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GAMMA DETECTING-INDICATING SYSTEM, AN/GKQ-4

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AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico

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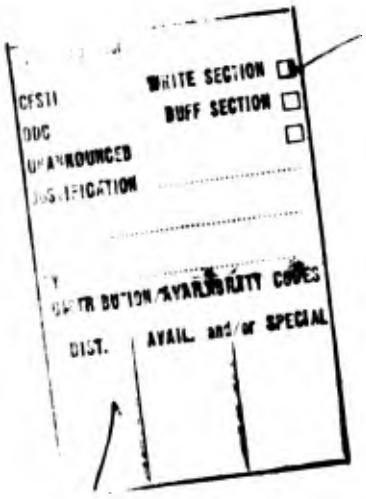

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FOREWORD

This report was prepared under Project Element 6.24.05.06.F, Project 1831, Task 183110. The instrument reported on was developed by Tracerlab, Inc., Richmond, California, under Contract AF 29(601)-5995.

Inclusive dates of research were 18 April 1963 to 15 June 1967. The report was submitted 28 February 1968 by the Air Force Weapons Laboratory Project Officer, Lt Paul A. Zielie (WLRB).

This technical report has been reviewed and is approved.

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ABSTRACT

(Distribution Limitation Statement No. 1)

This is a preliminary report describing the capabilities and operation of a prototype, wide-area, remote fallout monitor developed by the United States Air Force. This system is capable of detecting gamma intensities in a range of from 0.01 to 5000 R/hr, at up to 10 remote detecting locations, and transmitting this information by hard-line or radio telemetry to a single central location. The central station displays dose-rate information on individual meters and a single-strip chart recorder. An audio and visual alarm is given when a pre-set dose rate is reached. The system is able to operate on either 117 Vac, 60 Hz, or self-contained, rechargeable battery power in case of power failure. The final report will contain information concerning the development, design, and fabrication of this system.

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SECTION I

INTRODUCTION

To perform effectively in a nuclear radiation environment, critical installations should be provided with wide area fallout monitoring systems. Detectors should be strategically located around an installation with the information from these detectors being fed to one central point. From this central station, the installation commander can control stay times of personnel who must work in hazardous areas, plan evacuation routes, and resume normal operations when safe radiation levels are reached.

A prototype system of this type has been developed by the United States Air Force. This system, designated the AN/GKQ-4 Gamma Detecting-Indicating System, consists of one central station and up to 10 field stations.

SECTION II

GENERAL DESCRIPTION

The overall system is capable of detecting gamma radiation intensities in the range of from 0.01 to 5000 R/hr, displaying this information on a meter and recorder, and initiating an alarm when a pre-set radiation level is reached. The type of detector used is an ionization chamber filled with argon at 1 atmosphere pressure. The response of this chamber is essentially equal for all gamma rays in the energy range of from 80 keV to 3 MeV.

There are two modes of transmission between the field stations and the central station: radiotelemetry and land-line. In the present system, the telemetry frequency is 150 MHz and transmitter output is approximately 1 watt. Transmission distance in a telemetry mode is a maximum of 10 miles line of sight. Transmission distance in a land-line mode is dependent mainly on the type of cable used.

Because all stations transmit and receive on the same frequency, only one field station can relay its information to the central station at one time. The system can be placed in an automatic mode, where the field stations report information sequentially, or in a manual mode, where any selected field station will report continuously. Voice communication can be established between the central station and field stations to ease calibration and maintenance operations.

1. Method of Interrogation

Interrogation is by a two-toned coded, FM-modulated signal. The central station contains five tone generators that emit tones at 313, 349, 389, 434, and 584 Hz. From these five generators a series of 10 individual two-tone signals is formed. Each field station contains two-tone relays, which are tuned to respond to the appropriate interrogation signal. Both relays must close before a field station is activated.

In the automatic mode, each field station is interrogated sequentially, beginning with field station No. 1. After No. 1 is interrogated and reports, the tone signal for station No. 2 is transmitted. Station No. 2 reports, and

then No. 3 is interrogated, etc. After station No. 10 (or whichever station is last in the chain) reports, the cycle automatically restarts at No. 1. In the manual mode, any one field station can be selected, and the selected station will go through continuous cycles of interrogation and reporting.

2. Method of Detection and Transmission

When the ionization chamber is subjected to gamma radiation, a dc current, in the range of from 6×10^{-12} to 3×10^{-6} amperes, flows through the chamber. This current is detected by an electrometer, amplified, and converted into a sawtooth pulse. The final amplitude of this pulse is always the same, but the slope of the pulse changes with a change in input current. (The higher the current, the steeper the slope.) Thus, the output from the electrometer is a varying rate of sawtooth pulses. This pulse rate is directly proportional to the incident gamma flux, and varies from 0.0167 to 6300 Hz. A 0.01-R/hr gamma field causes a current of 6×10^{-12} amperes in the chamber, and the current is converted into a sawtooth pulse of 0.0167 Hz. Similarly, at 5000 R/hr a current of 3×10^{-6} amperes is produced, which is converted into a sawtooth pulse of 6300 Hz. The sawtooth pulses are converted to a square wave train of equal frequency and fed into the transmitter modulator.

All circuits of the field station are in continuous operation with the exception of the transmitter. Upon receipt of the correct interrogation signal, the transmitter is keyed on. Normal operating frequency for the transmitters in the prototype system is 150 MHz. When the square wave being fed into the modulator goes positive, the carrier frequency is shifted lower by approximately 18 KHz. When the square wave goes negative, the carrier frequency returns to normal. This type of transmission is called Frequency Shift Keying (FSK).

At low radiation intensities, the carrier frequency shifts at a slow rate. Approximately 200 seconds are required to transmit a dose rate of 0.01 R/hr. This means that a minimum of 2000 seconds (approximately 33 minutes) would be required to receive information from 10 stations. Waiting this length of time in a disaster situation would be intolerable. At high radiation intensities, however, the carrier frequency shifts at a fast rate, and only a short transmission time is necessary. The duration of the interrogation signal can be varied from 2 to 20 seconds. The field station that responds to this signal

will transmit for a period of time equal to 10 times the duration of the interrogation signal (20 to 200 seconds). This allows rapid surveys when high intensity radiation is present.

3. Method of Reception and Readout

At the beginning of the interrogation period, the central station transmitter is keyed on. At the end of this period, the transmitter is keyed off and one of the field stations begins to send FSK information. A circuit within the central station converts the FSK pulse rate to a dc current proportional to the logarithm of the pulse rate, and hence, proportional to the logarithm of the gamma radiation intensity. This information is displayed, in log form, on a meter and a recorder.

There is one meter for each field station, and these meters are of the "clamp" type. At the beginning of the receiving cycle, the needle on the meter corresponding to the transmitting field station is unclamped. At the termination of this cycle, the needle is reclamped. Thus, the final reading on the meter is retained until an input is again received from the same field station. The recorder is a two-pen strip chart. One pen records the number of the reporting station, and the other pen records the dose-rate information at that particular station.

4. Power Requirements

Normal operation of all stations is from 117 Vac, 60 Hz. Each station contains a set of batteries for emergency operation. The batteries at the field stations can maintain operation for a minimum of 20 days when the automatic sequential mode is used. The batteries at the central station can maintain operation for a minimum of 48 hours. The batteries are automatically kept at full charge during ac operation.

5. Installation

The central station consists of four separate units: transceiver, which contains the transmitter, receiver, command-control electronics, power supply and batteries; a console, which contains the meters, tone generators, audible and visual alarms, and transmission mode controls; a two-pen recorder; and a ground plane antenna. The transceiver is 21 inches wide by 15 inches deep by 12 inches high and weighs 104 pounds. The console is 22 inches wide by 19

inches deep by 25 inches high and weighs 90 pounds. The recorder is 12 inches wide by 10 inches deep by 7 inches high and weighs 46 pounds. Total weight is 240 pounds (excluding antenna).

Each field station consists of an ionization chamber, an electrometer, transmitter, receiver, command-control electronics, power supply and batteries, all housed in one case, and a Yagi array antenna. The station is 21 inches wide by 15 inches deep by 18 inches high and weighs 108 pounds.

Although each individual part can be considered to be portable, the system as a whole is designed for use at a fixed installation. This is particularly true if land-line cables are used. The need for ac power, arrangement of antennas, etc., all limit the mobility of the system.

The field stations of the prototype system were not hardened to withstand a nuclear blast. In a land-line system, where the cables are buried, the field stations themselves are the only components exposed to the elements. If the field stations are blast hardened, then the entire system can be considered hardened. If, however, a telemetry system is used, the antennas are the weak link. It would be extremely difficult, if not impossible, to build an antenna of this type to withstand a nuclear blast. If the antenna is destroyed, the whole field station is effectively destroyed. Therefore, in this situation, the need for blast hardening of the field stations is questionable.

SECTION III

CONCLUSIONS

One prototype of the AN/GKQ-4 system has been produced and evaluated. The major difficulty encountered during the evaluation was the "saturation" of the field stations at high dose rates. At 5000 R/hr, a correct indication of full scale was obtained. As the intensity of the radiation increased, the meter indication dropped, until at 10,000 R/hr a reading of zero was obtained. The difficulty was traced to the electronics of the field station and not the ionization chamber itself. This saturation effect is temporary. As the intensity of the radiation is reduced, correct indications are again received. The electronics of the field station will be changed to correct this problem if an advanced model is produced.

At least one major modification must be made before the system can be considered "operational." The existing unit transmits and receives at 150 MHz. Any operational system must use the 1700 to 1800 MHz band. (This is a Hq USAF decision.) This will mean a complete redesign of the transmitting-receiving capability, including antennas.

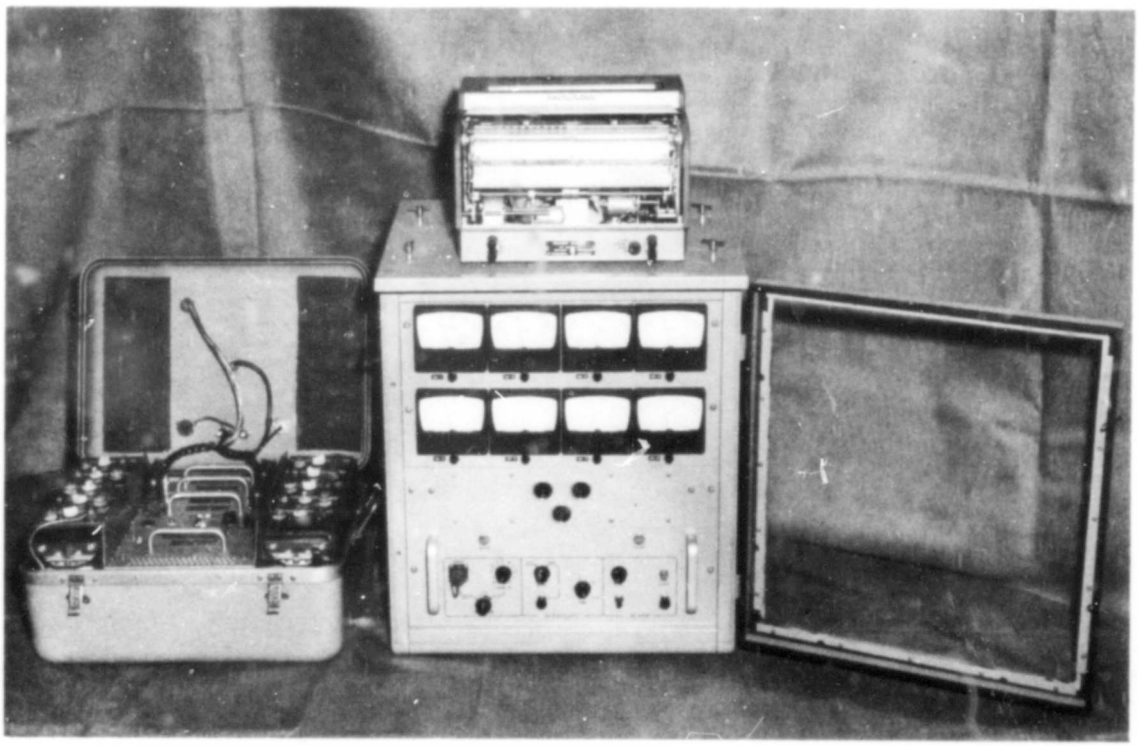

Figure 1. Central Station

This figure shows the console, transceiver, and recorder of the central station. The prototype has eight field stations and, therefore, only eight indicating meters are installed in the console. Space is provided for two additional meters. Under each meter is a red-light visual alarm. The three black discs under the meters are the audible alarm system (buzzers). In the bottom left corner of console front panel is a connector for the telephone head set, transmission function switch (FSK, land-line, or voice), and mode switch (automatic or individual station selection). Bottom center shows the automatic or manual selector switch and interrogation time control. The alarm can be set at any point over the entire range. The alarm controls are located at bottom right.

On top of the console is the recorder. The left-hand pen records dose-rate information and the right-hand pen records field station number. The switch at bottom right is the paper speed control (1 inch per minute or 1 inch per hour).

At the left of the picture is the transceiver. On the left and right sides of the transceiver are the 45-ampere/hour batteries. The center portion contains four modules, transmitter, receiver, command/control electronics, and power supply.

Figure 2. Field Station

Figure 3. Field Station with Cover Raised

These figures show the field station. The field station is identical to the central station transceiver with the exception of the ionization chamber and electrometer. The ion chamber is located on the case, with the electrometer housed in the enclosure under the chamber.

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