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Memo

date: *October 11, 2012*

to: *RSC*

from: *D. Beavis*

subject: *ATF Experimental Area Penetrations*

The ATF experimental area has several penetrations that are not discussed in the ATF SAD. The penetrations will be discussed in this note.

Laser and Cableway Ports

The east wall of the ATF experimental area has support facilities outside the shielding. These rooms are posted as Controlled Areas. There are a total of four penetrations on the wall with dimensions 4 inches by 7 inches and 47 inches long. Three penetrations are for lasers and one penetration is for cables. The ports are located just below the ceiling of the experimental area. The techniques discussed in reference 1 will be used to estimate the dose exiting these penetrations.

The estimates will be conducted assuming the beam will be operating[2] at 85 MeV with a power of 5.1 Watts. **For a 100% beam loss in beam line 1 adjacent to a penetration, the dose rate in the adjacent controlled area would be 8.4 mrads/hr.** A whole body dose one foot from the wall would be lower. The neutron dose would be substantially lower. For beam line 1 the only routine full beam loss would be the beam dump locations. These should be easy to measure during a radiation survey. A 100% beam fault in the beam optics is expected to last for less than 15 minutes. The fault dose would be 2 mrads at the exit of the penetrations for a small area.

The penetrations could have higher entrance dose in a major mis-steering fault which points the beam towards the penetration. The zero degree peak of the radiation can not get to the penetration. The distance from the 20-degree dipole to the first laser port is 5.6 meters. The angle of the radiation to the port is 15 degrees which provides a reduction factor for the laser port of $5*10^{-4}$. The dipole could bend 50 MeV towards the port. Using the 60 nano-Amperes at 50 MeV the radiation dose in the peak is $1.5*10^{6}$ rad/(kW-hr) at a meter. **The photon dose rate out the penetration is estimated to be 120 mrads per hour or a total dose of 30 mrads in 15 minutes.** A small shield of Pb downstream[3] of the dipole has been proposed and would reduce the radiation in a mis-steering event. A piece of Pb in the dipole does exist. Assuming that there is 4 inches of Pb then the dose to the penetration is reduced by a factor of 100. **The fault dose would then be 0.3 mrads.**

The same analysis could be repeated for the first dipole in beam line 2. The results will be similar. A Pb shield is proposed for the forward direction to cover the full range of mis-steering events. If the shield is added or verified to already exist then the dose in a fault is expected to be less than 1 mrad.

Building Penetration after the W-Plug

The shielding is penetrated near the quadruple just downstream of the movable W-plug. The area cannot be accessed to verify the shielding. The drawing appears to indicate about 3 inches of Pb between the beam line and the building seam. The Pb provides 1.44 TVLs of shielding for photons. The distance to the closest accessible area is near the I-beam which is 47 inches from the beam line. It does not appear possible to get to this location since it is inside a wall, but the radiation will start to disperse and start penetrating the wall. **For 85 MeV electrons with a beam power of 5.1 Watts the radiation near the I-beam is 129 rads/hr for a 100% beam loss.** It should be noted that based on the beam layout it does not appear possible for a full beam fault to occur in this location. The formulas that are used are conservative. However, this area most likely should undergo modifications or careful examination.

The beam optics should be studied carefully for this region to determine if and how much beam can be lost in this region. It may be necessary to open the wall and determine if it has been packed with shielding.

For the moment we will assume that 1% of the beam can be lost in this area for 15 minutes. **The fault dose near the I-beam would be 300 mrads. There may also be excess dose on the building roof, which should be carefully checked along with the end of the mezzanine.**

Gap Over Concrete Plug Door

The concrete plug door at the north-west end of the building has a large gap in the concrete at the top of the door. The gap could not be measured at the time but is about six inches high and goes across the full width of the double door. The gap will allow radiation to escape outside the shielding.

The beam stops in the experimental area are large routine sources. The beam stop in beam line 2 can produce a photon dose rate of 2000 rads/hr at the gap inside the shielding, if it did not have side shielding. The four inches of Pb on the side of the beam stop provides 1.92 TVLs for a reduction of photon dose to 26 mrads/hr. The penetration curves typically are not used for penetrations with this aspect ratio. The angle of the radiation to the gap axis is 13 degrees. It will be assumed that a reduction of 0.1 is provided for the radiation reaching the door. **The dose rate outside the building would be 2-3 mrads per hour for 5.1 Watts of 85 MeV electrons on the beam line 2 stop.**

The beam will yield $3.36*10^{8}$ n/(cm^{2}-hr) at a meter from the beam stop. The fluence to dose conversion factor of $2.65*10^{-5}$ mrem/(n/cm^{2}) will be used. The neutrons are assumed to be isotropic. Using the distance of 3.6 meters to the door is used along with the 0.1 reduction **through the gap a crude estimate outside the door is 30 mrem/hr of neutrons**. The dose will

quickly reduce with distance from the door. The side shielding of Pb has resulted in the dose be dominated by the neutrons.

At the low power testing of .14 Watts the neutron dose is estimated to be 0.8 mrem/hr. This is a routine operating condition.

The beam line 1 floor beam dump will also challenge the gap with radiation. The two main differences are the increased distance to the door gap which is 6 meters and the lack of side shielding. **The neutron dose rate will be 5 mrem/hr with 5.1 Watts of 85 MeV electrons**. The Photon dose is higher since there is not side shielding. Although the angle to the door gap is slightly greater than 90 degrees and the dose rate at 90 degrees will be used. **The resultant photon dose rate is estimated to be 36 mrads/hr.**

The dose rate for low power testing will be 1 mrad/hr.

The dose rate for photons from beam line 1 end stop is expected to be well shadowed by the width of the stop and therefore should not be larger than that estimated for the beam line 2 stop.
The highest fault dose would most likely be a full beam loss near the last 20-degree dipole in beam line 2. It is the same distance as the beam stop to the door and has no effective side shielding compared to the beam stop. The angle of radiation to the door may provide additional reduction and a reduction of 10^{-1} to 10^{-2} is used. **For a fault duration of 15 minutes the photon dose outside the door would be 5-50 mrads.**

Roof Opening and the Building Penetration at end of the Area

The closest fault source for these two locations is the last dipole in beam line 2. The method used in the ATF SAD appendix to calculate the dose through a labyrinth can be used to get a rough estimate of the potential dose out these two penetrations[4]. The radiation from a fault reflects off the surfaces near the opening. The amount of radiation on the surface of the back wall is multiplied by the surface area and a reflection coefficient and reduced by one over the distance squared to the exit point. The back wall surface has an area of about 5.8 m^2. The radiation at 20 degrees from the dipole will be approximately .2 of the zero degree radiation or 2650 rads/hr at a meter. The reflection coefficient is roughly 10^{-2} and the distance to the back wall is 5.6 m. The distance from the middle of the area to the outside of the building penetration is 2.65 m. **For a 15 minute fault the expected dose for photons is 170 mrads. For low power testing this would be 5 mrads.**

It has been proposed to add shielding for forward beam faults in another note. **If there is 4 inches of Pb the photon dose would be reduced to 2 mrad for a fault with 5.1 Watts of beam.** There is most likely additional material in the building penetration that provides incidental shielding. The external dose will quickly decrease away from the building.

The fault dose on the building roof is calculated the same. The area used for building penetration also can reflect radiation to the roof. The penetration at the back of the building is approximately two feet wide and spans the entire back of the building. However, most of the back wall of the building is covered by additional shielding that does not allow the radiation to reflect up the

penetration. The only two locations where this is not true are the area discussed above and the area near the labyrinth at the back north-east corner of the experimental area. The area above the labyrinth should have equal or less dose than the north-west portion of the building.

There are two possible changes to the analysis of the roof dose compared to the building. The first is that the distance to the building roof is farther. Using a distance from the center of the wall to the roof of 4 meters a reduction of .44 is obtained compared to the building penetration. The gap is much larger which does allow additional surface area to contribute the dose. Within the precision of this treatment it is therefore assumed that the dose rate on the roof is the same[5] as that outside the building penetration.

The neutron dose can be calculated in the same manner. The dose rate for the neutrons is 7.6 mrem/hr at a meter. The reflection coefficient will be approximately 0.1. **The neutron fault dose out the building will be 5 mrem for 5.1 Watts at 85 MeV.** This does not include any local shielding. Any local shielding will be less effective for the neutrons than photons.

References

1. D. Beavis memorandum on ATF linac tunnel penetrations; http://www.c-ad.bnl.gov/esfd/RSC/Memos/ATF/ATFLinac_9_28_12.pdf
2. Beam line 1 is operated a 1-2 mW, as per the ATF SAD. There may be fault currents above this power up to the maximum allowed beam power.
3. D. beavis memorandum on ATF Forward Shielding; http://www.c-ad.bnl.gov/esfd/RSC/Memos/ATF/ATFFow.Shield_10_9_12.pdf
4. See for example NCRP Report No. 144, sections 4.3.4-4.3.5.
5. This assumes that there is not effective shielding in the building penetration.