QUALIFICATION STATEMENT

FISHER CONTROLS, HEREBY CERTIFIES THAT ____________________ HAS RECEIVED TRAINING FROM AN AUTHORIZED REPRESENTATIVE OF FISHER CONTROLS AND HAS DEMONSTRATED AN UNDERSTANDING OF THE SAFE USE AND OPERATION OF THE TYPE LD 2220 PORTABLE LEVEL DETECTOR. HE/SHE HAS ALSO RECEIVED TRAINING IN RADIATION BASICS AND HAS DEMONSTRATED AN UNDERSTANDING OF THOSE PRINCIPLES. THE TRAINING HAS COVERED PRINCIPLES AND PRACTICES OF RADIATION PROTECTION, RADIOACTIVITY MEASUREMENT AND MONITORING TECHNIQUES AND BIOLOGICAL EFFECTS OF RADIATION. ____________________ IS QUALIFIED TO USE OR SUPERVISE THE USE OF THE FISHER CONTROLS TYPE LD 2220 PORTABLE LEVEL DETECTOR.

FISHER CONTROLS INTERNATIONAL, INC.

BY:____________________

DONNA BRESIN

RADIATION SAFETY OFFICER

____

(DATE)

RADIOACTIVE EMISSIONS FROM UNSTABLE ATOMS NATURAL AND MAN-MADE ISOTOPES AND RADIOISOTOPES	If all atoms were stable, we would have no radioactivity. However, a number of naturally occurring, as well as man-made isotopes are unstable and consequently radioactive. They are known as radioisotopes. When these atoms try to change to become stable, they do so by emitting particles, and these are the radiations which we observe as radioactivity.
RADIOACTIVE DECAY THE HALF-LIFE 0 = 100 1 = 50 2 = 25 3 = 12.5 4 = 6.25	When these radioactive atoms decay and become non-radioactive, they do so with a unique half-life. The naturally occurring radioisotopes, such as uranium and radium, have extremely long half-lives measured in billions of years. Some of the man-made radioisotopes have half-lives measured in seconds. As an example, at time zero you may have a hundred units of radioactivity in your source. At the end of one half-life, half of it has decayed away and now you're down to fifty units. After a second half-life, you're down to twenty-five units. At the end of a fourth half-life, 6.25 units. It continues on until essentially your radioactivity disappears. This is a quick and easy method of estimating the amount of radioisotope remaining if you know the type of isotope, its half-life, and how much you had to begin with.
THE UNITS OF RADIOACTIVITY THE CURIE $1\ \mu Ci \times 1000 = 1\ mCi$ $1\ mCi \times 1000 = 1 Ci$ 3.7×10^{10} d.p.s. = $1 Ci$	The unit of radioactivity is the curie. A curie is a lot of radioactive material. Consequently, we generally work with smaller quantities. A micro-curie for example. It takes a thousand micro-curies to make a millicurie and it takes a thousand millicuries to make one curie of radioactivity. A curie is simply the amount of material which has a decay rate of 3.7×10^{10} disintegrations per second. Most of the sources you'll be working with will be measured in millicuries. A common source is 10, 20, 50 or 100 millicuries.

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SOMETIMES A CURIE IS BIG SOMETIMES IT IS small SPECIFIC ACTIVITY mCi/gm	However, sometimes a curie can be big. Sometimes a curie is small. Suppose we were talking about a curie of radium in a thimble. That is a lot of radioactivity in a very small volume and that is a hazardous source. On the other hand, suppose we were talking about a curie of radium in a mountain all mixed up with the rocks, stone, and soil. In that case, you have the same amount of radioactivity in a much larger volume and you have no problem at all. What you need to know is specific radioactivity. Specific activity is measured in terms of amount of radioactivity per unit weight. Millicuries per gram is a common way of expressing it. Specific activity helps you decide whether you have a hazardous amount of activity or not.
α ALPHA PARTICLES β BETA PARTICLES γ GAMMA RADIATION X-RAY RADIATION n NEUTRONS	The other thing you need to think about when you're talking about radioactivity is the type of radiation that you're involved with. Some are more dangerous than others. Some are easily shielded. Some require massive shielding. Alpha and beta radiations are true particles. Gamma radiation and X-rays are little bundles of energy very similar to light. Neutrons are also true particles.
α ALPHA A HEAVY CHARGED PARTICLE (++) SHORT RANGE TOTALLY ABSORBED BECOMES A HELIUM ATOM	Alpha particles have their own characteristics. They are heavy. They have mass and a double positive charge. They have a very short range. They are easily absorbed, easily shielded. They penetrate only a few inches in air before being absorbed. Shielding is not a problem with alpha particles. When alpha particles are slowed down and absorbed, they turn into plain, ordinary helium atoms and disappear from concern.

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β BETA A LIGHT CHARGED PARTICLE (-) A FAST ELECTRON EASILY SHIELDED	The beta particle is a light charged particle with a single negative charge. It also has a short range. Beta particles may have a range of a few feet in air. Because of their mass and their charge, they are easily shielded. The walls of any common container are generally sufficient to totally absorb beta radiation. A beta particle is a fast electron, and when slowed down by shielding, it becomes an ordinary electron and disappears from concern.
γ AND X-RAYS BUNDLES OF ENERGY JUST LIKE LIGHT VERY PENETRATING SHIELDED BY MASS	Gamma and X-rays are bundles of energy like light, but are more energetic. Gamma and X-ray differ only in the frequency and the amount of energy they carry. They are very penetrating. They have no mass and no charge. Shielding is by mass. Massive amounts of shielding will absorb gamma and X-ray radiation. When they are absorbed, they simply disappear, just like light disappears when it is absorbed.
n NEUTRONS LOW MASS - NO CHARGE A PENETRATING PARTICLE SHIELDING BY HYDROGEN	Neutrons are totally different particles. They have low mass and no charge at all. They are penetrating particles. They are very difficult to shield by ordinary means. Shielding of neutrons is accomplished with hydrogen containing materials such as water. Hydrogen interacts with neutrons and slows them down. When they are slowed down, they interact, disappear, and are removed from concern.

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MEASUREMENT OF RADIATION EXPOSURE QUANTITY: THE ROENTGEN OR MILLIROENTGEN RATE: MILLIROENTGENS/HOUR	The unit for measurement of radiation exposure is the roentgen, or milliroentgen. The roentgen is a large amount of radiation exposure, and most of our discussion will center around the milliroentgen, which is one-thousandth of a roentgen. The other term we'll be dealing with is the rate of exposure and that's measured in milliroentgens per hour.
THE SURVEY METER MEASURES EXPOSURE RATE: mR/Hr TOTAL EXPOSURE IN MILLIROENTGENS IS mR/Hr x HOURS	To measure exposure rate, we use a survey meter. When properly calibrated, it reads milliroentgens per hour. You use it to calculate total exposure by measuring the exposure rate and the time in hours spent in that region. The product of the rate times the time gives total exposure. This is a calculation you'll be called upon to do frequently, because this is the way you calculate the exposure of a worker in an area of radiation.
EXAMPLES: 2 mR/Hr x 2 Hrs = 4 mR EXPOSURE 2 mR/Hr x 8 Hrs = 16 mR EXPOSURE 22 mR/Hr x .5 Hrs = 11 mR EXPOSURE	These examples show calculations of total exposure by multiplying exposure rate times the exposure time.

FFT:ds

γ AND β

EXPOSURE

Alpha and beta particles, which are easily absorbed, are hard to read on a survey meter. Suppose you had a relatively large alpha source and you were a foot away. You'd get a zero reading simply because the air is absorbing all of the radiation emitted from the sample. If you were a few feet away from a beta source, you'd also get a zero reading. The safety problems with alpha and beta emitters are contact, ingestion and inhalation. Working at a short distance from alpha and beta emitters, or placing them in common containers give you complete shielding. Simple precautions - working in a fume hood, keeping the materials in sealed containers - are all that are necessary to work safely with alpha and beta emitters.

SHIELDING OF

PENETRATING RADIATION

THE "HALF - THICKNESS"

IT VARIES WITH DENSITY

AND γ ENERGY

Shielding of penetrating radiation from gamma emitters and X-rays is a more serious problem. The trick is a term called the half-thickness. It varies with the density of your shielding material and with the energy of the radiation. The half-thickness is the amount of shielding material required to reduce the radiation intensity to half its original value.

CESIUM - 137

SHIELD	HALF-THICKNESS
WATER (1)	4"
STEEL (8)	1/2"
LEAD (12)	5/16"

1 = 50%

2 = 25%

3 = 12.5%

Here is an example. Cesium-137 is a widely used, moderately strong gamma emitter. If you use water, with a density of one, as a shield, it takes four inches to reduce the radiation intensity to half of its original level. With steel, which has a density eight times that of water, you need only use one-eighth the thickness, or a half-inch, to reduce the radiation intensity of 50%. If you use lead, with a density of twelve times that of water, it takes one-twelfth, or 5/16" to reduce the radiation intensity by 50%. One half-thickness reduces radiation intensity to 50%, two half-thicknesses reduce it to 25%, and three half-thicknesses reduce it to 12.5% of its original value.

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CONSERVATIVE GUIDELINES

SPECIFY SHIELDING TO AN INTENSITY OF 10mR/Hr AT 1 FT.

ABOUT 2" OF LEAD FOR MOST SOURCES

LOWER IS BETTER IN PRINCIPLE IF YOU CAN AFFORD IT

How much shielding is required? When you purchase a source, specify to the manufacturer that he use sufficient shielding to reduce the intensity to about 10mR/Hr at one foot. This is a conservative guideline. For most gamma sources, about two inches of lead is sufficient. Two inches of lead is about six half-thicknesses for cesium-137.

DISTANCE SHIELDING

3'	100 mR/Hr
6'	25 mR/Hr
12'	6.25 mR/Hr
BUT:	
18"	400 mR/Hr
9"	1600 mR/Hr
4 1/2"	6400 mR/Hr

Another type of shielding is distance shielding. Suppose you are three feet from a radioactive source and your survey meter reads 100mR/Hr. By doubling the distance, backing up to six feet, the radiation intensity is reduced to 25mR/Hr. It is reduced by a factor of four. By doubling the distance again to twelve feet, the intensity is again reduced by a factor of four to 6.25 mR/Hr. Similarly, as you move from three feet to 18 inches, you get an increase by a factor of four to 400mR/Hr. At 9 inches, the intensity is 1600mR/Hr, and at 4.5 inches, it is 6400mR/Hr. The moral is: (NEVER TOUCH A SOURCE.) Use tongs, forceps, pliers, etc.

TIME SHIELDING

EXPOSURE = RATE x TIME

EX. INSTALLING A SOURCE IN A SHIELD

RATE = 1000 mR/Hr

TIME REQUIRED = 10 SEC

$$\text{EXPOSURE} = \frac{10}{3600} \times 1000\frac{\text{mR}}{\text{Hr}} = 2.8\text{mR}$$

Another type of inexpensive shielding is time shielding. Since radiation exposure is the rate times the time, we can decrease exposure by decreasing the time spent with the source. For example, suppose you spend 10 seconds installing a source in a shield, and that the radiation intensity is 1000mR/Hr. The total exposure is only 2.8mR. A very short time period is a very effective shielding measure.

FFT:ds

HEALTH PHYSICS

WHAT IS PERMISSABLE?
WHAT IS USUAL?
WHAT IS HAZARDOUS?

WHEN TO MONITOR
HOW TO MONITOR

In health physics, we talk about what level of exposure is permissible, what is usual, and what is hazardous. We also talk about when to monitor and how to monitor exposure.

PERMISSABLE

5000 mR/YEAR

* 100 mR/WEEK *

ISOTOPE WORKERS 10-30mR/WK

X-RAY TECHNICIANS 10-30mR/WK

IN THE WORKPLACE

2mR/Hr RESTRICTED AREA

It is permissible, by the NRC and state regulations, to receive an exposure of 5000mR/year, which is about 100mR/week. There is a tremendous safety factor built into this permissible level. Isotope workers and X-ray technicians typically are exposed to 10-30mR/week, a level one-tenth to one-third of the permissible level.

WHAT IS HAZARDOUS?

TYPE	SHORT TERM EXPOSURE	EFFECT
On the job	20mR	None
Chest X-ray	50mR	None
Permissable	100mR	None
Fluoroscopy	10-15,000mR	None
G.I. Series	10-25,000mR	Possible Transient WBC
Accidental	50-75,000mR	Transient WBC
Accidental	100-150,000mR	Early Nausea Transient WBC
Accidental	200,000mR	Possible Fatality

This table indicates where hazardous short-term exposure begins. There are no documented effects until an exposure of 10-25,000mR is reached, where a transient decrease in white blood count (WBC) may occur. An accidental exposure of 200,000mR may cause a fatality.

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GUIDELINES * ALWAYS STAY WITHIN PERMISSABLE EXPOSURE LIMITS * ALWAYS REDUCE EXPOSURE TO THE PRACTICAL MINIMUM * NEVER CONDONE AN UNNECESSARY EXPOSURE	In spite of the fact that there are no documented effects from low exposure to radiation, these guidelines should always be followed.
MONITORING AREA SURVEYS FILM BADGES FOR PERSONNEL IN RESTRICTED AREAS i.e. above 2mR/Hr DON'T ISSUE FILM BADGES UNNECESSARILY A FILM BADGE IS NOT A PROTECTIVE DEVICE	When an area has a radiation level about 2mR/Hr, federal and state regulations require that it be designated as a restricted area. Never let a person walk into such an area unaware. Film badges should be issued to workers in a restricted area. The film badge gives a cumulative record of a worker's exposure. A film badge is not a protective device. Don't issue film badges for trivial reasons. Their importance and seriousness would be minimized.
REGULATIONS THE NUCLEAR REGULATORY COMMISSION (NRC) THE "AGREEMENT STATES" A LICENSE IS REQUIRED TO OBTAIN ANY SIGNIFICANT AMOUNT OF RADIOACTIVE MATERIAL	The use of radioactive materials is regulated by two bodies, the Nuclear Regulatory Commission, and the Agreement States. About half of the U.S. is regulated by the NRC. The other half is regulated by states who have agreed to assume responsibility for regulating these materials within their borders. The regulations for the NRC and the Agreement States are virtually identical. A license is required to obtain any significant amount of radioactive material. When you apply for a license, you will receive a copy of the regulations. These should be read and understood.

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SHIPPING CONTROLLED BY THE DEPARTMENT OF TRANSPORTATION SHIP SOURCE ONLY AS ADVISED BY THE MANUFACTURER OR A LICENSED DISPOSAL FIRM	Another topic is shipping of radioactive material. Shipping is controlled by the Department of Transportation regulations. These regulations are extremely complex and difficult to understand. Take the coward's way out. Ship sources only as advised by the manufacturer or a licensed disposal firm. They will tell you the correct way to handle shipment of radioactive sources.

Please review this booklet, the accompanying video tape and the questions on the following page to reinforce your knowledge of this material.

FFT:ds

QUESTIONS AND PROBLEMS

1. Why does radiation occur?

2. What does the term "half-life" describe?

3. What unit is used to measure radioactivity?

4. How is specific activity defined?

5. What types of radiation are particles?

6. What unit is used to measure radiation exposure?

7. What types of radiation are most penetrating?

8. What is the most common unit of exposure rate?

9. Calculate the total exposure of a worker subjected to 15mR/Hr for 30 minutes.

10. Why will survey meters not normally detect alpha and beta radiation?

11. Suppose when steel is used to shield a gamma source, the half-thickness is 1/2 inch. What will be the radiation level (in percent) if two inches of steel are used as shielding?

12. Suppose a radiation source has an intensity of 100mR/Hr at 5 feet. What will be the intensity at 10 feet?

13. Suppose a radiation source has an intensity of 100mR/Hr at 4 feet. What will be the intensity at 1 foot?

14. How does time affect the radiation exposure of a worker?

15. What is the maximum exposure allowed for a worker according to NRC regulations?

16. Under NRC regulations, when does an area have to be marked as a restricted area?

17. What do film badges monitor?

18. The NRC regulates radioactive materials in about half of the states. Who regulates radioactive materials in the other states?

FFT:ds

ANSWERS

1. Radiation occurs when unstable atoms try to change to become stable. (page 1)

2. The half-life is the time required for a radioactive source to decay to half its original value. (page 1)

3. The unit of radioactivity is the curie. (page 1)

4. Specific activity is defined as amount of radioactivity per unit weight. (page 2)

5. Alpha radiation, beta radiation, and neutrons. (page 2)

6. Radiation exposure is measured by the reontgen. (page 4)

7. Gamma rays and X-rays are most penetrating. (page 3)

8. The most common unit of exposure rate is the milliroentgen per hour, mR/Hr. (page 4)

9. 15mR/Hr x 1/2Hr = 7.5mR. (page 4)

10. Alpha and beta particles are easily shielded. (page 5)

11. Two inches of steel equals 4 half-thicknesses. Four half-thicknesses reduce the radiation level to 6.25% of its original level. (page 5)

12. Ten feet is twice five feet, so the radiation level is reduced by a factor of four, to 25mR/Hr. (page 6)

13. One foot is one-fourth of four feet, so the radiation level is increased by a factor of sixteen, to 1600mR/Hr. (page 6)

14. Increasing exposure time increases total exposure.
Decreasing exposure time decreases total exposure. (page 6)

15. 5000mR/year. (page 7)

16. An area is designated a restricted area when the exposure rate in the area is above 2mR/Hr. (page 8)

17. Film badges monitor total radiation exposure. They provide no protection form radiation. (page 8)

18. The other states regulate radioactive materials themselves. They have agreed to assume responsibility for regulating these materials within their borders. (page 8)

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APPENDIX E

NUCLEAR MEASUREMENT TERMINOLOGY

AGREEMENT STATE - A state of the U.S.A. which has entered into an agreement with the NRC to control byproduct material within the state and, thus, relieve the NRC of the responsibility. The Agreement State regulations are usually, about the same as the NRC regulations except that the states usually control radium and X-ray machines in addition to byproduct material.

Alabama	Nebraska
Arizona	Nevada
Arkansas	New Hampshire
California	New Mexico
Colorado	New York
Florida	North Carolina
Georgia	North Dakota
Idaho	Oregon
Kansas	South Carolina
Kentucky	Tennessee
Louisiana	Texas
Maryland	Washington
Mississippi	

ALPHA RADIATION - Radiation consisting of particles which have a relatively heavy mass and a positive charge. Not very penetrating but highly ionizing.

ATOM - The smallest unit of an element which still retains its identity as that element. An atom is made up of protons and neutrons (p + n = nucleus) and orbiting electrons.

BACKSCATTER GAGE - Gage where both the source and detector are on the same side of the sheet. Radiation strikes the material to be measured and some of the radiation is scattered back toward the detector.

BETA RADIATION - Radiation consisting of particles which have a relatively light mass and a negative charge - actually an electron. Penetrates up to about 1/4" of aluminum.

BREMSSTRAHLUNG RADIATION - Electromagnetic radiation produced by beta radiation striking an absorbor (same principle as X-ray tube). Lower energy than gamma radiation.

BYPRODUCT MATERIAL - Radioactive material that is controlled by the Nuclear Regulatory Commission (NRC). Radium is a radioactive material but it is not controlled by the NRC. The word "byproduct" came into use because the material is a byproduct of a nuclear reaction.

COAXIAL CABLE - Cable with two conductors - one conductor is at the center of the cable and the other conductor is usually a braid which surrounds the insulation around the center conductor. The insulation between the center conductor and the braid is called the di-electric. The braid is protected by a covering of plastic or synthetic rubber.

CURIE - That quantity of radioactive material that decays at the rate of 3.7×10^{10} disintegrations per second.

DOSE - A general form for denoting the quantity of radiation or energy absorbed. Specific forms are:

roentgen - exposure dose

rad - absorbed dose

rem - biological dose equivalent

1 roentgen (R) - That amount of X or gamma radiation that would produce one electrostatic unit of charge in one cm^3 of dry air.

1 rad - The absorbed radiation dose of 100 ergs/gram in any medium.

1 rem - Absorbed dose in rads multiplied by the quality factor of the radiation in question.

DOSIMETER - Quartz fiber electrometer which is charged by a battery and discharges when exposed to radiation. Can be direct reading or indirect reading. Measures the total radiation dose received, in mrem, and is carried by a person who works with radiation.

ELECTRON - One of three sub-atomic particles. Electrons have a negative electric charge of 1.6×10^{-19} coulomb and a mass of 1/1840 amu. They orbit the nucleus much like planets orbit the sun.

ELECTRON VOLT (eV) - A unit of energy equivalent to the energy gained by an electron in passing through a potential difference of one volt. Also, $1 \text{ eV} = 1.6 \times 10^{-12}$ erg.

ENERGY - Capacity for doing work. Radiation performs work by ionizing atoms and molecules. Energy of particulate radiation is dependent on the particle's velocity and energy of electromagnetic radiation is dependent on the wavelength (or frequency). In both cases, energy is measured in electron volts.

FILM BADGE - Small piece of film sensitive to radiation, placed in a light-tight holder and carried by a person who works with radiation. When the film is developed, the amount of darkening can be measured to determine the total radiation dose, in mrem.

GAMMA RADIATION - Electromagnetic radiation. Very penetrating. Attenuation is logarithmic.

GENERAL LICENSE - A license issued by the NRC to everyone (all persons in the U.S.A.) to use byproduct material in devices approved by the NRC provided that the person uses the material in a specified manner. The General Licensee does not receive a document or paper from the NRC nor does he apply for a General License.

GM TUBE (GEIGER-MUELLER TUBE) - Device that measures radiation field strength. Output is a series of voltage pulses of constant amplitude but with repetition rate proportional to field strength. Requires an external voltage, or power supply.

HALF VALUE LAYER (HVL) - The thickness of a specified substance which, when introduced into the path of a given beam of radiation, reduces exposure rate by one-half.

HALF-LIFE - Time required for a source to decay to one-half its initial millicurie value. Typical values are: Cs-137: 30 years. Co-60: 5.3 years. Sr-90: 28 years. Kr-85: 10.7 years. Am-241: 433 years. Radium: 1600 years.

HALF-LIFE, BIOLOGICAL - The time required for the body to eliminate one-half of an administered dosage of any substance by regular processes of elimination. Approximately the same for both stable and radioactive isotopes of a particular element.

HALF-LIFE, EFFECTIVE - Time required for a radioactive element in an animal body to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination.

$$\text{Effective Half-life} = \frac{\text{Biological half-life} \times \text{Radioactive half-life}}{\text{Biological half-life} + \text{Radioactive half-life}}$$

HARDNESS (X-rays) - A relative specification of the quality or penetrating power of X-rays. In general, the shorter the wavelength, the harder the radiation.

ION - An atom or molecule bearing a net electric charge, either positive or negative.

IONIZING RADIATION - Any radiation capable of producing ions in matter.

ISODOSE CURVE - A line connecting all points of equal radiation field intensity around a gage. Usually drawn on an outline drawing of a gage.

LEAK TEST - Test performed on a sealed source capsule to determine if there is a leakage of the radioactive material from the capsule. Test can be by immersion, wiping, etc.

MILLICURIE (abbreviated mCi) - One thousandth 1/1000 of a curie.

MILLIROENTGEN PER HOUR (abbreviated mR/hr) - One thousandths 1/1000 of a R/hr.

mrem (milli-Rem) - one thousandth 1/1000 of a rem.

NEUTRON - One of the three basic sub-atomic particles. The neutron has no electrical charge and a mass of 1 amu.

NUCLEUS - The center of an atom, made up of protons and neutrons. The total positive charge and most of the mass is contained in the nucleus.

PROTON - One of the three basic sub-atomic particles. The proton has a positive electric charge of 1.6×10^{-19} coulomb and a mass of 1 amu.

RADIATION - The emission and propagation of energy through space or a material medium. The energy may be in the form of electromagnetic waves (gamma-rays and X-rays) or particles (beta particles, alpha particles, and neutrons).

RADIATION SURVEY - A measurement of the radiation field intensity in the vicinity of a gage.

RADIATION SURVEY FORM - An outline drawing of a particular gage with blank fill-in spaces for the intensity of radiation at specified points around the gage.

REM (abbreviation means roentgen equivalent man) - A measure of the dose to body tissue in terms of its estimated biological effect relative to a dose of one roentgen of X-rays. Thus, if a person is in a radiation field of one R/hr for one hour, the dose received is one rem.

ROENTGEN PER HOUR (abbreviated R/hr) - A measure of radiation field intensity or dose rate. A roentgen is that quantity of X-radiation which will produce on electrostatic unit of ions in one cubic centimeter of air under standard conditions of temperature and pressure. This can also be expressed as 2.083×10^9 ion pairs per cc of air. Thus, a R/hr is a certain number of ions produced in air per unit of time.

SEALED SOURCE - Radioactive material encased in a capsule designed to prevent leakage or escape of the radioactive material.

SOURCE - Radioactive material encased, or not encased, in a capsule.

SOURCE DECAY - Depletion of radioactive material as the atoms of the material disintegrate and produce radiation. The decay is logarithmic.

SOURCE HOLDER - Device to contain the sealed source.

SPECIFIC LICENSE - A license issued by the NRC or agreement state to a specified company or person for a specified type and quantity of byproduct material, for a specified use. The company, or person, must apply to the NRC on Form NRC-313 and will recieve the Specific License on Form NRC-374. Agreement states have similar applications. If a company applies for a license, it must name an individual as the "user" of the byproduct material.

SURVEY METER - Portable device which measures radiation field strength in mR/hr. Used to make a radiation survey.

WIPE TEST - A leak test performed by wiping the surface of a sealed source capsule or the outside surface of a source holder with an absorbant material and analyzing the absorbent material for the presence of radioactive material.

WIPE TEST KIT - Contains materials to perform a wipe test.

Radiation Principles - Training Manual
(Outline)

I. Introduction

Scope of Training Manual
Description of Product

II. Radiation Characteristics

1. Types of Radiation

   a) Alpha, Beta, Gamma, and X-rays
   b) Neutron Radiation

2. The Americium 241 Source

3. Radiation Measurement & Monitoring Techniques

4. Exposure Limitations/Biological Effects

5. Operator Exposure

6. Safety Precautions

III. Storage and Maintenance Recommendations

1. Storing the Level Detector

2. Disposal of the Americium Source

3. Wipe Test Procedures

IV. Security

1. Licensing Requirements

2. Personnel Monitoring

3. Records and Reports

V. Regulations

1. Federal Regulations - Nuclear Regulatory Commission

2. State Regulations

3. International Regulations

TYPE LD 2220 PORTABLE NEUTRON
BACKSCATTER LEVEL DETECTOR USER'S MANUAL

A. Identification

Fisher Controls International, Inc.
Type LD 2220 Portable Neutron Backscatter Level Detector

B. Proposed Use

The device is for distribution to authorized recipients for use to accurately locate levels or interfaces inside closed vessels. Each unit will be utilized under the terms of a specific license. The Type LD 2220 is an unshielded portable device and is to be used in environments compatible with man. The device must be stored in its storage/shipping container in a securable area when not being used to prevent unauthorized access. The source detector assembly is at the end of a pole four-and-one-half feet away from the operator.

C. Radioactive Source

200 millicuries of Americium 241
N.S.S.I. Model AN-HP

D. Details of Construction

The source holder is an aluminum die casting; the source is threaded into the holder. An aluminum plate conceals the source; the plate is attached to the source housing with four machine screws. These screws have a wire security seal affixed to prevent tampering. A (helium filled) detector tube is mounted adjacent to the source; the source detector assembly is mounted on the end of a five-foot aluminum tube. A Ludlum Measurements Inc. Model 12 countrate meter is mounted at the other end of the tube.

E. Radiation Profiles

Radiation profiles of the device with a 200 mCi Am-241 source is shown. The device is unshielded, therefore, there are no profiles shown for a shielded model.

The device shall be stored in a securable area with only authorized access permitted. The device shall be stood up with the head end in the storage/shipping container. The container is clearly labeled identifying the radioactive contents.

With the head of the detector in the storage shipping container, radiation levels are at 21 mr/hr at the surface of the container and will not exceed .45 mr/hr at 36 inches.

WARNING: Under no circumstances is the source housing to be disassembled, modified, or the application of the device to be altered other than its specific use. Locks should be used in storage of the detector to determine possible removal by unauthorized personnel.

NOTE: Prior to labelling a container with U.S. D.O.T.-7A, it is necessary to conduct the tests called out in Title 49, 173.398b to assure that the package will meet the requirements. These test results must be maintained on file for review by the D.O.T.

F. Installation

The Type LD 2220 is an unshielded portable device which is only to be used by authorized personnel trained in basic radiation principles, monitoring and safety and in the safe use and operation of the device. When the device is not in use, it is to be stored in its storage/shipping container in a securable area.

G. Prototype Testing

The device has been drop tested to prove that the source remains intact in the aluminum housing, and that the integrity of the capsule is not damaged in any manner. It is ruggedly constructed to take normal operations abuse. The user should avoid dropping the instrument, banging the detector head or other actions which could physically damage the device.

H. Quality Control

Quality control checks prior to delivery of completed units to customers shall include:

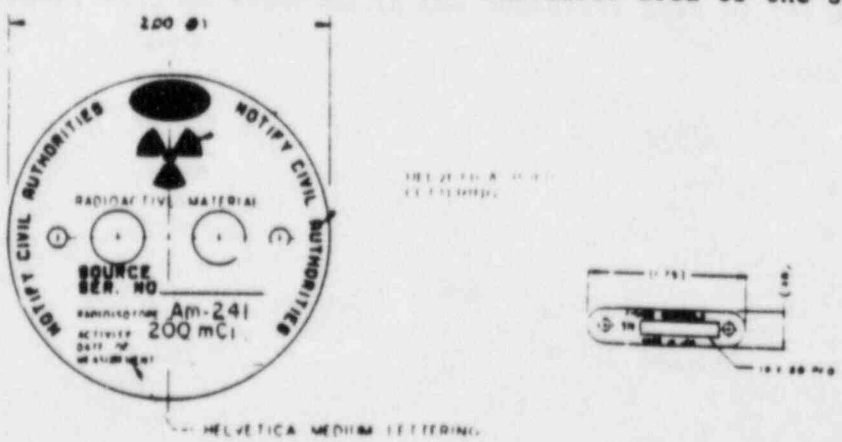
1. A copy of the survey of detector after loading with the 200 millicurie Americuim-241 source. An unshielded device, the radiation profile of each detector, will match the initial detector survey which is a part of the device evaluation. A copy of the initial survey will be retained for record.

2. Each detector will be fabricated as per Fisher Controls Type LD 2220 drawings and will be assembled and tested for detector and meter operation prior to source loading.

3. Each sealed source shall be wipe tested prior to placing in a detector for shipment to a customer.

I. Device Labeling

The following label will be attached in the immediate area of the source housing.



A label with the company name "Fisher Controls Company" is attached to the source detector assembly.

J. Level Detector

Type LD 2220

Purpose:

The Fisher Type LD 2220 level detector is designed to accurately locate liquid levels inside closed vessels. The Americuim-241 source in the head assembly emits fast neutrons. Mounted adjacent to the source is a detector tube which is sensitive only to slow neutrons. In free air, a slow background rate is normal. In close proximity to a liquid, some of the fast neutrons emitted by the source are slowed (moderated) and reflected back to the slow neutron detector which responds with an immediate increase in count rate. As the source detector assembly is moved up the outside wall of a liquid containing vessel, the count rate will drop abruptly to the background level when the liquid vapor interface is reached. The liquid level can normally be located to within an inch on most vessels. The instrument will give accurate levels for all common liquids which contain hydrogen in their structure such as water, hydrocarbons, acids, bases and most organic liquids. Operation is not affected by operating conditions such as temperature or pressure inside the vessel.

The fast neutrons are produced from a 0.200 Ci Americuim-241 source.

Field Use

The instrument is transistorized, weather proof, and ruggedly constructed to take normal operation abuse. It is easily carried by hand, over the shoulder or by a carrying strap to the location of use. It is good judgement to avoid dropping the instrument, banging the detector head or other actions which could physically damage the device.

To take an example of a field problem, the following concerns the location of the level in a hydrocarbon storage tank. This was a large heavy wall steel vessel with a spiral stairway to the top. As the operator approached the vessel, the meter selector switch was turned to the battery "check" position and then to range "B" and the audio switch "on." The meter reading was six divisions and a normal slow audio rate was noted. The operator stepped upon the stairway, touched the detector head lightly to the wall; the head angle adjusts to lay flat. He notes that the audio rate had clearly indicated the detector was well below the liquid level. The operator proceeded up the stairs, maintaining detector contact with the vessel wall and listening to the audio signal. About half way up the stairs, the audio signal dropped abruptly. The level at which the signal changed and marked it with chalk. The level detector was turned off and set aside. The tape with plumb bob was used to measure the distance from the tank base to the indicated liquid level. The level detector was returned to its storage cabinet.

The best way to learn the relationship between detector response and liquid level is by practice. Set up a test vessel about 2/3 full of water. The vessel should be open on top or transparent enough to visually observe the liquid level in the container. A bucket, waste bucket, glass bottle or beaker are all satisfactory. Practice holding the level detector by the foam grips and, with the source detector head touching the vessel, move it slowly up and down across the interface level. Note carefully the relationship of the detector head to the liquid surface level when the signal increases rapidly (moving from above to below the liquid level). The signal will rise to an even higher level as the detector is lowered below the surface level. The liquid surface level is the level at which the sharp signal increase is observed. Practice moving the detector head up and down until the relationship between signal and surface is readily apparent. Test yourself by changing the liquid level and covering the container so that the surface cannot be seen. Locate the liquid level with the detector several times, mark it and then compare with the true level as observed. Develop your confidence and ability before proceeding into the field.

N. Wipe Tests

1. Wipe tests must be made at intervals not exceeding six months. This test is to ensure that the source has not leaked or to detect a leak which might have developed since the last test.

   a. Obtain an approved wipe test kit or use one provided by Fisher Controls Company; one is included with the detector.

   b. Dampen one of the filter discs from the kit with water. Holding the damp disc with forceps or tongs, wipe the outside of the source assembly vigorously, thoroughly and quickly.

   c. Place the disc in one of the envelopes from the kit and return for analysis to the assembly agency as per instructions on the kit. Be certain that the envelope containing the disc is labeled with date, source serial number, name and address.

The wipe tests are normally made at six month intervals. The only reason to test more often are emergency wipes made following an accident or other reasons to support a source is leaking.

O. Safety

The Americuim-241 source used in the Type LD 2220 level detector is extremely rugged. The Americium is double encapsulated in heavy wall welded stainless steel. It is highly unlikely that an accident, including fire, explosion of impact could rupture the container resulting in loss or dispersion of the Americium.

K. Maintenance and Troubleshooting

Although rugged, the level detector can be physically damaged. If the instrument fails to operate, it may be due to physical damage to the detector head, cable, and meter. The neutron detector tube in the head is susceptible to impact damage and can be checked only by installation of a new tube or by testing it with a known "good" meter. Meter failure is usually indicated by an unsatisfactory battery check when good batteries have been installed. Visually checking the battery contacts for cleanliness from time to time is a good practice. Cable integrity can be checked with a volt-ohm meter. Check both for cable continuity and infinite high resistance between the cable center wire and the shield. See the Safety section of this manual for procedures involving the Americuim-241 source. A service manual for the survey meter electronics section is included with the device.

NOTE: Any maintenance or repair work involving the source or removal of the source cover plate (secured by seal wire) will be performed by authorized Fisher Controls Company or N.S.S.I. personnel ONLY.

L. Instructions for Shipment and Transportation

Special rules apply to transportation and shipment of radioactive materials. If any transportation of the source detector assembly or complete device is contemplated, all packages must comply with rules and regulations published by U.S. Department of Transportation, 46 C.F.R. Part 146, 49 C.F.R. Parts 173-179, and 14 C.F.R. Part 103.

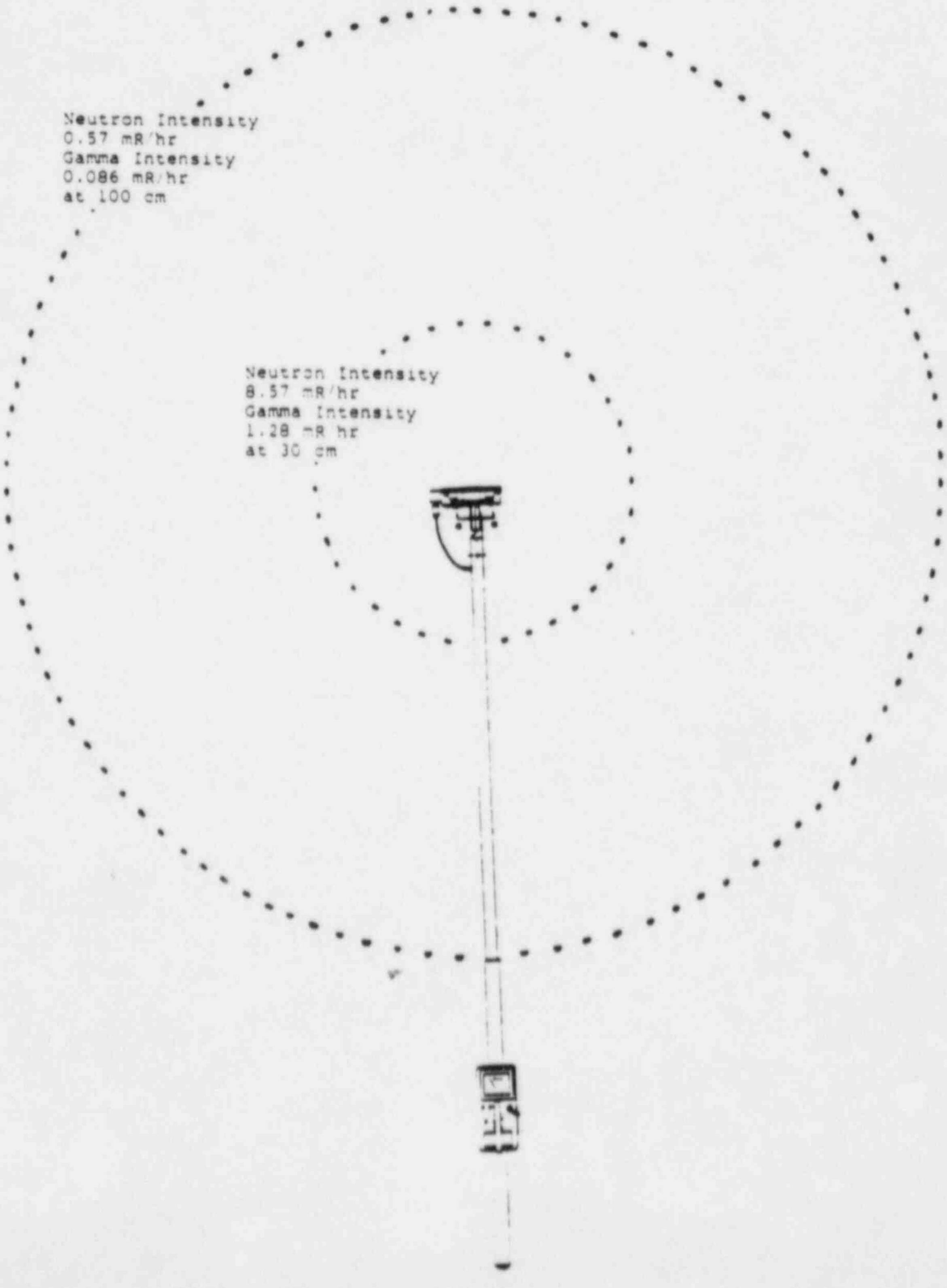
In the event of damage to the source, do not transport until the device has been inspected by a licensed individual and placed in an appropriate shipping shield.

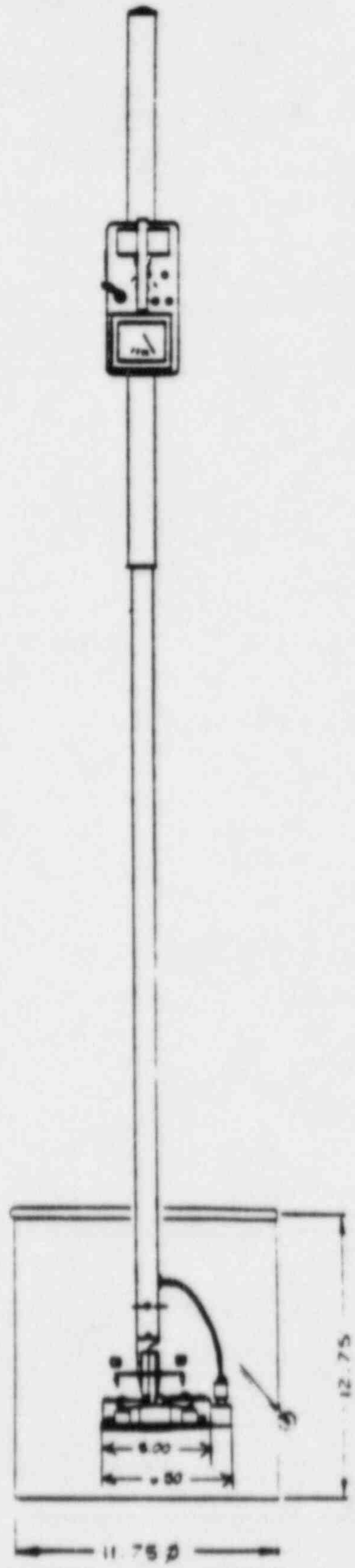
M. General Operation Procedure

In normal operation, the Type LD 2220 shall be handled only at the meter end of the instrument. The source detector assembly should generally be kept at a distance of three feet or more from the operator or other persons in the vicinity. A more detailed discussion of safe handling is included in the Safety section of this manual.

The device is designed to be easily operated from the meter end and two foam rubber grips are provided for ease of operation. Turn the selector switch on the survey meter to the battery check position and note the meter reading. If low, the two standard flashlight batteries in the meter should be replaced. If satisfactory, turn the switch to the range "B" position. Turn the audio switch "on" and the time constant switch to "slow." In free air, a meter reading of less than six divisions will be obtained. A slow audio rate will be readily apparent. This normal free air background rate will be constant. Battery life is approximately 48 hours (alkaline battery cells).

Type LD 2220
Isodose curves
0.2 Curie AM-241





Type LD-2220 in Storage/Shipping Container