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MASTER

SAFEGUARDS PERSONNEL MONITOR

J. L. Martinez, G. J. Cunningham
and C. R. Forrey

Golden

THE DOW CHEMICAL COMPANY
Rocky Flats Division

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ABSTRACT

The purpose of a safeguards monitor is to prevent the accidental or intentional diversion of special nuclear materials. The monitor must have high sensitivity for the radiometric scanning of items passing through it, and must have a fast response time. The personnel monitor designed at Rocky Flats meets these requirements by using two 24-inches by 6-inches by 2-inches plastic scintillators which are sensitive to both gamma and neutron radiation. The electronics used with these plastic scintillators consist of the standard photomultiplier, preamplifier, amplifier, and single channel analyzer combination. The output pulses are fed to an averaging integrator which compares the immediate count rate observed while a person is walking past the monitoring station to a current history of the time averaged background count rate. Statistical differences between the two rates cause an alarm to be sounded. Ratemeters, scalers, or graphical plotters may be incorporated if desired to give a visual presentation of the count data. Experimentally, the monitor will respond to $^1/_{16}$th inch brass shielded source of less than 0.5 gram plutonium-239 when carried by a person running between the detectors.

BACKGROUND

The Rocky Flats Plant is an Atomic Energy Commission facility operated by the Dow Chemical Company. As part of the operations, large amounts of plutonium in various chemical forms are handled or stored routinely.

Within the past few years, increasing emphasis by the AEC and the various contractors, such as Dow, has been placed on the safeguarding of special nuclear materials to insure their not being diverted for unauthorized uses. One potential diversion route from the Rocky Flats facility obviously concerns personnel carrying plutonium from a process area past the guard checking station. It is next to impossible for complete checks to be made upon personnel by the security force, particularly at shift change times when several hundred men and women pass the guard station in a few minutes.

The consideration of these factors led to the development of the Rocky Flats Personnel Safeguards Monitor, several of which are scheduled to be installed at the guard stations associated with the plutonium process areas.

To perform its function properly, the Personnel Safeguards Monitor must meet certain design criteria. It must have fast response, or be able to detect rapid changes in the radiation observed by the detectors. It must have high geometrical efficiency for the human body to prevent blind spots. It must be able to handle large numbers of people in a short period of time. It should have high sensitivity which means that a person intent on plutonium diversion is restricted to sub-gram quantities. It should be both gamma and neutron sensitive, which makes the shielding of plutonium more difficult than the simple use of high Z materials. It should be able to compensate for variations in the normal background radiation, and it should be low in cost.

The system developed at Rocky Flats meets these requirements.

DESCRIPTION

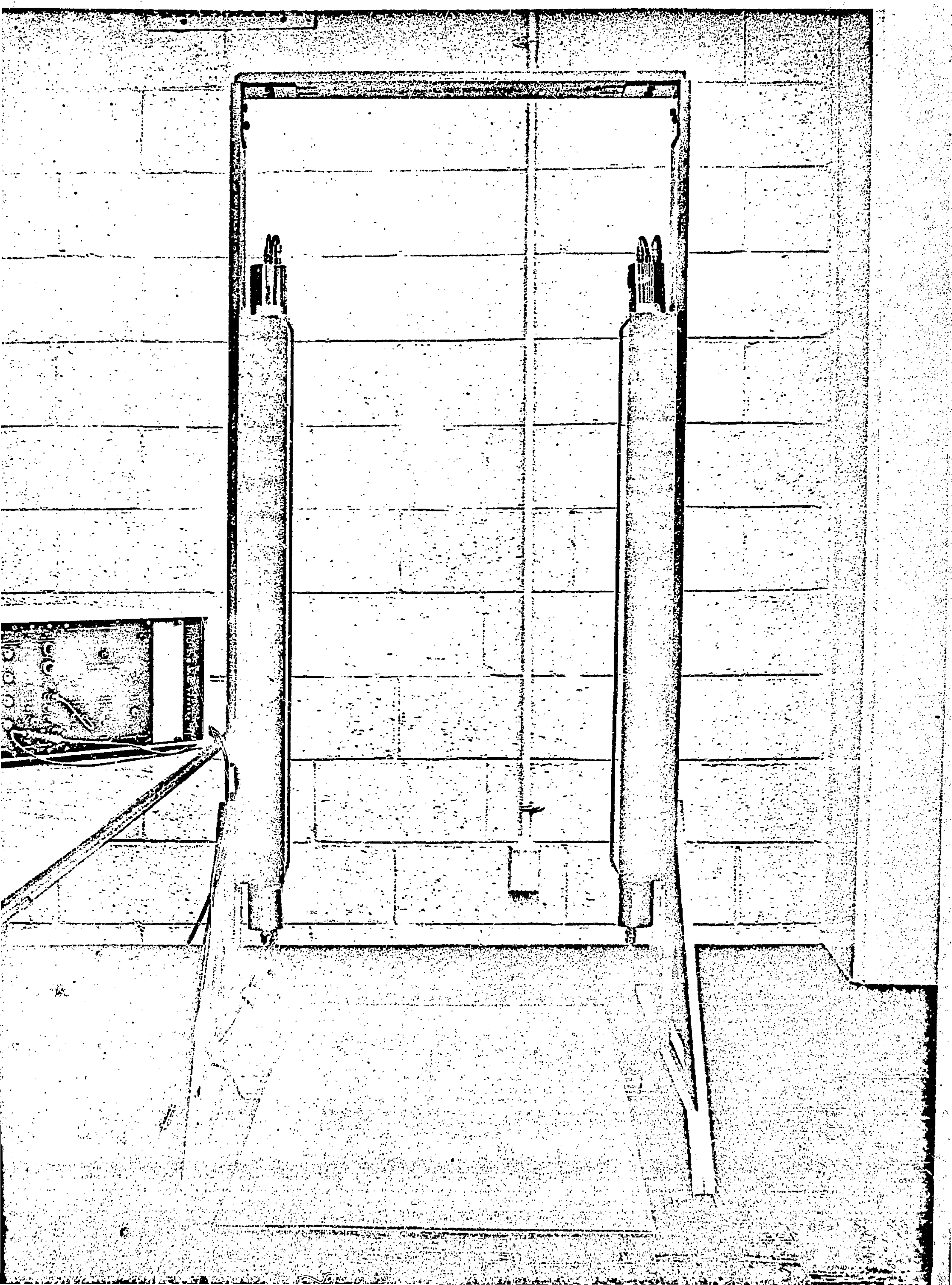
The Rocky Flats Safeguards Personnel Monitor consists of four major items (See Slide 1.): the nuclear detectors, a floor switchmat, the electronics, and the audible alarm.

The nuclear detectors consist of two slabs of plastic scintillator with dimensions of 24x6x2 inches (See Slide 2). The slabs have been machine-polished on all sides, and light pipes have been permanently attached at both ends so that two-inch diameter photomultiplier tubes may be optically coupled to the scintillator slabs. To increase the reflection coefficient on the plastic scintillator slabs, aluminized mylar was placed on their surfaces. Black electrical tape was then wrapped on top of the mylar coating to insure a light-tight assembly of the plastic scintillator and the photomultiplier tubes.

Mechanical protection to both units (photomultiplier and plastic scintillator) was afforded by enclosing the assembly in a metal box. This box was fabricated with $^1/_4$-inch aluminum sheet and steel angles to support the slabs. The ends of the metallic box which support the necks of the photomultiplier tubes were fabricated with $^5/_8$-inch thick aluminum sheet to provide additional rigidity to the entire structure. The radiation sensitive surface of the plastic slab was covered with 2024 aluminum sheet, $^1/_{32}$-inch thick. Minimum attenuation of low energy gamma from plutonium-239 was encountered from this arrangement. Notice the collar which supports the neck of the photomultiplier tube within the enclosure. This collar was spring-loaded against the ends of the metallic box so that pressure could be obtained at the point of optical coupling between the light pipe and the photomultiplier tube surface. It was found that even though the detector assembly was exposed to a certain degree of vibration, good contact between the light pipe and the photomultiplier tube was maintained.

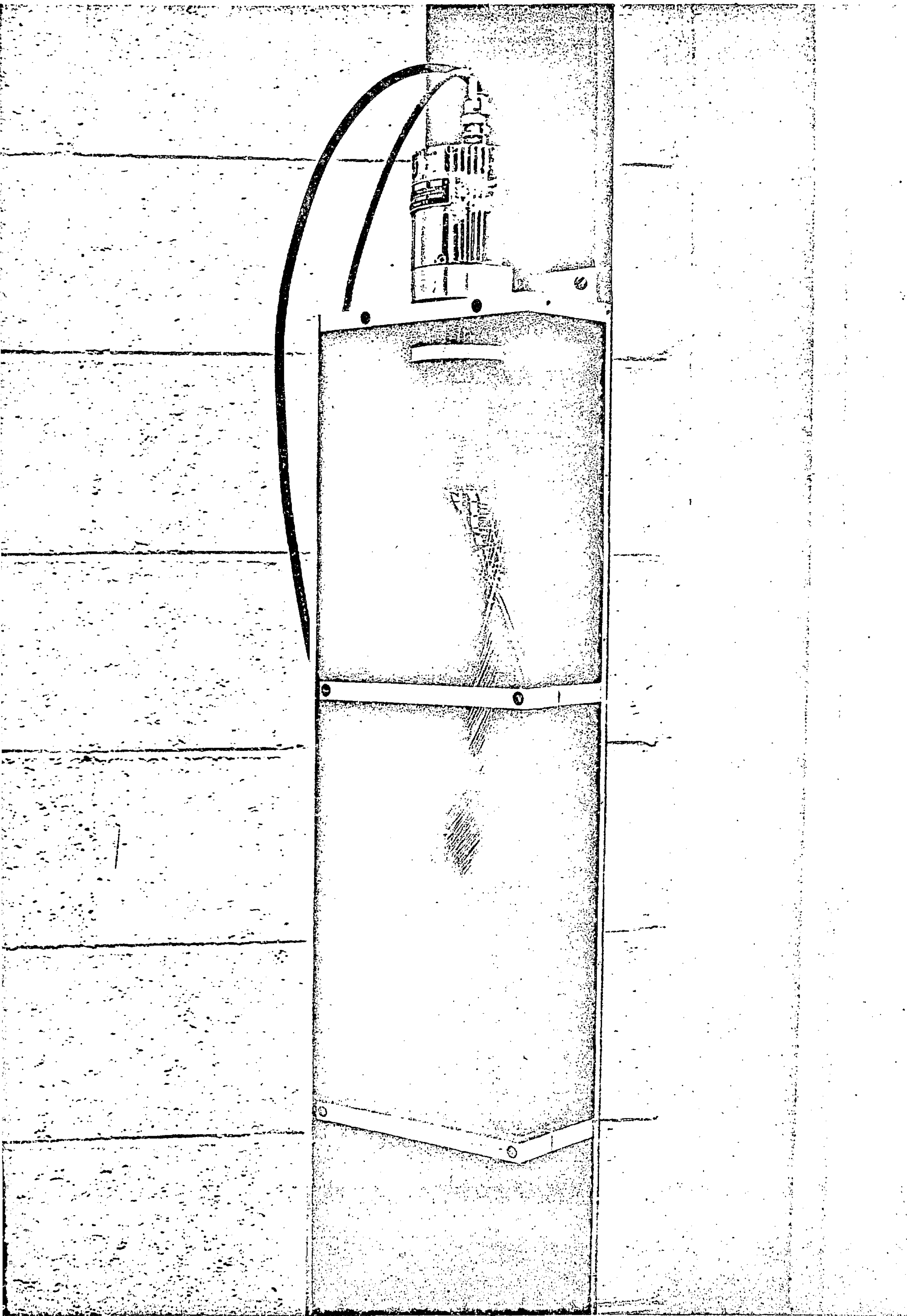
SLIDE 1.

THE LABORATORY MODEL OF THE ROCKY FLATS
PERSONNEL SAFEGUARDS MONITOR



SLIDE 2.

CONSTRUCTION OF THE
PLASTIC SCINTILLATOR HOUSING



Additional light tightness was obtained by painting all of the inner surfaces of the metallic container with a dull black paint. The detector assemblies were then mounted to the vertical boards of a simulated door frame whose width was adjustable. This adjustment permitted us to find the proper width for best sensitivity of the system in accordance with the average height and stoutness of an individual. It was found that a height of 78 inches, with 25 inches in width, fulfilled most of our requirements (See Slide 3.)

A floor switchmat, 5 feet in length, was placed with its mid-portion at the detector's location so that adequate "start" and "stop" counting periods could be obtained. This operation is essential to the proper functioning of the averaging integrator which, on a continuous basis, records the time-averaged background of the detectors until a person steps on the mat, at which time the recording of the background is stopped and a current count-rate reading is taken for a period of time lasting until the person steps off the floor mat. An immediate comparison of the stored background count and the count reading registered while the individual was walking on the mat is electronically made in the averaging integrator. If the stored background count happens to be statistically different from the count recorded when the person walked past the detectors, an audible alarm is triggered. The significance of the alarm is that the person was carrying a radioactive source. If the comparison of the readings is not statistically different, then the alarm is not energized, and the system returns to its original condition of maintaining a current time averaged background, which is to be compared with the reading obtained when another person walks past the detectors.

SLIDE 3.

SPATIAL LOCATION OF THE
DETECTORS TO AN AVERAGE PERSON

The remaining portion of the electronics is very straightforward. Light photons produced in the plastic scintillators are sensed by the photomultiplier tube and converted into electrical pulses. The pulses are amplified by the preamplifier located at the photomultiplier tube base, as shown in Slide 4, and the output signals are delivered to the input connector of a linear amplifier where additional amplification and shaping of the pulse takes place. The output signal from the linear amplifier has by now reached adequate amplitude so that it can be handled by a single channel analyzer. At this time, the incoming pulses, varying in amplitude throughout the range of the linear amplifier (0-10 volts), are selected by means of their amplitude so that all the desired pulses are accepted while the undesirable are rejected. The single channel analyzer thus enables one to select discrete energies, depending upon the radioactive material which is to be analyzed. These energies are selected by means of front panel dial settings on the single channel analyzer module.

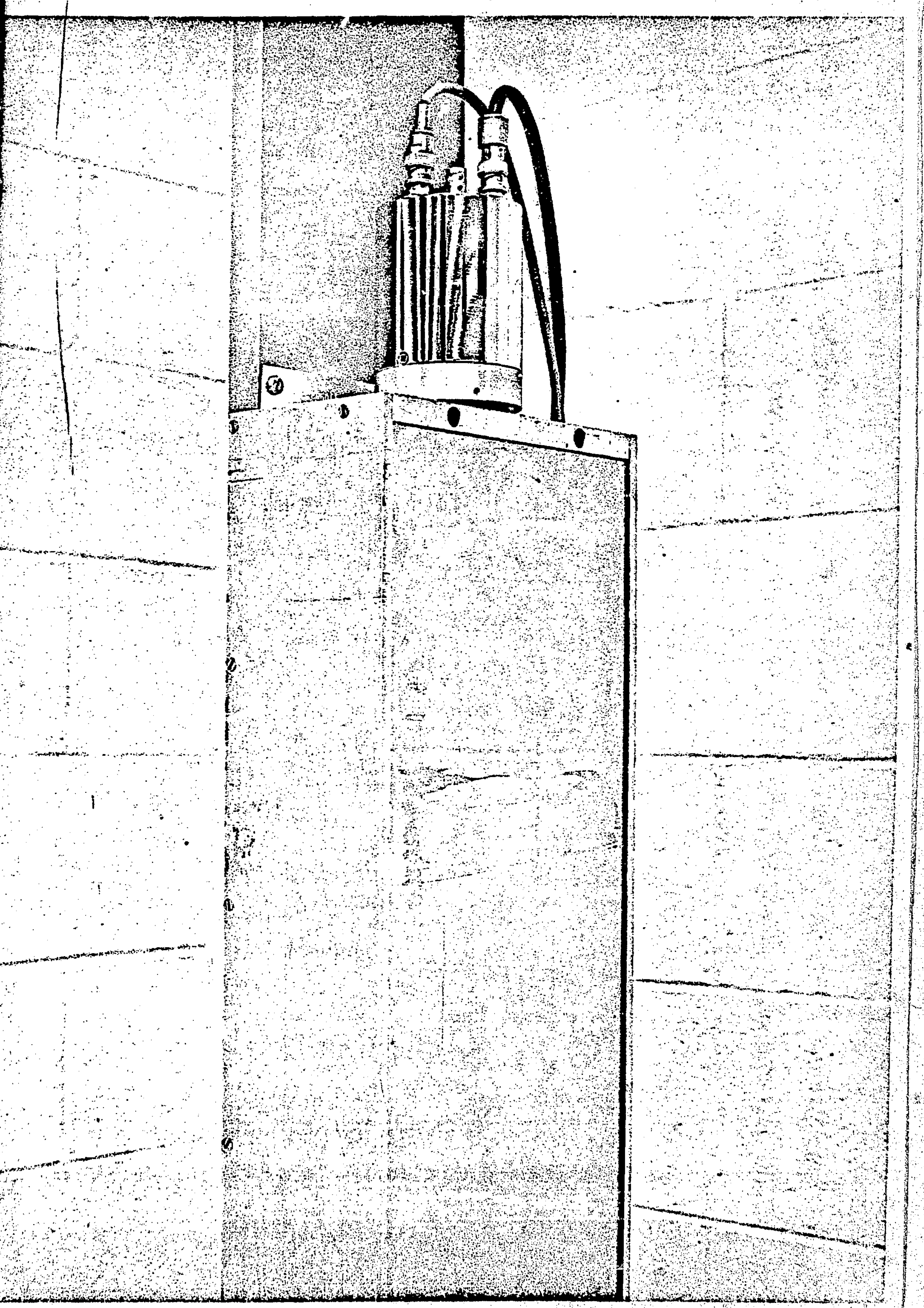
The output signal from the single channel analyzer has proper characteristics to match those of the input of the averaging integrator. These signals are usually very narrow pulses with constant amplitude and extremely high rise and decay times.

The operation of the averaging integrator is simply that of monitoring the background count, and storing this reading the moment that the switch-mat contacts are closed. The stored reading is then compared to the count rate obtained while the switchmat contacts are closed. A relay is energized whenever a statistical difference exists between the two readings compared.

SLIDE 4.

PHOTOMULTIPLIER AND PREAMPLIFIER

ATTACHMENT TO THE DETECTOR



The alarm consists of a 2,500 cycle tone which turns "ON" the moment the relay in the averaging integrator is pulled in. The sounding of the alarm the moment a person steps off the switchmap gives an indication to the guard on duty at the checking station that a radioactive source, with a count rate higher than the current background, has been sensed by the monitoring system.

The high voltage power supply used with this system is of the NIM bin modular type, and its source of power comes directly from the 115-volt AC supply. The unit has its own built-in power supply with enough regulation to provide a steady high voltage output for AC voltage variations of ± 10%. The current handling capability of this high voltage supply is 10 milliamps, which is sufficient for driving the dynode voltage divider of nearly any photomultiplier tube.

The cabinet for the electronic modules is of the NIM bin type which conforms to the standards set by the AEC. The bin includes a low voltage power supply to furnish all required voltages of ± 6 volts, ± 12 volts, and ± 24 volts DC to power all the modules used in this system.

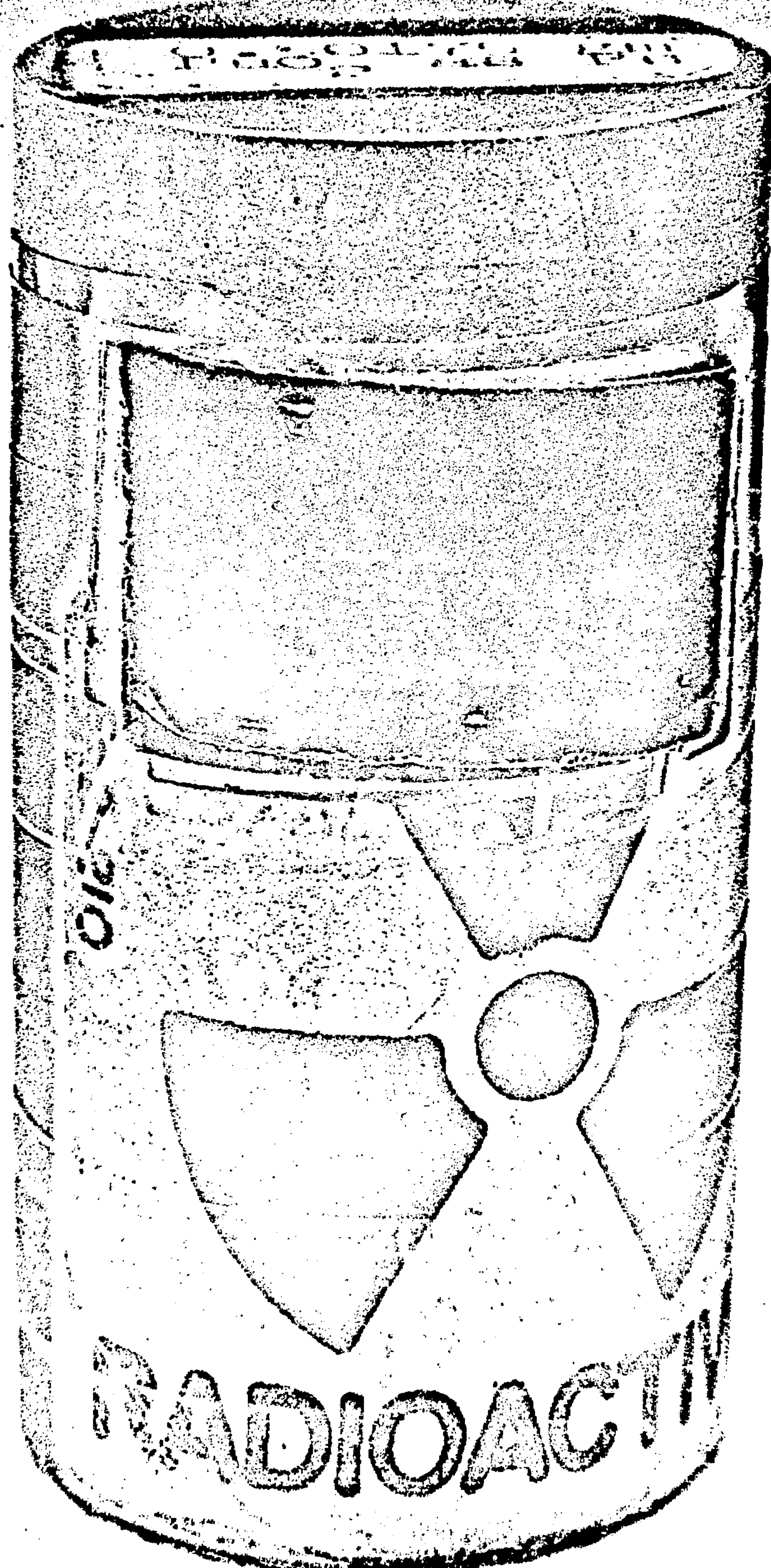
EXPERIMENTAL

To determine the low limits of detection of the system, a plutonium source containing 0.5 grams of plutonium as the oxide was used (See Slide 5.). This source consists of an inner glass vial which holds the plutonium, a second plastic vial surrounding this, and an outer brass container with $^{1}/_{16}$th-inch thick walls. This enclosure affords adequate protection for the plutonium, but does attenuate the radiation considerably.

The source was positioned in different areas within the boundary of the door frame, while one-second readings were recorded from the averaging integrator. The readings obtained were then

SLIDE 5.

THE ENCAPSULATED
PLUTONIUM SOURCE


RADIOACTI

compared with the time-averaged background counts to determine if sufficient statistical differences existed between the two sets of readings. A width distance of 25 inches between the two detectors appeared to be an optimum setting if the number of false alarms from items such as wrist watches are to be minimized.

The system just described will easily and consistently detect the 0.5 gram source thrown between the detectors. Blind spots were discovered at both the topmost part of the doorway and when the source is very near the floor.

To correct these deficiencies, the units planned for the safeguards installation will have larger plastic scintillators measuring 48-inches by 6-inches by 2-inches. It was also found that one light pipe and photomultiplier tube per detector were sufficient rather than the two originally used in the prototype model. Some loss in sensitivity is incurred, but it is not significant.

The total hardware cost for the monitor is less than $10,000 which makes the unit feasible for multiple installation in these days of the dollar shortage.