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# Memo

*date:* *October 9, 2012*

*to:* *RSC*

*from:* *D. Beavis*

*subject:* *Forward Shielding Criteria for ATF*

A simple approach to providing specification for forward shielding at ATF is presented. The criteria are based on simple curves provided in references. This conservative estimate should provide the required shielding in the forward direction for electron beams from 20 to 120 MeV, which spans the practical range of ATF. Monte Carlo methods can be used to provide more accurate criteria for the forward shielding. The method will then be applied to beam lines 1 and 2 at ATF.

The dose rate for an electon beam hitting a thick high-Z target can be obtained from Fig. 3.5 of NCRP Report No. 144. For 85 MeV the dose is $3*10^6$ rad/(hr-kW) at one meter. The 85 MeV ATF beam has a power of 5.1 Watts for 60 nano-Amperes. The photon dose rate is $1.53*10^4$ rad/s at 1 meter. We can now establish the shielding criteria for the beam for both routine and accidental (fault) losses. The shielding will be specified in terms of the required reduction in radiation. For routine 100% beam losses such as at a beam dump we obtain:

$$R_R = H_R*d^2/(1.53*10^7) ,$$

Where $R_R$ is the required radiation reduction to achieve a dose rate of $H_R$ (in mrem/hr) outside the shield for routine operations, and d is the distance (in meters) from the source to the outside of the shielding. Similarly for beam faults the required reduction is:

$$R_F = H_F *d^2/(1.53*10^7*F) ,$$

Where $R_F$ is the required reduction provided by the shielding, $H_F$ is the dose for a fault, d is the distance in meters, and F is the maximum fraction of an hour that a fault is expected to occur.

We can now use this to obtain the shielding requirements for beam stops where the 100% of the beam is expected to be lost. For a routine small loss the formula can incorporate a loss factor. The area outside the end of the experimental area is an uncontrolled area. Depending on the number of hours of operations and the different locations the beam is placed contribute to the determination of the desired average dose rate. We will use 100 micro-rads/hr for the photon dose outside the shield. We will also assume that d is 3 meters for the beam stops. A desired reduction of the shielding is $5.8*10^{-8}$, which is 7.2 TVLs.

Beam stop for beam line 2 has been examined. The beam stop is 4 inches of Pb providing 1.9 TVLs. The concrete wall at the back provides 2.3 TVLs. The Pb at the back of the original beam dump has been removed. Therefore this area appears to be a weakness in the shielding. Adjusting to the actual distance of 4.5 meters, the dose outside could be a factor of 500 above the desired 100 microrads/hr, ie 50 mrads/hr. This estimate is conservative and is probably high by an order of magnitude. Additional calculations can be conducted, but the hole should have concrete and Pb placed in it to achieve the desired reduction.

The beam stop in beam line[1] 1 has 8 inches of Pb and an additional 4 inches in the center. Downstream a Pb plate covers the wall of poly. With the concrete wall at the back this appears to be sufficient to exceed the criteria for less than 100 micro-rads per hour without taking credit for the Pb plate and the poly.

The insertion of intrusive instrumentation into the beam can induce large beam losses. These are discussed in the SAD and are typically controlled by local shielding at the locations where the loss occurs or where the degraded beam hits the beam pipe.

The dipoles can operate at any current the power supply can provide. The dipoles and power supplies are the same[2] as the first 20 degree bender in the Linac tunnel. The beam lines are designed for 20 degree bends. Beam line 1 has one dipole of 20 degrees. Since this is a fault condition and should rarely occur, it is assumed that a fault can last for 15 minutes with the dipole at any current. A fault dose of 1 mrem is assumed which requires the radiation to have the equivalent of 14 cm of Pb (2.7 TVLs) in its path. This estimate is conservative for the end wall at the back of the experimental area.

The dipole has Pb on the overbend side which should shadow the side shield wall. A 90 degree bend is most likely not possible so we will consider a 45 degree bend at 40 MeV. The beam would be aimed at the Controlled Areas on the side. Allowing a maximum fault duration of 15 minutes and an allowed fault dose of 10 mrem to ATF personnel a maximum amount of shadow shielding required would be 0.5 TVLs, which should already be provided by the Pb in the magnet gap. For angles just greater than 20 degrees to the beam line a mis-steered beam could be aimed at a portion of the back wall with no extra shielding. This may be covered by shielding distributed along the beam line.

The dose from neutrons has not been estimated since the forward photon dose is so much larger at zero degrees.

**Recommendations**

It is recommended that beam line 2 have 2-3 TVLs of shielding added to cover the abandoned re-entrant beam dump area. IF the plan is never to extend the beam line to the re-entrant cavity then the cavity should be completely reconfigured.

It is recommended that the first 20-degree bending diploes in the two experimental beam line have dedicated lead walls to prevent dose from mis-steering of the dipoles. This becomes easier to configuration manage than attempting to account for distributed shielding.

It is recommended that angles from close to 0 to just past 20 degrees be covered by a 4 inch thick Pb wall just downstream of the quadrupole triplet in beam line 1.

It is recommend that a similar wall be place downstream of the first 20 degree dipole in beam line 2, where beam line 3 is open. A small piece of Pb placed downstream of the dipole should be used to block angles larger than 20 degrees.

The second dipole in beam line 2 does not require additional shielding for this purpose since it is in series with the first dipole. However, I can probably be hit with a slight error in dipoles or a mistuned quadrupole. It is recommended that a fault study be conducted to check the weak areas on the sides and back.

**References**


1. Beam line 1 is operated at about 16 pico-Coulombs as discussed in the ATF SAD. This may make suggested changes less relevant in the beam line.
2. D. Beavis, "Mis-steering for First ATF 20-Degree Dipole", updated Oct. 5, 2012.