



High Heat Flux Test Facility (HHFTF) at IPR

Mar2018

High Heat Flux Test Facility (HHFTF) at IPR is one of the few test facilities in the world, designed to perform heat transfer experiments for water cooled components under intense heat load conditions. The facility uses a 200kW(45kV) electron beam as heat source. Pencil Beam (circular cylindrical beam) of electrons having Gaussian radial cross-section in the range $\sigma \approx 4\text{--}8\text{mm}$ can be rastered along pre-programmed rastering patterns at high frequency of 10kHz so as to generate desired uniform as well as non-uniform heat flux profiles over surface of the component being tested. The beam can be operated at full power either in pulsed mode (rise & fall time $\sim 1\text{ms}$) or in steady state mode. High Pressure High Temperature Water Circulation System (HPHT-WCS) of HHFTF is capable of supplying coolant water to components at maximum flow parameters of 160C temperature, 60bar pressure and 300 lpm flow rate. D-shaped double walled vacuum chamber of volume $\sim 5\text{m}^3$ having several diagnostic and vacuum pumping ports, is evacuated using combination of turbo molecular pump and cryo-sorption pump so as to generate controlled background operating pressure in the range of 10^{-6}bar to 10^{-4}bar . Vacuum chamber is designed to attenuate X-rays emitted during experiments within allowed safe limits. HHFTF is approved by AERB for radiation safety. HHFTF can be used for testing big sized vacuum compatible and water cooled components with heat receiving area of $1\text{m} \times 1\text{m}$ and weighing up to 1 ton. The facility is routinely being used to perform thermal hydraulic heat transfer experiments on plasma facing components and test mock ups for incident heat flux of the order of 10MW/m^2 under vacuum conditions.



200kW Electron gun horizontally mounted on vacuum chamber of HHFTF



Inside view of target handling system used to mount the test job

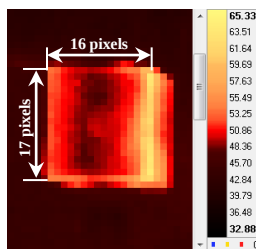


High Pressure High Temperature Water Circulation System (60 bar, 160C, 300 lpm)

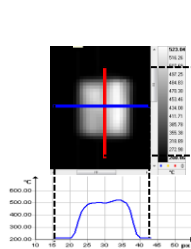
High Heat flux testing of test mockups with $500\text{ }\mu\text{m}$ thick W coating on CuCrZr/ SS316/ RAFMS water cooled substrates. W coating maintained at $\sim 500\text{C}$ for 1000 thermal cycles of duration 30-45 sec ON time and 15-30 Sec OFF time.



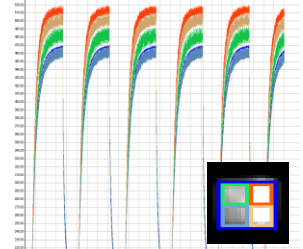
Tungsten coated Stainless Steel test mock-up ($30 \times 30\text{mm}^2$)



IR image of mock-up surface with spatial resolution of $\sim 2 \times 2\text{ mm}^2$

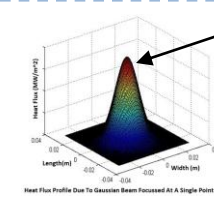


IR Image showing uniform heat flux over $30 \times 30\text{ mm}^2$ surface



Average surface temp. in four adjacent regions by IR camera

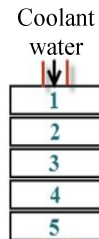
High Heat Flux testing performed using HHFTF on Tungsten mono-blocks diffusion bonded to CuCrZr tube passing through its centre. Thermal cyclic testing of these test mock ups are successfully carried out for heat flux up to 20MW/m^2 .



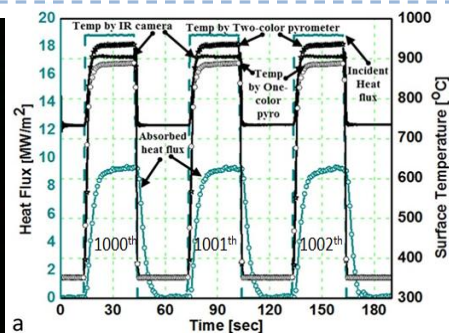
Gaussian Profile of Electron Beam Rastered at 10kHz on surface of the test mock-up



Tungsten mono-blocks with CuCrZr tube

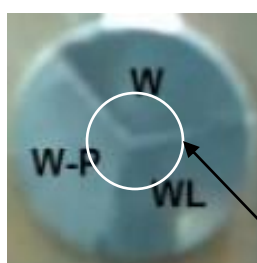


Pyrometer focus

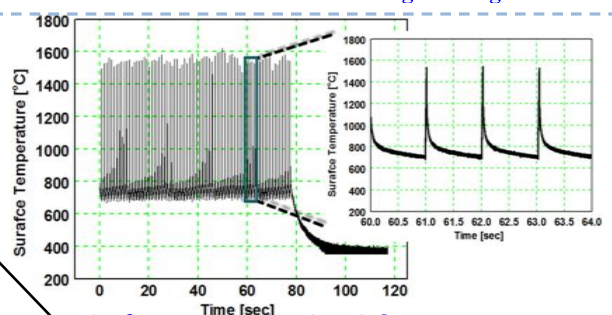


Surface temp. during 3 thermal cycles monitored using IR Diagnostics

Tungsten materials developed using powder metallurgy are subjected to thermal cyclic fatigue testing at energy density of $\sim 1\text{MJ/m}^2$ with pulse duration 20ms ON & 1000ms OFF. Beam with Gaussian cross-section is focused at centre of the 25mm diameter 5mm thick circular disc specimen made from three tungsten materials. Surface temp. monitored using Fast Pyrometer



Pure Tungsten (W; W-P) & Tungsten+1wt.% La_2O_3 (WL)



Surface Temp. using One Color Fast Pyrometer in central region of 10mm diameter



DIAGNOSTICS DEVICE SPECIFICATIONS

Thermocouples:

k type ungrounded (0°C - 1200°C),
1 mm diameter,



One color pyrometer KLEIBER KMGA 740 LO:

Temp Range: 350°C - 3500°C,
sampling rate: 10µsec
Spectral range: 2.0 ... 2.5 µm



IMPAC Two color pyrometer IGAR12-LO (MB13) :

Temp. Range: 350°C - 1000°C
Sampling rate: 2 millisecc
Spectral range: 1.52 µm / 1.64 µm



IMPAC Two color pyrometer ISR12 -LO (MB33) :

Temp. Range: 1000°C - 3000°C,
Sampling rate: 2 millisecc
Spectral range: 0.8 µm / 1.05 µm



FLIR SC 5200 IR camera:

Temp Range: RT- 1500°C, 2 – 1000 Fps,
Framerate: 320x 256/160 x 128 / 64 x 8 pixels
Temperature measurement accuracy: ±1 °C or ±1%



FLIR SC 5200MB IR camera:

Temp Range: RT-500, 1000-3000°C, 2 – 1000 Fps,
Frame Size: 320x 256/160 x 128/64 x 8 pixels
Temperature measurement accuracy: ±1 °C or ±1%

Data Acquisition & Control System for HHFTF

1. PXI based Real time data acquisition & control and PLC based sequential control provide automation of entire operation of HHFTF.
2. Effective user control with fast safety interlocks.
3. Real time control loop with loop time 20µs – 200µs for fast control and 10-100ms for slow control.
4. Total 112 channels for data acquisition & control.
5. Adjustable sampling rate from 90 Sample/s to 750 kiloSample/s per channel.
6. Acquisition of different selected parameters, online display of selected channel and offline analysis facility.
7. User administration and Access control.
8. Comprehensive GUI for visualization.
9. Data storage in TDMS format for pre/post processing.

Engineering/Data Analysis for HHFTF

Engineering Analysis and Computational Fluid Dynamic Simulations for heat transfer, Simulation of Experiments and Data Analysis of experiments using HHFTF are performed using standard available software such as - ANSYS, STAR CCM+, COMSOL, MATLAB.

Coolant calorimetry:

Fast Response RTD Pt 100,
4 mm diameter, 3 - Wire
Response less than 1 sec



Mass Analyzer:

Residual Gas Analyzer up to 300AMU



Photron High Speed Imaging camera

Monochrome CMOS sensor
1,280 x 1,024 pixels @ 2,000 fps
640 x 240 pixels @ 10,000fps
12-bit Dynamic Range



Acoustics sensors for CHF detection (upcoming)

Frequency Bandwidth: 5Hz to 300KHz



Portalok 7s Ultrasonic flow meter:

Range: 0.01 ... 25 m/s
Repeatability 0.25% of reading +/- 0.02 m/s



BIDIRECTIONAL CURRENT TRANSDUCER SERIES S273:

VOLTAGE SIGNAL: 0 to ±5Vdc FS (Full Scale),
ACCURACY: 1% FS



Safety Devices: X-ray Dosimeter,
X-ray Area Monitor
Accuracy: nSv/h

CALIBRATION FACILITIES

M390 Cavity Black body:

Range: 500- 3000°C,
Accuracy: ±0.25% of reading ±1°C
Stability: ±1°C
Uniformity: ± 0.1°C



Pagarus Plus 1200 thermocouple calibrator:

Range: 150- 1200°C,
Stability: ±0.05 – 0.2°C



Probable Usage of HHFTF

- (1) Experimental validation of the design and engineering of the water cooled components for heat transfer.
- (2) Study of damage in various materials caused by intense surface heat loads.
- (3) Study of thermal fatigue life time of single/multilayered structures at high temperature gradients.
- (4) Development and study of technological processes such as high-speed brazing, vacuum casting of metals, heat treatment.

Potential Users of HHFTF

- (1) Organizations working in the field fusion technologies for plasma facing components.
- (2) Research organizations working in the field of heat transfer studies using high pressure high temperature water.
- (3) Industries working for design, development and testing of vacuum compatible water cooled heat transfer components.