| **Condition**  **(DBIE)** | **Beam Loss/ Termination Point** | **Beam Loss Condition**  **(Watt)** | **Duration of Event** | **Frequency** | **Duty Cycle\*** | **Exposure Location** | **Dose rate**  **(mrem/h)** | **Dose/Event**  **(mrem)** | **Annual Dose\*\***  **(mrem)** | **Notes** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| N/A | Downstream of QCM | 1 | 8 hr | Continuous | 0.09 | West wall | 0.001 | 0.008 | 0.18 | Represents 0.1% of the beam power (0.1 uA) for high current operation (100 uA); assumes complete shielding at dump(s).  Cave 2 roof is posted radiological area not routinely occupied.  Cave 1 roof is RCA |
| 2nd floor office | 0.002 | 0.016 | 0.36 |
| Source lab | <0.001 | <0.008 | <0.2 |
| Cave 2 roof | 6 | 48 | N/A |
| Cv 1 roof boundary | 0.8 | 6.4 | 144 |
| N/A | HDICE Line | 1 | 60 min | 2/day | 0.36 | West wall | 0.044 | 0.044 | 7.9 | Full loss (0.1 uA) in low current mode (beam loss, or delivery of tune beam to F-cup)  Roof is posted radiological area and not routinely occupied |
| 2nd floor office | 0.025 | 0.025 | 4.5 |
| Source lab | 0.002 | 0.002 | 0.36 |
| He Vent/C2 roof | 25 | 25 | N/A |
| 1 | Downstream of QCM | 6750 | 30 min |  | N/A | Cave 2 entry gate | 1 | 0.5 | N/A | Accident condition for keV run mode – 225 keV @ 30 mA |
| 2a | Downstream of QCM | 3 | 30 minƭ |  | N/A | West wall | 0.003 | 0.0015 | N/A | Overcurrent condition (300 uA) in high current mode (accident is only excess current, not additional beam loss)  ƭ Duration may not be credible.  Bounded by 2b. |
| 2nd floor office | 0.006 | 0.003 |
| Source lab | 0.002 | 0.001 |
| Roof | 18 | 9 |
| 2b | HDICE Line | 3000 | 30 minƭ |  | N/A | West wall | 132 | 66 | N/A | Overcurrent condition (300 uA) in low current mode; loss point in HDICE line  ƭ Duration may not be credible |
| 2nd floor office | 75 | 37.5 |
| Source lab | 6 | 3 |
| He Vent/roof | 75000 | 37500\*\*\* |
| 3 | All | 1 | 30 min | All | | | This condition is considered normal operation under the first two scenarios | | | |
| 4 | Downstream of QCM | 1000 | 30 minƭ |  | N/A | West wall/  Labyrinth wall | 1/8 | 0.5/4 | N/A | Accidental full loss of high current mode beam (100 uA).  ƭ Duration may not be credible  Bounded by 2b. |
| 2nd floor office | 2 | 1 |
| Source lab | 0.8 | 0.4 |
| Roof | 6000 | 3000 |
| Cv1 roof boundary | 800 | 400 |

Routine operation Off-normal condition

\* Assumes 900 hours operation/y; 20% high-current, 80% low-current mode (25% of low current running at 100 nA)

\*\* Non-RCA design goal is 10 mrem/y, RCA design goal is 250 mrem/y

\*\*\* Credited Control required

***Credited Control Requirement -***

A credited control is required to prevent DBIE condition 2b. This assumes that an overcurrent condition of 300 uA can occur while in low current mode (beam to HDICE). If a beam loss/accounting system is used, it must prevent an event that would cause a dose of 15 rem. In low current mode, a total current limit of 100 nA would easily satisfy the condition.

If transport into HDICE line could occur in high current mode, will a BCM in that line continue to just look for any current above 100 nA, or will some accounting algorithm be in play?

Highest dose rate conditions for beam in the HDICE line equate to 0.069 mrem/uA-sec. If a current accounting approach is used, a limit of ~3,600 uA-min is needed to prevent the 15 rem dose.

***Other Requirements –***

10 CFR 835 also requires that controls be implemented such that potential doses above 1 rem in any hour are prevented through physical means (including safety interlocks). We should assume conservatively that this condition could persist continually, since it results from a loss of about 16.6 uA downstream of the QCM (1/6 the current of DBIE 4). If the PSS current monitoring system is used for this purpose, it would need a trip threshold of 59,760 uA-sec accrued in any hour. This configuration would prevent 1 rem/h conditions, but allow for a high radiation area condition on the roof of cave 2, which can be controlled by administrative means.

The 1 rem/h condition could also be caused by transporting 4 uA into the HDICE line. Again, if high current mode beam can be transported into this line, an integrated loss limit of ~14,400 uA-sec is required.

The highest dose rate under normal conditions in an uncontrolled area assumed to be continually occupied is 0.044 mrem/h (west side wall), and exists during HDICE, low-current mode. This meets the design criterion of 10 mrem/y, when duty cycle is considered. In this mode, controlling maximum current at or below 100 nA satisfies design criteria, under the duty cycle assumptions stated.

Radiation levels in occupied areas during high-current mode are distributed differently due to the location of beam loss. For a continuous loss, just below the 59,760 uA-sec limit (1 rem/h) mentioned above, the dose rate at the cave-1 roof RCA boundary would be ~133 mrem/h, and the dose rate at the west wall would be about 0.17 mrem/h. This causes two problems; a high radiation area on the roof of cave-1 and projected annual dose of about 30 mrem in the uncontrolled area outside the cave. The most limiting of these conditions is the high radiation area on the roof. It may be possible to limit this dose with the BCA system. If this approach was used, the aforementioned 59,760 uA-sec limit would be reduced by a factor 5/133, down to about 2246 uA-sec.

If the above is correct, a BCM/BCA system could operate with a 100 nA upper limit when in low current mode, and a 2246 uA-sec integral loss limit for high current mode and meet all dose constraints. CARMs and other controls would be defense in depth.