basic high temperature gas-cooled reactor features of refractory coated fuel, helium coolant and a graphite moderator which are supported by design studies and experience of over 30 years. The design is being developed based on selections made in response to well defined requirements for safe, reliable and economic power. The geometric arrangement of the reactor and steam generator vessels, the core and the heat removal components has been selected to exploit the inherent characteristics associated with high-temperature materials. The design utilizes passively safe features which provide a higher margin of safety and investment protection than current generation reactors.

Design features include an arrangement of four identical 350 MW(t) modular reactor units located in underground silos covered by a single reactor building. This Nuclear Island (NI) with the reactors and associated equipment is coupled to an Energy Conversion Area (ECA) with two turbine generators producing a combined total of approximately 540 MW(e). Nuclear heat is normally removed by a steam generation system featuring a once-through design. A shutdown cooling system utilizing water and a reactor cavity cooling system utilizing air driven by natural convection provide alternate heat removal paths. The design and development program, now in the preliminary design stage, is a cooperative effort by the U.S. government, the utilities and the nuclear industry.

2-13 Design details of HTR-Module and HTR-500

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Design Features of the HTR-Module

The modular HTR power plant is a universally applicable energy source for the co-generation of electricity, process steam or district heat.

The modular HTR concept is characterized by the fact that standardized reactor units with power ratings of 200 MJ/s (so-called modules) can be combined to form power plants with a higher power rating.

Consequently, the special safety features of small high-temperature reactors are also available at higher power ratings.

The safety features and the technical design are briefly described in the following, taking a power plant with two HTR-Modules as an example. Special attention will be given to the pressure vessel unit.

The principal safety feature of the HTR-Module is based on the fact that, even in the case of failure of all active cooling systems and complete loss of coolnat, the fuel element temperatures remain within limits at which there is practically no release of radioactive fission products from the fuel elements. This guarantees that the modular HTR power plant does not present any hazard to the environment either under normal operation or in the event of accidents.

Due to its feetures, the modular HTR power plant is suitable for construction on any site, but particularly on sites near other industrial plants or in densely populated areas.

Design Details of the HTR-500 Power Plant

The HTR-500 has been developed as a nuclear power plant for medium-sized and large power grids, either as a base load plant or for load-following applications according to the requirements of the grid. Furthermore, the HTR-500 is well suited for the cogeneration or supply of process steam for industrial applications. The HTR-500 has a thermal power output of 1390 MJ/s, which corresponds to an electrical rating of 550 MW.

The concept selected for the HTR-500 system incorporates to a large extent the THTR-300 technology licensed and realized in accordance with the current state of science and technology.

The reactor plant concept is marked by the integrated arrangement of all primary-system components within a burst-proof pre-stressed concrete reactor vessel in single-cavity design. The integrated arrangement provides protection against impacts from internal incidents as well as radiation shielding. The pressure vessel and important systems are arranged within the confinement building which provides protection against impacts from external events.

2-14 Design features of VG-400 and VGM reactor plants

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The principles of the compound and the constructions schemes of the separate components and parts of the reactors VG-400 and VGM are considered.
Comparative analysis of the alternative variants of the different construction of the equipment are considered.

3-1 Key licensing safety issues and draft review resuls of High Temperature Engineering Test Reactor (HTTR)

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The application for the construction permit of the High Temperature Engineering Test Reactor (HTTR) was submitted by the Japan Atomic Energy Research Institute (JAERI) to the Science and Technology Agency (STA) in February 1989. After about 10 months safety review, the STA concluded the draft of safety review results on the HTTR in December 1989, taking into consideration the unique features of the HTTR and has referred it to the Nuclear Safety Commission (NSC) for double-check safety review. This paper summarizes the essential items on the results of safety review by the STA, featuring and focusing on major characteristics of the HTTR.

In the safety review of the HTTR, the review was performed by confirming the basic items of the safety design and so on, for ensuring the safety of the public, employee etc., under the condition of not only the normal operation but also accidents. The review was performed based on such existing guidelines established by the NSC as "Examination Guide of Reactor Siting and Guidelines for Interpretation in their Application" and "Examination Guide of Safety Design for Light Water Nuclear Power Facilities and relevant standards established by the law and taking into account the characteristics of the HTTR and Differences of the HTTR from the LWRs.

Concerning the unique features of the safety design of the HTTR, the following key issues were reviewed with special emphasis; (1) fuel design, (2) design for graphite structure and high temperature structure, (3) design and safety assessment codes, (4) seismic design, (5) selection of evaluated events, (6) source terms and release paths and (7) irradiation tests and various modes of operation and test.

3-2 Licensing overview of the modular high temperature gas-cooled reactor

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NB Inc.
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The MHTGR is an advanced reactor concept being developed under a cooperative program involving the U.S. Government, the nuclear industry, and the utilities. The design utilizes the basic HTGR features of ceramic fuel, helium coolant, and a graphite moderator. However, the specific size and configuration are selected to utilize the inherent characteristics of these materials to develop passive safety features that provide a significantly higher margin of safety than current generation reactors. Results to date indicate that the design will meet the U.S. Environmental Protection Agency's Protective Action Guidelines for ionizing radiation at the site boundary, hence precluding the need for sheltering or evacuation of the public during any licensing basis event. This safe behavior is not dependent upon operation action and is insensitive to operator error.

This report discusses the MHTGR Licensing Plan. A discussion of the NRC preapplication phase review of the MHTGR is presented including a summary of the safety response to events challenging the functions relied on to retain radionuclides within the coated fuel particles. The regulatory interaction process related to the application for Preliminary and Final Design Approvals and a standard design certification is also presented.

3-3 Licensing safety issues and results of HTR-Module safety concept review by independent experts

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Humanity is facing great challenges. On the one hand, it is imperative to ward off the impending menace of an environmental catastrophe, on the other it is necessary to overcome poverty in the third world and to supply the increasing world population, particularly in third countries, with a sufficient amount of energy while at the same time preserving the natural environment.

One of the most convincing solutions to the future energy supply is nuclear energy. However, due to the accidents in Three-Mile Island and Tchernobyl, public acceptance of nuclear energy has suffered a severe blow.

The nuclear industry has taken note of the public concern and started acting accordingly by striving to develop a new generation of nuclear reactors featuring a high degree of passive safety properties.

As early as 1979, the development of the modular HTR was launched in the Federal Republic of Germany, taking exacting standards and lay-out criteria for a basis. The supplying industry soon realized that her own judgement was not sufficient and that the evaluation of the newly developed modular concept by neutral authorities and experts was absolutely indispensable in order to ensure the basis of this development.

Thus, the German Board of Experts on Environmental Questions critically reviewed the new modular concept as early as 1981 in a special expertise submitted to the Federal Government and gave a basically positive statement in this matter. Further evaluations of the modular concept were conducted in 1981/82 by a subcommittee of the Reactor Committee, in 1982 by the Rhineland Technical Control Board, and in 1984/85 by a counselling group established by the Federal Minister of the Interior.

Encouraged by the positive evaluations, a safety report was developed in the course of 1985 and 1986. In 1987, it was submitted and a review of the safety concept by independent experts was initiated.

3-4 Safety problems of HTGR, Licensing in the USSR and the applied research works

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A.Ja. Stolyarevsky, A.A. Chrulev
Union of Soviet Socialist Republics

Brief information concerning the safety problems of nuclear power in the USSR, the development of regulating and legislative documents is presented. Safety principles using in designing the reactor plants, features of safety problems of power and process plants are considered.
Main purposes and problems of the research works, carried out for substantiation of safety and some results of experimental and computational investigations are given. And further paths of safety enhancement are studied.

3-5 Research and development related to licensing of HTTR

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The research and development on HTGR in Japan Atomic Energy Research Institute (JAERI) were initiated by the program of the experimental very high temperature reactor (VHTR) in 1969. According to the experimental VHTR program, the various kinds of research and development works were started at that time for the experimental VHTR construction.

The items of research and development were design study of the experimental VHTR, material research, developments on helium engineering and construction of large test rig. Through the design study of the experimental VHTR, the survey of the technology to be developed and the basic data for VHTR design and construction, was performed to complete the research and development plan.

In 1987, the construction of the HTTR was decided instead of the experimental VHTR by the revision of the Long-Term Program for Development and Utilization of Nuclear Energy. According to this new program, JAERI plan of research and development was reviewed and supported the conclusion that no large modification of the existing plan was necessary.

JAERI was carrying out various kinds of research and development for the HTTR licensing and construction. These works were conducted in the Oarai in-pile Gas Loop, the Helium Engineering Demonstration Loop, Very High Temperature Reactor Critical Assembly and the others for long time.

This report covers research and development works performed for the HTTR licensing and construction.

3-6 Research and development associated with licensing of MHTGR

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The Modular High Temperature Gas-Cooled Reactor (MHTGR) currently under development by the U.S. Department of Energy for commercial applications has top-level goals of producing safe, economical power for the U.S. utility industry. The utility industry has been represented in formulating design and licensing requirements through both a "Utility User Requirements Document" and by participating in the DOE system engineering process known as the "Integrated Approach". The result of this collaboration has been to set stringent goals for both the safety and operational reliability of the MHTGR. To achieve these goals the designer must have access to a more comprehensive data base of properties, in several fields of technology, than is currently available. A technology development program has been planned to provide this data to the designer in time to support both his design activities and the submittal of formal licensing application documents. The US-DOE has chosen the Oak Ridge National Laboratory (ORNL) to take the lead in planning and executing these technology programs. When completed these will augment the designer's current data base and provide the necessary depth to meet the stringent goals which have been set for the MHTGR. It is worth noting that the goals of safety and operational reliability are complementary and the data required from the technology development program will be similar. Therefore the program to support the licensing of the MHTGR is not separate from that required for design, but is a subset of that which meets all the requirements that result from implementing the US-DOE's integrated approach. This paper will provide an overview of the technology development activities now in progress or planned by ORNL to meet these requirements. Work will be described in the fields of fuel development, fission product release and transport, graphite technology, metallurgical technology, reactor shielding, safety research and the validation of design methods in thermal/hydraulics.

* Research sponsored by the Division of HTGRs, Office of Advanced Reactor Programs, U.S. Department of Energy, under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

3-7 Research and development requirements before and beyond licensing the HTR-Module

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The broad research and development work for high temperature reactors carried out in the Federal Republic of Germany since nearly 30 years has led to a high level of maturity of HTR development and to a broad knowledge in the field of HTR physics and techniques:

- Basic physical phenomena are well understood.
- The limits of materials and components are explored.
- The necessary data and methodological tools for plant design and for licens ing procedures are available.

Looking at the licensing question of the HTR-Module, one should have in mind that in Germany 25 years ago the AVR-reactor has been licensed that according to younger expert opinions the plant fulfills basically the todays safety requirements.

During the ten years of HTR-Module development the concept has been subjected to several safety reviews. All these reviews and evaluations came to a very positive conclusion. There was no doubt that the safety concept is suitable to meet the safety related licensing requirements in the FRG. This includes explicitly those items of the safety concept which differ from current solutions for LWR, in particular the enclosure system for radioactive substances and the passive after-heat removal system.

The dominating influence on the R+D program results not from the licensing question. Like in any other technical area the development is going on steadily: novel materials and techniques, higher general safety requirements and the advanced reactor designs inspire and require additional investigations. The results hopefully lead to simpler components and plant design, to more economical solutions and to safety improvements and proofs mainly in the hypothetical area.

APPENDIX C

ACTIONS AND COMMITMENTS

RESULTING FROM

MEETINGS AT THE JAERI HEADQUARTERS OFFICE TOKYO, JAPAN

MARCH 23, 1990

CONCERNING THE US-DOE/JAERI COLLABORATION AGREEMENT ON HTGR TECHNOLOGY

Agreement from Coordination Meeting
at JAERI on March 23,1990

ANNEX

0 1) By March 30, JAERI will identify the specific dates for the next steering committee meeting which will be held in Washington, D.C.

1 2) DOE will write a letter to JAERI in which the cause and the fact that the fission chambers could not be tested in the FSV are stated. In the letter, DOE will propose continuation of Annex 1.

1 3) JAERI will consult with its manager to continue Annex 1 with an Amendment. By March 30, DOE will provide to JAERI a cost and schedule to complete the efforts. JAERI will recommend a date to initiate the testing of the fission chambers. ASSUME THIS TO BE AFTER APRIL 1, 1991

0 4) By March 30, DOE will provide a draft for extending the current umbrella agreement.

2 5) DOE will prepare cost and schedule to the irradiation of new fuel from JAERI in HFIR. DOE will strive to provide the cost and schedule data by April 15,1990. Millunzi will confirm by March 30,1990, if the April 15 date is possible. No change in the existing Annex is required to carry out the modification.

2 6) JAERI would like to replace the fuel on test HRB-22 with more advanced fuel. The reason is that the data to be provided by the present fuel would not be available in time for use in licensing activities. The delay on restarting HFIR caused the availability of data to be delayed beyond the date required for HTTR licensing, safety analysis and submissions. Further it would be of much more value to JAERI to irradiate the advanced fuel to obtain data at elevated temperatures for longer times than that required for the present fuel.

A.C. Millunzi 3/23/90
A.C. Millunzi, DOE

S. Saito 3/23/90
S. Saito, JAERI

USDOE/JAERI HTGR COLLABORATION
ANNEX 3 AND ANNEX 4
COORDINATING COMMITTEE MEETING, MARCH 23, 1990, AT JAERI HEADQUARTERS
AGREEMENTS AND COMMITMENTS

ANNEX 3

1. JAERI to supply IG110 graphite block of approximate size of 60 x 200 x 200 mm	Apr 1990
2. ORNL to supply geometries of the multiaxial fracture test specimen	Apr 1990
3. ORNL to propose additional oxidation studies on IG110 graphite under TPPG 5 towards some collaborative research	Apr 1990
4. JAERI to review the revised TPPGs 1-7 for submittal to the Steering Committee	Apr 1990
5. ORNL to revise a draft,joint JAERI/ORNL, letter to the Steering Committee recommending endorsement of TPPGs 4-7	Apr 1990

ANNEX 4

JAERI will complete review of M1 to 4 by April 16th and send to ORNL for input to the steering committee in June for budget consideration in DOE USFY 91(Oct 1st ,1990).

JAPAN ATOMIC ENERGY RESEARCH INSTITUTE		OAK RIDGE NATIONAL LABORATORY	
M. Eto (signed)	3-23-90	H. Jones (signed)	3-23-90
M.Eto	Date	H.Jones	Date
H. Nakajima (signed)	3/23/90	J. L. Scott (signed)	3-23-90
H.Nakajima	Date	J.L.Scott	Date
M. Suzuki (signed)	3/23/90		
M.Suzuki	Date		

APPENDIX D

ITINERARY

Friday, March 16 (Evening)	Travel	Oak Ridge to U.S. West Coast.
Saturday, March 17 & Sunday, March 18	Travel	U.S. West Coast to Tokyo, Japan.
Monday, March 19	Tokyo	JAERI Symposium.
Tuesday, March 20	Tokyo	JAERI Symposium.
Wednesday, March 21	Tokyo	Free Day (Japan National Holiday)
Thursday, March 22	Travel	Tokyo to Oarai and Tokai, Japan.
	Oarai & Tokai	Visit to Oarai & Tokai Research Establishments.
	Tokai	Visit to Nuclear Fuel Industries, Tokai, Japan.
	Tokai	Meeting on Annex 3.
Friday, March 23	Travel	Tokai to Tokyo, Japan.
	Tokyo	Meeting at JAERI Headquarters, Tokyo, Japan.
Saturday, March 24	Travel	Tokyo, Japan to U.S. West Coast.
Sunday, March 25	Travel	U.S. West Coast to Knoxville.

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