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To: RSC, J. Skaritka, C. Folz, M. Palmer, M. Fulkerson, J. Li

From: D. Beavis

Subject: Shielding for the UED Klystron

It was noted last week that the spool piece on the Klystron had no shielding. This was the condition that it was operated by Photon Sciences (PS) at the SDL facility. A design review of the Klystron from 2010 was provided¹ that noted the bottom tank was from a previous Klystron and then the spool piece was made to match it to the Toshiba 3770A tube. There was no information on the actual radiation criteria for the tube design. The Toshiba documentation² notes that with the installed shield kit the dose rate at full power one foot from the tube will be 2 mrad/hr. The Toshiba documentation does not cover the bottom potion of the Klystron.

The interior details of the Klystron and the tube are unknown at this time and a detailed evaluation of the radiation risk is not possible. However, with the peak operating parameters of the tube and the limitations in reaching those parameters by the Pulse Forming Network (PFN) that is installed we can estimate a worst case condition for the tube. The tube has a peak current of 400 Amps and with the connected PFN a pulse duration of 2 micro-seconds with a limit of 10 pulses per second³. This equates to an average current of 26 mA with a maximum voltage of 300 kV. These two numbers will be used to estimate the maximum radiation out the spool piece.

The routine operation has the electrons terminate on the water cooled collector at the top of the tube. This area has a shield kit and is designed for 50 pulses per second with pulse duration of 6.5 micro-seconds. Although details of the inside are not presently available the geometry of the tube is such that the spool piece should be well shadowed from the x-rays created at the collector. The shielding for the spool piece will be examined assuming that there is a fault in the tube that causes the 300 kV electrons to hit a thin object contained inside the spool piece.

MCNPX was used to direct 300 keV electrons on a piece of steel with a radius of 0.05 cm and a length of 0.2 cm. The electrons are directed at the center axis of the target cylinder. The spool piece is approximated as a steel cylinder with an internal radius of 30 cm and a wall thickness of

¹ See Feng Gao, et. al., Nov. 5, 2010; Powerpoint Review file
² See reference material linked; http://www.c-ad.bnl.gov/esfd/RSC/Memos/MemoAttachments\Toshba-E3730A Klystron 1 (3).pdf
³ D. Beavis, July 22, 2015, Appendix I by M. Montemagno; http://www.c-ad.bnl.gov/esfd/RSC/Memos/7_17_15_UED.pdf
1 cm. The spool piece has no other material inside for the model. The Photon dose was tallied on a surface 30 cm away from the spool piece. The photon dose rate for the operating condition of 10pps, pulse duration of 2 micro-seconds, 300keV, and peak tube current of 400A is 369,000 mrem/hr. This is a very large dose rate and most likely is not possible. To completely rule out such conditions would require additional details of the tube, the mounting system, and computer modeling.

Credit can be taken for the fact that there are active processes such as operator procedures, equipment safety interlocks, and past history that has establish that these types of faults have not been detected. It is likely that such a fault is not credible for an hour. Therefore, a reduction factor of 0.1 will be used in the shield design and in a goal for the maximum dose rate of 100 mrad/hr or less. This means that a reduction of 2.7*10^-3 is desired. 1.25 cm of lead will provide a reduction of nearly this amount. The surrounding area is posted as Controlled Area—TLD required. A Pb shield of thickness or an equivalent shield will be required for the Klystron to be operated. Project personnel are preparing a shield for the UED spool piece.

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4 The TVL from figure E.14 of NCRP Report 51 is used for Pb.
5 If additional facts are provided then the shield requirements may be changed as appropriate.