

MICHIGAN  
STATE HIGHWAY DEPARTMENT  
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ANALYSIS OF PROPOSED RESEARCH PROJECTS  
INVOLVING WORK WITH RADIOACTIVE ISOTOPES

by

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Highway Research Project 52 G-61

Research Laboratory  
Testing and Research Division  
Report No. 189(a)  
May 15, 1953

## PREFACE

This report was first submitted as Research Report No. 189 on February 11, 1953. Distribution was made within the Department, to the University of Michigan Phoenix-Memorial staff (Dr. Henry J. Gomberg, Assistant Director), and to the Michigan State College Isotope Committee.

In the light of certain recommendations made by Dr. Gomberg and by Dr. L. F. Wolterink of the MSC Isotope Committee, particularly with respect to Project I (recommendations concurred in by the Special Training Division of the Oak Ridge Institute of Nuclear Studies and by the Isotope Division of the Atomic Energy Commission), the report has been revised slightly. It is herewith reproduced as Research Report No. 189 (revised), May 15, 1953.

Approval has now been received from the U. of M. Phoenix-Memorial staff and from the MSC Isotope Committee to begin work on the first four projects of this report.

INTRODUCTION

This report presents an analysis of certain of the most pressing of the Michigan State Highway Department's proposed research projects involving work with radioactive isotopes.

The analysis is broken down into: (1) projects which it is desired to begin immediately, using existing housing and facilities of the Research Laboratory in the R. E. Olds Engineering Building Annex on the campus of Michigan State College, and using equipment and materials as outlined; and (2) projects which it is felt necessary to defer until such time as additional housing and facilities are available.

The report has been prepared for distribution within the Department, for submission to the Michigan State College Committee on Radioactive Isotopes for approval, and for submission to the University of Michigan Phoenix Project staff for counseling and guidance.

Included in the report is an estimate of probable expenses for equipment and materials for four immediate projects and three deferred projects, plus expenses for equipping the proposed radioisotopes laboratory. These expenses are broken down by project.

It is to be observed that practically all the proposed equipment, and in many cases the materials also, would be applicable to additional research projects as these are authorized. For this reason, a tentative list of eventual studies is included, although this must be considered incomplete at this time. No additional equipment is foreseen to be necessary over and above that cited for projects (1) through (?), inclusive.

Also included in this report is a reproduction of the floor plan for the proposed new Radioisotopes Laboratory, together with estimated expenses for complete equipment.

**A. Immediate Projects**

Projects which it is desired to begin immediately include the following:

1. Durability of traffic-marking paints.
2. Air content of hardened concrete.
3. Stripping test for asphalt.
4. Gamma ray radiography.

**B. Deferred Projects**

Projects which it is felt will have to be deferred until such time as additional housing and facilities are available include the following:

5. Field determination of soil density and compaction.
6. Field determination of soil moisture.
7. Determination of thoroughness of mixing.

**C. Eventual Projects**

Some of the projects on which it is intended eventually to conduct research with radioisotopes include the following:

8. Adhesion of paint films to wearing surfaces.
9. Studies of concrete-curing phenomena and efficiencies of membrane-curing compounds.
10. Plastic flow in concrete.
11. Permeabilities, porosities and surface characteristics of aggregates; selective moisture adsorption of aggregates; evaluation of aggregate sources.
12. Adhesion of joint-sealing compounds to concrete.
13. Composition of bituminous substances.
14. Wearing characteristics of pavement surfaces.
15. Corrosion studies.
16. Permanent pavement-marking stripes.
17. Skidding resistance studies.
18. Snow and ice control methods.
19. Detection of incipient crack formation in concrete surfaces and of beginning spalling tendencies, by selective adsorption and concentration of isotopes.
20. Studies of concrete and aggregate breakdown caused by application of repeated cycles of freezing and thawing.

ESTIMATE OF COST  
(Equipment and Materials)

Estimated expenses included in this report are as follows:

I. Immediate Projects

<u>Project</u>	<u>Equipment</u>	<u>Materials</u>	<u>Misc. (10%)</u>	<u>Total</u>	<u>Grand Total</u>
1	\$1,989.00	\$ 71.00	\$206.00		\$2,266.00
Additional for the following projects:					
2	30.00	30.00	6.00	\$ 66.00	
3	34.50	15.00	5.50	55.00	
4	<u>854.80</u>	<u>120.00</u>	<u>98.00</u>	<u>1,072.80</u>	
Total (2-3-4)	\$ 919.30	\$165.00	\$109.50	\$1,193.80	<u>1,193.80</u>
Grand Total (1 through 4)					\$3,459.80

II. Deferred Projects

Additional for the following projects:

5	\$3,507.50	\$ 30.00	\$353.75	\$3,891.25	\$3,891.25
6 - 7*	(See note)				

III. Radioisotopes Laboratory

Complete Equipment	\$8,475.00	none	\$848.00	\$9,323.00	<u>\$9,323.00</u>
				GRAND TOTAL	\$16,674.05

\* NOTE: No additional equipment is required for projects (6) and (7). Materials for these projects, yet to be determined, are relatively inexpensive. No accurate estimate can be given at this time. It is understood that deferred projects (5) through (7) and eventual projects (8) through (20) will not be started prior to completion of the Radioisotopes Laboratory.

## IMMEDIATE PROJECTS

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It is proposed that projects in this category be started as soon as possible, without waiting for the availability of new quarters. The radiation levels involved would be low, and it is felt that with purchase of the indicated equipment control could be exercised with existing housing and facilities.

PROJECT I - DURABILITY OF TRAFFIC-MARKING PAINTS

Purpose - To determine thicknesses of traffic-marking stripes, both with and without beads, with especial emphasis on the amount of paint remaining. To be used in conjunction with studies pertaining to the durability of pavement-marking paints and traffic stripes.

Equipment Needed

Alternate (1)

Tracerlab Cat. No. BG-1 Backscatter Beta Gauge, \$3,300.00 f.o.b. Boston. It is recommended that this instrument not be used until the method is proved with other equipment.

Alternate (2)

Landsverk Electrometer Co. (affiliated with Technical Associates) Model L-75-B Analysis Unit, 0.0002 mg/cm <sup>2</sup> window . . . . .	\$	82.00	
Landsverk Model L-77 Light Source . . . . .		20.00	
Central Scientific Co. Cat. No. 73536 Stopwatch for use with the above . . . . .		27.00	
	\$	129.00	\$ 129.00

Alternate (3)

Nuclear Instrument and Chemical Corp. Model 183 Count-o-matic Scaler . . . . .	\$	850.00	
Tracerlab Cat. No. TGC-2 Mica End Window Counter (two at \$53.50) . . . . .		107.00	
Technical Associates Model LS-6 (AEC Cat. No. AL-14A) "Schenectady" type Vertical Lead Shield, complete . . . . .		275.00	
Technical Associates Model AB-2 Absorber Set . . . . .		65.00	
Tracerlab Cat. No. E-12 Rectangular Lead Storage Container, 2" lead wall thickness . . . . .		120.00	
Tracerlab Cat. No. E-17 Remote Handling Tongs . . . . .		48.00	
	\$	1,465.00	\$1,465.00

Personnel Safety Equipment Common to All Methods

Nuclear Instrument & Chemical Corp. Model 2611 P Count Rate Meter, portable . . . . .	\$	300.00	
Tracerlab Cat. No. SU-8 Pocket Dosimeter (direct-reading ioniz. chamb.) two at \$47.50 . . . . .		95.00	
	\$	395.00	\$ 395.00
Total for recommended equipment . . . . .			\$1,989.00

Materials Needed

Alternate (1)

None (furnished with gauge).

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Alternates (2) and (3)

1 millicurie 38-FB Strontium 90 (25 years half life),  
\$1.00, plus \$10.00 handling charge . . . . . \$ 11.00

10 millicuries Tl-204-P Thallium 204 (2.7 years  
half life), \$50.00, plus \$10.00 handling charge . . . . . 60.00  
\$ 71.00 \$ 71.00

Total for Materials and Equipment . . . . . \$2,060.00

Miscellaneous . . . . . \$ 206.00  
\$2,266.00

General Description

The principle of making thickness measurements by backscattered beta particles was worked out and reported by Clarke, Carlin and Barbour (Electrical Engineering, vol. 70, pp. 35-37, January, 1951). The principle rests upon the fact that if a material of low to moderate stopping power for beta rays is applied as a coating over an "infinite thickness" of a second material possessing high stopping power for beta rays, the thickness of the coating material will be a function of the intensity of backscattered beta radiation. By "infinite thickness" is meant a thickness so great that further thickness is without effect.

Practical application requires a suitable source of beta rays, a means of determining accurately the backscattered intensity, and satisfactory stability of support.

It is proposed that alternate (2) equipment be used in conjunction with general-purpose alternate (3) equipment in order to prove the applicability of the method to determinations of pavement-marking stripe thicknesses. Alternate (2) equipment is portable and can be used in the field. Large-scale use, however, might warrant purchase of alternate (1) equipment.

It is also proposed that the tracer technique be utilized as advocated by the University of Michigan Phoenix-Memorial staff, using thallium 204 as the radioactive tracer. In this technique, the radioactive material is mixed into the paint. Thickness of paint film is measured by counting rate.



PROJECT II - AIR CONTENT OF HARDENED CONCRETE

Purpose - To determine the air content and density of hardened portland cement concrete by the method of gamma ray absorption.

Equipment Needed

Equipment as listed under headings "Alternate (3)" and "Personnel Safety Equipment Common to All Methods" in outline of project entitled "Durability of Traffic-marking Paints."

Nuclear Inst. D22 Geiger Counters: two . . . . .	\$ 30.00	
	<u>30.00</u>	\$ 30.00

Materials Needed

10 millicuries 55-F Cesium 137 (37 years half life)		
\$20.00 plus \$10.00 handling charge . . . . .	\$ 30.00	
	<u>30.00</u>	\$ 30.00

General Description

When radiation passes through matter, some of it is absorbed. The density of the matter is one factor influencing the amount of absorption.

It was calculated at Oak Ridge that the highly monoergic gamma rays from cesium 137 can probably be used to measure the density of hardened concrete with sufficient precision to determine the air content.

This would involve lead collimation of a cesium 137 source of sufficient intensity, absorption of the collimated radiation by the sample of concrete of known thickness, measurement of the amount of absorption, and calibration (1) of the geometry and (2) against composition of the sample. What effect the composition will have would have to be determined; it is possible that the effect of composition will be low or negligible. It is certainly possible that it can be compensated for.

<u>Miscellaneous</u> . . . . .	\$ 6.00	<u>\$ 6.00</u>
	TOTAL	\$ 66.00

PROJECT III - STRIPPING TEST FOR ASPHALT

Purpose - To devise a stripping test for asphalt in which the amount of stripping can be determined by the tracer technique.

Equipment Needed

Equipment as listed under headings "Alternate (3)" and "Personnel Safety Equipment Common to All Methods" in outline of project entitled "Durability of Traffic-marking Paints."

Large stainless steel tray to provide safe working surface for sample preparation in hood. 20 inches by 30 inches. . . . .	\$ 26.00	
Radioactive waste disposal drum with foot-operated cover . . . . .	8.50	
	\$ 34.50	\$ 34.50

Materials Needed

1 millicurie 20-PC Calcium 45, 180 days half life, \$5.00 plus \$10.00 handling charge . . . . .	\$ 15.00	
	\$ 15.00	\$ 15.00

General Description

A stripping test of this description was devised by the Atlantic Refining Co. of Philadelphia. Crushed paving stones are soaked in a dilute solution of radioactive calcium chloride (20-PC is purchased as the chloride). The stones are removed, coated with asphalt and immersed in water. Appearance of radioactivity in the water is evidence of stripping, and the amount of activity is claimed to constitute a measure of the stripping.

It is proposed to investigate the above test and to improve it if possible.

<u>Miscellaneous</u> . . . . .	\$ 5.50	\$ 5.50
TOTAL		\$ 55.00

PROJECT IV - GAMMA RAY RADIOGRAPHY

Purpose - (1) To photograph the interior of hardened concrete in order to locate, identify, and inspect the condition of steel dowel bars, load-transfer devices, steel reinforcement, etc.; (2) to examine structural steel welds and castings by radiography for determination of soundness; and (3) to employ gamma ray photography in photographing the interiors of solid objects wherever indicated.

Equipment Needed

Equipment as listed under heading "Personnel Safety Equipment Common to All Methods" in outline of project entitled "Durability of Traffic-Marking Paints."

Tracerlab Cat. No. E-31A High Intensity Source Container (Lead Storage Pot), 4" wall thickness . . .	\$ 225.00	
Cardboard Film Holders, 7" x 17", 10 at \$ .50 . . .	5.00	
Gamma-sensitive Films, pkg. of 75 . . . . .	24.80	
May possibly prove desirable: Grid or Bucky Diaphragm . . . . .	ca 300.00	
Lead Shielding Bricks, 30 at \$10.00 . . . . .	300.00	
	\$ 854.80	\$ 854.80

Materials Needed

800 millicuries Cobalt 60 (5.3 years half life), \$50.00 plus \$10.00 for target plus \$10.00 handling charge plus \$50.00 for encapsulation in capsule furnished by AEC, plus \$125.00* deposit on returnable container . . . . .	\$125.00*	120.00	
		\$ 120.00	\$ 120.00

\*As noted, \$125.00 deposit on returnable container.

General Description

Gamma radiography is superior to x-ray radiography for at least three reasons: (1) gamma rays are more penetrating than x-rays, (2) a point source can be more nearly approached at any given intensity, and (3) equipment and materials are highly portable. In addition, it is far less costly and requires no source of electric power.

Radiography of steel structures in hardened concrete has been successfully accomplished under conditions of favorable steel-to-concrete thickness ratio, and favorable steel-to-film distance factor. Where these conditions are highly unfavorable a moving grid of the Bucky diaphragm type can be used to shield the film from scattered radiation. Close approximation to a point source is considered desirable in order to minimize the penumbra effect, a condition which is further minimized by use of long source-to-film distances and short steel-to-film distances. Reduction of the penumbra effect increases sharpness of the photograph.

Point source is secured by virtue of the physical size of 800 mc of cobalt 60. This consists of a piece of cobalt wire 1/8 inch in diameter and 1/8 inch in length. The radioactive wire is encapsulated at Oak Ridge in a metal capsule 1/2 inch O.D. by 0.561 inch in length. The capsule does not contribute to the radioactivity. It is made in two sections, one end being either brass or aluminum and having an eye for handling with hook or line. The other end is of steel for magnetic handling.

Radiographs of 1-inch by 18-inch steel dowel bars centered in a 9-inch by 12-inch by 28-inch concrete block were taken using a 50 mg. radium source owned by Michigan State College. Inasmuch as the source was weak (50 milligrams) and divided among 16 silver needles of varying lengths, it was impossible to approximate a point source. Recourse was therefore had to a 48-inch film-to-source distance. A lead intensifying screen was used, but not a diaphragm. Although under these unfavorable conditions an exposure of nearly two weeks was required, results indicated that the method has possibilities.

Miscellaneous . . . . .	\$ 98.00	\$ <u>98.00</u>
	TOTAL	\$1,072.80

DEFERRED PROJECTS

It is proposed that projects in this category should not be started prior to completion of the proposed Radioisotopes Laboratory. For this reason, the listing of deferred projects is preceded by estimated equipment cost and floor plan of the laboratory. See Figure 1 for floor plan.

EQUIPMENT FOR PROPOSED RADIOISOTOPES LABORATORY

In addition to equipment detailed in proposals (1), (2), (3), and (4)

Fume Hood and Table Assembly, Blower and Stack, Kewaunee No. 3655 . . . . .	\$3,300.00	
Laboratory Bench and Sink, Kewaunee No. 3650 . . . . .	1,800.00	
Two Storage Cabinets . . . . .	250.00	
Atomic Instrument Co. Model 1070 Decade Automatic Scaler . . . . .	1,195.00	
Nuclear Instrument & Chemical Corp. Model D34 Mica End Window Counters, two . . . . .	95.00	
Model D22 Geiger Counters, two . . . . .	30.00	
Technical Associates Model LS-6 (AEC Cat. No. AL-14A) "Schenectady" type Vertical Lead Shield, complete . . . . .	275.00	
Tracerlab Cat. No. E-12 Rectangular Lead Storage Container, 2" lead wall thickness. . . . .	120.00	
Tracerlab Cat. No. E-18A Remote Pipetting Device . . . . .	110.00	
50 Lead Shielding Bricks . . . . .	500.00	
2 Plastic Shields for Beta Radiation . . . . .	40.00	
10 Small Tongs . . . . .	30.00	
6 Syringe-type Pipettors . . . . .	90.00	
2 Stainless Steel Trays . . . . .	50.00	
3 Radiation Standards, calibrated . . . . .	45.00	
Analytical Balance . . . . .	450.00	
2 Tracerlab Cat. No. SU-8 Pocket Dosimeters (direct-reading ioniz. chambers) . . . . .	95.00	
	<u>\$8,475.00</u>	\$8,475.00
10 percent Contingency Fund . . . . .		<u>\$ 848.00</u>
	TOTAL	<u>\$9,323.00</u>

PROJECT V - FIELD DETERMINATION OF SOIL DENSITY AND COMPACTION

Purpose - To develop portable or mobile equipment for obtaining rapid, non-destructive and accurate determinations of density and compaction of soils in the field, by the method of gamma ray scattering.

Equipment Needed

Equipment as listed under headings "Alternate (3)" and "Personnel Safety Equipment Common to All Methods" in outline of project entitled "Durability of Traffic-marking Paints."

Victoreen Instrument Co. 1B85 Thyrode Counter Tube . . . \$	7.50	
Nuclear Instrument and Chemical Corp. Model 166 Decade Scaler with automatic time operation	500.00	
110-volt, 60-cycle generator, portable . . . . .	500.00	
1 Mobile Laboratory . . . . .	2,500.00	
	<u>\$3,507.50</u>	\$3,507.50

Materials Needed

10 millicuries 55-F Cesium 137 (37 years half-life) \$20.00 plus \$10.00 handling charge . . . . .	\$ 30.00	
	<u>\$ 30.00</u>	\$ 30.00

TOTAL \$3,537.50

General Description

As reported in Technical Development Reports Nos. 127, 161, and No. 194, Civil Aeronautics Administration, Technical Development and Evaluation Center, Indianapolis, Indiana, October, 1950, February, 1952, and March, 1953, respectively.

The method consists of providing a source of gamma rays which is effectively shielded from the counter tube, yet which is made to traverse and penetrate the soil. Geometry is arranged such that only (as nearly as possible) those rays which are scattered by the soil are counted. Since scattering is a function of soil density, counts per minute become a measure of the density.

A great deal of work has already been done in developing and applying this technique, both at Cornell University and at the University of Saskatchewan. Both surface meters and depth probes have been developed, with varying radii of effectiveness. Design is extremely versatile.

Miscellaneous . . . . .	\$ 353.75	<u>\$ 353.75</u>
		\$3,891.25

## PROJECT VI - FIELD DETERMINATION OF SOIL MOISTURE

Purpose - To develop portable or mobile equipment for obtaining rapid, non-destructive and accurate determinations of soil moisture by the method of neutron scattering.

### Equipment Needed

Equipment as listed under headings "Alternate (3)" and "Personnel Safety Equipment Common to All Methods" in outline of project entitled "Durability of Traffic-marking Paints."

Equipment listed under Project (5).

### Materials Needed

Neutron sources with silver or indium foil. Exact nature and quantities to be determined.

### General Description

As reported in Technical Development Reports No. 127, No. 161, and No. 194, Civil Aeronautics Administration, Technical Development and Evaluation Center, Indianapolis, Indiana, October, 1950, and February, 1952, and March, 1953, respectively.

The method consists of providing a source of fast neutrons which is effectively shielded from the counter tube, yet which is made to traverse and penetrate the soil. Geometry is arranged in such a manner that only (as nearly as possible) those neutrons of "slow" velocities, which have been scattered and slowed down as a result of collisions with hydrogen atoms in the water molecules, are able to bombard and activate the silver or indium foil, which is wrapped around the counter tube and emits beta particles after activation, these being counted and counts per minute taken to be a measure of moisture content.

A great deal of work has already been done in developing and applying this technique, both at Cornell University and at the University of Saskatchewan. Both surface meters and depth probes have been developed, with varying radii of effectiveness. Design is extremely versatile.



## PROJECT VII - DETERMINATION OF THOROUGHNESS OF MIXING

Purpose - To establish the degree of thoroughness of mixing of highway materials, such as portland cement concrete, bituminous concrete, etc.

Method - Tracer technique using radioactive isotopes.

### Equipment Needed

Equipment as listed under "Alternate (3)" and "Personnel Safety Equipment Common to All Methods" in outline of project entitled "Durability of Traffic-marking Paints."

### Materials Needed

Radioactive isotopes of amounts and identities to be determined.

### General Description

It becomes of fundamental importance in many field applications, and in laboratory applications as well, to know for certain that adequate mixing has taken place in operations involving the mixing of materials. A classic approach to this problem has been to take samples at intervals until succeeding samples have the same proportions. Determination of proportion, however, is time-consuming, and any method giving a more rapid result would be considered with favor.

Incorporation of a radioactive isotope into a mixture would provide such a rapid method. A basic assumption would be that complete mixing has occurred when succeeding samples of the same weight would give the same number of counts per minute. Decontamination of the mixer would be facilitated by selection of an isotope having a short half-life. Chemistry of the isotope would have to be considered in relation to the ingredients of the mix, along with its propensity to exchange selectively with stable forms within the mix. Absorption and scattering phenomena would also have to be considered.

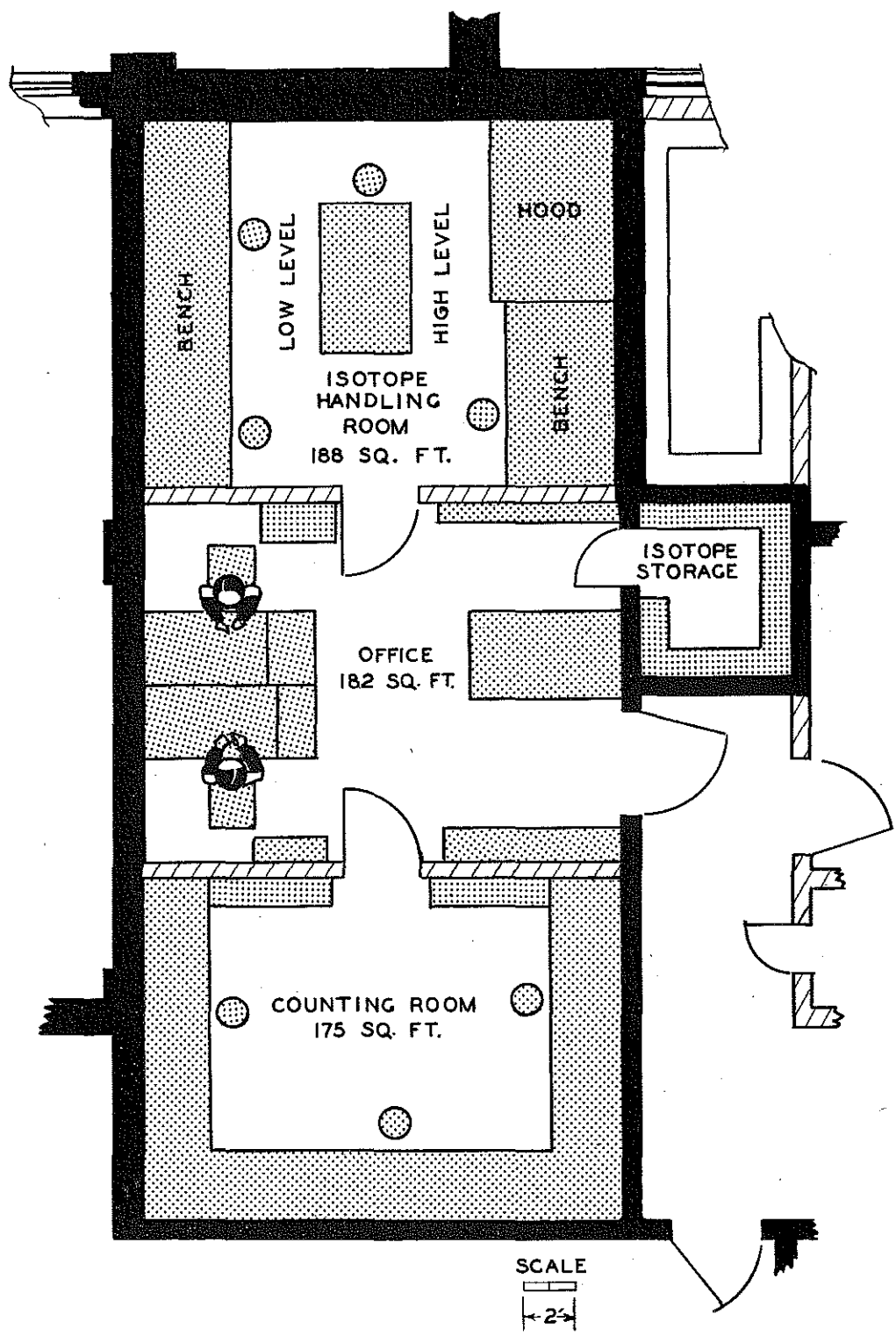


FIGURE I

**RADIOISOTOPE LABORATORY**  
MINIMUM REQUIREMENTS