SINGLE PASS COLLIDER MEMO CN-349

TITLE: Radiation Transmission Measurements on a Small Warm Ion Chamber.

SLAC-CN--349

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Introduction. The SLD is meant to be self-shielding for radiation. Initial calculations indicate that the SLD will satisfy the radiation criteria of less than 1 mrem/hr normal running and less than 25 rem/hr for full beam targeting inside the SLD. However, there is the possibility that low energy neutrons may filter through the iron with energies around 100 keV or so, and need to be absorbed by placing a thin 'skin' of polyethylene on the outer shell of the SLD. Also, transmission of both photons and neutrons through the gaps in the end caps occupied by the ion chambers is very difficult to calculate since the geometry of the ion chambers themselves is complex, and their effects on radiation transport difficult to predict.

The results would indicate that the SLD is a good enough self-shield for both photons and low energy (giant resonance) neutrons, both through the main body of the detector and up the gaps of the end plates. However, high energy neutrons traveling up the gaps of the end caps may still pose a problem during the accident situation.

Location of measurements Measurements were made on a small WIC composed of 17 iron plates each 2 inches thick, with 14 ion chambers placed in the 1/2 inch gaps between the plates. The ion chambers were about 7 feet in length and almost 4 feet high. Initial measurements were made in the LASS building. The WIC rested on a concrete pedestal which brought it almost 4 feet above the floor. Horizontally, it was located between a large iron tank and a concrete wall, with other apparatus occupying the space beyond the end of the WIC. All of this made for poor measuring conditions. Therefore, the WIC was moved to the bay of PEP IR-12 where it could be suspended from a crane high above the floor and well away from any scattering walls. It was realized that even this wasn't a good enough location, since neutrons scatter even from walls and floors that are far away, but it was the best we could manage.

Equipment. A moderated BF_3 detector was used to measure neutron fluences in the energy range of a few keV to a few MeV, and an Andersson-Braun rem counter for measuring neutron dose rates. Sensitivity of the BF_3 is $14 \text{ c/n} - \text{cm}^{-2}$, and the A-B rem counter $2.4 \text{ c} - \text{sec}^{-1} / \text{mrem} - \text{hr}^{-1}$.

The source was PuBe with an output of about $2 \times 10^7 \text{ n} - \text{sec}^{-1}$. This has a somewhat higher average neutron energy than that from giant resonance neutrons, but should be reasonable for these measurements.

For γ - ray measurements, a BICRON Microgray scintillation counter was used, along with the SLAC portable scintillation counter. The gamma-ray source

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was Cs-137 with an energy of 661 keV.

The sources themselves were placed inside small shields to minimize room scattering. For the Cs-137 gamma-ray source, the shield was the 2 inch thick lead container with the end cap removed. For the Pu-Be neutron source, a 6 inch thick cave of borated polyethylene bricks was constructed with an opening which faced the WIC.

Measurements. Figure 1 gives a general schematic of the WIC. Figure 2 is a side view giving the relative locations of source and detectors. For the neutron measurements, the WIC was suspended from the crane with the bottom about 8 feet from the floor. The bottom was only 29 inches from the floor for the gamma-ray measurements. The reason for the different heights was simply that the neutron detectors are remote units, and were easily positioned opposite a gap on top of the WIC when it was raised in the air. The Bicron or SLAC survey meters on the other hand, had to be carried and read out locally, which was impossible to do when the WIC was suspended too high. For the gamma-ray source, there was little transmission through the lead container, and so scattering off the floor was not a problem. The neutron source, however, even when placed inside its borated- polyethylene cave, still had almost 50 % leakage in the backward direction, and so the extra height was valuable.

Essentially, sources were placed in their fixed positions, and measurements made at the same location they would be made when the WIC was in place, but with the WIC removed. The WIC was then swung in place between source and detector and the measurements repeated. In this geometry, the source could be positioned either under an empty gap, under a gap with an ion chamber in it, or under an iron plate for transmission measurements through the parallel gaps. For transmission measurements through the full WIC thickness, the sources were turned sideways with the detectors at the same height, and then the WIC was lowered between them.

Results - Measurements through gaps.

1. The gamma-ray transmission through the ion chamber (in the 46 inch vertical direction) was 6.7×10^{-2} . This is the ratio of ion chamber gap-to-empty gap. The same measurements through the long dimension (84 inches long for the ion chambers, and 4 feet for the iron plates) taken in the LASS building gave a transmission of 1.8×10^{-2} , but in this measurement, the room scattering for the no-WIC case may have been a contributing factor. If we assumed the increased attenuation was due only to the increased length of ion chamber, then the attenuation from the 38 extra inches of ion chamber would be about 0.27.
2. For photons, there was no difference between dose rate in open air and dose rate up an empty gap; i.e., there is no channeling of photons up the gap. Since the photons are pretty well collimated at the source, this is to be expected.
3. With the gamma-ray source opposite one IC gap, there is little transmission through the iron plate to the top of the adjacent gap (i.e., 5×10^{-4} to adjacent

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- gap, 1.7×10^{-4} to the next gap beyond that).
4. For neutrons, the transmission through a gap with an ion chamber was 5.9×10^{-2} (fluence) and 2.9×10^{-2} (dose) when compared to measurements made in open air at the same distance.
 5. The neutron numbers fall off slowly at the top of adjacent gaps as one moves across the plates (0.43% in the next gap, and 0.40% in the gap beyond that). This may be due in part to neutrons leaking out the borated-polyethylene bricks and starting up these channels and in part to neutrons which scatter out of the primary gap and are transmitted through the iron plates to the adjacent gaps.
 6. Adding iron between source and gap lowers the neutron fluence and dose rates pretty much as expected (i.e., 2 inches iron lowers the fluence to 0.66%, dose rate to 0.59%, while 4 inches of iron lowers fluence to 0.52% and dose rate to 0.33%).

Results - Measurements through the WIC body thickness.

1. The calculated transmission of 0.6 MeV gamma-rays through 34 inches of iron is extremely small (i.e., less than 10^{-20}). Thus, any positive measured doses must be due to room scattering. The actual measured dose rate was 5.6×10^{-5} . Moving the detector away from the WIC caused the measured dose to increase, indicating scattering around WIC.
2. Neutron transmission through the 34 inches iron plus 14 ion chambers was 2.2×10^{-2} (fluence) and 1.2×10^{-2} (dose). This is about 10 times higher than would be calculated assuming a total of 8.4 cm polyethylene thickness for the 14 ion chambers. This increase can be accounted for entirely by room scattering of the neutrons which have leaked from the borated-polyethylene cave. We note here that the borated-polyethylene cave only attenuates the source neutrons by a factor of 2 in the backward direction.

Extrapolation to SLD. Photons - End Caps: The yield of photons at 90° from a thick target is $1.5 \times 10^3 \text{ rad} - \text{m}^2 - \text{kW}^{-1} - \text{hr}^{-1}$. For 72 kW at a distance of 3.9 m, the dose rate would be (with no attenuation)

$$D = \frac{1.5 \times 10^3 \times 72}{(3.9)^2}$$

$$= 7.1 \times 10^3 \text{ rad/hr.}$$

The attenuation of 4 inches of iron ($\lambda = 42g - \text{cm}^{-2}$) is 0.15. The measured attenuation through a 46 inch long ion chamber in a gap is 6.5×10^{-2} . If this latter value were the attenuation from a 3.9 m long ion chamber (which is unreasonable), then the dose rate up the gaps of SLD would be

$$D = 7.1 \times 10^3 \times 0.15 \times 6.5 \times 10^{-2}$$

$$= 69 \text{ rad/hr}$$

However, the dose rate measured through an 84 inch gap (still with only 48 inches of iron, however) was 0.27 times that through the 46 inch chamber. If the dose rate decreased by 0.27 for every 38 more inches of ion chamber, then the extra attenuation of an ion chamber 3.9 m long over that of the measured 46 inch chamber would be about 2.5×10^{-2} . Thus, the photon dose rate at the top of the end plates of the SLD would be

$$\begin{aligned} D &= 69 \times 2.5 \times 10^{-2} \\ &= 1.7 \text{ rad/hr} \end{aligned}$$

Neutrons - End Caps: For a source term, we can use 1.25×10^{12} neutrons per 4π steradians per kW. With $8n - \text{cm}^{-2} - \text{sec}^{-1}$ equivalent to 1 mrem/hr, at a distance of 390 cm, for 72 kW, and with a buildup in the iron of 1.4, this leads to a dose rate of

$$\begin{aligned} H &= \frac{1.25 \times 10^{12} \times 72 \times 1.4}{4\pi (290)^2 8} \\ &= 5.9 \times 10^6 \text{ mrem/hr} \\ &= 5.9 \times 10^3 \text{ rem/hr.} \end{aligned}$$

The neutron dose attenuation from 46 inches of ion chamber was 1.2×10^{-2} , but this probably was partially a measure of the neutrons scattered around the WIC, and not necessarily through the ion chamber. If we were to use this value for 46 inches only and make no allowance for increased attenuation from the extra length, the neutron dose rate at the top of the end cap would be

$$\begin{aligned} H &= 5.9 \times 10^3 \times 1.2 \times 10^{-2} \\ &= 71 \text{ rem/hr.} \end{aligned}$$

It isn't reasonable, however, to assign the same attenuation from 154 inches (390 cm) in SLD as from the 46 inches in the model, but rather we would assume the extra 108 inches would give additional attenuation (about 1.5×10^{-4}). Thus, the expected dose rate from giant resonance neutrons should be well below the 25 rem/hr criterion; i.e.,

$$\begin{aligned} H &= 71 \times 1.5 \times 10^{-4} \\ &= 1.1 \times 10^{-2} \text{ rem/hr.} \end{aligned}$$

Photons - Main Body. The measurements with the small WIC were such that transmission of photons couldn't be measured; i.e., the transmission is expected to be extremely small, such that no dose from photons will ever reach the outer surface.

Neutrons - Main Body. For giant resonance neutrons, the source term again would be $1.25 \times 10^{12} \text{ n} \cdot \text{cm}^{-2} \cdot \text{sec}^{-1}$, which becomes $7.8 \times 10^3 \text{ rem/hr}$ without any attenuation; i.e.,

$$H = \frac{1.25 \times 10^{12} \times 72 \times 1.4}{4\pi (400)^2 \cdot 8 \cdot 1000}$$

$$= 7.8 \times 10^3 \text{ rem/hr.}$$

We know, however, that there will be attenuation in the Pb calorimeter and in the outer Fe calorimeter. Because of room scattering, we were unable to measure actual transmission through the WIC; it must be less than the measured 1.2×10^{-2} , and therefore we feel confident in using the calculated values. From the Pb calorimeter, we expect 4.5×10^{-2} , and from the Fe calorimeter, 4.9×10^{-3} . Thus, the overall dose rate from giant resonance neutrons would be

$$H = 7.8 \times 10^3 \times 4.5 \times 10^{-2} \times 4.9 \times 10^{-3}$$

$$= 1.7 \text{ rem/hr.}$$

Conclusions. These measurements would seem to indicate that dose rates at the top of the SLD end caps and through the SLD main body from both photons and low energy neutrons will be below 25 rem/hr for the accident situation. However, better measurements still need to be done on the finished SLD, especially to locate any holes in the shielding.

For the end caps, the limiting factor will be high energy neutrons. The dose rate at the top of the caps from this source with only the attenuation from 4 inches of iron on the inner sleeve would be about 87 rem/hr for the accident situation. There will be some attenuation (due to scattering out) of these neutrons in the ion chamber, but the amount of this scattering is unknown, and there's really no way to measure it without a high energy source.

FIG 1