Radiation Control Group Notes

It is intended to introduce a new series of internal communications concerned with radiation control matters. These are intended to deal with technical matters likely to be of interest to only a few people or with subject matter concerned with regulations or codes of practice for which the wide distribution given to the CEBAF technical note series would be inappropriate.

RCG Note 90-002 is being issued in advance of RCG Note 90-001.

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On the Use of Geiger-Muller Radiation Detectors in with Pulsed Beams

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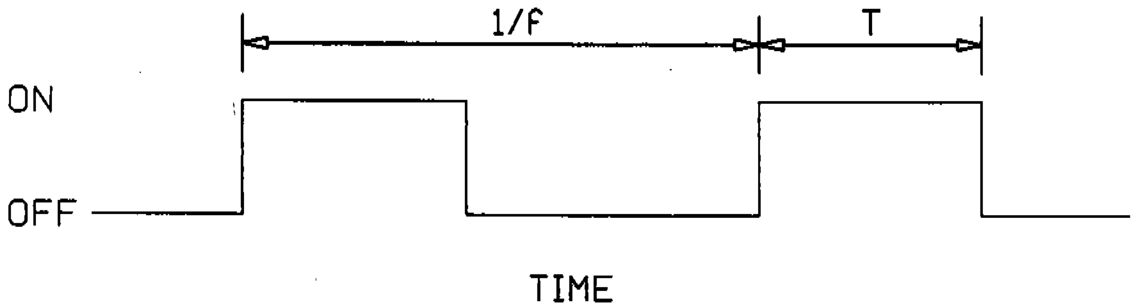
Introduction

It is intended to operate pulse mode during commissioning and tune up, therefore it is necessary to examine the behavior of detectors with significant count resolving times. In this category Geiger-Muller detectors are of special importance because they are probably the cheapest and most commonly used devices in radiation protection. Geiger-Muller tubes have characteristic dead-time which make them suspect in pulse radiation fields. For this discussion we adopt the analysis set out in (McC 88).

Assumed accelerator beam has the following pulse structure



Where:

T = Source pulse length
f = Source pulse frequency

Let:

τ = Resolving time of detector system
m = Observed counting rate
n = True counting rate (if τ were 0)
Dealing only with the case when:

$$T < \tau < (1/f - T).$$

(Then one can have a convergent maximum of one count per source pulse, that is, $m < f$. Also, the detector will be fully recovered at the start of each source pulse.)

Then:

> Probability of observed count per source pulse $= \frac{m}{f}$
> Average number of true events per source pulse $= \frac{n}{f}$
> (can be > 1)

From Poisson distribution:

$$P(>0) = 1 - P(0)$$

$$= 1 - e^{-\bar{x}}$$

Thus:

$$\frac{m}{f} = 1 - e^{\frac{-n}{f}}$$

or

$$m = f(1 - e^{\frac{-n}{f}}).$$

solving for n to provide a correction formula:

$$n = f\, ln\left(\frac{f}{f-m}\right).$$

It is noted that under these conditions, neither the length of the resolving time τ nor the detailed dead-time behavior of the system (e.g., whether it is paralyzable) have any effect on the correction.

The following curves show the correction to be applied to two different Geiger-Muller tubes commonly used at CEBAF. Curves are given for 100 Hz, 20 Hz and 5 Hz, to illustrate the strong dependence on pulse repetition frequency. The Eberline Geiger-Muller monitors have the following count/dose weight:

HP-270	1200 cpm $\equiv$ 1mR/h.
HP-290	80 cpm $\equiv$ 1mR/h.

However, it must be remembered that these detectors have background levels which determine the minimum sensitivity of the system.

Conclusion

We have shown that with beam pulse repetition rates of 100 Hz, as proposed for the FET, it is feasible to use an Eberline SRM-100 instrument with an HP-270 detector for alarm purposes at levels less than 2.5 mR/h; the set level would, however, have to be approximately 2.0 mR/h as shown in figure 1. Should radiation levels exceed this then the instrument must be disregarded. For dose rates of about 50 mR/h the HP-290 may be used with the appropriate corrections given in figure 2. The other figures 3-6 show the responses at lower repetition rates.

This is stressed most strongly that if it is proposed as an operational requirement to change the repetition rate from 100 Hz to a lower value then adequate correction of the detector responses must be made beforehand. In addition to Geiger detectors a number of ion-chamber detectors are available for FET; those are much less subject to errors from pulsed radiation, because ion-chambers are based on total charge collection principles.

References

McC88 R. C. McCall et al Health Physics Manual of Good Practices for Accelerator Facilities, SLAC-327 April 1988.

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Figure 1

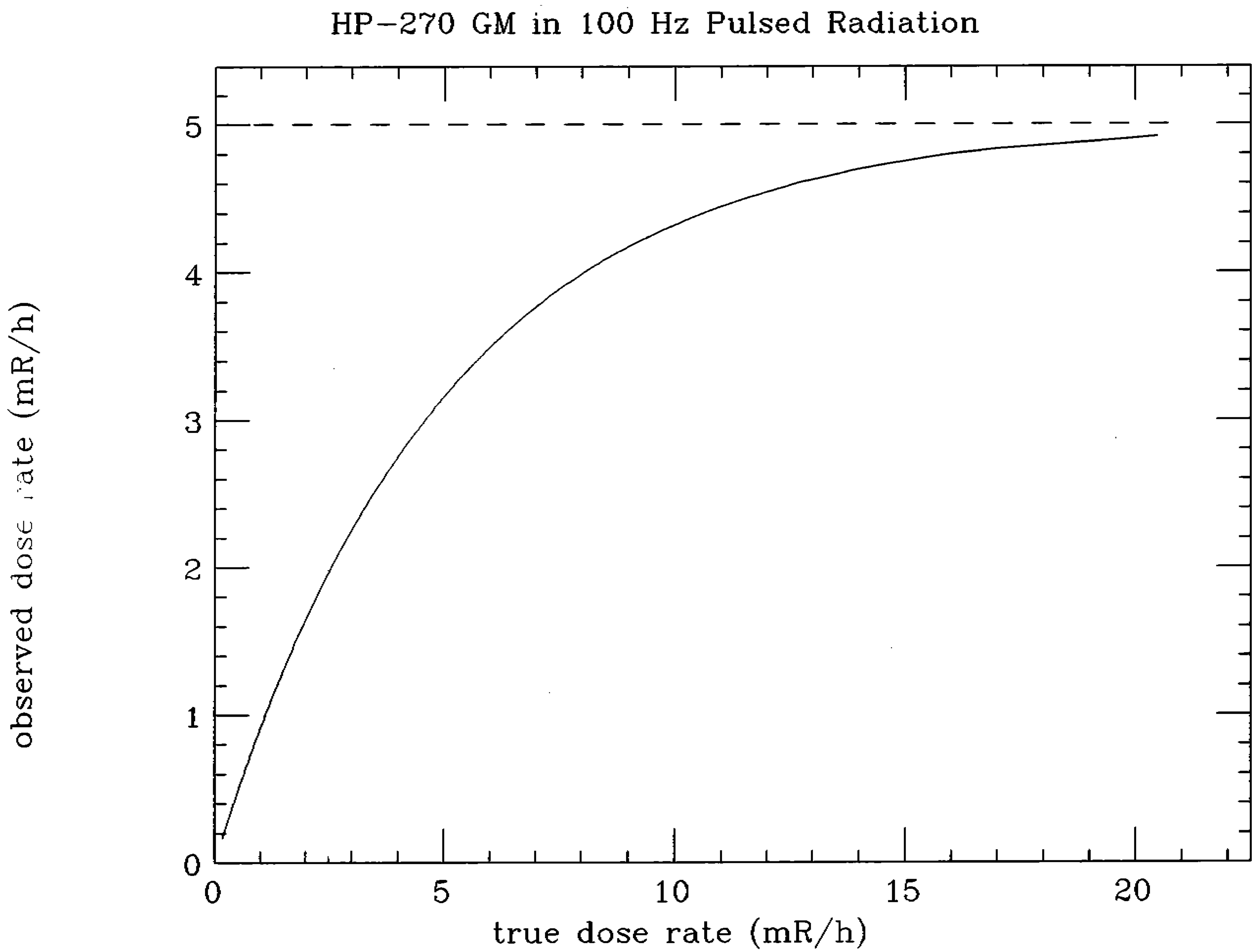
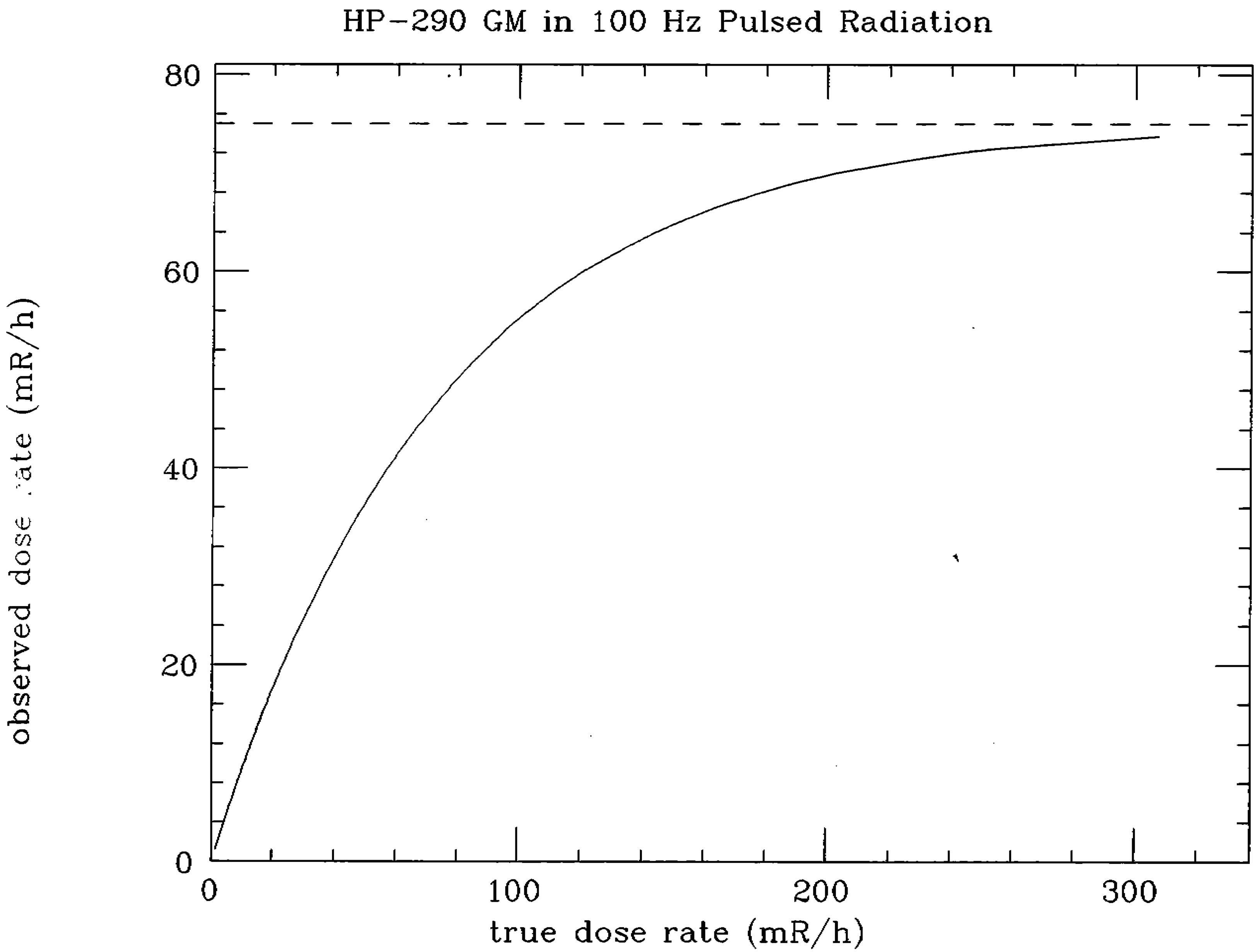

HP−270 GM in 100 Hz Pulsed Radiation
observed dose rate (mR/h)
true dose rate (mR/h)
0
1
2
3
4
5
0
5
10
15
20

Figure 2



HP-290 GM in 100 Hz Pulsed Radiation
observed dose rate (mR/h)
true dose rate (mR/h)
0
20
40
60
80
0
100
200
300

Figure 3

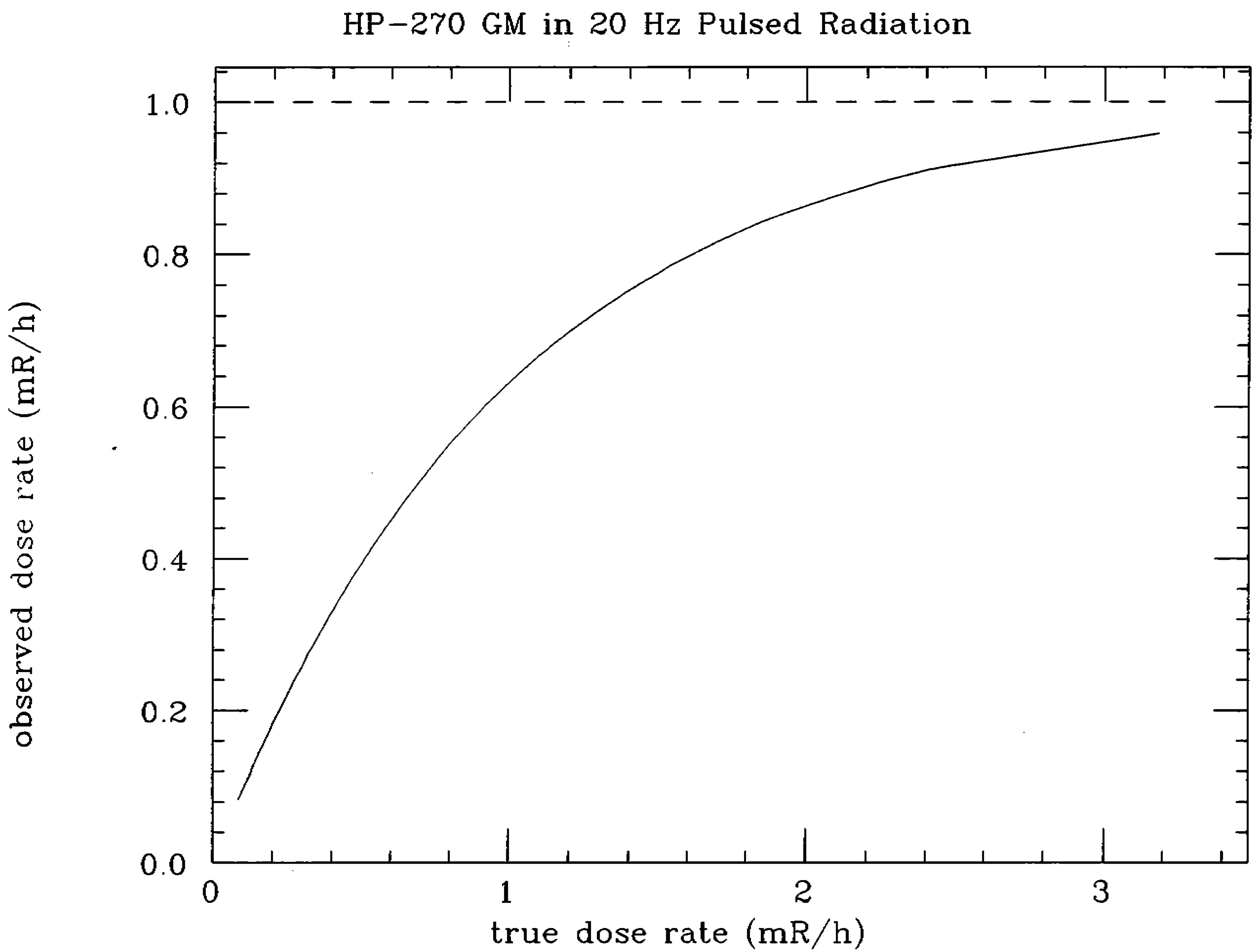

HP−270 GM in 20 Hz Pulsed Radiation
observed dose rate (mR/h)
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
true dose rate (mR/h)

Figure 4

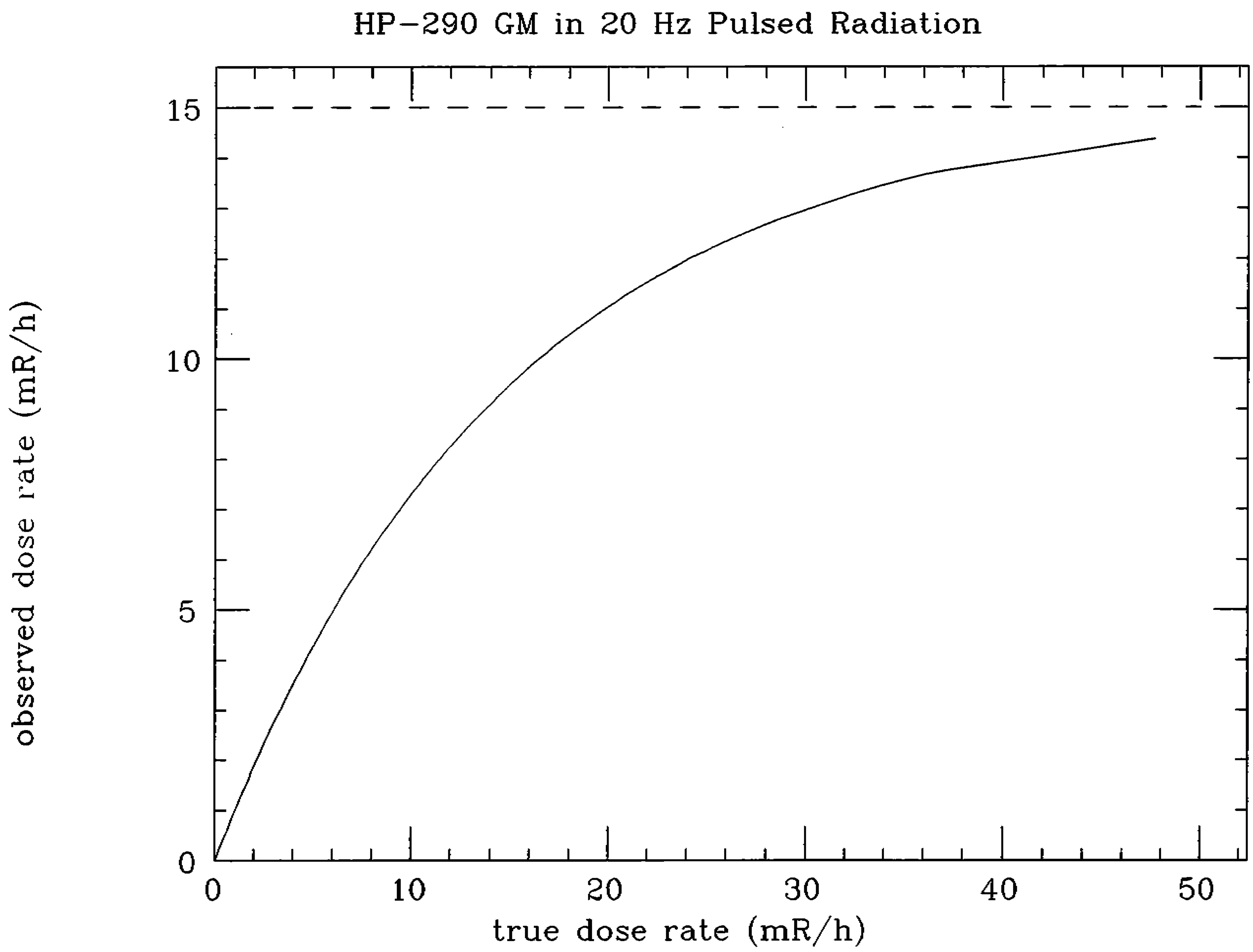

HP−290 GM in 20 Hz Pulsed Radiation
observed dose rate (mR/h)
true dose rate (mR/h)
0
5
10
15
0
10
20
30
40
50

Figure 5

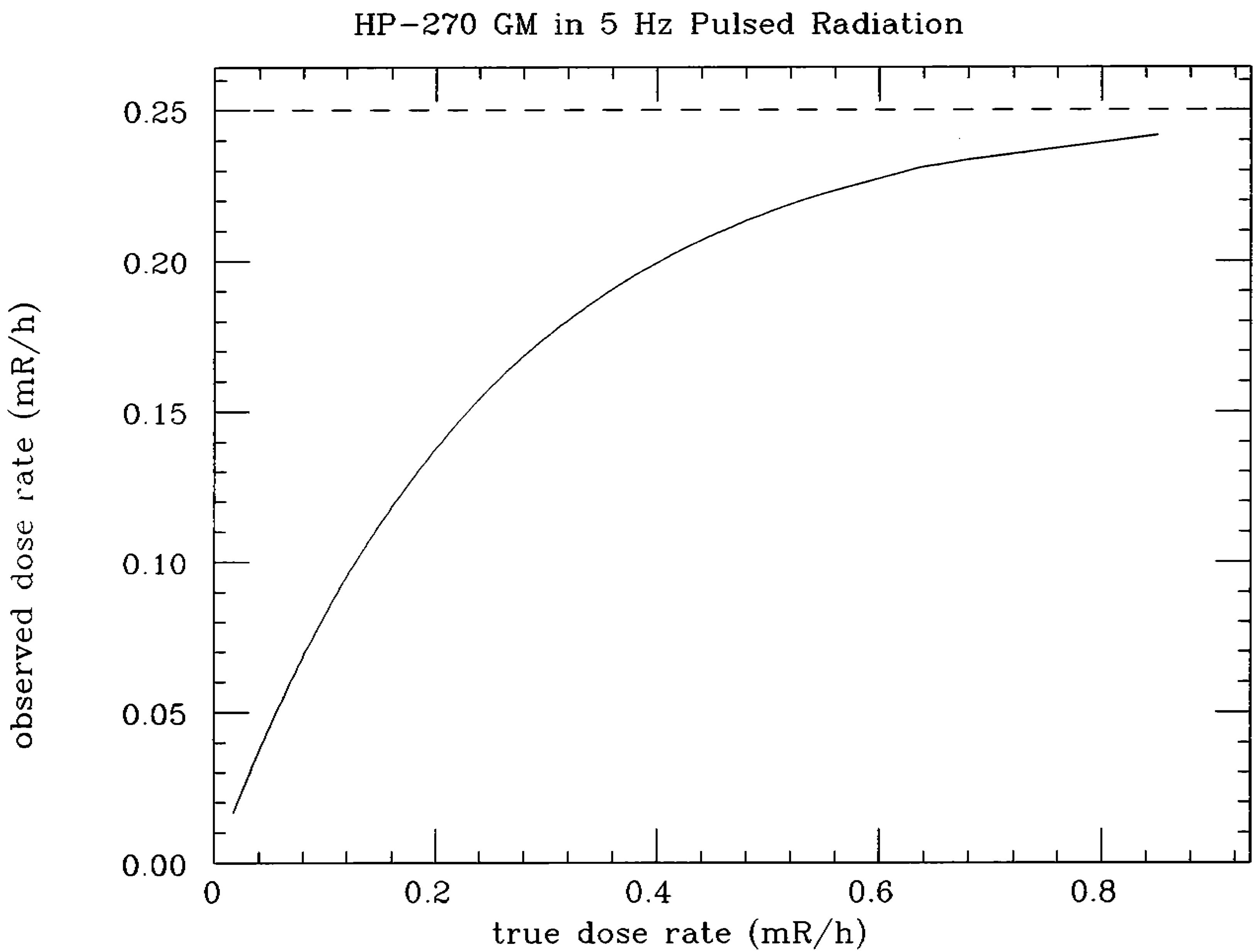
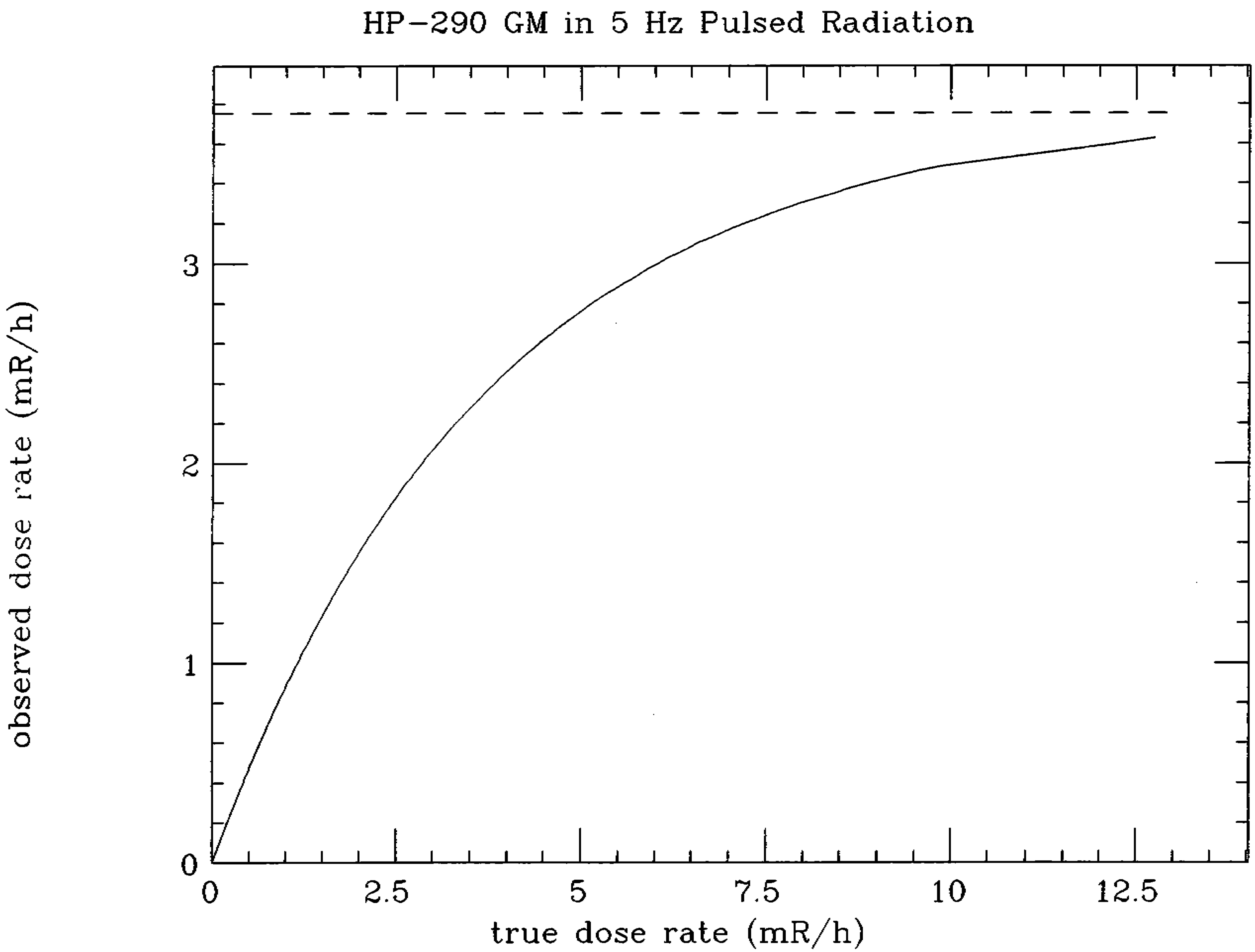

HP-270 GM in 5 Hz Pulsed Radiation
observed dose rate (mR/h)
0.00
0.05
0.10
0.15
0.20
0.25
true dose rate (mR/h)
0
0.2
0.4
0.6
0.8

Figure 6


HP-290 GM in 5 Hz Pulsed Radiation
observed dose rate (mR/h)
0
1
2
3
0
2.5
5
7.5
10
12.5
true dose rate (mR/h)