Fusion Engineering and Design xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

SIRHEX—A new experimental facility for high heat flux testing of plasma facing components

André Kunze [a,*], Bradut-Eugen Ghidersa [a], Flavia Bonelli [b]

[a] Karlsruhe Institute of Technology (KIT), Institute for Neutron Physics and Reactor Technology, Germany
[b] Politecnico di Torino, Dipartimento Energia, Italy

HIGHLIGHTS

- Commercial infrared heaters have been qualified for future First Wall experiments.
- In first tests surface heat flux densities up to 470 kW/m were achieved.
- The homogeneity of the heat distribution stayed within ±5% of the nominal value.
- With the heaters a typical ITER pulse can be reproduced.
- An adequate testing strategy will be required to improve heater lifetime.

ARTICLE INFO

Article history:
Received 26 September 2014
Received in revised form
19 December 2014
Accepted 21 January 2015
Available online xxx

Keywords:
High heat flux
Plasma facing components
Blanket
First Wall
HELOKA

ABSTRACT

SIRHEX ("Surface Infrared Radiation Heating Experiment") is a small-scale experimental facility at KIT, which has been built for testing and qualifying high heat flux radiation heaters for blanket specific conditions using an instrumented water cooled target.

This paper describes the SIRHEX facility and the experimental set-up for the heater tests. The results of a series of tests focused on reproducing homogeneous surface heat flux densities up to 500 kW/m^2 will be presented and the impact of the heater performance on the design of the First Wall test rig will be discussed.

1. Introduction

In the past years the Karlsruhe Institute of Technology (KIT) has developed manufacturing technologies for Test Blanket Module (TBM) components especially for the so called First Wall (FW) [1]. Facing the fusion plasma directly, the FW is subject to cyclic loads of high surface heat flux. In order to investigate its thermo-mechanical behavior under these conditions and to qualify the manufacturing procedure it is foreseen to test a reduced scale FW mock-up in the Helium Loop Karlsruhe (HELOKA) facility at KIT [2].

To reproduce the high heat loads, a surface heater with fast response time and capable of generating a homogeneous surface heat flux up to 500 kW/m^2 is required [3]. Following an investigation of various heating methods it has been chosen to use an infrared radiation heater consisting of a tungsten filament inside a quartz glass (fused silica) tube with a reflective coating on one side of the tube. As the heated surface area is fairly large (0.34 m^2) several such tubes have to be used to achieve a homogeneous heat distribution. In order to qualify the heater and to find the best configuration of the tubes, a small-scale experimental facility has been built at KIT, the "Surface Infrared Radiation Heating Experiment" (SIRHEX). In the following the facility with the experimental set-up and results of the first experiments performed in SIRHEX will be detailed.

2. The SIRHEX facility

The facility consists of a test stand where infrared heaters are installed facing an instrumented water cooled target. The

* Corresponding author at: Karlsruhe Institute of Technology (KIT), Institute for Neutron Physics and Reactor Technology (INR), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany. Tel.: +49 72160822579.
E-mail address: andre.kunze@kit.edu (A. Kunze).

http://dx.doi.org/10.1016/j.fusengdes.2015.01.026

Fig. 1. Open vacuum vessel with experimental setup behind water cooled aluminum shields.

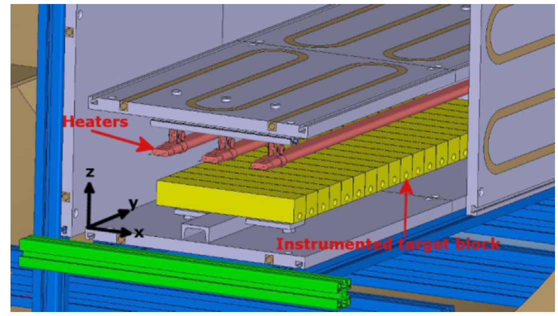

Fig. 3. Cutaway 3-D view of the test setup.

experimental stand is surrounded by water cooled radiation shields. Everything is installed in a 1.8 m diameter vacuum vessel. Fig. 1 shows the open vacuum vessel with the test assembly. The test setup will be detailed further in the next section.

Cooling water is taken from pipes with a diameter of about 50 mm (2″) which are connected to the existing water cooling system in the building where SIRHEX is housed. The cooling system operates at 6 bar and is capable to reject up to 700 kW of heat power. For the current tests only about 50 kW cooling power is used.

3. Heater qualification tests

3.1. Objectives

For the tests commercially available infrared radiation heaters manufactured by the company Heraeus Noblelight GmbH are used. Fig. 2 shows a sketch of one of the heater tubes. The heated length of the tungsten filament is 710 mm, which corresponds to the length of the reduced scale FW mock-up. The quartz glass tube is covered with a so called quartz reflective coating (QRC) on one side which, according to the manufacturer, reflects more than 60% of the radiation and is especially suited for high temperature applications in vacuum. In industrial applications these heaters are normally used to produce heat flux densities <250 kW/m^2 in continuous operation, but for short periods of time also higher values can be achieved.

Several of these tubes have to be arranged closely together in a small distance to the heated surface to generate a homogeneous heat distribution. In order to judge if the heaters can be used for First Wall experiments the following questions have to be answered:

1. Is it possible to reach heat flux densities up to 500 kW/m^2 at a temperature of 500 °C on the surface of the FW?
2. How homogeneous is the heat distribution?
3. How many cycles is the heater able to withstand?

The cycles considered here are defined by the typical ITER pulse: 30 s ramp-up, 400 s at maximum power and 60 s ramp-down [3]. The test environment has to be vacuum to have the same conditions as for FW experiments.

3.2. Test setup

Fig. 3 shows the test setup with two of the shielding aluminum plates removed. Three heaters are mounted to the top plate which can be moved up and down to adjust the distance between the heaters and the target. In addition, the heaters can be moved individually in the horizontal direction to adjust the distance between them. The plates are for shielding the environment from thermal radiation and to allow establishing a heat balance for the experiment.

The target consists of 20 stainless steel blocks each having a dimension of 250 × 40 × 40 mm^3 and a 12 mm hole for cooling water 25 mm below the surface. For the material a similar type of steel (P91: X10CrMoNb9-1) is used as for the FW mock-up. One of the blocks in the middle of the target assembly is equipped with several thermocouples (0.5 mm diameter):

- to measure the temperature profile along the surface of the block there are 13 thermocouples in a row brazed to the surface;

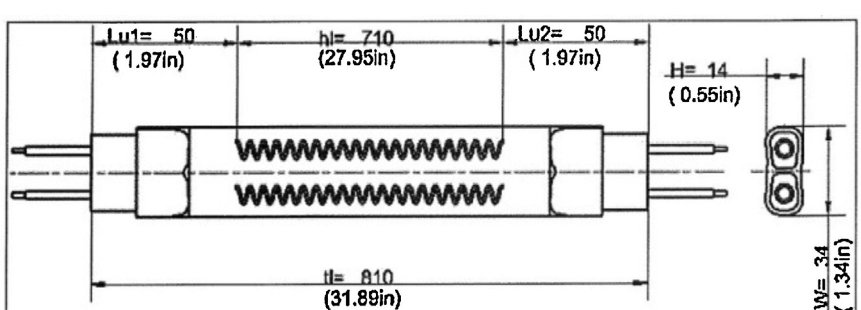

Fig. 2. Drawing of the heater, which is actually made of two filaments in two tubes merged together to a single more stable tube.

Please cite this article in press as: A. Kunze, et al., SIRHEX—A new experimental facility for high heat flux testing of plasma facing components, Fusion Eng. Des. (2015), http://dx.doi.org/10.1016/j.fusengdes.2015.01.026