GROUND WATER , AIR-BORNE AND SOIL ACTIVATION FROM THE OPERATION OF THE TEMPORARY BEAM ABSORBER IN THE MI 8 GEV BEAM LINE

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Recently we have designed a temporary beam absorber [1] which will be used during the 8 GeV beam line commissioning. In this report we address the ground water, air-borne and soil activation arising from the use of the absorber.

1. Ground Water Activation :

The beam absorber will be installed at location 833 in the beam line tunnel. A drawing of the absorber is shown in Fig. 1. The total dimensions of the beam absorber is 54 in (W) x 54 in (H) x 122 in (L). The vertical distance between the aquifer and the bottom of the beam line tunnel floor in the vicinity of the beam absorber is about 34.75 ft[@] To estimate the contamination of ^{3}H and ^{22}Na nuclei in the ground water we adopt the **Concentration Model** [3,4]. The following quantities are used in our calculations :

- the highest star density in the uncontrolled soil = 4.0×10^{-8} star/cc, (see Fig.2, star density contours for temporary beam absorber from CASIM calculations).
- the distance between the lowest boundary of "99% volume" [3] and the aquifer (dolomite) = 28.7ft,
- the density of the soil = 2.25 gm/cc (moist soil),
- the weight of the water divided by the weight of the soil that corresponds to 90% leaching [3,4] : 0.27 for ^{3}H and 0.52 for ^{22}Na.

Using Eq. 3 of reference 3, we get the initial concentration of the ^{3}H and ^{22}Na nuclei as 7.2×10^{-17}pCi/ml-year/8GeV proton and 1.5×10^{-18}pCi/ml-year/8GeV proton, respectively. Assuming instantaneous mixing of the produced radioactive nuclei in the ground water, we obtain the final concentrations of

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[@] The floor elevation of the 8 GeV beamline tunnel is 713.5 ft. Excluding the floor slab of thickness 1.75 ft, the elevation of the highest star density region in the uncontrolled soil is 711.75 ft. The elevation of the dolemite is taken to be 677 ft [2].

5.2×10^{-18} pCi/ml-year/8GeV proton and of 4.8×10^{-22} pCi/ml-year/8GeV proton from ^{3}H and ^{22}Na nuclei respectively. The EPA and DOE, however, allow 20 pCi/ml-year from ^{3}H nuclei and 0.4 pCi/ml-year from ^{22}Na nuclei in ground water. Thus we find that the upper limit on the total 8-GeV beam stopped in the absorber without contaminating the ground water above the EPA allowed limits will be **3.8×10^{18} protons /year**.

2. Airborne Radioactivity :

Airborne radioactivity measurements have been made at various locations around Fermilab accelerators including the one near the 8 GeV beam extraction region of the Booster [5]. We use these measurements to predict the expected airborne radioactivity hazard at the 833 beam absorber.

During steady operation of the Booster, extraction losses at MPØ1 are about 3%. With extraction of 5.3 E15 p/h, the resulting Derived Air Concentration (DAC) was about 0.5. The problem at hand is very similar to this case.

The expected average beam intensity on the 8 GeV temporary beam absorber during the commissioning period is 3.6E14 p /hour [1]. We assume 100% beam loss at the beam absorber location. But the beam absorber is a 1' x 1' x 7.5' iron slab with 4.5' x 4.5' x 10' long concrete block around. The highest star density at the surface of the iron slab and the outer surface of the concrete are estimated to be 5.0E-5 star/cc and 5.0E-7 star/cc respectively (see Fig. 2). Now we make the following assumptions to estimate the air-borne activity :

1. the air-borne activity scales as the star density,
2. the core of the beam absorber is similar to the MP01 septum magnet and hence, under identical conditions of beam interactions, the maximum star densities on the surface of the of the septum magnet and the iron slab of the beam absorber would be identical.
3. Air mixing at MPØ1 is negligible. We assume that air circulation conditions are similar around the beam absorber at 833. Air exchange at the 833 location would reduce the magnitude of the airborne radioactivity concentrations.

Thus, the expected DAC at the temporary beam absorber during beam operation is:

$$DAC = 0.5 \times (3.6E14/(0.03 \times 5.3E15)) \times (5E\text{-}7/5E\text{-}5)$$
$$= 0.01$$

The airborne radioactivity consists primarily of short-lived positron emitters with half lives on the order of minutes. Delay times related to obtaining enclosure keys after beam operation is terminated and transit time to the beam enclosure leads to rapid reduction in these already inconsequential levels. This level of airborne radioactivity is far below that required for posting requirements of 10CFR835.

3. Soil Activation :

The radioactivity induced in the soil forming the bulk shielding around an accelerator enclosure is of special interest from the point of view of ground water contamination which is explained in section 1. However, a number of other long lived radioactive elements can be seen in the soil samples from the area around the beam absorber shielding. Some of these radioactive elements have life times comparable to the ^3H and ^{22}Na isotopes. According to Sullivan [6] the total radioactivity "s" in units of $MBq.W^{-1}$ of beam power, due to the presence of isotopes in the earth with half-life >50 days produced by the secondaries that **penetrate a 2.62 ft (80 cm) concrete shield** is given by,

$$s = 15 \times E^{-0.2} \times \ln[(T+t)/t] \ \ MBq.W^{-1}$$

where t and T are the cooling time and the irradiation time in years, respectively. E is the beam energy in GeV.

For the beam absorber in the MI-8 beam line the irradiation time T = 1/2 years. We have calculated the radioactivity using the above formula for t = 1 year and t = 20 years. The total concrete shielding (including the concrete wall) around the iron core is about 3.25 ft in this case. Thus the radioactivity per watt of beam power loss in the absorber is (less than),

$$s = 15 \times 8^{-0.2} \times \ln[(0.5+t)/t] \ \ MBq.W^{-1}$$
$$= 4.0 \ \ MBq.W^{-1} \text{ for } t = 1 \text{ year}$$
and
$$= 0.24 \ MBq.W^{-1} \text{ for } t = 20 \text{ years}$$

The expected average total beam power on the MI-8 beam absorber is,

$$P = 1.602 \times 10^{-10} \times 3.6E14 \times 8\ (GeV)/3600$$
$$= 128\ W$$

Thus the total activity S in the soil is

$$S = 512\ MBq = 0.014\ Ci \quad \text{after 1 year}$$
$$= 30\ MBq = 8.3 \times 10^{-4}\ Ci \quad \text{after 20 years}$$

which will be distributed in > 20000 cubic ft of soil. Thus the average activity will be about 25 pCi/cc after 1 year of cooling and 1.5 pCi/cc after 20 years of cooling. However, if this area or any section of the beam line tunnel is to be decommissioned or remodeled in future, the soil will be tested and necessary precautions will be taken in accordance with FRCM [7] .

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