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ARCHER Project: Progress on Material and component activities for the Advanced High Temperature Reactor

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Abstract – *The ARCHER (Advanced High-Temperature Reactors for Cogeneration of Heat and Electricity R&D) integrated project is a four year project which was started in 2011 as part of the European Commission 7th Framework Programme (FP7) to perform High Temperature Reactor technology R&D in support of reactor demonstration. The project consortium encompasses conventional and Nuclear Industry, Utilities, Technical Support Organizations, Research & Development Organizations and Academia. The activities involved contribute to the Generation IV (GIF) International Forum and collaborate with related projects in the US, China, Japan, and the Republic of Korea in cooperation with IAEA and ISTC. This paper addresses the progress of the work on ARCHER materials and component activities since the start of the project and underlines some of the main conclusions reached.*

I. INTRODUCTION

The European FP7 ARCHER Project [1] investigates the requirements for the helium cooled High Temperature Reactor (HTR). The ARCHER Project is a four year programme that builds on the HTR technology foundation established in Europe, in former national UK and German HTR programmes and European Framework Programmes (FP4, FP5 and FP6), with the FP6 RAPHAEL project completed in April 2010 [2], [3], [4], representing the former acknowledged achievement (see Figure 1). The HTR is graphite moderated and uses a high core outlet temperature of a level sufficient to support high temperature processes and can deliver heat in various forms. The ARCHER Project is primarily aimed at the short and mid-term needs of cogeneration or process heat requirements. Some technologies studied in RAPHAEL have been considered as mature or close to being mature and so have not been continued within ARCHER.

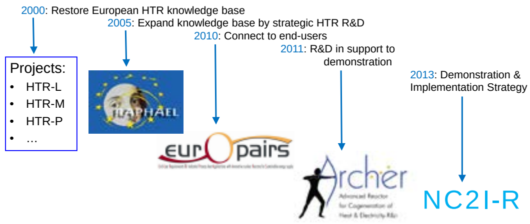


Fig 1: Nuclear Cogeneration related European Projects

The HTR offers significant advantages for the longer-term development of sustainable energy and in particular for heat and process applications and hydrogen generation. A European FP7 project called EUROPAIRS [5] examined this potential bringing together a partnership of (V)HTR nuclear and process heat suppliers. The industrial process heat market today (in energy terms) is of the same size as the electricity market. Worldwide, this market is growing and almost entirely based on combustion of fossil fuels which are increasingly scarce and suspected of inducing climate change. By replacing fossil energy imports, nuclear cogeneration can provide a significant contribution towards increased security of energy supply in a CO_2 lean Europe and can strengthen the key benefits associated with a robust European industry including economic development, employment, and supply of products and materials.

The ARCHER project consists of five subprojects involving co-ordination and system integration, safety and licensing, fuel and fuel cycle, materials and components and knowledge management. This paper addresses the progress of the work on materials and component technologies within ARCHER. The HTR is one of six advanced fission systems of interest for meeting the Generation VI International Forum (GIF) goals and its development critically depends not only on advances made in nuclear fuels but also in their systems and structural materials. These materials and components have to withstand severe environmental conditions (such as high temperatures, significant neutron irradiation and strong corrosive environments) in combination with complex loading and operational cycles and longer design life requirements. The challenges with regard to nuclear materials and components include not only operation in critical conditions but also compliance with the highest levels of safety and protection, whilst giving due regard to decommissioning, dismantling and waste processing issues.

II. MATERIAL AND COMPONENT ACTIVITIES IN ARCHER

A description of the materials and components programme within ARCHER for the High Temperature gas cooled system has been previously presented in the HTR2010 Conference [6]. The purpose of the ARCHER materials and components subproject is to study the materials and components that have reached a maturity level that promotes them as potential candidates for a demonstrator. The project addresses priority materials for HTR deployment including 1) Graphites to be selected and used for the reactor core; 2) Metals for key components addressing a gap analysis of nickel based materials and welds for use in high temperature heat exchangers and components where the code data is lacking. For components ARCHER establishes the basis for the introduction of 3) a Compact heat exchanger involving the design, manufacture and testing of a Mock-up to establish its structural feasibility for the HTR Demonstrator; 4) the basis for the introduction of the steam generator as the initial HTR primary heat exchange component.

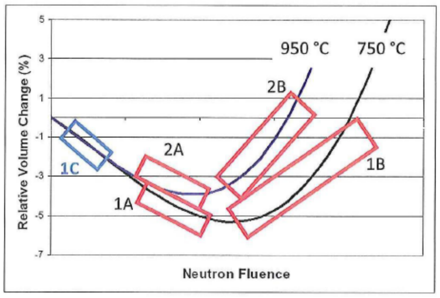
Within ARCHER, WP1 addresses the potential material grades for the graphite core in order to provide recommendations on near term and long term graphite selection requirements and issues. This involves investigation of material behaviour that has been irradiated in a material test reactor in the former RAPHAEL Project [2]. WP2 looks at the limits of currently available industrial high temperature metals considering the technology gaps in the available data and addressing manufacturing and remaining creep and transient influences on selection and behaviour, focusing primarily on Alloy 800H. This includes tests in a representative corrosion environment and under fatigue and creep conditions. WP3 investigates a promising Plate Stamped Heat Exchanger design (PSHE) using a full size mock-up (but limited in the number of plates: ~20 instead of 330 for the real module) supported by testing at higher than operating temperature in a large loop with analysis and material studies for estimation of heat exchanger robustness and capability. WP4 investigates the Steam Generator Unit (SGU) as a means of transferring heat and makes recommendations on current technology limits and proposals for future R& D.

II. GRAPHITES FOR THE REACTOR CORE

The choice of graphite for the reactor core is limited to those that are currently recommended and available from the manufacturers. These have been studied within the RAPHAEL Project with key irradiation experiments performed and providing results at levels >22 dpa at 750°C and >13 dpa at 950°C. Irradiation significantly affects the physical as well as mechanical properties and within RAPHAEL the information has been generated in such a way as to provide a description of the material performance for both the prismatic and pebble bed designs of HTR. Within the RAPHAEL project there was sufficient resources to complete the low dose post irradiation examination (PIE) and screening checks and for the higher dose experiments the full PIE was planned to be carried out in the ARCHER project.

The main objective of WP1 is to determine the irradiation behaviour of each graphite tested, and then to down-select from a design point of view the better graphites for the HTR core. To this end, the graphites are assessed mainly in terms of peak shrinkage, the dose at which the peak shrinkage, or "turn-around" occurs, the dose to reach original dimensions/volume, the anisotropy in the dimensional change behaviour and the scatter in the data. The work includes the PIE of the high dose experiments performed in RAPHAEL at 750°C and 950°C (INNOGRAPH-1B and INNOGRAPH-2B) and the assessment of the data for each graphite. The assessment will provide important information on graphite behaviour needed for core design purposes. Graphite manufacturers will be directly involved and benefit will also be taken from the past experience within the UK on the commercial Advanced Gas Reactor (AGR) programme.

In additional, a low dose experiment has been carried out at 750°C (INNOGRAPH-1C), with the first drum of samples maintained at 650°C (as with RAPHAEL) in order to get some results at this lower temperature. Within RAPHAEL a task on modelling of graphite behaviour was started and this work is continued within ARCHER and included within this low dose experiment task. The objective is to obtain data in the low dose region (1-2dpa) for those properties that are more rapidly affected by fast neutron irradiation (Young's modulus, strength and thermal diffusivity/ conductivity). It is thought that the micro-structural changes that arise in graphites at low dose have an effect on their medium and high dose behaviour. It is hoped to obtain a fuller understanding of micro-structural changes at low dose for modelling and the development of new graphite grades with improved irradiation tolerance at medium to high doses within this task. Such advances will help to minimize or reduce the extent and requirement for future irradiation testing. The RAPHAEL results will provide irradiated samples which will be investigated using optical, scanning electron microscopy (SEM) and transmission electron microscopy (TEM) as well as three-dimensional nano- and micro-X-ray tomography images from virgin and irradiated graphites. The low dose tests are performed on the recommended graphites and include some fuel graphite samples for which improvements over the previous A3.3 German grade have been made. This is the first look at fuel graphite performance and these tests will provide some initial indicators ahead of a much more extensive and needed testing series. The irradiation program for selecting graphites for the HTR core are shown in Figure 2. Test 2A was performed in the HTR-M1 FP5 Programme, tests 2B, 1A and 2A in the RAPHAEL project and test 1C in ARCHER.



1. INNOGRAPH-1A 750°C, low/medium dose (FP5)
2. INNOGRAPH-1B 750°C, high dose (RAPHAEL)
3. INNOGRAPH-2A 950°C, low/medium dose (RAPHAEL)
4. INNOGRAPH-2B 950°C, high dose (RAPHAEL)
5. INNOGRAPH-1C 750°C, low dose (ARCHER)

Fig. 2: Irradiation programs covering the full design curve for current HTR graphite grades

Progress in the PIE of the high dose irradiated samples has been notable with results obtained for different graphite grades in the high dose regime. As indicated in Figure 1 the results from the samples have taken the dimensional change behaviour beyond turn round to the expansion phase and past the zero change line. Information on graphite behaviour in this area provides important verification evidence for graphite performance for Regulators since it gives assurance on behaviour after the turn round stage has been reached. Such information is particularly valuable for the Pebble Bed design for which dose levels of this order may be experienced by areas of the core that are not replaced during the plant lifetime. Some representative results for graphite are shown in Figure 3 for the 750°C temperature condition. Results are shown for the behaviour with-grain and against-grain showing its anisotropic behaviour. For the PIE measurements a full set of dimensional data has been obtained. Selected samples for the Dynamic Young's Modulus (DYM), Coefficient of Thermal Expansion (CTE) and Thermal Diffusivity (TD) have also been obtained which vary depending on the irradiation dose. The DYM data showed the expected increase at lower dose to a plateau, followed by a further increase at medium dose, and finally a decrease at high dose. As expected, the CTE was found to have decreased and reached a stable plateau at medium dose, with indications of a slight increase at high dose. The TD and conductivity values, which typically fall rapidly at low dose, had also reached a plateau at medium dose. Some samples also showed a further reduction in TD/conductivity at high dose which is consistent with other graphites irradiated in the past. Note that the number of TD measurements was limited because of the levels of activity and size (high-dose swelling) mainly at 950°C. The results from these full PIE experiments are being assessed to establish the better graphites from the core design viewpoint with the results interpreted into a set of design curves. In addition to physical properties micro-structural examination has also been carried out, also strength tests to assess the change in strength properties with increasing irradiation dose.

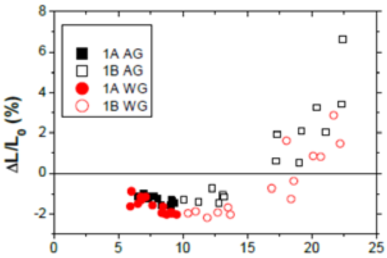


Fig. 3: Dimensional Change tests against levels of Neutron Fluence for a Graphite sample irradiated at 750°C

The development of results from the low dose experiment is well advanced. The experiment utilizes experience from the RAPHAEL experiments using 8 drums, each with 3 columns, to contain the samples. The rig contains 24 thermocouples to monitor and control temperature during the irradiation and the sample holders contain nine neutron fluence detector sets which are analysed after the irradiation. The sample holder is filled with helium to prevent oxidation of the graphite samples. The nominal temperature of the experiment is 750°C with the top drum containing approximately 30 samples at a nominal temperature of 650°C (as for the INNOGRAPH-1A experiment). Four major graphite grades have been selected plus some minor grades with their location with respect to the original block from which they were machined identified.

Grade	Manufacturer	Coke	Process	Major/minor
NBG-10	SGL	Pitch	Extrusion	Major
NBG-18	SGL	Pitch	Vibro-moulding	Major
PCEA	GrafTech	Petroleum	Extrusion	Major
PPEA	GrafTech	Pitch	Extrusion	Major
IG-110	Toyo Tanso	Petroleum	Iso-moulding	Minor
IG-430	Toyo Tanso	Pitch	Iso-moulding	Minor
LPEB/BAN	GrafTech	Needle	Extrusion	Minor
LPIB	GrafTech	Needle	Iso-moulding	Minor
NBG-17	SGL	Pitch	Vibro-moulding	Minor
NBG-20	SGL	Petroleum	Extrusion	Minor
NBG-25	SGL	Petroleum	Iso-moulding	Minor
PCIB	GrafTech	Petroleum	Iso-moulding	Minor

Table 1: Graphites in low Dose irradiation experiment

The experiment was started in 2013 and three cycles of irradiation have been carried out. The experiment suffered some delays due to reactor none availability however PIE of the samples has now been completed and the results are currently being examined to assess their behaviour. A significant benefit from these results will be the X-ray diffraction (XRD) and microscopic investigations since these samples will provide important information to assist in the development of modelling tools for the prediction of graphite behaviour. This work will be done in the latter project stages assisted by the University of Manchester.

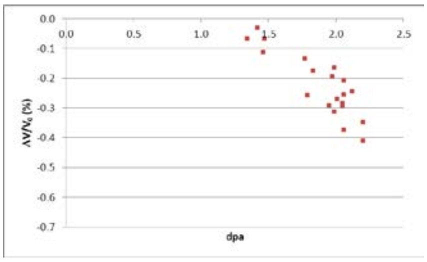


Fig. 4: Low Dose Test: Dimensional Change against Neutron Fluence for Graphite irradiated at 750°C

III. HIGH TEMPERATURE ALLOYS

Materials for key components such as the Intermediate Heat Exchanger (IHX) require industrial materials to operate for significant periods of time at high temperature. The effects of creep and environment are therefore critical, also the manufacturing process and any interaction with cyclic operation (fatigue). Industrially developed alloys suitable for such applications include IN 617, Haynes 230 and Alloy 800H. Former investigations within RAPHAEL [2] have examined the effects of creep, ageing effects and cold work on Haynes 230. Within ARCHER the focus of the work on metals is towards Alloy 800H addressing time and cycle dependent effects on material behaviour (creep/fatigue) and developing an understanding of the influence of different manufactured forms on material behaviour and application. Aspects such as condition monitoring (miniaturized samples), performance in a corrosion environment (loop tests), and sub-critical crack growth are being investigated.

Alloy 800H has been examined and tested to understand the material's capability at temperatures between 650<850°C with specific work on thin plate and welded joints undertaken for the IHX. In addition to conventional testing, a literature review of the effects of heat treatment, welding process and welding parameters on different types of cracking has been performed. This includes solidification cracking in the weldment, liquation cracking and/or ductility dip cracking in the heat affected zone and relaxation cracking in large welded components due to residual stresses in air, steam and helium (He). Thin plate and welded material has been investigated with regard to issues of residual stress and environment and the need for reliable prediction for long term operation.

A specific task on material procurement and data collation has been performed which feeds into the existing database with the purpose of expanding the available information to include feedback from the involved industrial partners. The information is being sourced from materials research programmes, a gap analysis and information required for the development of design code needs. The procurement and transfer of material for the tests was completed during the first year of ARCHER. Two blocks of Alloy 800H (dimension: 500mm x150mm x16mm) plus two WIG-welded plates (dimension: 500mm x150mm x16mm) were provided by ThyssenKrupp VDM to MPA Stuttgart to forward to all partners according to their requirements. The partners then machined their own samples on their respective sites for their test programmes. Results of tests on high temperature alloys within previous HTR programs have also been summarized and properties of selected alloys (e.g. Alloy 800H, Hastelloy X, Alloy 617, Haynes 230) specified in detail. Work was also carried out to evaluate data gaps in the MATDB data base which contains over 2600 stress data for Alloy 800H. The existing data set contains tensile, creep, low cycle fatigue and creep crack growth data, together with information on welds and effects of irradiation. Specific tests have also been carried out to establish fatigue and creep-fatigue and effects of cyclic behavior. Tests have been performed on a WIG-welded plate of Alloy 800H, also four relaxation tests on cross-weld specimens and four Gleeble tests with simulated heat treatment followed by slow strain rate tensile tests (10^{-6}/s). Tensile tests at room temperature (RT), 700°C, 800°C, show a significant reduction in strength between 700 and 800°C and that fatigue life is substantially affected by tensile holds. A good agreement is obtained for the strength of welds with recent results published by ASME in the development of ASME Section III NH for Alloy 800H.

With regard to corrosion, a survey of corrosion data generated in former HTR and related programmes has been carried out to provide information on candidate materials for V/HTR systems and mechanisms of degradation of these materials in V/HTR helium coolant. Experiments utilising a high temperature furnace (HTF) were also performed on different materials (P91, Alloy 800H including weld, 316SS) up to 900°C for exposure times up to 1500h and pressure of 1 bar and low flow rate. Post evaluation of the results included microstructure investigations, mass change, general corrosion, hardness and fracture toughness changes. In addition some tests were performed in a high temperature helium loop (HTHL) up to 900°C on Alloy 800H (parent and weld) and P91 steel at pressures up to 4.5 bar with a high flow rate.

Following exposure in the HTF the 316SS showed a significant decrease in fracture toughness; for P91 the decrease was moderate. The main influence was temperature. The corrosion layer for P91 was made up from chrome and manganese oxide. For Alloy 800H, after exposure, surface and subsurface layers were examined and the change in weight of the specimens recorded. Further high temperature alloys to be tested are Inconel 738, Inconel 713 and Austenitic steel N155. An extreme flooding event meant that further tests had to be rescheduled and a planned in-pile test will not be available before the end of the ARCHER programme and will not now take place. Final results are to be reported at the end of the project.

IV INTERMEDIATE HEAT EXCHANGER

WP3 specifically addresses the needs and development of the compact and modular Intermediate Heat Exchanger (IHX) technology. The gas to gas IHX is a critical component that can provide improved efficiency and economy of the reactor but requires considerable development to achieve a robust and compact arrangement that is capable of resisting the high temperature environment for long periods. The work focuses on the design and development and includes the manufacture and testing a mock-up of a promising PSHE under realistic temperature conditions. The work was broken down into five tasks covering design calculations, welding and machining, manufacture, tests in the CLAIRE Loop at CEA and materials tests on representative welded features.

Table 1: WP3 IHX Tasks

Task 1 – Design of IHX Mock-up	**CFD, thermal and stress analysis**
Task 2 - Welding and Machining	**laser welding trials/ tests & development of welding tools**
Task 3 – Manufacture of Mock-up	**800H sheets have been supplied for manufacture**
Task 4 - Tests in CLAIRE Loop	**Planned during 2013**
Task 5 – Supporting materials tests	**Ongoing – creep tests on representative plate and welded joints**

For the design activity iterative sizing and computer fluid dynamics (CFD) and finite element analysis (FEA) were carried out to minimize thermal and mechanical stresses under steady and transient conditions so that the length and height could be chosen to provide smooth thermal gradients throughout. The header position for the IHX and mock-up was optimized and the shape of the plate carefully studied to limit the occurrence of any flow recirculation areas. Plate thicknesses were selected according to pressure differences between fluids and the outside and the width so that external welding would be sufficient to withstand the pressure differences for different load cases. Depending on the loading, the parts would be subjected to tension, compression or bending and the worst damage effect was used to size and optimize the component.

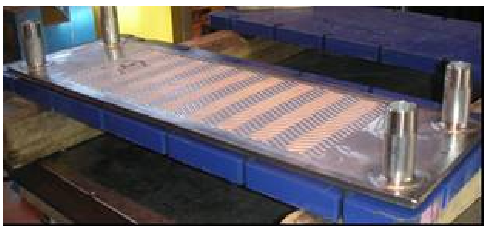


Fig. 5: Stainless steel mockup to check CFD thermal and Hydraulic laws

The mock-up was designed and manufactured using Alloy 800H with laser welding used for the manufacture. The welding and machining processes have been optimized to ensure a high quality for the component. The mock-up has the same dimensions as the real IHX module, but contains fewer plates (20 instead of 300), without loss of representation. CFD and thermo-mechanical calculations were used to provide a comparative platform to assess the performance and lifetime of the mock-up and the full size IHX module. Calculations are to be compared and validated with test results, incorporating specific material and weld data obtained during the project and from tests on welded features. The specific tests carried out as part of this investigation on the mock-up material and joints provide direct information for the mock-up lifetime estimation. These include: tensile properties of plate and welded structures (covering specific features in the mock-up heat exchanger to check against thicker section plate properties); creep tests on plate and welded structures [650–850^{o}C] including tests on laser welded joints and thin section plate. Comparison with European Creep Collaborative Committee (ECCC) data and testing on machined specimens taken from welded features plus longer term creep data are used to understand the strength and behaviour at elevated temperature. Tests focus on creep and strength testing of welds and parent plate to determine weld factors. Also, in conjunction with the more general Alloy 800H activities and tests in work package 2, a set of inelastic properties (stress-strain) was established for performing an Inelastic analysis (Chaboche Model) for comparison with elastic fatigue life predictions.

For the lifetime assessments a review of data for Alloy 800H design properties for thin and thick sections has been completed. Although a significant amount of material test and property data are available for thicker section Alloy 800H (typically plate or bar material exceeding 15mm section), the amount of testing on Alloy 800H or other variants of Alloy 800 in sections of 5mm or less is low. The main technological limits for the IHX are creep (long term effect) and thermal fatigue which are so far limiting applications to <850°C. The testing has been carried out in air at ~750-800°C. These conditions will be defined to be representative of operating conditions and to provide a conservative testing envelope for the mock-up. The output from the calculation and test investigations include limits of operation and recommendations for improving the design and for establishing and extending the operational envelope of the proposed full size IHX module.

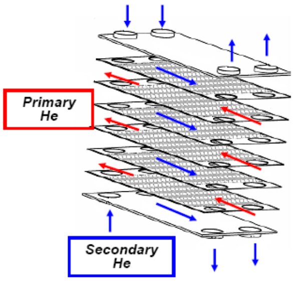


Fig.6 Detail of IHX module

Significant progress has been made on the analysis and design evaluation with CFD and 3-D FEA completed using elastic techniques to identify highest levels of stress and their acceptability against Design Code requirements. For Task 2 which includes machining actions and development of the welding tools, this was completed in the first two years of the project and the required parameters and welding tools developed. Laser welding has been used for the manufacture which showed some notable distortion initially showing the need to optimize the welding procedures for Alloy 800H. Once this was overcome a mock-up was successfully manufactured and inserted in the CEA Claire Loop for tests at 750°C/800°C plus thermal transients with representative number of cycles. The results from the tests will be used along with CFD and FEM post-test calculations for lifetime estimates. Tests in the Claire Loop were started at the beginning of 2014 and are continuing for as long as possible in order to obtain a viable result for the project for comparison with the calculated assessments. Figure 7 below shoes the mock-up positioned in the CLAIRE loop under test.

Fig.7 Tests in the CLAIRE Loop

V: HEAT TRANSPORT CIRCUIT

Steam Generator concepts are currently in use in several HTR demonstrators overseas. All seven constructed HTR, including prototypes and the grid-connected THTR-300, were delivering their heat to steam generators operating at temperatures significantly lower than the reactor’s capabilities. Steam Generators are also in use in the UK AGR’s which operate with gas outlet temperatures ~640°C. The objective of this work package is to provide an assessment of the technological limits of the steam generator and its associated heat transport circuit, to identify the main requirements and risks associated with SGU deployment on HTRs and to recommend key areas of improvement and future development to ensure a robust design for process heat application.

Individual tasks have been performed to provide information on operating and transient conditions, on the development of steam generator design options, on manufacture and inspection issues, and on steam generator thermal hydraulic and structural integrity issues. The picture will be completed with a cost/benefit analysis of the chosen lead concept. The WP4 brings together designers of steam generators and HTR and takes full advantage of industrial developments and advances in conventional technology applications. The manufacture and inspection task examines the helical tube bundle, tube to tube plate joints and transition pieces, and considers predominant failure mechanism and environmental issues. Alternative materials, tritium permeation, tube failure information and safety requirements are also being examined. The objective is to provide recommendations on steam generator deployment for HTRs for process steam application including identification of technology limits and proposals for future R&D to extend those limits further.

The work has progressed in specifying Steam Generator operating conditions using information provided by Alstom from their existing experience of SG’s in operation and from AREVA on their HTR Module experience. Thermal data, key requirements and earlier concepts have been described along with material requirements and lifetime issues. The information on the Module contains a description of the primary and secondary side and summarizes the conduct of operations and transients following a main heat transfer malfunction. Later tasks address key aspects of manufacture (tube bundle, including tube to tube-plate joints, etc.), issues of integrity, failure mechanisms, manufacturing risks. Detailed work on these concentrate on the issues associated with the Lead SG Concept chosen within the project.

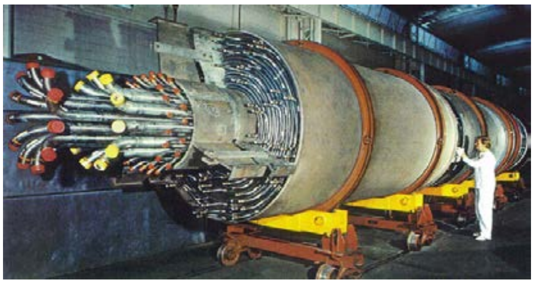


Fig.8 HTR Cooler THTR 300

VI: CONCLUSIONS

The ARCHER Integrated Project started in February 2011 focusing on HTR short and mid-term needs for cogeneration or process heat requirements. ARCHER uses information from the FP7 Support Action EUROPAIRS involving both end-users and promoters and will develop key technology areas further towards VHTR demonstration [7]. In former projects important results have been obtained in the areas of core physics, fuel, waste treatment and disposal, materials, components, safety and system integration raising the worldwide interest of the V/HTR community. This paper addresses the key activities and results of the HTR materials and components subproject within the ARCHER project and summarises the findings and results on graphites, metals, the IHX and SGU to further the advancement of the HTR for cogeneration application. These results also represent an important input to the GIF as a contribution from the European R & D activities. It is anticipated that the ARCHER results will complete key areas of technology and understanding and help to forward the HTR development towards the development of a demonstrator for cogeneration.

VII: Acknowledgement

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References

[1] ARCHER Website: www. archer-project.eu
[2] RAPHAEL reactor for process heat, hydrogen, and electricity generation sixth Framework Project. Available from: www.raphael-project.org.
[3] D Buckthorpe, J S Genot, RAPHAEL: Synthesis of Achievements on Materials and Components and Future Direction. 5th International Conference on High Temperature Reactor Technology, HTR 2010, Prague, Oct 2010.
[4] S Groot, et. al. The European ARCHER Project Proposal HTR Research towards Demonstration. 5th International Conference on High Temperature Reactor Technology, HTR 2010, Prague, Oct 2010.
[5] E. Bogusch, et al., EUROPAIRS: the major Nuclear Cogeneration Project in FP7. HTR2010, Paper 44, Prague, Czech Republic, October 2010
[6] D. Buckthorpe et al. ARCHER:- Material and Component Challenges for the Advanced Gas Cooled High Temperature Reactor, ENC2012, Manchester, UK 10-12th December 2012.
[7] D. Hittner et al. VHTR, a success story, ENC2010, Barcelona, 30 May – 2 June 2010.