THE DOW CHEMICAL COMPANY

MIDLAND, MICHIGAN

January 10, 1964

Mr. William O. Miller
Isotopes Branch
Division of Licensing and Regulation
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Mr. Miller:

Reference is made to your letter of January 2, 1964, L and R: IB:WOM (52872), on the extent and nature of the training given to radiographic personnel. Copies of the attachments to section 6(f) of the application form AEC-313R are enclosed.

Attachments A, B, and C section 6(f) were used in a sixteen hour formal radiation safety training course held in 1961. All of the present staff of radiographers have received this course.

Attachment 6(f)-A is an outline of the instruction in fundamentals of radioactivity and radiation protection. Attachment 6(f)-B contained regulations from part 20 and 31 pertaining to radiation protection for radiographers. Attachment 6(f)-C is a sample test given at the end of the training course.

In December 1963 a three hour review was held with all radiographers present. Enclosure B was reviewed briefly, then enclosures 6(e)-A, B, and C were discussed in detail. A formal review of regulations, operating procedures and emergency procedures will be held semi-annually from now on, coinciding with the wipe-test of the radiographic sources.

I trust that this will complete our application as indicated in your letter.

Very truly yours,

William H Beamer

William H. Beamer, Chairman
Radiation Hazards Committee
Building 1602

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Enclosures: 6(f)-A, B, C
6(e)-A, B, C

ACKNOWLEDGED

Attachment
6(f)-A

I. FUNDAMENTALS OF RADIOACTIVITY WHICH ARE IMPORTANT IN RADIATION SAFETY

1. Structure of the Atom -

   a. Composed of a nucleus and orbital electrons. The electrons determine chemical properties - since radioactivity is a nuclear phenomenon, the chemical and physical properties of stable and radioactive isotopes of the same element are identical.

   b. Isotopes - are atoms of the same element which differ only by weight, and the fact that some isotopes are stable and others are radioactive.

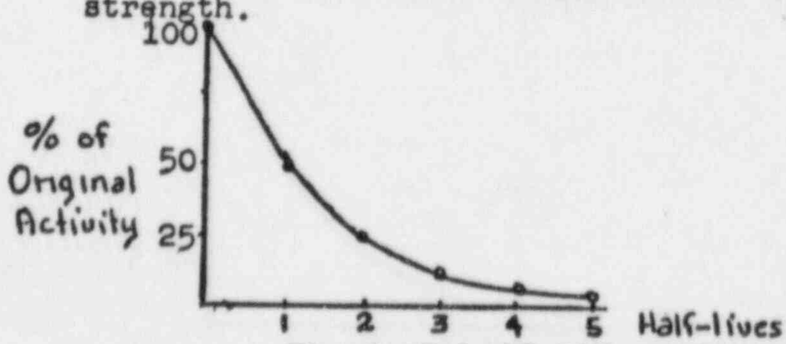
   c. Symbols - isotopes are designated by the chemical symbol and the mass number, e.g. Carbon has isotopes C^{10}, C^{11}, C^{12}, C^{13}, C^{14}, C^{15}. Only by prior knowledge can one tell a radioactive isotope from a stable one by this designation. (Examples I^{131}, Cs^{137}).

2. Radioactivity -

   a. Results from unstable nuclear forces which cause the emission of energy from the nucleus.

   b. Is a statistical process, which means that with a large number of atoms, precise laws governing radioactive decay can be applied.

   c. Half-life, $T_{1/2}$ is the time it takes a given quantity of radioactive material to decay to one half its starting activity. In the second half-life it will decay from ½ to ¼ its starting activity. Since decay is exponential, theoretically it never disappears completely, but for our purposes, seven half-lifes reduce it to less than one percent of its original strength.



Physical half-life refers to the $T_{1/2}$ of the radioactive isotope itself, which is a property of the isotope (which cannot be altered by man-made forces).

"Biological half-life," T_b, refers to the time it takes the human body to rid itself of ½ the original dose of material.

"Effective half-life" T_{eff}, refers to the time it takes for a dose to the human body to be reduced by ½, which is a function of both $T_{1/2}$ and T_b.

d. Modes of decay - radioactive isotopes may decay in a number of ways: they can give off α rays only, β rays only, or $\alpha + \gamma$ rays, or $\beta + \gamma$ rays. There are other ways, but they are not pertinent to our interests here.

e. The curie - is the unit of radioactivity which simply means that 3.7×10^{10} disintegrations per second are occurring in one curie of radioactive material. The milli curie is $\frac{1}{1000}$ of a curie of 3.7×10^{7} dps. A micro curie is one-millionth of a curie or 3.7×10^{4} dps.

L. G. Silverstein
8/14/62

II. PROPERTIES OF RADIATION IMPORTANT IN RADIATION SAFETY

1. Penetrating ability -

   α very short range, can't penetrate outer layer of skin.

   β & e longer range, can cause serious skin burns.

   γ very penetrating, will reach all organs of the body from external source.

2. Absorption in matter -

   α are completely absorbed in a few microns of tissue or other substances.

   β & e absorbed in a few millimeters of tissue, or shielding material e.g. ½" lucite or other plastic will absorb even the most energetic β. Laboratory glassware will shield β effectively, but secondary radiation (Bremsstrahlung) may result.

   γ will penetrate anything to some extent. Absorption is exponential; for safety purposes lead or concrete do a good job. Amount of shielding necessary depends upon energy of γ strength of the source primarily. Shielding calculations should be left to experts. Most sealed sources are adequately shielded as installed; shielding is no help if it is in one place and the source is somewhere else.

3. Energy of radiation -

   a. The Mev is the unit of energy - it stands for "million electron volts," is applied to α, β, γ and x-rays, which are referred to as "ionizing radiations" because they cause ionization of matter through which they pass. Visible light rays have energies of 2-4 electron volts, are non-ionizing.

   b. α's are monoenergetic, i.e. only one energy from a given source. All have same range in matter.

   c. β rays are emitted in a continuous spectrum of energies from any given radioactive source, so we speak of the maximum beta energy, E_{max}.

   d. e-electrons from accelerators are essentially monoenergetic.

   e. γ rays are usually monoenergetic from a given source, but more than one energy may be emitted. γ's are degraded, i.e. lose energy, so that a range of energies results. Shielding is based upon the maximum energy involved.

4. Ionizing Ability -

   α. High specific ionization (much energy transferred over a short path) leads to intense tissue damage from internal exposure to α radiation.

   β & e Intermediate ionizing ability, but all energy is transferred to tissue from an internal exposure.

   γ. Low specific ionization, and large percentage of γ's escape from the body.

5. Bremsstrahlung - means x-rays that are produced when radiation is absorbed by shielding material. It increases with atomic number of material, so lightweight plastic is best β shield. It is quite significant with millicurie quantities of P^{32}, Sr^{90} and other high energy beta emitters.

6. Tissue damage is directly related to penetrating ability, energy and specific ionization of radiation.

L. G. Silverstein
8/14/62

III. UNITS IMPORTANT IN RADIATION SAFETY

1. Units -

   a. The curie (c) is a unit of radioactivity which equals 3.7×10^{10} disintegrations per second (dps). The millicurie (mc) is $\frac{1}{1000}$ of a curie and is in common use for the small sources used in level and thickness gauges. When talking about "permissible levels" in the human body, in air or in water, we need an even smaller unit, the microcurie, (μc), one-millionth of a curie.

   b. The roentgen (r) is the unit of external radiation exposure. Its precise definition is too complex and controversial to present here. It is a measure of the ionizing ability of the radiation measured. The milliroentgen (mr) is commonly used when permissible levels and measurements pertaining to safety are involved.

   c. 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. It is mentioned here because most state and federal regulations use the rem unit. The mrem or millirem is actually used. In most work with radioactivity and x-rays, the mrem and mr units can be used interchangeably.
      r/hour, mr/hour, mrem/hour, are units of radiation dose rate.

   d. The rad is the unit of absorbed dose. It is defined as 100 ergs/g. of material. The material should be stated. "Tissue rad" means 100 ergs/g. of soft human tissue.

   e. The relative biological effectiveness (RBE) of a given type of radiation is the ratio of the damage done in tissue by the radiation in question to the damage done in tissue by an equal amount of x-ray.

$$\text{RBE} = \frac{\text{200 Kv X-rays}}{\text{Amount of radiation to produce equivalent biological effect.}}$$

$$\text{REM} = \text{RAD} \times \text{RBE}$$

Table of RBE Values

Type of Radiation	RBE
x-ray, e, β	1
Protons	10
Slow neutrons	5-10
Fast neutrons	10
Alpha particles	20
Other heavy nuclei	20

Since RBE is an experimental quantity, the values may change from time to time.

f. Counts per minute (cpm or c/m) are read directly from geiger counter scales and are related to disintegrations per minute (dpm or d/m) by a correction factor which takes into account geometry, window and air absorption, etc. Cpm in radiation safety work usually refers to contamination in a laboratory or on a wipe sample, and is usually compared to "background" radiation of about 50 cpm for a geiger counter.

g. Miscellaneous Units (MSU or U-M, depending upon your football allegiance). As in every other field many new, obscure and confusing units are in use. and old ones are constantly misused. Those listed above are sufficient for an understanding of radiation safety. If you read the radiation literature, first find out if the author has stated exactly how he is using the various units. If not, the article may not be useful.

L. G. Silverstein
8/13/62

IV. SUMMARY OF BIOLOGICAL EFFECTS OF RADIATION

1. Changes occur at basic level - the atoms and molecules within cells.

2. Cells contain 10^9 to 10^{10} molecules, over 90% water. Irradiation of H_2O produces a variety of very active substances, notably peroxides.

3. Chemical changes can kill the cell or cause abnormal functioning such as decreased motility or formation of giant cells.

4. Cells differ in radiosensitivity or degree of response to radiation, in relation to their function, their stage and degree of development or cell division, and their rate of metabolism. Immature cells, cells in early stages of division, and cells with high metabolic rates are most sensitive to radiation.

5. Order of radiosensitivity of body organs.

   a) Blood and blood forming organs most sensitive.

   b) Skin and G.I. Tract.

   c) Lungs and kidneys.

   d) Bone, muscle, and nerve cells least sensitive.

6. Acute, whole body exposure can produce death or severe injury. Symptoms are non-specific, similar to the "flu" or a bad hangover. Acute symptoms or injury cannot occur from millicurie amounts in sealed sources.

7. Genetic effects

   a) Experiments have proven a potential hazard but have not given us reliable figures yet.

   b) Lack of knowledge is sufficient reason to be conservative in our present permissible levels of radiation exposure. Present levels are well below the bodily injury range and constitute little hazard to future generations.

8. Life-span shortening - has been demonstrated in rats at higher levels than present permissible exposure. The possibility of this effect is another reason for conservatism in accepting radiation exposure.

9. Mental attitude - neither "spastics" nor "ostriches" have proper perspective on radiation. The only solution to modifying either extreme viewpoint is education.

10. Treatment of radiation injuries - no practical treatments are available, so the best solution is to avoid exposure. Supportive therapy and measures which minimize absorption of radioactivity are valuable in case an exposure occurs.

L. G. Silverstein
8/13/62

V. PERMISSIBLE EXPOSURE TO RADIATION

1. All "permissible levels" of exposure - to radiation, chemicals, heat, and noise - in the field of industrial health are determined from the best available knowledge of animal experiments and human experience. These levels are set low enough that there will be no detectable injury to the workman from continuous exposure during his working lifetime.

2. Radiation limits were first based on observed effects on people occupationally exposed.

3. Limits were reduced in 1950 because of animal experiments indicating shortening of life span.

4. Limits were further reduced in 1958 because of possible hazard to future generations.

5. Present limits are far below levels which have caused detectable bodily injury to human beings.

6. Present limit is that lifetime exposure will not exceed 5 rem times the man's age minus eighteen.

   $$L.E. \leq 5(Age-18) \text{ rem.}$$

   a. Not more than 1250 mrem to the whole body is permitted in any one calendar quarter.

      13 weeks x 40 hours = 520 hours.

      1250 mrem ÷ 520 hours = 2.4 mrem/hour
      is maximum permissible continuous exposure rate.

      Because Biology is not that exact a science, 2.5 mr./hr. is acceptable.

   b. Hands and forearms, feet and ankles may receive up to 18 3/4 rem. per calendar quarter.

   c. Skin of whole body may receive up to 7½ rem per calendar quarter.

7. Permissible internal exposure is defined by setting "MPC's" (maximum permissible concentrations) for isotopes in air and water. The only practical way to control internal exposure is to keep isotopes confined in sealed sources or containers. Wipe tests check sealed sources, contamination checks and air monitoring serve to warn us if unsealed isotopes are being handled carelessly.

L. G. Silverstein
8/13/62

VI. RADIATION SAFETY INSTRUMENTS AND TECHNIQUES

1. Need for instruments -

   a. Human senses cannot detect ionizing radiation.

   b. Two basic measurements in radiation safety work are:

      (1) External radiation - the rate is measured in mr/hr, integrated dose in mr.

      (2) Contamination levels of benchtops, equipment, clothing and atmosphere are measured in cpm above normal background.

2. Principles of radiation detection instruments -

   a. All detection methods depend upon the interaction of radiation with matter.

   b. Instruments differ in the medium in which ionization takes place and in the method by which ionization is detected and indicated.

      (1) Photographic emulsions.

      (2) Gas counters.

      (3) Scintillation counters.

3. Individual instruments - their use and limitations.

   a. Photographic emulsions.

      (1) Film badges are widely used for routine monitoring of personnel for external radiation - β, γ, x-rays, neutrons.

      (2) Advantages -

         (a) Permanent record.

         (b) Small, lightweight and rugged.

         (c) Cheap.

         (d) Simultaneous recording of more than one type of radiation.

         (e) Wide range.

(3) Limitations -

(a) Not direct-reading (provide no immediate warning of overexposure).

(b) Processing and reading films is a complex and critical process.

(c) Results aren't as accurate as electronic instruments.

(d) User must be faithful in wearing it and storing it properly.

b. Gas Ionization -

(1) Collection of ions formed by the action of ionizing radiation in a gas, is the principle utilized in these instruments.

(a) Electroscope - charged fibre moves downscale as air is ionized by radiation and ions collect on fibre to neutralize charge.

1. Lab model is simple, compact and rugged, but slow and tedious to use.

2. Pocket chamber or dosimeter can be made direct-reading, it is small, light rugged, relatively cheap, but it is sensitive to shock such as dropping, and it is not sensitive to beta or low-energy x-rays. Pocket chambers are used in addition to film badges, when non-routine exposures are expected.

(b) Ionization Chamber - ions produced within chamber are collected by an electrode to produce a small current which is proportional to the radiation rate.

1. Meters are direct-reading, can be made portable and can be made sensitive to α, β or γ by use of proper windows. The amplifier circuits and batteries can cause trouble and thin windows are quite fragile.

(c) Proportional counter - produces a pulse which is proportional to the energy of the particle detected.

1. Counters are quite efficient for α as well as β-γ, but are not portable.

(d) Geiger-Muller Counter - gas amplification produces large pulse for all radiations detected, pulse not proportional to particle energy.

1. Meter can be portable, very sensitive, and many special tubes are available for specific purposes. Tubes and batteries do fail, as do meter-readers in the interpretation of the readings. Natural background must be considered as well as artificial background from sealed sources or isotopes.

c. Scintillation Counters - detect visible light pulses which are produced by radiation activating the phosphor.

(1) Wide variety of phosphors available for specific uses or radiations, light pulses are proportional to particle energy, phosphors very sensitive. Some portable survey meters utilize scintillation counting, but they are generally more expensive than ion chamber or G-M meters.

4. Summary -

a. Instruments should be chosen to fit the properties of the radiation to be measured.

b. Principles of operation of instruments should be known so that the proper choice can be made, and the limitations recognized.

c. Portable survey meters have several limitations: because tubes and batteries fail occasionally, meters should be checked against a reference source before use, calibration should be checked regularly because of rough usage and battery aging, and meters have a time lag - they should be allowed a few seconds to reach maximum before measurements are recorded.

L. G. Silverstein
8/13/62

AEC Radiation Safety Requirements for Radiographic Operations Parts 20 and 31

1. Definitions

(a) "Radiographer" means any individual who performs or who, in attendance at the site where the sealed source or sources are being used, personally supervises radiographic operators and who is responsible to the licensee for assuring compliance with the requirements of these regulations and the conditions of the license.

(b) "Radiographer's Assistant" means any individual who, under the personal supervision of a radiographer, uses radiographic exposure devices, sealed sources or survey instruments in radiography.

(c) "Radiographic Exposure Device" means any instrument containing a sealed sourve fastened or contained therein, in which the sealed source or shielding thereof may be moved, or otherwise changed, from a shielded to unshielded position for purposes of making a radiographic exposure.

2. Equipment Control

(a) Limits on Level of Radiation for Radiographic Exposure Devices- Radiographic exposure devices measuring less than four (4) inches from the sealed source storage position to any exterior surface of the device shall have no radiation level in excess of 50 milli-roetgens per hour at six (6) inches from any exterior surface of the device.

Radiographic exposure devices measuring a minimum of four (4) inches from the sealed source storage position to any exterior surface of the device and all storage containers for sealed sources shall have no radiation level in excess of 200 milli-roentgens per hour at any exterior surface, and ten (10) milli-roentgens per hour at one meter from any exterior surface. The radiation levels specified are with the sealed source in the shielded (off) position.

(b) Locking of Radiographic Exposure Devices- Each radiographic exposure device shall be provided with a lock or outer locked container designed to prevent unauthorized or accidental removal or exposure of a sealed source and shall be kept locked at all times except when under the direct surveillance of a radiographer or radiographer's assistant.

Each storage container likewise shall be provided with a lock and kept locked when containing sealed sources except when the container is under the direct surveillance of a radiographer or radiographer's assistant.

Locked radiographic exposure devices and storage containers shall be physically secured to prevent tampering or removal by unauthorized personnel.

Radiation Survey Instruments

The licensee shall maintain sufficient calibrated and operable radiation survey instruments to make physical radiation surveys as required by part 20 and part 31. (Part 20 201 Surveys - as used in the regulations in this part, "survey" means an evaluation of the radiation hazards incident to the production, use, release, disposal or presence of radiocative materials or other sources of radiation under a specific set of conditions. When appropriate, such evaluation includes a physical survey of the location of materials and equipment and measurements of levels of radiation or concentrations of radioactive material present.) Each radiation survey instrument shall be calibrated at intervals not to exceed (3) months and after each instrument servicing and a record maintained of the latest date of calibration. Instrumentation required by this section shall have a range such that two (2) milliroentgens per hour through one roentgen per hour can be measured.

Leak Testing Repair Tagging, etc.

Each sealed source shall be tested for leakage at intervals not to exceed six (6) months.
The leak test shall be capable of detecting the presence of 0.005 microcuries of removable contamination on the sealed source.

Quarterly Inventory

Each licensee shall conduct a quarterly physical inventory to account for all sealed sources received and possessed under his license. The records of the inventories shall be maintained for inspection by the commission and shall include the quantities and kinds of byproduct material, location of sealed sources and the date of the inventory.

Utilization Logs

Each licensee shall maintain current logs which shall be kept available for inspection by the commission showing:
(a) a description of the radiographic exposure device or storage container
(b) the identity of the radiographer to whom assigned; and
(c) the plant site where used and dates of use.

Personal Radiation Safety Requirements

Licensee shall not permit any person to act as a radiographer until such person:

(a) Has been instructed in subjects outlined in Appendix A (Radiation Safety course).
(b) Has received instruction in the regulations in this part.
(c) Has demonstrated competence to use radiographic exposure devices, sealed sources and related tools and survey instruments.
(d) Has received copies and instructions in the licensee's operating and emergency procedures.

Operating and Emergency Procedures

(a) The handling and use of licensed sealed sources and radiographic exposure devices to be employed such that no person is likely to be exposed to radiation doses in excess of the limits established in Part 20. (Essentially 100 MR/WK.)
(b) Methods and occasions for conducting radiation surveys;
(c) Methods for controlling access to radiographic areas;
(d) Methods and occasions for locking and securing radiographic exposure devices, storage containers and sealed sources;
(e) Personnel monitoring and the use of personnel monitoring equipment;
(f) Transporting sealed sources to field locations, including packing of radiographic exposure devices and storage containers in the vehicles, posting of vehicles and control of the sealed sources during transportation;
(g) Minimizing exposure of persons in the event of an accident;
(h) The procedure for notifying proper persons in the event of an accident; (Part 20 403 Notification of Incidents

(a) not applicable to present radiographic work
(b) Each licensee shall within 24 hours notify the manager of the appropriate Atomic Energy Commission Operations Office by telephone and telegraph of any incident involving licensed material possessed by him and which may have caused or threatens to cause:
(1) Exposure of the whole body of any individual to 5 rems or more of radiation; exposure of the skin of the whole body of any individual to 30 rems or more of radiation; or exposure of the feet, ankles, hands, or forearms to 75 rems or more of radiation; or
(2) The release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 500 times the limits specified for such materials in Appendix B, Table II; (Co^{60} (s.) 1×10^{-8} μc/ml in air and (i.) 3×10^{-10} μc/ml.)

(3) A loss of one day or more of their operation of any facilities affected; or
(4) Damage to property in excess of $1,000.

(i) Maintenance of records.

Personnel Monitoring Control

(a) The licensee shall not permit any person to act as a radiographer's assistant unless, at all times during radiographic operations, each such person shall wear a film badge and either a pocket dosimeter or a pocket chamber. Pocket dosimeters and pocket chambers shall be capable of measuring doses from zero to at least 200 milliroentgens. A film badge shall be assigned to and worn by only one person.

(b) Pocket dosimeters and pocket chambers shall be read and doses recorded daily. A film badge shall be immediately processed if a pocket chamber or pocket dosimeter is discharged beyond its range. The film badge reports received from the film badge processor and records of pocket dosimeter and pocket chamber readings shall be maintained for inspection by the commission.

Security

During each radiographic operation the radiographer or radiographer's assistant shall maintain a direct surveillance of the operation to protect against unauthorized entry into a high radiation area as defined in Part 20. (Any area where a major portion of the body could receive in any one hour a dose of 100 MR.

Posting

Notwithstanding any provisions in Part 20 204 (c) areas in which radiography is being performed shall be conspicuously posted as required by Part 20 203 (b) and (c) (1).
(Requires signs indicating "Caution High Radiation Area")

Radiation Surveys and Survey Records

(a) No radiographic operation shall be conducted unless calibrated and operable radiation survey instrumentation is available and used at each site where radiographic exposures are made.
(b) A physical radiation survey shall be made after each radiographic exposure during a radiographic operation to determine that the sealed source has been returned to its shielded condition.
(c) A physical radiation survey shall be made to determine that each sealed source is in its shielded condition prior to securing the radiographic exposure device and storage container.
(d) Records shall be kept of the surveys require by paragraph (c) of this section and maintained for inspection by the commission.

Appendix A Part 31

Educational Requirements

1. Fundamentals of radiation safety
2. Radiation detection instrumentation to be used
3. Radiographic equipment to be used
4. The requirements of pertinent Federal Regulations
5. The licensee's written operating and emergency procedures.

Name:______________________________ Date:______________

Test Questions
Radiographers Radiation Training Course

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.

True ( )
False ( )

2. Both alpha and beta rays are made up of particles.

True ( )
False ( )

3. The attenuation of alpha radiation requires careful consideration of problems of shielding.

True ( )
False ( )

4. Alpha emitters offer serious problems of internal radiation.

True ( )
False ( )

5. Gamma radiation will penetrate anything to some extent.

True ( )
False ( )

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

True ( )
False ( )

7. Bremsstrahlung frequently results from the shielding of beta radiation.

True ( )
False ( )

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

True ( )
False ( )

9. High specific ionization means that much energy is transferred over a short path.

True ( )
False ( )

10. Materials of high specific ionization are particularly hazardous due to external radiation.

True ( )
False ( )

11. Tissue damage is directly related to penetrating ability, energy and specific ionization of radiation.

True ( )
False ( )

12. The roentgen is a unit of radioactivity which equals 3.7×10^{10} disintegrations per second.

True ( )
False ( )

13. The roentgen is a unit of external radiation exposure.

True ( )
False ( )

14. The roentgen is a measure of the ionizing ability of the radiation.

True ( )
False ( )

15. The curie is a unit of radioactivity which equals 3.7×10^{10} disintegrations per second.

True ( )
False ( )

16. 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.

True ( )
False ( )

17. The roentgen and the roentgen equivalent man are equivalent.

True ( )
False ( )

18. 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.

True ( )
False ( )

19. Counts per minute and disintegration per minute are the same.

True ( )
False ( )

20. All radiation survey instruments give the same background reading.

True ( )
False ( )

21. Radiation injury occurs in cells by causing changes in the atoms and molecules.

True ( )
False ( )

22. Blood and blood forming organs are the most radio sensitive.

True ( )
False ( )

23. Skin and the G.I. tract are the least radio sensitive organs.

True ( )
False ( )

24. Immature cells, cells in the early stages of division and cells with high metabolic rates are the most sensitive to radiation.

True ( )
False ( )

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

True ( )
False ( )

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

True ( )
False ( )

27. Life span shortening has been demonstrated by experience of human beings with radioactive materials and radiation.

True ( )
False ( )

28. Experiments with animals have proven a potential hazard due to genetic effects but have not given us reliable quantatative information yet.

True ( )
False ( )

29. Lack of knowledge is sufficient reason to be conservative in our control of radiation exposures.

True ( )
False ( )

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

True ( )
False ( )

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

True ( )
False ( )

32. All exposures must be kept below 2.5 mr per hour.

True ( )
False ( )

33. Maximum permissible concentrations take into account biological half life, radiation half life and organ sensitivity.

True ( )
False ( )

34. The half life of a material is the length of time it takes any given sample to decay.

True ( )
False ( )

35. It is possible to predict when any particular radioactive atom will decay.

True ( )
False ( )

36. Although radioactive materials can go through decay schemes which involve several other radioactive materials they eventually all decay to a stable isotope.

True ( )
False ( )

37. Materials can not be made radioactive by exposing them to external radiation from radiographic sources.

True ( )
False( )

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

True ( )
False( )

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

True ( )
False( )

40. The effective half life is a function both of the half life and of the biological half life of the material.

41. The A.E.C. limit on the level of radiation for a radiographic exposure device measuring a minimum of four (4) inches from the source storage position to any exterior surface of the device is 200 milliroentgens per hour and ten (10) milliroentgens per hour at one meter from any exterior surface. The radiation levels specified are with the sealed source in the shielded (off) position.

True ( )
False( )

42. Having locked storage containers for the two cobalt^{60} sources is sufficient protection to prevent tampering or removal by unauthorized personnel.

True ( )
False( )

43. The main reason in having a radiation survey instrument at the site during radiographic work is to measure levels of radiation in case of a mishap.

True ( )
False( )

44. The cobalt^{60} sources should be tested for leakage at intervals not exceeding six (6) months.

True ( )
False( )

45. A written record available for inspection by the A.E.C. is needed indicating the plant sites and dates of use for the cobalt ^{60} sources.

True ( )
False ( )

46. Since X-ray units are not governed by A.E.C. regulations there are no set regulations or records required to be kept.

True ( )
False ( )

47. The portable X-ray units should not be operated if any individual in the immediate area would be exposed to levels of radiation greater than 5 MR./HR.

True ( )
False ( )

48. 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.

True ( )
False ( )

49. Reading an individual's pocket dosimeter once each week is sufficient to account for the recommended weekly dose limit of 100 milliroentgens.

True ( )
False ( )

50. 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.

True ( )
False ( )

51. In the event of an accident involving an excessive exposure to radiation a member of the Environmental Research Laboratory should be notified second only to the Dow Medical Department.

True ( )
False ( )

52. The A.E.C. must be notified within twenty-four hours of any radiation exposure to an individual in excess of the 1 1/4 REM allowed per calendar quarter for the whole body.

True ( )
False ( )

53. The levels of radiation for radiographic work using the cobalt^{60} sources are such that a sign or signs bearing the words "Caution High Radiation Area" are needed to be posted in the area.

True ( )
False ( )

54. The levels of radiation for radiographic work using the portable X-ray units are such that a sign or signs bearing the words "Caution Radiation Area" are needed to be posted in the area.

True ( )
False ( )

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

True ( )
False ( )

56. 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.

True ( )
False ( )

57. A physical radiation survey and a written record thereof is required by A.E.C. to determine that the cobalt^{60} sources are returned to their shielded condition prior to securing.

True ( )
False ( )

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