OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

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AIRCRAFT FLIGHT RECORDER LOCATION BY RADIATION TECHNIQUES

R. G. Niemeyer

NOTICE

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ISOTOPES DEVELOPMENT CENTER

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ABSTRACT

Two methods for locating aircraft flight-recording instruments have been proposed — (1) a radioactive locator beacon attached to the flight recorder to be located by probing with a scintillation instrument, and (2) a radiation detector and signal generating device to be located by probing with a partially shielded Co^{60} source.

INTRODUCTION

The Federal Aviation Agency has in recent years been concerned by the loss of flight-recording instruments which have been torn away from the fuselage of the aircraft during the impact of a crash. The rapid recovery of this instrument is considered essential. A radioactive locator beacon has been proposed as a means of locating the protected tape of the recorder, especially in instances where it may be under water or imbedded in mud.

The beacon should be attached to or located within the tape deck itself, should not operate until a predetermined deceleration force has been applied, and should have a long life, low weight, small size, and crash survivability. The nature of the source radiation and the amount present in the beacon should yield a range of detection of at least 10 ft in air, 3 ft in sea water, and 2 ft in earth. In addition, the equipment should be so designed that, when it is mounted anywhere in the aircraft, persons may work nearby for prolonged periods of time without exceeding current standards of safe radiation dosage. Finally, the beacon should have a shelf-life (non-operating condition) of at least 6 months followed by an operating-life of 14 days after a crash and should require no external power.

An alternative method of locating flight recorders would utilize a sensitive radiation detector and signal generating device fastened to the flight recorder tape deck. The flight recorder would be located by probing with a partially shielded Co^{60} source until the radiation detector is actuated and sonar or audible signals are transmitted and detected by receiving equipment carried by the search crew.

RADIOACTIVE LOCATOR BEACON

The radioactive locator beacon must emit penetrating gamma radiation to meet the specified ranges of detection through water and mud. Cobalt-60, as cobalt metal, was selected as the radioactive source because it provides the required gamma radiation (e.g., the radiation will penetrate 2 ft of mud, 3 ft of water, and 10 ft of air), has a half-life of 5.3 yr, and has an extended record of safe use in many radiation devices.

The use of the smallest detectable source is desirable in order to minimize the shielding requirements and to reduce the radiation hazards involved in the recovery operation. Eight millicuries of Co^{60} will be adequate to meet the detection requirements of the Federal Aviation Agency (see Appendix). The dose rate 1 ft from the exposed source in air would be ~125 mr/hr and at 10 ft, ~1.2 mr/hr. Thus, little difficulty would be encountered in handling this size source, and there would not be a significant hazard to crash survivors or rescue personnel.

The three currently employed types of flight recorders have insufficient space available inside the case for a shielded radioactive source. The conceptual design for the beacon is based on a Co^{60} source mounted external to the flight-recorder tape deck within a high density shield from which the source will be ejected on impact. Both uranium metal and tungsten-nickel alloy are excellent shielding materials. Uranium is the better shielding material but must be encased in stainless steel cladding for alpha containment and fire resistance. Total weight of the proposed locator beacon will be ~25 lb.

Shield Design No. 1

An 8-mc Co^{60} source, enclosed in a stainless steel capsule, is mounted at the center of a 4-in. spherical shield. The sphere is designed so that it will separate into two sections upon impact. The larger section will fall away and expose the source; the smaller section, to which the source is attached, is firmly attached to the flight recorder by means of a mounting bracket (Fig. 1.).

In the event of an airplane crash, the entire assembly will continue moving forward because of its inertia. The radioactive source shield, being firmly anchored to the fuselage, will be held back, the shear pins will break, and the source will be exposed.

Shield Design No. 2

In the alternative method, the shield is composed of three segments held together by trigger-activated pins (Fig. 2.). Upon impact, the trigger device (Fig. 3.) would pull the pins out of the slots so that all three pieces of the shielding would fall away and the source attached to the instrument by a chain or a braided steel cable would be entirely exposed.

The pin locking the segments of the shield together is held in a cocked position behind a sear. Upon impact, the plunger will be forced past the sear allowing the spring to complete the motion of withdrawing the locking pin from the shield. The spring could be replaced by an explosive cartridge designed to detonate at a predetermined impact force.

Experimental Results

Radiation measurements have been made in simulated mud, water, and air by use of test equipment set up in a manipulator cell (Fig. 4.). The dosage was measured in air at distances of 30, 39.4, and 47 in. from the source and from these data the strength of the Co^{60} source was calculated to be 2.38 curies.

The source was contained in a 1/4-in.-diam by 19/32-in.-long stainless steel capsule, which was then placed inside a 5/16-in.-diam hole drilled in the end of a 2-1/2-in.-diam lead cylinder. The effect of scattered radiation in the cell was minimized by placing lead brick shielding around both the source and the detector.

In order to obtain measurements through mud and water, three boxes (12 x 12 x 12 in. ID) made of 1/2-in. plywood were placed end-to-end between the source and the detector. The boxes were lined with a thin sheet of plastic to prevent leakage of the mud and water. Ordinary tap water was used for the test; the mud was prepared by mixing top soil and tap water (measured density = 1.7 g/ml). The results of the test measurements are listed in Table 1. Figures 5, 6, and 7 show the variation of the log of the dose rate with varying amounts of mud, water, and air placed between the source and the detector. Table 2 contains a list of calculated dosages from small Co^{60} sources.

Table 1. Cobalt-60 Source Measurements
in Simulated Air, Mud, and Water Conditions

Absorption Medium	Distance From Source (in.)	Radiation Dose
Air	30	6.8 r/hr
Air	39.4	3.1 r/hr
Air	47	2.3 r/hr
3 empty boxes	47	1.1 r/hr
1 box water - 2 empty boxes	47	300 mr/hr
2 boxes water - 1 empty box	47	82 mr/hr
3 boxes water	47	26 mr/hr
1 box mud - 2 empty boxes	47	145 mr/hr
2 boxes mud - 1 empty box	47	14 mr/hr
3 boxes mud	47	1 mr/hr

Table 2. Calculated Dosages in Small Cobalt-60 Sources

Co^{60} Source (mc)	Calculated Environmental Readings (mr/hr)			Dose rate (mr/hr) Surface of 4-in. Spherical Uranium Shielding
	2 ft mud	3 ft water	10 ft air	
1000	5.9	10.9	1400	1634
500	2.95	5.45	700	817
250	1.48	2.73	350	408
125	0.77	1.36	175	204
62.5	0.37	0.68	87.5	102
31.25	0.19	0.34	43.8	51
15.63	0.09	0.17	21.9	25
7.81	0.05	0.09	10.9	12.8

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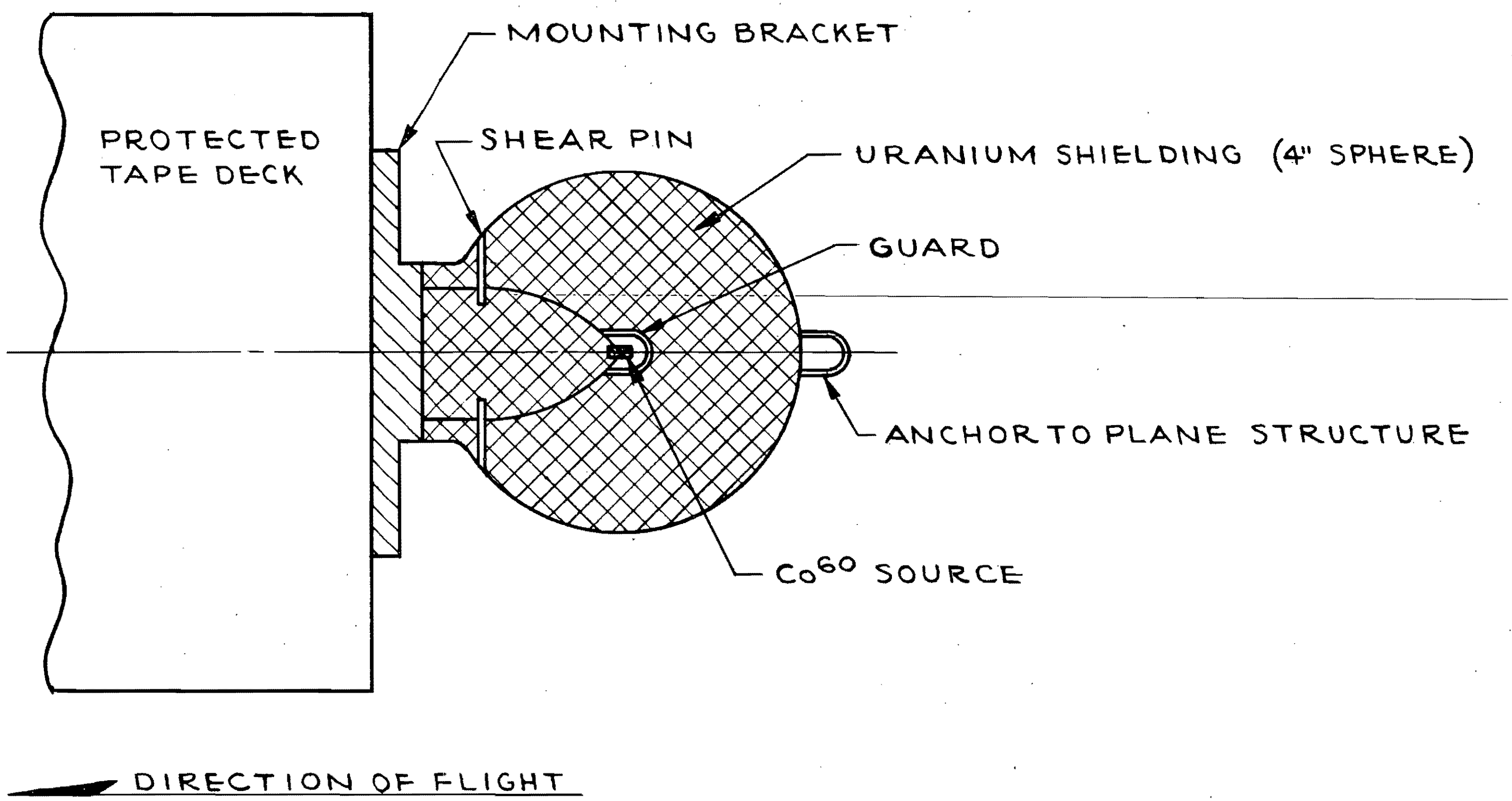

Fig. 1. Radioactive Locator Beacon

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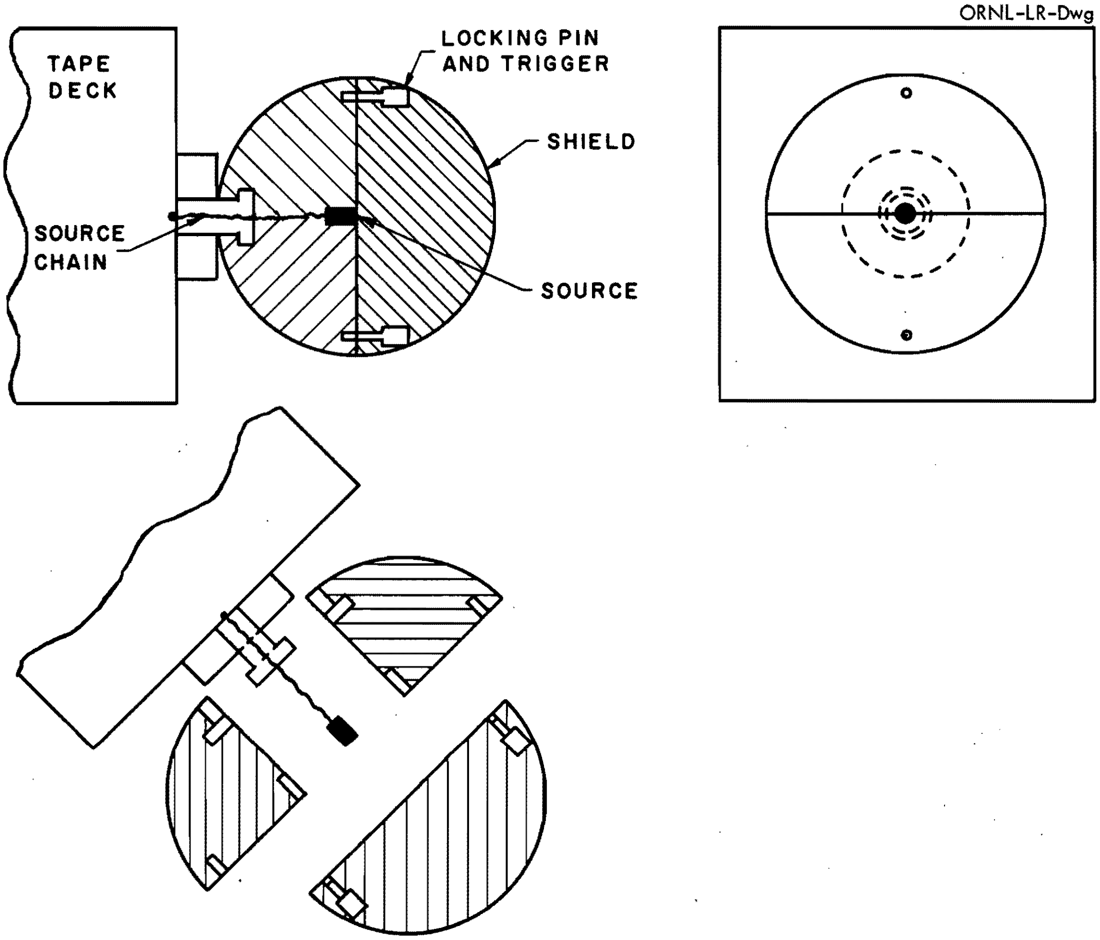

Fig. 2. Flight Recorder Locator Beacon

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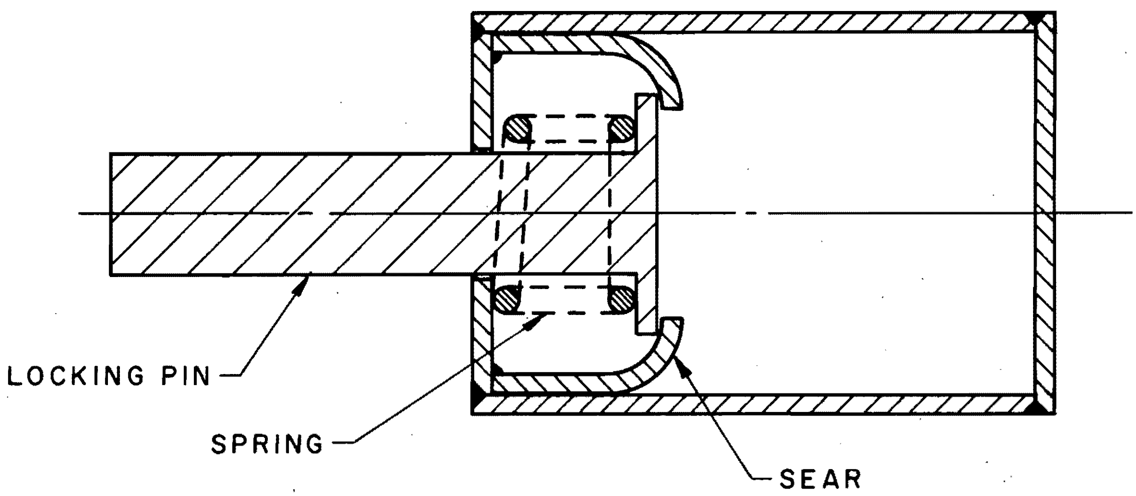

Fig. 3. Locking Pin and Trigger Mechanism

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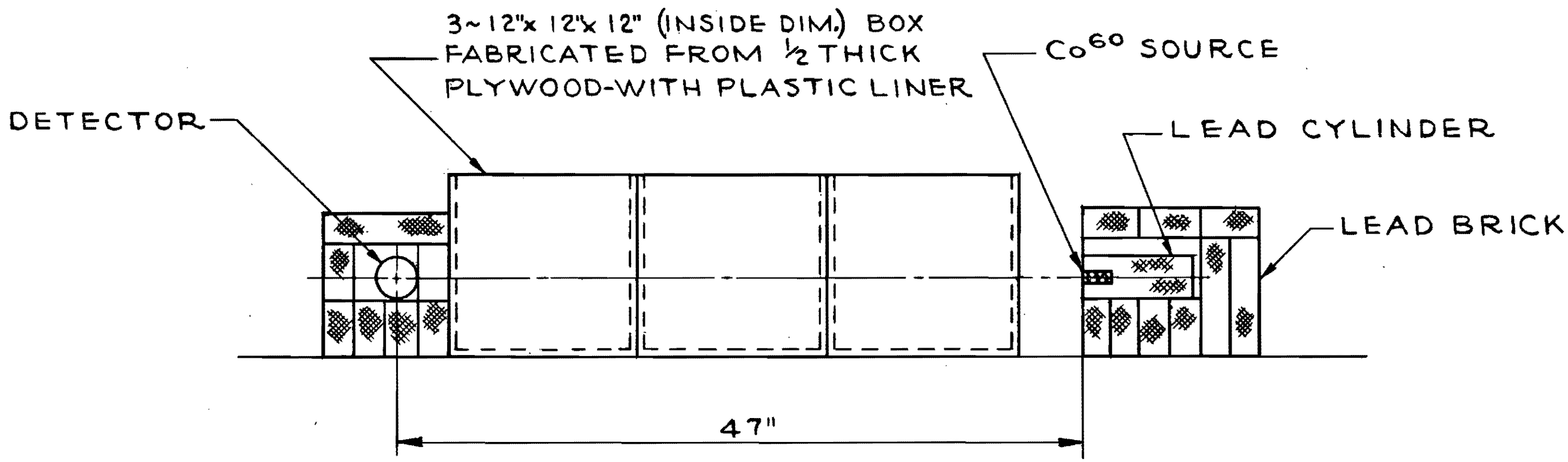

Fig. 4. Source Testing Equipment

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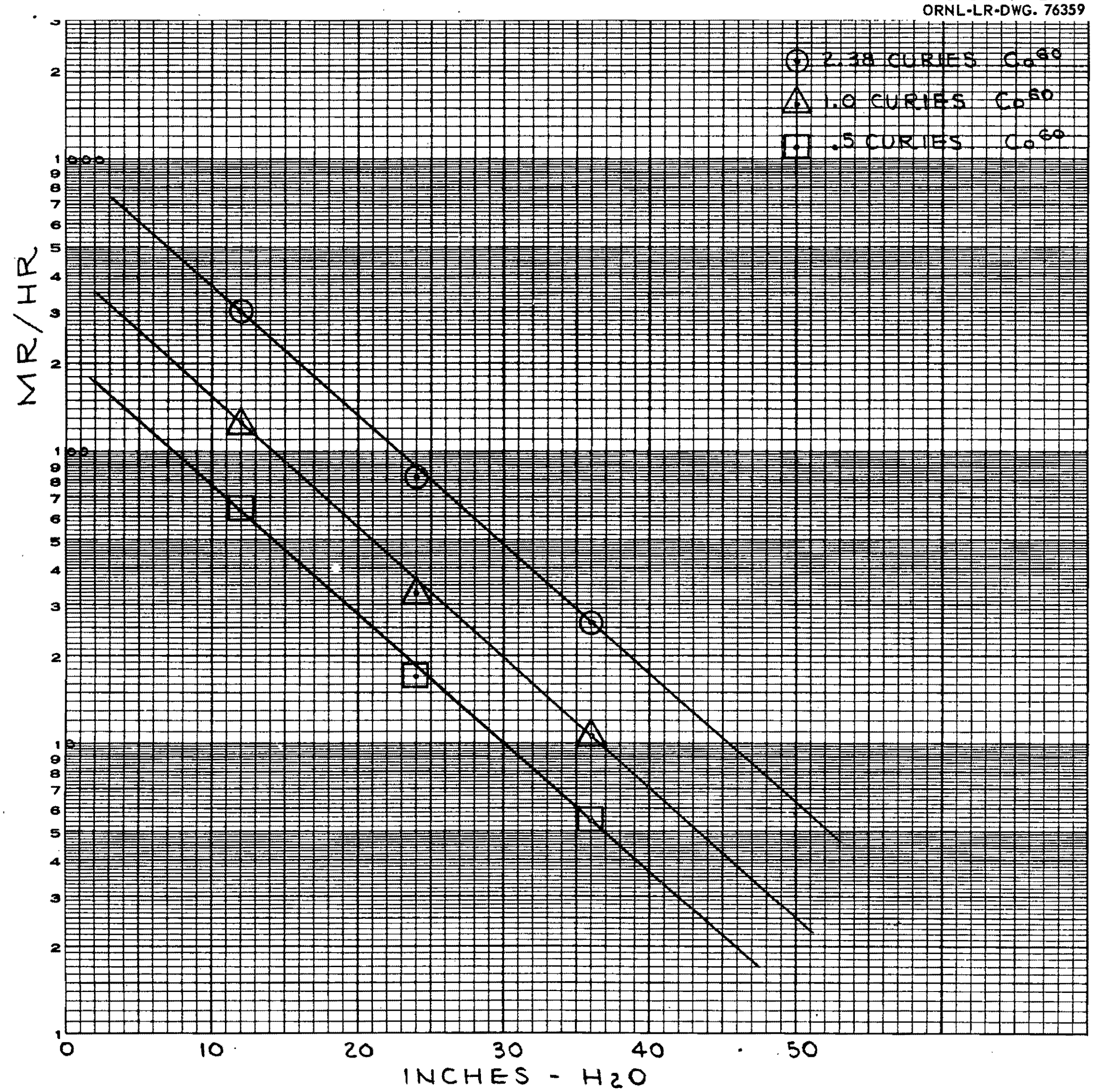

Fig. 5. Co^{60} Radiation Readings in H_2O

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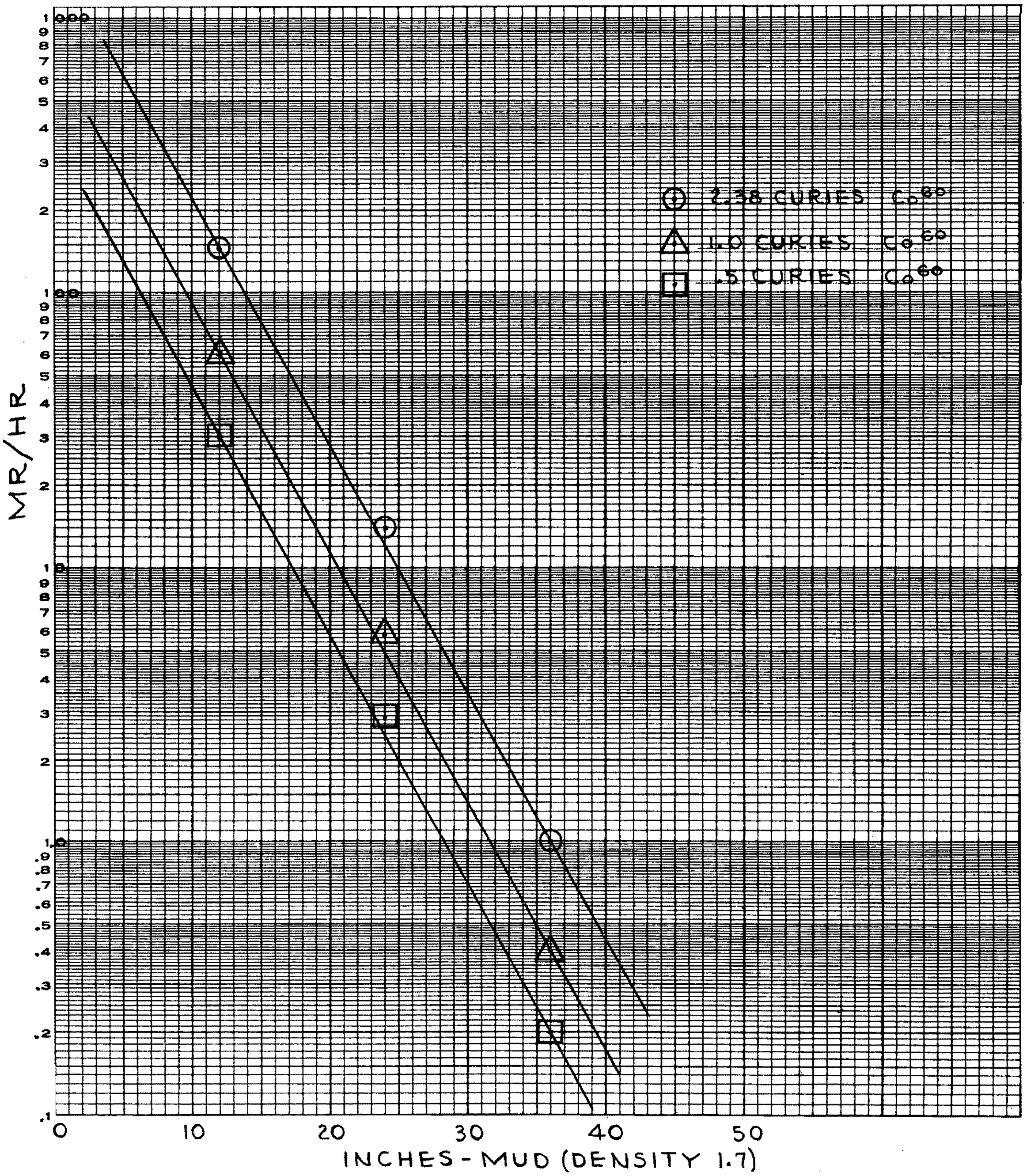

Fig. 6. Co^{60} Radiation Readings in Mud

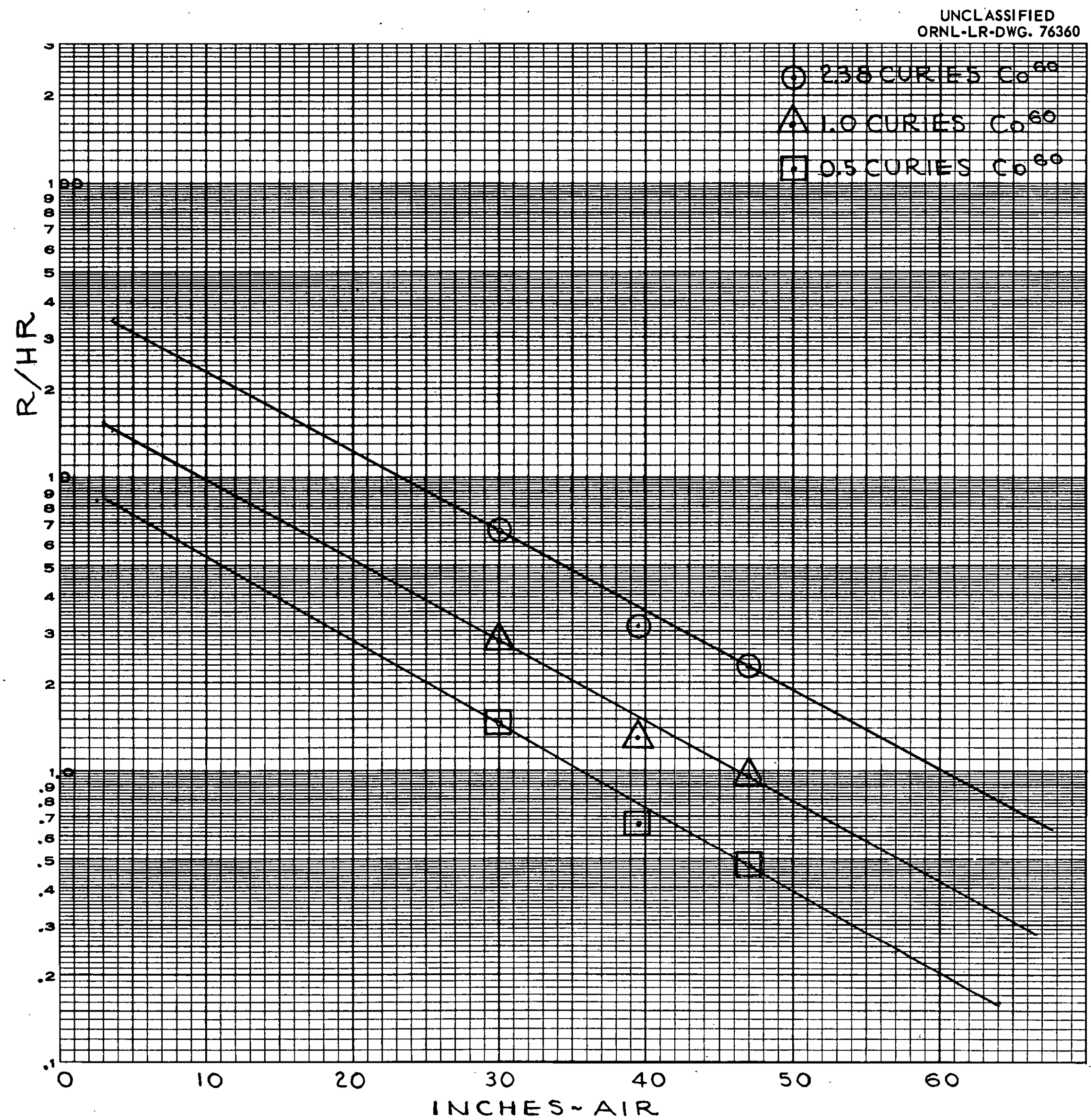

Fig. 7. Co^{60} Radiation Readings in Air

RADIATION DETECTOR AND SIGNAL GENERATING DEVICE

Another method of locating flight recorders involves a radiation detector such as the audible personal radiation monitor (PRM) type device developed by Oak Ridge National Laboratory which would be fastened to the flight recorder tape deck along with sonar and possibly audio signal generating equipment. In this case the flight recorder would be located by probing with a partially shielded Co^{60} source. When the source is brought near enough, the PRM-type detector would electronically activate the sonar and audio equipment. If the tape deck were on land it would be located by the audible alarm and if in water or mud, by a sonar detector.

The use of this type of system has many drawbacks which might be difficult to overcome. One of the FAA requirements is that "every consideration should be given to long life, low weight, small size, and crash survivability." Considerable development work and testing would be required to establish the best packaging methods and to ascertain the reliability of such a system.

With the assumption that a dose rate of 0.2 mr/hr would be a practical value for activating the PRM-type locator through the specified shielding materials, a Co^{60} source of about 30 mc would be required. The use of a partially shielded source of this size introduces significant radiation hazards, and the required shielding would not be easily portable.

CONCLUSIONS

The most reliable method for locating flight recorders appears to be by means of a radioactive locator beacon. Such beacons when utilizing a Co^{60} source have essentially 100% reliability, for they do not rely on fragile electronic equipment or batteries but obtain their energy from spontaneous radioactive decay. This type beacon easily meets the FAA requirements of a shelf-life of 6 months followed by an operating life of 14 days. Environmental temperatures ranging from -62°C to +1100°C would have no effect on its operation. The isotope beacon can readily withstand the FAA requirement of altitude, vibration, impact shock, and total immersion in sea water. The beacon is very rugged, easy to fabricate, and requires virtually no maintenance or testing. The recovery operation will require a portable scintillometer, such as a model 389H Super Scintillac made by Victoreen Instrument Company.

It is recommended that radiation measurements in mud, water, and air should be repeated using an 8-mc Co^{60} source and a scintillometer to confirm the optimum size source and to develop recovery procedure with a scintillation type instrument. A protected tape deck should be irradiated under the most severe conditions which might occur in actual use and should be tested to determine if the radiation has any detrimental effect on the magnetic tape or the thermal insulation. Detailed design and development work on the trigger mechanism should be undertaken to insure satisfactory operation of the locator beacon. A prototype beacon should be fabricated and tested to ascertain that all required conditions for usage are met, including activation of the beacon on impact, crash survivability, and recovery.

APPENDIX

FAA SPECIFICATIONS

Project 302-10-1D
October 25, 1962

Radioactive Locator Beacon

1.0 General. This beacon will be attached to or incorporated in the design of electronic equipment which is installed aboard an aircraft and which must be speedily recovered in the event of a crash. Every consideration should be given to long life, low weight, small size, and crash survivability. The beacon need not operate until a predetermined G force has been applied, although it will be necessary to check periodically whether it is functioning properly. Auxiliary ground equipment such as probes may be utilized and may be more sophisticated than the airborne equipment. All equipment shall be constructed in accordance with the best commercial practice.

Operating Range. The range of detection should be at least ten feet in air, three feet in sea water, and two feet in earth.

Harmful Radiation. The equipment shall be designed to be mounted anywhere on the aircraft. This includes close proximity to persons for prolonged periods of time without exceeding current standards of safe radiation dosage.

Operating Life. The beacon shall have a shelf life of six months (non-operating condition) followed by an operating life (following a crash) of fourteen days.

Power Supply. No external power shall be required.

Environmental Conditions. The equipment must function properly under the operating environmental conditions after having soaked in the non-operating environmental conditions and having passed through the crash environmental conditions. The equipment is not required to function in the non-operating or the crash environmental conditions.

Non-Operating Standard Environmental Conditions.

Temperature	-62°C to +71°C
Humidity	95% to 100% at 50°C ± 3°C for 48 hrs
Altitude	55,000 feet ± 5%
Vibration	.030" double amplitude from 10 to 55 cps with a maximum acceleration of 5 G; and a constant acceleration of 5 G from 55 to 500 cps

Non-Operating Crash Environmental Conditions.

Impact Shock	1000 G for 11 millisecond, half sine wave pulse
Temperature	1100°C for 30 minutes following shock

Operating Environmental Conditions.

Temperature	-54°C to +71°C
Humidity	100% to sea water immersion

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