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ORNL

FOREIGN TRIP REPORT

ORNL/FTR-2970

DATE: July 26, 1988

SUBJECT: Report of Foreign Travel of John E. Jones Jr. Director, Reactor Programs, ORNL

TO: Alexander Zucker

FROM: John E. Jones Jr.

PURPOSE: To attend programmatic review meetings in the Federal Republic of Germany under the USA/FRG Implementing Agreement for Cooperation in Gas-Cooled Reactor Development; and to attend meetings in the United Kingdom regarding proposed cooperative programs in high-temperature gas-cooled reactor technology between the U.S. Department of Energy and the UK Atomic Energy Authority.

SITES VISITED:	6/27-6/28	Kernforschungsanlage (KFA)	Jülich, FRG
	6/29-7/1	Risley Nuclear Power Development Laboratory	Risley, UK

(Combined trip report by A.C. Millunzi, DOE-HQ; G. C. Bramblett, General Atomics; and J. E. Jones Jr., ORNL, attached)

REPORT OF FOREIGN TRAVEL JUNE 24-JULY 2, 1988 TO FEDERAL REPUBLIC OF GERMANY AND UNITED KINGDOM

by

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Abstract

Reviews were conducted at Kernforschungsanlage (KFA) Jülich of the U.S. and Federal Republic of Germany (FRG) high-temperature gas-cooled reactor (HTGR) programs under the US/FRG Umbrella Agreement, with emphasis on those technology development areas where cooperation is ongoing and planned. Specific subprogram areas are safety; materials; fuels, fission products, and graphite; and Arbeitsgemeinschaft Versuchs-Reaktor (AVR). The purpose was to assess the status of the cooperation, reach agreement on any changes needed, and identify new areas of cooperation. Overall, the agreement has been both effective and beneficial. Ongoing activities complement and support U.S. technology development plans.

Discussions were held in the United Kingdom (UK) at the Risley Nuclear Power Development Laboratory regarding a potential graphite technology exchange program between the U.S. Department of Energy and the UK Atomic Energy Authority. A draft agreement was reviewed and appeared to be satisfactory to both parties and ready for signature. A summary of potential areas of activity in the exchange had been prepared by U.S representatives and was discussed and found to be acceptable to UK representatives.

Introduction

This report covers programmatic review meetings at the Kernforschungsanlage (KFA), Jülich, Federal Republic of Germany (FRG) on Safety; Materials; Fuel, Fission Products, and Graphite; and Arbeitsgemeinschaft Versuchs-Reaktor (AVR) Subprograms under the USA/FRG Implementing Agreement for Cooperation in Gas-Cooled Reactor Development. Andrew. C. Millunzi, U.S. Department of Energy (USDOE), led the U.S. delegation to the meetings and was accompanied by John E. Jones Jr. of Oak Ridge National Laboratory (ORNL) and George C. Bramblett of General Atomics (GA).

The report also summarizes discussions and results of meetings at the Risley Nuclear Power Development Laboratory, United Kingdom (UK), regarding cooperative programs in high-temperature gas-cooled reactor (HTGR) technology between the U. S. Department of Energy and the UK Atomic Energy Authority (UKAEA).

Meetings at KFA Jülich, FRG on Cooperation in HTGR Technology Development June 27-28, 1988

Introductory Session

FRG participants at the introductory session included Dr. Erwin Balthesen, Bundesminster für Forschung und Technologie (BMFT); and Dr. Heinz Nabielek, Dr. Norbert Kirch, and Dr. Werner von Lensa of KFA. Millunzi reviewed the substantial progress of the USA program, highlighting the fact that the program is now into the Preliminary Design Phase involving General Atomics, Bechtel, and Combustion Engineering (CE) in the nuclear island design and Stone and Webster Engineering Corporation (SWEC) and CE in the balance-of-plant (BOP) and control and instrumentation system design. He noted the favorable report on the MHTGR Conceptual Design by the Nuclear Regulatory Commission (NRC) staff during the recent meeting with the Advisory Committee on Reactor Safety (ACRS) Subcommittee on Advanced Concepts as well as over 40 other meetings with NRC on the MHTGR concept. He also outlined the technology development work, especially noting start of the COMEDIE Experiment in 1989.

In response to questions, Millunzi clarified the budget situation in the USA, the Gas-Cooled Reactor Associates (GCRA) role, and the purpose of the module demonstration. The latter item was to clarify that the module demonstration is not for safety tests or to satisfy a "license-by-test" requirement. Rather, the module test is primarily to demonstrate economics and performance. Millunzi said a private sector initiative in the USA to demonstrate the MHTGR during the mid to late 1990s was being pursued. International participation in such a demonstration is also possible.

In turn, Dr. Balthesen summarized the FRG program, especially highlighting the development experience from AVR and the Thorium High-Temperature Reactor (THTR). He noted that this program at KFA is at a level of about 75M DM/year, including about 20M DM for AVR. In addition, BMFT supports cost-shared systems technology development contracts in industry at a total government cost of about 35M DM/year. These contracts are two thirds government funded presently but will be 50-50 in the future. Dr. Werner von Lensa later described the areas of development involved in this work which is outlined in Appendix 1 along with the participating organizations.

Loss-of-coolant tests at AVR, which involve U.S. participation, are going well. Preliminary results appear to confirm the expectations regarding passive safety. AVR is scheduled to shut down at the end of CY 1988, but may possibly operate longer since they have fuel for several more months. It would be technically possible for AVR to run up to nine months longer. Shutdown may be delayed because of the need for a new storage facility to store the fuel currently in the core and because of the complexity of the shutdown licensing procedure. Depressurization tests will likely be performed in the November/December time period, although they do not have a license for this experiment yet.

THTR was transferred officially to the utility on June 1, 1987. It is generally operating at full power. THTR has generated more than 1300 GW hours since being turned over to the utility. Availability of 85% has been achieved during the time when operation was scheduled. In other words, unscheduled outages were limited to 15%.

They have had a problem with damaged pebbles caused by a combination of (1) dense packing of the core due to people standing on the core during the initial fuel loading period, and (2) an unusually large number of operations of control rods ramming into the core during the initial startup and testing phase. Control rods are not required to be inserted in the core during normal operation, because reflector control rods are sufficient. This problem is believed to be resolving itself with time as the damaged fuel moves through the core. (The use of prismatic fuel in the MHTGR precludes this problem.)

The next major planned shutdown period will be in the fall to install a cooling device in the room above the steam generator. They have had to limit power during some periods to protect insulation in this region, because temperatures were higher than expected (55°C expected, 60°C experienced).

They may have a fuel supply problem for THTR. Nukem facilities are being shut down as current inventory is processed. They now have fuel available for operating through 1990 and expect to have fuel for operation through 1991 when Nukem completes inventory. A new fuel pebble production line is being considered at the HOBEG facility; however, it must be upgraded. Fuel kernels would be supplied by Alkem in FRG or possibly General Atomics in the USA.

Other THTR issues involve regulation. THTR has a license for 1100 full-power days. The license must then be renewed. Also, after 600 full-power days, they

must have facilities available for intermediate spent fuel storage. They will reach this point in mid 1989. Options for intermediate fuel storage are under consideration.

Regarding advanced concepts, the HTR-500 reference or lead plant has been delayed. A contract to start the design phase leading to an independent (not site-specific) license is expected to be signed next month. FRG and Swiss (10%) utilities are supporting this effort. Technology development support is being provided by KFA.

HTR-100 has only a low level of effort at this time. They are working toward a possible contract with a South German utility (Lower Saxony region) also for site-independent design.

The ongoing HTR module design effort by Siemans/Interatom is also concentrating on the licensing effort and is supported primarily by Seimans with a small amount of funds from FRG utilities. KFA is also providing technology development support to the HTR modul design.

The state of Nordrhein-Westfalen may terminate its support for high-temperature process heat work in 1989. As a result, high-temperature process heat activities in FRG will be reduced.

Safety Research Subprogram

Dr. W. Kröger, who directs safety research at KFA, joined the meeting for discussion of the USA/FRG Safety Research Subprogram. He provided us with a general perspective of overall safety activities in FRG. He currently has a special program to look into safety of THTR. His approach in carrying out the risk-oriented safety studies is to try to reduce risk through cost beneficial modifications. They also strive to improve safety through accident management.

Kröger stated that there is no urgent need to do anything regarding safety for the THTR; they are only making recommendations for improvements in 1988. These recommendations will be reviewed and discussed in 1989.

The KFA is planning to combine Prof. Schulten's Institute for Reactor Development with the Safety Institute when Schulten retires. The combined organization will include 60 to 70 people and will focus on safety. KFA has about 100 technical people now working in the HTR Program.

A recently reviewed and updated USA/FRG Safety Research Subprogram Plan was finalized in December 1987 and published in March 1988 (DOE-HTGR-87-101). Dr. Kröger summarized the status of our safety cooperation from his perspective. In general, the cooperation is excellent. There has been some impact on priorities and schedules due to the demands of the THTR work. He perceives both countries completing efforts to validate codes used in safety analysis, and that cooperation can enhance both programs and save money.

The USA (F. A. Silady and John Cleveland) and FRG (W. Kröger) subprogram managers will meet in the fall of 1988.

Dr. Kröger indicated that their program for FY 1989 has been revised and that a copy of the revised program could be made available to the U.S. Specific revisions to the revision and update of the subprogram plan will be completed by Kröger with Silady and Cleveland from the U.S. Kröger noted the importance of keeping the generic nature of the safety program intact.

Millunzi expressed concern about the impact of changes at KFA on the proposed cooperative safety work and urged FRG to initiate discussion of safety criteria. Kröger indicated he thought FRG would be in position to discuss new safety criteria raised by the USA in the near future. At this time, there are no official safety criteria for advanced reactors in FRG. This might be viewed as a research topic in FRG. They proposed that the USA side present and discuss its criteria in FRG with industry and regulatory people. It was noted that someone from Lower Saxony (state government) and perhaps BMU (counterpart to NRC) might attend the GCRA/IAEA meeting in the USA this fall. It was also suggested that the U.S. advanced safety criteria be discussed with them at that time.

Materials Subprogram

Later in the afternoon, we met with Prof. Nickel and Dr. Schubert from the Institute for Reactor Materials to review the subprogram plan for materials. In this area, there was a very recent meeting between Rittenhouse of ORNL and Schubert and Nickel to review the technical status of this work. Some specific notes from discussions follow.

PWS-M7, Joint Creep Evaluation of Alloy 617 and Alloy 800. Millunzi suggested that Combustion Engineering would participate in the joint evaluation of data along with ORNL. Plans will be made for a meeting of representatives to be held in FRG in the winter of 1989.

PWS-M8, Joint Evaluation of Low-Cycle Fatigue Experimental Results on Alloy 800. Mr. Schuster of FRG will visit ORNL in May of 1989 to collaborate with Mr. Strizak and others to reach agreement on the format and amount of fatigue data to be evaluated.

PWS M9, Short-Term Elevated Temperature Properties of Pressure Vessel Steels. There is a milestone for agreement on data exchangers and additional testing in March of 1989. Mr. Millunzi asked that the technical managers prepare a paper summarizing their interim understanding, status, and agreement on expectations from additional tests in preparation for the meeting on this milestone.

PWS M1, Neutron Irradiation Effects (proposed project work statement). Millunzi also requested that the technical task managers develop a paper

summarizing the interim status of technology concerning pressure vessel steel in preparation for a March 1989 milestone to define additional efforts.

Prof. Nickel and Dr. Schubert noted that they are planning a broad review seminar on structural design codes in the Federal Republic of Germany at KFA early in February of 1989. This meeting would include participation from the international community, and they are requesting participation from the U.S., including papers from ORNL and Combustion Engineering. A more formal invitation will be forthcoming. Prof. Nickel and Dr. Schubert will visit the U.S. in September of 1988, visiting General Atomics and Gas-Cooled Reactor Associates (GCRA) in San Diego on the 26th; and arriving in Oak Ridge on Tuesday evening, the 27th, for visits on Wednesday and Thursday. They will be in Washington on Friday, September 30, and leave on Saturday to return to FRG.

The cooperation in materials is going quite well. The FRG attitude toward cooperation with the U.S. in materials is very positive at this time. This is evidenced by the first new project work statements posed in several years during the recent meeting. This enthusiasm stems from a closer alignment of current U.S. and FRG materials interest than in past years.

Fuels, Fission Products, Graphite Subprogram

Subsequently we met with Dr. Balthesen and Dr. Nabielek to review the fuels, fission products, and graphite subprogram plan. Nabielek noted that we had had a partnership in this area since 1977 and a long history of cooperation. Regarding the fuel irradiation experiment HFR-B1 in Petten, this test began irradiation in June 1987 and will terminate in late 1989. Nabielek noted that an interruption of the Petten irradiation is possible because of potential delays in fuel delivery for the Petten reactor from Nukem. Nabielek indicated that KFA will complete the post-irradiation examination on the Petten particles subject to the availability of hot cells in KFA. It was noted that Dick Burnette, formerly of General Atomics, has been employed by Petten to assist with this experiment. Several key issues remaining in the operation of HFRL-B1 were discussed. Emphasis of the discussions was on assuring quality data from the experiment.

A key issue in the future is the performance of the postirradiation examination on this capsule. Nabielek confirmed that KFA will complete the postirradiation examination on Petten particles subject to the availability of hot cells in the 1990-1991 time period. As part of the exchange, the U.S. will provide in-reactor, postirradiation examination, and fuel heatup results from the HRB-21 irradiation experiment.

A number of detailed items in the project work statements were reviewed. It was noted that there is a need to revise schedules to reflect the current expectations in the cooperation. The U.S. (Kania) will provide a marked-up schedule revision to FRG for review and consideration prior to the Subprogram Manager's meeting this fall.

During the previous U.S/FRG management level meeting held in July 1987 at KFA, it was agreed that the two parties would exchange near-term development plans in the area of fuels, fission products, and graphite. KFA has responded by providing DOE with their Fuel Project Working Program 1988 and their Long-Range Fuel Project Overview Program 1987-88. These programs were provided in German to DOE, GA, and ORNL, and translation has caused us a considerable delay. Millunzi raised two concerns regarding the reports received. First, the FRG document is specific for only 1988, and very general for the out-years. U.S. plans are specific for all three years. Further he noted the concern that the FRG industry work on HTR development may not be fully reflected in the document received from FRG whereas the U.S. plans include all work in the U.S. No final resolution of this issue was reached, but the U.S. side agreed to respond promptly after a thorough review of the recently translated FRG plans is completed.

AVR Subprogram

The subprogram plan for the AVR test program was discussed with K. Krüger. This was a fairly brief discussion which focused on review and discussion of the recently completed loss-of-coolant experiment which involved the participation of John Cleveland from the USA and discussion of the schedule and plans for future experiments in the AVR. A suggestion was put forward by FRG for an exchange involving U.S. participation in fission product transport tests at AVR in exchange for FRG access to the COMEDIE experiment results. Consideration of this proposal will involve further review of the proposed AVR fission product transport tests and U.S. data requirements.

This exchange is very active and productive. It is proceeding well with good cooperation on both sides.

General Discussions With KFA Management

On Tuesday morning, we met with Dr. Schroeder, who is on the Board of Directors of KFA, to discuss the overall relationship with KFA in the HTR cooperation. Dr. Balthesen joined us for this discussion. Dr. Shroeder was very pleased with the cooperation and enthusiastic about its continuation. He indicated that the HTR program at KFA would continue at about the same level for the next five years. He was not encouraged with the prospects for a gas-cooled reactor project in Germany because of the political forces. FRG does have strong cooperative activities ongoing with the USSR and China. Millunzi briefly reviewed the program activities in the U.S. program and prospects for the future of gas-cooled reactors in the U.S.

General Discussions With BMFT Management

On Tuesday afternoon, Millunzi and Balthesen traveled to Bonn to brief new BMFT management personnel on the status of the US/FRG Umbrella Agreement and the DOE MHTGR Program.

Visit to THTR

Jones and Bramblett traveled to Uentrop on Tuesday afternoon for briefing and tour of the THTR reactor. Mr. Heske was kind enough to escort us on this tour and provide an excellent briefing on the status of the facility and program. Appendix 2 provides a brief summary of the main design data for the THTR. The plant was operating at 61% power at the time of our visit.

Overall, we were very favorably impressed with the facility and the operating staff with which we met. It is impressive to be able to approach the PCRV with the reactor running and without receiving any radiation dose.

We did receive a number of briefing documents on the THTR facility which are available from either Bramblett or Jones.

Visit to AVR

On Wednesday morning, Bramblett briefly visited the AVR site and received a very complete introduction to the facility. Handout information on AVR was provided and is available from Bramblett.

Meetings at Risley on US/UK Graphite Technology Exchange June 30—July 1, 1988

Introductory Session

We traveled to the United Kingdom for meetings with representatives from the UK/AEA and the Central Electric Generating Board (CEGB) for discussions of potential areas of activity for an exchange of graphite technology between US/DOE and the UK/AEA. A meeting was held at the Risley Laboratory near Warrington, England. We met initially with John Bramman of the UK/AEA International Collaboration Branch and Norman Prince of the Gas-Cooled Reactor Directorate. The principal purpose of the visit was to finalize the technology exchange agreement, to discuss the technology areas to be emphasized in collaboration, and to brief our counterparts in the UK on the status of the U.S. MHTGR program. During the initial discussions, it was determined that the draft agreement appears to be satisfactory to both sides and ready for signature. Mr. Bramman further indicated that the agreement would be signed the following week in the UK and subsequently forwarded to DOE for signature. We believe all parties were pleased to have the agreement in place in the very near future.

In the introductory session, they advised us that CEGB was to be broken up as a part of the privatization initiative in the UK. The new structure would consist of approximately 12 power distribution companies with area boards, one large generating company with all nuclear units comprising about 70% of the national generating capacity, and one small generating company with no nuclear units comprising about 30% of the national generating capacity. They noted that this

privatization initiative had demanded a great deal of time and attention in recent months. Mr. Prince is in the technology assessments division engaged in safety and performance assessments for gas-cooled reactors. They explained that the high-level decision to shift from the advanced gas-cooled reactors to light water reactors in UK limited their efforts and interest in gas-cooled reactor systems. They noted that there was a possibility for a small replacement reactor unit at Calder Hall in the next several years for which a small gas-cooled reactor could be considered. This unit would be owned by BNFL (British Nuclear Fuels Limited). They indicated that the experience with Magnox gas-cooled reactors in the UK had been quite good, but that experience with the advanced gas-cooled reactors (AGRs) had been mixed with some units performing very poorly while others performed much better. They noted that the recent AGRs just coming on line at Torness and Heysham II encompass the best features of the first-generation AGRs, and they will be looking to their performance with a great deal of interest. Mr. Prince noted that John Askew of UKAEA is a very strong advocate of the MHTGR concept, and that both he and Askew were very interested in the safety features of the MHTGR but somewhat concerned about the economics.

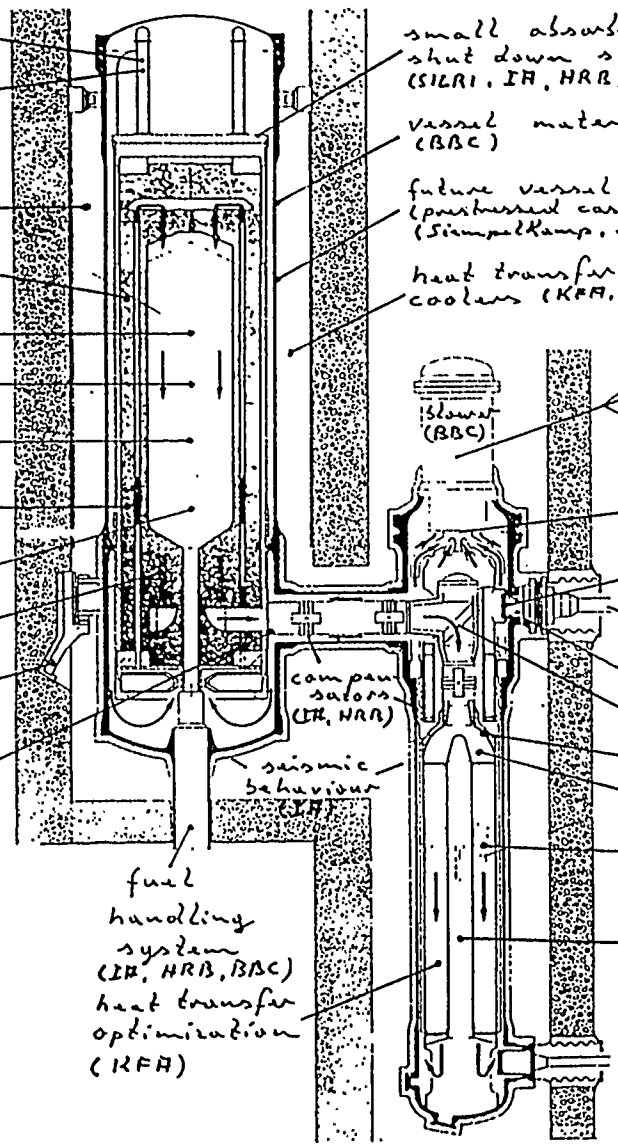
Graphite Technology Exchange

Mike Tucker of CEGB joined the meeting to participate in the discussion of graphite technology exchange. Appendix 3 is a summary of potential areas of activity in the exchange prepared by the U.S. and presented for discussion at the meeting. These areas were fully acceptable to the U.K. Tucker noted that he felt that the UK had some strength in the modeling capability and that the U.S. was strong in statistical methodologies. All parties felt that these items were broad enough to provide benefits to both countries from the exchange. Millunzi suggested that that a desirable feature of the exchange would include status reports from time to time with joint authorship from the U.S. and the UK at appropriate milestones. It was indicated that there would be a technical coordinator for each side. Mike Tucker would serve as the UK technical coordinator. It was indicated that ORNL would nominate the coordinator for the U.S. side, probably Walt Eatherly; and that Russ Vollman of General Atomics would serve as co-coordinator for the U.S. Mike Tucker suggested a meeting of the technical coordinators in September following the carbon conference. This was generally agreeable to both sides. Millunzi suggested that both sides prepare for the meeting by preparing an internal review summary document and exchanging background material.

Seminar on Status of U.S. HTGR Program

At Risley, Millunzi and Bramblett each presented a seminar highlighting the status of the U.S. HTGR program. The seminars were well attended and created a great deal of interest and discussion. It was indicated during the discussion that there is an emerging interest in small modular units in the UK, but that this interest remains at a low profile because of the official government policy to proceed with large light water reactors.

Examples for R + D - work



Work on systems

- accident analysis (IA, KFA)
- accident management methods
- inspection / repair concepts (IA, special companies)
- design criteria (TÜV, GRS, FAG, MPA, HRB, IA, KFA)
- plant dynamics (TÜV, universities, IA, HRA)
- instrumentation (KFA, IA, HRA)
- valves (HRA)
- sensors gas (HRA)
- filters (special companies)
- gas cleaning device (Linde etc)
- seismic loads (IA, universities)
- burn up measurement (IA, AVR)
- minimization of radiation load on personal (IA)
- plant removal concepts (IA, Battelle)
- gas explosions (Battelle, IA)

Advanced Licensing criterias

Applications

- process steam in industry (LURGI)
- enhanced oil recovery (KFA, universities)
- aluminium production (LURGI)
- oil refinement (LURGI)

Appendix 2

Main Design Data

for THTR

Overall Plant Data		
Core thermal power	750	MJ/s
Net electrical power	296	MW
Primary system data		
Core diameter	5.60	m
Core height	6.00	m
Number of fuel element spheres (equilibrium core)	675000	
Volume of pebble bed	125	m^3
Power density	6	MJ/sm^3
Helium flow rate	296.3	kg/s
Helium temperature at steam generator outlet	250	°C
Helium temperature at steam generator inlet	750	°C
Mean operating pressure of helium	39	bar
Fuel element diameter	6	cm
Heavy metal content	0.96	g U-235 (93% enriched)
	10.2	g TH-232
Number of incore rods	42	
Number of reflector rods	36	
Number of coolant gas circulators	6	
Number of steam generators	6	
Dimensions of the prestressed concrete reactor vessel		
Inside diameter	15.90	m
Inside height	15.30	m
Thickness of the cylindrical walls	4.45	m
Thickness of the bottom head	5.10	m
Thickness of the top head	5.10	m
Operating pressure	39	bar
Test pressure	46	bar
Secondary system data		
Turbine:		
Main steam flow	930	t/h
Main steam pressure/temperature	177.5	bar/530°C
Reheat steam pressure/temperature	46.5	bar/530°C
Feedwater temperature	180	°C
Condenser vacuum/Cooling water temperature	0.0685	bar/26.5°C
Cooling water flow	31720	m^3/h
Type of turbine		1 HP, 1 MP, 1 LP casing, double-flow LP section
Number of extraction steam bleeds	5	
Generator:		
Actual power output	307.5	MW
Apparent power output	410	MVA
Rated voltage	21	kV
Frequency	50	Hz
Type		two-pole
Cooling of rotor		hydrogen
Cooling of stator windings		water
Natural draft dry-cooling tower:		
Cooling water flow	31720	m^3/h
Cold water temperature	26.5	°C
Feedwater pumps:		
Number		5.3 MW each
Power		1 Motor
Drives		2 Turbines

Appendix 3

Potential Areas of Activity for the US/UK Graphite Technology Exchange

This exchange, although primarily phrased in terms of an interchange of information, must also include discussion of future plans and collaborative experiments to the extent such are feasible and constructive. In our discussions with both Kelly (UKAEA) and Tucker (CEGB), such collaboration has been visualized.

The areas of collaboration which are definitely of interest to ORNL and GA, and which we believe are of mutual benefit, are:

1. Graphite creep, both data bases and modeling.

2. Graphite fracture, including methods of measurement, data, and modeling.

3. Nondestructive test methods, proof testing, and statistical treatment of strength and other failure criteria.

4. Data on residual stress and other factors which can have bearing on the general problem of behavioral differences between small specimens and large components under radiation damage.

5. Exchange in the general area of design methods and structural design criteria for graphite components.

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