Robert Lowenstein, Acting Director, Division of Licensing and Regulation

MAY 15 1961

Robert W. Kirkman, Director
Compliance Division, NYOO

TRANSMITTAL OF LICENSE COMPLIANCE INSPECTION REPORT - 10 CFR 30

CMP:PJK

Transmitted herewith is the following inspection report involving noncompliance:

EASTMAN KODAK COMPANY
Kodak Park Works
Rochester 4, New York

License Nos. 31-461-3 w/amends. thru 6
31-461-5 w/amends. thru 7

During the course of the inspection the following items of noncompliance were observed:

<u>License -3</u>

Condition 12 of License -3
- in that the licensee permitted work with byproduct material to be supervised by E. W. Junker when the only user authorized by this condition was on vacation. (See item 10 of the report details.)

Condition 14B of License -3
- in that the licensee had not conducted leak tests of the sealed Co-60 sources held under this license at 6 month intervals. (See item 13C of the report details.)

20.203 "Caution signs, labels and signals"
(b) - in that an area within the tank, designated as D-35, within which a person can receive a dose to the whole body in excess of 5 millrem, was not posted as required by this section. (See item 11 B of the report details.)

COMPLIANCE

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(c) - in that an area within the tank, designated D-35, within which a person can receive a whole body dose in excess of 100 millrem in any one hour, was not posted as required by this section. (See item 11B of the report details.)

(f)(1) - in that a container, within which was stored 14 millicuries of Co-60, was labeled with the words, "Danger - Radiation Hazard" and the standard radiation symbol, but was not labeled with the words, "Radioactive Material". (See item 11B of the report details.)

(f)(4) - in that the 2 containers within which were stored a 100 mc Co-60 sealed source and a 14 mc Co-60 sealed source were not labeled with the date on which this activity had been assayed. (This item was corrected in the presence of the inspector.) (See section 11B of the report details.)

(f)(1&4)- in that the storage well within which was stored 5 c of Co-60 bore no label of any kind. (See item 11B of the report details.)

License -5

Section 20.203

(f)(4) - in that the glove box within which was stored 0.5 mc of Fe-59, although labeled with the words, "Caution - Radioactive Material" and the standard radiation symbol, do not bare a statement of the kind, quantity or date of assay of the material within it. (See item 11B of the report details.)

Although work conducted under License -4 was not inspected, the following item of noncompliance, involving material held under this license, was observed:

Section 20.203 "Caution signs, labels and signals"
(f)(1&4) - in that the 2 containers within each of which was stored a 10 mc sealed Co-60 source, were not labeled with the standard radiation symbol, the words, "Caution - Radioactive Material" or a statement of the kind, quantity and date of assay of the material contained. (See item 11B of the report details.)

The items of noncompliance were discussed with Dr. W. L. Sutton, Director of the Radiation Safety Program and with Dr. Charles Fordyce, Technical Advisor to Clarance Wynd, Vice President and General Manager of the Kodak Park Works. Sutton and Fordyce stated that they would be happy to take any corrective action required by the Commission. With regard to 20.203(f)(4) citations for License -3&5, these items were corrected in the presence of the inspector.

No personnel hazard is apparent and no follow up will be scheduled.

It is recommended that a letter be sent to the licensee listing the items of noncompliance and requiring correction of them.

Enclosure:
1 cy of Rpt.

cc: Div of Cmp., Hq.
w/orig. of Rpt.

Form AEC-417
(4-58)

UNITED STATES ATOMIC ENERGY COMMISSION

COMPLIANCE INSPECTION REPORT

1. Name and address of licensee

EASTMAN KODAK COMPANY
Kodak Park Works
Rochester 4, New York

2. Date of inspection

April 19, 1961

3. Type of inspection Reinspection

4. 10 CFR Part(s) applicable

20 - 30

5. License number(s), issue and expiration dates, scope and conditions (including amendments)

License No.	Date	Exp. Date
31-461-3	6/23/60	6/30/62

amend. 6 (amended in its entirety)

SCOPE:
- A. 100 millicuries of Cobalt 60 as a sealed source (Technical Operations No. SK-747), to be used in the development of gamma ray sensitometer.
- B. 14 curies of Cobalt 60 as a sealed source (ORNL),
- C. 7.4 millicuries of Cobalt 60 as a sealed source (Technical Operations, Custom),
- D. 20 millicuries of Cobalt 60 as a sealed source (Technical Operations, Custom), all to be used for testing sensitivity of photographic emulsions to gamma rays.

CONDITIONS: #11-The licensee shall comply with the provisions of Title 10, Part 20, Code of Federal Regulations, Chapter 1, "Standards for Protection Against Radiation." #12-Byproduct material shall be used by, or under the direct supervision of, V. G. McIninch. #13-Byproduct

(CONT'D)

6. Inspection findings (and items of noncompliance)

Eastman Kodak Company employs approximately 22000 persons at the Kodak Park Works in Rochester. Approximately 30 persons work with byproduct material which is utilized for film calibration, research and development. The inspection covered organization and administration, byproduct material, facilities and scope of operations, instrumentation and calibration, radiological safety precautions and procedures, procurement, waste disposal, and records. During the course of the inspection the following items of noncompliance were observed:

License -3

Condition 12 of License -3
- in that the licensee permitted work with byproduct material to be supervised by E. W. Junker when the only user authorized by this condition was on vacation. (See item 10 of the report details.)

Condition 14B of License -3
- in that the licensee had not conducted leak tests of the sealed Co-60 sources held under this license at 6 month intervals. (See item 13C of the report details.)

(CONT'D)

7. Date of last previous inspection

July 30, 1959

8. Is "Company Confidential" information contained in this report? Yes ☒ No ☐
(Specify page(s) and paragraph(s))

DISTRIBUTION:
[illegible]
1 cy - DL&R
2 cys - NYOO

[illegible]
(Inspector)

Approved by: Robert W. Kirkman, Director
New York
(Operations office)

May 11, 1961
(Date report prepared)

If additional space is required for any numbered item above, the continuation may be extended to the reverse of this form using foot to head format, leaving sufficient margin at top for binding, identifying each item by number and noting "Continued" on the face of form under appropriate item.

16—73314-2 U. S. GOVERNMENT PRINTING OFFICE

RECOMMENDATIONS SHOULD BE SET FORTH IN A SEPARATE COVERING MEMORANDUM

ITEM 5 (CONT'D)

License No.	Date	Exp. Date
31-461-3 amend. 6	6/23/60	6/30/62

(amended in its entirety)

CONDITIONS: continued-
material as sealed sources shall not be opened. #14-Each sealed source containing Cobalt 60 shall be tested for leakage and/or contamination in accordance with the following:

A. An appropriate test for leakage and/or contamination shall be performed on the sealed source surface, or on the accessible surfaces of the device in which such a sealed source is permanently or semipermanently mounted. The test shall be performed upon receipt of a source from another person, unless the licensee receives certification from the person making the transfer that the sealed source had been tested within thirty (30) days prior to transfer and found free of any removable radioactive material.

B. Following completion of the test prescribed in A, each sealed source shall be tested for leakage and/or contamination at intervals not to exceed six (6) months.

C. The test performed pursuant to A or B shall be sufficiently sensitive to detect 0.05 microcuries of removable beta and/or gamma emitting radioactive material. Records of Leak test results shall be maintained by the licensee.

D. If the test performed pursuant to A or B reveals removable radioactive material, the licensee shall take immediate action to prevent spread of contamination and shall notify the Isotopes Branch, Division of Licensing and Regulation, U. S. Atomic Energy Commission, Washington 25, D. C. within thirty (30) days after completion of the test.

E. Repair of sources shall be performed by the manufacturers of the sources or by persons specifically licensed by the Commission to perform such repairs.

#25-Except as provided otherwise by this license, the licensee shall possess and use byproduct material described in Items 6, 7 and 8 of this license in accordance with statements, representations, and procedures contained in his application dated May 10, 1960.

31-461-5 amend. 7	7/7/60	7/31/62

(amended in its entirety)

SCOPE: A. 2 millicuries of Silver-110 in any form for use in studying the extent of physical development under normal development conditions.

ITEM 5 (CONT'D)

B. 1 millicurie of Carbon-14 in any form for use in studying the orientation of stearic acid molecules on metal surfaces;
C. 25 millicuries of Sulfur-35 in any form for use in studying fundamental photographic processes.
D. 20 millicuries of Iodine-131 in any form to be used for the determination of the mass of silver in developed spots on photographic films.
E. 3 millicuries of Iron-59 in any form for use in studying the distribution of iron in the "zone refining" of silver chloride.

CONDITIONS: #11-The licensee shall comply with the provisions of Title 10, Part 20, Code of Federal Regulations, Chapter 1, "Standards for Protection Against Radiation". #12-Byproduct materials shall be used by, or under the supervision of, A. E. Ballard, or Carl W. Zuehlke. #13-Byproduct material shall not be used in products distributed to the public. #14-Except as specifically provided otherwise by this license, the licensee shall possess and use byproduct material described in Items 6, 7 and 8 of this license in accordance with statements, representations, and procedures contained in his application dated June 28, 1960, and applications dated September 10, 1956, December 4, 1957, March 24, 1958, August 19, 1958.

ITEM 6 (CONT'D)

20.203 "Caution signs, labels and signals"

(b) - in that an area within the tank, designated as D-35, within which a person can receive a dose to the whole body in excess of 5 millrem, was not posted as required by this section. (See item 11B of the report details.)

(c) - in that an area within the tank, designated D-35, within which a person can receive a whole body dose in excess of 100 millrem in any one hour, was not posted as required by this section. (See item 11B of the report details.)

(f)(1) - in that a container, within which was stored 14 millicuries of Co-60, was labeled with the words, "Danger - Radiation Hazard" and the standard radiation symbol, but was not labeled with the words, "Radioactive Material". (See item 11B of the report details.)

(f)(4) - in that the 2 containers within which were stored a 100 mc Co-60 sealed source and a 14 mc Co-60 sealed source were not labeled with the date on which this activity had been assayed. (This item was corrected in the presence of the inspector.) (See section 11B of the report details.)

(f)(1&4) - in that the storage well within which was stored 5 c of Co-60 bore no label of any kind. (See item 11B of the report details.)

ITEM 6 (CONT'D)

License -5

Section 20.203
(f)(4) - in that the glove box within which was stored 0.5 mc of Fe-59, although labeled with the words, "Caution - Radioactive Material" and the standard radiation symbol, do not bare a statement of the kind, quantity or date of assay of the material within it. (See item 11B of the report details.)

Although work conducted under License -4 was not inspected, the following item of noncompliance, involving material held under this license, was observed:

Section 20.203 "Caution signs, labels and signals"
(f)(1&4) - in that the 2 containers within each of which was stored a 10 mc sealed Co-60 source, were not labeled with the standard radiation symbol, the words, "Caution - Radioactive Material" or a statement of the kind, quantity and date of assay of the material contained. (See item 11B of the report details.)

PART 30 INSPECTION

EASTMAN KODAK COMPANY
Kodak Park Works
Rochester 4, New York

Date of Inspection: April 19, 1961 (Announced Reinspection)

Persons Accompanying Inspector:

None (State Department of Labor notified but unable to attend)

Persons Contacted:

Dr. Charles Fordyce, Technical Assistant to the General Manager
Mr. E. W. Junker, Film Test Division, Radiation Safety Supervisor
G. L. McIninch, Senior Development Engineer
Ray Miller, Senior Chemist
Richard Scherberger, Industrial Hygienist
Dr. W. L. Sutton, Plant Physician, Radiation Safety Officer

DETAILS

9. Previous Inspection Activities

An initial inspection of the licensee was conducted on April 28, 1958. A reinspection was conducted on July 30, 1959. During the course of the reinspection no items of noncompliance related to these two licenses were observed.

10. Organization and Administration

Byproduct material held under License -3 is used exclusively by the Film Test Division which is headed by H. R. Sprental. Sprental reports to R. M. Wilson, Manager of Film Manufacturing, who in turn reports to the Vice President and General Manager of the Kodak Park Works, Clarence Wynd. G. L. McIninch, Senior Development Engineer in the Film Test Division, directly supervises work with byproduct material. Mr. E. W. Junker, is the Department Radiation Safety Supervisor. Eight persons actually work with byproduct material in such a manner as to be exposed to dose rates in excess of 0.5 mr/hr. The names of these persons and their years of experience with byproduct material are listed as Exhibit "A".

Byproduct material held under License -5 is used in the Analytical Chemistry Department which is headed by Dr. C. W. Zuehlke. Zuehlke reports to C. J. Stout, Director and Vice President of the Company. Stout confers with Wynd on matters relating to radiation safety. Ray Miller, Senior Chemist, uses byproduct material under the direction of Zuehlke. H. N. Clear, serves in the capacity of Radiation Safety Supervisor for the Department. Dr. H. Spencer, a Research Chemist and Mr. Barry Blackburn, a Technician also use byproduct material in the Analytical Chemistry Department, under the direct supervision of Zuehlke. Condition 12 of License -5 reads, "Byproduct materials shall be used by, or under the supervision of, A. E. Ballard, or Carl W. Zuehlke." Training and experience of these users are also found in Exhibit "A".

Condition 12 of License -3 reads, "Byproduct material shall be used by or under the direct supervision of V. G. McIninch."

Junker stated that McIninch,as always,supervised the used material under this license except for a period of two or three weeks when he was on vacation. Junker stated that he supervised work with licensed material during this period.

Radiation safety activities are centered in the Medical Department which is directed by Dr. J. H. Sterner. Dr. W. L. Sutton reports to Sterner and is responsible for the radiation protection program. Under Sutton's supervision two industrial hygienists, R. F. Scherberger and Frank A. Miller provide health physics services. Training and experience of Sutton, Scherberger and Miller appear in Exhibit "A".

A radiation protection committee for the Kodak Park Works meets from 4 to 5 times a year and includes the following members:

Dr. Fassett
Dr. Sutton
Dr. Charles Fordyce
Dr. Julian Webb
Mr. James Lees

This committee serves in an advisory capacity and passes on all new isotope uses and major changes in byproduct material applications.

11. Byproduct Material, Facilities and Scope of Operations

A. The following table presents information on the byproduct material on hand at the time of the inspection. Applicable license limits are also included for reference:

Isotope	(Activity/Form) On Hand	(Activity/Form) Authorized
License -3		
Co-60	Less than 100 mc/sealed T.O. No. SK-747	100 mc/sealed T.O. No SK-747
Co-60	5 c/sealed ORNL	14 c/sealed ORNL
Co-60	less than 7.4 mc/sealed T.O. custom	7.4 mc/sealed T.O. custom
Co-60	14 mc/sealed T.O. custom	20 mc/sealed T.O. custom
License -5		
Ag-110	.886 mc	2 mc/any
C-14	1 mc	1 mc/any
S-35	13.1 mc	25 mc/any
Fe-59	.5 mc	3 mc/any

B. Scope of Operations

License -3

The use of byproduct material under License -3 can be divided into 3 categories:

1) A radiation source sealed within an automatic/gamma ray sensitometer.
2) A large calibration source for film standardization.
3) Replacement sources for the sensitometer and sources for occasional film standardization.

Gamma Ray Sensitometer

The 7.4 mc Co-60 source is sealed within an automatic gamma ray sensitometer whose design and function are fully described in Exhibit "B". The design and operation of this device assure that the person using it can not be exposed to dose rates in excess of 0.05mr/hr and further, can not remove the source or shielding. The machine is used by at least 40 persons and is operated almost every day.

The sensitometer is stored in Room 630-11 of building 6A. The device was labeled with a standard symbol with the words, "Caution - Radioactive Material" and a statement of the kind, quantity and date of assay of the material contained. In addition, the room was posted with a sign bearing the standard radiation symbol and the words, "Caution - Radioactive Material". It was also observed that a copy of Form AEC-3 was posted on the wall of this room.

Calibration Source

The 5 c Co-60 source is the only source generally used for film calibration. It is attached to a wire cable and is stored in a well which extends 16 feet below ground level. The well is located in the center of a large metal tank which is identified as D-35. A drawing of this tank is included as Exhibit "C". The door providing access to this tank is locked and Junker is in charge of the key. A concrete wall 30" thick and 8 feet high is mounted just inside the access doorway. Controls are mounted on the doorway side of this wall which permit the operator to raise the source from its storage well without being exposed to high radiation levels. A 3" thick lead plug, which is also attached to the cable seals the storage well mouth when the source has been lowered into it. The device for raising the source is interlocked with a steel mesh door which prevents access to the high radiation field within the tank. Thus, it is impossible to lift the source from the well if the door leading to the radiation area is opened and it is impossible to open the door when the source is in the unshielded position. However, as noted in Exhibit "C" it is possible for a man to crawl, with some difficulty, through an opening, between the other end of the concrete wall and the tank side, which leads into the high radiation area. There was no label attached to the 5 c source or its control cable. No dose rate above background was observed on the shielded top of the source storage well.

Established procedures require that in order to use this source one must obtain permission from Junker and McIninch and sign a logbook before obtaining the key to the access doorway. An automatic timing device which is started and stopped by movement of the source cable is used to record the length of time that the source is exposed. This time must also be recorded in the use log when the key is returned. Finally, before the key is givento the user, Junker also assigns him a pocket dosimeter, and when the key is returned the user is required to enter the dosimeter reading in the source use log. The names in Exhibit "A" that are marked with an asterisk are those of persons who have used the 5 c source for the past 2 years. These names were obtained from the source use log.

A 100 mc Co-60 source and a 14 mc Co-60 source, both held under License -3, were stored in 2 boxes inside D-35. The container, within which the 100 mc source was stored, bore a lable which displayed the standard radiation symbol, the words, "Caution - Radioactive Material" and a statement of the kind, and quantity of material contained. However, no date of assay had been entered. The proper date was added to this label in the presence of the inspector. A dose rate of 5 mr/hr was observed on a Juno held 1 foot from the storage container. The container within which the 14 mc Co-60 source was stored bore a label displaying the standard radiation symbol and the words, "Danger - Radiation Hazard". In addition, entries had been made listing the kind and quantity of material in the container. No date of assay had been entered. In the presence of the inspector, the date of assay was added to this label. A dose rate of 10 mr/hr was observed on the Juno held 1 foot from this container.

Two 10 mc, sealed Co-60 sources in separate containers were also stored in D-35. These sources were being held under License 31-461-4. A Juno held 1 foot from each container indicated a dose rate of 15 mr/hr. Each of these 2 containers was not posted with the standard radiation symbol or the words, "Caution - Radioactive Material". In addition, there was no statement of the kind, quantity or date of assay of the material contained on either container.

The door to D-35 was posted with a sign bearing the standard radiation symbol and words, "Caution - Radioactive Material". In addition, a copy of Form AEC-3 was posted on the operator's side of the concrete wall. It was noted however, that signs bearing the words, "Caution - Radiation Area" and "Caution - High Radiation Area", had not been posted inspite of the fact that measurements with a Juno revealed dose rates of from 5 to 7 mr/hr behind the concrete wall and 25 mr/hr at contact when the interlocked doorway when the 5 c source was unshielded. The source use log book showed the source to have been exposed for periods greater than 1 hour. The location of sources, signs and measured dose rates are indicated in Exhibit "C".

License -5

Materials held under License -5 are used as tracers in following chemical processes. The table below summarizes the quantity used per experiment and the frequency of use of material on hand:

Isotope	Quantity Used Per Experiment	Frequency of Use
Ag-110	10 uc	Used steadily, 2 experiments per week.

Isotope	Quantity Used Per Experiment	Frequency of Use
C-14	--	Has not been used for 1 year.
S-35	30 uc	Used steadily, 2 experiments per week.
Fe-59	1 mc	Experiment lasts 3 months only one experiment done.

All of the above material, with the exception of Fe-59, was stored in containers that bore labels displaying the standard radiation symbol, and the words, "Caution - Radioactive Material" and a statement of the kind, quantity and date of assay of the material within. The glove box within which the .5 mc and Fe-59 were stored bore a label displaying the standard radiation symbol, and the words, "Caution - Radioactive Material". However, there was no statement of the kind, quantity and date of assay of this material. This information was added to the glove box label in the presence of the inspector.

All of the material held under License -5 is stored and used in an isotope laboratory on the second floor of building 54. This laboratory is designated as room 214 and is locked when not attended by persons who normally work with licensed material. It was noted by the inspector that the door to the laboratory was posted with a sign bearing the standard radiation symbol and the words, "Caution - Radioactive Material".

Condition 13 of License -3 reads, "Byproduct material as sealed sources shall not be opened". Sutton reported that byproduct material as sealed sources had never been opened.

Condition 13 of License -5 reads, "Byproduct material shall not be used in products distributed to the public". Sutton stated that byproduct material held under this license has never been used in products distributed to the public.

12. Instruments

The following instruments were on hand at the time of the inspection:

Instrument	Manufacturer	Model
(Instruments held at Industrial Hygiene Office for use as required.)		
2 GM survey instruments	Nuclear Chicago	2612
1 Ionization chamber survey instrument	Jordan	AGB 10SR (contains 1 mc Sr-90 calibration source)
1 Cutie Pie	Nuclear Chicago	2586
1 Alpha survey meter	Victoreen	356

Instrument	Manufacturer	Model
Condenser R meter	Victoreen	
1 count rate meter	Nuclear Chicago	1620 A
1 scaler (with thin window and windowless proportional counter chambers)	Nuclear Chicago	186
(Instruments at Isotope Lab)		
1 count rate meter (with thin window GM tube)	Eberline	RM3
1 GM survey instrument	Nuclear Chicago	2612
Scaler (with GM tube or proportional chamber)	Tracerlab	
One utility scaler (with GM tube and proportional chamber)	Tracerlab	

Sutton reported that all portable survey instruments have been calibrated against a 20 milligram radium source. He stated that this calibration took place in February 1961, and that it was the only calibration that had been done. Scalers are regularly checked with generally licensed sources.

13. Radiological Safety Precautions and Procedures

A. Instructions

Sutton reported that the company relies on on-the-job training to assure that all persons who work with radioactive material received adequate instruction. In addition, Sherber, Junker and Clear have received three hour sessions of lectures in radiation safety. These lectures, which were given by Sutton, covered biological effects of radiation, instrumentation and its use, and the operation of the Kodak Radiation Protection Program.

B. Surveys

Sutton reported that surveys are conducted on a regularly scheduled basis as well as whenever the work requires them. Material held under Licenses -3&5 is surveyed at least 4 times a year. In addition, each new source is surveyed upon receipt and when it is put into use. On-the-job surveys are also conducted as required. According to Sutton, these surveys include dose rate measurements and contamination checks.

Sutton displayed records of surveys covering the period from 1956 to the present. In each case, surveys had been made under the most adverse conditions. The records were reviewed by the inspector and were found to contain information on the surveyor, the method of conducting the survey, the date, and the radiation levels observed.

C. Leak Testing

All sealed sources held under License -3 had been received before the date that a leak testing requirement was added to the license. The first reference to leak testing appears in Condition 14 of Amendment 6 of the license, which was issued on June 23, 1960. The Kodak leak test records indicate that 3 of the sealed Co-60 sources (7.4 mc, 20 mc and 100 mc) were leak tested on March 8, 1961. The records further showed that the 5 c Co-60 source was leak tested on February 23, 1961.

The inspector pointed out that the leak testing of sealed Co-60 sources is required at 6 month intervals. Sutton stated that it was Kodak's intention to leak test on a 6 month schedule but that, through an oversight, slightly more than 6 months had elapsed before the first leak test was conducted.

Leak testing of byproduct material held under License -5 is not required.

D. Personnel Monitoring

Personnel monitoring is accomplished through the use of film badges. The badges are supplied and evaluated by Kodak. Badges worn when material held under License -5 is used, are changed only once every 5 or 6 months. Badges used for operations with material held under License -3 are changed monthly. The disadvantages involved in using film badges for long periods of time (possibly of damage, exposure to moisture, excess heat, etc) were fully discussed with Sutton.

Sutton displayed records of film badge evaluation covering the period from 1958 to the present. These records were reviewed by the inspector. No overexposures were observed. The majority of exposures were reported as minimal.

14. Procurement Procedures, Control and Procurement Records

Sutton reported that he reviews and approves all orders for byproduct material and assures that license limits are not exceeded. An established company procedure assures that Sutton is notified when byproduct material is received. Packages containing byproduct material are not opened unless Sutton has given permission for this to be done.

Sutton reported that records of the receipt of byproduct material have been regularly maintained since before 1956. He displayed records covering the period from 1959 to the date of this inspection. These records were reviewed by the inspector and were found to include information on the date, supplier, isotope and quantity of the material received. In no instance of the receipt of quantities of byproduct material in excess of those authorized, was observed by the inspector.

15. Waste Disposal and Disposal Records

Byproduct material is disposed of in 3 ways:

1) Use of the sanitary sewer system
2) Transfer to ORNL
3) By burial at a reserved site within the area occupied by the company

Sutton reported that records of disposal have been kept since 1956.

He displayed records covering the years 1959, 1960 and 1961. These records were reviewed by the inspector and were found to contain information on the date of disposal, quantity of material disposed of, isotope method of disposal, and the person performing the disposal. No case of the disposal of quantities in excess of these listed in Part 20 were observed.

Name	Position	Years of Experience with Byproduct Material	Special Training
MEDICAL DEPARTMENT RADIATION SAFETY PERSONNEL			
F. MILLER	INDUSTRIAL HYGIENIST	5	1 WEEK RADIATION MONITORING TRAINING AT UNIVERSITY OF ROCHESTER; 2 COURSES IN RADIATION BIOL... CANECIUS COLLEGE
R SCHERBERGER	INDUSTRIAL HYGIENIST	5	1 WEEK RAD MONITORING TRAINING ...; 2 WEEK RADIATION SAF... COURSE AT NEW YOR... UNIVERSITY; 2 COURSES IN RADIATION BIOL... CANECIUS COLLEGE
W. SUTTON	PLANT PHYSICIAN HEAD OF RADIATION SAFETY PROGRAM	7	M.D. AEC SPECIAL FELLOWSHIP INDUSTRIAL MEDICINE 50% RADIATION BIOLOGY

EXHIBIT A. EASTMAN KODAK COMPANY
BYPRODUCT MATERIAL USERS, PAGE 3.

PHO[illegible] [illegible]NG
Volume 4, Number 2, March-April 1960

An Automatic Gamma-Ray Sensitometer Using Cobalt-60 Foil Sources

V. G. McIninch, *Film Testing Division*, and H. M. Cleare,
Research Laboratories. Eastman Kodak Company, Rochester, N.Y.

A sensitometer is described for exposing film between lead-foil intensifying screens in a four-step sensitometric series, using thin cobalt-60 foils as the radioactive sources. With source activities totaling about 7 millicuries, exposure times for industrial-type x-ray film range from 10 to 200 sec. Film samples in lead-screen cassettes are stacked in a hopper outside the source shielding. From the hopper they are automatically transported to the exposing position in sequence, exposed, and discharged outside the shielding. Shielding is sufficient to reduce the radiation to a factor of two or three above background. The mathematical theory of the design of the sensitometer is also presented.

In the quality-control testing of x-ray emulsions, the Film Testing Division of Eastman Kodak Company utilizes exposures from a variety of x-ray and radioactive sources. One type of test involves obtaining a sensitometric series of exposures to gamma radiation typical of that used in the field of industrial radiography. In such radiography, the film is usually exposed while sandwiched between lead-foil intensifying screens. From the sensitometric exposure series, the characteristic curve of the emulsion sample, and hence speed, contrast, etc., for this type of application, is obtained.

For many years, such an exposure series was made by modulating the radiation from a radium source with lead step tablets.[1] A variety of systems, including time-scale and multi-source intensity-scale exposure methods, as well as step-tablet modulation have been reported by others for similar purposes.[2,3] In general, such methods require either exposure times of several hours using sources of low enough activity for safe and easy manipulation, or extensive shielding and safety precautions with sources of sufficient activity to yield adequate exposure in a short time. Space requirements and radiation-scatter problems frequently make shielding with absorbing materials impractical. Distance may be substituted for shielding but it then becomes necessary to conduct the exposures in locations inconveniently remote from personnel-occupied or film-storage areas.

With the large increase in recent years of industrial radiography using high-energy x- and gamma-rays, the development of a more convenient testing facility which would not involve long delays for exposure became necessary. The principal specifications for this development were: (1) exposure times not to exceed 1 hr for the slowest emulsions to be tested; (2) operation sufficiently automatic that an operator is not required in constant attendance; (3) radiation shielding sufficient to permit location of the device relatively near film-storage areas in the same laboratory as other equipment involved in testing these types of film. This last specification led to the choice of 0.7 milliroentgen per hour as a design objective for the maximum radiation leakage outside the shielding. With regard to personnel safety, this leakage figure limits maximum possible radiation dosage to at least a factor of 10 below applicable limits recommended by the National Committee on Radiation Protection.

Sensitometer Design Principles

If the requirement of a short exposure time were to be satisfied by simply increasing the source strength, the sensitometer would require some 40 curies of cobalt-60 and tons of shielding. Such a method of providing a sensitometric exposure series is an exceedingly inefficient means of utilizing the radiation flux emitted by a source since less than 0.1% of the flux reaches the required exposure area of the film. The remaining 99.9+% must be absorbed in massive shielding without contributing to the exposure.

If exposures can be made with the film in intimate contact with the radioactive source, then nearly

Presented at the National Conference, Chicago, 27 October 1959. Communication No. 2047 from the Kodak Research Laboratories, received 2 October 1959.

1. V. G. McIninch and S. W. Foor, unpublished data, Film Testing Division, Kodak Park Works, Eastman Kodak Co., 1947.
2. D. P. Jones, *Phot. Eng.*, 6: 167 (1955).
3. W. C. Brandsma, E. J. Pence, and T. T. Reboul, *Phot. Sci. & Eng.*, 1: 9 (1957).

half of the available radiation flux reaches the film.* Consequently, a much smaller source can be used and the shielding problems are considerably simplified.

A number of systems for producing a sensitometric exposure series or continuous "wedge" exposure by placing the film very near a distributed source were analyzed mathematically. Both linear and planar sources were considered with various relative film and/or source motions. Several of these systems may have been workable but most of them involved complex mechanical systems for producing the relative source-film motion.

The least complicated design, finally selected, uses a separate planar source for each step of an intensity-scale exposure series. The film to be exposed is sandwiched between lead-foil intensifying screens and rapidly brought into as close contact as practical with the sources. The film is held in this position for the duration of the exposure and then rapidly retracted to terminate the exposure.†

The sources must be spaced so that radiation from one source does not appreciably affect the exposure of film areas over adjacent sources. Thus, only a limited number of steps of an exposure series can be obtained on a reasonable-size film sample. Additional steps, however, can be obtained by exposing additional samples for other times. This procedure is valid since, unlike light exposure, there is no reciprocity failure or intermittency effect with x- or gamma-rays at all exposure levels below that required for reversal.[4,5] Thus, either an intensity-scale or time-scale exposure series, or a mixture of the two, can be used without materially affecting the results.

Also, at least for practical radiographic purposes, the sensitometric-curve shape, except for placement along the log exposure axis (speed), is independent of the x- or gamma-ray source used for exposure. Therefore, curve shape can be obtained from an x-ray exposure (a more readily modulated source of ionizing radiation), and the exposure to the gamma-ray sources can be used to establish speed, thus completely defining the sensitometric curve of the film for the gamma-ray source in question. The validity of this procedure has been verified by Newton et al.[6] and is in agreement with work done by Tochilin et al.[7] and more recently by Splettstosser and Seemann.[8]

Design Considerations

In order to determine the source diameter, activity, spacing from the film and from adjacent sources, etc., the radiation field equation near a plane-circular source was derived mathematically (see Appendix I). This equation has been derived previously by others.[9] It is assumed that the source is of zero thickness. Since a practical source can only approximate this condition, the equation for a source in the form of a right circular cylinder was also derived. The general case for the radiation field near such a source cannot readily be expressed in closed form. However, the special case of the intensity along the axis of the cylinder was derived and evaluated (see Appendix II). For thin sources such as those used in the final sensitometer, the assumption that the source could be considered as a plane was found to be valid within a few percent for the intensities along the axis of the cylinder.

Figure 1 illustrates the calculated distribution of intensity, normalized for a source of radius (a), at the film plane as a function of distance (b) from the axis of the source. The four curves are for different source-to-film distances (h). The curves are normalized so that they are applicable to various source radii, source-to-film distances, displacements from the axis, and source activities ($q\Gamma$).

Most x-ray films exposed in this sensitometer are coated with an emulsion on each side of the film support. Assuming a source-to-film distance of 0.015 in., the emulsion adjacent to the source receives approximately 1.2 times as much exposure as the more distant emulsion. This difference in exposure will produce a sensitometric curve shape that is slightly different from that obtained by exposing each emulsion equally, because of the nonlinear relationship between exposure and density. This results in an error of only about 1% in determining the gamma-ray speed of the radiographic films.

The following specifications were used with the derived equations to determine required source dimensions and placement:

1. The film-to-source distance should be 0.015 in. to allow space for a lead-foil intensifying screen in contact with the film, an abrasion-resistant cover on the lead screen on the side toward the source, and a protective cover over the radioactive material.

2. With a uniformly distributed source, the exposure of the film should be uniform to within ±1% over a 0.25-in. diameter area in the center of the exposed region.

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*For all practical purposes, the radiation flux from an element of area of a flat cobalt-60 source is independent of the angle of emission since the self-absorption for gamma radiation may be neglected. The sensitivity of the film also remains essentially constant with respect to angle of incidence since its absorption is small for gamma radiation. It should be noted that, unlike light, x-radiation or gamma radiation is so penetrating that grains are exposed throughout the volume of the emulsion. Hence, the cosine law does not hold either for the gamma-ray emitter or for the film as a receiver.

†A somewhat similar sensitometer is described by Brandeau et al.[3] These instruments were developed independently but are basically identical in method of exposure.

4. M. Ehrlich and W. L. McLaughlin, *J. Opt. Soc. Amer.*, 46: 797 (1956).

5. M. Ehrlich, *ibid.*, 801.

6. J. A. Newton, W. R. Rust, and E. W. Junker, unpublished data, Film Testing Division, Kodak Park Works, Eastman Kodak Co., 1957.

7. E. Tochilin, B. W. Shumway, and G. D. Kohler, *Radiation Res.*, 4: 467 (1956).

8. H. R. Splettstosser and H. E. Seemann, unpublished data, Research Laboratories, Eastman Kodak Co., 1959.

9. W. V. Mayneord, *Brit. J. Radiol.*, 5: 675 (1932).

EXHIBIT B PAGE 2

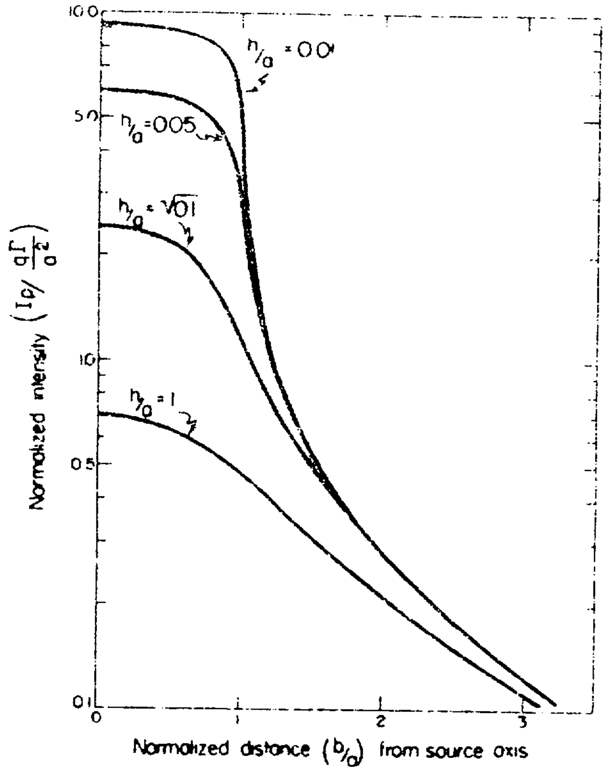

Fig. 1. Radiation distribution about a thin disk of uniformly emitting radioactive material. The normalized intensity vs. distance from the axis of the source is plotted for four ratios of height-to-source radius (h/a). The radiation field is symmetrical about the axis of the source (b/a = 0). (The equation is derived in Appendix I.)

3. Radiation reaching this 0.25-in. diameter area from adjacent sources should contribute less than 1% to the exposure.

4. Adjacent sources should produce exposures differing by a factor of 2.

5. The most active of the four sources should produce sufficient exposure in 10 sec with lead screens, to develop to a density of 3.0 on the most sensitive x-ray films.

To satisfy all these specifications, the sources must be at least 0.72 in. in diameter, the center-to-center spacing of adjacent sources must be at least 1.85 in., and the most active source requires 3.9 millicuries of cobalt-60.

Source Bar and Shielding

Figure 2 shows the final machine utilizing four sources, in a design fully meeting the requirements for short exposure times and safe, automatic operation in an occupied area.

The sources consist of either circular foils or electroplatings of cobalt-60, 0.75 in. in diameter and 0.001 in. or less in thickness, sealed in a stainless-steel bar, as shown in Fig. 3. They are spaced 2 in. apart on centers and in contact with 0.005-in.-thick

Fig. 2. Cobalt-60 sensitometer.

stainless-steel "windows" in the face of the bar. The total activity of these sources is a little more than 7 millicuries, distributed in the ratios 1:2:4:8, i.e., each source differs from adjacent ones by a factor of 2.

This source bar was made to specification, loaded, and sealed by Technical Operations, Inc., Burlington, Mass. It is mounted on a tungsten alloy (Heavimet) cylinder in a steel-jacketed lead container (Fig. 4), which serves both as shipping container and as part of the shielding of the complete instrument. For shipment, the source bar is rotated away from the container opening, as in Fig. 4, so that the Heavimet cylinder shields the opening.

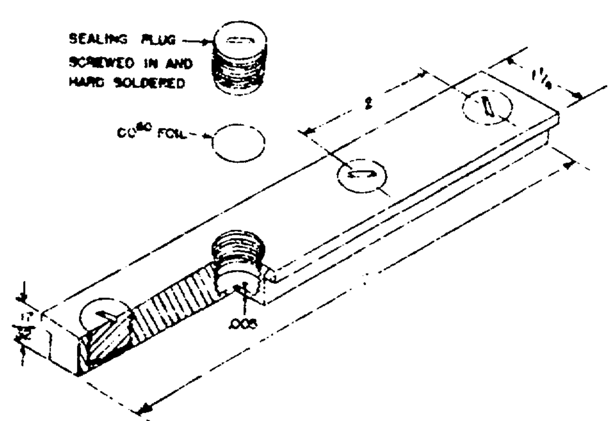

Fig. 3. Cobalt-60 source bar. The bar and plugs are made of stainless steel. The four cobalt-60 sources are either foils as shown or thin electroplatings.

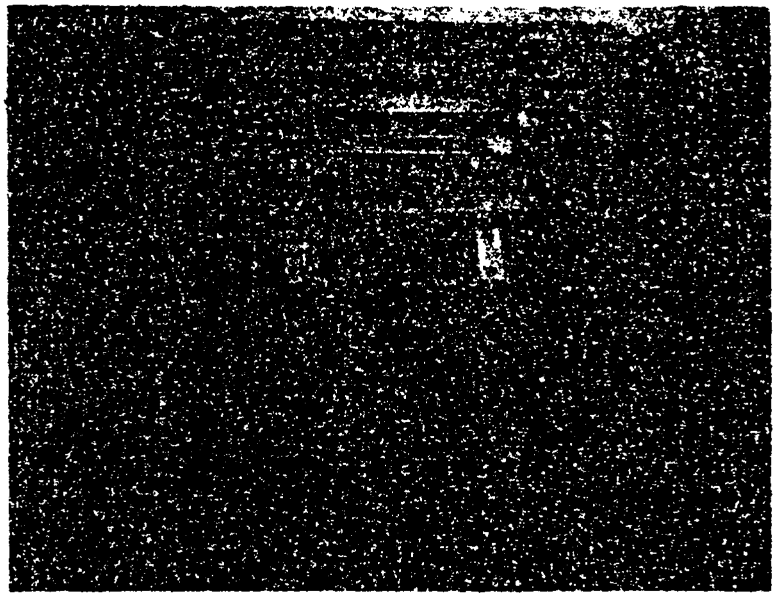

Fig. 7. View of sensitometer with upper shielding, shipping container, feed hopper, and table top removed. Carriage is shown pushing a cassette toward the elevator platform. Two additional cassettes are in the hopper position.

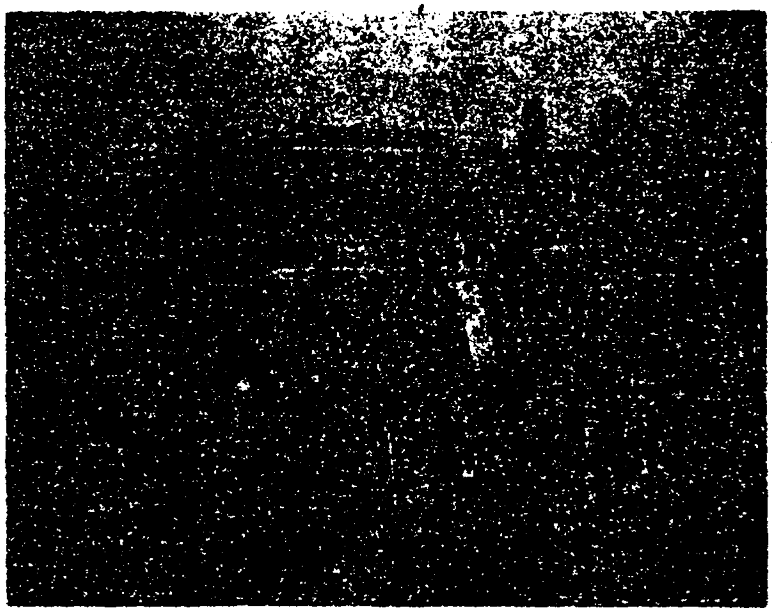

Fig. 8. Cassette in exposing position against a dummy source bar which is mounted in normal position on a temporary alignment jig. The carriage is retracted for picking up the next cassette from hopper position.

Cassette-Transport Mechanism

The cassettes containing film samples are manually loaded, window side up, in the feed hopper (see Fig. 5), in batches of 50 or less. When the sensitometer is started, the bottom cassette is transported by a pneumatically driven carriage through the feed channel in the shielding and positioned on the platform of an elevator mechanism. This elevator is driven to three positions by two pneumatic cylinders in series. From the load (central) position it lifts the cassette about 2 in. to press it against the source bar and closes a switch to start a timer (top of Fig. 2) which has been preset by the operator. At the end of this preset time, both cylinders of the elevator mechanism retract, lowering the cassette to a point below the loading position where a cam pushes it off the elevator platform into the ejection chute through which it discharges to a catch bin outside the shielding. The discharge action also resets the timer and starts a repeat cycle with the next cassette. The machine continues to cycle automatically until the last cassette in the feed hopper has been discharged. If desired, additional cassettes for the same exposure time may be added at any time until the hopper is full. Figures 7, 8, and 9 show the machine with sections of the shielding removed to expose the transport mechanism.

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Fig. 9. Pneumatic cylinders, limit switches, and coiled (flexible) air and electrical lines of the elevator mechanism as seen by removing service access panel in the lower shielding.

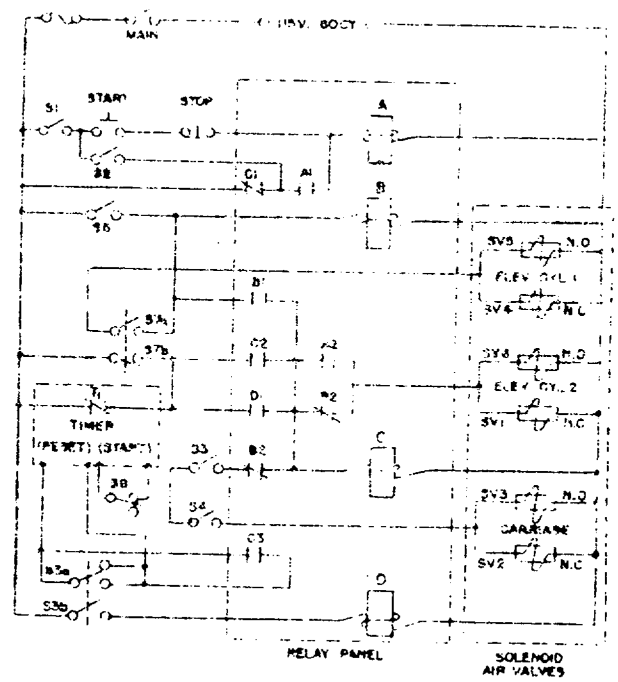

Fig. 10. Schematic diagram of electrical control circuit.

Sequence Control and Electrical Circuit

The compressed-air supply to the three double-acting pneumatic cylinders, which power the mechanical motions for transporting and positioning the film cassettes, is controlled by solenoid valves in the electrical circuit shown in Fig. 10. The control elements in this circuit are the manual start-stop buttons, the preset timer, and limit switches mechanically operated by the pneumatic cylinders near the ends of their strokes. The operation is strictly sequential in that each phase of the cycle is dependent on completion of the preceding one. Table I, in the next column, lists the control switches in sequence of operation, along with their mode of actuation and the function controlled.

With the air-pressure regulator set at 35 psi, the operating time for a complete cycle is about 3.6 sec plus the exposing time.

The exposure timer is a Freed Transformer Co. electronic-counting-type preset timer, utilizing 60-cycle line frequency as the timing base. Five decade selector switches on the timer panel permit setting the timed interval in 0.1-sec increments from 0.1 to 10,000 sec. It is automatically reset at the end of a cycle by the sequential operation of limit switch S3a and relay contact C3 as the cassette elevators reach down (discharge) position.

TABLE I

Switch	Operated by	Function controlled
Main	Operator	Energizes circuit
S1, S2	Cassette in hopper	Enables start circuit
S3a	Both elevator cylinders down	Resets timer
S3b	Both elevator cylinders down	Enables start circuit
S4	Elevator cylinder 2 down	Enables start circuit
Start	Operator	Starts elevator cylinder 1 up
S5	Elevator cylinder 1 up	Starts carriage in (Moves cassette to elevator platform)
S6	Carriage in	Starts carriage out
S7a, S7b	Carriage out	Starts elevator 2 up (Moves cassette to expose position)
S8	Elevator cylinder 2 up	Starts timer
T	Timer at preset time	Starts elevators down (Discharges cassette)
S3a, S3b, S4	Both elevator cylinders down	Starts cycle repeat
Stop	Operator (optional)	Prevents cycle repeat

Notes: Timer is reset by a momentary "open" in reset circuit.
Timer operates when start circuit is open.

Radiation Protection During Maintenance

The complete carriage mechanism is mounted on an easily removed plate which projects into the feed channel. Removal of this plate provides an opening large enough for the insertion of a 1.25-in.-thick Heavimet slab to block off radiation from the elevator-mechanism space. This permits removal of the service panel in the lower shielding for access to the elevator mechanism without chance of exposure to abnormal radiation levels. The complete elevator mechanism is also mounted on a single plate which may be removed through the opening provided by removal of the service panel.

It is anticipated that the cobalt-60 sources will be renewed when they have decayed to about half their initial activity (after 5 years). To avoid a long "down time" for the sensitometer while new sources are being installed, a second shipping-container assembly was built which can be loaded in advance with the new source bar. The exchange can then be made with a down time of as little as 1 hr. The old source bar, in its shipping container, may then be returned to the supplier for disposal and reloading as required.

Source Calibration

A photographic photometry method was used to calibrate the effective exposures produced at the exposure plane in the sensitometer. A conventional radiographic cobalt-60 capsule, certified as to gamma-ray intensity by the National Bureau of Standards, was used as the reference source. The photographic medium used was a specially selected and seasoned coating of Kodak Industrial X-ray Film, Type AA.

Under carefully controlled conditions, samples of the film were exposed to the reference source, to the sources in the cobalt-60 sensitometer, and to 80-kv x-rays in a 20-step time-scale sensitometer. All samples were processed together in a sensitometric processing machine, using conventional x-ray solutions. The x-ray exposures were used to determine precisely the shape of the x-ray sensitometric curve of the film and the reference-source exposures were used to establish the gamma-ray log E scale for this curve. Values from this scale corresponding to the densities of the cobalt-60 sensitometer exposures were then taken as the log E values for the instrument for the particular exposure time involved.

The exposures to the reference source were made in the laboratories of Technical Operations, Inc., Burlington, Mass., whereas the other exposures were made, and the processing was done, in Rochester, N.Y. This necessitated an appreciable time lapse between the reference exposures and processing. Therefore, a latent-image-keeping exposure series was made during this period and the results were used to correct for the small changes encountered. Also, special vaporproof packaging was used to minimize the effect of variable atmospheric conditions on the keeping properties of the film during transit. Statistical study of the calibration data indicates that the values obtained are accurate within ±0.03 in log E.

Performance

The four-step exposure series produced by this instrument does not alone give sufficient information for an accurately defined sensitometric curve. However, in conjunction with a more detailed x-ray exposure series for defining curve shape, it does give complete and reliable information for evaluating the gamma-ray sensitometric properties of films. The response of the sample to x-ray exposure is also usually desired at the same time and x-ray sensitometers are available in the same laboratory area for this purpose. Therefore, very little additional work is involved in evaluating the two sets of exposures in a common curve, and this is more than offset by the convenience of location of the exposing facility and the greatly reduced exposure times required. Furthermore, if more detailed data for a curve from cobalt-60 exposure only are desired, they can be obtained simply by exposing two or more sample strips at different exposure times.

As an example of the exposure time required, a density of 3.5 to 4.0 was produced on Kodak Industrial X-ray Film, Type AA, by the most intense source in about 1 min, at the time of calibration of the source bar. Other materials required from 10 sec for the fastest films, to about 20 min for the slowest films normally tested with gamma-ray exposure. Since cobalt-60 decays at a known exponential rate (half-life of 5.26 years), it is necessary to adjust these exposure times frequently to compensate for the loss in intensity. In practice, this adjustment is made once each month, which holds the exposures constant within 0.01 in log roentgens. In about 5 years, the exposure times will have doubled, at which time it is anticipated the source bar will be replaced with a new one.

Some difficulty was encountered in obtaining the desired uniformity over the area of the electroplated sources used in the original source bar. This nonuniformity of source activity causes a mottle pattern within the spot area which requires precise positioning in the densitometer to get reproducible results. With a densitometer having a 5-mm reading aperture, density variation equivalent to about 0.02 in log exposure is obtained within the central 1-cm circular area of the steps. The most intense source, which is a foil rather than an electroplating, shows much better uniformity. Preparation of foil sources of desired strengths is being investigated so that future source bars can be prepared in this way rather than by electroplating.

Acknowledgments

We wish to extend special thanks to Dr. Eric T. Clark, of Technical Operations, Inc., for his cooperation and suggestions in the design and construction of the cobalt-60 source bar. Also, we thank W. B. Hausler and R. J. Herberger, of the Kodak Park Engineering Division, for their contributions to the mechanical and electrical design and to J. A. Newton, F. H. Holland, and E. W. Junker,

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of the Kodak Park Film Testing Division for experimental work, checking calculations, and similar operations in the various schemes considered in this development.

APPENDIXES

APPENDIX I — Derivation of the Radiation Field Distribution Around a Thin Flat Disk of Uniformly Emitting Radioactive Material

Assumptions:

1. The source is assumed to have zero thickness.
2. The self-absorption of the source is negligible.

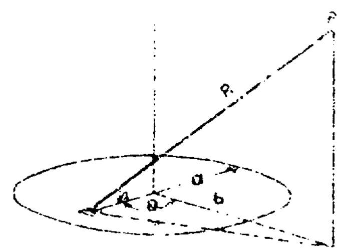


Figure 11

The intensity I_p at a point P, Fig. 11, a distance b from the axis and a distance h from the plane of a uniformly emitting radioactive disk of radius a is proportional to the summation of intensities contributed by the individual elements of area $r\,dr\,d\theta$ and is inversely proportional to the square of the distance R from these elements of area.

Therefore:

$$\Delta I_p = \frac{q\Gamma}{\text{Area}} \cdot \frac{\Delta\ \text{Area}}{R^2}$$

where q is the activity of the source and Γ is the gamma-ray dose-rate constant relating gamma-ray intensity to source activity. (For Co 60, Γ = C 13.5 cm²-r/mc-hr) Then,

$$I_p = \frac{q\Gamma}{\pi a^2} \int_0^a \int_0^{2\pi} \frac{r\,dr\,d\theta}{r^2 + h^2 + b^2 - 2br\cos\theta}$$

Integrating between these limits yields:

$$I_p = \frac{q\Gamma}{a^2} \ln \frac{a^2 - b^2 - h^2 + \sqrt{(a^2 - b^2 + h^2)^2 + 4b^2h^2}}{2h^2}$$

For the special case of point P lying on the axis of the disk ($b = 0$), the general solution reduces to

$$I_p = \frac{q\Gamma}{a^2} \ln \frac{a^2 + h^2}{h^2}$$

APPENDIX II — Derivation of the Radiation Field Along the Axis of a Right Circular Cylinder of Uniformly Emitting Radioactive Material

The intensity I_p at a point P, Fig. 12, on the axis and a distance h from the end of a uniformly emitting right circular cylinder of radioactive material of radius a and

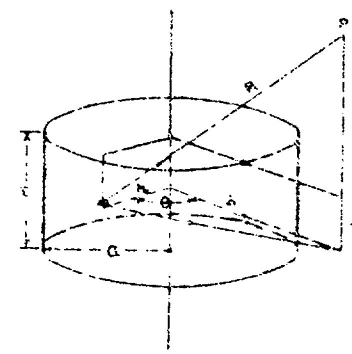


Figure 12

height t is proportional to the summation of intensities contributed by the individual elements of volume $r\,dr\,d\theta\,dz$ and is inversely proportional to the square of the distance R from the element of volume. The self-absorption of the source is assumed to be negligible.

Therefore:

$$\Delta I_p = \frac{q\Gamma}{\text{Volume}} \cdot \frac{\Delta\ \text{Volume}}{R^2},$$

where q is the activity of the source and Γ is the gamma ray dose-rate constant.

Then,

$$I_p = \frac{q\Gamma}{\pi a^2 t} \int_0^t \int_0^a \int_0^{2\pi} \frac{r\,dr\,d\theta\,dz}{r^2 + b^2 - 2br\cos\theta + (h + z)^2}$$

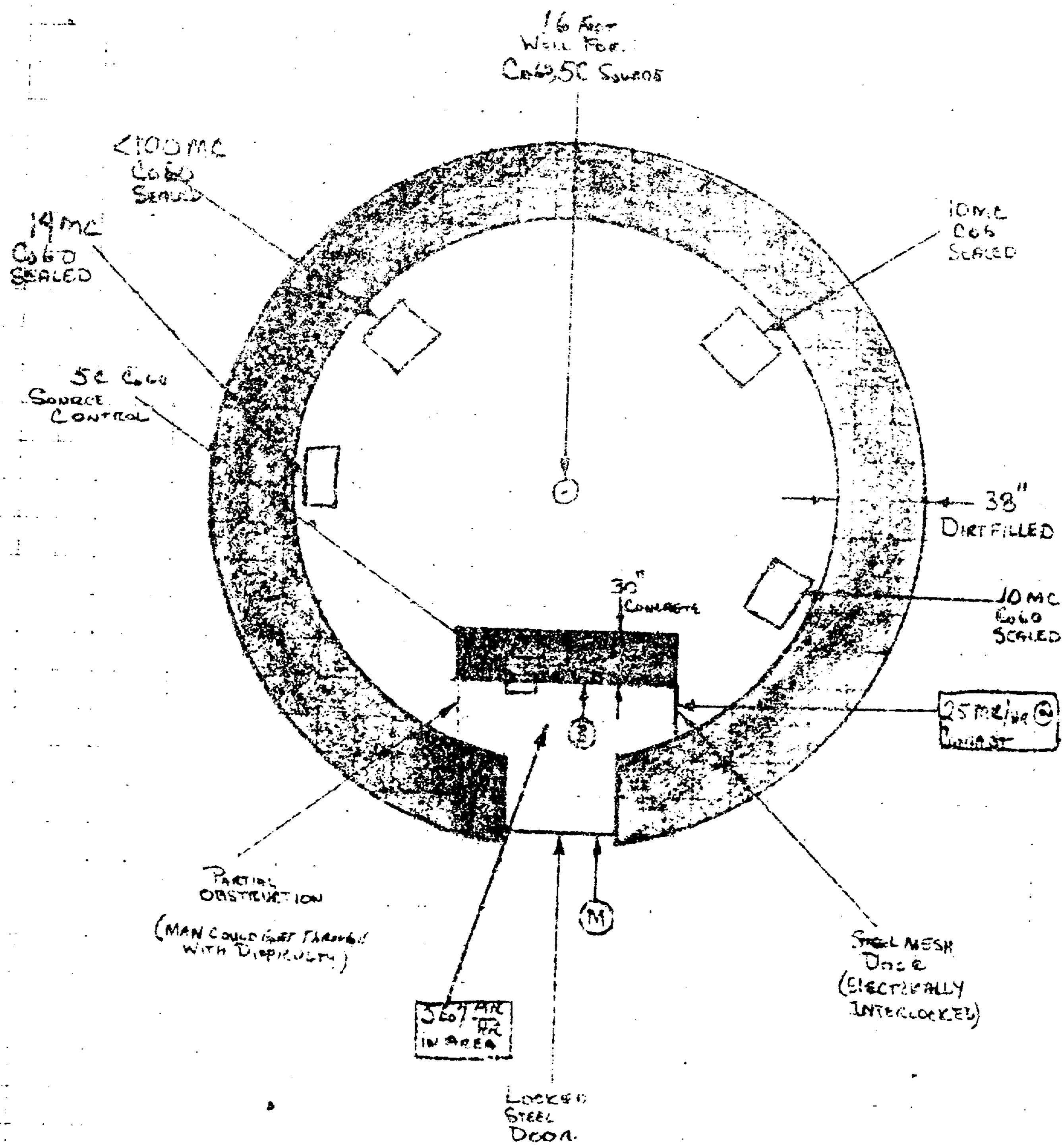
This expression cannot readily be integrated in a closed form but for $b = 0$ (a special case for the field along the axis):

$$I_p = \frac{q\Gamma}{\pi a^2 t} \int_0^t \int_0^a \int_0^{2\pi} \frac{r\,dr\,d\theta\,dz}{r^2 + (h + z)^2}$$

This may be integrated in the closed form:

$$I_p = \frac{q\Gamma}{a^2 t}\left[h \ln \frac{h^2}{h^2 + a^2} + (h + t)\ln \frac{(h + t)^2 + a^2}{(h + t)^2} + 2a\left(\tan^{-1}\frac{h + t}{a} - \tan^{-1}\frac{h}{a}\right)\right]$$

No reference to this derivation has been found in the literature.



Ⓜ = "Caution Radioactive Material" with Symbol

③ = Form AEC-3

☐ = Readings taken with ___ with 5C Source Exposed

Exhibit C Eastman Kodak Company D-35