NRC INTERNATIONAL TRIP REPORT

Subject

This trip report summarizes activities related to my attendance at:

1. ASME B&PV Code Sec III Subgroup (SG) Meeting on Graphite Core Components GCC), March 24-26, 2010, Shanghai, China;
2. Generation IV International Forum (GIF) VHTR Graphite Working Group (GWG) Meeting, March 29-30, 2010;
3. Korea Institute of Nuclear Safety (KINS), Daejeon, Korea, March 31, 2010; and,
4. Korea Atomic Energy Research Institute (KAERI), Daejeon, Korea, April 1, 2010.

Dates of Travel, Countries, and Organizations Visited

March 23 – 28, China.
March 28 – April 1, 2010, Republic of Korea, KINS and KAERI.

Author, Title, and Agency Affiliation

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Sensitivity

This report does not contain any proprietary or sensitive information.

Background/Purpose

The ASME Division 2 Section III SG on GCC meets twice a year outside the U.S. in order to leverage the worldwide nuclear graphite technical experts' knowledge and efforts in developing the graphite design code for high temperature gas cooled reactors. I am a member of this SG and attended the SG meeting in Shanghai to review and discuss the latest balloted version of the draft code with other SG members. Following this meeting, I attended the meeting of the GIF GWG, which is in the process of developing a materials handbook for very high temperature reactor (VHTR), which will include a database of nuclear graphite properties. As stipulated in the NRC's NGNP HTGR Research Plan, the NRC is depending on the availability of such database and other worldwide data on nuclear graphite to assess the applicant's pre-application technical papers on proposed design and expected operating conditions of the NGNP. As such, my attendance contributes to the staff readiness for design certification review. I met with the technical staff of the KINS and exchanged technical data and information on the regulatory data needs for graphite in VHTR. Finally, I met with KAERI researchers and provided technical information on NRC's graphite research, and in turn learned about KAERI's recent activities related to their HTGR plans. By participating in these meetings, the staff maintains and improves the technical expertise in nuclear graphite technology, including regulatory safety information.

Abstract

This trip report summarizes my participation in the four meetings, which were earlier identified in the "Subject". The agenda for the ASME Sec III SG meeting, held in Shanghai, China, is shown in Exhibit A. This meeting was attended by nuclear graphite specialists with expertise in manufacturing, quality control, design of nuclear components, plant operation, and modeling graphite properties and behavior from the U.K., Japan, Korea, China, South Africa, U.S.A., and the ASME staff. After more than 5 years of effort, the SG has developed a draft code case, which has been successfully balloted at the SG level, and other SGs within ASME. It is expected that this code case will be published in 2011, although there are several gaps in the code case, which will be addressed in future years. A highlight of the meeting was the tour of the Toyo Tanso, China facilities, where graphite blocks manufactured in Japan will be machined into reactor components for the Chinese HTGR.

Outside of Scope

Discussion

This trip report summarizes the information which I gathered from attending the meetings mentioned in the "Subject".

1. ASME B&PV Code Sec III Subgroup (SG) Meeting on Graphite Core Components GCC), March 24-26, 2010, Shanghai, China.

The agenda for the ASME Sec III SG meeting, held in Shanghai, China, is shown in Exhibit A. This meeting was attended by nuclear graphite specialists with expertise in manufacturing, quality control, design of nuclear components, plant operation, and modeling graphite properties and behavior from the U.K., Japan, Korea, China, South Africa, U.S.A., and the ASME staff.

The SG members presented a status update on interaction with various other SG on familiarizing and facilitating the successful ballot of the GCC code case. It appears that the GCC code case is currently the most advanced compared to other SG working on code development for HTGR. Sec XI SG related to inservice inspection requirements for GCC is yet to be developed. However, the designs are still in the conceptual stage, and volunteers to draft this part of the code are not yet available. Preliminary contacts have been made and it is expected that this effort will begin soon. Contacts have also been made to the SG on nonmetallic materials (NMM); however this subgroup is very busy with issues related to polyethylene piping and has showed only peripheral interest at this time. A new Division 5 has been proposed under the ASME organization which will be solely responsible for VHTR and liquid metal reactors (LMR). A SG member has also interacted with the promoters of Div 5 and has briefed them on the progress of the GCC code development activities.

I recommended NRC's approval of this code case to move forward, with the understanding that the NRC staff has not yet reviewed this code case in detail. It is my opinion that after more than 5 years of effort, the SG's effort to produce a draft code case, has come a long way since the NRC began to support this effort with a contract to ORNL during 2003 to initiate code development within ASME. The draft code is based on existing metal codes, adapted to the specific ceramic design incorporating nonlinearity, inter-dependence of properties, multi-axial loading considerations, probabilistic fracture mechanics, and statistical analysis of the strength distribution for graphite.

The code is based on an assumption that the failure/cracking of a GCC part does not result in the loss of functional integrity of the graphite core assembly. In determining limits, it is possible to design parts by comparing calculated stresses to strength limits based on specimen test results, and incorporating adequate design margin. For graphite, fixed design margins do not ensure uniform reliability; and, variability in the graphite grade must be accounted for. It is possible to characterize the material variability statistically, and from this determine the required design margin. The design margins need to be provided by means of reliability targets, allocated for stress categories based on part classification. The probabilistic failure assessment must guard against brittle failure.

This draft code has been successfully balloted at the SG level, and other SGs within ASME. It is expected that this code case will be published in 2011, although there are several gaps in the current code case, which will be addressed in future years.

The SG members reviewed a proposed strategy for next code action and updates and plan for the next round of actions on code. There were several areas which were identified as needing more action and research to obtain technical information. There included: (a) graphite fatigue rules; (b) appendix on irradiation damage; (c) appendix on oxidation; and (d) requirements for damage tolerance of graphite structure.

A new effort was identified, which would fall into the GCC. This effort involves developing codes for graphite-graphite (C-C) composites and ceramic matrix composites (CMC), such as SiC-SiC. A researcher from ORNL presented a recent review of the status of the C-C and SiC-SiC composites and technical subject areas where need exists to generate additional data on properties relevant to VHTR operation.

During this meeting, an engineer from British Energy (BE) presented some information on the use of eddy current testing on irradiated graphite bricks by the examination of fuel channels in the reactor. The method showed promise for detecting discontinuities by way of changes in electrical resistivity. B.E. is considering using this technology for inservice inspection in the future.

A highlight of the meeting was the tour of the Toyo Tanso, China facilities, where IG-110 graphite blocks manufactured in Japan will be machined into reactor components for the Chinese HTGR. This is a very large facility and is expected to begin operation during August 2010. The facility will have state-of-the-art computer numerical control (CNC) finishing machinery and nondestructive testing and evaluation equipments. When in full operation this facility will produce more than 25,000 precision-segments of various HTGR graphite components for HTR-PM[1], which make up the graphite core.

2. Generation IV International Forum (GIF) VHTR Graphite Working Group (GWG) Meeting, March 29-30, 2010.

The second official GIF GWG meeting was held in KAERI, Daejeon, Korea. The agenda for this meeting is shown in Exhibit B. At this meeting, the participant States, mainly U.S.A., European Union (EU), and Korea discussed the exact nature of information which will be added to the database and handbook development, milestone dates, and clarifying the concept of value of information provided to GIF by the participant States. When the handbook is fully developed, the data contained in the handbook will be used for code development, and for the assessment of VHTR designs.

For GIF GWG activities, the Project Arrangement (PA) has been signed by all participants (CA, EU, FR, JP, KR, ZA, CH, US), with last signature on 16 September 2009. During this meeting, discussions were held regarding the handling of the information submitted to the project, especially the information which will be made available to the participant States before it is

[1] China's High Temperature Gas-cooled Reactor Demonstration Project is located in Shidao Bay Nuclear Power Plant. The site work of Huaneng Shidao Bay Nuclear Power Demonstration Project has been underway since April, 2008. During Phase 1, a 2x250 MWth (210 MWe), high temperature gas-cooled nuclear reactor is planned to be built. The project has received environmental clearance in March 2008 and the beginning of construction is planned for August 2010, with commissioning planned for 2013 - 2014. As reported, this will be a demonstration plant for 18 further modules at the site, for a total 3800 MWe.

made available to the public. The status of the development of materials handbook was discussed. Uploading of documents has started; however, some members have not started the process yet. It was decided to grant access to data when "good faith" is proven through the uploading of documents. Reconciliation of data from different signatories requires more efforts than initially expected, as methods are not as standardized as for metals for instance. W Ren, ORNL, who is handling the development of the Materials Handbook, proposes to attend GWG meeting to be held in UK during September 2010 in order to facilitate this process.

Mark Davies (EU) discussed the status of their work on task entitled, "Graphite Irradiation Effects". The INNOGRAPH 1B (750 °C) and INNOGRAPH 2B (950 °C) experiments to high fluence were terminated in February (HFR is currently shut down for a major repair). Screening measurements (dimensional change on approximately half of the samples) for 2B is expected to be completed by June and for 1B by December. Full post-irradiation examination (PIE) is proposed to be conducted in the 7th Framework Programme, which is expected to start around April 2011. EU also continues to participate in the task on "Graphite Codes and Standards Development (ASME and ASTM)."

Timothy Burchell (U.S.) reviewed unirradiated graphite information and discussed the data management system development, on behalf of Dr. Weiju Ren of ORNL, who could not attend this meeting. The EU, ORNL, and INL have provided examples of unirradiated creep test datasheets. The other signatories did not provide such datasheet. A review of these datasheets indicated that: (a) characterization of graphite is not as standardized as that of metals; (b) terminologies, testing methods, data management formats etc. vary from one organization to another; and (c) consequently, technical communication between organizations is not barrier-free. Therefore, the reconciliation of data attributes, processing methods, formats etc. of different Signatories requires more efforts than initially expected.

A new approach has been planned to overcome the difficulties in developing the Graphite Section. One popular graphite characterization system will be used to provide an outline for blueprint as a basic data management structure. The system will: (a) layout the basic terminologies and attribute names, and (b) delineate the basic database schema. A small beta version of the Graphite Section will be built using the basic blueprint for GWG review and comment. This will provide something tangible to facilitate communication and discussion. Reconciliation will then begin in the beta version to satisfy requirements and needs of different Signatories. Currently, ASTM Standards are considered as the candidate for providing the outline for basic blueprint.

Se-Hwan Chi (KAERI) presented recent data on "Specimen Size Effects on Flexural Strength and Weibull Modulus of Three Nuclear Graphite Grades: IG-110, NBG-18, and PCEA." Their results showed that maximum differences in the flexural strength of three different specimen size were between 8 and 37%. Flexural strength showed an anisotropy effect and grade dependency. Weibull moduli of flexural strength appeared to depend on graphite grade and test specimen size. The Weibull moduli based on the integrated flexural strength data of all the three different sizes were lower than other reported data. The results suggested that testing of several subsets of specimens of different specimen size may be a viable way for Weibull modulus determination.

On behalf of the U.S., Timothy Burchell presented the status of NGNP activities, relevant to GWG tasks. At ORNL, all pre-irradiation examination of creep specimens for capsule AGC-1 has been completed. The AGC-1 specimens are now under irradiation in ATR. The ORNL has also completed all AGC-1 "sister" specimen characterization and testing (destructive). They continue to participate in ASTM/ASME Codes & Standards activities. They have extended the multiaxial test facility capability to the fourth stress quadrant (axial compression and internal pressure [tensile hoop]).

South Africa was not present. However, their progress was reported by Davies of the EU. PBMR has completed tensile testing of graphite up to 1500 °C. All testing have been put on hold because of the limited activities of PBMR henceforth.

Outside of Scope

Out side of scope

Next Step

There are no specific activities that are needed for follow up by the NRC staff. However, I recommend that NRC staff continue to attend meetings of this nature and maintain current awareness and knowledge on the technical challenges related to licensing and regulation of future gas cooled reactors in the U.S. The staff should continue to engage in technical information exchange and international research cooperation to provide technical safety data on nuclear graphite for license evaluation.

Points for Commission Consideration/Items of Interest

There are no issues that require Commission attention.

Attachments

Attachments follow.

"On the Margins"

None.