Collider-Accelerator Department

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Memo

Date: *May 4, 2016*

To: *RSC, J. Tuozzolo, D. Phillips, C. Folz, I. Pinayev, D. Passarello, and V. Litvinenko*

From: *D. Beavis*

Subject: *Closing CeCPoP Open Items for High Power Operations*

Several radiological issues for CeCPoP either need to be closed or allowed to remain open during initial beam operations above 1 Watt. The commissioning sequence has hold points at power levels increasing by a factor of ten. Each hold point requires evaluation of radiation protection and machine protection issues before continuing to the next power level. This provides a graded approach to allow some items to be evaluated at low or intermediate beam power. This note will identify issues that will be evaluated as part of this process or provide documentation so that the issue can be closed. Some issues involve judgements on what is credible and acceptable risk. If members are uncomfortable with the anticipated risk then they can contact me and we will find an appropriate resolution.

During the March 10, 2016 meeting the committee had two items about the ventilation system. The issues were related to the air activation without the dump shield. The dump shield is now in place with one backward shield missing. The production of radioactive gases is reduced by many orders of magnitude with the shield in place. Therefore, the concern related to the ventilation system exhaust point being a location for release of radioactive gases is not a strong concern. Unless there is an objection the items related to the ventilation system will be closed or made as post start. The RCT survey at the release point by nature is a post start item. The release point is likely on the roof of 1002A and would require the RCT to climb a vertical ladder. Climbing the ladder is likely a greater risk than any potential ^{13}N and ^{15}O released. The calculation of radioactive gas production is given below with the shield in place.

The 704 cavity presently has difficultly going above about 10 MV. Initial beam operations may start at about 12 MeV. This is below the energy threshold for ^{15}O production and the ^{13}N production will be decreased. It is hoped that the voltage and beam energy can be increased before the end of the run.

The committee requested (April 5, 2016 meeting) that a beam power limit be placed on the RSC check-off list to limit the dose rate to less than 100 mrads/hr from the cryogenics port at the posted boundary for elevated work. The committee requested a calculation for the dose rate with the elevated work boundary moved to the end of the retaining wall[1]. Figure 1 displays the x verse

[1] The posting has been moved in preparation of higher power operations.

y photon dose rate for 8500 Watts of 25 MeV beam. The peak dose rate is 1200 mrads/hr (2400 to 3000 mrads/hr with two penetrations[2]). The peak occurs 37 feet above the ground. This is higher than the outside of the IR roof. There are locations at RHIC where the hadron machine can produce dose to 1,000 mrem during a short maximum beam fault. Many locations can approach hundreds of mrem/hr during a maximum hadron beam fault. Achieving a goal of 100 mrad/hr would require shielding unless the no elevated work is extended to the ring road.

A beam power limit of 1kW will be placed on the check-off list to allow members to comment. The maximum dose rate would be 300 mrads/hr with the elevated work forbidden boundary moved. I do not consider it credible for exposure to occur at this elevation, but it is physically possible. Changes to the RHIC work permit requirements could be instituted to alleviate any concerns.

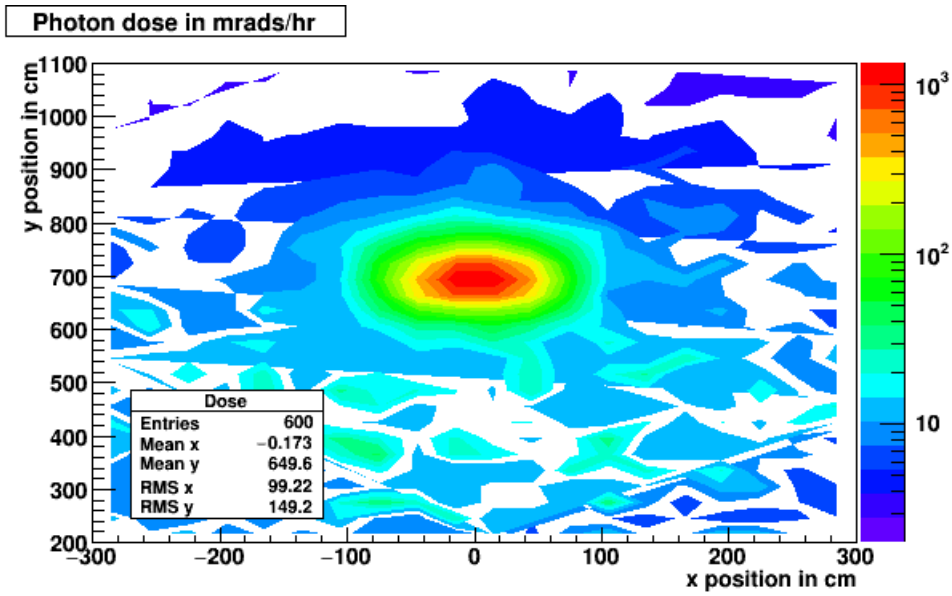

Figure 1: The photon dose rate outside the cryogenics beam pipe at the end of the retaining wall for 8500 Watts of 25 MeV electron beam loss. The peak of 1200 mrads/hr is 37 feet above ground level.

The beam dump shielding has been placed around the water cooled beam dump. The shield blocks have labels to prevent unauthorized removal. One piece of backward shadow shielding is missing. This piece is not essential for early operations and is expected to be placed before substantial beam power is delivered to the beam dump. The beam will be allowed to the beam dump with appropriate limits pending the installation. There is an Autocad drawing of the dump shielding, but no drawing from the design room. OPM 9.1.12 allows for small shields to be documented[3] via photon graphs. The RSC Chair has inspected the shielding, worked on the design, and ensured that labels were on the shield. The IRR team leader has agreed that this is acceptable with the photographs as allowed by the OPM. The shielding will have an approved QA1 drawing shortly after startup.

[2] This simple addition could be an over estimate. Shifting the scrapping location upstream by 3 meters results in a factor of ten reduction in dose rate out of a single cryogenics pipe. The centers of the pipes are nearly a meter apart.
[3] See section 5.13.5; http://www.c-ad.bnl.gov/esshq/snd/opm/Ch09/09-01-12.PDF

The shielding and barrier removal procedure[4] OPM 8.13 is being modified to accommodate the use of the notice stickers to prevent removal of small shields and equipment that could impact radiation safety if modified.

The beam dump has been modeled with the local shielding. Figure 2 shows the beam dump with the local shielding in a side view. The air surrounding the beam dump has been extended 1 meter beyond the front, back, and side of the beam dump. The total ionization in the air volume is $8.5*10^{-13}$ MeV per electron. Using 7.4 ozone molecules[5] per 100 eV a concentration of $1.5*10^{-8}$ ozone molecules per cc is estimated. This is well below the TLV of $1.*10^{-7}$. Air mixing will greatly reduce the concentration. We can examine the concentration for a volume similar to that used in the dump report[6]. The ionization will scale as the track length but the air volume will go as the cube in the change in the dimensions. A concentration of $9*10^{-10}$ is obtained by simple scaling verse $3.4*10^{-8}$ without shielding. The local shielding has reduced the ozone concentration well below the TLV.

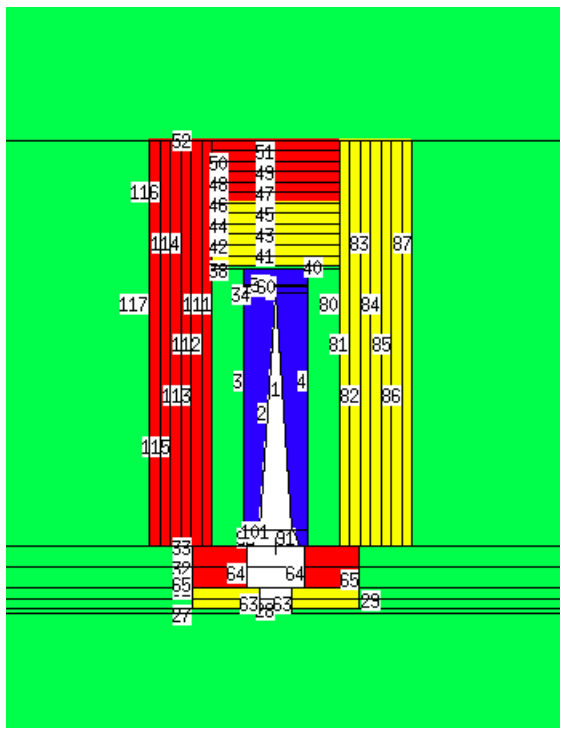

Figure 2: Side view of the copper beam dump with the Pb (yellow) and steel (red) shielding. The outside of the shielding is surrounded by air (green).

The local shielding is important in reducing the air activation. The same model can be used to calculate the photon fluence escaping the shield with energies high enough to make ^{13}N (10.55 MeV) and ^{15}O (15.67 MeV). The calculations were conducted for 25 MeV electrons striking the beam dump. Some simple approximations were made to estimate of the concentrations of ^{13}N

[4] http://www.c-ad.bnl.gov/esshq/snd/opm/Ch08/08-13.PDF

[5] W.P. Swanson, Radiological Safety Aspects of the Operation of Electron Linear Accelerators, IAEA Report No. 188, 1979.

[6] D. Beavis, March 2, 2016; http://www.c-ad.bnl.gov/esfd/RSC/Memos/3_02_16_CeCPoP(2).pdf

and ^{15}O. The total number of photons with energies greater than 10 MeV (15.5 MeV) is $6.6*10^{-6}$ ($3.6*10^{-7}$) gammas per electron. The production rates assuming a path length of 500 cm are $8.7*10^{3}$ ^{15}O/s and $3.0*10^{5}$ ^{13}N/s. These can be converted to the activity saturation concentrations by assuming a cylinder 1,000 cm long and 500 cm in diameter and using the half-lives resulting in 0.015 pCi/cm^3 of ^{15}O and 0.51 pCi /cm^3 of ^{13}N. The concentrations are below the immersion DAC of 6 pCi/cm^3. The primary factor for the large ratio of ^{13}N to ^{15}O is the ratio of gammas rays above threshold.

The calculation without shielding[6] had concentrations well above the immersion DAC values. There was a small overestimate of the ^{13}N concentration due to the inclusion of (g,np) reactions in the cross section that was used. The calculation used here has only the (g,n) reaction. The present calculation does not include the air between the copper dump and the Pb and steel shielding. The air inside the local shielding can be crudely estimated by using the ratio of the path lengths which would be 2/500 times the values in footnote 6. The contributions to the air volume used above would be 3 pCi/cm^3 for ^{13}N and 0.1 pCi/cm^3 of ^{15}O.

The ratio of ^{13}N to ^{15}O is typically 9 to 1 for a high energy electron machine. The energies used for CeCPoP are close to the production thresholds and the ratio grows in favor of the isotope with the lower threshold (^{13}N). The item from the minutes on the ratio will be closed.