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OPERATIONAL PROBLEMS WITH RADIATION SURVEY METERS THE UNIVERSITY AND ACCELERATOR PERSPECTIVES*

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ABSTRACT

This article describes problems encountered with commercial survey meters. The desired qualities of such instruments for use around accelerators are listed. Attempts to meet the accelerator monitoring needs by modifying commercial instruments and by in-house research and development are described.

INTRODUCTION

At The Stanford Linear Accelerator Center (SLAC), health physics duties are divided between my own group, Radiation Physics, and that led by Gary Warren — Operational Health Physics and Environmental Monitoring. The Stanford Campus has its own health physics group led by Dr. Roland Finston. I gratefully acknowledge the help given to me by discussions with both of these groups while preparing this paper. The problems with instruments which are discussed in this paper, come from all three of these groups.

Current Status of Radiation Survey Meters — the unsatisfactory status that exists can be easily shown by the number of different kinds of survey meters in use. At SLAC we have at least 17 different kinds of survey meters plus a new prototype. Ten of these survey meters have some kind of limitation so that we can not trust them in the hands of untrained people. Therefore, they are used only by the Health Physics professionals and technicians. Four of these limitations are due to energy response, five of them are due to inability to measure pulsed fields accurately and one is too

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complicated to use by someone who has not studied it. Stanford University similarly has at least 20 types of survey meters on the Campus. Some of them are limited to trained users also.

This points to the present necessity of having two categories of users — those who are trained in the use of survey meters and those who are not.

DESIRED QUALITIES FOR A SURVEY METER FOR SLAC

First, a survey meter should be able to stand magnetic fields of several hundred gauss. This means there can be no reed relays inside. It also means that the instruments must not have steel cases. We have had at least one vendor's survey meter firmly stuck to the permanent magnet on the outside of one of our klystrons when he tried to demonstrate it. Second, it should not be subject to interference from RF. Third, the scale must be readable in subdued light or must be illuminated. Fourth, it has to cover a temperature range of about $-10°C$ to $60°C$. Much of our work is done outside and the meter can get at least that hot if left in the sun for a short time. Fifth, it must be rain proof. Sixth, the energy dependence must be good enough to keep unskilled users out of trouble. That does not necessarily mean that it be able to measure high energy gamma-rays and scattered x-rays from our klystrons completely accurately but if it under-estimates the dose rate from the klystrons by a factor of more than five, for example, it may cause unnecessary esposures to the users. Seventh, it has to use standard batteries. C or D cells or 9 volt transistor batteries or readily available, rechargable batteries are the only things we would accept in the future. A possible exception might be a high voltage battery for an ioniation chamber. Many of our older survey meters used types of batteries which are no longer available, and we have had to make improvisations in order to keep them in operation. Eighth, remote readout is very desirable and, ninth, the instrument must be rugged.

PROBLEMS ENCOUNTERED WITH COMMERCIAL SURVEY METERS

Some of the commercial instruments have relays to avoid switching problems especially in ion chamber instruments. In the magnetic fields we have around SLAC this simply means we never know what range we are on. Most of the survey meters are too fragile — counter windows, cables, connectors, and battery holders are all too subject to failure during use. I already mentioned problems with steel cases. Some of the new instruments use LCD displays with no lights to illuminate them. Much of our work is in areas where the light is poor and sometimes we work outside at night. Instruments without lights are completely inadequate. Some of them have inadequate temperature compensation. If you look through the manufacturers literature many of the instruments are only specified for use up to 50°C. We have measured temperatures inside cases up to 60°C if left in the sun for a while. Many of the instruments, which includes all of the G-M counter instruments, will not handle pulsed radiation. Maintenance is difficult on many of the survey meters. Most of them have no indication of high voltage operation and while they show battery condition there is no indication that high voltage for the detector is actually produced. High voltage failure is one of the most common failures. Uncommon types of batteries are problems which we have had recurrently in the past. Virtually none of the commercial instruments have remote reading capabilities. We found one survey meter with a built-in alarm that drew so much current for the alarm that it could not maintain its high voltage for the counter. If the alarm occurred while unattended, it completely drained its Ni-Cad battery even if it was line connected at the time.

MODIFICATIONS TO COMMERCIAL INSTRUMENTS

The Radiation Physics Group at SLAC has always been too small to be able to have a continuous R&D effort in radiation survey meters so much of our work has been in responding to specific urgent problems. We have made modifications to many of the commercial instruments which we use. An example is shown in Fig. 1, where we have one of the older models of Radectors. We have moved the Neher-White chamber outside of the case using a connector so that it can be located at a distance from the meter if desired. By this means, we can use the Radector with about 150 feet of cable successfully. We have made similar modifications in several other commercial instruments. The instrument mentioned above with the alarm problem, had circuit modification made to increase its charging current and an incondescent lamp replaced by a flashing LED to decrease the alarm current. Battery holders have been replaced frequently. Better cable connectors and cables have been installed and increased protection for thin counter windows provided.

RADIATION SURVEY METER DEVELOPMENTS AT SLAC

In the early days we decided we would have to build a survey meter of our own for use at SLAC since we found nothing commercial that was very satisfactory. Our first instrument was developed for us by another group at SLAC and 50 of them were made. Unfortunately, it was a very poor survey meter and since it was painted bright yellow it became known as the SLAC Lemon. These 50 instruments were all rebuilt using circuitry designed in my own group. As they were rebuilt they were painted orange to distinguish them from those which had not been rebuilt. This naturally became the SLAC Orange. This instrument shown in Figs. 2(a) and 2(b), uses an ion chamber pressurized to 60 PSIG. The lowest range is 3 mR/hr full scale and the highest range 3 R/hr full scale. It has a meter light. It has provisions for a remote meter which can operate with nearly any length of cable which we desire. This is not as good as being able to remote the instrument since one cannot change the range, remotely. The chamber is filled with ethane which gives us a reasonable neutron response and has some argon added to bring up the low energy response where the absorption of the aluminum chamber becomes significant. It weighs 4-1/2 pounds. It is quite rugged and it has mostly met the needs we have. However, the meter was a bad choice. It responds to mechanical motion and gravity too much for a portable instrument. It is also developes a tendency to stick at either end of the scale. The batteries for both the chamber voltage and for the electrometer operation became unavailable after some years and the chambers were rather expensive to build. Also the upper range was a little too low for some applications. Figure 3 shows a close up of the ion chamber and you can see how battered it has become. This one still works without any problems but we have had some that were battered even worse and became inoperable. In Fig. 4 is shown a version of this instrument which we modified to give us a higher range and also to give us a cheaper chamber that would avoid the use of the unavailable high voltage battery. This ionisation chamber is unsealed and has a thin end window. The highest range on the instrument was 30 R/hr full scale. We painted this version purple to distinguish it from the others and, of course, it became the SLAC Grape. This version has also been reasonably successful except that we had to give up our lowest range and the chamber is somewhat fragile. Overall, these two survey meters have given us very good service for a period of nearly 20 years.

We again became interested in improving our survey meters about two years ago as our original supply gradually disappeared, either having had shielding blocks dropped on them, fallen out of trucks, dropped down 35' ladders, been stolen, etc. Figures 5(a) and 5(b) show a scintillation survey meter we have developed since then. Strangely, it has not developed any kind of nickname at all. I suppose that nobody could think of a white fruit. This instrument avoids most of the problems of the past. The handle as you will probably recognize, is the handle from Black and Decker portable tools and contains rechargable nickel-cadmium batteries. This is an idea that came from Chalk River and we have been very pleased with it. The handles are cheap and easy to replace. You can keep a supply of charged handles on hand at any time. It has a good wide range from 1 mR/hr full scale to 10 R/hr full scale. The energy response is excellent. In measurements made at Battelle it was reported to have a better energy response than the Victoren 440. It was feared that the photomultiplier tube would be too sensitive to magnetic fields. It is shielded with Co-netic foil and iron pipe with a wall thickness of 0.080 inches. A 200 gauss field causes less than 10% reading error and there is a strong pull on the instrument at this field strength which gives the user a warning. This survey meter is very popular due to its light weight (2-3/4 pounds) and the small diameter of the probe.

The only problem that we have discovered is that it will not handle pulsed radiation at high enough levels before it begins to fail. The best we have been able to do so far is to get it to follow quite well up to about 500 mR/hr for 2 microseconds wide pulses. At 2 R/hr it reads about a factor of 2 too low. The scintillator that we use is Bicron air equivalent plastic scintillator which has arsenic added to the scintillator in order to bring its effective atomic number up to that of air. Like most plastic scintillators, its decay constant is in the nanosecond range. What one would really like to have is a slow scintillator that will spread 1 or 2 microsecond pulses from the accelerator out over periods of milliseconds or even a second.

Figures 6(a) and 6(b) show a new prototype ion chamber survey meter that we have built and are just now testing. We think that we have solved most of the problems that we have had in the past. there is no problem with pulsed radiation. We have found no trouble with RF radiation sensitivity. The temperature range is excellent. The battery, of course, is the same Black and Decker handle as before and the ionisation chamber is a rather simple one to make. It can be disassembled and repaired easily. It has no thin window for beta-rays but the wall is quite thin. It uses air at one atmosphere and is unsealed. The electronics is all CMOS, so battery drain is very low. For a meter light, we disassembled a disposabe flashlight and re-arranged the components. This should last the life of the instrument. The prototype weighs 3-1/4 lbs. but, if we produce it, it will be lighter. We cannibalised an old survey meter for the case and it is nearly empty. We have no operational experience yet.

I have not mentioned neutron survey meters in this talk. In general, they share all the problems of other types of survey meters and have a few special ones of their own. Their worst special problem is that a reasonable understanding of the neutron spectra and direction involved is essential for understanding the results of the measurements. We use both Andersson-Braun and Hankins type moderator-BF3 remmeters. These fall into the class of instruments to be used only by well trained personnel.

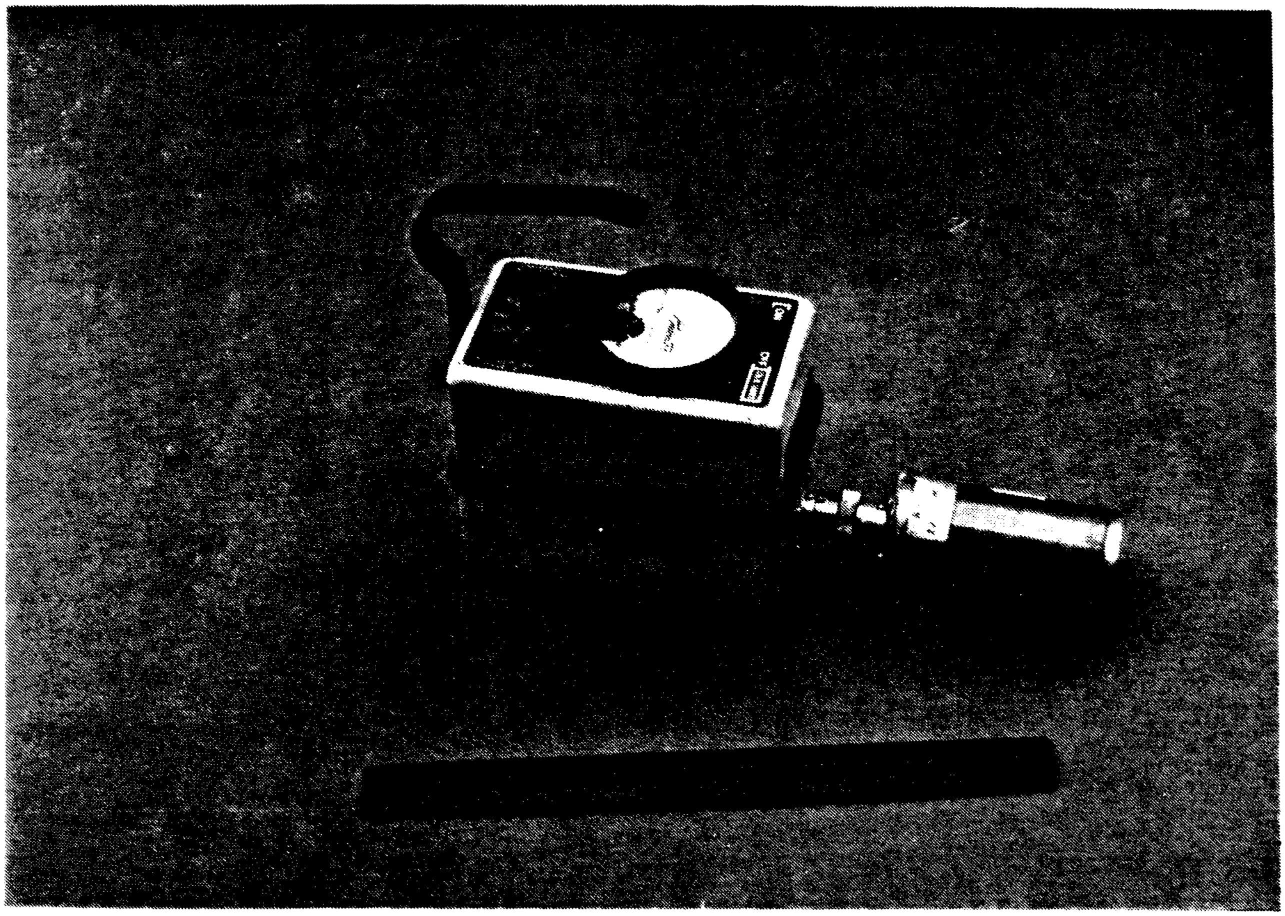
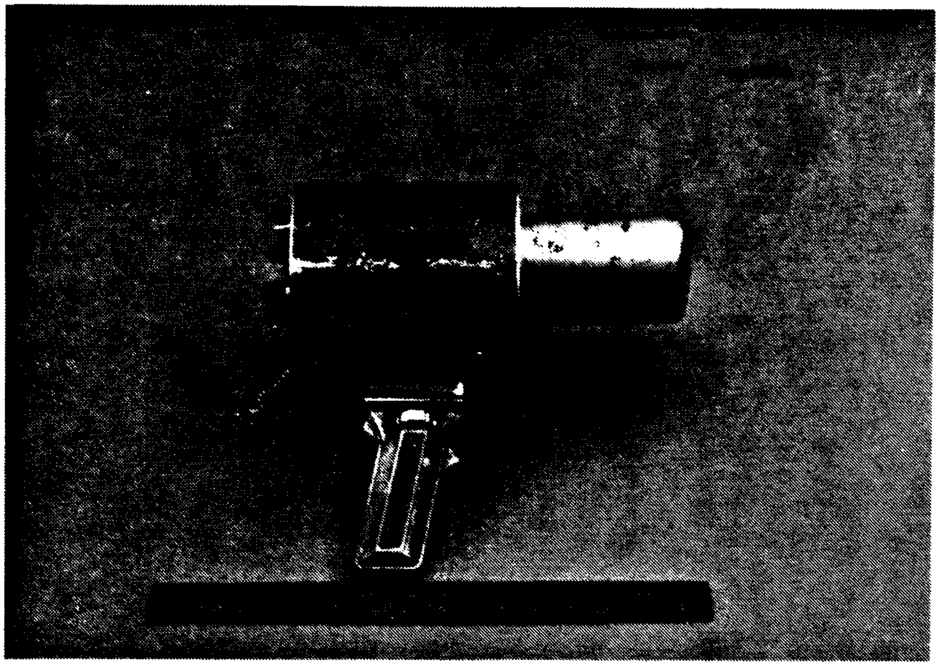


Fig. 1. A modified Victareer radector.

(a)



(b)

Fig. 2. (a) and (b) The SLAC “orange” survey meter.

Fig. 3. A survey meter ionization chamber after 18 years field use.

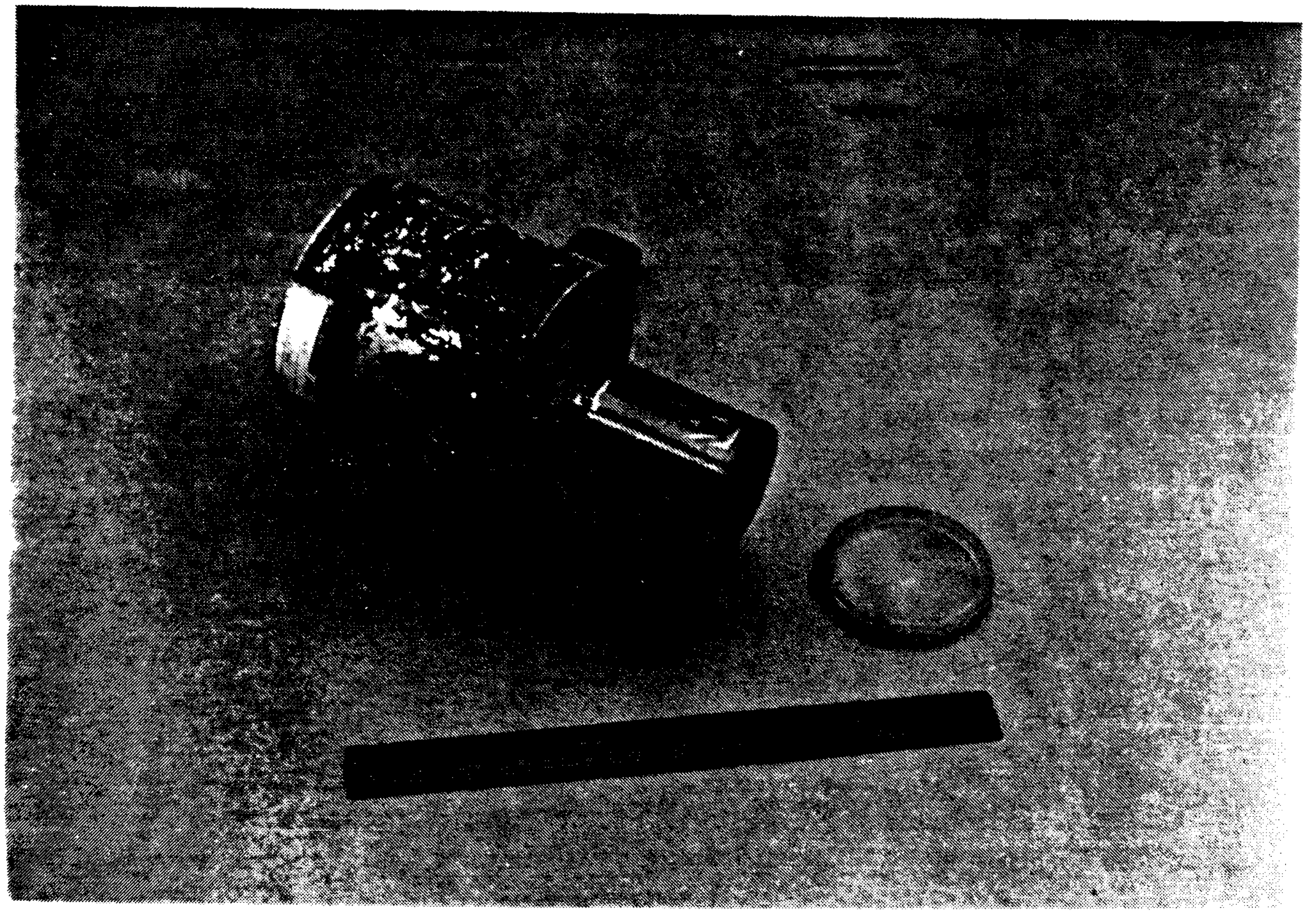


Fig. 4. The SLAC "grape" survey meter.

(a)

(b)

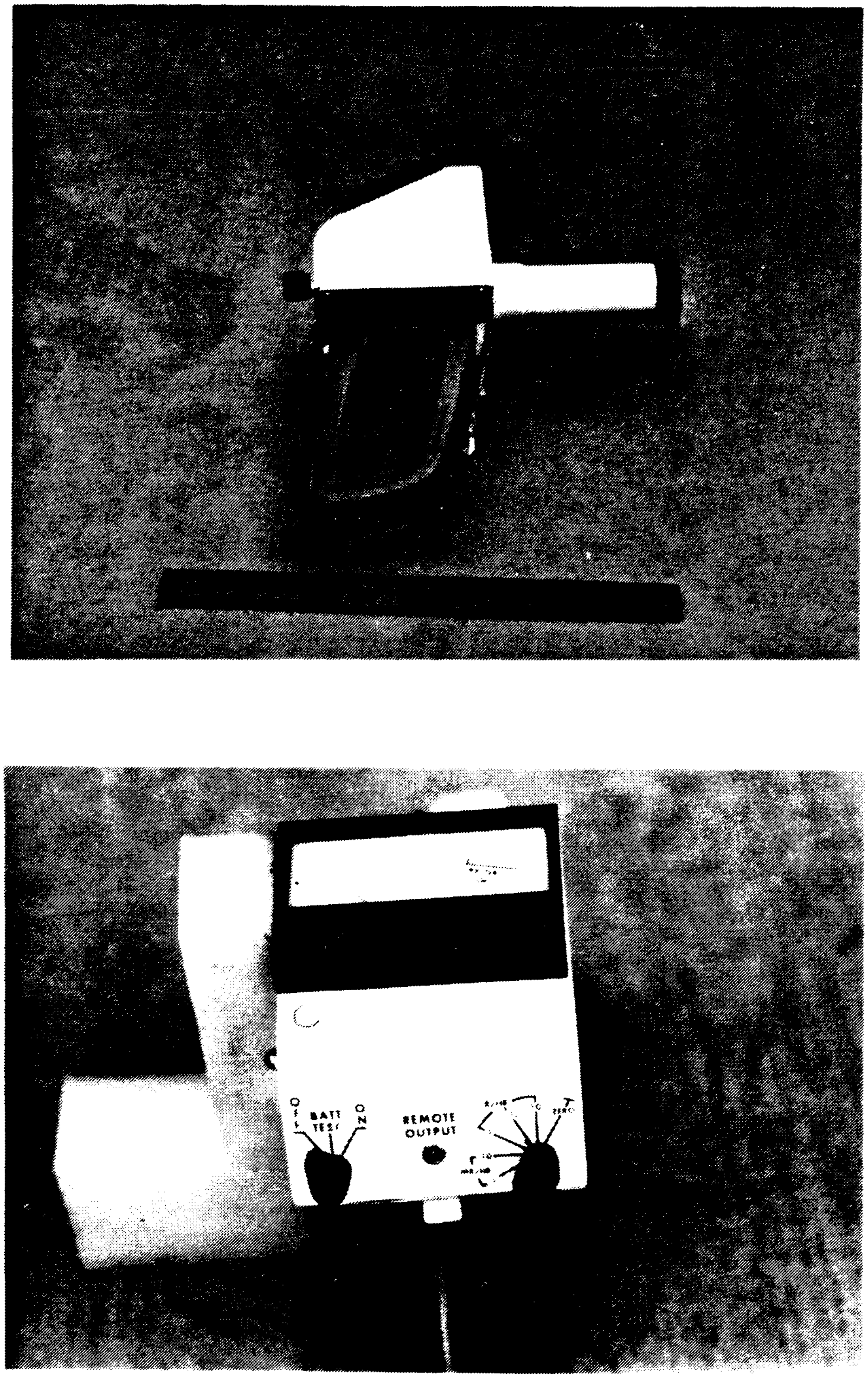
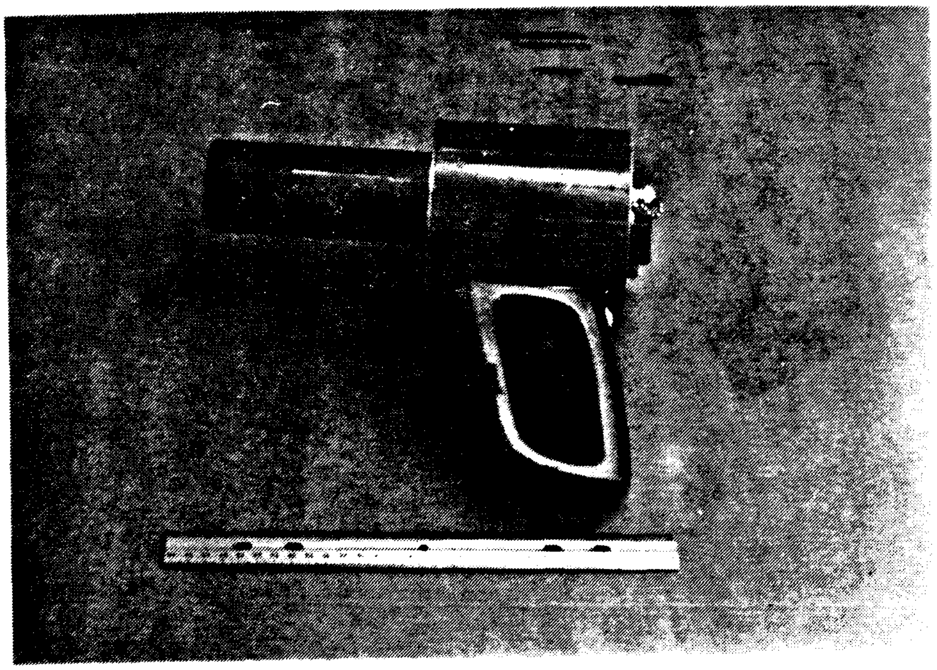


Fig. 5. (a) and (b) The SLAC scintillation survey meter.

(a)



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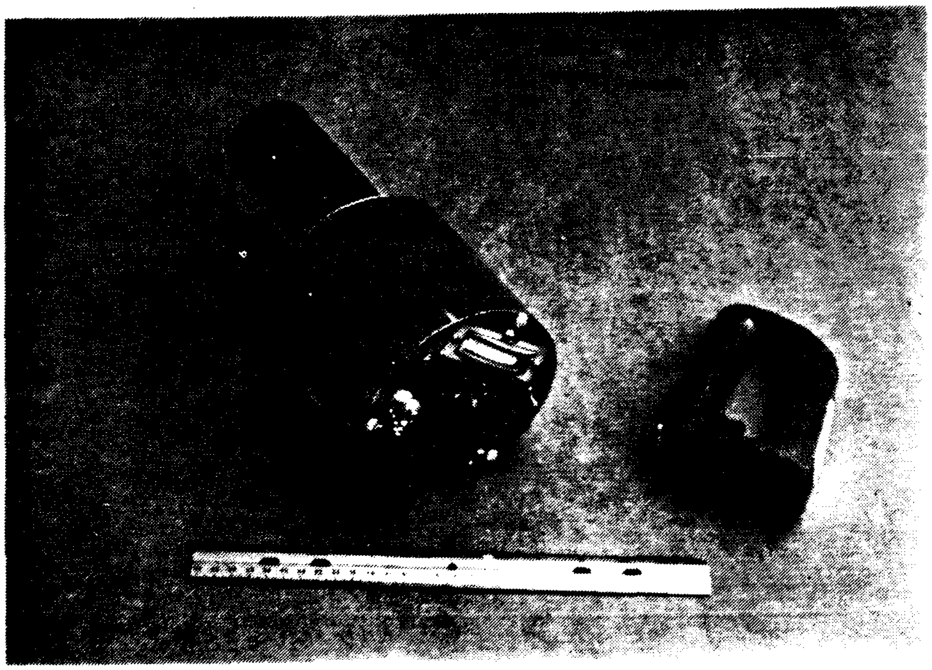

Fig. 6. (a) and (b) The SLAC prototype ionization chamber survey meter.