RADIATION PHYSICS NOTE 100

Impact of Proposed Changes to Standard Bicron/Thyac Survey Instrument Operation Mode on Fermilab

March 1993
Rev. 1

Vernon Cupps, Fred Krueger, Tony Leveling, and Alex Elwyn

Introduction:

For over 20 years Fermilab has used the Bicron/Thyac survey instruments in the rate mode to screen potentially radioactive material. During that time period, potentially radioactive material has been classified as radioactive if it caused a Bicron/Thyac survey instrument to register 2000 or more cpm above ambient background. These survey instruments use a NaI(Tl) detector and typically employ a meter readout for the rate mode. The NaI(Tl) detector was chosen due its very high efficiency for detecting gamma rays which are the primary form of radiation emitted by Fermilab produced radionuclides.

In the fast response rate mode, the instrument meter responds to the number of counts accumulated during a 1 second time period and thus appears in continuous motion to the naked eye. This, of course, makes it necessary for the operator to estimate the average position of the meter needle on the meter face. If the instrument is operated in the scaler mode, the operator must wait a full minute for the counts to accumulate and be displayed on some type of digital readout. No operator judgment is required for this operational mode. Meter readout modes offer the advantage of faster evaluations while the scalar modes offer the advantage of better statistical precision.

Definitions:

For the purposes of this analysis, the definitions found in reference 1 will be essentially adhered to. Those definitions, in slightly different wording, are as follows:

<u>Critical Level</u> (L_c): This is the count rate above ambient background at which one can be 95% confident that it is statistically different from a background induced count rate. There is thus still a 5% probability that that count rate is not a true positive value and is in fact a background induced count rate. At this count rate there is only a 50% chance that any real activity it might represent will be detected.

<u>Detection Limit</u> (L_d): This is the count rate, above ambient background, at which one can be 95% confident it represents actual radioactivity in the sample being counted. It is the count rate generated by the smallest quantity of radioactive material which can be detected with 95% confidence that it is statistically different from background at the 95% confidence level. At this count rate there is still a 5% probability that a repeat measurement will not be

distinguishable from background at a 95% confidence level.

Theory:

For any single channel counting instrument, such as survey instruments which count particles in a broad energy range, the count level at which one can distinguish added radioactivity from background radiation is a function of the standard deviation for measurements of the background radiation, the time interval for which the background radiation is counted, and the time interval for which the subject material is counted.

The Bicron/Thyac survey instruments would exhibit the following theoretical statistical limits for the rate and scalar readout modes.

Rate mode: In the fast response rate mode, the Bicron electronics display a count rate time averaged over 1 second on the instrument meter. This, of course, means that the effective count time is 1 second or $\frac{1}{60}$ of a minute. If one now assumes that the only counting errors of significance are those resulting from statistical effects and that the ambient background produces a count rate of 2000 cpm, then the following limits result using the appropriate formulas from reference 1 with k equal to 1.65:

$$L_c = 1.65\left(2 \cdot \frac{2000}{\frac{1}{60}}\right)^{\frac{1}{2}} = 808 \text{ cpm}$$

$$L_d = \frac{1.65^2}{\frac{1}{60}} + (1.65) \cdot 2 \cdot \left(2 \cdot \frac{2000}{\frac{1}{60}}\right)^{\frac{1}{2}} = 1780 \text{ cpm}$$

If one now substitutes the typical background range of 1500-2500 cpm seen at Fermilab into these equations, the following ranges for L_c and L_d are obtained:

$$700 \le L_c \le 904$$

$$1563 \le L_d \le 1971$$

These ranges are fully consistent with those specified in reference 2 and with the long-standing release criteria of 2000 cpm above background.

Scalar Mode: In this mode of operation, the Bicron operates like a typical single channel Counter/Timer. Each electrical pulse generated by the detector above a certain threshold value is registered as a count during a 1 minute time period. The sums of these counts are digitally displayed during the 1 minute count time. Thus one counts for a time period 60 times as long as that used in the rate mode. If one again assumes that the only significant source of error is statistical and the background typically ranges from 1500 to 2500 cpm then the following ranges for Lc and Ld are obtained:

$$90 \le L_c \le 117$$

$$184 \le L_d \le 236$$

Clearly the statistical precision of measurements in this mode are almost an order of magnitude

better than in the rate mode. This is however the only advantage offered by this counting mode.

Implications:

The most obvious question to ask now is "What will it cost Fermilab to implement a screening criterion which uses the Bicron operating in the scalar count mode?". A universal response to this question from those at Fermilab who have worked with waste screening for many years is that it will have a dramatic negative effect on Fermilab operations. It will require:

(1) Additional manpower to directly implement -- both initially and on a continuing basis.

(2) A significant increase in waste disposal costs.

(3) An initial equipment investment of approximately $100,000.

(4) Significant increase in the cost of disposal contracts for non-radioactive waste.

(5) A one time cost of retraining all radiation technicians at Fermilab.

(6) Additional record keeping mandated by ANSI 13.6 and DOE Order 1324.2A and other additional administrative burdens.

Use of the Bicron in the scalar operation mode for waste screening would certainly have an immediate negative impact in the six areas mentioned above and perhaps in other areas not yet anticipated.

At this time it has only been possible to obtain estimates for items (1) and (3). It should be noted that items (2) and (4) individually will almost certainly be significantly larger than items (1) and (3) together. However it is believed that items (1) and (3) are sufficient to make the point that changing Fermilab's current release criteria cannot be rationally justified.

In the scaler mode of operation, the Bicron Analyst survey instrument has a 1 minute integration/count time, i.e., the user must hold the survey instrument in a single orientation with respect to material being measured for a full minute. This will increase by approximately a factor of 10 the time required for radiation technicians to screen materials at Fermilab for radioactivity. Accelerator Division has conservatively estimated that it will require an additional 2 FTE radiation technicians to implement the use of the scalar readout mode in material screening activities. The Radiation Physics Technical Support Group estimates that it will require another 0.4 FTE radiation technician. Rough estimates from other divisions/sections of the direct additional manpower required to implement this change in the Fermilab release criteria are:

Research Division	3	FTE
Computer Division	1	FTE
Technical Support Section	2.5	FTE
Facility Engineering Section	1	FTE
Physics Department	0.5	FTE
Business Services Section	0.2	FTE
Laboratory Services Section	0.2	FTE
Directorate	0	FTE

It should be reemphasized that these are estimates and they are most likely conservative, i.e., the cost to Fermilab could be greater. Adding these estimates yields an increase of 10.8 FTE radiation technicians at Fermilab. One FTE will cost Fermilab approximately $50,000/yr. This would then translate into a cost of $540,000/yr. to Fermilab in direct increased manpower required to implement this simple change in the release criteria. Over a period of 10 years the additional cost would be 5.4 million dollars assuming no inflation. Add item (3) to this and the partial cost to Fermilab would be 5.5 million dollars over the next 10 years.

We should now investigate what the conventional wisdom in radiation physics would have to say about this situation. The current release criterion protects the public against a contact dose rate of 10 microrad/hr (see reference 2). This is less than $\frac{1}{3}$ the average yearly individual dose equivalent (34 mrem/yr) received by people living in the United States due to natural background radiation as documented in reference 3. If the release criteria were changed to 200 cpm above background, it would protect the public against a contact dose rate of 1 microrad/hr!

What does the current release criteria of 2000 cpm above ambient background imply for the public? In the absurdly improbable situation documented in reference 2, a member of the public would receive a dose equivalent of 88 mrem/yr. This is still well below the guidelines contained in Chapter III of DOE Order 5400.5. In a more probable, but still relatively unlikely situation, suppose that a member of the public obtained some object released by Fermilab that registered just under 2000 cpm above background on a Bicron survey instrument. Suppose further that this person spent 1 hr/day every day of the year in close proximity (i.e., within 1 foot of the object) to that object. The total resulting exposure would be 0.9 mrem for the entire year. This is a dose equivalent rate not measureable by any currently known detector.

Reference 4 defines and discusses the Negligible Individual Risk Level (NIRL). This level is defined as "the level of average excess fatal health risks from radiation exposure from any individual source or practice below which further effort to reduce individual exposure is **unwarranted**." Reference 4 estimates this level as a 10^{-7} risk. This risk level corresponds to an average individual dose equivalent level of 1 mrem/yr. The current Fermilab release criterion meets this risk level even for the unlikely scenario of the preceding paragraph.

Reference 5 states:

(i) No practice shall be adopted unless it produces a positive net benefit.

(ii) All exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account.

If Fermilab should change its release criteria to the 200 cpm dictated by use of the scalar readout mode it would reduce the potential individual dose equivalent exposure from 0.9 mrem/yr. to approximately 0.09 mrem/yr. This would cost Fermilab a minimum of $680,000/mrem. Most likely it would cost Fermilab, and ultimately the American taxpayer, well over $1,000,000/mrem when the other costs are factored in; an absurdly large sum of money to reduce the potential individual dose equivalent by 0.81 mrem/yr. or to reduce the individual risk from 10^{-7} to 10^{-8}. By any reasonable standard this is a ridiculously high cost with no expectation of any measurable return on the investment. Changing the release criteria would produce no positive net benefit for Fermilab or its surrounding communities.

Reference 6 deals with the cost-benefit analysis of radiation protection measures from a somewhat more quantitative view. If we define X as the cost of radiation protection, Y as the cost of detriment, and S as the collective dose then the optimization condition that the increase in the cost of protection per unit collective dose balances the reduction of detriment per unit collective dose can be expressed by:

$$\frac{\partial X}{\partial S} = -\frac{\partial Y}{\partial S}$$

The detriment,Y, is usually expressed as a linear function of the collective dose,S:

$$Y = \alpha \cdot S$$

where α is variously quoted as $10/man-rem to $2000/man-rem. We now know enough to solve for the collective dose equivalent rate at with the cost balances the detriment. Assuming the upper limit for α and our previously determined cost per year of $550,000 this collective dose equivalent rate would be 2.8×10^2 man-rem/yr. Suppose we have a landfill with disposal personnel in and out during the work day. Accounting for weekends and holidays, there are approximately 265 work days per year during which exposure to items occupying the landfill could occur. Assume further that an object exhibiting almost 2000 cpm above background on contact when surveyed with a Bicron is in the landfill, that the work day is 12 hours long, and that the population around the immediate area of the object (between 1 ft. and 200 ft.) varies linearly with distance from the object. Neglecting attenuation and buildup, the total collective dose equivalent would be approximately 7.7×10^{-3} man-rem/yr. This is a number almost 5 orders of magnitude below the value at which the cost would balance the detriment.

Finally, would any environmental damage result from continuing to use the current Fermilab release criteria? Twenty years of experience with local landfills and disposal companies suggests that the answer is no. No measurable increase of the radiation background in the surrounding communities has ever occurred due to material released from Fermilab. Even if material registering 2000 cpm above background was released it would result in only an extremely localized 30% increase in the natural radiation background. Since all the gamma emitting radionuclides produced at Fermilab have half lives of 5.3 yrs. or shorter(most are much shorter), that localized background enhancement would quickly dissipate. There is no logical scenario or evidence that would support a thesis that Fermilab's current release criteria will damage the environment.

Summary:

Changing the Bicron survey instruments operation mode from a ratemeter readout to a scalar readout will enhance the statistical precision of screening measurements performed here at Fermilab. However the price of that change to Fermilab is prohibitive. No measurable increase in the protection of personnel from radiation would result from the change and no significant enhancement of the environment would be realized either. Hence, according to all the current conventional wisdom of radiation protection, there is no compelling reason to change Fermilab's current release criteria.

REFERENCES

1. Joseph C. Lochamy, The Minimum Detectable Activity Concept, NBS SP456, 1976.

2. Fermilab Radioactivity Release Criteria for Materials and Equipment, Revision 1, 10/92.

3. NRCP Report No. 94, Exposure of the Population in the United States and Canada from Natural Background Radiation.

4. NRCP Report No. 91, Recommendations on Limits for Exposure to Ionizing Radiation.

5. ICRP Publication 26, Recommendations of the International Commission on Radiological Protection.

6. ICRP Publication 37, Cost-Benefit Analysis in the Optimization of Radiation Protection.