



BNL-213871-2020-TECH

NSLSII-ASD-TN-329

# HEX 2-piece ID Absorber: Steady and Transient Thermal FEA

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April 2020

Photon Sciences

**Brookhaven National Laboratory**

**U.S. Department of Energy**

USDOE Office of Science (SC), Basic Energy Sciences (BES) (SC-22)

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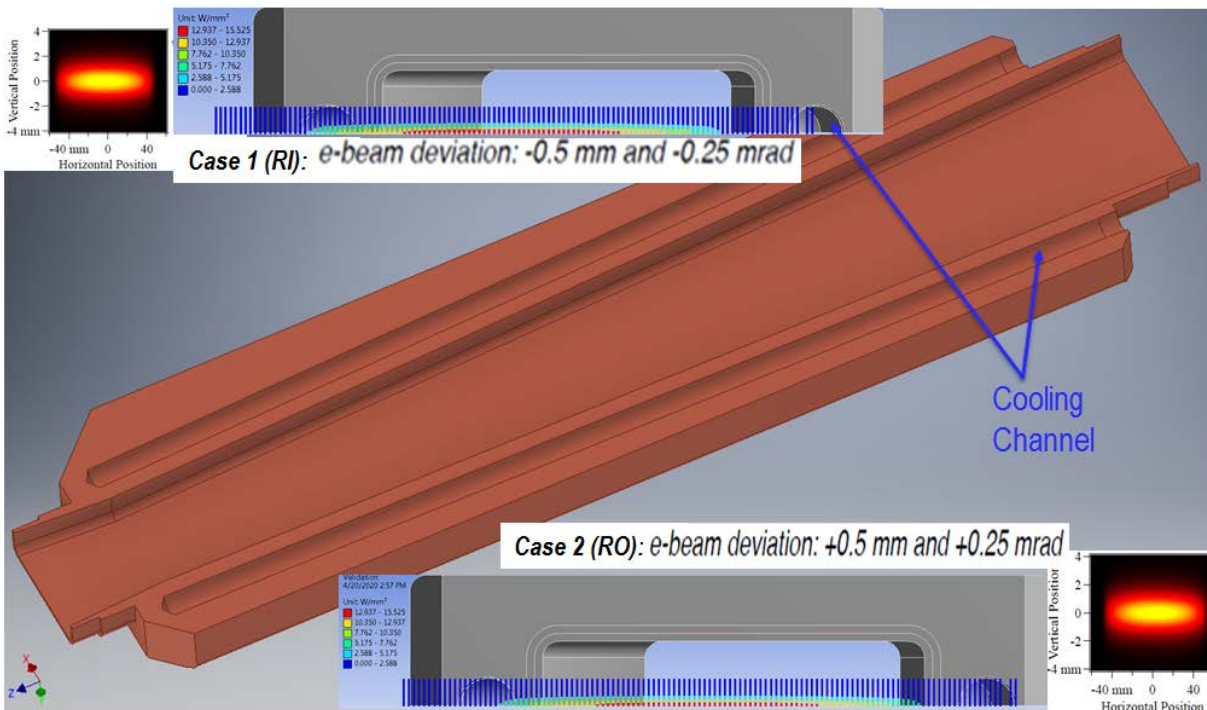
<b>NLSL II TECHNICAL NOTE</b> BROOKHAVEN NATIONAL LABORATORY		NLSLII-ASD-TN-329
AUTHORS	<b>James Rank, Marco Musardo, Charlie Hetzel</b>	DATE <b>4/2/2020</b>
TITLE <b>HEX 2-piece ID Absorber: Steady &amp; Transient Thermal FEA</b>		

## 1. Introduction

Radiation fans from Insertion Devices and Bending Magnets are “trimmed” by various water-cooled absorbers located strategically downstream of those sources. Mostly, the absorber surfaces onto which power is deposited are constructed from Glidcop Al-15 (rarely OFHC copper). On the basis of Tech Note 327 a re-design for improved thermal performance has evolved to a two-piece ID Absorber configuration; one between dipole chamber and quadrupole, another after the sextupole, each with reduced incident angle. The ring’s Active Interlock (AI) system protects against overheating by disabling mis-steered beam within an allotted time. SRP (Synchrotron Radiation Protection) protocol has a limiting maximum allowable temperature of 100°C at any point when subject to mis-steered beam for a fixed period before AI activation. After 0.2 msec, radiation exceeding +/- 0.5mm offset and +/- 0.25 mrad angular error from the HEX SCW will trip in fault. AI specification allows 1.0 msec to fully dump the electron beam.

## 2. Surface Heating by HEX Super Conducting Wiggler Radiation Fan

From SRW output, the power intercepted by the ID Absorber indicates the total load (<2.4 kW) is symmetric about the horizontal mid-plane as depicted by the beam-view insets of Fig 1. As its geometry is also symmetric about the mid-plane, here we model just the upper half of the absorber (isometric view of cut shown inverted) with incident radiation equal to half the total power. As established by SRP historically, the two extremes of compounding errors (offset plus angular error) are considered as separate “worst-cases”. Case 1 gives radiated power biased toward the ring-inner (RI) side as in the upper insets; whereas for Case 2, radiation is biased to the ring-outer (RO) side of the ID Absorbers per the lower insets.



**Figure 1:** Power distribution for two extreme cases of mis-steered beam; FEM solid model (top half of DS absorber).

### 3. Steady State FEA with Cooling Flow and Beam Heating of HEX ID Absorber

Power distributions mapped onto the incident absorber surfaces are applied by transforming from the calculated SRW output which projects onto a plane orthogonal to the electron beam as shown in Fig 1. We apply circumferentially to the wall of the lone cooling channel film coefficient  $9 \text{ mW/mm}^2$  from water flow at the ring ambient temperature of  $25^\circ\text{C}$ .<sup>2</sup> Resultant heat flux and temperature distributions on body and on channel wall ID are in Figs. 2 and 3.

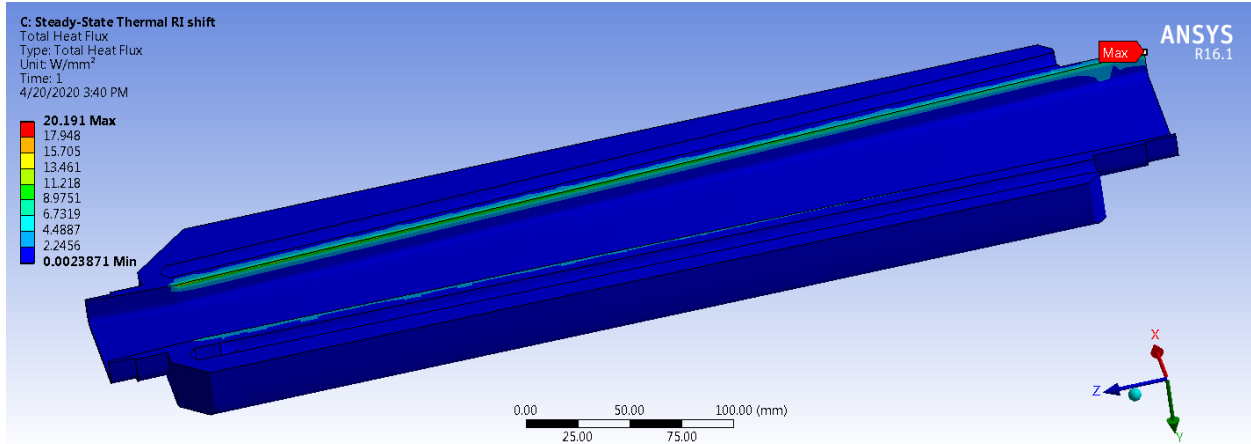


Figure 2A: Steady state heat flux for Case 1 (RI shift) on downstream ID Absorber.

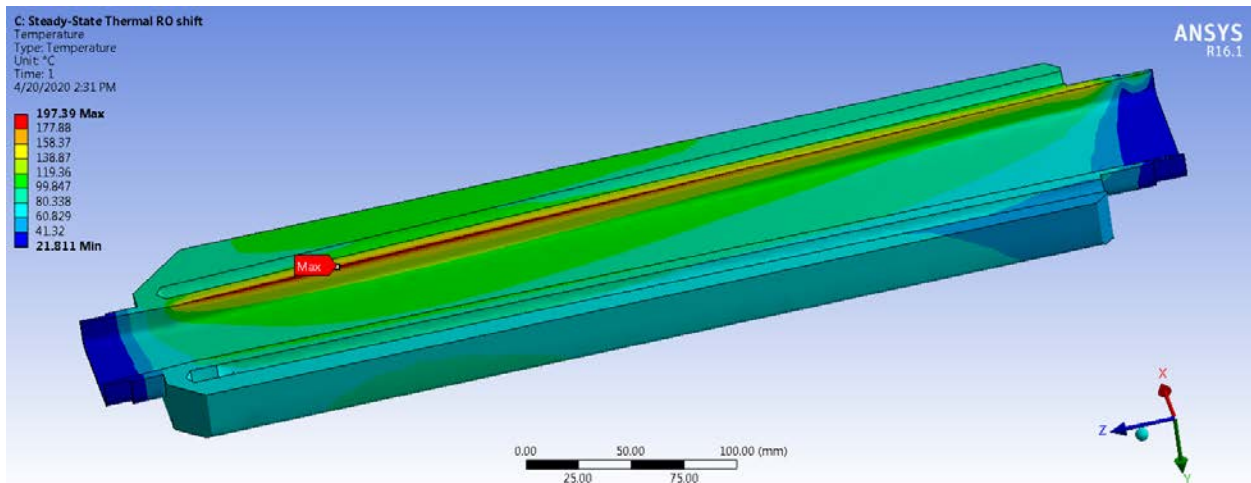
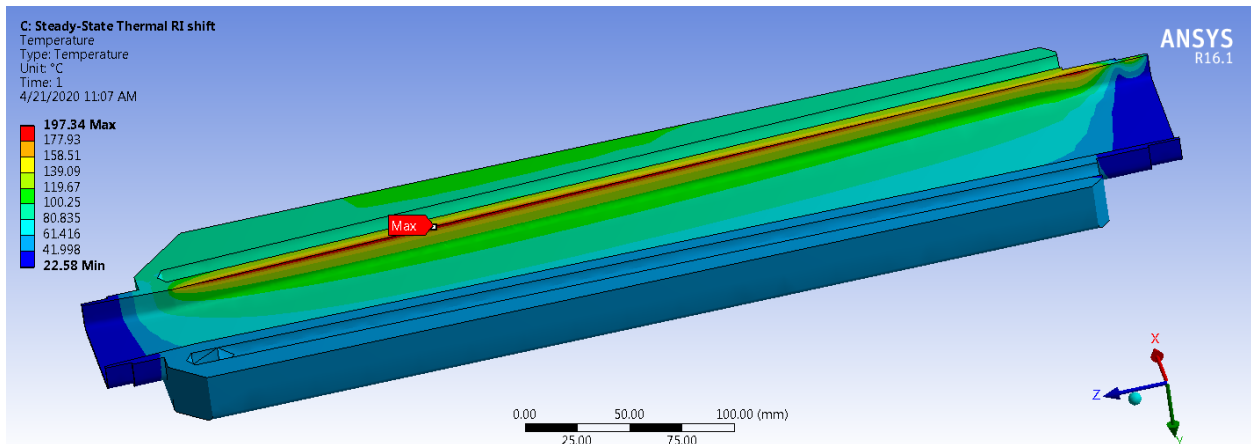


Figure 2B: Steady state temperature distribution for Cases 1 (RI), and 2 (RO shifts) on downstream ID Absorber.

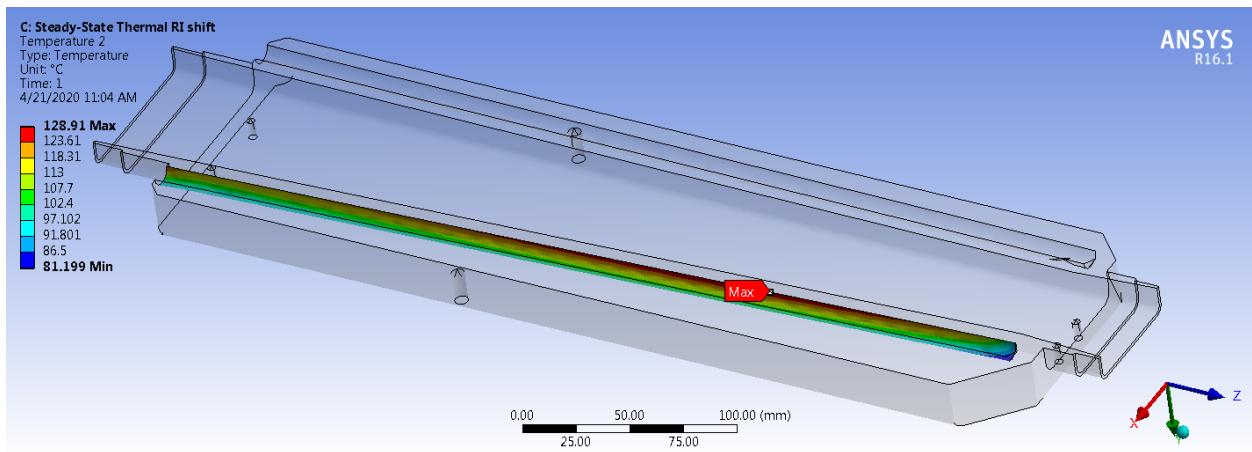


Figure 3: Peak temperature along ID of water-cooling channel nears boiling point after steady beam heating.

#### 4. Transient Thermal FEA with Cooling Flow and Beam Heating of HEX ID Absorber

Using similar SRW power cases and cooling parameters we now analyze thermal behavior over various short periods before heating is terminated with dump of the mis-steered electron beam. Each case is safely below the allowable limit at 1msec, which is approached only after 100 msec.

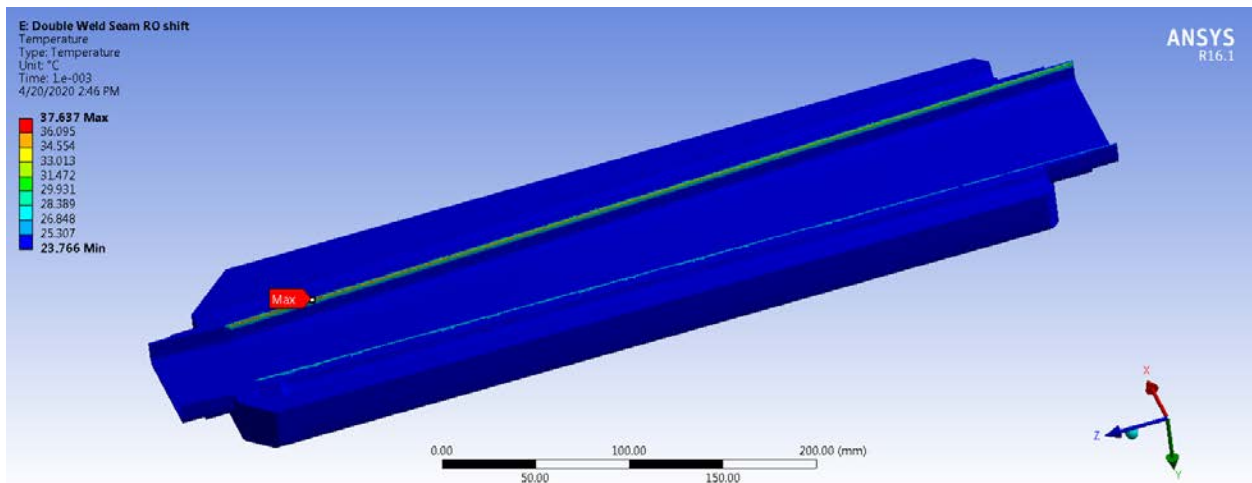
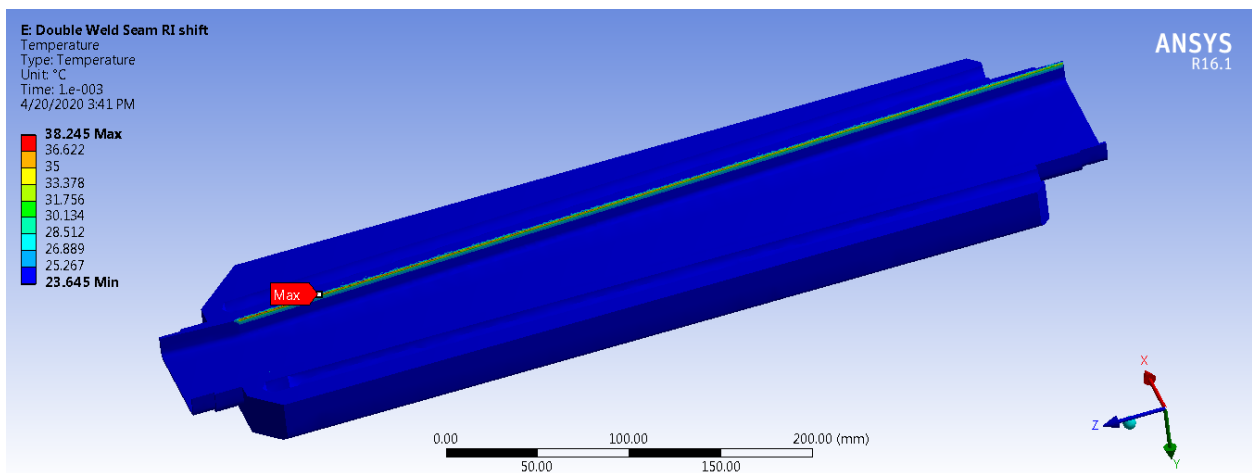
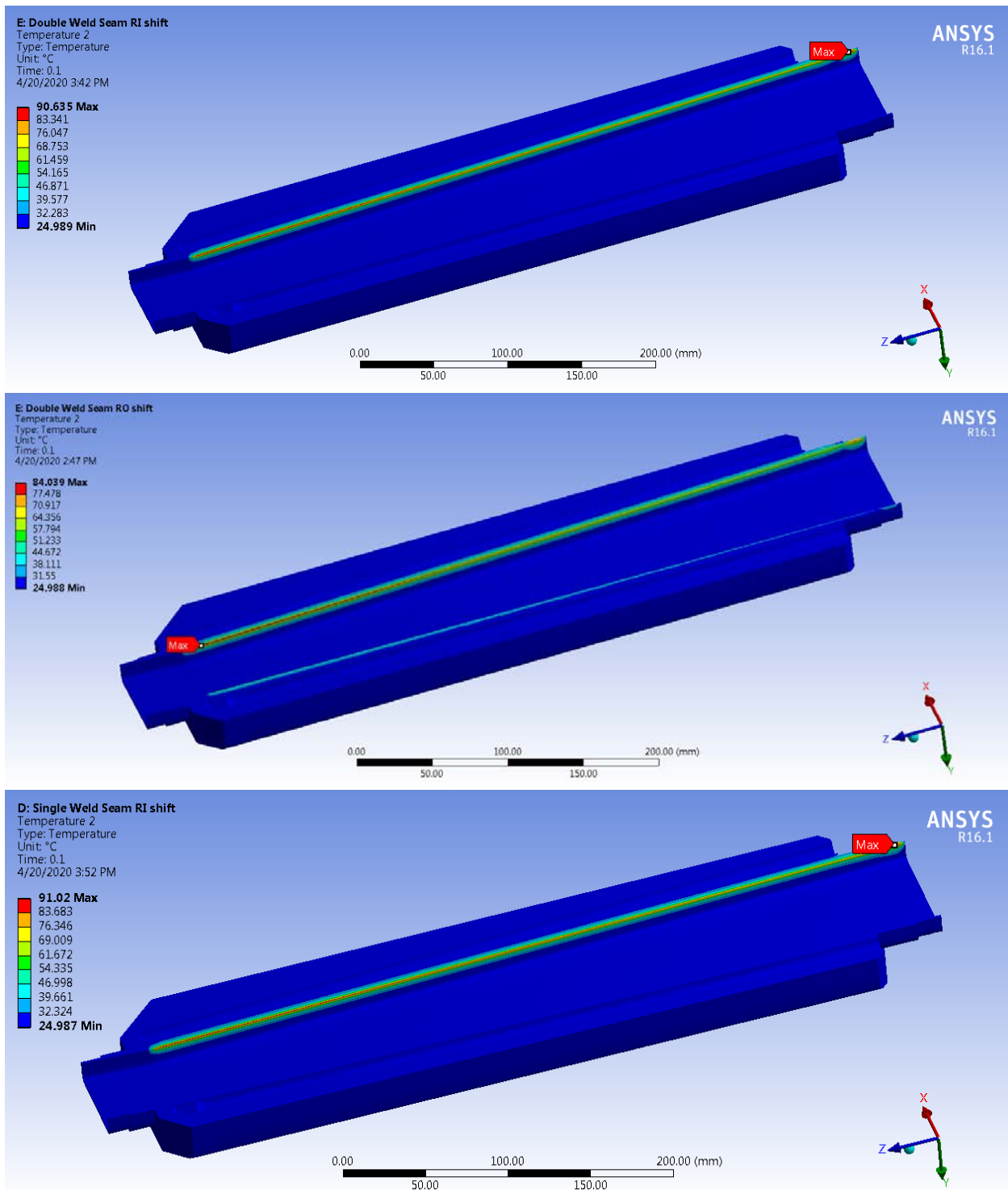


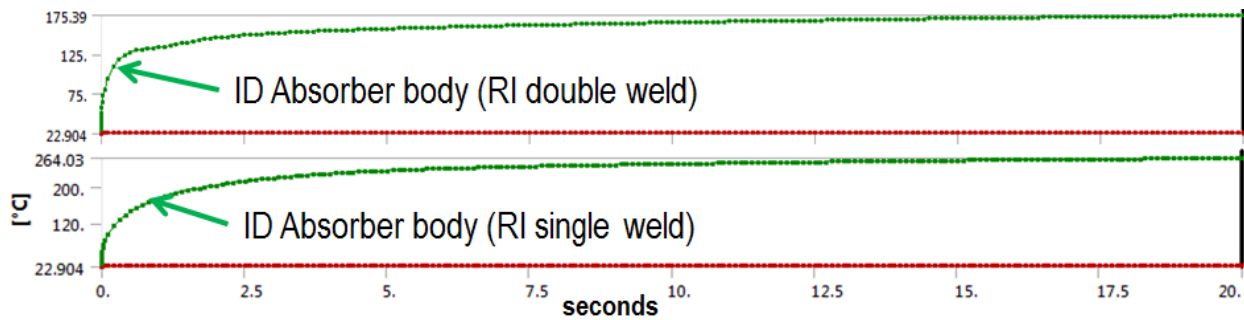
Figure 4: Cases 1 (RI) & 2 (RO shift) temperature distributions on ID Absorber after 1 msec of beam heating.



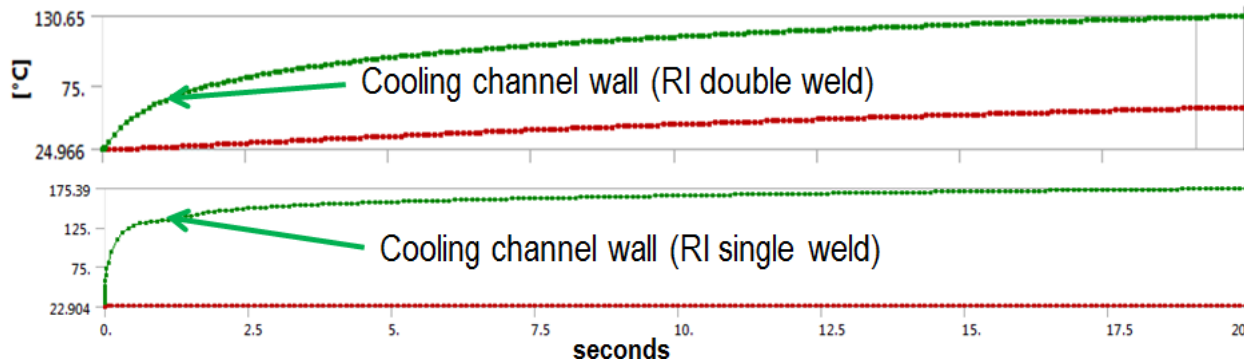
**Figure 5:** Cases 1 (RI) & 2 (RO shift) temperature distribution after 100 msec (and dependence on weld neck prep).

Highest temperatures occur in the case of mis-steer toward the ring-inner side having the larger angle of incidence. And with this second absorber piece located further downstream, radiation fans significantly even near the thin upstream weld neck with its low thermal mass where, after 100 msec, peak temperature now occurs here. NOTE: For this reason an added heat sink from a second external (non-vacuum seal) weld reduces the peak (Figs. 5 & 6) and is hence assumed elsewhere. The small reduction of peak with this second weld becomes quite significant in final equilibrium, as shown in the temperature history of Fig. 6 (higher by up to 90°C at steady state).

Fig. 6 also exceeds the 100°C SRP limit soon after 100 msec, whereas equilibrium is reached only after >20 full seconds of heating. With a second weld the warmed channel walls barely reach boiling (130°C at 60 psi supply pressure). Without it boiling occurs in seconds per Fig 7.



**Figure 6:** Peak temperature history on absorber body approaching thermal equilibrium with and without second weld.



**Figure 7:** Peak temperature history anywhere on inner wall of water cooling channel approaching thermal equilibrium

## 5. Conclusion

A new 2-piece HEX ID Absorber has been designed to overcome the peaks of the former configuration as demonstrated in Tech Note 327. Gaussian beam power distributed about the horizontal mid-plane per SRW calculations allows a half-symmetry condition for the finite element model.<sup>3</sup> In steady state the Glidcop never exceeds either its softening temperature nor the more stringent fatigue-limited maximum allowable temperature of 300°C per APS.<sup>1</sup> As seen in the “extended transient” case of Fig. 7, after a 20 second heating of the channel walls to above 130°C cooling water (at 60 psi supply pressure) may boil as equilibrium is reached.

All cases of Figs. 4 and 5 show that in transient heat transfer over short periods up to 100 milliseconds peak temperatures remain below the SRP allowable 100°C before AI trip will dump beam. An important finding relates to the downstream absorber piece now with broadened fan partly intercepted by the entrance weld neck. Fig. 6 shows the thermal sink influence of a second structural stitch weld which can reduce high steady state peaks near the weld neck.

In light of the above, we conclude that a properly constructed 2-piece HEX ID Absorber is an improvement to the original 1-piece design and satisfies the AI criteria for allowable peak temperature reached before AI protection takes effect.

### NOTES:

1. “Thermal Fatigue Life Prediction of Glidcop® AI-15”; V. Ravindranath, S. Sharma, B. Rusthoven, APS, Argonne National Laboratory; M. Gosz, Illinois Institute of Technology; L. Zhang, J. Biasci, ESRF; MEDSI 2000
2. Here we preserve the customary presumption of cooling channel flow at constant temperature (and a predetermined Reynolds number) as was applied in all earlier SRP cases. In fact, this assumption is non-conservative. Rather, the transfer of heat to inlet water as it flows along each channel of the warming absorber (perhaps serially for given external routings) will raise the cooling temperature asymptotically. For the STEADY STATE CASE that temperature rise can be significant and is dependent on a cooling flow rate which is constrained both by the diameter of channel and piping, as well as limits on available capacity of the ring-distributed copper cooling system. This is the subject of [Technical Note #328: "Validation of assumptions in heat transfer studies of absorbers made historically in NSLS2 SRP cases"](#), J. Rank, 1/2020
3. Refer to email entitled “Tech Note NSLS2-ASD-TN-312” with attachments “HEX Power Density-MM-3-17-20.pdf” for SRW power density plots, M. Musardo, 3/17/2020