Form AEC-313R
(9-62)

UNITED STATES ATOMIC ENERGY COMMISSION

APPLICATION FOR BYPRODUCT MATERIAL LICENSE— USE OF SEALED SOURCES IN RADIOGRAPHY

Form approved.
Budget Bureau No. 38-R137

SEE ATTACHED FORM AEC-313R INSTRUCTIONS—USE SUPPLEMENTAL SHEET WHERE NECESSARY
BE SURE ALL ITEMS ARE COMPLETED AND THAT ALL NECESSARY ATTACHMENTS ARE FURNISHED. IF ANY PORTION OF THE APPLICATION IS NOT APPLICABLE SPECIFICALLY SO STATE. DEFICIENT OR INCOMPLETE APPLICATIONS MAY BE RETURNED WITHOUT CONSIDERATION.

1(a) NAME AND ADDRESS OF APPLICANT
The Dow Chemical Company
Midland, Michigan 48640
Attention: H. R. Hoyle, 1707 Bldg.

2. PREVIOUS LICENSE NUMBER(S) (Indicate if application is for renewal or amendment of an existing byproduct material license)
Renewal of AEC License Number 21-00265-04

1(b) APPLICANT IS: An individual ☐ A partnership ☐ A Corporation ☑ An Unincorporated Association ☐ Other ☐ If applicant is other than an individual, the applicable section on the reverse side must be completed.

3. LOCATION(S) WHERE SEALED SOURCES WILL BE USED AND/OR STORED. (If use will be made in states other than named in 1(a), they should be listed here.)
Temporary job site anywhere in U.S. (Condition 10 of current license).

4. SEALED SOURCES TO BE USED IN RADIOGRAPHY

	BYPRODUCT MATERIAL (Element and Mass No.)	SOURCE MODEL NUMBER	NAME OF MANUFACTURER	MAXIMUM ACTIVITY PER SOURCE	NUMBER OF SOURCES
A.	Cobalt 60	Model A-242-5	Technical operations	5 Ci	One
B.					
C.					

5. RADIOGRAPHIC EXPOSURE DEVICES AND/OR STORAGE CONTAINERS TO BE USED WITH SOURCES LISTED ABOVE

	MODEL NUMBER	NAME OF MANUFACTURER (If custom made, attach complete design specification.)
A.	525	Technical operations
B.	416 Source Changer	Technical Operations
C.		

6. THE FOLLOWING INFORMATION IS ATTACHED AS A PART OF THIS APPLICATION: (Check appropriate blocks and attach information called for in the instructions with this form.)
See enclosure

	Not Applicable	Attached	Previously Submitted
(a) Description of radiographic facilities (Instruction 6–a)	☑	☐	☐ on ____ (DATE)
(b) Description of radiation detection instruments to be used (Instruction 6–b)	☐	☑	☐ on ____ (DATE)
(c) Instrument calibration procedures (Instruction 6–c)	☐	☑	☐ on ____ (DATE)
(d) Personnel monitoring equipment (Instruction 6–d)	☐	☑	☐ on ____ (DATE)
(e) Operating and emergency procedures (Instruction 6–e)	☐	☑	☐ on ____ (DATE)
(f) Training program (Instruction 6–f)	☐	☑	☐ on ____ (DATE)
(g) Internal inspection system or other management control (Instruction 6–g)	☐	☑	☐ on ____ (DATE)
(h) Overall organizational structure (Instruction 6–h)	☐	☑	☐ on ____ (DATE)
(i) Leak testing procedures (Instruction 6–i)	☐	☑	☐ on ____ (DATE)

CERTIFICATE (This item must be completed by applicant)

7. THE APPLICANT AND ANY OFFICIAL EXECUTING THIS CERTIFICATE ON BEHALF OF THE APPLICANT NAMED IN ITEM 1, CERTIFY THAT THIS APPLICATION IS PREPARED IN CONFORMITY WITH TITLE 10, CODE OF FEDERAL REGULATIONS, PART 30, AND THAT ALL INFORMATION CONTAINED HEREIN, INCLUDING ANY SUPPLEMENTS ATTACHED HERETO, IS TRUE AND CORRECT TO THE BEST OF OUR KNOWLEDGE AND BELIEF.

The Dow Chemical Company
Applicant Named in Item 1

By: [signature]

Chairman, Radiation Safety Committee
Title of Certifying Official

DATE ____________

WARNING.—18 U.S.C., Section 1001, Act of June 25, 1948; 62 Stat. 749; makes it a criminal offense to make a willfully false statement or representation to any department or agency of the United States as to any matter within its jurisdiction.

FORM AEC-313R (9-62)

0796

LEGAL STRUCTURE OF APPLICANT

If applicant is a corporation, complete Items 8 through 11; if applicant is a partnership, complete Items 12 through 14; if applicant is an unincorporated association or a legal entity other than a partnership or corporation, complete Items 15 and 16. Attach separate sheets where space provided proves inadequate.

CORPORATION

8. STOCK OF APPLICANT CORPORATION

NO. OF SHARES AUTHORIZED	NO. OF SHARES ISSUED	NO. OF SHARES SUBSCRIBED	TOTAL NUMBER OF:	
			(a) Stockholders	(b) Subscribers

Items 8 through 11 previously submitted in application dated July 19, 1963.

9. Is applicant corporation directly or indirectly controlled by another corporation or other legal entity? YES ☐ NO ☐
If answer is "YES" give name and address of other corporation or other legal entity and describe how such control exists and the extent thereof.

10. (a) Identify by name and address any individual, corporation, or other legal entity (1) owning 10 percent or more of the stock of applicant corporation issued and outstanding or (2) subscribing to 10 percent or more of the authorized but unissued stock of the corporation.
(b) Identify by name and address all officers and directors of the corporation.

11. Identify the State, District, Territory, or possession under the laws of which the applicant is incorporated.

PARTNERSHIP

12. Name and address of each individual or legal entity owning a partnership interest in the applicant.

13. State the percent of ownership of the applicant partnership held by each of the individuals or legal entities listed in Item 12.

14. Identify the State, District, Territory, or possession under the laws of which the applicant partnership is organized.

OTHER

15. Describe the nature of the applicant and identify the State, District, Territory, or possession under the laws of which it is organized.

16. State the total number of members or persons holding an ownership in the applicant, identify each by name and address, and indicate the ownership interest thereof.

U.S. GOVERNMENT PRINTING OFFICE : 1965 OF—787-493

AEC FORM-313R: (6) ENCLOSURES TO FORM

(a) Not applicable because the source is designed for and used as a portable field instrument.

(b)

Manu-facturer	Model No.	Type of Radiation Detected	Maximum Range (mr/hr)	Number Available	Intended Use
Eberline	E-120G	Gamma	1,000	1	Surveys
Victoreen	592B	Gamma	1,000	2	Surveys

(c) Instruments are calibrated quarterly by the Dow Industrial Hygiene Laboratory using an NBS certified 10 mg radium source. Semi-annually, the high end of the range is calibrated using the radiographic source itself, with actual dose rates determined by using a Model 570 Victoreen r-meter and Model 621 chamber.

(d) Film badges and reports are supplied by R. S. Landauer Jr., and Company, Science Road, Glenwood, Illinois.

Pocket dosimeters were purchased from Nuclear Associates, Inc. Model 866 has a range of 1 r full scale; Model 862 reads 200 mr full scale. (The Model 862 has a label "Dosimeter Corporation of America, Cincinnati, Ohio 45242.)

(e) See enclosed.

(f) See enclosed.

(g) The Midland Location radiographic operations are under the direct supervision of Harry R. Field, Welding Engineering Supervisor. Mr. Field has 19 years experience in radiographic work using X-ray and isotopic sources, and has supervised an eight man group of radiographers in Midland for 14 years. He also manages the Dow Welding School which qualifies welders in accordance with ASME recommendations, for Dow and other Michigan industries.

An audit of licensed isotope usage is conducted monthly by a qualified health physicist in the Industrial Hygiene Laboratory in conjunction with film badge exchange for the radiographers. The survey meter is checked for proper

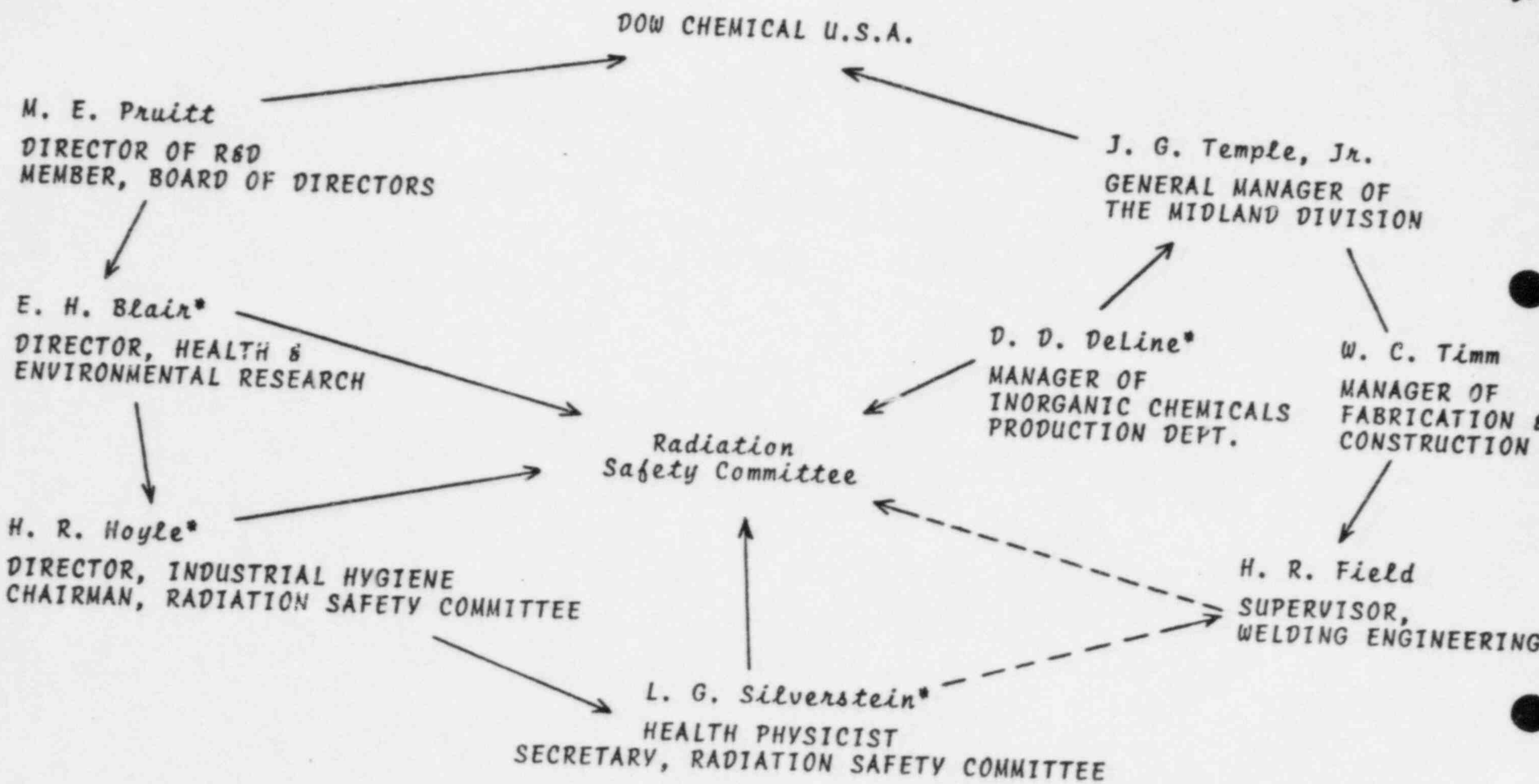
operation and calibration date, and the log book is checked for proper quarterly and daily inspection entries. Meter calibration, source wipe test, physical inventory, and quarterly inspection are all included on a computer "tickler file" system that issues reminders to the Welding Engineering Supervisor and the Director of Industrial Hygiene two weeks ahead of the deadline, to assure compliance.

The source is included on a separate preventive maintenance computer program for the Midland Division which issues a quarterly request for vertification of ownership, location, and presence of required warning signs. This notice goes to the source owner and to Industrial Hygiene for follow up if it is required.

(h) All AEC licensed activities at the Midland Location are under the supervision of the Radiation Safety Committee which meets at least semi-annually to review all records and activities relating to radiation safety and AEC license compliance. The Committee meets more often as the need arises. The Committee Chairman is H. R. Hoyle, Director of the Industrial Hygiene Laboratory and the Secretary is L. G. Silverstein, Certified Health Physicist and Senior Research Industrial Hygienist in the Industrial Hygiene Laboratory. Other members are Dr. O. U. Anders, Senior Reactor Supervisor (TRIGA) in the Midland Division Analytical Laboratories, D. J. Ducommun, M.D., Midland Division Medical Department, Dr. R. R. Langner, Midland Division Manager of Industrial Hygiene Services, D. D. DeLine, Manager of the Midland Division Inorganic Chemicals Production Department, and Dr. E. H. Blair, Manager of the Corporate Health and Environmental Research Department. Mr. DeLine reports to J. G. Temple, Jr., Midland Division Manager and Dr. Blair reports to Dr. M. E. Pruitt, Director of Research and member of the Board of Directors of Dow Chemical U.S.A. A chart showing lines of communication is enclosed. Mr. DeLine's responsibility is to assure that the Midland Division Manager is fully advised of Committee actions that pertain to the Midland Division, which includes the radiographic source. Mr. Field reports to the Committee in person semi-annually.

AEC FORM-313R: (6) ENCLOSURES TO FORM - Page 3

(i) Wipe tests will be done by a qualified health physicist in the Industrial Hygiene Laboratory. Routinely, the wipe test is made at the exit port of the source container by removing the locked storage plug and wiping the exit orifice with a cotton swab. The swab is submitted to the Special Services Section of the Midland Division Analytical Laboratories and is analyzed as described in the enclosure "Radioassay of Wipe Test Samples Containing Cs-137, Co-60, Po-210, Pm-147, Ra-226, Sr-90, Tl-204, and H-3." Doctors Blanchard and Takahashi have 20 and 15 years experience, respectively, in radiochemistry.



*Committee Members

<u>Committee members not shown above</u>: D. J. Ducommun, M.D., Midland Division Medical Department; O. U. Anders, Midland Division Analytical Laboratories; R. R. Langner, Midland Division Industrial Hygiene Services.

TRAINING PROGRAM

The Welding Engineering Supervisor, Mr. H. R. Field, has responsibility for proper training of radiographers and radiographer's assistants. He has presented such training at the Dow Welding School since 1965.

A. Initial Training & Qualification

1. New Radiographer's Assistants will complete the Radiographer's Assistant Training Course outline shown on the enclosed pages. Qualification as radiographer's assistant will consists of passing a written examination with a score of 70% or more plus satisfactory demonstration, under the supervision of a qualified radiographer, that he is competent to use the radiation source and radiation survey meter which will be employed in his assignment. This demonstration will be observed personally by the Welding Engineering Supervisor who will judge the individual's competence under actual field conditions. Personnel failing the test and/or field demonstration will receive additional training and/or practice. They will then be re-examined.

   After six months on-the-job work and training under a qualified radiographer, a radiography assistant will be considered eligible for promotion to full radiographer.

2. During the latter portion of a radiographer's assistant on-the-job period of six months, he will complete the remaining training required by AEC regulations for a full radiographer. This training is outlined on the following pages. He will then be given a written examination which must be passed by a score of 75% or more. After the full six months as radiographer's assistant, the individual must demonstrate to the Welding Engineering Supervisor, under field conditions and without supervision, competence to use the radiation source and radiation survey meter which will be employed in his assignment as radiographer. After satisfactory completion of the examination and equipment demonstration, the individual is considered eligible for promotion to full radiographer.

3. Personnel with previous training and experience as a <u>radiographer</u> will have such training, qualification, and experience verified by the previous employer(s). He will complete a minimum of ten hours training in the company's AEC license, operating and emergency procedures, and use of the radiation source and radiation survey meter. He will also receive training in any of the other AEC required subjects which cannot be verified as having been satisfactorily completed previously.

   To qualify as a full radiographer for this company, the individual must pass the same written examination as specified in 2, above, with a score of 75% or more, and satisfactorily demonstrate to the Welding Engineering Supervisor competence in unsupervised use of the radiation source and radiation survey meter. He must also complete a minimum of two weeks on-the-job training as a radiographer's assistant under a qualified radiographer prior to assignment as a full radiographer for this company.

B. <u>On the-job training</u> in and for the various groups of employees have been specified in 1, 2, and 3, above.

C. <u>Periodic Training</u>

Monthly safety meetings are held by H. R. Field who conducts job checks of crews in the field. Personnel receive oral instructions in regulatory, license, and procedure changes, and also receive copies of all changes in procedure and license conditions. An annual radiation safety review is conducted by a qualified health physicist.

D. <u>Course Outlines & Examinations</u>

See the following pages.

TRAINING PROGRAM OUTLINE

For Radiographer's Assistants
See Section IV. A. 1.

I. Introduction to Radioactive Materials and Radiation (1 hour)

II. Radiation Detection Instrumentation to be Used (1 hour)

   A. Use of Radiation Survey Instruments

      1. Operation
      2. Calibration
      3. Limitations

   B. Survey Techniques (1 hour)

   C. Use of Personnel Monitoring Equipment (1 hour)

      1. Film Badges
      2. Pocket Dosimeters and Chargers

   D. Demonstration and Practice with Above (2 hours)

III. Radiographic Equipment to be Used (5 hours)

   A. Exposure Device

   B. Leak Testing of Sealed Sources

   C. Demonstration and Practice with Above

IV. Company's Operating and Emergency Procedures (3 hours)

V. Study and Review (1 hour)

VI. Test (Written) (1 hour)

[illegible] TOTAL: (16 hours)

TRAINING PROGRAM OUTLINE

0796

For New Radiographers
See Section IV. A. 2.

I. Review of Radiographer's Assistant Training (6 hours)

II. Fundamentals of Radiation Safety (4 hours)

   A. Characteristics of Gamma Radiation

   B. Units of Radiation Dose (mr) and Quantity of Radioactivity (curie)

   C. Hazards of Excessive Exposure to Radiation

   D. Levels of Radiation from Licensed Material

   E. Methods of Controlling Radiation Dose

      1. Working Time
      2. Working Distance
      3. Shielding

III. Requirements of AEC Regulations (2 hours)

   A. Part 19

   B. Part 20

   C. Part 34

IV. Dow AEC License (1 hour)

   A. Inclusions

   B. Exclusions and Limitations

V. Study and Review (2 hours)

VI. Test (Written) (1 hour)

MINIMUM TOTAL: (16 hours)

TRAINING PROGRAM OUTLINE

Previously Qualified Radiographers
See Section IV. A. 3.

I.	Review* of Sections I, II and III of the radiographer's assistants and the same sections of the new radiographers training programs	(4 hours)
II.	Company's Operating and Emergency Procedures	(3 hours)
III.	Dow AEC License for Radiography	(1 hour)
	A. Inclusions	
	B. Exclusions and Limitations	
IV.	Study and Review	(1 hour)
V.	Test (Written)	(1 hour)
	MINIMUM TOTAL:	(10 hours)

*If previous training in these subjects can be verified by previous employer(s). If such training cannot be verified, the individual will receive full training in the subjects which are not verified.

WRITTEN TESTS

On the attached pages are several sets of test questions. The written test for full radiographer qualification will consist of a minimum of 50 questions selected from the complete group of test questions. The written test for qualification as radiography assistant will consist of a minimum of 25 questions selected from those whose numbers are circled. The circled questions apply to the training given to the radiography assistants.

Radiographers must score a minimum of 75% on these written tests and radiography assistants must score at least 70%.

RADIATION SAFETY EXAMINATION -- RADIOGRAPHER TRAINING COURSE

Name ________________________________ Date ________________

The following statements are true or false. Indicate, with a check, the best answer.

1. Since gamma radiation is very penetrating, more of its energy will be absorbed in body tissue than would be the case with other forms of radiation. T_ F_

2. The attenuation of alpha radiation requires careful consideration of problems of shielding. T_ F_

3. Alpha emitters offer serious problems of internal radiation. T_ F_

4. Gamma radiation will penetrate anything to some extent. T_ F_

5. Bremsstrahlung frequently results from the shielding of beta radiation. T_ F_

6. Bremsstrahlung is the kind of radiation which is similar to X-ray. T_ F_

7. All alpha radiation from a given source will have the same energy and the same range in matter. T_ F_

8. Tissue damage is directly related to penetrability, energy and specific ionization of radiation. T_ F_

9. The roentgen is the radioactivity which equals 3.7×10^{10} disintegrations per second. T_ F_

10. The roentgen is the unit of external radiation exposure. T_ F_

11. The roentgen is a measure of the ionizing ability of the radiation. T_ F_

12. The curie is a unit of radioactivity which equals 3.7 x 10^{10} disintegrations per second. T_ F_

13. The roentgen equivalent man (rem) is a unit based on the roentgen which takes into account the relative biological effectiveness of various types of radiation. T_ F_

14. The roentgen and the roentgen equivalent man are equivalent. T_ F_

15. The relative biological effectiveness of a given type of radiation is the ratio of the damage done in tissue by the radiation in question to the damage done by an equal amount of radium. T_ F_

16. Counts per minute and disintegrations per minute are the same. T_ F_

17. All radiation survey instruments give the same background reading. T_ F_

18. Radiation injury occurs in cells by causing changes in the atoms and molecules. T_ F_

19. Blood and blood forming organs are the most radiosensitive. T_ F_

20. Skin and the GI tract are the least radiosensitive organs. T_ F_

21. Immature cells, cells in the early stage of division, and cells with high metabolic rates are the most sensitive to radiation. T_ F_

22. The safety of the individual workman is the primary criteria for the setting of acceptable levels of exposure to radiation. T_ F_

23. Acute symptoms or injury can be expected if the hazards due to handling of radioactive material presently used for radiography in Midland are not controlled. T_ F_

0795

24. Life-span shortening has been demonstrated by experiments with human beings with radioactive materials and radiation. T_ F_

25. Experiments with animals have proven a potential hazard due to genetic effects but have not given us reliable quantitative information yet. T_ F_

26. Lack of knowledge is sufficient reason to be conservative in our control of radiation exposures. T_ F_

27. Present control levels are well below the bodily injury range and constitute little or no hazard to future generations. T_ F_

28. Present standards which limit exposure to radiation are based upon well established experience with human beings. T_ F_

29. All exposures must be kept below 2.5 mr/hr. T_ F_

30. Maximum Permissible Concentrations take into account biological half-life, radiation half-life and organ sensitivity. T_ F_

31. The half-life of a material is the length of time it takes any given sample to decay. T_ F_

32. It is possible to predict whenever any particular radioactive atom will decay. T_ F_

33. Although radioactive materials can ge through decay schemes which involve several other radioactive materials, they eventually all decay to a stable product. T_ F_

34. Materials can be made radioactive by exposing them to external radiation from radiographic sources. T_ F_

35. The biological half-life of a material refers to the time it takes the human body to rid itself of one-third of the original dose of the material. T_ F_

36. The effective half-life refers to the time it takes for a dose to the human body to be reduced by one-half. T_ F_

37. Effective half-life is a function both of the physical half-life and the biological half-life of the material. T_ F_

38. The AEC limit on the level of radiation for a radiographic exposure device measuring a minimum of four inches from the source storage position to any exterior surface of the device, is 200 mr/hr and 10 mr/hr at one meter from any exterior surface. (The radiation levels specified are with the sealed source in the shielded position.) T_ F_

39. Having locked storage containers for the Co-60 source is sufficient protection to prevent tampering or removal by unauthorized personnel. T_ F_

40. The main reason for having a radiation survey instrument at the site during radiographic work, is to measure levels of radiation in case of a mishap. T_ F_

41. The Co-60 source should be tested for leakage at intervals not exceeding six months. T_ F_

42. A written record available for inspection by the AEC is needed indicating the plant sites and dates of use for the Co-60 radiography source. T_ F_

43. Since X-ray units are not governed by AEC regulations, there are no set regulations or records required to be kept. T_ F_

44. Portable X-ray units should not be operated if any unauthorized individual in the immediate area would be exposed to levels of radiation greater than 5 mr/hr. T_ F_

45. A film badge is not needed to be worn by an individual operating radiographic equipment unless he is likely to be exposed to levels of radiation greater than 5 mr/hr. T_ F_

0735

46. Reading an individual's pocket dosimeter once each week is sufficient to account for the recommended weekly dose limit of 100 mr. T_ F_

47. An individual's film badge should be immediately processed if the pocket dosimeter worn in conjunction with the film badge reveals a radiation exposure greater than the range of the dosimeter. T_ F_

48. In the event of an accident involving an excessive exposure to radiation, a member of Industrial Hygiene should be notified second only to the Dow Medical Department. T_ F_

49. The AEC must be notified within 24 hours of any radiation exposure to an individual in excess of the 1.25 rem/calendar quarter for the whole body. T_ F_

50. The levels of radiation for radiographic work using the Co-60 source are such that a sign or signs bearing the words, "Caution: High Radiation Area," are needed to be posted in the area at all times. T_ F_

51. The levels of radiation for radiographic work using the portable X-ray units are such that a sign bearing the words, "Caution: Radiation Area," are needed to be posted in the area at all times. T_ F_

52. A pocket chamber or dosimeter is a more reliable way of determining an individual's accumulated exposure to radiation than the film badge. T_ F_

53. The use of a radiation survey instrument is not needed for determining levels of radiation during radiographic operations as long as all persons involved wear film badges and pocket dosimeters. T_ F_

54. A physical radiation survey and a written record thereof is required by the AEC to determine that the Co-60 source is returned to its shielded condition prior to securing. T_ F_

55. The radiation survey instrument must be calibrated at least quarterly. T_ F_

The following questions/statements are multiple choice; circle the best answer.

1. An excellent radiograph is obtained under given conditions of exposure with the film located at a distance of 36" from the target of the X-ray tube. If the tube is now placed only 18" from the target and all exposure conditions, except time, are held constant, the new exposure time will be:

   (a) unchanged.
   (b) longer by approximately 8%.
   (c) shorter by approximately 55%.
   (d) only about 25% as long as the original exposure time.

2. Lead is frequently employed in shielding against radiation from X-ray and gamma ray sources because of its:

   (a) extremely low cost.
   (b) high absorption for given thickness and weight.
   (c) ability to emit electrons when irradiated.
   (d) ability to defract alpha particles.

3. The penetrability of an X-ray beam is governed by:

   (a) Kilovoltage or wavelength.
   (b) time.
   (c) milliamperage.
   (d) source to film distance.

4. Co-60 used in nondestructive testing emits:

   (a) alpha particles.
   (b) neutrons.
   (c) gamma rays.
   (d) X-rays.

5. The time required for one-half the atoms in a particular sample of radioactive material to disintegrate is called:

   (a) the inverse square law.
   (b) a curie.
   (c) a half-life.
   (d) the exposure time.

6. What does the term r/hr refer to when speaking of intensity?

(a) Radiation limits for humans.
(b) Roentgens per hour.
(c) X-rays per hour.
(d) Radiation and hydrogen.

7. Upon completing an X-ray exposure and turning the equipment off:

(a) personnel should wait for a few minutes before entering the exposure area.
(b) personnel should wear a lead-lined apron before entering the exposure area.
(c) personnel may enter the exposure area without fear of radiation exposure.
(d) personnel should take a reading with a Geiger counter before entering the radiation area.

8. The most widely used unit of measurement for measuring the rate at which the output of a gamma ray source decreases is the:

(a) curie.
(b) roentgen.
(c) half-life.
(d) MEV.

9. All amounts of exposure to X-rays or gamma rays:

(a) will have a cumulative effect which must be considered when monitoring for maximum permissible dose.
(b) will be beneficial since they buildup an immunity to radiation poisoning.
(c) will have no effect on human beings.
(d) will have only a short term effect on human tissues.

10. A dose of ____________ would be dangerous, if not fatal, if applied to the entire body in a short period of time.

(a) 1.5-15 R.
(b) 25-70 R.
(c) 200-800 R.
(d) all of the above doses would most likely be fatal.

16. X-ray exposure may be due to the:

    (a) direct beam from the X-ray tube target.
    (b) scatter radiation from arising from objects in the direct beam.
    (c) both (a) and (b) above.
    (d) both (a) and (b) above, plus residual radiation that exists for the first few minutes after the X-ray machine has been turned to the OFF position.

17. Materials which are exposed to gamma radiation below a few million volts:

    (a) should not be handled for at least 3 minutes after exposure has ceased.
    (b) should be stored in a lead-lined room.
    (c) will not be dangerous to handle after exposure to radiation has ceased.
    (d) should be monitored by means of a Geiger counter.

18. A primary disadvantage of the fountain pen type of ionization chamber used to measure the amount of radiation received by personnel is:

    (a) the delay necessary before the results of the measurement are known.
    (b) the inaccuracy of such devices in measuring the scatter radiation.
    (c) the inability of such a device to provide a permanent record of exposure.
    (d) the cost of recharging such devices.

19. Very short wavelength electromagnetic radiation produced when electrons traveling at high speeds collide with matter is called:

    (a) X-radiation.
    (b) beta radiation.
    (c) gamma radiation.
    (d) none of the above.

20. The exposure of personnel to X- and gamma radiation can be determined by means of:

    (a) film badges.
    (b) dosimeters.
    (c) radiation meter.
    (d) all of the above.

21. An advantage of the fountain pen type of ionization chamber used to monitor radiation received by personnel is:

(a) it provides a permanent record of accumulated dosage.
(b) it provides an immediate indication of dosage.
(c) it is the most sensitive detector available.
(d) all of the above are advantages.

22. In making an isotope measurement in an unshielded area, you find the dose rate 6 feet from the source at 1200 mr/hr; what would the dose rate be at 24 feet?

(a) 75 mr/hr.
(b) 100 mr/hr.
(c) 200 mr/hr.
(d) 300 mr/hr.

23. An unshielded isotope source gives a dosage rate of 900 mr/hr at 10 feet; what would the unshielded dosage rate be at 30 feet?

(a) 100 mr/hr.
(b) 300 mr/hr.
(c) 600 mr/hr.
(d) 2700 mr/hr.

24. The best method of controlling radiation dose while doing radiographic work is:

(a) decreasing time, decreasing distance, decreasing shielding.
(b) decreasing time, increasing distance, increasing shielding.
(c) decreasing time, decreasing distance, increasing shielding.
(d) by telephone.

LGSilverstein:4/22/74

WRITTEN EXAMINATION FOR QUALIFYING RADIOGRAPHERS
TO USE BYPRODUCT MATERIAL

INSTRUCTIONS: One hundred questions are provided which are subdivided into five groups of twenty questions each. The groups represent specific areas of instruction required by AEC Title 10, Part 34. The numbers that are underlined indicate the questions that are mandatory on each examination. The examiner will underline the numbers of six additional questions in each group. Each question shall be given equal weight in grading and a score of 75% or better is required to pass. Time limit for completion of the test will be two hours. The examiner will review and discuss each question that is answered incorrectly with the student.

A. Fundamentals of Radiation Safety and Characteristics of Gamma Radiation

1. What is the type of radiation emitted by radioisotopes that is useful for industrial radiography?

2. Is the energy level of radiation emitted by a given isotope a constant or does it decrease as the curie strength of the isotope decreases?

3. What is the different between the dose rate and dose when measuring radiation?

4. What is the unit of measurement for the ionizing effect of gamma radiation on man?

5. What is the unit of measurement which expresses the number of disintegrations per second that is the equivalent to the effect of one roentgen of gamma radiation on man?

6. What is the unit of measurement which expresses the number of disintegrations per second which takes place in a given quantity of radioactive material and which is used as a measurement of strength of an isotope?

7. Define the half-life of an isotope.

8. What is a radioisotope?

9. What is the inverse square law relating distance from a radiation source to the intensity of radiation?

10. When an isotope has gone through 3 half-lives, what fraction of its initial strength is left?

11. What is the HVL thickness of lead for Co-60?

12. Does the HVL thickness of an absorber vary as the intensity of radiation varies? Explain.

13. What parts of the body are regarded as <u>least</u> sensitive to radiation exposure? As <u>most</u> sensitive?

14. What is meant by "half-value layer" (HVL) of an absorber for a particular kind of radiation?

15. If the radiation intensity from a source is 10 r/hr at a distance of 2 feet, how much would it be at the following distances?

    (a) 4 feet: ____________________

    (b) 10 feet: ____________________

    (c) 20 feet: ____________________

    (d) 1 foot: ____________________

16. Calculate the dose received from a 10 curie Co-60 source in ten minutes at a point two feet from the source after the radiation has passed through one HVL of lead.

17. Will radiation produce greater biological effects on minors or adults? Explain.

18. What would be the probable result of a radiation exposure to the whole body of 600 r, received at a single exposure?

19. Would a single exposure of 600 r to only one hand be fatal? Explain.

20. What three principles must be applied for controlling exposure to radiation?

B. Radiation Detection Instrumentation

21. What does a survey meter measure?

22. What does a pocket dosimeter measure?

23. What does a film badge measure?

24. How do survey meters and pocket dosimeters differ in the way they measure radiation?

25. What radiation health physics instrument must a radiographer carry on a field trip?

26. What personnel monitoring devices must a radiographer's assistant wear?

27. What minimum and maximum ranges are required for a radiation survey meter?

28. In case of an emergency, a dosimeter can be used to establish does rate. Describe how this can be done.

29. Pocket dosimeters are designed to measure:

(a) gamma rays and X-rays only.

(b) gamma rays, X-rays and beta particles.

(c) gamma rays, alpha and beta particles.

(d) alpha and beta particles only.

30. Can film badges be transferred from one user to another? Why?

31. How often must survey meters be calibrated?

32. How would you test the accuracies of your dosimeter and survey meter using a 5 curie source of Co-60?

33. When performing radiography, when must radiation surveys be made and what survey results must be recorded?

0796

34. List the radiation levels indicated on a survey meter when:

    (a) Range switch set on 0.1, meter reads 6: ____________mr/hr

    (b) Range switch set on X100, meter reads 25: ____________mr/hr

    (c) Range switch set on X1, meter reads 65: ____________mr/hr

    (d) Range switch set on X10, meter reads 8: ____________mr/hr.

35. Why are small aluminum and copper filters built into film badge holders?

36. Suppose your survey meter was found to be broken or badly out of adjustment on a field trip. What would you do?

37. Are you permitted to use a survey meter which has no calibration expiration date attached to it? Why?

38. Why is it so important to survey your exposure device after each exposure is made?

39. Will excessive heat affect the accuracy of a film badge reading? Explain.

40. Why do most film badges contain two films of different speeds?

C. Radiographic Equipment & Its Use

41. If a radiographic exposure device measures 5 inches from the sealed source storage position to the exterior surface of the device, what is the maximum allowable dose rate at the surface?

42. What is the maximum allowable dose rate at 6 inches from the exterior surface of an exposure device that measures 3 inches from the sealed source storage position to any exterior surface of the device?

43. Why are exposure devices which are made of depleted uranium smaller than those made of lead?

44. What is a collimator?

45. What is the maximum strength of the source of Co-60 you are allowed to use in the Tech/Ops Model 525?

46. Who is authorized to wipe test the source? Exchange it?

47. Outline the operating procedure that you would follow in making a radiographic exposure.

48. How often must a sealed source be leak tested? What is the maximum allowable removable activity?

49. How would you collect a leak test sample from a radiographic sealed source?

50. Describe the procedure you would follow if your source should become uncoupled from the device cable while in the exposed position.

51. If a leak test of a gamma ray source shows excessive leakage, what must be done?

52. Is the indicator light enough to assure that the source has been retracted into the container?

53. For a 30 minute exposure in an unrestricted area, your "Caution - Radiation Area" sign could be placed where your survey meter read __________mr/hr.

54. What is the isotope and amount used in a Tech-Ops Model 525 camera?

55. Can the position of a source, i.e., fully exposed or fully retracted, be accurately determined by counting the number of hand crank revolutions? Why?

56. Why are Co-60 cameras so much heavier than Ir-192 cameras when both are rated for the same curie capacity?

57. How could you make a set of remote handling tongs in an emergency when you have only a kit of conventional hand tools available?

58. What portion of a crank operated, remote control exposure device should be inspected most frequently to avoid creating a hazardous situation?

(a) The locking mechanism on the camera.

(b) The control cable crank assembly.

(c) The hookup between the pigtail and the control cable.

(d) The closure plug used to secure the source in safe position.

(e) All are important.

59. What can happen if you try to force the flexible control cable and source through the guide tube with the hand crank?

60. Why should control cables and guide tubes be protected from grit and cleaned frequently?

D. The Requirements of AEC Regulations

61. No person can act as a radiographer until he has received copies of and instruction in the regulations covered in AEC Title 10, Part ____ and Part ____.

62. The standards for protection against radiation are set forth in Part ____ of AEC Title 10.

63. Regulations covering licenses for radiography and radiation safety requirements for radiographic operations and set forth in Part ____ of AEC Title 10.

64. Any radiographic area to which access is controlled by the licensee is called a ____.

65. Define a radiation area.

66. Define a high radiation area.

67. Unless special records are maintained, a radiographer is not permitted to receive a radiation dose to the whole body in excess of __________ rem per calendar quarter.

68. If special forms are maintained, a radiographer may receive a radiation dose to the whole body of ________ rem per calendar quarter.

69. Regulations covering surveys are found in Paragraph ________ of Part 20 of the AEC Regulations, Title 10.

70. Is a dose of one roentgen due to X- or gamma radiation considered to be the same as a dose of one rem? Why?

71. What is your responsibility as a worker (employee) as outlined in Form AEC-3, "Notice to Employees"?

72. What is the minimum age limit for a radiographer or radiography assistant?

73. No individual under 18 years old may receive a radiation dose in excess of ______% of 1.25 rem per calendar quarter.

74. Name two types of personnel monitoring equipment required by AEC regulations.

75. Fill in the maximum allowable exposures of individuals to radiation in restricted areas (rem per calendar quarter:

    (a) Whole body; head and trunk; active blood forming organs; lens of eyes; or gonads. ____________

    (b) Hands and forearms; feet and ankles. ____________

    (c) Skin of whole body. ____________

76. Make a rough sketch of the radiation symbol used on caution signs and indicate the colors which must be used for the symbol and its background.

77. Can you use a "Caution - Radioactive Material" sign to post a high radiation area? Explain.

78. What are the locking requirements for radiographic exposure devices? For storage containers?

79. Define a radiographer.

80. Are you required to post the storage compartment of the transporting vehicle?

E. Operating & Emergency Procedures

81. Where must a radiographer record his pocket dosimeter readings?

82. What records must the radiographer retain a copy of at the job site?

83. When must pocket dosimeters be recharged?

84. What would you do if your exposure device was lost or stolen?

85. When must a radiographer complete a survey log form?

86. What is the requirement for surveillance of a radiographic exposure device when it is in use?

87. What company document must each radiography assistant have?

88. List three documents that the company must make available to each radiographer.

89. How must you restrict each temporary radiographic area to control access (other than remote, temporary areas)?

90. How do you restrict and control access to remote, temporary radiographic areas?

91. You barricade a temporary radiographic area and the dose rate measured at the barricade is 2.5 mr per hour. How many signs must you use to post the area, where must they be placed and what words are on the sign?

92. What is the radiation intensity emitted from one curie of Co-60 at a distance of one foot?

93. What radiation dose rate is allowed at the outside of a truck used to transport a radioactive source? At the driver's location?

94. When working at a customer's plant, what steps must you take to advise customer personnel that you are working?

95. Can a radiographer's assistant keep the job site under surveillance, or is a radiographer required to do this?

96. Suppose someone ignores your signs and barriers and insists on entering the radiation area. What measures would you take?

97. What would you do if you checked your pocket dosimeter and found it had gone off-scale?

98. What would you do if you have a wreck with a truck carrying an exposure device loaded with a source?

99. You get a rain out day on a field day. What portion of the survey log report must you still fill out?

100. On a survey log report, are the exposure device serial number and source serial number the same? Explain.

0796

ANSWERS

A. <u>Fundamentals of Radiation Safety and Characteristics of Gamma Radiation</u>

1. Gamma radiation.
2. A constant.
3. Dose rate is the amount of radiation present. Dose is accumulated radiation.
4. Roentgen.
5. rem.
6. Curie.
7. A half-life is the time required for one-half of the radioactive atoms in a particular isotope to disintegrate.
8. An atom of an element with the same number of protons but a different number of neutrons in the nucleus than the stable form which emits radiation.
9. The intensity of the radiation varies inversely as the square of the distance.
10. One-eighth.
11. 0.49.
12. No, because the wavelength is the same.
13. <u>Least</u>: bone marrow and nerve.
    <u>Most</u>: bone marrow which contains the blood forming cells, the lining of the digestive tract and the gonads.
14. Material required to reduce the radiation intensity to one-half.
15. 4 feet: 2.5 r/hr
    10 feet: 400 mr/hr
    20 feet: 100 mr/hr
    1 foot: 40 r/hr

16. 3 r.

17. Minors, because they have faster growing cells.

18. Fatal.

19. No. You may injure the hand but the vital organs will not be damaged.

20. Time, distance, shielding.

B. Radiation Detection Instrumentation

21. Measures the quantity or rate of ionization in air.

22. Accumulated dose.

23. Personal dosage.

24. (a) Survey meter, rate of radiation.
(b) Pocket dosimeter, the dose of radiation.

25. Survey meter.

26. Dosimeter and film badge.

27. 2 mr/hr, minimum; 1 r/hr, maximum.

28. By setting the dosimeter on zero, placing it at a distance and leaving a measured time, then reading. Dose divided by time equals the dose rate.

29. Gamma rays and X-rays only.

30. No a film badge is used to determine the amount of radiation one person receives and if someone else used it, you couldn't determine that amount.

31. Every 90 days.

32. Set survey meter and dosimeter at 10 feet from source. Survey meter should read 700 mr/hr and after 6 minutes, dosimeter should read 70 mr/hr.

33. Survey must be taken on every exposure, while exposure is being made and after every exposure to make sure the source is secure. Readings when should is secure and readings at 2 mr/hr distance.

34. 0.6 mr/hr. 2500 mr/hr. 65 mr/hr. 80 mr/hr.

35. To detect energy range of radiation.

36. Shut down operations until survey instrument was replaced.

37. No. Survey meters have to be calibrated every ninety days.

38. To make sure source is secured in exposure device.

39. Yes. Heat may fog film.

40. To cover a wide dosage range.

C. Radiographic Equipment and Its Use

41. 200 mr/hr.

42. 50 mr/hr.

43. Depleted uranium has a greater density than lead. Therefore, it requires a smaller amount to meet safety requirements.

44. A shielding device which limits the radiation to the area of interest.

45. 5 curies.

46. Health physicist. Welding Engineering Supervisor and health physicist.

47. (a) Check with survey meter to make sure source is secure.
 (b) Determine distance for 2 mr/hr readings, put up barriers and "Caution Radiation" signs, put up "High Radiation" signs and calculate exposure time at 100 mr/hr.
 (c) Put film on weld.
 (d) Crank out source and survey perimeter during exposure.
 (e) Crank source in.
 (f) Chec.. with meter to make sure source is secure.
 (g) Read pocket dosimeter and record all survey results in log.

48. Not to exceed six months.
 0.0005 microcuries.

49. Call health physicist.

50. (a) Shield the source as soon as possible.
    (b) Rope off the area so no one can get in the 2 mr/hr area.
    (c) Send radiography assistant to call Welding Engineering Supervisor and Industrial Hygiene.

    If you have no way to secure the source, wait until you get further instructions. Make sure no one gets into the area.

51. The device should be locked and returned to the storage area. Care should be taken to avoid any unnecessary contact with the equipment. The supervisor and Industrial Hygiene should be notified immediately and no further handling of the equipment is allowed until it has been proved safe.

52. No. The survey meter must be used because of the possibility of mechanical and electrical failure.

53. 4 mr/hr.

54. Co-60, 5 curies.

55. No. The cable may slip.

56. It takes more lead to stop the wavelengths of Co-60 than for Ir-192.

57. The thumb screw or ring stand clamps may be turned with a slotted stick and a pair of pliers wired to a stick and a rope used to operate the pliers.

58. (e)

59. You may not be able to retract the source.

60. To keep from getting hung up and not being able to retract the source.

D. The Requirements of AEC Regulations

61. 20 and 34.

62. 20.

63. 34.

64. Radiation area.

65. Any area accessible to personnel at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 mr/r or in any five consecutive days a dose in excess of 100 mr.

66. An area where the whole body or a portion of the body would receive 100 mr in any one hour.

67. 1.250 rem.

68. 3 rem.

69. 20.201.

70. Yes. REM is a measure of the dose of any ionizing radiation to body tissue in terms of its biological effect relative to a dose of one roentgen of a 200 KVP X-ray.

71. You should familiarize yourself with the provisions of the radiation regulations and the operating procedures which pertain to the work in which you are engaged. You should observe their provisions for your own protection and the protection of your co-workers.

72. 18.

73. 10%.

74. Dosimeter and film badge.

75. (a) 1.25 r.
(b) 18.75 r.
(c) 7.50 r.

76. Purple (magenta) with yellow background.

77. No. Personnel can enter an area with radioactive material. Personnel cannot enter high radiation area.

78. Exposure device must be locked when not in use, and when stored it must be locked also, and must be locked with chain to a solid object when not observed.

79. Radiographer: A person who examines the structure of material by nondistructive methods utilizing sealed sources of byproduct materials.

80. Yes.

E. Operating & Emergency Procedures

81. Log book.

82. Log book, operating and emergency procedures.

83. Beginning of the day before you go to work.

84. Notify the local civil authorities. Notify the Welding Engineering Supervisor and health physicist who will advise the AEC.

85. As soon as possible after making exposure.

86. Constant surveillance.

87. Operating and emergency procedures.

88. AEC license, state regulations, AEC regulations.

89. By roping off the area and posting radiation signs every 90 degrees.

90. Constant surveillance of area.

91. 4 signs 90 degrees apart with the words "Caution - Radiation Area."

92. 14.400 mr/hr.

93. 2 mr/hr. 1 mr/hr.

94. You must advise all superintendents, foremen and supervisors that you will be working in the area.

95. Assistant can do it.

96. Secure source and go to his supervisor.

97. Shut down operations. Survey the area and send film badge in as soon as possible; find out results before continuing operations.

98. Survey the area with meter; if meter is broken, stay at scene. Rope area off, send for meter. Do not leave area; keep constant surveillance.

99. Transportation and number of source and cameras and job location.

100. No. The exposure device number is the number of the camera and the source number is the serial number of the source capsule.

Attachment G(f)

~~PROGRAM~~ RADIOGRAPHER QUALIFICATION TEST

0796

1. What is a radiograph? X-Ray? Isotope?

2. What is the main difference between X-Ray and Gamma-Ray? Explain.

3. What are the main factors to be considered in the production of an acceptable radiograph?

4. What is the basic difference between the various grades of film and when should each be used.

5. What is a penetrameter and how is it used? How is the size (thickness) determined? Size of holes?

6. Radiation survey instruments shall be calibrated every ______ months. How many mr's are allowed per week, quarter, year? What safety equipment is required at each radiographic site?

7. What is meant by the ratio of source to film distance? What is the minimum source-to-film distance allowed by API 1104?

8. What is meant by diagnostic film length, Icicle, Concave root?

9. What is the maximum allowable off-set of the plane of radiation of an internal and external exposure of a girth weld? ______

10. What are lead screens? Why are they used? What thickness of lead screens is recommended for X-Ray over 150 KV? Iridium?

11. What is secondary radiation? What is necessary to protect film from secondary radiation?

12. How do you determine the usable life of the developer? Fixer? What is the recommended temperature range for developing solution?

13. Where will the penetrameters be located on a radiograph? How many penetrameters will be used on each film if three exposures per weld are taken?

14. Name and describe at least five types of artifacts?

15. What safety precautions should a radiographer take to protect himself and others?

16. What is a film badge? ~~Ionization chamber~~ Pocket dosimeter? Radiation Survey meter? How are they used and when?

17. What are the various passes of a manual electric-arc weld called?

18. What are the common defects of a manual weld?

19. What is the maximum allowable length of the following defects:

Type

Inadequate Penetration
Incomplete Fusion
Burn Through Area
Isolated Slag Inclusion
"Wagon Track" slag
Porosity
Cracks
Internal Undercut
External Undercut

20. Describe the shadow image of each of the above types of inclusions or defects.

21. Do you feel that the training and experience you have qualifies you to be a Radiographer? Why?

RADIOGRAPHER QUALIF ATION TEST

1. An excellent radiograph is obtained under given conditions of exposure with the film located at a distance of 36 inches from the target of the x-ray tube. If the film is now placed only 18 inches from the target and all exposure conditions except time are held constant, the new exposure time will be:

a. longer by approximately 80 per cent.
b. unchanged
c. only about 25 per cent as long as the original exposure time.
d. shorter by approximately 55 per cent.

2. Lead is frequently employed in shielding against radiation from X-Ray and gamma ray sources because of its:

a. extremely low cost.
b. ability to emit electrons when irradiated.
c. high absorption for a given thickness and weight.
d. ability to diffract alpha particles.

3. The most common causes for excessively high density radiographs are:

a. insufficient washing and overdevelopment.
b. contaminated fixer and insufficient washing.
c. overexposure and overdevelopment.
d. overexposure and contaminated fixer.

4. The time required for one half of the atoms in a particular sample of radioactive material to disintegrate is called.

a. the inverse square law.
b. a curie
c. a half life
d. the exposure time.

5. The ability to detect a small discontinuity or flaw is called:

a. radiographic contrast.
b. radiographic density.
c. radiographic resolution.
d. radiographic sensitivity.

6. If a film is placed in a developer solution and allowed to develop without any agitation:

a. it will be impossible to fix the radiograph permanently.
b. there will be a tendency for each area of the film to affect the development of the areas immediately below it.
c. there will be a general "fogging" condition over the entire radiograph.

7. The selection of the proper type of film to be used for the x-ray examination of a particular part depends on:

a. the thickness of the part.
b. the material of the specimen.
c. the voltage range of the available x-ray machine.
d. all three of the above factors.

8. ~~Irradiate 60 capsule~~ An IR-192 source will have a half-life to:

a. 5.3 years
b. 1.2 years
c. 6 months
d. 75 days.

9. Lead foil in direct contact with x-rays film:

a. intensifies the scatter radiation more than the primary radiation.
b. intensifies the primary more than the scatter radiation.
c. should not be used when gamma rays are emitted by the source of radiation.
d. decreases the contrast of the radiographic image.

10. Radiographic sensitivity, in the context of defining the minimum flaw, depends on:

a. graininess of the film.
b. the contrast of the flaw image on the film.
c. the unsharpness of the flaw image in the film.
d. all three of the above.

11. In order to decrease geometric unsharpress:

a. Gamma rays should proceed from as small a focal spot as other considerations will allow.
b. Gamma rays should proceed from as large a focal spot as other considerations will allow.
c. the film should be as far as possible from the object being radiographed.
d. the distance from the anode to the material examined should be as small as is practical.

12. Scattered radiation caused by any material, such as wall or floor, on the film side of the specimen is referred to as:

a. primary scattering
b. undercut
c. ~~reflected~~ scattering
d. back-scattered radiation.

13. Excessive exposure of film to light prior to development of the film will most likely result in:

a. a foggy film
b. poor definition
c. streaks
d. yellow stain

14. White crescent-shaped marks on an exposed x-ray film are most likely caused by:

a. crimping film before exposure.
b. crimping film after exposure.
c. sudden extreme temperature change while processing.
d. warm or exhausted fixer.

15. Frilling or loosening of the emulsion from the base of the film is most likely caused by:

a. water or developer on unprocessed film.
b. warm or exhausted fixer solution.
c. developer solution contamination.
d. low temperature of processing solutions.

16. As a check on the adequacy of the radiographic technique, it is customary to place a standard test piece on the source side of the specimen. This standard test piece is called a:

a. reference plate
b. penetrameter
c. lead screen
d. illuminator

17. A penetrameter is used to measure:

a. the size of discontinuities in a part.
b. the density of the film.
c. the quality of the radiographic technique.
d. the amount of film contrast.

18. Lead foil screens are used in radiography:

a. to improve the quality of the radiograph by preferentially reducing the effect of scatter radiation.
b. to reduce the exposure time.
c. neither a or b are reasons for using lead foil screens.
d. both a and b are reasons for using lead foil screens.

19. When the minute silver grains on which the x-ray film image is formed group together in relatively large masses, they produce a visual impression called:

a. air bells
b. reticulation
c. graininess
d. frilling

20. Static marks, which are black tree-like or circular marks on a radiograph, are often caused by:

a. improper film handling techniques.
b. foreign material or dirt imbedded in screens.
c. film being bent when inserted in a cassette or holder.
d. scratches on lead foil screens.

21. The purpose of agitating an X-ray film during development is to:

a. protect the film from excessive pressure.
b. renew the developer at the surface of the film.
c. disperse unexposed silver grains of the film surface.
d. prevent reticulation.

22. When manually processing films, the purpose for sharply tapping hangers two or three times after the films have been lowered into the developer is to:

a. disperse unexposed silver grains on the film surface.
b. prevent frilling.
c. dislodge any air bubbles clinging to the emulsion.
d. all of the above.

23. The purpose of fixation is:

a. to remove all the undeveloped silver salts of the emulsion.
b. to leave the developed silver as a permanent image.
c. to harden the gelatin.
d. all of the above.

24. For best results when manually processing film, solutions should be maintained within a temperature range of:

a. 65°F and 75°F
b. 65°C and 75°C
c. 75°F and 85°F
d. 75°C and 85°C

25. Water spots on films can be minimized by

a. rapid drying of wet film,
b. immersing wet film for 1 or 2 minutes in a wetting agent solution.
c. by using a fresh fixer solution,
d. by cascading water during the rinse cycle.

26. The most common material used to provide protection against x-rays is:

a. high density brick.
b. an alloy of 70% steel and 30% copper
c. tungsten
d. lead

27. A graph which expresses the relationship between the logarithm of the exposure applied to a photographic material and resulting photographic density is called:

a. a bar chart
b. an exposure chart
c. the characteristic curve
d. a logarithmic chart

28. Short wavelength electromagnetic radiation produced during the disintegration of Nuclei of radioactive substances is called:

a. X-radiation
b. gamma radiation
c. scatter radiation
d. back scatter radiation

29. The density difference between two selected portions of a radiograph is known as:

a. unsharpness
b. radiographic contrast
c. specific activity
d. subject density

30. When producing radiographs, if the milovoltage is increased:

a. the subject contrast decreases.
b. the film contrast decreases.
c. the subject contract increases.
d. the film contrast increases.

31. The accidental movement of the specimen or film during the exposure or the use of a focus-film distance that is too small will:

a. produce a radiograph with poor contrast.
b. make it impossible with poor contrast.
c. result in unsharpness of the radiograph.
d. result in a fogged radiograpn.

32.. The sharpness of the outline in the image of the radiograph is a measure of:

a. subject contrast
b. radiographic definition
c. radiographic contrast
d. film contrast

1. What does the term (R/h) refer to when speaking of intensity?

   a. Roentgens per hour
   b. radiation limits for humans
   c. x-rays per hour
   d. radiation in hydrogen

2. A curie is the equivalent of:

   a. .001 millicuries
   b. 1,000 millicuries
   c. 1,000 megacuries
   d. 100 megacuries

3. The exposure of personnel to X- and gamma radiation can be determined by means of:

   a. film badges
   b. dosimeters
   c. radiation meters
   d. all of the above

4. An advantage of the fountain-pen type of ionization chamber used to monitor radiation received by personnel is:

   a. it provides a permanent record of accumulated dosage.
   b. it provides an immediate indication of dosage.
   c. it is the most sensitive detector available.
   d. all of the above are advantages.

5. In making an isotope exposure in an unshielded area, you find the dose rate 6 feet from the source is 1200 Mr/hr. What would be the dose rate at 24 feet?

   a. 75 Mr/hr
   b. 100 Mr/hr
   c. 200 Mr/hr
   d. 300 Mr/hr

6. Overexposure to x-ray or gamma rays may cause damage to human:

   a. blood tissue
   b. skin
   c. internal organs
   d. All of the above

7. Dosimeter should be re-charged:

   a. every 24 hours
   b. every week
   c. every day
   d. every month

8. Under Section 20 of the A.E.C. regulations paragraph #405, you are allowed how man MR's for the following periods of time.

a. __________ per Day
b. __________ per Week
c. __________ per Quarter
d. __________ per Year

9. The Typical Survey Meter used in our type of Industry is required to have MR's readings from __________ to __________.

10. When using a Survey Meter with a typical scale of X1-X10-X100 like the Victoreen 592B and you had a reading of 4 on your indicator or gauge how many MR's would this be on the scale?

a. X1 __________
b. X10 __________
c. X100 __________

11. The A.E.C. requires that the pocket desimeter have a range from ______ MR's to at least ______ MR's.

12. Radiation Area signs should be posted at the ______ MR line.

13. What is a Beam Camera?

14. What is a Panoramic Camera?

15. What represents the approximate quanity of radiation emitted from a one gram source of Radium in one hour at a distance of one meter?

a. roentgen
b. curie
c. millicurie
d. rad

16. Under the present A.E.C. regulations the exposure device shall have no radiation level in excess of:

a. ______ mr at exterior surface.
b. ______ mr at six inches from exterior surface.
c. ______ mr at one meter from exterior surfa e.

17. What three precautions would you follow when storing a source?

1.
2.
3.

18. When must a Survey Meter be re-calibrated?

a. every 6 months
b. every 3 months
c. every 30 days
d. every year

19. When must a Source have a Leak Test?

a. every 3 months
b. every year
c. every 6 months
d. every 30 days

20. If a source fails to return to its proper position list the following steps you would take.

1.
2.
3.
4.
5.

21. The Film Badge must be turned in and a new Badge issued:

a. weekly
b. monthly
c. daily
d. yearly

22. If you lose a film Badge what would you do?

23. When traveling on the freeways & turnpikes throughout the United States, what areas are you strickly forbidden to have radioactive material?

24. What is the half-life of iridium 192?

STANDARD FOR WELDING PIPELINE API 1104 11th EDITION

THE FOLLOWING 25 QUESTIONS ARE IN REFERENCE TO THE API CODE BOOK. EACH QUESTION WILL HAVE A BLANK WHERE YOU WILL HAVE TO FILL IN THE PROPER WORD OR NUMBER.

1. The term ________________ as used in this standard indicates a mandatory requirement.

2. Nondestructive test methods give __________ dimensional results only.

3. INADEQUATE PENETRATION OF WELD ROOT

Inadequate penetration without high-low present, is defined as the __________ filling of the weld root. Any individual condition due to this type of inadequate penetration shall not exceed ________. The total length of such condition in any con 12 in. length of weld shall not exceed _________. If the weld is less than 12 in. lo then the total length of such condition shall not exceed ______ per cent of the weld length.

4. INADEQUATE PENETRATION DUE TO HIGH-LOW

High-Low is defined as a condition where the pipe and/or fitting surfaces are misalig High-Low is not objectionable provided that the root of adjacent pipe and/or fitting joint is completely tied-in(bonded) by weld metal. When one edge of the root is expo or (unbonded), the length of this condition shall not exceed __________ at individua locations or __________ in any continuous 12. in. length of weld.

5. INCOMPLETE FUSION

Incomplete fusion at the root of the joint or at the top of the joint between the wel metal and the base metal shall not exceed ________ in length. The total length of such conditions in any 12 inch length of weld metal shall not exceed _________. the weld is less than 12 in. long, then the total length of such conditions shall not exceed ______ per cent of the weld length.

6. INCOMPLETE FUSION DUE TO COLD LAP

Incomplete fusion due to cold lap is a discontinuity between two adjacent weld leads between a weld bead and the base metal. For the purposes of this standard, incomplet fusion due to cold lap is a sub-surface discontinuity and thus it differs from incomp fusion. Individual incomplete fusion due to cold lap discontinuities shall not excee __________ in length. The total length of incomplete fusion due to cold lap in any continuous 12 in. length of weld shall not exceed ____________.

7. FOR PIPE 2-3/8 IN. O.D. AND LARGER BURN THROUGHS

Any unrepaired burn-through shall not exceed ________ or the ________ of the pipe wal whichever is smaller, in any dimension. The sum of the maximum dimensions of separa unrepaired burn-through in any continuous 12 in. length of weld shall not exceed ____ Radiographs of repaired burn-throughs shall show that these have been properly repair

8. ELONGATED SLAG INCLUSIONS (WAGON TRACKS) FOR PIPE 2-3/8 IN. OD AND LARGER.

Any elongated slag inclusions shall not exceed 2 in. in length or ________ inches in width. The total length of elongated slag inclusions in any continuous 12 in. length of weld shall not exceed ________. Parallel slag lines shall be considered as separate conditions if the width of either of them exceeds________.

9. ISOLATED SLAG INCLUSIONS

The maximum width of any isolated slag inclusions shall not exceed ________. The total length of isolated slag inclusions in any continuous 12 in. length of the weld shall not exceed ________, nor shall there be more than ________ isolated slag inclusions of the maximum width of ________ in this length.

10. SPHERICAL POROSITY

The maximum dimension of any individual spherical gas pocket shall not exceed ________ ________ per cent of the pipe wall thickness, whichever is the lesser.

11. CLUSTER POROSITY

Cluster porosity which occurs in the finish pass shall not exceed an area of ________ with the maximum dimensions of any individual gas pocket within the cluster not to exceed ________. The total length of cluster porosity in any continuous 12 in. length of weld shall not exceed ________.

12. PIPING (WORMHOLE) POROSITY

Piping (wormhole) porosity is an elongated discontinuity which results when the gas rises through the solidifying weld metal. The maximum dimension of the radiographic image associated with wormhole porosity shall not exceed ________ or ________ per cent of the pipe wall thickness, whichever is the lesser.

13. HOLLOW BEAD

Hollow bead is elongated linear porosity occurring in the root pass. The maximum length of this discontinuity shall not exceed ________. The total length of hollow bead in any continuous 12 in. length of weld metal shall not exceed ________ and individual adjacent discontinuity exceeding ________ length shall be separated by at least 2 in. of sound weld metal.

14. CRACKS

Shallow crater cracks or star cracks which are located at the stopping point of weld beads and which are the result of weld metal contraction during solidification are not considered injurious defects unless their length exceeds________. With the exception of these shallow crater cracks, no weld containing cracks, regardless of size or location shall be acceptable.

15. ACCUMULATION OF DISCONTINUITIES

Excluding high-low condition, any accumulation of discontinuities having a total length of more than ______ in a continuous weld length of 12 in. or more than ______ per cent of the continuous weld length if the total weld length is less than 12 in. is unacceptable. Accumulation of discontinuties which total more than ____ per cent of the weld length associated with an entire joint is unacceptable.

16. UNDERCUTTING

Undercutting is the burning away of the side walls of the welding groove at the edge of a layer of weld metal, or the reduction in the thickness of the pipe wall adjacent to the weld and where it is fused to the surface of the pipe. Undercutting adjacent to the cover bead on the outside of the pipe shall not be ________ shaped nor shall it exceed ________ or ________ per cent of the pipe wall thickness, whichever is smaller, in depth; nor shall it exceed ________ in length or ________ the length of the weld, whichever is smaller. Undercutting adjacent to the root bead on the inside of the pipe shall not exceed ________ in length or ________ of the length of the weld, whichever is smaller.

17. REPAIR OR REMOVAL OF DEFECTS AUTHORIZATION FOR REPAIRS

Defects except ________ in the root and filler beads may be repaired with prior company authorization. Defects, except ________ in the cover pass may be repaired without prior company authorization. Cracks shall not be repaired.

18. TESTING TESTING OF REPAIRS

Such repaired areas shall be ________ or inspected by the same means previously used. No further repairs shall be allowed in these areas.

19. PENETRAMETERS

________ shall be made of ________ ________ radiographically as the material being welded.

20.

Weld Thickness, Inches	Penetrameter Thickness
Up to 1/4 Incl.	
Over 1/4 through 3/8	
Over 3/8 through 1/2	
Over 1/2 through 5/8	
Over 5/8 through 3/4	
Over 3/4 through 7/8	
Over 7/8 through 1	
Over 1 through 1¼	
Over 1¼ through 1½	
Over 1½ through 2	

21 FILM DENSITY

Film shall be exposed so that the average H & D density shall not be less than ________ and so that this density through the thickest portion of the weld shall not be less than ________.

THIS PART OF THE TEST IS IN REFERENCE TO THE EVALUATION OF 25 FILMS. ON EACH FILM THERE WILL BE A DEFECT IN THE WELD OR THE FILM WILL NOT HAVE THE PROPER TECHNIQUE OR PROCESSING. AFTER EACH OF THE FOLLOWING NUMBERS YOU WILL LIST YOUR EVALUATION OF THE FILM IN DETAIL AND YOUR DECISION OF ACCEPTING OR REJECTING THE WELD.

	EXPLANATION OF FILM	ACCEPT OR REJECT
# 1		
# 2		
# 3		
# 4		
# 5		
# 6		
# 7		
# 8		
# 9		
# 10		
# 11		

	EXPLANATION OF FILM	EVALUATION OF FILM TEST ACCEPT OR REJECT
# 12		
# 13		
# 14		
# 15		
# 16		
# 17		
# 18		
# 19		
# 20		
# 21		
# 22		
# 23		
# 24		
#25		

THE DOW CHEMICAL COMPANY
MIDLAND, MICHIGAN
RADIOCHEMISTRY [illegible]ESEARCH LABORATORY

6(a) attachment

FILE C[illegible]

REPORT NO.

Authors

I. T. Takahashi ITT
F. A. Blanchard FAB

Date 3-3-65

RADIOASSAY OF WIPE TEST SAMPLES CONTAINING Cs^{137}, Co^{60}, Po^{210}, Pm^{147}, Ra^{226}, Sr^{90}, Tl^{204}, and H^{3}

A liquid scintillation counting method has been set up for counting a variety of isotopes appearing in swab tests of sealed sources found in this Company. Using a 3-channel spectrometer with a punch tape output, one can rapidly screen 200 swab samples containing Tl^{204}, Co^{60}, Cl^{36}, Sr^{90}-Yr^{90}, Sr^{89}, Pm^{147}, Cs^{137}, C^{14}, Ra^{226} and Po^{210}. A computer program is available to process the counting data and report all samples containing more than 0.00002 µc.

TYPE OF REPORT: Research PAGES: STAGE

INTRODUCTION

In order to comply with AEC regulations, it has been necessary to make biannual leak tests of the exterior surfaces of the radioacti sealed sources in use at The Dow Chemical Company. According to ou By-Products Material License, the test should be sufficiently sensi tive to detect 0.005 µc of removable beta or gamma emitting radio- active materials. If any removable contamination is found, it must be reported to the AEC within five days after completion of the tes

The Biochemical Research Laboratory has been making these tests, us cotton swabs to wipe an area around the source to pick up any loose contamination. It has been our job to radioassay these wipe sample Since these samples consist of approximately 200 swabs containing some beta, gamma or alpha emitter, we needed a quick and sensitive method which would rapidly screen 200 swabs for various kinds of radioactivity. We selected a liquid scintillation counting method for this purpose because of the ease of sample preparation and the availability of a 3-channel spectrometer with punch tape output.

RADIOASSAY METHOD

Scope

This method will detect a lower limit of 0.00002 µc of beta or alph radioactivity on cotton swabs used to wipe sealed sources containin Cs^{137}, Co^{60}, Po^{210}, Pm^{147}, Ra^{226}, Sr^{90}, Tl^{204}, and H^3.

Apparatus

Packard Tri-Carb Liquid Scintillation Spectrometer, Model 3324.
Glass counting vials, 5 dram, screw cap, Wheaton Glass Co.

Reagents

Liquifluor 25X concentrate: 100 gm of PPO and 1.25 gm of POPOP per liter of toluene, Pilot Chemicals

Liquifluor 1X: 40 ml Liquifluor 25X concentrate diluted to 1 liter with toluene

Procedure

Cotton swabs used to wipe the sealed sources are placed into Wheato

counting vials. The swabs are covered with 10 ml of Liquifluor A clean swab is also placed in a counting vial and covered with ml of Liquifluor 1X. This is used as the background sample.

The channels of the Tri-Carb 3000 are set at 50-1000. The gain settings selected for the 3 channels are the balance point gain settings for Cl^{36}, C^{14}, and H^3 standard swab samples. These gai settings cover all energy regions of interest. The table below indicates for each isotope the channel in which the bulk of the counts appear.

Isotope	Cl^{36} Channel (2% gain)	C^{14} Channel (10% gain)	H^3 Channel (50% gain)
Cs-137	x		
Co-60		x	
Po-210	x		
Pm-147		x	
Ra-226	x		
Sr-90	x		
Tl-204	x		
H-3			x

From the gain spectra of standard swab samples, the balance point gain setting for counting the samples in a 50 to 1000 window can be determined. Knowing that a relationship exists between the bet energy, the gain at balance point, and counting efficiency, a counting efficiency can be estimated for each of the isotopes in the Cl^{36}, C^{14}, and H^3 channels. On our instrument when the counting efficiencies were calculated for each isotope, we found we could compute an average efficiency for each channel for the isotopes listed in the previous table. These values were 91%, 69%, and 6% for the 3 channels.

The background is determined by counting the blank swab for at least 10 min. This background cpm can then be used to set up the background subtract on a Tri-Carb 3000 spectrometer if one is planning to calculate the results manually or it can be fed into a computer program if the calculations are to be done by a computer.

Three to seven repeat counts are tak n on the swab samples with t time set at two to 10 min. The repeat counts are averaged for ea sample.

All samples containing more than 50 dpm (0.00002 μc) are reported This means if the maximum counting channel of a sample is the Cl^{36} or C^{14} channel and it shows more than 40 net cpm, it is reported. If the maximum counting channel is the H^3 channel, if more than 3 net cpm are present, it is reported.

Calculations

C = Average cpm in channel with maximum counts

B = Background cpm

E = Per cent counting efficiency in channel with maximum counts

$$\frac{(C - B)}{2.22 \times 10^6 E} 100 = \mu c \text{ per sample}$$

Automatic Calculations

The above calculations have been programmed in Algol for the Burroughs B-5000 computer by F. A. Blanchard (APELSCATR-3K: Wipe Test, Program 297-7, Deck 864). This program uses punch tape data from a 3-channel liquid scintillation spectrometer, averages the counts, computes cpm, subtracts the predetermined background cpm, selects the maximum counting channel, computes the μc per sample in the maximum channel using the predetermined counting efficiency, and computes from the repeat counts the standard deviation of the average μc per sample. The program will print out μc per sample for all samples greater than 0.00002 μc and will print out a warning for all samples that exceed the AEC reporting level of 0.005 μc.

The only imput constants needed to use this program are a file number for the data, the predetermined background cpm for each channel, and the predetermined counting efficiency for each channel.

Liquid Scintillation Counting of th Samples

The swabs immersed in scintillator solution were counted on the Tri-Carb 3000 with the discriminators set at 50-1000 in each of the three channels. The gain was varied from 0.2% to 100%. The gain spectrum obtained for each isotope showed a balance point gain setting where the counts were a maximum. A plot of beta E_{m} versus balance point gain was made using the data from the gain spectra.

The counting efficiency was determined at the balance point gain setting for the swabs which were prepared from solutions of known radioactivity. Using this data, a plot was made of the counting efficiency versus balance point gain setting.

Results

A. Gain Spectra

The gain spectra for the standard swab samples are shown in Fig. 1 The Tl-204 swab and Co-60 swab showed gain spectra similar to the standards. The Sr^{90}-Yr^{90} swab showed a gain spectrum with only on maximum. The two beta rays could not be resolved in the wide wind used for this experiment.

The unknown Po-210 swab, which is a 5.3-Mev alpha emitter, showed a maximum at a gain setting corresponding to that of a 0.69-Mev beta ray. The unknown Ra-226 swab showed a broad gain spectrum with the bulk of the counts appearing at gain settings between 1 and 4%.

A balance point gain setting for each isotope in a 50-1000 window was determined from the gain spectrum of the swabs containing C^{14}, H^{3}, Cl-36, Cs-137, Pm-147, Sr-89, Co-60, and Tl-204. Since Peng (2) has shown that a relationship exists between gain setting and the maximum energy of the beta ray, a plot of these two variables was made and is shown in Fig. 2. An almost linear relationship was found except in the low energy end of the curve. Thus for any beta emitter on a swab, the balance point gain at which it would count in a 50-1000 window could be found from this curve.

STANDARDIZATION OF RADIOASSAY METHOD

Preparation of Swab Samples

Solutions used:

		DPM/ml
1.	Polyacrylamide-C^{14} in water	2.825×10^5
2.	Sulfinated polyvinyl toluene-H^3 in water	2.172×10^6 (1-11-65)
3.	Sodium chloride-Cl^{36} in water	1.470×10^4
4.	Cesium-Cs^{137} bromide in water	5.275×10^4 (1)
5.	Promethium-Pm^{147} chloride in HCl	3.26×10^4 (1-27-65)
6.	Strontium-Sr^{89} chloride in HCl	2.468×10^4 (1-27-65)
7.	Cobalt-Co^{60} chloride in water	unknown activity
8.	Thallium-Tl^{204} nitrate in water	" "
9.	Strontium (Sr^{90}-Yr^{90}) sulfate in water	" "

Actual wipe samples with unknown activity

Swab used to wipe Po^{210} source

Ra^{226} source

The aqueous solutions listed above were pipetted onto cotton swabs with a 0.1 ml serological pipet. Duplicate cotton swabs were prepared. The swabs were dried at room temperature for 3 1/2 hrs. All the swabs except those containing Cs-137 were immersed directly into 10 ml of Liquifluor 1X and then counted in the Tri-Carb 3000 Liquid Scintillation Spectrometer.

The swabs containing the gamma emitter, Cs-137, were first counted in a well counter (1) to determine the dpm on the swab. Taking into account the decay scheme of the isotope, the number of betas per minute was determined. These swabs were then immersed in 10 ml Liquifluor 1X and counted in the Tri-Carb 3000. The gamma contribution to the counts on the Tri-Carb was determined by wrapping the swab in sufficient Pb foil to block off the beta rays but not the gamma rays. This Pb-wrapped swab was immersed in 10 ml of Liquifluor and counted.

Counting Efficiency

The counting efficiency was calculated for each of the standard swabs (C-14, H-3, Cl-36, Cs-137, Pm-147, Sr-89). These were plotted against the balance point gain setting (Figure 3). A curve approaching 100% counting efficiency at low gain settings was obtained. This curve could then be used to determine the counting efficiency of any beta emitter for which a standard was not available. The counting efficiencies of Tl-204 and Co-60 on swabs were obtained from this curve.

Since a standard of Sr^{90}-Yr^{90} was not available, the theoretical balance point gain setting and the counting efficiency was found for each isotope using Figs. 2 and 3. Using this data and the gain spectrum of isotopes having similar beta-ray energies to Sr-90 and Yr-90, a theoretical gain spectrum for each isotope was plotted. Assuming an equilibrium mixture of the two isotopes was present on the swab, a sum curve was obtained similar to the observed one. From this the apparent counting efficiency was found to be 177.5% for Sr-90 at the single maximum in the gain spectrum. The total beta activity could be found by using a counting efficiency of 88.8%.

By counting the Cs-137 swab with and without lead foil, it was found that the 0.662 Mev gamma ray only contributed a few per cent to the counting efficiency. So it was assumed in the case of Co-60, the gamma rays also did not contribute many counts.

The alpha emitter, Po-210, was assumed to be counting at close to 100% counting efficiency (3). Since the decay scheme of Ra-226 was unknown and a variety of products was present, its counting efficiency was assumed to be close to 100%.

It was found from the balance point gain setting and counting efficiencies in the 50-1000 window that 3 different gain settings could be selected to screen a mixture of these swab samples in a 3-channel liquid scintillation spectrometer. The 3 windows chosen were balance point gain windows for Cl-36, C-14, and H-3 with gain

settings of 2, 10 and 50%, respectively. Also, three average counting efficiencies could be selected for calculating the μc per sample. This data as well as the balance point gain settings and counting efficiencies are shown in Table I.

Based on a minimum detection limit of 10 counts per minute above background, the detection limit in each channel with the gain settings of 2%, 10%, and 50% was 5×10^{-6}, 7×10^{-6}, and 75×10^{-6} microcuries respectively.

The largest error introduced in using an average counting efficiency for each channel is 10% in the total activity due to Sr^{90}-Yr^{90}. The error is less than 4% for the other isotopes.

REFERENCES

(1) Cs-137 swab analyzed by Dave Briden of the Activation Analysis Group.

(2) Peng, C. T., Anal. Chem. 32, 1292 (1960).

(3) Horrocks, D. L. and Studier, M. H., Anal. Chem. 30, 1747 (1958).

Table I. Counting Efficiency of Various Isotopes at Three Selected Gain Settings

Isotope	Energy of Predominant α or β, Mev	Gain, %	Counting Efficiency, %	Counting Efficiency in 50-1000 Window Containing Maximum Counts: Cl^{36} Window (2% Gain)	C^{14} Window (10% Gain)	H^3 Window (50% Gain)
H^3	0.018	52	5.7			5.7
C^{14}	0.155	10.5	68.3		68.3	
Pm^{147}	0.223	10	70.0		70.0	
Co^{60}	0.306	5.9	82.0		68.2	
Cs^{137}	0.52	2.9	91.7	89.8		
Cl^{36}	0.714	2.5	94.9	94.5		
Tl^{204}	0.765	2.5	94.9	94.5		
Sr^{89}	1.463	1.3	98.0	89.0		
Sr^{90}-	0.61	2.9	93.0	92.0] 162.5*		
Yr^{90}	2.18	0.8	98.0	70.5		
Po^{210}	5.3	2.4	100	95		
Ra^{226}	4.66	1.5	100	95		
			Average**	91.3 ± 4.9	68.8 ± .57	5.7

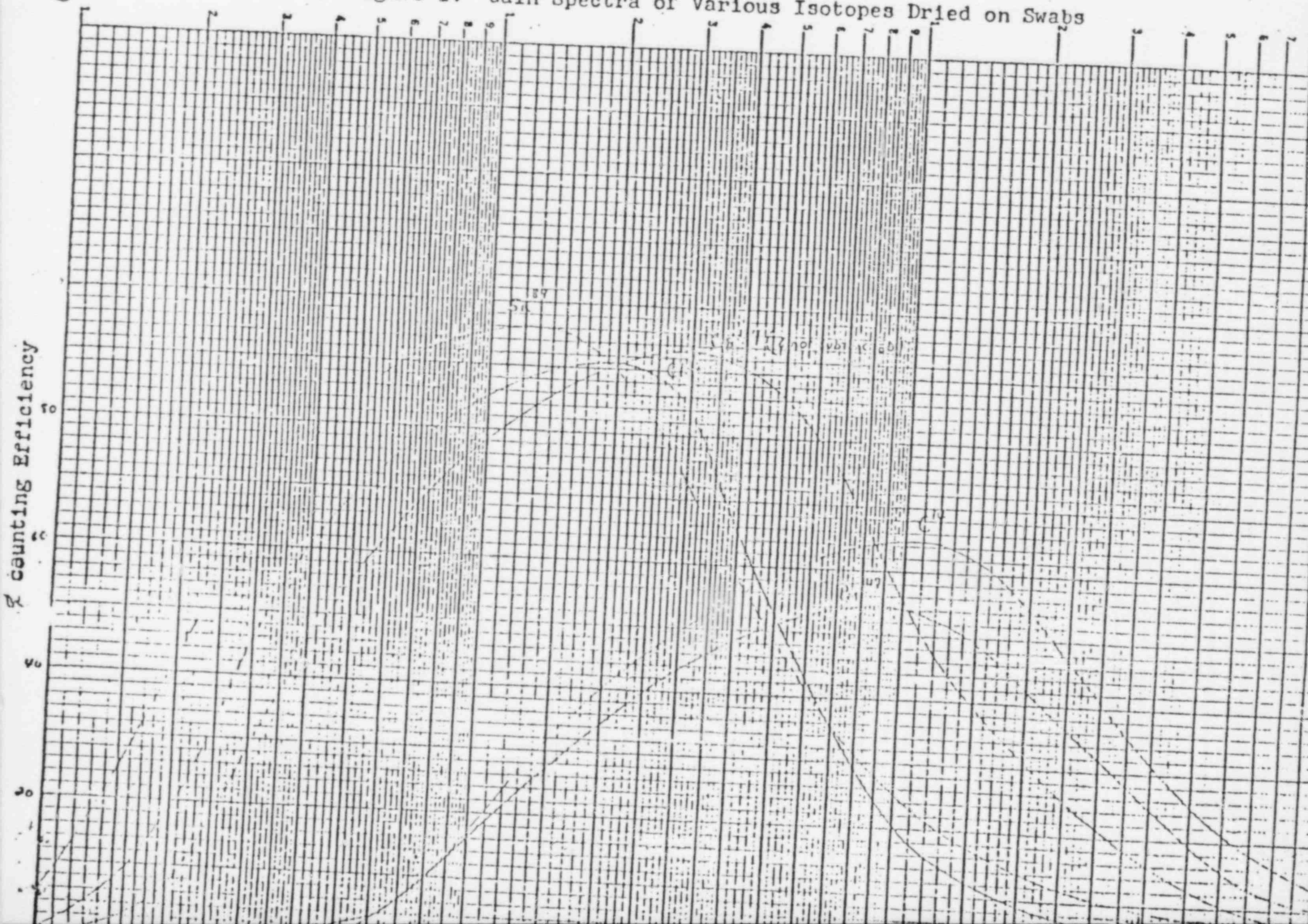
*Total beta activity, counting efficiency = 81.3%

**Average to the nearest whole equals 91, 69, and 6% counting efficiency for the 3 channels.

0796

K&E SEMI-LOGARITHMIC 3 CYCLES X 70 DIVISIONS 46 5493 KEUFFEL & ESSER CO.

Figure 1. Gain Spectra of Various Isotopes Dried on Swabs



0796

Figure 2.

Relationship between Maximum Beta Energy
and Balance Point Gain

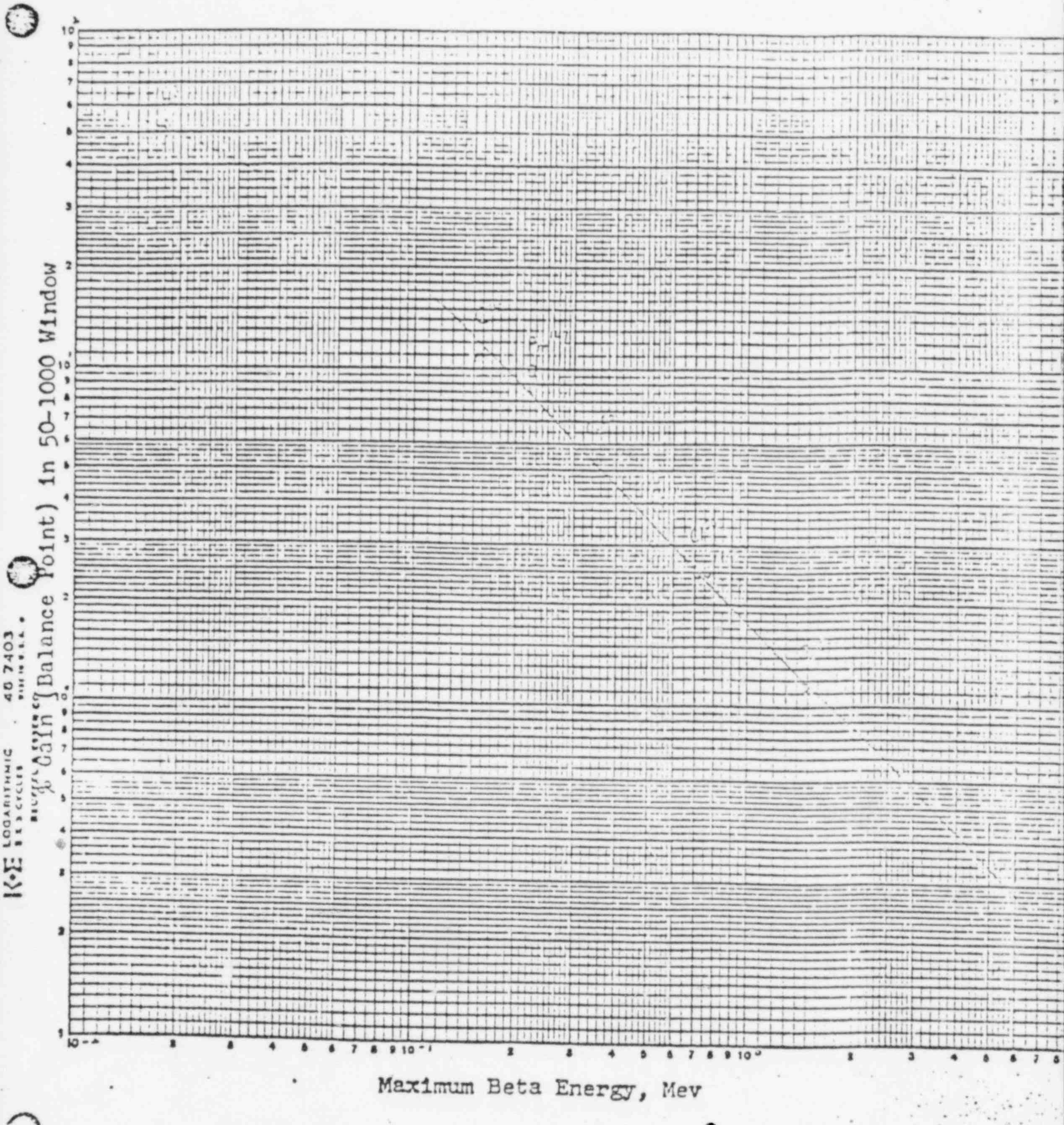


Figure 3. Relationship between Counting Efficiency and Balance Point Gain Setting