MEETING REPORT

The Technical Committee Meeting consisted of five half-day sessions with the papers grouped into five different categories: Safety considerations, project prospects, design status, cost and economic aspects and research and development. The list of participants of the meeting is given in Appendix I.

The technical content of most of the papers presented at the meeting has been incorporated in a recently published IAEA report; Technical Report Series No. 312 Gas Cooled Reactor Design and Safety, May 1990. The Table of Contents of this report is given in Appendix II. In addition, about one-half of the papers have been included in a special issue of Energy, The International Journal dedicated to High Temperature Gas-cooled Reactors. This special issue will be published in December 1990. The Table of Contents of this special issue is given in Appendix III.

This meeting report summarizes the Technical Committee Meeting in terms of the program in each country as an overview of all of the papers presented by the authors from each country. All papers presented at the TCM are also included in this report without editing.

THE GAS-COOLED REACTOR PROGRAM IN THE SOVIET UNION (USSR)

The design characteristics of the two HTGR-type plants which are receiving the major attention in the USSR, were presented. The 200 MWt VGM is very similar to the HTR-Module under development in Germany except for the incorporation of an auxiliary cooling loop for decay heat removal and the inclusion of an intermediate heat exchanger in the main heat transport loop. The intention is to initially operate the plant at 750°C core outlet temperature with only the steam generator and circulator in the main loop and then, in a second operational phase, to add the intermediate heat exchanger and raise the core outlet temperature to 950°C. The other design is the VG-400 plant which is rated at 1060 MWt and incorporates four main heat transport loops, each consisting of an intermediate heat exchanger followed by a steam generator/main circulator. The four loops are located in eight paired cavities in the sidewall of a cylindrical prestressed concrete reactor vessel containing the reactor core. Both of the USSR designs utilize a pebble bed core and both are designed for the ultimate application to industrial process heat/cogenerated electricity supply.

The results of several development programs related to the HTGR designs were also present. Of particular interest were the reports on the development of HTGR coated particle fuel and pebble bed fuel elements. The fuel development has been a major program in the USSR for several years and the manufacturing processes are very similar to those used in Germany and the United States. The investigations have included every thorough characterization of the properties of each fuel component including the fuel kernels, coatings and the matrix graphite for pebble bed elements.

Several experiments including a description of the experimental apparatus used to investigate the kinetic behaviour of pebble bed cores, the interaction between the core and the control rods and the drive mechanisms for the control rods were also discussed.

Several reports were given on the development of heat exchangers, graphite and other HTGR equipment and on several HTGR application studies.

THE GAS-COOLED REACTOR PROGRAM IN GERMANY

An overview of the status of electricity generation in Germany indicated that the reserve margins in Germany are presently very large and, with projected near-term growth rates in demand of 1% per year or less, very few new power plants are foreseen as needed for several years. The HTR situation in Germany, including the shutdown in power generation of the AVR in December, 1988 and the announced intention to shutdown the THTR-300 were reviewed. Germany intends to continue support for HTR technology and the maintenance of a technical basis sufficient to revive the option when needed.

The operating experience and plans for the THTR-300 were presented. In September 1988, the plant was shutdown for a scheduled inspection. At that time, inspection of one of the hot gas ducts, through which hot helium passes from the core exit to the steam generator entrance, revealed some damage. Several bolt heads from the central attachment fixture on the thermal insulation cover plates had broken off. In addition, several graphite dowels that hold the lower outer graphite blocks lining the hot gas duct had been displaced. All 6 ducts were subsequently inspected and it was found that, out of about 2600 bolts, 35 bolt heads had come off. Analysis determined that the bold heads had failed due to a concentration of stresses resulting from thermal expansion of the metallic foil insulation coupled with a reduction in ductility of the bolt material as a result of neutron irradiation. The cover plates have 4 corner attachment fixtures in addition to the central attachment and further analyses concluded that the plant could still be safely operated.

Late in 1988, however, a reevaluation of the risks associated with the continued operation of THTR was made. Several risk factors have changed since the initial contract for THTR was signed. These include the termination of an ongoing fuel supply by NUKEM, inability to assure spent fuel storage facilities, the possibility of additional requirements being imposed prior to obtaining a long term operating license and the increased estimated cost for decommissioning. These risks total to a figure over twice as large as originally estimated, placing a potentially large burden on the HKG consortium that owns the plant. The HKG partners asked for increased participation by both the Federal and State governments. This was not successful and, in order to limit the risks, the HKG partners gave notice of their intent to shutdown and decommission THTR. THTR generated almost 2.9 billion Kwh of electricity since the beginning of power production in late 1985 and verified many of the unique characteristics of HTGR-type plants during the operation.

The three reference concepts being developed in Germany, the HTR-500, the HTR-Module and the Gas-Cooled Heating Reactor, the GHR 10, were described. The conceptual design and site-independent safety report on the HTR-500 have been completed. On the HTR-Module, a revised safety analysis report was submitted in September 1988 and a final statement on the safety concept of the HTR-Module from the Reactor Safety Committee is expected in the fall of 1989.

Several safety aspects of HTGR's and the safety research being performed at KFA, Jülich were described. The shift in emphasis in safety research of HTGR's to investigations on the efficiency of several physical mechanisms to mitigate design basis and beyond-design basis events was noted. The results of several research programs including fission product retention capability of coated fuel particles at elevated temperatures, fission product retention by graphite, the kinetics of the steam-graphite and oxygen-graphite reactions in practical configurations and the results of the recent tests in AVR on depressurized core cooldown by conduction and radiation were presented.

The behaviour of HTGR's under accident situations extending into the beyond design basis regime is largely understood and accepted by licensing authorities. A preliminary version of a film of recent AVR safety tests was also presented to illustrate the impressive safety response of small HTGR's.

THE GAS-COOLED REACTOR PROGRAM IN THE UNITED STATES (US)

A presentation on electricity supply and nuclear power in the US showed that, although the growth in overall energy consumption still remains low, the demand for electricity continues to expand at rates closely corresponding to that of the Gross National Product, about 2.5% per year. The need for additional capacity is becoming apparent in many areas of the country as reserve margins are becoming precariously low. The 108 operating nuclear plants in the US. are now producing about 20% of total demand but this percentage will start to decrease in the 1990's even as the few remaining plants under construction are completed. A reversal of the forthcoming downtrend will occur only if the impediments to nuclear power in the US are overcome. The MHTGR was viewed as an option whose characteristics appear to mesh well with the requirements for the revival of nuclear power.

A review of the operations of the FSV plant and the plans for the future were presented. The scheduled shutdown to replace bolting material on the helium circulators which had taken place in July 1988, had extended to March 1989 due again primarily to moisture ingress into the primary system. The ingress was from a small breach in the core support section of the liner cooling system which had caused a similar problem several years previously. The plant was brought back into operation in April 1989. From the beginning of power generation, the FSV plant has generated over 5.4 billion Kwh of electricity.

The financial situation regarding FSV was discussed and it was noted that extensive efforts had been undertaken to assure the continued operation of the plant. However, the costs of operation, maintenance, fuel fabrication and providing for capital improvements on what has, unfortunately, become a unique facility could not be entirely covered by the allowable 4.8 cents per Kwh return on electricity generated, with any reasonably attainable capacity factors. As a result, in early December, 1988, the PSC Board of Directors made the decision to permanently shutdown the plant. The present plan, providing that significant problems do not develop, is to continue operation at approximately 80% power for the remainder of 1989 followed by a coastdown of decreasing plant output by 5% per month during the first half of 1990. A significant program is underway to prepare for the defueling and decommissioning of the reactor.

The schedule of the on-going DOE program on the MHTGR was discussed. The signing of five year contracts between DOE and the several industrial entities for the continuing design and prelicensing effort on the reference 4-module MHTGR plant was noted. The schedule for the work, which is now in the early preliminary design phase, was presented and involves a continuing extensive interaction with the US Nuclear Regulatory Commission (NRC) with the aim of obtaining a Final Design Approval in 1996.

A paper covering the safety approach of the MHTGR in the US and the response of the plant to several events that were foreseen to potentially challenge the ability to retain radionuclides within the coated fuel particles

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was presented. The events include those that would be considered design basis as well as beyond design basis and in all cases the passive safety features prevented and mitigated radionuclide release levels to well below the limits established by the requirements. The history of interactions with the NRC was then recounted and a summary of the generally favourable conclusions from the NRC's recently released draft Safety Evaluation Report was presented.

THE GAS-COOLED REACTOR PROGRAM IN JAPAN

The presentations from Japan provided an update of the HTGR development program in Japan with particular emphasis on the status of the HTTR. The budget for the construction of the HTTR was approved by the Japanese Government in early 1989 and JAERI submitted the safety analysis report to the Science and Technology Agency in February. A construction permit is expected in the Spring of 1990 and completion of construction on a site at JAERI's Oarai Research Establishment is planned for 1995. The main features of the HTTR, a 30 MWt test reactor using prismatic-type fuel elements, whose major objectives will be to establish basic technologies for advanced HTGR's and to perform as an irradiation test reactor for research in high temperature technologies were described.

An update of the studies by the Research Association on High Temperature Gas-Cooled Reactor Plant on the viability of HTGR concepts in Japan was presented. In 1988, the Association entered Phase II of its efforts with emphasis on assessment of the applicability of the module HTGR under the more severe seismic and extremely limited siting conditions typical of Japan. Two working groups were established. The first group initiated an examination of the specific regulatory and siting requirements in Japan with reference to the utility/user design requirements evolved during Phase I. The second working group initiated some detailed comparison studies on the differences between the US MHTGR and the German HTR-Module in responding to various transients. The group has also started to evolve various scenarios for the introduction and long term deployment of the HTGR in Japan.

THE GAS-COOLED REACTOR PROGRAM IN OTHER COUNTRIES

The status of the HTGR reserach and development program in the People's Republic of China (PRC) was presented. The program was initiated in 1974 with basic research in coated particle fuel, graphite technology and HTGR component development. The program is presently in its third phase and in addition to the continuing research, is performing design, safety and application studies on the modular HTGR. In addition, a project study on a 10 MWt HTR Test Module was initiated in 1988. The study is being jointly sponsored by the INET in the PRC and Seimens/Interatom and KFA in Germany. Construction of the Test Module is being contemplated at the site of the INET, northwest of Beijing. The main objective of the facility will be to verify and demonstrate some of the unique features of the modular concept. The configuration of components is identical to the German HTR-Module. A pebble bed core, smaller in dimensions than the HTR-Module, with a maximum output of 20 MWt (for later enhanced capability) is used. Application studies were presented for enhanced oil recovery in the Shanjasi section of the Shengli oil field using high temperature/high pressure steam and some remarks were given regarding the start of the cogeneration study for the Yangsham Petroleum Corporation located in southwest Beijing.

A paper discussing the feasibility study, initiated in 1988, on the construction of a MHTGR demonstration plant near the city of Zhongquing in Southwest China was presented. Zhongqing is the largest city in a very important developing district but suffers from a severe shortage of electricity supply due to the more than 40% dependence on hydropower. Dry seasons force work stoppages of 3 to 4 days each week. The construction of new coal-fired plants is difficult due to transportation problems and, although additional hydropower resources are available, the dry season type problem would not be solved.

The working team has surveyed eight possible sites and selected, after a preliminary evaluation, a site about 30 km east of the city, near the Yangtze River. An evaluation of the possible supply of as much of the equipment, material and labor scope by Chinese industry has been made and the cost of two alternate technical schemes have been derived; a 2 x 350 MWt U.S. MHTGR plant with a 300 MWe turbine generator and a 4 x 200 MWt German HTR- Module plant with a 340 MWe T-G set. Even with more than 90% of the conventional part of the plant supplied by the Chinese industry the capital cost for the nuclear plants are currently estimated to be too high. Nevertheless, nuclear could be the option for the future if the participation of vendors to help defray the high introduction costs for the modular HTGR nuclear plant in China was available.

An overview of the potential for the introduction of HTGR's in Czechoslovakia was presented. Nuclear-generated electricity, using the Soviet-type of pressurized water reactors presently provides about 27% of demand but the remainder is generated almost entirely by burning indigenous brown coal. The high level of pollution from these plants and from chemical industry plants, primarily located in the North Bohemian region of the country, is causing considerable concern and is being given special attention by authorities. With industry, in total, consuming more than 60% of the fossil energy resources, the need for process heat applications of the HTGR, particularly the higher temperature applications of steam-methane reforming and coal gasification, was emphasized.

The Swiss industry's broad participation in several international projects and design programs on the HTGR which has extended for over 20 years was discussed. Switzerland's more recent interest in the small gas-cooled district heating reactor, the 10-20 MWt GHR-10, whose conceptual design was recently completed in conjunction with ABB in Germany was noted. The PROTEUS facility at the Paul Scherrer Institute which is available for performing ciritical experiments on small HTGR cores and the interest in international cooperation for such experiments was also discussed. The purpose would be to enable analytical code verification of some of the unique reactor physics aspects of this type of reactor.

The results of the continuing studies on the application of HTGR's for heavy oil recovery in Indonesia were presented. The recent studies expanded on preliminary studies performed in 1986/87 and indicated that, with the present low prices for oil, it was not possible to show an economic advantage for the reactor application. However, with the expected future escalation in oil prices, the economic viability of the reactor application would be apparent. Various concepts for regional development in Indonesia which is very rich in several natural resources and has a strong desire to establish a domestic industrial infrastructure to exploit these resources were presented. The desire to establish an internal vendor supply industry for HTGR materials and equipment if the HTGR is deployed in Indonesia was expressed.

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