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Berkeley, California

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University of California, Berkeley, California

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ABSTRACT

A simple and inexpensive radiation detection device has been constructed sensitive to gamma fluxes in the range from a few to a few hundred roentgen per hour. Thus one can distinguish between dangerous and relatively safe radiation levels such as one might expect from radiological warfare, low level atomic blasts, or from "rigged" hydrogen bomb explosions.

The device consists of two cadmium tungstate crystals in a light tight container which can be held close to one eye to exclude external light. A radium activated phosphorescent material is included for light intensity comparison purposes. The thicker crystal can be discerned in a gamma radiation of a few R/hr, and its light output matches that of the fluorescent material at levels of 20 to 30 R/hr. The light from the thinner crystal matches that of the phosphorescent material at about 100 R/hr.

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* Now at the Chromatic Television Laboratories, Oakland, California.

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INTRODUCTION

The purpose of this investigation was to develop a device suitable for the qualitative analysis of radiation fields such as would result from atomic warfare. For optimum usefulness it should be small, simple, reliable, rugged, inexpensive, and contain no parts likely to break or wear out. The postwar deterioration of international relations and the development of atomic weapons by governments other than our own has unfortunately made the need for such an instrument both urgent and universal.

The device was designed to indicate the level of gamma radiation, to the exclusion of beta rays, although this is not a fundamental limitation of the system. The reason for this choice is that, "In considering the radioactivity of . . . fission products, the gamma radiation is of the greatest significance, since its penetrating power is very much larger than that of the beta particles"* and "The total energy of the beta particles produced in fission is . . . similar in magnitude to that of the gamma radiation. However, because the beta particles do not penetrate to such great distances as do the gamma rays, the energy of the former would, as a general rule, only be of significance in borderline cases."**

One of the first means of detecting radiation was the scintillation method, where particles incident on a zinc sulfide screen gave off visible light flashes. This principle of conversion of non-visible radiation into visible light in a suitable material was selected as the most promising approach. A numer of different materials were investigated and further studies made on the most promising.

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* The Effects of Atomic Weapons, U. S. Government Printing Office, June, 1950, par. 8.10.

** Ibid. par. 8.13.

GAMMA ACTIVATED MATERIAL

The key to this approach to the problem of a simple inexpensive gamma detection device is the selection of the proper indicating material. Ideally, its properties should include the following:

A. Sensitivity to suitable levels of radiation.
B. Availability in sufficient quantities for widespread use.
C. Stability under normal extremes of temperature, moisture and handling.
D. Inexpensiveness.

A variety of crystals and powders were tested, using a gram of radium as a radiation source. Among these were zinc sulfide powder, cadmium tungstate, x-ray screen, sodium iodide crystal and powder, anthrecene, thallium activated sodium iodide crystal, and calcium and cadmium tungstate crystals. Of these, only the latter three gave off sufficient visible light at low radiation intensities. Since the sodium iodide crystal was hygroscopic, efforts were made to "pot" it in a transparent thermo-setting plastic but they were unsuccessful. Hence, attention was concentrated on the two tungstate crystals.

Two types of tests were conducted - one for quantitative data using an RCA 931-A photomultiplier tube, the other involving visual examination of the crystals. In the tests using the photomultiplier tube, an aperture adjacent to the tube shielded all but a known area of each crystal, so that the area examined was identical in all tests. Tests were conducted at a fixed high d. c. voltage, the tube current being recorded as a function of the radiation intensity. Although calcium tungstate gave a higher photomulitplier current reading than cadmium tungstate, visual inspection showed that the cadmium tungstate gave off more visible light under identical circumstances. (See Fig. 1.) This apparent discrepancy is ascribed to the fact that the calcium crystals more nearly match the response of the multiplier tube, whereas the cadmium corresponds more nearly to the eye sensitivity. Thus most of the tests were performed using cadmium tungstate crystals.

The multiplier was also checked at various radiation levels with the aperture masked and no crystal present, to ensure that the tube itself was not overly sensitive to variations in incident gamma energy.

Fig. 2 shows the variation of light output vs. roentgen/hr. for several gamma energies.

As would be expected, the sources with lower energy gamma radiation give more light since more of their energy is lost in the crystal and converted into visible light. The sources used were radium with about 1.8 Mev gamma, cobalt^{60} with 1.1 and 1.2 Mev gamma, and I^{131} with 0.38 Mev gamma. "The mean energy of the gamma rays from . . . . fission products is 0.7 Mev."*

EFFECT OF VARIATIONS IN CRYSTAL THICKNESS

Fig. 3 shows the variation in light output as a function of R/hr for a number of thicknesses of crystal. The apparent saturation effect for thick material may be due to the fact that the thickest sample was round, not flat like the others, and to light absorption in the crystal itself.

A paste made up of ground up crystal pieces in a suitable binder, and painted on a backing material, gave a light output similar to that of the thinnest crystal tested.

EFFECT OF BACKING MATERIAL

The material backing up the crystals was varied to determine its effect on the light output. These tests were run using both cloudy and clear crystals. Surprisingly enough, the cloudy crystals not only gave out more light, but were also more sensitive to the backing material. Fig. 4 shows this effect. From this it appears that the light output can be almost doubled by proper selection of a background material. The two crystals were analyzed in an emission spectrometer, but there was no apparent difference to account for the cloudiness in one of the two crystals.

FLUORESCENT MATERIAL

In order to obtain a means of calibration and also to reduce as much as possible the effects of the dark adaptability of the human eye, it was decided to incorporate a suitable phosphorescent material in the design. The requirements were that it be self excited at the proper illumination level, stable, inexpensive, easy to apply, and relatively insensitive to incident light and gamma radiation.

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* Op. cit. par. 8.11.

Most materials tested were satisfactory except for the slow decay after exposure to light. The most satisfactory phosphorescent material found was a modified Undark vivid green No. 80M, manufactured by the U.S. Radium Corporation. Its light decay and gamma sensitive properties are portrayed in Fig. 5. In about 1/2 minute after exposure to light it is down essentially to its normal level. It is not activated seriously by exposure to gamma radiation of the intensities of interest.

EFFECT OF BETA PARTICLES ON CRYSTALS

The crystals were checked with two sources giving off beta radiation, I^{131} with a 0.6 (max.) Mev beta and P^{32} with a 1.7 (max.) Mev beta. Since there were two layers of masking tape covering the crystal to prevent light leakage into the multiplier tube, it is believed that very little of the 0.6 Mev beta from the I^{131} penetrated to the crystal. On the other hand, the P^{32} source gave off a much more energetic beta radiation (and no gamma), falling off rapidly with distance due to the absorption in air, but giving up more energy to the crystal when incident upon it. A higher intensity beta source would be needed to extend this study.

LAYOUT OF CRYSTAL ASSEMBLY

Figure 6 shows crystal assemblies which have been used. Many arrangements are possible, including designs with five to ten crystals of varying sensitivity arranged adjacent to a calibrating light source.

It was found desirable to cover the crystal and fluorescent material array with a suitably holed diaphragm to give sharply defined limits to each light source, and to impose a shield between adjacent light sources to prevent any light leakage underneath the diaphragm.

HOLDER DESIGN

The holder has several functions to fulfill. Primarily, it must form a light, tight, shield, shaped at one end to fit the eye, and must support the crystal assembly at an appropriate distance from the eye. Secondarily, it would serve as a carrying case, and protect the detection equipment. In addition, it could be constructed to allow or prevent penetration of beta particles. Figures 7 and 8 show two types of holders, using small glass (or plastic) lens to bring the sensitive elements into focus. Some holders were made about 2-1/2 inches long, without a lens. While this is too short a distance for the eye to give a sharp focus, the light output from the sensitive elements was still readily visible.

OPERATION

In normal use, the instrument is held tightly against one eye, with the other eye closed. If the fluorescent material is exposed to an external light source just before use, it will be quite bright, decaying at approximately the rate at which one's eye becomes dark adapted, so that in about 1/2 minute both instrument and operator are ready to function. To determine the approximate radiation field intensity one would note the number of crystals giving off light, and the intensity of the crystal light relative to the fluorescent standard. For instance, in a unit with two crystals, the most sensitive could begin to fluoresce at a few roentgen per hour and match the intensity of the calibrating source at 20 or 30 R/hr., while the second crystal could "appear" at about 50 R/hr. and "match" at about 100 R/hr. An even simpler usage would require one to know merely that one light spot (the fluorescent standard) indicated an uncontaminated or relatively "safe" area; two spots a "contaminated" area where one could remain for a brief period; and three spots, a dangerous, highly contaminated area which should be left immediately. Resulting dosages could be extremely high based on laboratory standards, but are realistic from a military or civilian defense standpoint, based on a 100R MSD* for a short term accumulated dose.

Preliminary and entirely unofficial field tests of sample instruments at the AEC's Nevada Proving Grounds were very encouraging. Test units, in the hands of untrained nonscientific personnel readily detected the presence of radiation fields less than 10 R/hr. in broad daylight.

CONCLUSION

A portable radiation detector has been developed which operates at the levels of interest in case of radiological warfare. It is pocket-size, lightweight, simple, stable, self-contained, convenient and easy to use. Its adaptability to mass production should make it inexpensive and easy to make.

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* Median sickness dose, i.e., one-half those so afflicted become sick.

It is expected that this detector will find its main application as a warning device and preliminary survey instrument, with widespread distribution to operational echelons of military and civilian defense personnel, and to interested civilians.

ACKNOWLEDGMENTS

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Hofstadter and McIntyre, Phys. Rev. 78, 617, (1950).

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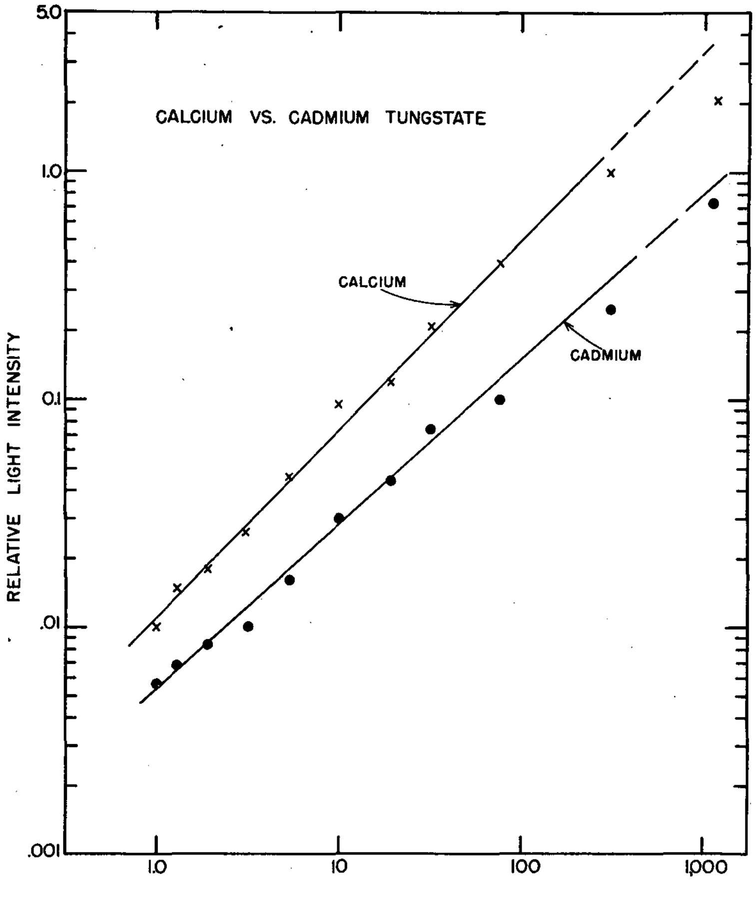
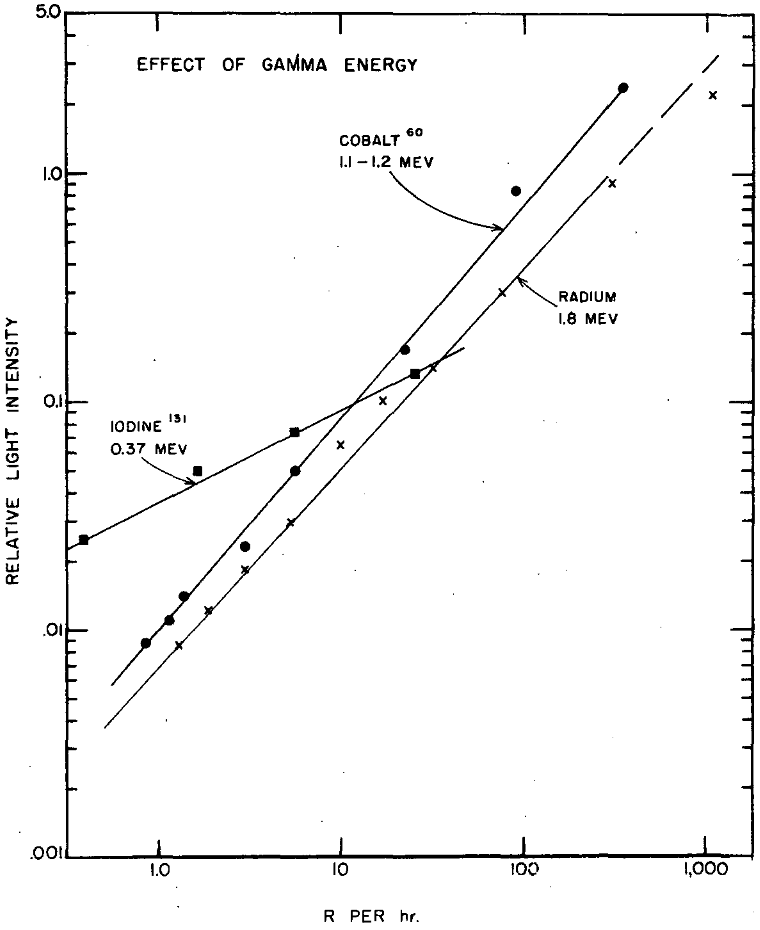

CALCIUM VS. CADMIUM TUNGSTATE
CALCIUM
CADMIUM
RELATIVE LIGHT INTENSITY
5.0
1.0
0.1
.01
.001
1.0
10
100
1,000
R PER hr.

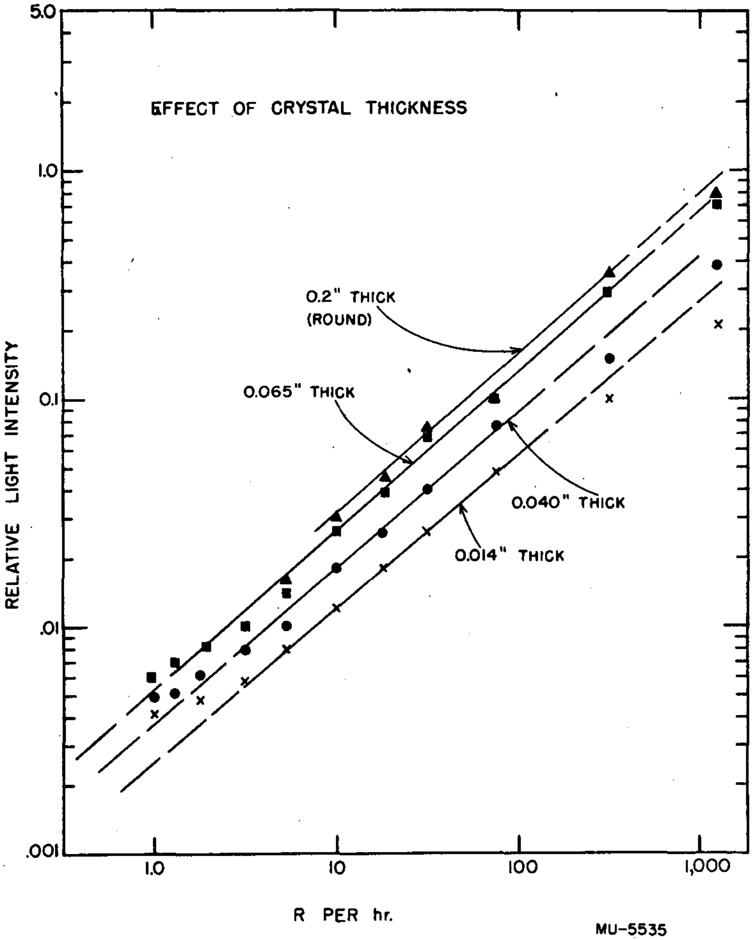
MU-5533

FIG. 1


EFFECT OF GAMMA ENERGY
COBALT ^{60}
1.1 – 1.2 MEV
RADIUM
1.8 MEV
IODINE ^{131}
0.37 MEV
RELATIVE LIGHT INTENSITY
R PER hr.
5.0
1.0
0.1
.01
.001
1.0
10
100
1,000

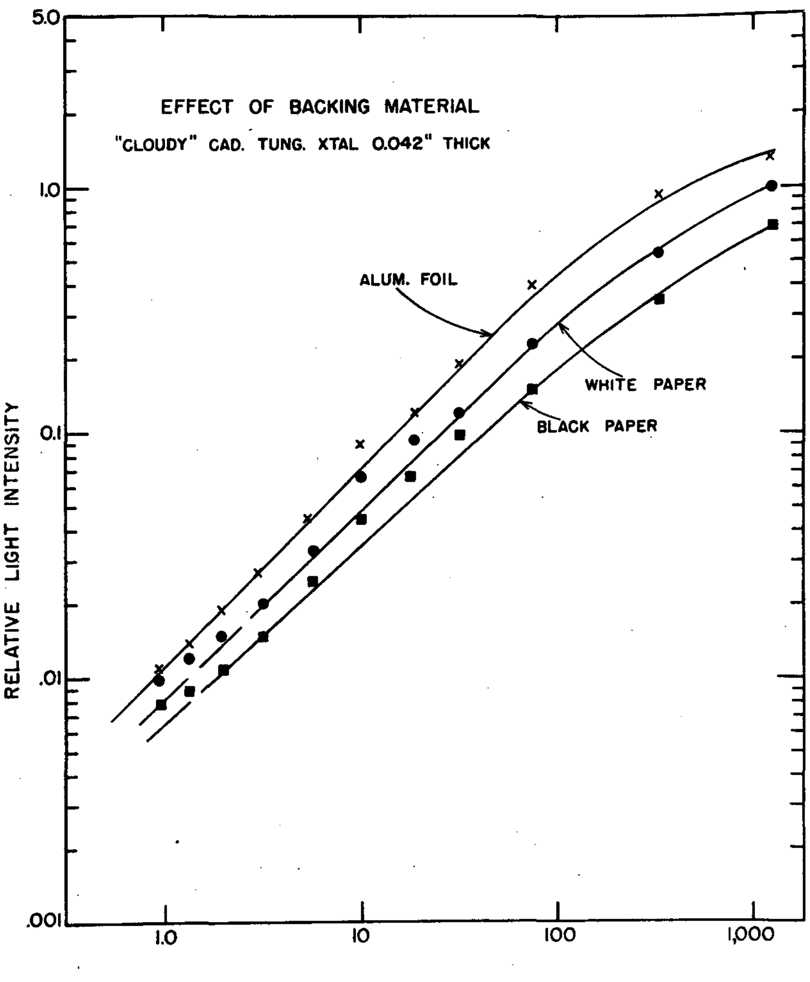
MU-5534

FIG. 2


EFFECT OF CRYSTAL THICKNESS
5.0
1.0
0.1
.01
.001
RELATIVE LIGHT INTENSITY
1.0
10
100
1,000
R PER hr.
0.2" THICK (ROUND)
0.065" THICK
0.040" THICK
0.014" THICK

MU-5535

FIG. 3


EFFECT OF BACKING MATERIAL
"CLOUDY" CAD. TUNG. XTAL 0.042" THICK
ALUM. FOIL
WHITE PAPER
BLACK PAPER
RELATIVE LIGHT INTENSITY
5.0
1.0
0.1
.01
.001
1.0
10
100
1,000
R PER hr.

MU-5536

FIG. 4

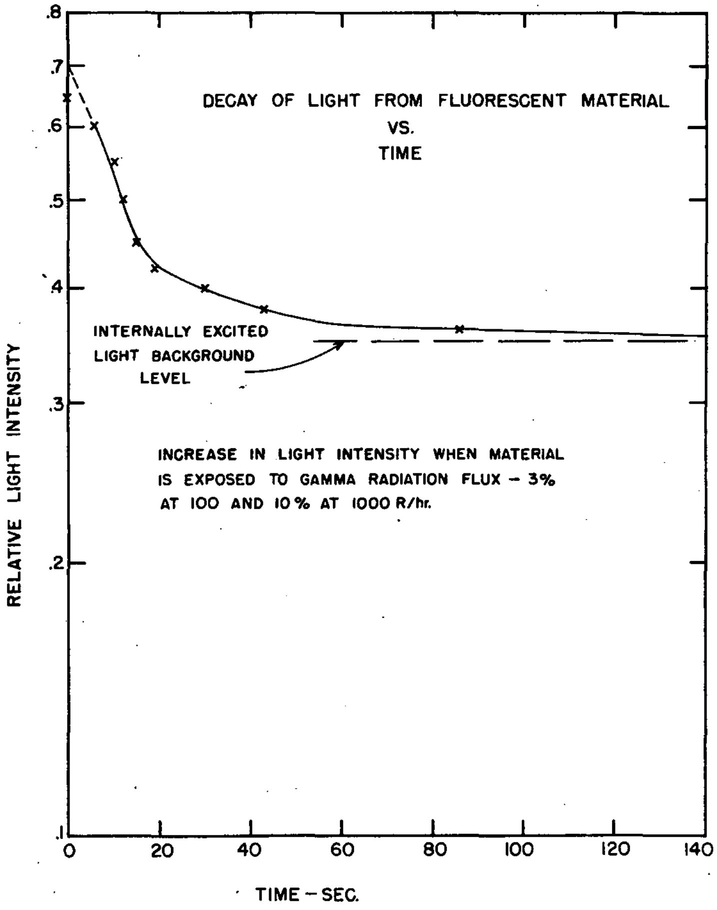
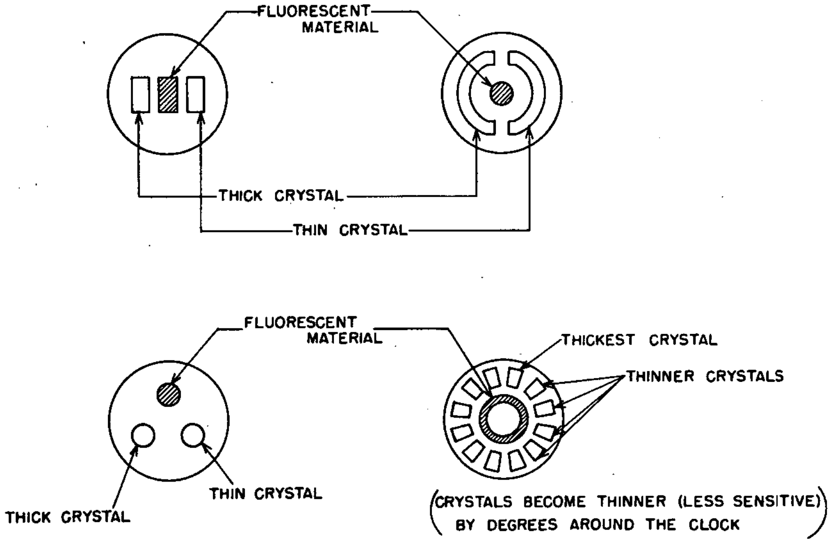

DECAY OF LIGHT FROM FLUORESCENT MATERIAL
VS.
TIME
INTERNALLY EXCITED
LIGHT BACKGROUND
LEVEL
INCREASE IN LIGHT INTENSITY WHEN MATERIAL
IS EXPOSED TO GAMMA RADIATION FLUX – 3%
AT 100 AND 10% AT 1000 R/hr.
RELATIVE LIGHT INTENSITY
.8
.7
.6
.5
.4
.3
.2
.1
0
20
40
60
80
100
120
140
TIME – SEC.

FIG. 5

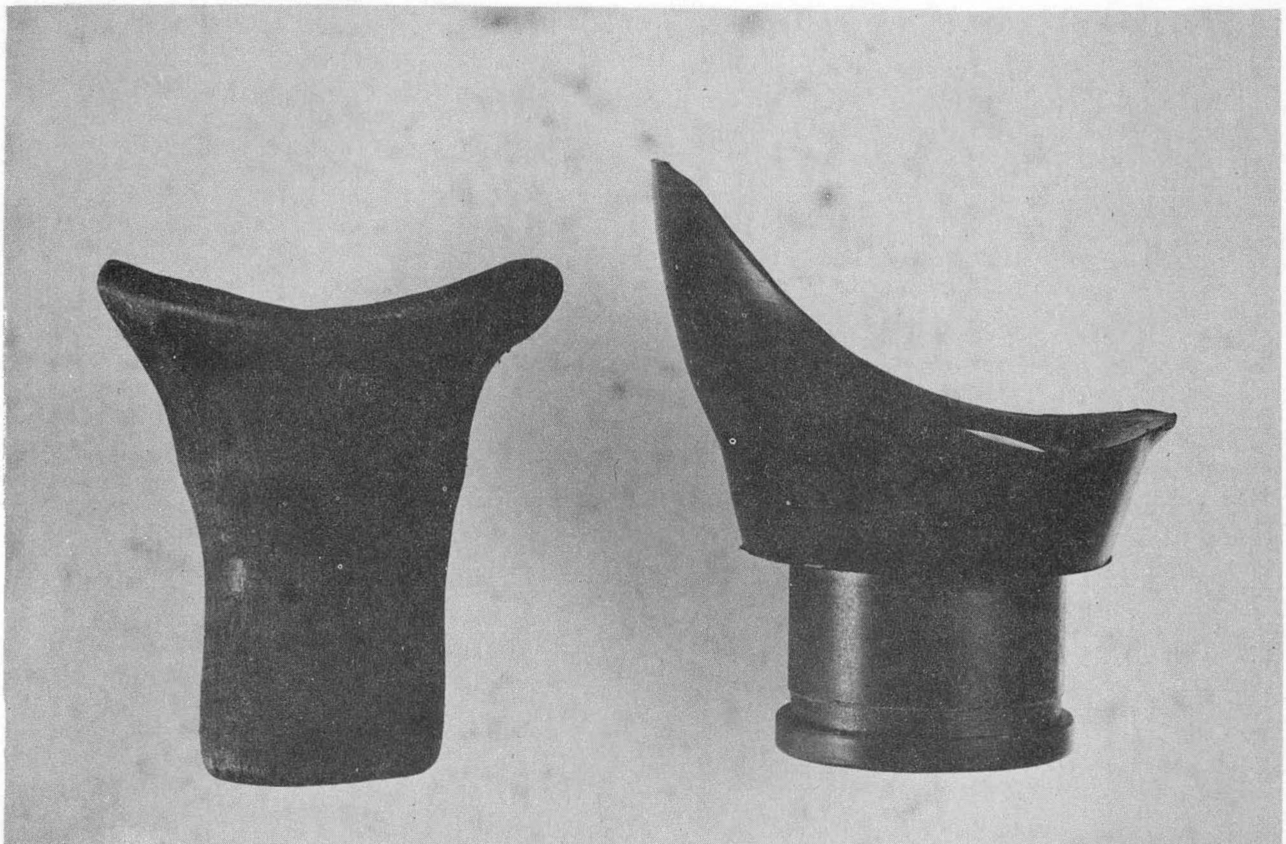
MU-5537



TYPICAL ARRANGEMENTS OF SENSITIVE ELEMENTS

MU-5550

Fig. 6



ZN-629

Fig. 7

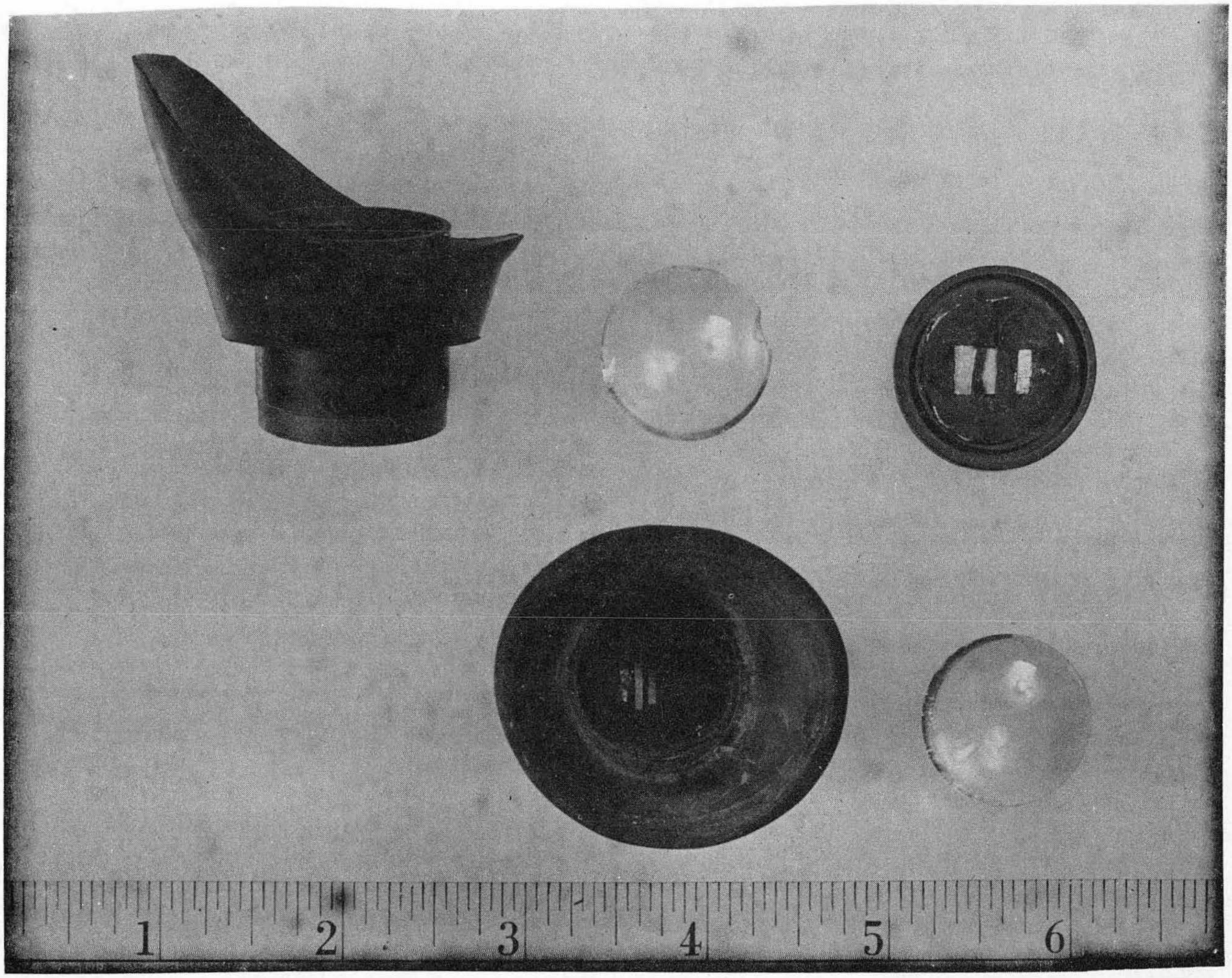


Fig. 8