Radiation Physics Note 60

The Sensitivity of the Railhead Gate Radiation Monitor

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A large area radiation monitor has been installed at the railhead gate on McChesney Road to detect unauthorized transport of radioactive materials. The device was purchased from TSA Systems, Inc. It consists of an 8" by 8" by 10 ft high weatherproof steel cabinet pillar containing two plastic scintillation detectors of ~280-in^3 active volume each, along with the necessary power supplies and electronics to process the signals from the phototubes. A self-contained alarm monitor unit is integrated with the detector and provides both audible and visual alarm indication under high radiation conditions.

The system automatically monitors background radiation and updates the display at regular intervals. A microwave detector mounted on the guard shack is used as a vehicle sensor. Sensing a vehicle the radiation detector goes into a fast count mode (i.e., it updates the display more often), and tests for an alarm condition at very short intervals. The radiation alarm level is calculated on the basis of preset variation from background. The algorithm used is:

$$\text{Alarm Level (above B)} = S\,(1+N),$$

where B is background counting rate, S=B/20, and N is a constant selected by internal dipswitches. It is currently set at N=4. Thus the alarm level is set at approximately five times the variance (σ) in the background counts for typical background rates of approximately 400 count-sec^{-1}.

The detector pillar is mounted on the side of the roadway a distance of approximately 8 feet from the center of the ingoing traffic lane just inside the railhead gate. Vehicles proceeding to the railhead must stop at the guard shack before entering the area. It is estimated that traffic moves through the gate at speeds of 5-10 mph.

TSA Systems, Inc., who developed the monitor, did not provide documented "demonstrated sensitivities" in the specifications for the single pillar unit (Model VM-250). In the purchase requisition Fermilab required that the detector respond by alarm to the transport of an unshielded 10 μCi ^{137}Cs source at a perpendicular distance of 8 feet in a vehicle traveling at ~10 mph. The present measurements were undertaken to check detector response as installed.

To test the sensitivity of the unit (with N=4) an automobile carrying radioactive materials was driven back and forth through the gate simulating actual situations. ^{137}Cs sources, a bar of depleted uranium 2" x 2" x 5" (long), and some small pieces of commonly found radioactive materials (mostly iron) were transported past the detector at 7-10 mph, and detector counting rates were recorded. (^{137}Cs was used since it emits 661 keV γ-rays, similar in energy to other radioactive items found at Fermilab) Some of these measurements were performed in April, 1986 shortly after installation. More extensive observations were carried out in August, 1986 after permanent power was brought to the gate area. Background rates were about 400 cts-sec^{-1} in April, and ~550 cts-sec^{-1} in August. The results are shown in Table 1.

The observations for the radioactive sources are plotted as a function of activity in Fig. 1. The two lowest points gave N values below N=4, which was the factory preset alarm level, and did not sound the alarm. The system did alarm as expected for a ^{137}Cs source of 7.5 μCi since N =4. The radioactive items (A+B+C+D) had an unknown activity but gave Thyac reading of 5.5×10^5 cpm on contact, and also set off the alarm with an observed value of N=4.5. They corresponded therefore to an activity of ~10 μCi of ^{137}Cs. From the data shown in Table 1, an activity of ~10 μCi corresponds to a contact exposure rate for Cs-like radioactivity of ~5 $mR\text{-}hr^{-1}$. The straight line representing the equation shown in Fig. 1 is based on a fit to ^{137}Cs data for activities less than ~30 μCi.

In summary, the radiation monitor as installed appears to satisfy the specification required by the purchase requisition. As set-up with N=4, the device alarms when an automobile carrying a ^{137}Cs source of $\gtrsim$7.5 μCi or its equivalent passes within about 8 feet of the detector traveling at 5-10 mph. Although not investigated at the present time, the alarm level can be set (by the user) to improve sensitivity if desired. This probably will increase the level of false alarms, however.

The sensitivity of the single pillar unit to radioactive materials transported away from the railhead area in the far traffic lane could not be properly assessed because of somewhat erratic vehicle sensor response. With the microwave detector mounted as it presently is, an automobile approaching the gate from the railhead can pass by undetected, apparently dependent upon its position relative to the centerline of the roadway. Thus, the radiation

detector unit will not go into its fast-count mode, and so may miss a possible alarm conditon. Preliminary observations suggest that the sensor responds much less erratically to the approach of a taller and wider vehicle (even a pickup truck, for example). It is suggested that as far as possible the gate on the far traffic lane remain closed so that both ingoing and outgoing traffic proceed through the ingoing lane only.

Thanks to Billy Arnold and Bill Freeman for help with these measurements.

TABLE 1: Results of measurements with sources and other radioactive materials. Background rates were ∿400 counts-sec^{-1} in April and ∿550 counts-sec^{-1} in August.

Date	Material	Activity[a]	Contact Exposure Rate[b] (mR-hr^{-1})	Counts-sec^{-1} (approx.)	N[c]	Did System Alarm?
April 1986	^{60}Co	1.6 μCi	---	460	3	No
	^{137}Cs	18 μCi	---	550	7.5	Yes
	^{137}Cs	25 μCi	---	600	10	Yes
	^{137}Cs	121 μCi	---	1500?	55	Yes
	Depl. Uran.	2.6 mCi	---	600	10	Yes
August 1986	^{137}Cs	3 μCi	1.7	590	1.5	No
	^{137}Cs	7.5 μCi	4.1	655	3.8	Yes
	^{137}Cs	1.8 μCi	8	785	8.5	Yes
	^{137}Cs	121 μCi	44	1400±100	31±4	Yes
	Item A[d]	10000 cpm	---	550	0	No
	Item B	20000 cpm	---	570	.7	No
	Item C	220000 cpm	2.1	620	2.5	No
	Item D	300000 cpm	---	630	2.9	No
	A+B+C+D	550000 cpm	---	675	4.5	Yes

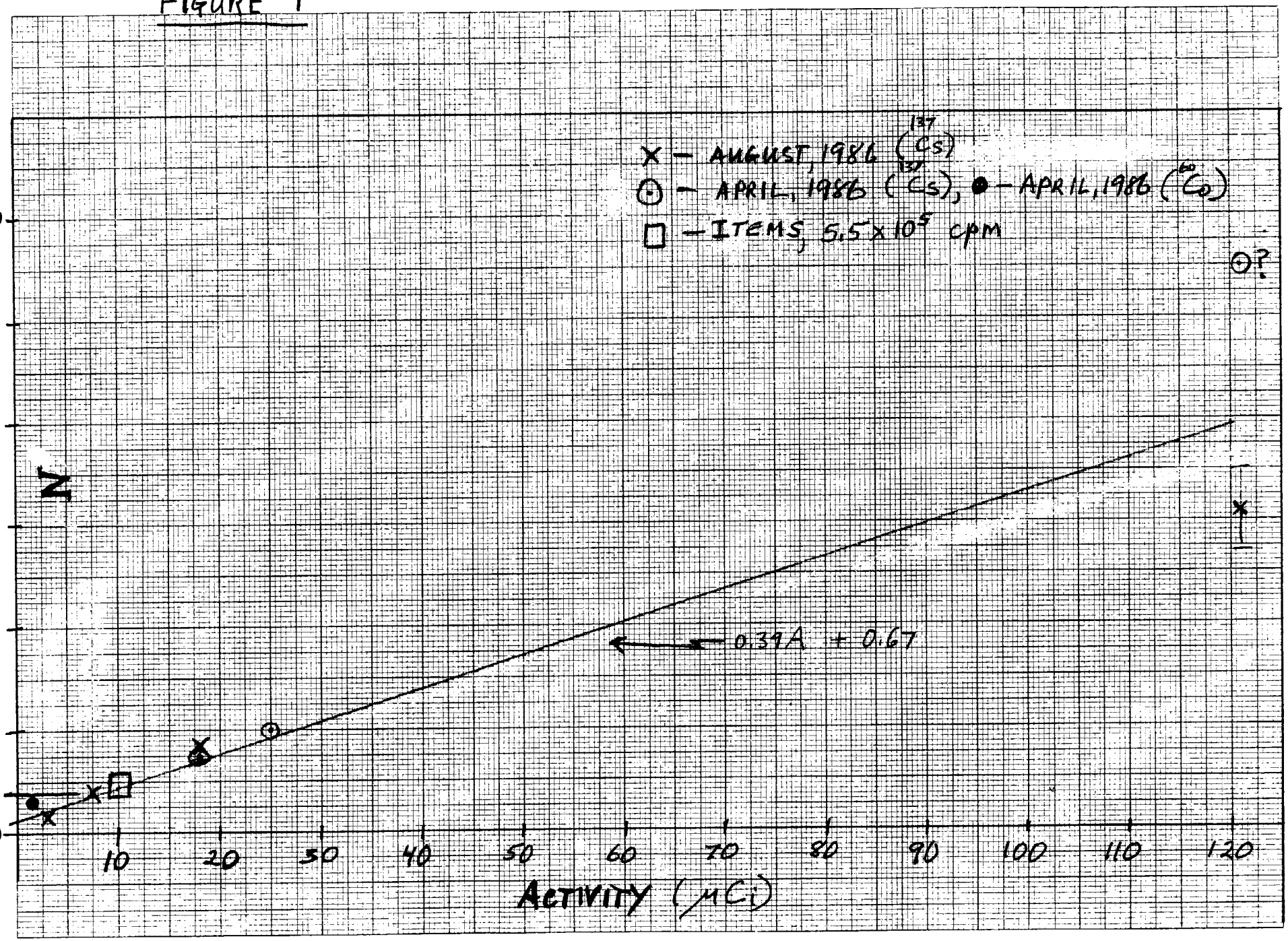
a) ^{60}Co and ^{137}Cs sources have been corrected for decay from time of acquisition.

b) Contact dose rates with a Ludlum Model 14C-1 survey meter.

c) N is defined as the difference between observed and background (B) counting rates divided by the quantity S=B/20, as discussed in the text.

d) The contact counting rates for these radioactive items are based on the use of a Thyac survey meter.

FIGURE 1


X – AUGUST, 1986 (^{137}Cs)
⊙ – APRIL, 1986 (^{137}Cs), ● – APRIL, 1986 (^{60}Co)
□ – ITEMS, 5.5×10^5 cpm
⊙?
N
60
50
40
30
20
10
4
0
0.39A + 0.67
10
20
30
40
50
60
70
80
90
100
110
120
ACTIVITY (μCi)