BNL-101904-2014-TECH

AD/RHIC/RD/121;BNL-101904-2013-IR

Dose Equivalent Estimates at the 12 O'clock IR

A. J. Stevens

July 1998

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

AD/RHIC/RD-121

RHIC PROJECT

Brookhaven National Laboratory

Dose Equivalent Estimates at the 12 O'Clock IR

A. J. Stevens

July 1998

Dose Equivalent Estimates at the 12 o'clock IR

I. Background

12 o'clock is the intersection region reserved for a future large detector at RHIC. The current (6/98) shield block configuration at this IR was constructed some time ago, with the knowledge that some combination of additional shield blocks and access restriction would eventually be needed.

Fig. 1 (Ring Center Side) and Fig. 2 (Side Opposite Ring Center) are scale drawings corresponding to the shield configuration on the plan mid-plane. The shaded areas in these figures represent light concrete. Note that in both drawings (especially Fig. 1), the point labeled "Hot Spot" presents a shallow-angle view to upstream magnets through relatively thin sections of light concrete. [It is the opinion of this author that this aspect of the shield was not recognized until recently.]

Most of this note describes the results of straightforward CASIM calculations with a cylindrical version of the geometries shown in Fig. 1 and 2. On the ring center side (Fig. 1), the CASIM star density was calculated at the position of the existing curb (22.56m from the beam line), as well as along lines representing an existing fence and the IR service building. It is assumed that the curb (where a new fence would be constructed) and the existing fence define low-occupancy distances of closest approach to the IR, whereas the service building represents a high-occupancy region for radiation workers. On the side opposite ring center, there are (nominally) no people present. The "assumed fence line" in Fig. 2 marks the end of existing fence which crosses the tunnel. Although the dose was calculated at this distance, a new fence could be erected considerably further from the beam line.

II. CASIM Results with Existing Shield

Results are shown in the tables below for dose equivalent estimates from CASIM star density at the "Hot Spot", and positions discussed above as a function of source point with the canonical 4 times design DBA assumption that 2.28×10^{13} 250 GeV protons can be lost on either Q3 or Q2 and half this number on either D0 or DX.

Table 1 Dose Estimates for DBA Fault on Ring-Center Side

Location	Source (Worst Case)	Dose (Worst Case)
Hot Spot	Q3	149 rem
Curb	Q3	730 mrem
Existing Fence	Q3	2.25 rem
Building	Q3	1.05 rem

Table 2 Dose Estimates for DBA Fault on Side Opposite Ring-Center Side

Location	Source (Worst Case)	Dose (Worst Case)
Hot Spot	Q3	34.6 rem
Assumed Fence Line	DX	337 mrem

The situation on the side opposite ring center is considerably better than on the side where people are required to be. The 1.05 rem in Table 1 exceeds the criteria of 500 mrem for a high occupancy area restricted to radiation workers which means that the situation on the ring center side cannot be remedied by additional fence restrictions; additional shielding is required. On the side opposite ring center, by contrast, a new fence at a transverse distance a factor of 1.6 greater than the assumed line in Fig. 2 would reduce the dose well below the 160 mrem criteria for an uncontrolled low occupancy area.

III. Test Calculations with Added Shield

In order to determine the effect of additional concrete shielding, the regions labeled "Additional Shield" in Figs. 1 and 2 were added to the geometry. In the beam direction this adds 152 cm. (5 ft.) on the ring center side and 146 cm. (4.8 ft.) on the opposite side. With this "test change" the estimates corresponding to Tables 1 and 2 are shown in Tables 3 and 4 below.

Table 3 Dose Estimates for DBA Fault in Test Geometry on Ring-Center Side

Location	Source (Worst Case)	Dose (Worst Case)
Hot Spot	Q3	35 rem
Curb	DX	208 mrem
Existing Fence	Q3	355 mrem
Building	DX	215 mrem

Table 4 Dose Estimates for DBA Fault in Test Geometry on Side Opposite Ring-Center Side

Location	Source (Worst Case)	Dose (Worst Case)
Hot Spot	Q3	18.5 rem
Assumed Fence Line	DX	254 mrem

IV. Calculations with Design for Additional Shield

On 06/16/97 R. Marascia identified additional shield blocks which could be used to increase the shielding on the Ring-Center side. The configuration is shown in Fig. 3. It is better than the Test Calculation geometry in that, for the first 4 ft. in the transverse direction, the added length in the beam direction is 7.5 ft. instead of the 5 ft. in the Test Calculation. The CASIM results for this geometry are shown in Table 5 below.

Table 5 Dose Estimates for DBA Fault with Design Shown in Fig. 3 (Ring-Center Side)

Location	Source (Worst Case)	Dose (Worst Case)
Hot Spot	Q3	13.5 rem
Curb	DX	174 mrem
Existing Fence	Q3	296 mrem
Building	DX	159 mrem

The "Existing Fence" position at which the maximum dose occurs is in a narrow corridor between a vertical drop (which is the reason for the fence) and the side of the support building. This region is readily controlled by posting. Erecting a new fence/gate a few feet away from the curb would satisfy the 160 mrem criteria.

V. Problems Associated With the Top of the Berm

In general, three considerations exist on top of the berm. For intersection regions (IRs) other than 10 o'clock, access restrictions must be sufficient to insure that dose through the roof does not "illuminate" the distance of closest approach to the restricted area. A second requirement stems from the high β quads close to the IRs. Here, the DBA fault often (depending on the IR) exceeds the 160 mrem criteria (with the usual 4 time design intensity and doubled neutron quality factor) even for a solid earth shield. Finally, at all the IRs except 2 and 4 o'clock, large cryogenic penetrations in the berm mandate access restrictions. The first two of these considerations are discussed here for 12 o'clock, and the cryogenic penetration in Section VI below.

The roof of the 12 o'clock enclosure is not accessible from the berm since the "drop" from the berm to the roof exceeds 6 ft. The dose through the roof to a person standing on the edge of the berm has not been calculated; based on previous estimates this author has assumed that the dose would substantially exceed the 160 mrem criteria and that access should not allow a person to "see" the roof.

Based on a personal inspection, this author estimates the berm thickness (which is nominally 13 ft.) to be greater than 12.5 ft. over an extensive region near the 12 o'clock IR. A DBA fault on a high beta quad, neglecting the large cryogenic penetration, gives 197 mrem[1] on the berm top, which exceeds the 160 mrem criteria. One option for solving this problem considered in isolation is to add more soil. However, the cryogenic penetration is also in the region of the high β quads, and adds to the dose in this area.

VI. Dose Through the Cryogenic Penetrations

The dose through the large penetration at 6 o'clock, a rectangular "slot" 2 ft. by 5 ft., had been estimated[2] by methods (utilizing approximations) which preceded the acquisition of the Lahet Code System (LCS). The conclusion of Ref. [2] was that the penetrations should be fenced off at distances of 20 ft. in the beam direction and 14 ft. in the transverse direction.

The penetrations at 12 o'clock (and at 10 o'clock) are cylindrical shafts of radius 2.5 feet, **which is a factor of 2 larger area than at 6 o'clock**. LCS calculations were made in this geometry with "point detectors" at the distances which had previously been specified (the 20 ft. and 14 ft. transverse distances), as well as at a point immediately adjacent to (15 cm. away from) the cylindrical opening and on top of the opening. The last point is necessary because of the "oversized" nature of the shaft; the pipes emerge from the shaft on one side, so that a person on top of the berm could, in principle, crouch over the center of the opening! [No such possibility exists at 6 o'clock where the pipes essentially fill the shaft.] Re-scattering in air was included in the calculation.

These penetrations are essentially directly above the high quads, so that the DBA fault scenario is 100% of the beam, which is taken to be the equivalent of 4.48×10^{13} 100 GeV neutrons (at 4 times design). The results (which as usual double the neutron quality factor) are shown in Table 6.

Table 6. LCS Dose Estimate of "Excess" Dose Near Cryo. Penetration

Location	DBA Dose Estimate
20 ft. distant in beam direction	51 mrem
14 ft. distant in transverse direction	23 mrem
Adjacent to Shaft	49 rem
Directly over Shaft	95 rem

The first aspect of these results that needs discussion is the rather odd result that the dose at a transverse distance of 14 ft. (measured from the edge of the cylinder) is less than the dose at a distance of 20 ft. In the transverse direction, a 14 ft. distance takes a person somewhat down the slope of the berm, which means that the comparison (3 ft. above the **local** berm elevation) is not being made at the same elevation. The lower elevation is simply more favorable with respect to the shine from the cylindrical shaft. In a similar manner, the dose would be worse if the detector point assumed a person was standing on a ladder at some constant transverse distance.

Comparison of these results with the previous (pre-LCS) estimates of the 6 o'clock area is also interesting. In Ref. [2], the "excess" low energy dose at the boundary was estimated (perhaps guesstimated) at 24 mrem. This is in surprisingly good agreement with the 51 mrem given that the hole is twice as large. If one scales[3] the 95 rem result to the 6 o'clock geometry, the result is 36 rem, which exceeds the previous estimate of "about 12 rem"[4] by a factor of 3. This is similar to the difference noted in other comparisons between LCS estimates and approximations that had been previously employed for large penetrations.[5] This is likely an overestimate since the physics of Lahet (version 2.7) is believed to overestimate neutron production.

Recall that the solid earth result exceeded the 160 mrem criteria slightly. Adding in the excess from the cryogenics penetration at (say) the 20 ft. distance on the top of the berm implies that about 1.5 additional feet of earth would be needed to make this point acceptable in a DBA fault. The trade-off between fence and additional earth is discussed next.

VII. Access Restrictions at 12 o'clock at Safety Limit Intensity

Fig. 4 shows a fence boundary which satisfies the criteria assuming the additional shield discussed in Section IV and shown in Fig. 3 is actually installed. The "front part" of the fence (shown in darker outline in Fig. 4) is 5 ft. outside the existing curb (79 ft. from the beamline). On the left hand side, it abuts the existing headwall and on the right side, the Cryo. Support building (1012A). The jog inwards shown at the support building is simply to allow access through the door shown. Although no gate in the fence is shown in the figure, a (presumably large) gate would certainly be needed. The remainder of the fence can be thought of as continuous (again, no gates are shown), with ends at abutting a headwall on the left hand side of the figure and an existing fence atop a headwall on the right hand side. The total length of the fence is very close to 800 ft.

Note that the very long distance of the fence on the side opposite side of ring center (118 ft. from the beamline) and the length of the fence at this distance (180 ft.) is determined by the shielding shown in Fig. 2. **It is assumed that the expense of building up the shield on this side would be prohibitive when compared to the cost of the fence**. Given this presumption, it is clear that adding earth would save very little in length of fence. If another 1.5 ft. of earth were added and rectangular fencing 45 ft. by 33 ft. (the 20 by 14 ft. distances from the edge of the cryo. penetration), one could draw in the fence line on the right and left hand sides Fig. 4 by a small amount, but at the considerable expense of adding earth.

It seems clear that **additional** access restriction should exist in the immediate region of the cryogenics penetrations. This could either be a "block house" made of patio blocks around the cap of the penetrations, or an interlocked fence within a fence (or both).

VIII. Considerations for Early Running

The plan for the "test run" is said to be an intensity of 3 bunches of protons at 10^{10} per bunch with acceleration to 100 GeV. Faults of this energy-intensity would produce lower doses than the numbers presented in this report by a factor of 3000.[6] Even the 149 rem in Table 1 (if the design shield were not in place) becomes 50 mrem at a point difficult to access physically and easy to control by posting. The primary problem in such a test would be establishing effective controls to limit the beam intensity.

The Project has adopted a safety policy that would limit the intensity during the first year to one half of design. This reduces the previous estimates by a factor of 16.[6] Clearly some, if not all, of the access restrictions described in the previous section must be in place before physics running begins, as such numbers as 95 rem and 49 rem in Table 6 and 35 rem in Table 2 go to "a few rem." It would probably be possible to reduce the total length of fence by somewhere between 25% and 50% (at the expense of "moving" the fence later), but this has not been studied in detail. It is likely that any interlocks (on, perhaps, the "fence within a fence") around the cryogenics penetrations exits could be deferred until after the first year of running.

References/Footnotes

1. This level (within 10%) is for faults on Q3 or Q2 going toward the crossing point or Q2 going away from the crossing point.

2. Memorandum from A.J. Stevens to S. Musolino dated 08/23/96, Subj: "Fence Locations Around Cryogenic Bypass Holes."

3. The scaling uses the first-leg labyrinth attenuation expression of Goebel.

4. Memorandum from A.J. Stevens to S. Musolino dated 06/14/96, Subj: "Updated Evaluation of Straight-Through Penetrations."

5. Memorandum from A.J. Stevens to S. Musolino dated 08/26/97, Subj: "Scaling Gollon's Duct and Labyrinth Calculations."

6. This reduction includes removing the factor of 2 neutron QF increase which is artificial if considering the best estimate of possible reportable dose.

Scale: 1" (drawing) = 673.4 cm. 100 cm. = .1485" (drawing)

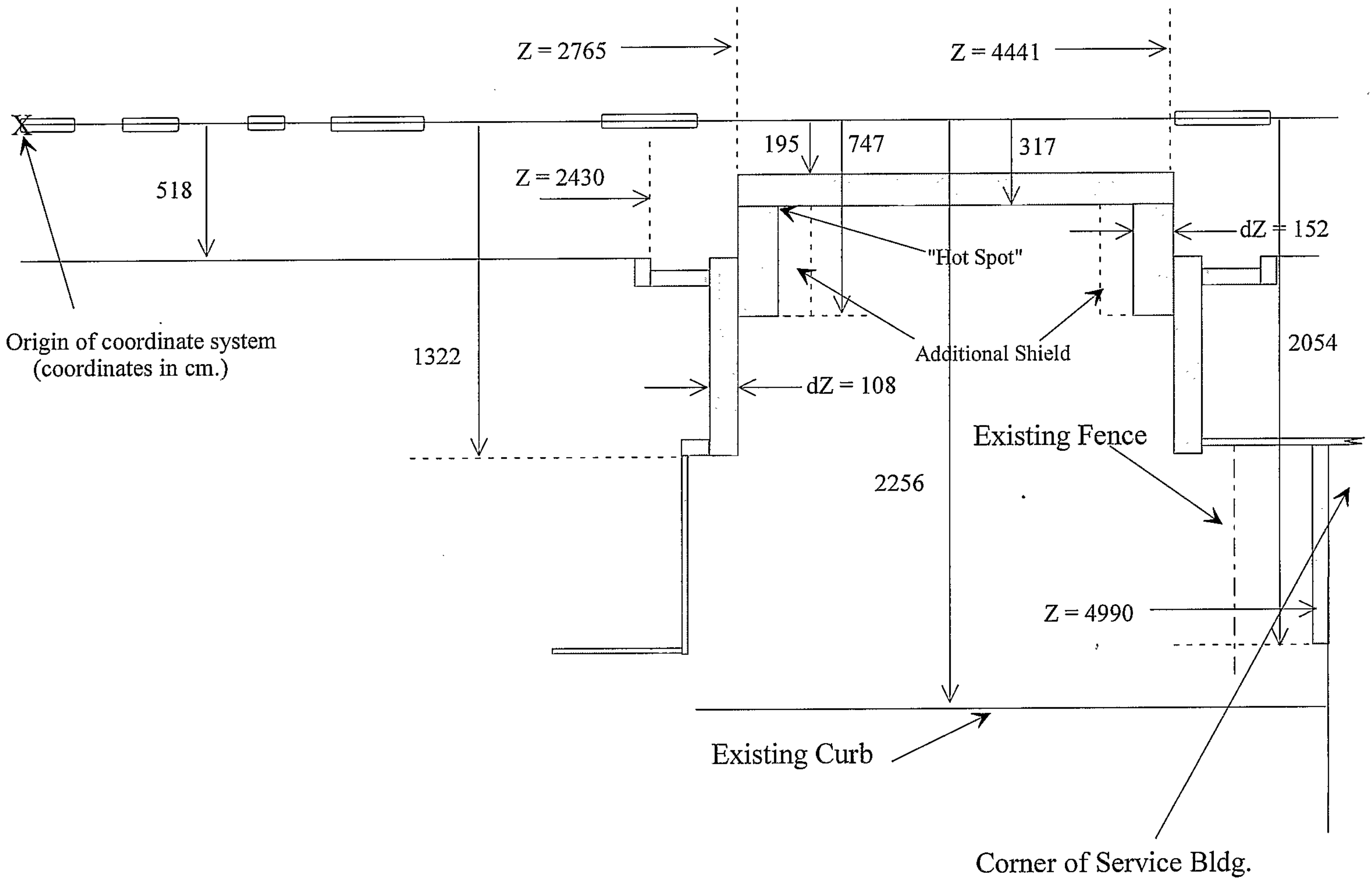

Fig. 1 Twelve O'clock Area: Ring Center Side at Beam Elevation

Scale: 1" (drawing) = 673.4 cm. 100 cm. = .1485" (drawing)

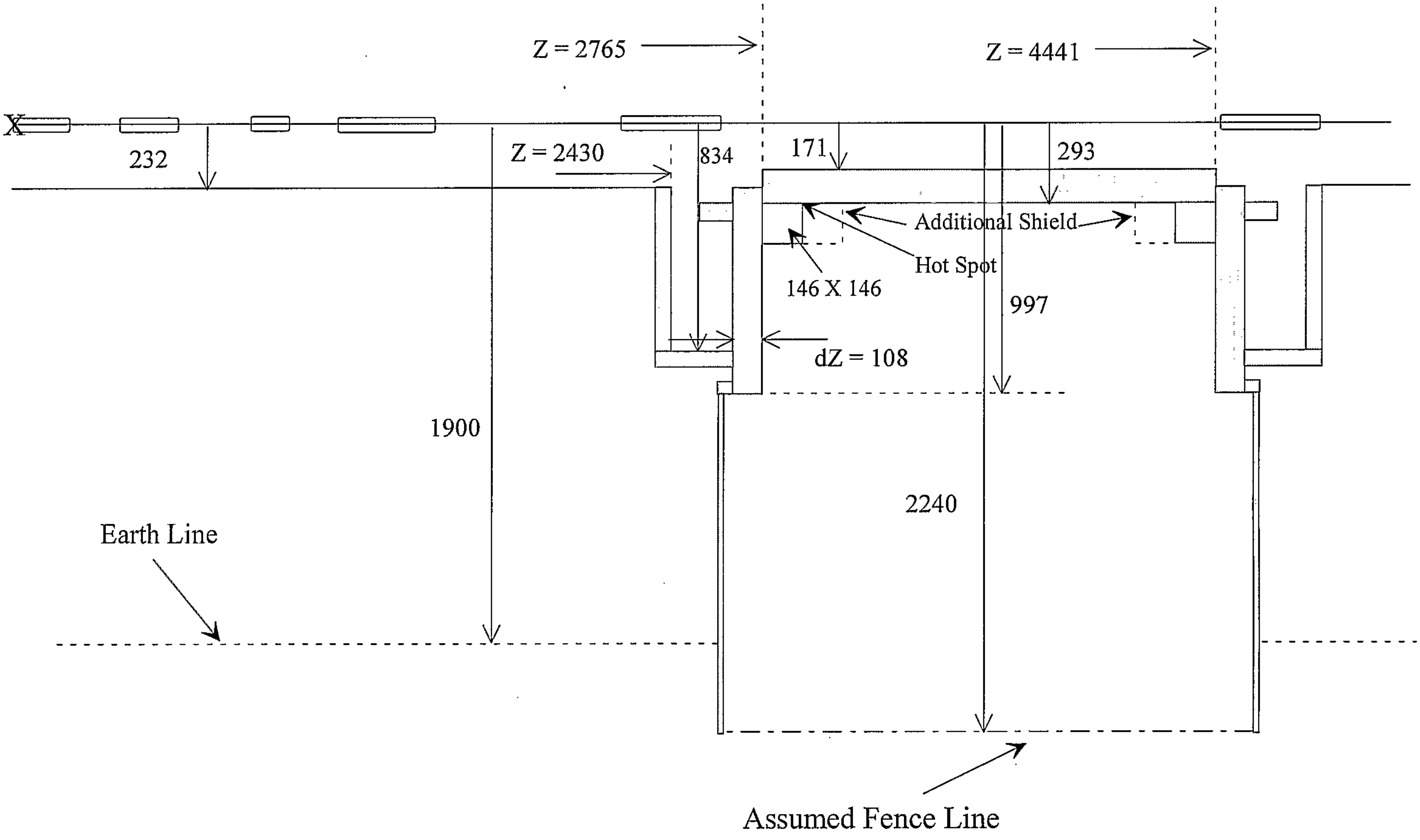

Fig. 2 Twelve O'clock Area: Side Opposite Ring Center at Beam Elevation

Scale: 1" (drawing) = 673.4 cm. 100 cm. = .1485" (drawing)

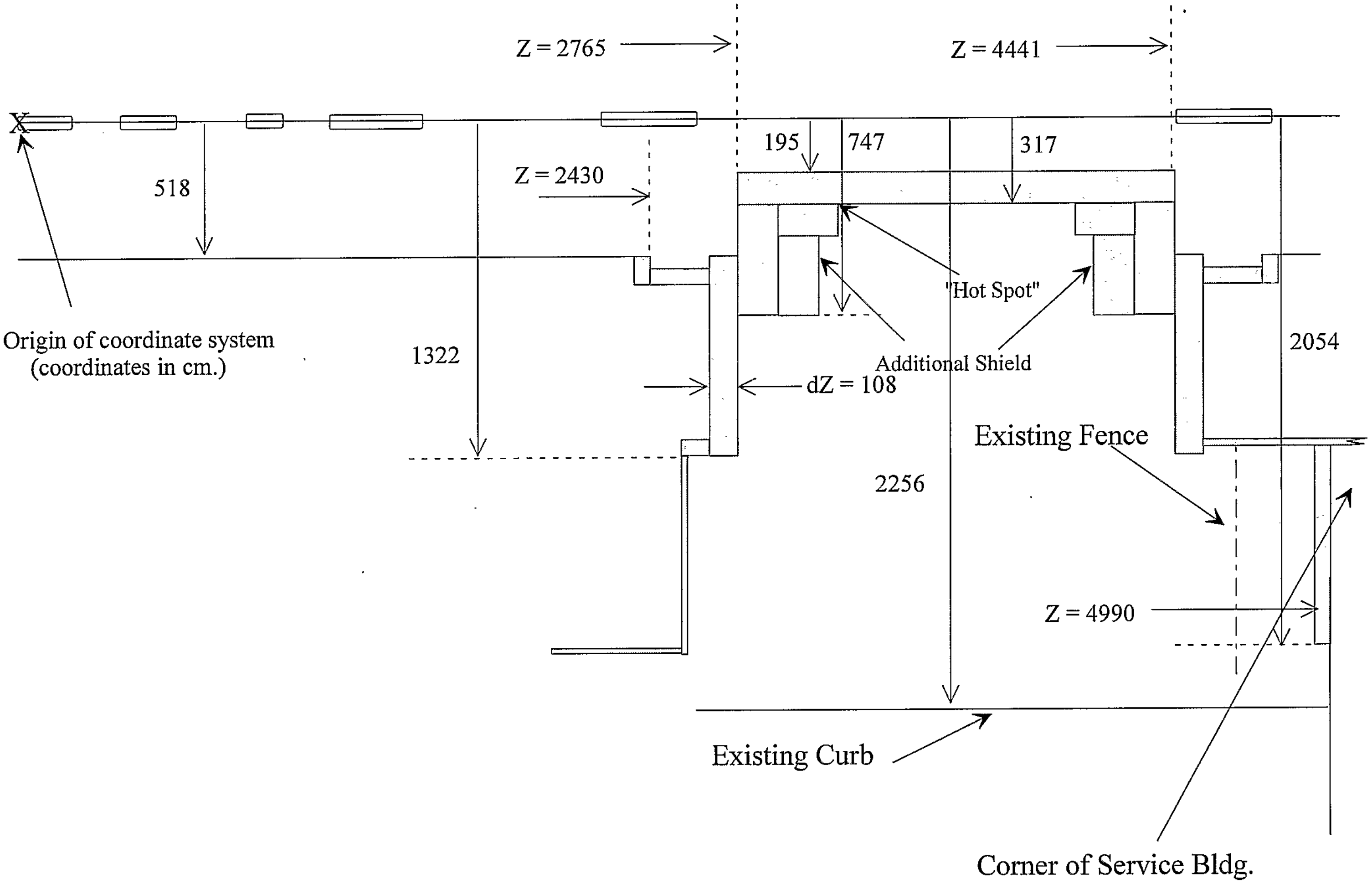

Fig. 3 Twelve O'clock Area: Ring Center Side at Beam Elevation with Added Design Shield

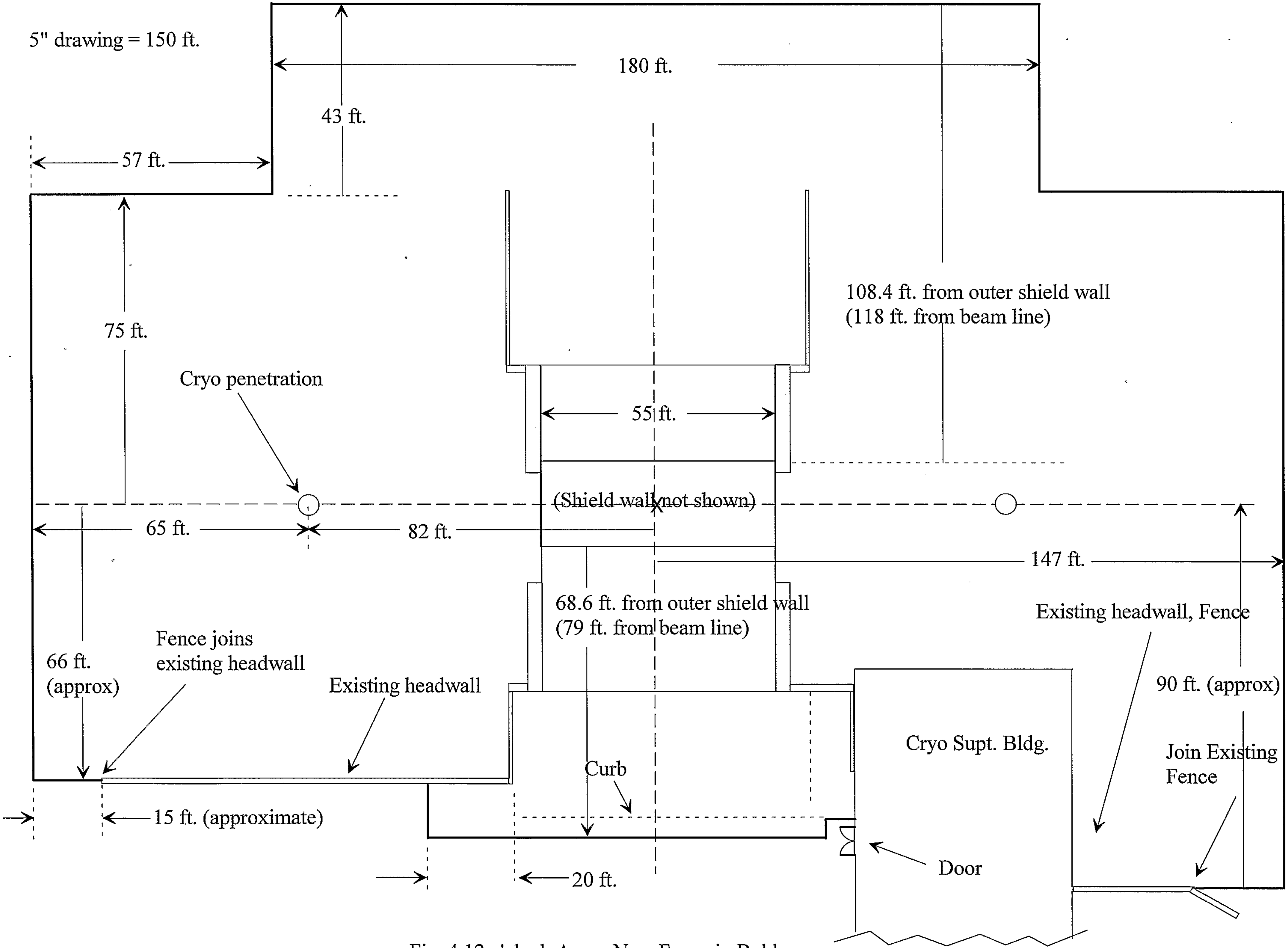

Fig. 4 12 o'clock Area. New Fence in Bold