OK TRACERS, INC.
Route 3, Box 247-Q
Duncan, Oklahoma 73533
(405) 255-2808

October 25, 1988

Mr. C. L. Cain
Mr. Jack Whitten
U.S. Nuclear Regulatory Commission
Nuclear Materials Licensing Section
Region IV
611 Ryan Plaza Drive, Suite 1000
Arlington, TX 76012

Subject: Request for Amendment to Materials License 35-21353-01, OK Tracers, Inc. Licensee

Dear Sirs:

OK Tracers, Inc. of Duncan, Oklahoma, is requesting that the above referenced license be amended to include the following radionuclides:

Radionuclide	Chemical & Physical Form	Possession Limit
Hydrogen-3	Any	200 Curies
Carbon-14	Any	2 Curies
Cobalt-60	Any	500 millicuries
Cobalt-57	Any	500 millicuries
Krypton-85	Any	25 Curies

The authorized use of these nuclides will be used as tracers injected into oil and/or gas producing formations in actual secondary recovery systems, liquid and gas flooding, for the purpose of evaluating production patterns.

It is understood that each secondary recovery system to be evaluated by this technique will require individual approval (amendments) to this license. No injections will be performed without the appropriate license amendment or Agreement State authorization.

Also, it is requested that Antimony (Sb-124) in any chemical and/or physical form at a maximum possession limit of 500 millicuries be added to this license. The authorized use for this nuclide will be for use in the manufacture of labeled oil and gas well frac proppants; processing of liquid oil and gas tracer materials; distribution to persons authorized to possess licensed materials pursuant to the terms and conditions of a specific license issued by the Nuclear Regulatory Commission or Agreement State; and for use in tracer studies in oil and gas wells.

Enclosed is a check made payable to the U.S. Nuclear Regulatory Commission in the amount of $170.00 for this amendment fee.

Your earliest consideration and response to the request is greatly appreciated.

Respectfully submitted,

Dan G. Kelly

Dan G. Kelly

DGK:da

Enclosure

4622447

CHAPTER 7
TRACER SERVICES

7.1 Introduction to Tracer Services

Radioactive materials are furnished in a variety of forms, each selected and prepared for a specific application.

Radioisotopes offer a very versatile approach to help determine what happens "down the hole". Since a radioisotope can be added to almost any material being placed in a well, a gamma log can then locate the radioisotope, thus indicating where the material was placed.

Because the specific activity of OK Tracers radioactive materials is low, there is virtually no personnel danger involved when properly handled. Under normal conditions, well and equipment contamination will be negligible, if it occurs at all. In addition, these isotopes are always handled by trained operators.

Fresh, full strength isotopes are shipped direct from central locations so that the maximum measurement can be obtained from them.

A calibrated Geiger counter is required to be present on all radioactive jobs both to evaluate the radiation hazards as well as any contamination. Residual radiation at the wellhead should be less than 0.1 mR/hr. It is absolutely essential that none of the tracer be spilled on the ground. If this happens it must be cleaned up immediately.

The maximum allowable whole body exposure for monitored personnel should not be more than 100 milliroentgens per week. For our purposes this will be accepted as a maximum eye exposure. It is a requirement of the radioactive work that a calibrated "Geiger Counter" must be used to monitor the work area. It can be used to reliably estimate the operators personal exposure. At some point on the treatment report the type instrument used should be "unique in identification." Procurement of dosimeters and chargers may be desirable at each field camp where single jobs approach usage of 100 mCi or more of any isotope.

The treatment report should be completed as soon as possible after the job. Accompanying this should be a copy of a document showing the origin of the radioactive materials. A material requisition and a copy of the suppliers invoice or bill of lading is required. If only a portion of an original order is used on a job then the copy of the original document showing the origin of the material should show previous usage checked off. The purpose of all records is to establish a running balance of all isotopes covered by a state or NRC license.

It must be reemphasized that caution is required in handling radioactive materials.

7.2 Radioactive Propping Agents

Radioactive Propping Agents were developed to help answer such fracturing questions as, "Where did it fracture?" "How thick a facture?" "Did the fracturing procedure produce, or change, the desired fracture pattern?" "Should the fracturing method or materials be changed?"

The radioisotope on the Propping Agents was especially selected for its chemical and physical properties. It is permanently affixed to the proppant and can be used with any type of fracturing fluid, including acid. It will not be removed by well fluids, or by treating agents that may be used.

Radioactive Propping Agents are prepared by uniformly coating the regular propping agents with a permanent layer of radioactive Scandium, Iodine, or Iridium. In addition, Radioactive Propping Agent is actually a propping agent. Once it is mixed, ordinarily it will not segregate during the job to give false indications upon logging.

Radioactive Propping Agents are commonly blended throughout all the propping agent used during the fracture job. In this manner radioactive material is included in all fractures. On the other hand, it is sometimes added to the last portion of propping agent used on the job. In either case, overflush should be minimized since there is evidence that excess overflush can move the propping agents away from the wellbore.

With either technique used, a subsequent gamma log helps locate the propping agents and interpretation of this log may furnish a great deal of information regarding the actual conditions existing in the well.

Although originally designed for fracturing, Radioactive Propping Agents have been successfully used in cementing operations.

7.3 Tracing Sand and Other Props

This radioactive tracing sand or Other Propents is customarily supplied as 10 mCi Ir-192 on approximately three pounds of sand or Other Propents. If a shorter half-life material is required Iodine-131 can be substituted for Iridium-192. Scandium-46 is also available. It is packaged in unshielded 1 quart press lid metal cans. One can of this sand will emit about 50 milliroentgens per hour at 12". A total of 10 cans or 100 mCi Ir 192 sand will read about 100 milliroentgens at 2 feet. The emission at the surface of each can (10 mCi) will be more than 1000 per mR/hr. For this reason do not directly hold the can by hand. It is recommended that positive locking - Posi-Grip Tongs be used for multiple can handling or when it is desired to slowly add the sand.

7.4 Iodine-131

I-131 is a water solution of radioactive Iodine. It was specifically selected for use in tracing fluids. I-131 can be specially ordered for use in oil or acid base fluids. CAUTION!! Order Iodine 131 in an acid stable solution if using in acidic tracing fluids. If the ordinary water solution of Iodine 131 is added to an acidic fluid, radioactive iodine gas can be liberated.

I-131 can be a valuable tool for locating channels, points of entry, casing holes or leaks, communication zones, and controlling or locating well fluid levels during remedial work.

I-131 contains a short half-life material. One millicurie will effectively tag two barrels of fluid. The fluid is then ordinarily circulated to dissolve and mix two components. A gamma log may be run after or during the job to indicate just where the fluid has gone and give some information as to how it got there.

For fluid tracing, a liquid should be used. The use of solid particles often leaves doubts as to whether the fluid has been found and traced completely, or, whether only an accumulation of filtered out solids has been located.

Although designed for use in fluids, I-131 has been used successfully in cement slurries. When using liquid Iodine 131 in quantities of 50 mCi or greater it is absolutely necessary to have a bio-assay of the thyroid made at an optimum time elapse of 8 hours after completion of the job.

7.5 Scandium-46

Sc-46 is a water solution of radioactive Scandium It was selected for use in cement slurries because of its chemical and physical properties. When added to an alkaline slurry, such as cement, the radioisotope comes out of solution and remains in the solid phase of the slurry. Some other radioactive isotopes remain water soluble and become a part of the water phase of a cement slurry.

While specifically selected for cements slurries, this versatile isotope can be used for many other oil field operations. One sixth millicurie per barrel of fluid or slurry is normally sufficient to furnish a significant count on a gamma log. Usually the fluid isotope is added to the mixing water before the tracing job is started.

Radioactive liquids will be packaged in small bottles in shielded containers. Immediately surrounding the bottle inside the shield will be an absorbent paper packing. By first removing this packing and then measuring it for radioactivity it will be possible to establish whether the the radioactivity has leaked from the bottle. A reading of greater than 0.1 mr will be a positive indication of a leak. At this time attempt to ascertain the extent of the leak by taking a true reading on the packing. Use distance if necessary to reduce the reading to within the range of the instrument. The contaminated packing should be placed in a plastic bag for safe handling. Attempt to determine any potential for leakage outside of the container shield. This decision will be based on volume of liquid lost. Determine or run a comparison of radioactivity in the bottle versus radioactivity on the absorbent packing. Report any leaking incident to calling Dan Kelly at home 405/255-0242.

The actual handling of the bottle containing radioactive liquids should be tongs at least 8" long. (Suitable tongs are available from Duncan.) The bottle cap can be opened by grabbing with a pair of duck bill pliars or equivalent. Carefully transfer the liquid in the bottle into the diluent in tank. Rubber gloves and goggles or a protective face shield should be employed for this operation. Replace bottle and packing into shield container and return to Duncan or other vendor for disposal. Packing can be disposed of if not radioactive.

Sc-46 is recommended to help in locating cements tops, even a month or more after the cement job or where temperature location methods are unsatisfactory. It can indicate whether or not a channel took cement, or where the squeeze cement has gone. Used in the last part of the cement, it can furnish much information about the cement around the shoe, such as channels, contamination, etc. Also, Sc-46 in the slurry can be useful for determining cement placement in other areas of the hole, such as checking the sheath opposite a zone to be perforated.

461306

Ir-192 or Sc-46 can be used very effectively to tag hydrochloric acid in matrix acidizing operations. both are acid solutions of the heavy metals, iridium and scandium. Either isotope will be chemically attached to the formation being treated releasing the metal of lower atomic number such as sodium, potassium, etc.

Upon completion of the acidizing treatment a gamma log will indicate the injection profile. Either may be used in conjunction with diverting agents for evaluation of effectiveness.

7.6 Iridium-192

Ir-192 is a water solution of radioactive Iridium. It is a suitable substitute for and can be used under identical circumstances.

7.7 Radioisotope Data

Code Name	Isotope	Half-Life	Recommended Use	Quantities Used
Tracing Sand	Scandium-46	85 days	Tag Frac Sand,	1 mCi/5000 lbs.
	Zirconium-95	65 days		1 mCi/3000 lbs.
	Iodine-131	8 days	gravel pack,	1 mCi/2000 lbs.
	Iridium-192	74 days	Sand control, and	1 mCi/3000 lbs.
	Silver-110m	255 days	Squeeze Cement	1 mCi/3000 lbs.
Other Props	Scandium-46	85 days	Tag Super	1 mCi/5000 lbs.
	Iodine-131	8 days	Props in	1 mCi/2000 lbs.
	Iridium-192	74 days	Frac Operations	1 mCi/3000 lbs.
	Silver-110m	255 days		1 mCi/3000 lbs.
I-131	Iodine-131	8 days	Tag Cement, Fluid Tracing	1 mCi/2 bbl.
Sc-46	Scandium-46	85 days	Tag Cement, Tag Acid, Fluid Tracing	1 mCi/10 bbl.
Ir-192	Iridium-192	74 days	Tag Cement, Tag Acid, Fluid Tracing	1 mCi/6 bbl.
Au-198	Gold-198	2.7 days	Tag Acid, Tag Cement, Fluid Tagging	1 mCi/10 bbl.
La-140	Lanthanum-140	40 hours	Tag Acid, Tag Cement, Fluid Tagging	1 mCi/10 bbl.
Zr-95(Nb)	Zirconium-65	65 hours	Tag Acid, Tag Cement, Fluid Tagging	1 mCi/6 bbl.
Na-24	Sodium	24 hours	Tag Acid, Tag Cement, Fluid Tagging	1 mCi/15 bbl.

7.8 Cementing

7.8.1 Introduction

Radioisotopes are useful tools in oil well cementing. They will provide positive indication of cement location and an indication of cementing quality.

Here are some of the advantages of radioisotopes in cementing operations.

Superior to temperature logs because:

- Temperature logs are difficult to obtain and frequently erratic.
- Use of low heat of hydration cementing materials results in poor temperature logs.
- Time delays will result in poor temperature surveys but will have no effect on radioisotope detection.
- A temperature log may be eliminated if a gamma log is to be run.
- When all the cement is made radioactive a general picture of the cement job is available. This will aid in evaluating the consistency of cementing job.
- Precise placement of squeeze cement can be determined.
- Isotopes are available with half-lifes of between 8 and 255 days. (Longer ½ life isotopes can also be supplied.) Proper selection will minimize effects on subsequent logging operations.

7.8.2 Applications

Location of Cement Tops

The location of the top of cement can be accurately determined if the first portion of the cement is made radioactive. A corresponding temperature log is less definite and in the case of deep fat holes may have little value. The addition of radioisotope to the first portion of the cement can also be considered as insurance against failure to locate top due to too long a delay before survey.

The Condition of Cement Around Casing Shoe and Other Zones

The condition of cement around the casing shoe and other critical zones can be determined by means of radioactive tracer in the cement slurry.

General Conditions of Cement Around Casing String

If all the cement used in the cementing operation is made radioactive, a gamma log of the cement string will furnish a general picture of the cement job. The gamma log will show washouts, channels and contaminated cement. The information obtained is of great importance during well completion or when remedial work is considered.

Location and Distribution of Squeeze Cement

Radioisotopes when used in squeeze cement will trace its distribution. In addition to the actual placement it will show filled channels, communication zones and whether the packer or plug held. These log interpretations will serve as an aid to minimal squeeze jobs with fewer failures. Iodine 131 is not recommended for use in squeeze cementing because of its solubility.

Location of Cement Tops in Stage Cementing

In stage cementing, the top of each stage of cement can be located by adding radioisotope to the first part of cement in each stage. A gamma log will then show the top of each cement stage.

Origin of Cement Recovered From Hole When Setting Liner

Occasionally when a setting a liner, the hole may make cement and the operator has to decide whether it comes from the top or bottom of the liner. This problem may be easily solved if radioisotopes are used in the cement. Either the first or the last of the cement put away can be made radioactive. Then, if some cement is recovered, one can tell where it came from by determining whether or not it contains any radioactivity by means of a portable Geiger counter. Two separate isotopes or two different concentrations of the same isotope could be used in the cement going to the top and bottom of the liner. If more than two points of identification are desired, it is possible to use two isotopes or two concentration of one isotope. If two different isotopes are used, the isotope in the cement should be differentiated by the use of absorbers to distinguish between three points of interest. If two different concentrations of considerable magnitude of difference are used, the cement can be distinguished by counting rate difference.

7.9 Radioactive Plug Markers

This radioactive plug marker was designed to augment the mechanical indicator on the plug container, and to furnish positive evidence that the plug has left the container.

One or two small nails, plated with a radioactive metal, are driven into the side of the plug with a hammer. If very heavy plug containers are used, more than two markers may be desirable.

After insertion of the marked plug into the container, a geiger probe is used to locate the marked plug in the container. The probe is then strapped into position on the plug container. As soon as the plug is pumped down, the meter should drop to the background (nearly a zero) reading. (NOTE: It has been reported that on occasion, the plug will move upward when pumping is started. This causes the needle on the scale to fall off. If this should occur, it may be necessary to relocate the geiger probe on the container. This method gives positive proof that the plug has left the container.

Technical Data

Each marker contains approximately 10 microcuries of Fe-59. The half-life is 45 days or 1 microcurie of Co-60 half-life 5.2 years.

They will be supplied in a unit of ten markers to any qualified employee requesting them. They can be renewed by request. One unit - ten markers (nails) are an exempt quantity by NRC Regulations. They cannot be warehoused in any location, and should remain in the possession of qualified personnel. The markers are radioactive and should not be carried in a pocket. They should be removed from the radioactive tape as used. They should be handled with a glove. The tape will identify them as being radioactive.

7.10 Pit Strips and Column Markers Co-60

7.11 Radioactive Tracers for Flood Systems

The potential exists for injection of radioactive tracers into the injection wells of a waterflood for tracing purposes. Each specific project of this nature will be custom designed by Dan G. Kelly. Each project will require a specific license so some lead time will be required on the project.

The following list of isotopes are among potential injectors:

Tritiated Water
Iodine 125
Iridium 192
Promethium 147
Scandium 46
Cobalt 58
Silver 110^{m}
Sulfur 35
Strontium 85
Zinc 65

Final section of isotopes for use in flood will require core samples of the injection substrate.

For gas floods, isotopes such a krypton, tritium, tritiated methane, tritiated propane, etc., are available but require special licensing.

For consultation on such projects call Dan G. Kelly - Duncan, Oklahoma.

CHAPTER 8

STANDARD PROCEDURES FOR HANDLING RADIOACTIVE MATERIALS

8.1 The Assignment of Responsibility for the Supervision of All Services Utilizing Radioactive Materials.

A. It is the respon: .bility of the Radiation Safety Officer to supervise and coordinate al/ radioactivity services and to oversee and advise on all matters regarding the handling and use of radioactive materials used in tracer operations. Each person designated by the R.S.O. shall be a Qualified Operator.

B. The qualifications of those selected for the duties mentioned in Paragraph 1 shall include sufficient technical experience to understand the physical and chemical principles involved in the application of tracer services, and they must be qualified individual users under the conditions of the NRC and/or State licenses to carry out these services. Training includes specialized classroom instruction by the Radiation Safety Officer or qualified personnel and to assist a Qualified Operator with at least one tracer operation.

C. The duties of those selected under Paragraph 1 shall be to generally supervise all radioactivity services carried out in their area of responsibility and under the licenses. They will also be held responsible for seeing that the necessary records of personnel exposure, radioactive material procurement and disposal, surveys of the surrounding area after the completio of each tracer job and all other details peculiar to tracer operations are properly obtained and for transmitting these records and reports which are to be distributed and filed by the R.S.O. They will also be held responsible for necessary periodic checks of radioactive sources for leakage, compliance with procedures for handling such sources and any additional details of radiological safety associated with the services that may be assigned by proper authority. It is also their responsibility to report immediately to the Halliburton Radiation Safety Officer any violation or act which might endanger anyone's health or safety in any manner.

D. Operators of any radioactive tracer services shall be qualified individual users, and shall be held directly responsible for these operations being conducted in a safe manner, and records and reports made.

E. OK Tracers shall appoint individuals as Radiation Safety Officers, whose qualifications and duties are defined elsewhere. These Radiation Safety Officers will be available for assistance to the field in all matters involving radiation safety. All Qualified Operators will report to them. They shall make periodic inspections for field compliance with regulations and shall perform such other duties as the Company may direct.

F. In such cases where Duncan personnel carry out field work on unusual jobs with the assistance and cooperation of the various operating divisions, the safety on these operations and compliance with regulations shall be in responsibility of the Duncan based qualified representative. This same home office representative shall be fully responsible for obtaining and transmitting records and reports used in exercising all the responsibilitie stated or implied under Paragraph c.

8.2 Procedures for Performing Radioactivity Services

A. Tracer services shall be carried out as nearly routine and in compliance with established procedures as circumstances will permit. It is the responsibility of the tracer operator to determine before beginning a job that there is no probability of contaminating a fresh water zone or public gas supply. If there is any question concerning such contamination or any other problem of radiation safety which cannot be easily resolved, it is the responsibility of the operator to consult the Radiation Safety Officer before proceeding with the job.

B. Only those services for which a job description has been provided in this manual shall be performed. This is in compliance with conditions listed in the NRC and State licenses. Special procedures suggested by the customer shall be cleared through the Radiation Safety Officer. In cases where the services are performed in cooperation with other service companies the responsibility shall lie with the company providing the radioactive material under their own license. For example, if OK Tracers provides the tracer to locate a cement top, it is the responsibility of the OK Tracers qualified user to oversee the safety of all personnel on the job, to check the pump truck and associated equipment for contamination and carry out all other procedures and precautions required by such an operation. If the service company providing the pump truck supplies the tracer under their license, then it is their responsibility to carry out the above procedures. However, it is still the responsibility of OK Tracers personnel to be certain that their procedures are carried out properly with regard to the safety of OK Tracers personnel and equipment on the job. In addition, it is the responsibility of the OK Tracers qualified user on the job to double check all such procedures, see that OK Tracers personnel are provided with personnel monitoring equipment and other such equipment as is required, and determine that the precautions and procedures taken by the other service company are adequate and in compliance with safety regulations insofar as such compliance affects the safety and welfare of personnel and equipment.

C. Qualified Operators are encouraged to consult the home office, directly as often as they desire, concerning special or routine tracer services, but the final decisions are the responsibility of the Radiation Safety Officer.

8.3 Personnel Monitoring Procedures

These procedures shall be carried out without exception in all operations involving exposures or potential exposures to radiation from radioactive material.

A. A "survey meter" shall be used during all tracer operations involving exposure to radioactive materials other than certain sealed sources. Film badges or pocket dosimeters will be sufficient for all personnel involved in the transportation or handling of radioactive sources used in services for which a job description has been published. Pocket dosimeters and chargers should be made available and adequately maintained by each District. When used, pocket dosimeters shall be read at the beginning and conclusion of each job and all exposures recorded on Radioactive Treatment Report, Figure 1. The Radiation Safety Officer shall be notified immediately by the Operator of any pocket dosimeter reading greater than 200 mrem in a 24 hour period. The Operator in making his report shall inform the R.S.O. in sufficient detail so the Radiation Safety Officer may decide whether or not the exposed individual shall be temporarily removed from any additional exposure or receive a medical examination, or to recommend other precautionary measures.

B. Portable survey meters shall be supplied by the local area in sufficient quantity to take care of their own requirements. These requirements shall include sufficient meters in working condition so that there will always be one present on each and every job where radioactive materials are used. Meters are to be calibrated at six month intervals using two points on each range. The survey meters should be sent to Authorized Service Center for repair and calibration.

8.4 Records and Location of Records

The records shall be maintained and distributed in accordance with the following:

A. Personal Exposure Record, Radioactive Treatment Report Forms, will be sent directly from Duncan. This form shows calculations for measuring both beta and gamma exposure. The personnel exposure records of all employees engaged in radioactive work will be kept on file at each District location and copies mailed to the appropriate Radiation Safety Officer. Copies of these records will be maintained in the Duncan files for all personnel. Records of personnel terminated may be removed from the local files. Personnel exposure records shall always be available to the individual concerned, and it is the duty of the Radiation Safety Officer to keep all exposed personnel thoroughly informed concerning their exposure. Correspondence concerning personnel exposure records shall be directed to the Radiation Safety Officer, Duncan, Oklahoma.

B. An "Occupational External Radiation Exposure History" form must be completed in advance for any person who will be exposed to radiation as part of his duties, and be forwarded to the Radiation Safety Officer in Duncan.

C. Radioactive Treatment Report (Figure 1), applicable to the services rendered, shall be made on all tracer or isotope jobs performed or attempted. This sheet must be completed in detail and shall include the record of the survey meter readings of the individuals and survey of the surrounding area for contamination. Any person handling more than 50 millicuries of liquid Iodine-131 in any one time shall have a thyroid check performed, as described later in this manual and the results recorded on the data sheet.

D. A record of all tracer material received and the disposal of such material through use, transfer, or decay must be maintained on "Radioactive Treatment Report". One form must be used for each treatment performed. This form, with the receiving document, and transfer documents, is to be maintained in Local and Duncan file for five years.

E. The driver of a vehicle transporting radioactive material is required to have in his possession shipping documents describing the material being transported (See Figures 11, 12 and 13). The completed documents may be used to comply with requirements that use logs being kept for sources. The driver is also required to have on his person a film badge or pocket dosimeter for measuring body exposure during the transporting process.

F. "Survey Meter Calibration Record", is to be maintained in the Local file and by the Radiation Safety Officer. These forms are to be retained for two years.

8.5 Licenses

A. All applications for new licenses, amendments to existing licenses, and all correspondence with NRC or State agencies shall be conducted by the Radiation Safety Officer. Applications will be necessary for new isotopes, new uses, and different physical forms of presently licensed isotopes.

B. The Radiation Safety Officer shall be responsible for knowledge of and compliance with all State and local regulations within each Division.

C. All licenses give the authority and responsibility of designating qualified individual users to the Radiation Safety Officer. In order to ensure personnel are qualified, formal training courses shall be conducted by the Radiation Safety Officer while responsibility for on-the-job training is with the Qualified Rayfrac Operators.

8.6 Procedure in Case of Accident or Overexposure (See Chapter 10 also)

A. The following events will be reported to the Radiation Safety Officer by telephone immediately:

(1) Possible cases of overexposure indicated by pocket dosimeter reading, other measurements, or calculation.
(2) Accidents involving contamination of personnel clothing.
(3) Accidents involving contamination of well locations or equipment on location which cannot be immediately and safely decontaminated.
(4) Loss of radioactive material of any kind or amount which places it beyond the control of personnel.
(5) The exposure to radiation of personnel other than Halliburton employees in excess of 2 mr per hour.

These notifications are to be followed by written reports by the Qualified Operator with 10 days containing all relevant details on the "Emergency Procedures Report", Figure 5.

B. The Radiation Safety Officer will report the above incidents to the various agencies as required, and will act as the representative with the agencies.

C. All overexposure shall be immediately transmitted to the Radiation Safety Officer. The Radiation Safety Officer shall immediately inform the exposed person, determine the cause and submit a written report of his finding and may, at his discretion, recommend a physical examination in such cases.

8.7 Standard Procedures for Handling Radioactive Material in the Field

8.7.1 Determine Isotope Needed

Determine what isotope and activity will be needed to tag the job adequately from Chapter 7 of the "Radiation Safety" manual or contact the Radiation Safety Officer (RSO).

8.7.2 Ordering the Isotope

Order the required isotope and activity from the supplier. When ordering, state when the material is needed if it is to be delivered. If it is to be picked up, give the time and date of pick up. Due to normal radioactive decay it is necessary to be fairly accurate when short half-life materials are involved. A good example would be Gold 198 with a 2.6 day half-life. If the material is delivered or picked up prematurely it may be necessary to re-order to have an adequate amount of material on hand at the job site. There are several isotopes available for use. Iridium 192 and Iodine 131 are the isotopes that are routinely used. Other isotopes are available and include: Scandium 46, Silver 110^{m} and Gold 198. Gamma Ray energies and half-life usually determine the isotope of choice. Routinely, the customer will know what isotope he wants to use. If there is some question as to what isotope or amount of isotope contact the RSO.

8.7.3 Receiving Procedures

When the material is received at any office the following procedures must be used:

A. Conduct a visual inspection of the package. If it appears damaged or wet it is essential that the delivery vehicle be detained to insure that it is not contaminated.

1. If wetness or damage is found, take the following action:

a. Take geiger counter (survey meter) reading at 1 meter from the package surface.
b. Compare it to the Transport Index (T.I.) on the transportation label.
c. Take meter reading of the package surface.

If a. and b. are the same, it is not likely that the inner containers are leaking and if c. is 200 mR/hr or less, the survey is complete.

If a. is significantly higher than b. retain the transporting vehicle and conduct the following:

i. With <u>gloved hands</u>, remove inner containers temporarily and place them about 30 feet from the outer container on a piece of plastic sheeting or other liquid resistant material.
ii. Use geiger counter to assure there is not contamination on your hands.
iii. Check the inside of the outer container. If reading is the same as background, no leakage has occurred.
iv. If c. is greater than 200 mR/hr, leakage could exist - notify RSO immediately for further instructions.

2. If no wetness or damage is apparent, place the package in storage building or area.

8.7.4 Storing Materials

If shipment is not damaged or if the damaged package is not leaking or contaminated it must be placed in the storage building or area unless it is to be sent directly to the job site.

The package should be put into the shielded area or in the best geometrical location to reduce radiation exposure levels.

After the material is placed in the storage location, take the geiger counter and insure that radiation exposure levels are as low as reasonable achievable.

The maximum reading should be recorded.

46130b

The storage area should be secured so that casual removal of the material cannot occur.

The storage area must be posted with a sign on the entrance stating, "Caution, Radioactive Material". If radiation levels exceed 2 mR/hr on the outer surface of the storage area "Caution, Radiation Area" signs must be posted at the 2 mR/hr boundary.

8.7.5 Removing Materials from Storage

When removing radioactive materials from storage a calibrated and operable geiger counter should be in hand. The person removing the materials from storage must wear a personnel monitor (TLD). Only the material to be used on the job should be removed. The amount of activity removed should be listed on the radioactive treatment report. After the material is removed, the storage area must be secured to prevent unauthorized entry. Perform this removal as quickly as possible to avoid unnecessary radiation exposure.

8.7.6 Transportation to Job Site

Prior to loading the vehicle, a reading should be taken with a geiger counter where the container is to be placed. This location should be as far away from the driver and other passengers as possible. This reading is to be recorded under "Delivery Vehicle - Before" on radioactive treatment report (RTR). This will more than likely produce a background reading and a basis to determine if the vehicle is contaminated after removal of the radioactive material.

A. The supplier ships the radioactive tracers in DOT 7A type containers and it is marked as such. We must transport the tracer in that DOT 7A package. The inner boxes or the can themselves are not Type A containers. Many locations are removing the tracer containers from the shipping container and transporting them from the District to the job locations. This is an illegal transport. Some locations are making 7A containers which can be used. If any location is interested in making their own shipping container contact the office of the RSO for guidelines.

   The shipping container for tracer materials must be labelled or stencilled with the words "DOT 7A TYPE A" and "RADIOACTIVE MATERIAL, n.o.s.".

   A shipping paper (see Figure 7) is required for each transport of radioactive material from the confines of the licensed facility. Sample shipping papers are shown in Figures 7, 8 and 9 for your reference. The shipping paper must include all the information shown on the sample papers.

   Place containers in vehicle.

   Secure the container in the vehicle so that is can not shift or be "tossed" about during transportation. If the vehicle is "open", such as a pickup truck, the container must be secured against shifting and bouncing out.

B. The drivers seat and seats where other passengers will ride should be surveyed. The readings should not exceed 2 mR/hr. If the reading is greater than 2 mR/hr, the package should be rearranged to decrease the exposure rate to less than 2 mR/hr. If this cannot be accomplished passengers should be transferred to another vehicle.

   After the vehicle is loaded, a survey of the outer surfaces must be taken and recorded. Place the geiger counter detector (probe) on the outer surface of the vehicle. Readings are to be taken on the back, front and both sides. These readings are to be recorded on the RTR under vehicle survey - after vehicle loading.

If the container is labelled with a radioactive "Yellow III", the vehicle must be placarded with "Radioactive" placards - one on front, back and both sides (a total of four). The geiger counter is to be put into the vehicle transporting the material to the job site. It should be carried in the driver's area or compartment. This makes it conveniently accessible if there is a vehicle accident. When transporting material, it is permitted to stop along the way provided the materials are secured from unauthorized removal.

Radioactive materials are not to be loaded into the transport vehicle and taken to a residental area the evening preceding transportation to the job site. THIS ACTIVITY IS STRICTLY PROHIBITED.

8.7.7 Pre-Use Survey at Job Site

Prior to unloading the radioactive materials at the job site a pre-use survey must be conducted and recorded. This survey is taken to provide a base to be used later in the determination of job site contamination.

Areas in which radioactive materials are to be handled, used or possibly reversed from the well are to be surveyed with a geiger counter prior to use of the material. The probe should be moved slowly and relatively close to the surface without touching it. The Beta window or shield should be open and audible signal on if available. The areas to be surveyed are as follows:

A. Blender Tub or Mixing Tub - the area on the truck where the radioactive material will be added to the slurry or liquid to be pumped.

B. Job Area - the area at which the radioactive material will be off loaded, opened and handled.

C. Waste Pit - survey the area near where material would be reversed into the pit. The meter should be held at waist level during this survey.

D. Personnel/Clothing - each person who handles or uses radioactive material must be surveyed prior to use. This includes hands, arms, body, legs, and shoes.

E. Injector Unit - if an injector pump is to be used, survey it and any reservoir in which radioactive material may be mixed.

Upon completing these surveys, the readings are to be recorded on the RTR under "Before".

8.7.8 Operator Protection

To be adequately protected while handling radioactive material the following principals must be applied:

Time - The smaller the amount of time you are near the radioactive material the smaller your exposure and dose will be.

Distance - Keep as much distance between you and the source as possible. As you double your distance you decrease the exposure rate by a factor of four (4).

Shielding - Get something between you and the radioactive material. The denser or heavier the material the better the shielding.

When tracer materials are being used, it is required that disposable vinyl, plastic, or rubber gloves are worn by the operator. If moderate of large quantities of tracer materials are used, protective clothing should also be used. After completion of the job these items should be considered contaminated and treated as such. They should be disposed of in the same manner as empty cans which contained the radioactive tracer.

There is to be NO SMOKING, EATING, OR DRINKING while handling radioactive material.

Do not handle the geiger counter with the gloves on your hands. If the meter becomes contaminated it will be impossible to conduct any of the required surveys and get accurate readings.

Your personnel monitor (TLD) should be placed under the protective clothing if worn, or under the regular clothing if disposable protective clothing is not being used. Contamination on the TLD monitor will give false indication of personnel exposure. The TLD holder should be surveyed along with personnel/clothing on the RTR before and after use of the radioactive material.

Use the remote handling devices (tongs) whenever possible. Remember, the more distance you have the less the exposure you receive.

8.7.9 Actual Use of Radioactive Tracer

There are three basic ways to tag a slurry or volume of liquid with radioactive material.

A. Batch Mix

The batch mix is usually the easiest to conduct and control. A measured volume of radioactive tracer is mixed into a measured volume of liquid or slurry that is to be pumped. When tagging a batch mix it is important to circulate the batch after it has been tagged to insure a uniform mixture.

When batch mixing Iodine 131 it is most important to use caution. Iodine 131 is quite volatile - it vaporizes easily. When the bottle is opened iodine vapors escape. It is important that the bottle be opened at arms length and with the wind from your back. This will help you from inhaling iodine vapors. Again, it is emphasized that liquid resistive disposable gloves be used when handling liquid radioactive materials.

B. Gradual Tag - Manually

Manually tagging a large volume which is pumped over an extended period of time presents several problems and much more of a hazard than batch mixing. The increased time spent handling the containers of radioactive material increases your exposure. It is necessary to handle the containers with tongs to increase your distance from the source, thus decreasing your exposure. It is essential to wear protective clothing while tagging over an extended period of time. The longer one handles tracer material, the more chances one has to become contaminated.

C. Continuous Tag-Injection Unit

The injector unit, if available, is usually used when large amounts of radioactive material is to be used or when a small amount is used during a long pumping time. Continuous tagging with an injection unit presents some different problems for the operator. Again, he should be gloved and wearing some type of disposable protective clothing - an apron or coveralls. The injector unit usually has some type of reservoir for the tagged material. This enables the operator to load the reservoir and back away from the unit to decrease his exposure rate. It is important and required to be in the vicinity of the unit to keep unauthorized individuals out of the area. One must also be near the unit to insure that it is operating properly and to stop the tagging if necessary.

Of course, in the two continuous tagging methods the isotope is added in relationship to the pumping rate. It is important to be in contact with the treater to insure the proper tag is being maintained. This should also alert you to any problems that may be occurring requiring a shut off of the tracer material.

When using large quantities of radioactive tracer, keep the material to be used in a area which is convenient and that can be observed but not too close to the operator. Again to decrease your exposure it is necessary to employ the radiation protection principals of time, distance and shielding. By placing the material to be used several steps away your exposure will be decreased significantly. While the tracer is being used, an area survey must be conducted in that area. This is used to give an indication as to the radiation field in which the operator is working. The reading is to be recorded on the RTR under "Job Area During Tracer Injection".

8.7.10 Disposition of Contaminated Material at Well Site

Any material that has been used to handle or mix the tagged material should be considered contaminated and treated as such. It should remain isolated until it is determined that it is not contaminated. If it can not be declared "clean" then it must be returned to the District office for proper disposal. All cans, bottles, gloves, coveralls or aprons should be considered contaminated materials and should be placed in the shipping storage area. NOTHING IS TO BE DISCHARGED AT THE WELL SITE.

8.7.11 Post-Use Survey

After the tracer job has been completed, perform a survey of the areas which the tracer was handled and used. Again the survey should conducted with the probe Beta shield open, moving it relatively slow and close to the surface. If a reading greater than 0.1 mR/hr is obtained the following should be conducted:

Determine if the reading is caused by removable contamination. To make this determination, use a dampened cloth with gloved hands and wipe area in question. Take that sample and depart from the area and survey with the geiger counter. If contamination is noted on the cloth it is removable. Return to the area and attempt to define the contaminated area. Once defined, begin clean up by working from the edge into the middle of questioned area. Clean up must be continued until the removable contamination yields less than 0.1 mR/hr just short of contact.

If the contamination cannot be removed, contact the RSO for further instructions.

If the reading is less than 0.1 mR/hr, record readings in the spaces required on the RTR.

8.7.12 Transportation to Camp

All radioactive wastes and unused radioactive material must be returned to the camp for proper disposal. Transportation to the camp is to be done just as it was transported to the job site. Follow the same procedures as listed in item 8.7.6 of these procedures.

8.7.13 Returning Material to Storage

All material returned from the job site must be secured in the radioactive material storage building or area. A survey is to be conducted with a geiger counter after the material is stored to insure levels do not exceed 2 mR/hr on the surface of the restricted area. The restricted area is the outside of the building or the surface of the fence surrounding the building. If 2 mR/hr levels are exceeded, the configuration of the containers should be changed. If levels cannot be returned to an acceptable range, "Caution, Radiation Area" signs must be posted. Remember, the storage area or building must be secured at all times when material is located in it.

8.7.14 Disposal of Contaminated and Unused Material

The current policy of disposal is returning material to Duncan, Oklahoma. This may be shipped by Company vehicle, or commercial carrier. In any event, a material transfer must be completed. All waste and unused material are to be transferred to Dan Kelly, RSO. A copy of this form must be kept at the District as a disposal record. Shipping papers are also required. Remember, if a measurement of greater than 1 mR/hr at three feet is detected, the transporting vehicle must be placarded with "Radioactive" placards on all four sides.

The materials are to be shipped in a Type 7A container. The container which the supplier used should be used for shipping. It does need a minor modification, however. The shipper is required to be identified on each package.

Short lived radioactive material should be held for decay. This eliminates the need to ship materials to Duncan for disposal. Isotopes with a half-life of less than 8.5 days (I-131 and Au-198) qualify for this method of disposal. If the isotope and/or contaminated material is held for ten half-lives it can be disposed of as regular trash provided the following are conducted:

A. Survey container with geiger counter. The reading must be less than 2X background to discard the material into regular trash. The survey is required due to the fact that the wrong isotope has been sent on some occasions. If you do not survey you could be throwing away "Hot" materials.

B. After survey indicates a lack of activity, all labels stating radioactive material on them must be removed or obliterated. This keeps people from reporting an incident when they find a container marked as radioactive material.

C. A record of the survey (actual reading in mR/hr) must be kept. This can be listed on the receiving report. The date and person's name who conducted the survey must be listed along with the statement "Held for decay, discarded in regular trash".

8.7.15

If you have any questions regarding the ordering, receiving, storing, transporting, handling, use or disposal of radioactive material contact:

Dan Kelly
Duncan, Oklahoma 405/255-0242

8.8 Procedures for Reversing Radioactive Tagged Material to the Surface

8.8.1

Reversing of radioactive material from a well in a residential area or near a potable water well must be caught and removed from the well site.

8.8.2

When radioactive material is reversed into the waste pit or into a hole dug at the well site a survey with the geiger counter is required as follows:

A. Reserve Pit - A reading must be taken at three (3) feet above the surface on the edge close to the discharge location. This reading should not exceed 0.1 mR/hr. If this limit is exceeded, measures must be taken to restrict and post the area with "Caution, Radioactive Material".

B. Pit Dug at the Well Site - The hole should be deep enough to accommodate the volume of material reversed plus a three (3) feet surface dirt cover. A reading must be taken at three (3) feet above the surface after coverage has been completed. The reading must be less than 0.1 mR/hr or the area must be restricted and posted with "Caution, Radioactive Materials".

8.8.3

Whenever radioactive material is reversed and placed in the waste pit or in the hole dug for disposal, the form, Figure 21 must be completed and submitted to the Radiation Safety Office.

If there is a question concerning these procedures, please contact one of the following individuals:

Dan Kelly Duncan, Oklahoma 405/255-0242

8.9 Jobsite Decontamination Procedures

The following procedures are to be followed in case of spillage of radioactive material during routine operations on a job location.

8.9.1 Isolate Area Immediately - and maintain this as a restricted area until decontamination can be performed and verified.

8.9.2 Containment procedures and/or abatement procedures may be necessary to prevent the contamination from being spread and removed by wind, rain, water, and mechanical tracking.

8.9.3 Before any decontamination procedure is attempted, initial survey of the contaminated area, ground, or equipment must be performed in order to assess initial levels of contamination and to gauge the effectiveness of the decontamination process as well as verify the completion of the decontamination operations

8.9.4 All personnel participating in the decontamination operation shall be monitored and shall wear Anti-C clothing including; rubber gloves, coveralls, and shoe covers. Respiratory protection may be necessary if the potential exist for airborne radioactivity due to the nature of the clean-up measures.

8.9.5 Care must be exercised in removing the contaminated material due to the potential for cross contamination.

8.9.6 Radioactive waste generated as a result of the decontamination procedures must be containerized in a tight container, labeled with appropriate caution labels, and transported/returned to an authorized storage location for final disposition.

8.9.7 At the completion of the clean-up operation, all equipment and personnel involved shall be monitored for evidence of contamination, and if found must be decontaminated at the jobsite, or the contaminated article or equipment containerized (e.g. plastic wrapped) before leaving the jobsite.

8.9.8 After the verification of decontamination by survey, a record of the incident must be documented on Figure 2 "Emergency Procedures Report" and this attached to the field "Radioactive Treatment Report" as a permanent record on file.

8.9.9 A Radiation Safety Officer (RSO) must be notified immediately if the spillage of radioactive material:

A. Involves extensive contamination.

B. Involves the possibility of personnel internal deposition by ingestion or inhalation of radioactive material.

C. Involves the contamination of non-Company equipment and/or the possibility of internal depositon by ingestion or inhalation of non-Company personnel.

D. Involves personal injury to Company or non-Company personnel and/or property damage to non-Company equipment.

8.10 <u>JOBSITE DECONTAMINATION PROCEDURES</u>

Note: The following procedures are to be followed in case of spillage of radioactive material during routine operations on a job location.

1. ISOLATE AREA IMMEDIATELY - and maintain this as a restricted area until decontamination can be performed and verified.

2. Containment procedures and/or abatement procedures may be necessary to prevent the contamination from being spread and removed by wind, rain, water, and mechanical tracking.

3. Before any decontamination procedure is attempted, initial survey of the contaminated area, ground, or equipment <u>must</u> be performed in order to assess initial levels of contamination and to gauge the effectiveness of the decontamination process as well as verify the completion of the decontamination operation.

4. All personnel participating in the decontamination operation shall be monitored and shall wear Anti-C clothing including; rubber gloves, coveralls, and shoe covers. Respiratory protection may be necessary if the potential exist for airborne radioactivity due to the nature of the clean-up measures.

5. Care must be exercised in removing the contaminated material due to the potential for cross contamination.

6. Radioactive waste generated as a result of the decontamination procedures must be containerized in a tight container, labeled with appropriate caution labels, and transported/returned to an authorized storage location for final disposition.

7. At the completion of the clean-up operation, all equipment and personnel involved shall be monitored for evidence of contamination, and if found must be decontaminated at the jobsite, or the contaminated article or equipment containerized (e.g. plastic wrapped) before leaving the jobsite.

8. After the verification of decontamination by survey, a record of the incident must be documented on Halliburton's "Emergency Procedures Report" and this attached to the field "Radioactive Treatment Report" as a permanent record on file.

9. A Radiation Safety Officer (RSO) <u>must</u> be <u>notified</u> <u>immediately</u> if the spillage of radioactive material:

   a. Involves extensive contamination.

   b. Involves the possibility of personnel internal deposition by ingestion or inhalation of radioactive material.

   c. Involves the contamination of non-Company equipment and/or the possibility of internal deposition by ingestion or inhalation of non-Company personnel.

   d. Involves personal injury to Company or non-Company personnel and/or property damage to non-Company equipment.

461306

8.11 RADIATION SURVEY PROCEDURES

SURVEY AND SURVEY METER USE

A. Required Use

1) Storage Area Surveys.
2) Vehicle Surveys.
3) Use Area (jobsit.) Surveys.
4) Package Receiving Surveys.
5) Contamination Surveys.
6) Personnel Contamination Surveys.

B. Survey Meter Selection and Preparation

1) Select appropriate meter.
2) Use only a in-calibration survey meter.
3) Run through "Battery Check" procedure.
4) Allow meter to "Warm-up" 5 minutes.
5) Run through "Meter Function Test" utilizing a "Coleman Latern Wick" as a check sources.
6) Alwasy select the "Most Sensitive" Multiplier scale for initial use.

C. Survey Meter Use - Guidelines

1) Follow through "Survey Meter Selection and Preparation Procedure B" prior to performing survey.
2) Always determine the area radiation level background (bkg.) and record prior to performing intended survey.
3) Always select the "most sensitive" multiplier or position range before initiating the survey.
4) Always approach the source of radiation from a distance of at least fifteen (15) feet, while using the most sensitive range multiplier switch.
5) The "Beta Shield" on the GM detector probe should be in a closed position.
6) Maintain the survey meter indicating needle in the mid-scale range by selecting the proper multiplier switch.
7) The use of audio speaker in the meter base is Optional.
8) Never approach a source of radiation with a survey meter scale reading greater than the maximum reading possible on the low range meter (50 mR/hr) and a maximum of 100 mR/hr on a high range survey meter.
9) Never touch the GM detector probe directly on a source of radiation.
10) Do not use the GM Survey Meter in close proximity to a source of high radio frequency device or high magnetic field device.

D. Frequently Performed Surveys

1) Storage Area Survey:

- Utilize a form diagram of the storage building or storage container to record the results of the survey.

- The "Storage Area Record" should contain the following minimum information:

- Person performing survey.
- Date of survey.
- Model and Serial Number of survey meter.
- Last calibration date of survey meter (sticker on meter).
- Total activity (mCi) in storage at time of survey.
- Recorded radiation background (bkg.) reading at time of the survey.
- Survey all personnel occupied areas adjacent to or in close proximity to sources of radiation.
- If a storage room or building is utilized, a survey of all outside walls taken near the surface of the outside wall and at the location on the wall giving the highest recorded reading.
- Occupied areas mentioned in previous items are not permitted radiation levels in excess of:

* 2.0 mR/hr - if the source of radiation exist for as long as one hour (1 hr.).

OR

* 0.6 mR/hr - if the source of radiation exist and a person could receive an exposure of 100 mRem in a seven consecutive day period.

- Recorded survey meter readings should be in mR/hr unless otherwise stated.

2) Vehicle Survey:

- A form diagram of the vehicle should also be used to record the survey results.
- Measurements should be taken and recorded for all four sides of the vehicle.
- A measurement should be made at the driver's seat and passenger's seat in each occupied seat of a vehicle.

  * Less than 2 mR/hr --

    a driver's location if the driver is not wearing any type of personnel monitoring.

- The vehicle survey should contain the same minimum information as specified for the storage area survey.
- Location or position of the source of radiation within the vehicle should be indicated on the form diagram of the vehicle.

3) Package Receiving Survey:

- Package receiving survey is required when receiving

  *°½ 100 mCi liquid I-131

  ° Any activity of liquid Ir-192, Sc-46, and Ag-110^{m}

  *°½ 100 mCi La-140 liquid

  ° 3 Ci Ir-192, I-131, and Sc-46 coated sand

- Utilize the attached set of procedures entitled, Liquid Radioactive Material Receiving Survey to. performing and recording the results of a "Package Receiving Survey".

- If a grossly contaminated package is found or even suspected, immediately isolate the package in a Remote area away from personnel and telephone a Radiation Safety Officer for further instructions.

4) Use Area Survey:

- Use a survey meter to determine the 2 mR/hr imaginary line around an Radioactive Injector Unit or on a blender if tagging through the blender tub.

- Prevent access by non-monitored personnel within the 2 mR/hr area during tagging operations by utilizing a rope barrier or through constant visual surveillance by the Operator.

CHAPTER 9
PACKAGING, TRANSPORTING AND STORING TRACERS

9.1 Picking up, Receiving and Opening Radioactive Material Packages

9.1.1 Pick Up (Figure 18)

Appropriate OK Tracer personnel who pick up a package of radioactive material from a common carrier's terminal shall pick up the package as quickly as reasonably possible upon receipt of notification from the carrier of its arrival.

9.1.2 Receiving

Each camp should have inplace standard procedures for receiving and securing radioactive material packages that we receive anytime during operations. These procedures are very important in reducing unnecessary radiation exposure to the general public and monitored Company personnel as well as reducing the possibility of the accidental release of radioactive material to the environment. To achieve the goals, the following procedures Must Be followed:

1) All radioactive material packages must be picked up after proper receipt and relocated to the approved storage area as expeditiously as possible.

*NOTE: There is no excuse for allowing radioactive material packages to remain on warehouse docks, inside offices, and in personnel occupied rooms or areas for extended periods of time.

2) Appropriate personnel must receive the radioactive material package from the delivery service by signing and dating a proper receipt record (shipper's certificate, shippers' invoice, or other document containing all necessary information) and by making a notation of receipt in the "Radioactive Material Utilization Log" as required by regulation.

9.1.3 Packages to be Monitored During Opening

Federal and State regulations require that certain categories of radioactive material packages be checked for loss of container integrity and/or contamination.

1) Packages of radioactive material containing the following categories of radioactive materials must be monitored and opened according to Halliburton's prescribed procedures. These categories of radioactive mterials are as follows:

a. All liquid radioactive material of any quantity including Ir-192, Sc-46, I-131, Au-198, La-140 and as well as other liquid isotope (see Figure 16).
b. The solid form of any isotope or the isotope coated on a solid material (e.g. sand, beads) that is received as a single receipt and in which the isotope content exceeds the following:

Isotope	Quantity Requiring Monitoring
Ir-192	3,000 mCi
I-131	3,000 mCi
Au-110^{m}	3,000 mCi
Sc-46	3,000 mCi
Au-198	20,000 mCi
La-140	20,000 mCi
Cs-137	20,000 mCi

2) The monitoring (wipe test and physical surveys) must be performed as soon as practicable after receipt, but no later than three (3) hours after the package is received at the off during day-light hours, or eighteen (18) hours if received after dark.

9.1.4 "Package Opening Procedures

1) Visually inspect the exterior of each outer package of radioactive material for evidence or sign of damage (e.g. wetness, discoloration of packing, crushed, and punched holes) or leakage.

2) If damage or leakage Is Suspected, Stop Procedure and immediately notify a Radiation Safety Officer (RSO) for further instructions.

3) If damage or leakage Is Not Suspected, then continue the opening procedures as follows:

a. Put on a pair of disposable gloves.

b. Wipe the external surface of the outer package with a cotton swab, filter paper, or piece of tissue papaer and in a low background area check the wipe with a GM survey meter by bringing the meter detector into close (but not touching) proximity of the wipe and observing any activity above background. If any activity is observed above background, immediately notify a RSO.

c. Monitor the unopened packaged with an appropriate GM survey meter. If the radiation level exceeds either 200 mR/hr at the surface, or 10 mR/hr at thr e (3) feet from the surface of the package, stop the procedure and immediately notify the RSO.

d. Carefully place the package in the upright position and open the outer package (following manufactor's directions, if supplied) and remove packing slip. Carefully remove necessary packing material (bracing, filler material) but do not discard the material. Visually examine the inner container for any evidence of damage or leakage. Check the inner package to verify contents (compare requisition, packing slips and label on actual radioactive material container) and visually check integrity of final source container (inspect for breakage of seals or vials, loss of liquid, discoloration of packaging material). If one suspects that radioactive material has leaked outside its container or observes a broken container, stop the procedure and immediately notify a RSO.

e. Always assume the final source container (e.g., vial, bottle) to be contaminated on the exterior surface and always handle this container with remote handling equipment while wearing the disposable gloves.

4) If a receipt entry has not been recorded in the "Radioactive Material Utilization Log", then immediately record the necessary information in the Log.

5) After the package and packaging material have exhausted their usefulness, Monitor the package and packaging materials with a GM survey meter before discarding:

a. If contaminated (any meter reading above background level), then treat as radioactive waste.

b. If not contaminated; remove, obliterate, or deface radioactive labels/wording before discarding to regular trash.

6) RECORD KEEPING - Record the results obtained from the examination, opening, and survey of the radioactive material package on the form entitled "Liquid Radioactive Material Receipt Record", or "Radioactive Material Package Receipt Record".

9.2 Packaging Requirements

All radioactive tracers must be packaged in DOT Type 7A containers.

9.2.1 The supplier ships the radioactive tracers in 7A type containers and it is marked as such. We must transport the tracer in that 7A package. The inner boxes or the cans themselves are not Type A containers. Many locations are removing the tracer containers from the shipping container and transporting them from the District to the job locations. This is an illegal transport. Some locations are making 7A containers which can be used. If any location is interested in making their own shipping container contact the office of the R.S.O. for guidelines.

9.2.2 The shipping container for tracer materials must be labelled or stencilled with the words "DOT 7A TYPE A" and "RADIOACTIVE MATERIAL, n.o.s.".

9.2.3 The shipping container must be labelled with two appropriate radioactive labels on opposite sides. (See Figure 7) Two Radioactive White I labels (See Figure 7) are affixed on opposing sides when the radioactive dose rate at the surface of the package is .5 mR/hr or less and the dose rate at three feet (Transport Index or T.I.) from the surface of the package is zero (0) or equal to background. Two Radioactive Yellow II labels (See Figure 7) are used when the surface reading is above .5 to 50 mR/hr and the T.I. is 1.0 mR/hr or less. The Radioactive Yellow II labels are required for each densometer; mounted or portable. Two Radioactive Yellow III labels (See Figure 7) are used when the surface reading is above 50 and 200 mR/hr or less and the T.I. is above 1.0 and 10.0 or less mR/hr.

9.2.4 The two Radioactive White I labels must identify the radioactive material such as Iridium-192, and it must indicate the quantity in curies.

9.2.5 The two Radioactive Yellow II or III labels must identify the radioactive material, the quantity and the Transport Index (T.I.).

9.3 Shipping Papers

A shipping paper (See Figure 10) is required for each transport of radioactive material from the confines of the licensee's facility. Sample Shipping Papers are shown in Figures 11, 12 and 13 for your reference. The shipping paper must include the following information.

9.3.1 The applicable DOT proper shipping name. For tracers this "Radioactive Material, n.o.s.," which includes empty containers.

9.3.2 The applicable Identification Number (U.N. or N.A.). For tracers this is UN 2982.

9.3.3 The name of the radionuclide.

9.3.4 A description of the physical and chemical form of the radionuclide. For I-131, Sc-46 and Ir-192 this is "Liquid". For tracer sand or props this is "Solid, coated on Sand or Other Props".

9.3.5 The activity contained in each package, measured in curie (Ci) or millicurie (mCi).

9.3.6 The category of labels applied to each package ("Radioactive White - I", "Radioactive Yellow - II" or "Radioactive Yellow - III").

9.3.7 The Transport Index (dose rate at 1 meter) assigned to each package bearing "Radioactive Yellow II" or "Radioactive Yellow III" labels.

9.4 Vehicle Placarding

The transport vehicle must be placarded by the licensee on the front, rear and each side with the appropriate DOT placard (RADIOACTIVE), (See Figure 6) if the package being transported bears the "Radioactive Yellow III" labels. Vehicles transporting "Radioactive White I" or "Radioactive Yellow II" labels do not require placarding.

9.5 Securing Cargo Within Vehicle

Licensees transporting packages of radioactive materials must provide for adequate blocking, bracing, or tie down of the package(s) to prevent shifting or movement during normal transport.

9.6 Security of Material During Transport

Licensees are required to provide security measures adequate to prevent the unauthorized removal of the radioactive material from its place of storage during transport. This many involve locking the package(s) within an external, permanently attached compartment of the vehicle, or within the cargo compartment itself. In either case, it is necessary to remove the keys from an unoccupied vehicle.

9.7 Radioactive Storage Facilities

A substantial structure would include an above ground storage area or an underground storage facility. A primary consideration for underground storage is it must be free from ground or surface water entry.

9.7.1 Security control for any type of described storage facilities is an absolute necessity. Entry into the facility must be controlled by keeping the facility locked and a sign (magenta colored letters on a yellow colored background) stating "Restricted Area - Authorized Entrance Only". Only Operators or trained personnel are permitted access.

9.7.2 The exterior walls of the facility, or the fence if the facility is so constructed, must have two signs so displayed as to be visible and legible from any direction of approach.

a. One sign states "Caution - Radioactive Materials", with magenta colored letters on a yellow colored background. It also displays the radiation symbol. This sign is available from Duncan. (See Figure 8).

b. The other sign states "Caution - Radiation Area" in the same colors and with the radiation symbol. It is available from the Duncan. (See Figure 9)

9.7.3 Inventory records must be accurately maintained for the storage facility. The "Radioactive Tracer Storage Record" form, Figure 15 can be very beneficial if properly used. This form can be used until the entry space is fully completed then placed on file for a permanent record. It is suggested that this form be placed at or near the storage facility and the entries made simultaneous to placing or removing radioactive material in or from the facility.

9.7.4 Periodic Storage Facility Surveys are required. This survey using a protable survey meter should be accomplished at any time the radiation geometry or configuration changes. This implies that a survey should be performed immediately after placing radioactive material into the storage facility are immediately after removing radioactive material from the storage facility. The "Periodic Storage Facility Survey", Figure 17 if properly used will suffice.

9.7.5 Wipe tests or smear tests should be performed on the floors and walls of the storage facility at intervals not exceeding one year. More often if tracers are added to and removed from frequently or at anytime a spillage occurs and must be decontaminated. The storage facility floor must be kept free of removable contamination to prevent the spread of contamination by shoe soles of operators going in and out. A suggested procedure follows:

a. Using a filter paper, cotton ball or cotton swabs, moistened with water containing detergent, carefully wipe several 10 square centimeter areas (4" X 4"). Wear plastic or rubber gloves when doing this.

b. When the wipes or smears are complete, place the wipes in separate sealable plastic bags, label each as to location (within the storage facility) and send to Duncan to the attention of the R.S.O. for analysis.

c. You will be advised of the results and a procedure for decontamination as may be required.

d. All reports and results must be kept on file.

461306

CHAPTER 10
EMERGENC'. INSTRUCTIONS FOR SPILLS, WRFCKS AND FIRES

10.1 Emergency Assistance

Mr. Dan G. Kelly Route 3, Box 247Q Duncan, Oklahoma 73533	Home:	405/255-0242

NRC - Regional Offices

Region I, King of Prussia, PA	215/337-5000
Region II, Atlanta, GA	404/221-4503
Region III, Glen Ellyn, IL	312/932-2500
Region IV, Arlington, TX	817/465-8100
Region V, Walnut Creek, CA	415/943-3700

10.2 Procedure to be Followed in Case of Spillage of Radioactive Materials

10.2.1 Isolated Area: Confine the contamination to the smallest possible area. Notify R.S.O.

a. In case of spillage, on the highway, due to an accident.

1. Rope or mark off the area of possible contamination in such a manner that personnel cannot enter the contaminated zone.
2. Post signs around the area, if possible.
3. Ask aid of local police in keeping people away, if it is necessary.
4. Immediately contact the R.S.O. or His designate.

b. In case of spillage at or near warehouse dock.

1. Block off contaminated area as above indicated.
2. Have warehouseman help in isolating the area, preventing any traffic of material or personnel into or through the area.
3. Immediately contact the R.S.O. or His designate.

10.2.2 Issue TLD badges and/or personal dosimeters to every one assisting in decontamination. Explain the procedure to be followed and use the minimum number of persons necessary to deal with the spill, in accordance with permissible exposure levels. Contact the R.S.O. for advise or assistance.

10.3 Instructions for Drivers

10.3.1 Procedure to be followed in case of spillage of Radioactive Materials.

a. The driver and all occupants of a vehicle transporting radioactive materials must be equipped with an operable rate meter and TLD badges for measuring the accumulated dose rate during transportation.

<u>Isolate area immediately.</u>

In case of spillage, on highway, due to accident.

1. Rope or mark off the area of possible contamination in such a manner that personnel cannot enter the contaminated area.
2. Post signs around area, if possible.
3. Ask aid of local police in keeping people away, if it is necessary.

b. In case of spillage at or near warehouse dock.

1. Block off contaminated area and have warehouseman to help in isolating the area, preventing any traffic of material or personnel in or through the area.

2. Notify, by telephone, the person to whom the radioactive shipment was addressed; the RSO, phone 301/258-6045, whichever is the nearest.
3. Prevent, by all possible means, any spreading of contamination and entrance of unauthorized personnel into the area.
4. DO NOT ATTEMPT to clean up or remove any material from or through contaminated area, until authorized persons arrive with the proper equipment to assist in the clean up.

10.4 Procedure to be followed in case of fire.

10.4.1 Upon establishing a radioactive storage or decontamination facility at any location, the local municipal fire department should be notified in writing all the details including, storage facility design, storage container designs, identity of radioactive materials, quantity of radioactive materials, form of radioactive materials and containment of all radioactive materials.

a. The municipal fire department will be prepared to react to a fire if adequately informed. <u>Call the fire department immediately</u>.
b. Permit no personnel access to the fire area. Put no water on the fire.
c. If the fire is sufficiently contained to a small area use smothering type of extinguishers to put out the flames and prevent spread.
d. Do not assume the fire is extinguished. Permit the municipal fire department to proceed with their investigations.
e. Notify the RSO and His local designates as quickly as possible for advise in performing radiation surveys necessary for recovery operations once the fire is extinguished.
f. The RSO will respond as necessary.
g. Emergency telephone numbers are on the front page of this chapter. It is suggested these be posted near each telephone service within the service camp.

CHAPTER 11
INSTRUCTIONS FOR HANDLING TLD BADGE MONITORS

11.1 The Radiation Safety Officer will assess the need for personnel monitoring. The information required by law for each person to be monitored is the persons last name and two initials, social security number, and birth date.

11.2 The Radiation Safety Officer will supply the information to:

Attn: Mr. George O'Bannion
Nuclear Sources & Services, Inc.
P. O. Box 34042
Houston, Texas 77034
713/641-1379

11.3 A Purchase Order will be issued to Nuclear Sources & Services for the TLD badges required. This must be accomplished on a quarter year basis, allowing thirty days for Nuclear Sources and Services, Inc. (N.S.S.I.) to receive the correspondence and respond. Copies of this Purchase Order must be sent to Dan C. Kelly, Route 3, Box 247Q, Duncan, Oklahoma 73533.

11.4 The District will be directly invoiced by N.S.S.I. Upon receipt of the invoice, stamp your approval and send to Dan C. Kelly as addressed above.

11.5 Any transfers or terminations of the badged employees must be reported immediately to both Dan C. Kelly and N.S.S.I. If an employee is terminated his badge should be returned to N.S.S.I. immediately along with the termination date. This will remove the employee from the TLD badge listing. If an employee is transferred it will be necessary to advise N.S.S.I. of the transfer and left up to the manager or engineer where he is transferred to assume responsibility for monitoring. If not required at the new location, the badge should be returned to N.S.S.I. with his name and social security number for deletion from the TLD badge listing. OK Tracers will be charged twenty dollars for a badge not returned to N.S.S.I.

11.6 Each new badge or TLD insert will have an adhesive backed tag with a badge number (above the name) and the employees name. These are to be promptly distributed upon receipt and the old badges or inserts collected and returned to N.S.S.I. The number located below the name on the small white label is N.S.S.I.'s customer number and not the badge number.

11.7 A "Control" badge will be received by each location each quarter. The "Control" badge is designed to be used for measuring normal or background radiation in your area as well as a monitor for exposure to the badges during transportation. It should be placed in a convenient area where no radioactive substances are kept. This control badge should be returned with the employees badge. SUGGESTION: The control badge should be placed in an area convenient to all badged employees. When the assigned badges are not in use they should be left with the control badge. For analysis purposes the dose rates are equal to personnel exposure minus control badge exposure.

11.8 The TLD badge should never be worn during a visit to a hospital, doctor or dentist. X-ray affects the badge just as gamma and beta radiation does.

11.9 TLD badge results are received at this office on computer printout. The printout will be copied and sent to each location. A monitored individual is entitled to receive notification of his exposure upon written request. Each individual is to be given his exposure records at termination of employment. A monitored person will be contacted immediately if results of the TLD badge indicate an exposure near or in excess of 1,250 mr during the three month period. NOTE: KEEP ALL RESULTS ON FILE AVAILABLE FOR INSPECTION.

12.10 Badging of personnel is not expensive if properly managed. N.S.S.I. charges a ten dollar fee for placing an employee on the TLD badge list. Each quarterly badge charge is three dollars and the charge for analysis is three dollars. This cost per employee is thirty-four dollars for the first year and twenty-four dollars each year thereafter. The charge for a badge not returned is a minimum of twenty dollars.

12.11 It should be noted that the badge is to be properly attached to the individual near the chest area any time he is working near or handling radioactive materials. There is printing on one side of the monitor which states "Wear This Side Next To Body". This must be observed for proper exposure analysis.

12.12 A lost, (See Figure 19) misplaced, damaged or misused TLD badge should be reported immediately to the R.S.O. and to N.S.S.I. and a request made for replacement. The damaged or misused badge should be returned to N.S.S.I. immediately for hopeful salvage of results. If at any time a lost or misplaced badge is recovered (regardless of time lapse) it should be properly identified and returned to N.S.S.I. for analysis.

CHAPTER 12

RECORD MAINTENANCE PROGRAM FOR RADIOACTIVE MATERIAL

12.1 FILE RA-1: Required Documents

12.1.1 License: The radioactive material license including all applicable amendments for the State or Federal regulated area in which materials are stored and used. If you are in doubt as to what agency regulates your operations, call the RSO.

12.1.2 Operating and Emergency Procedures: In most cases these items are found in the "Radiation Safety" manual. Periodic updates are issued by Duncan. These updates in procedures must be kept with the "Radiation Safety" manual.

12.1.3 Regulations for Control of Radiation: Each regulatory agency has a published set of rules and regulations pertaining to the use of radioactive material. A current copy of these regulations is required to be at each District office that handles radioactive material. Again, if you do not know which set of regulations you need to contact the RSO.

12.1.4 Notice of Violations: This is issued by the regulatory agency after completion of an inspection or incident investigation. It is a detailed outline of alleged items of non-compliance noted during the inspection or investigation. In some cases these must be posted. In all cases they must be maintained on file.

12.1.5 Corrective Action Letters: This is OK Tracer's official response to alleged items of non-compliance. This response will be composed by the RSO with the help of the District who was cited. A copy will be sent to that District to be filed.

NOTE: All documents listed in File RA-1 are required to be made available to all employees as per the "Notice to Empoyees". The location where these documents are kept must be posted on or near the "Notice". It is suggested that the District Engineer maintain these documents for review.

12.2 FILE RA-2: Personnel Monitoring and Training Records

12.2.1 Personnel Exposure Records: The quarterly reports received from N.S.S.I. must be reviewed and maintained for inspection.

12.2.2 Pocket Dosimeter Records: A copy of the "RTR" (radioactive treatment report) with pocket dosimeter readings must be maintained in this file for each individual monitored in this fashion.

12.2.3 Radiation Training Records: For an individual to be qualified to handle radioactive materials he must complete the following:

1) Successfully complete a formal classroom training session.

2) Perform a tracer job from beginning to end while physically supervised by a qualified operator.

3) Have documents on file verifying both of the above mentioned activities.

12.2.4 Employee Termination or Transfer Notice: At the termination or transfer of an employee monitored for radiation exposure, a notice must be sent to the RSO. A copy must be maintained on file for inspection. After this notification to the RSO a copy of the individual radiation exposure will be sent to him as required by regulation.

Information included on the termination notice should include: Name, Social Security Number, Date Terminated, and Forwarding address. It is most important to have the individual return his monitor for processing prior to termination or transfer.

12.2.5 Employee Overexposure Reports: Copies of the written notification given to an employee when the quarterly exposure exceeds regulatory limits which is usually 1250 millirems.

12.2.6 Overexposure Reports to Regulatory Agencies: After each reported exposure in excess of regulatory limits, an investigation will be conducted to determine the validity of the reported exposure. A report is then submitted to the regulatory agency. A copy of this report is to be maintained by the District whose employee exceeded the specified limits.

12.2.7 Lost/Damaged TLD Badge Report: If a badge is lost or damaged an exposure must be assigned to the individual involved. This assignment will be made by the RSO after determining the exposure that would be expected from handling a particular amount of activity. This will vary from isotope to isotope and on the frequency of handling. This determination must be kept on file.

12.3 FILE RA-3: Material Control

12.3.1 Radioactive Material Receipt Records: A record that radioactive materials were received must be maintained. That record must be signed by the individual who physically received the shipment. This record must indicate the isotope, physical form and activity received. Usually the suppliers invoice gives us the needed information and it will accompany the shipment.

12.3.2 Radioactive Treatment Report (RTR): A copy of the RTR must be completed and kept on file for each use of a radioactive material.

12.3.3 Disposal Records: A record showing disposal of all radioactive material must be maintained. If materials are transferred to Duncan, an M.T. must be completed. If it goes to a rad waste broker a copy of their receiving report is required. If the isotope is held for decay - a survey must be conducted prior to disposal. A reading of <u>less than</u> 2X background must be observed prior to discard. Also, all labels stating radioactive material must be obliterated. The date of discard and the reading from the survey must be recorded to verify that the radioactive material had decayed prior to disposal. If the labels are obliterated and the survey yields less than 2X background then the material may be placed in the regular trash.

12.3.4 Material Transfers: Any time radioactive material is transferred from one District to another or to Duncan an M.T. must be completed and a copy maintained by both the shipper and receiver.

12.4 FILE RA-4: Physical Inventories, Inspections and Surveys

12.4.1 Quarterly Inventory: Once each quarter, (every 90 days) a physical inventory of all radioactive materials must be conducted and recorded. This inventory includes all tracer materials. This is a sight inventory. Do not take someone's word for it. This inventory can be conducted on the form illustrated in Figures 14 and 15. This must be maintained for inspection. A quick check of required labelling is suggested during this inventory.

12.4.2 Six-Month Inspection and Maintenance Records: Every six months the following is to be conducted and recorded:

Storage Facility:

1) Locks, doors, windows and fences

2) Required posting
   a. Caution, Radioactive Material
   b. Caution, Radiation Area
   c. Authorized Personnel only

3) Conduct and record a survey of the area around the facility.

Each piece of safety equipment including tongs, disposable gloves, disposable coveralls or aprons, dust masks and goggles should be checked to insure proper functioning and availability.

If an injector pump is used, it must be checked for proper operation. If it is mounted on a trailer or vehicle, that should also be inspected (brakes, lights, tires, placards, etc.).

12.4.3 Physical Radiation Survey Records: Surveys that are conducted should be recorded. Of course, the radioactive treatment report calls for certain surveys and those should be recorded on that form. Other surveys including storage location surveys and periodic facility surveys should also be recorded. Figure 17 in the "Radiation Safety" manual entitled "Periodic Storage Facility Survey" is available for your use.

12.4.4 Survey Meter (Geiger Counter) Calibration Records: The Geiger Counter must be calibrated every six (6) months or after each repair, which ever is more frequent. Records of these calibrations must be maintained for inspection. A change of batteries does not affect the calibration of a meter. If your meter has exceeded the desired six month interval please have it calibrated at your earliest convenience. If you are not sure where to send it, contact one of the RSO's.

46130b

12.5 Summary of Radiation Records Requirements

File No.	Title of Record	When Completed
RA-1	License	Updated as needed.
RA-1	Operator and Emergency Procedures (Manual)	Updated as needed.
RA-1	Regulations for Control of Radiation	Updated as needed.
RA-1	Notice of Violations	Updated as needed.
RA-1	Corrective Action Letters	When received from R.S.O. office.

Note: The documents in File RA-1 are those which are required to be made available to all employees as per "Notice to Employees". These are in the Manual on file in the Office.

File No.	Title of Record	When Completed
	"Notice to Employees"	Posted on Bulletin Board
RA-2	Personnel Exposure Reports	Received quarterly.
RA-2	Pocket Dosimeter Records	For each dosimeter as it is used.
RA-2	Radiation Training Records	When course is competed.
RA-2	Employee Termination or Transfer Notice	At termination or transfer.
RA-2	Employee Overexposure Reports	As needed.
RA-2	Overexposure Reports to Agenices	As needed.
RA-2	TLD Company's Added Exposure Letter	As needed.
RA-2	Lost/Damaged TLD Badge Report	As needed.
RA-3	Radioactive Material Purchase Contract or Purchase Order	As needed.
RA-3	Radioactive Material Receipt Records dated and signed	As needed.
RA-3	Shipper's Certification for Radioactive Materials	As needed.
RA-3	Shipper's Invoice	As needed.
RA-3	Radioactive Treatment Reports (RTR)	As needed.
RA-3	Shipping Papers (Company Vehicle)	As needed.
RA-3	Disposal Records	As needed.
RA-4	Six-Month Inspection & Maintenance Records	Every 6 months for each sealed source, piece of safety equipment, and storage facility.

File No.	Title of Record	When Completed
RA-4	Physical Radiation Survey Records	As required.
RA-4	Survey Meter Calibration Records	Every 6 months.

CHAPTER 13
PROCEDURES FOR PERFORMING BIOASSAYS

*NOTE: ANY PERSONNEL WHO USES OR WHO ASSIST IN OPERATIONS WHICH UTILIZE, AT ANY ONE TIME, MORE THAN 50 MILLICURIES OF I-131 IN A UNCONTAINED FORM SHALL HAVE BIOASSAYS PERFORMED WITHIN ONE WEEK FOLLOWING A SINGLE OPERATION.

13.1 Purpose: The measurement of radioactivity in the excreta from the body can be used together with a biological model for radionuclide movement in body tissues and organs to estimate the radioactivity in the body.

13.2 Precautions:

1) Take precautions to ensure the sample or container, or both, are not contaminated at the time of sample collection.

2) All sample containers must be properly labolled and sealed with a tape as well as properly identified.

3) Sample containers must be stored in clean areas away from any sources of potential contamination.

4) Sample containers must not be reused.

13.3 Sample Collection and Handling:

1) A urine sample must be taken within 72 hours after handling of 50 mCi of I-131 but sample collection <u>must</u> <u>not</u> be taken until 6 hours after handling.

2) All samples must be collected in clean unused designated sample containers available at each Camp.

3) Urine samples volume should be at least 250 ml. to allow proper sensitivity of analysis.

13.4 Sample Preparation and Shipment:

1) The urine sample container closure should be sealed with tape to avoid accidental spillage during shipping.

2) Complete the urine sample container stick-on label and securely attach it to each container.

3) Carefully package the samples to prevent loss or breakage of containers, and breakage due to freezing should be considered.

4) Enclosed a packing slip within the package clearly identifying the analysis to be performed, the number of samples shipped, the sending location and the container identification information.

5) The sample package must be sent by an overnight delivery service.

6) Ship all urine bioassays samples to the following location for evaluation unless otherwise instructed.

CONTROLS OR ENVIRONMENTAL POLLUTION, INC.
1925 Rosina Street
Santa Fe, New Mexico 87502
Telephone number: 1-800/545-2188

13.5 Receipt of Bioassay Results:

1) Immediately notify the appropriate Radiation Safety Officer upon receipt of the bioassay results from CEP.

2) File the bioassay results for further reference and inspection by the appropriate regulatory Agency.

CHAPTER 14

RADIOACTIVE TREATMENT REPORT (RTR)

14.1 Introduction

Each shipment of radioactive material (tracer) made to a jobsite must be accompanied by a partially completed RTR. The instructions contained herein are to assist you in completing the RTR form (Figure 4).

14.2 General Instructions

14.2.1 A RTR must accompany the transport of any activity (amount of radioactive tracer to a jobsite.

14.2.2 This single RTR form is to be used for either Radioactive Injector or Hand Tagging (blender, RCM) operations with some modifications in the recording.

14.2.3 The following information on the RTR must be completed prior to the radioactive material (tracer) leaving the designated storage location (Halliburton Camp).

A. Well information and Location -- #(1-7)

B. Material Record -- Items #(8), #(11)

C. Survey Meter Used -- Items #(15-17)

D. Exposure data if applicable -- Items #(18-20)

E. Vehicle Survey -- Item #(23)

F. Physical Radiation survey -- Item #(28)

G. Operator, Badge Number, Date -- Items #(37-41)

14.2.4 Listed below are the items of information needed for completion of Radioactive Treatment Report (RTR), which is the required field use report for the utilization of radioactive tracer. An explanation for each item is included to assist you in properly completing the form. Please call one of us at the following telephone numbers should you need clarification of any of the items.

Dan G. Kelly Duncan, Oklahoma (405)255-0142

A. Items #(1-7)
Well/Customer Information - Complete all the blanks with as much information as available and make an attempt to complete remaining blanks after the job is completed.

B. Items #(8)
Isotope Tracer Used - Be very careful in indicating the radioactive tracer used. Be sure and write-in any isotope tracer that is not listed on this form. Take note that there is liquid and sand coated forms of several isotope tracers.

C. Items #(9-10)

P. O. Number/mCi - The P. O. Number and Number mCi are useful information when no radioactive tracer is kept on hand and tracer is ordered on a job by job basis.

D. Item #(11)

Radioactive Material Sent to Jobsite - This is simply the total activity in mCi of radioactive tracer that was sent to the jobsite. This tem must be completed prior to departing the storage location.

E. Item #(12)

Radioactive Material Used - Indicate the total number of mCi of radioactive tracer actually used on the job. If a partial container of tracer is used, be sure and estimate the amount (mCi) used and amount (mCi) remaining.

F. Item #(13)

Disposition of Unused Radioactive Material - It is very important that the unused portion (mCi) of the radioactive material sent to the jobsite be indicated here. Additionally, a statement must be included that specifies the exact number of empty containers (cans, vials, syringes, etc.) and that these empty containers were returned to storage for ultimate disposal.

G. Item #(14)

Type of Service - Simply indicate the type of job (frac, acid, cement, injection profile, water flood, etc.) that the radioactive tracer is used in conjunction with.

H. Items #(15-17)

Survey Meter Used - Indicate the survey meter unique identification information as requested. The survey meter calibration interval is 6 months and importantly the meter must be within a current 6 month calibration interval for the entire RTR to be considered as a valid legal record.

**Please take note that an operable recently calibrated survey meter must accompany each radioactive tracer transport to a jobsite and be cautioned that a Government Radiation Control Inspector can legally shut-dow the radioactive tracer addition operation portion of a frac, acid, or cement job, but can not shut the entire job down. The survey meter must be labeled with a calibration sticker somewhere on the meter base.

I. Items #(18-21)

Exposure Data - This data involves the use of a self-reading pocket dosimeter for personnel monitoring in lieu of the standard issue TLD badge. Anyone that uses, transports or handles loose radioactive tracer must be provided with either a TLD or Direct Reading Dosimeter (DRD). If you use a DRD, then complete these blanks. Take note that the DRD must be zeroed daily. Additionally, any Halliburton personnel or Customer personnel must be provided by Halliburton with adequate personnel monitoring and required documentation recorded for each user.

J. Items #(22), (24), (26), (27)

Background Radiation Levels - A background radiation level measurement must be taken and recorded prior to any documented survey being performed. This background reading must be taken away for the source of radiation and should be representative of the general area radiation levels. The background reading or measurement must be taken with the meter detector at the same approximate location and distance as would be the item or area surveyed. Survey meter will most likely need to be on the most sensitive scale for this measurement. Record the background reading in mR/hr at the indicated locations on the RTR Key.

K. Item #(23)
Vehicle Survey (After Vehicle Loaded) - This survey is a physical radiation survey of the radiation levels on the exterior of the actual transport vehicle, whether it be a car, pickup truck, closed vehicle, sand injection trailer or liquid injection trailer. The "After Vehicle Loaded" Survey is to be taken and recorded immediately after vehicle is loaded and must be prior to departing the assigned storage or radioactive tracer pick-up location. Actual survey guides include:

1. Radiation measurements must be taken on the outside of the vehicle or trailer at the same specified distance from the outside surface (six inches is good) of the vehicle or trailer.

2. Radiation measurements must also be taken at the same approximate level off the ground level.

3. Record the maximum level measured for each side of the vehicle in appropriate blanks.

4. The measurement for the "Front" of the vehicle is the measurement taken at the vehicle's front or the tongue of a trailer.

5. Always indicate the position of the radioactive materials by placing an "X" in the vehicle at the source position.

L. Item #(25)
Vehicle Survey (Prior to Return) - This survey is to be performed after the tracer addition has been completed on the job, the empty containers have been loaded in the return vehicle and the return vehicle is ready to return to it's assigned location. The procedures for performing this survey are identical to the "After Vehicle Loaded" survey. The same distance at which measurements were taken on the "After Vehicle Loaded Survey" must be used during the "Prior to Return to Camp" Survey.

M. Items #(28), #(28-A)
Physical Radiation Survey DELIVERY VEHICLE - This survey is not a duplication of the Vehicle Survey, (Items #23 and #25) as the "Delivery Vehicle" Survey here is a check for loose radioactive tracer contamination in the transport vehicle. The Before Survey is a survey of the position, location or empty transport container prior to the radioactive tracer being placed in it's transport mode. Again, the distance at which the detector is positioned from the tracer transport location must remain constant during all surveys. The After Survey is simply a survey of the same position, location, or empty transport container in the transport vehicle after the empty tracer containers (cans, vials, syringes) have been removed from the transport vehicle.

1. Both the Before and After Delivery Vehicle Surveys are taken with the survey meter detector as close to the surface (approximately one inch) off the vehicle floor, or the bottom of a transport container as possible as you are looking for loose radioactive tracer contamination.

** The sand injection unit and the high pressure liquid injection (HPLI) unit will, by experience, contain constant radioactive contamination, the majority being inside system components. This the "Delivery Vehicle Survey" Before and After will show measurable radiation levels utilizing a Geiger survey meter. It is, however suggested that the Before and After Survey be performed and recorded by placing the survey meter detector inside the injector trailer at waist height and recording the reading. This measurement must be taken in the same approximate position in the trailer for both the Before and After survey.

N. Item #(29), #29-A)

Physical Radiation Survey BLENDER TUB - This survey is applicable only if radioactive tracer is added to the blender tub. If the blender tub is not used, simply record a N.A. (Not Applicable) in the Before and After blanks. If radioactive tracer is to be added to the blender tub, a survey of the tub Before and After must be performed. This survey should be taken with the meter detector hanging down inside the cavity of the tub at the same approximate position for both the Before and After Survey. Low Level radioactive contamination is anticipated with the larger activity (quantity) jobs. After job survey with a survey meter reading greater than background would not be unusual. It is imperative that the actual measured radiation level be recorded.

O. Item #(30), #(30-A)

Physical Radiation Survey JOB AREA - Job area as used here is interpreted as the ground area immediately under the surrounding any piece of equipment (blender, injector unit, pump, storage area, discharge manifold, iron, etc.) that was involved in the transporting, mixing, injection or carrying (iron) of radioactive tracer in tagged fluid/proppant. The physical survey should follow the following guidelines.

1. The meter detector should be positioned at a distance of six inches from the ground surface and the meter setting at the most sensitive scale.

2. A survey meter reading of three times background (3 background) or greater indicates the presence of contamination.

3. Jobsite accessory equipment that becomes contaminated should be decontaminated at the jobsite if possible, but nonetheless, decontamination must be performed at the Halliburton Camp as soon as practical after the equipment arrives back at the yard.

4. Extensive job area contamination must be reported to a Radiation Safety Officer (RSO) immediately after the extent of contamination is know.

5. Additionally, a RSO must be immediately notified of any incident involving the contamination of non-Company equipment or the personal injury of Company or non-Company personnel involving the use of radioactive tracer or radioactive densometers.

P. Item #(31), #(31-A)

Physical Radiation Surveys WASTE PIT - The waste pit survey Before the job is necessary to establish the presence or absence of existing radioactive material in the pit for future reference. The Before survey should be performed at the waste pit fringe area (liquid/pit perimeter) several feet on both sides of a well waste pit return flow line. This survey in contrast to the other physical radiation surveys should be with the meter detector at a distance of three feet 3') from the ground surface with contamination being a measurement of greater than 0.1 mR/hr at three feet. Any waste pit with a reading of greater than 0.1 mR/hr at 3 feet must be "Posted" with "Caution Radioactive Material" signs. The After survey is not normally necessary under most conditions unless tagged well fluids are flowed back to the waste pit during the job, thus requiring an After survey with the survey results being recorded. Record a N.A. in the After blank if no tagged well returns during the job are involved.

Q. Item #(32), #(32-A)

Physical Radiation Survey PERSONNEL/CLOTHING - This survey involves the survey of Rayfrac Operator personnel's body surface and his street clothing underneath the disposable Anti-C apparel. The Before and After survey are both necessary as the Before survey records a background. A survey meter reading of twice background (2 background) indicates low level contamination. Personnel clothing contaminated must be removed and bagged in a plastic bag. Contaminated personnel body surfaces require immediate decontamination.

R. Item #(33)

Job Area During Tracer Injection - This is the maximum measured radiation level in the immediate area in which radioactive tracer is used by a Rayfrac Operator. This is simply the radiation level in mR/hr at the Rayfrac Operator's use location. This involves performing a physical radiation survey and recording the actual levels measured.

S. Items #(34-36)

Signature/Employee Number/Badge Number - This information is for a Qualifying Operator that is assisting the Qualified Rayfrac Operator. This information is left blank if only Qualified Rayfrac Operators are involved with tracer addition. The TLD badge number is the number printed above the person's name on the badge holder label, not the number below.

T. Items #(37-39)

Signature/Employee Number/Badge Number - This information is for the using Qualified Rayfrac Operator.

U. Item #(41)

Date - Indicate the date the RTR was completed.

46/306

FIGURE 1

RADIOACTIVE TREATMENT REPORT (RTR)

Well Owner ____________________ Well Name ____________________

State ______________ County ______________ Field ______________

Service Ticket No. ______________ Ticket Date ______________

MATERIAL RECORD

(Circle One)

2 - RAC-2 - I-131
3 - RAC-3 - Sc-46
4 - RAC-4 - Ir-192
5 - Tracing Sand - Ir-192
6 - Super Props
8 - Tracing Sand - I-131
9 - Tracing Sand - Ag-110^{m}

P.O. Number ______________ mCi ______________

R/A Material Sent to Jobsite: ________ mCi

R/A Material Used: ________ mCi

Disposition of Unused R/A Material: ______________

____

____

Type of Service: ______________

Survey Meter Used:

Make ______________

Serial Number ______________

Last Calibrated ______________

Exposure Data:

Dosimeter

Make ______________

Serial Number ______________

Reading Before ______________

Reading After ______________

PHYSICAL RADIATION SURVEYS

Vehicle Survey

After Vehicle loaded:

Side ____

Front ____ [ ] Rear ____

Side ____

Prior To Return To Camp:

Side ____

Front ____ [ ] Rear ____

Side ____

1. Indicate position of source in vehicle with "X"
2. Measure and record radiation at each extremity of the vehicle
3. Place copy on vehicle when transporting radioactive sources

	Before	After
Delivery Vehicle	______	______
Blender Tub	______	______
Job Area	______	______
Waste Pit	______	______
Personnel/Clothing	______	______

* All meter readings expressed in mR/hr unless otherwise stated, and taken as near the surface as is reasonable.

Job Area During Tracer Injection ______________

Signature of Qualifying Operator ______________ Emp. No. ________ Badge No. ________

Signature of Rayfrac Operator ______________ Emp. No. ________ Badge No. ________

Halliburton Camp ______________ Date ________

Immediately upon completion of job, complete this form and mail to OK Tracers, Dan G. Kelly, Route 3, Box 247Q, Duncan, OK. You must keep a copy of this report for your R/A files for inventory purposes.

Figure 2

EMERGENCY PROCEDURES REPORT

1. Customer: ______________________________

2. Customer's Supervisor: ______________________________

3. Company Supervisor: ______________________________

4. Cause of Emergency: ______________________________

____

____

____

5. Source or Isotope: ______________________________

6. Quantity of Isotope (curies) believed to have been spilled: ______________________________

____

7. Safety precautions immediately enacted: ______________________________

____

____

8. Were there any suspected over-exposures and if so, who: ______________________________

   1. ______________________________
   2. ______________________________
   3. ______________________________
   4. ______________________________

9. Personnel radiation survey, for those working in the Restricted Area:

	Name	Head	Face	Body	Hands	Legs	Feet
1.							
2.							
3.							
4.							

10. On the sketch of the job site, mark the location of the exact spill: ______________________________

____

Figure 2 (continued)

11. Make an isodose chart if the level of the spill is greater than 10 mr @ 1 foot.

    a) one foot: ______________________

    b) three foot: ______________________

    c) six foot: ______________________

12. Check the air space for contamination: ______________________

13. Results of wipe tests after clean up emergency procedures are undertaken:

    Position No. 1: ______________ (dpm)

    Position No. 2: ______________ (dpm)

    Position No. 3: ______________ (dpm)

14. Suggestions to future prevention of this accident: ______________________

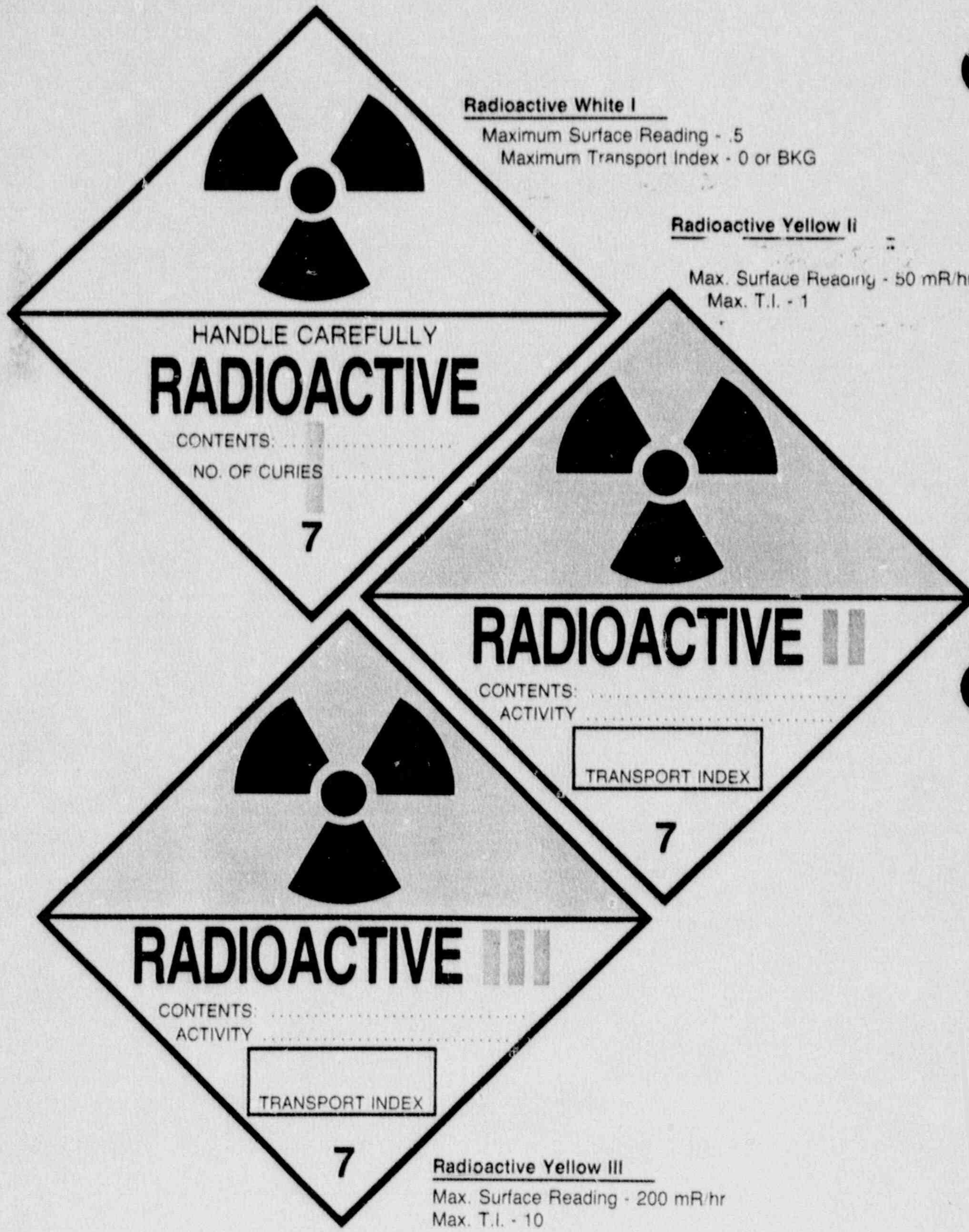
____

____

____

Figure 3
Transport Placard

Figure 4 - DOT Labels



Radioactive White I

Maximum Surface Reading - .5
Maximum Transport Index - 0 or BKG

Radioactive Yellow II

Max. Surface Reading - 50 mR/hr
Max. T.I. - 1

Radioactive Yellow III

Max. Surface Reading - 200 mR/hr
Max. T.I. - 10

Figure 5

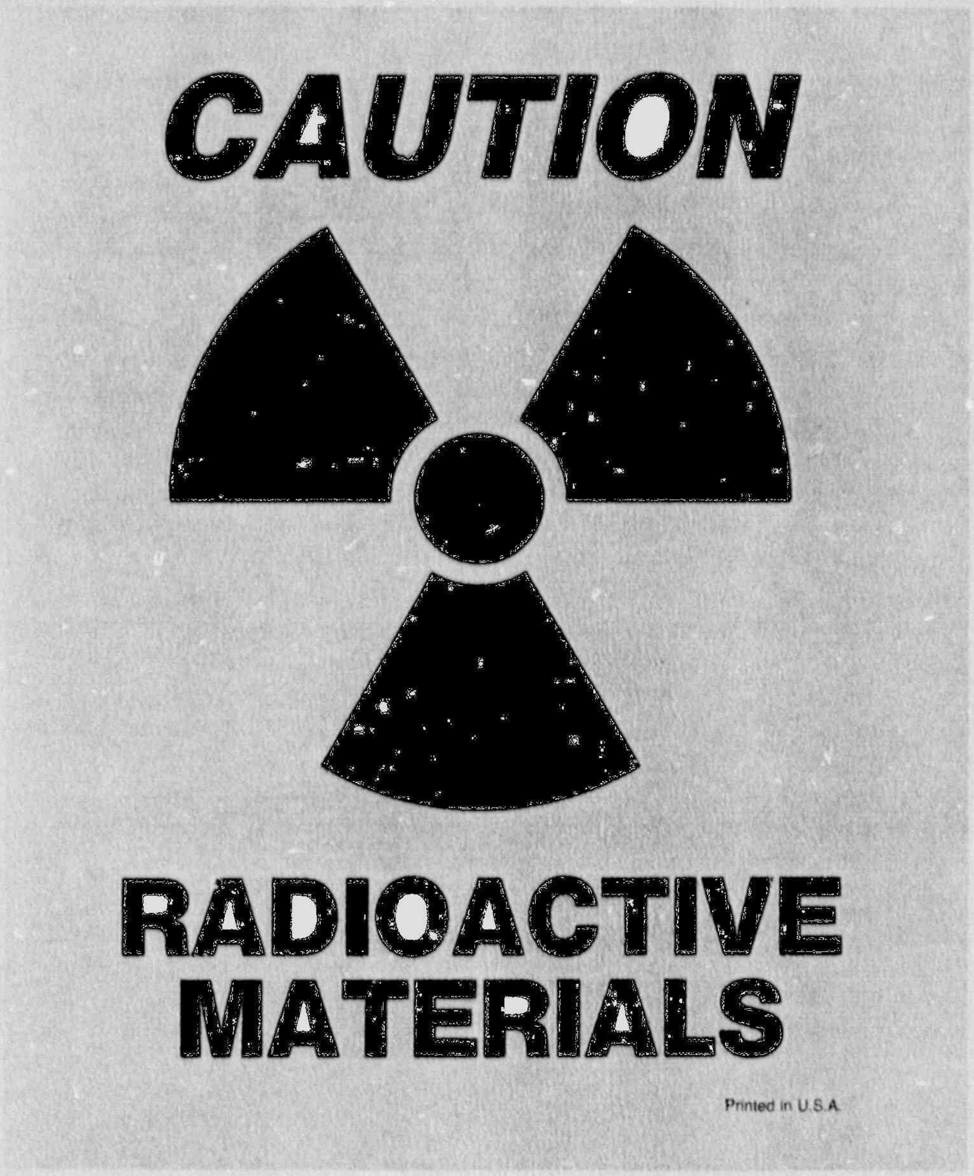


Figure 6

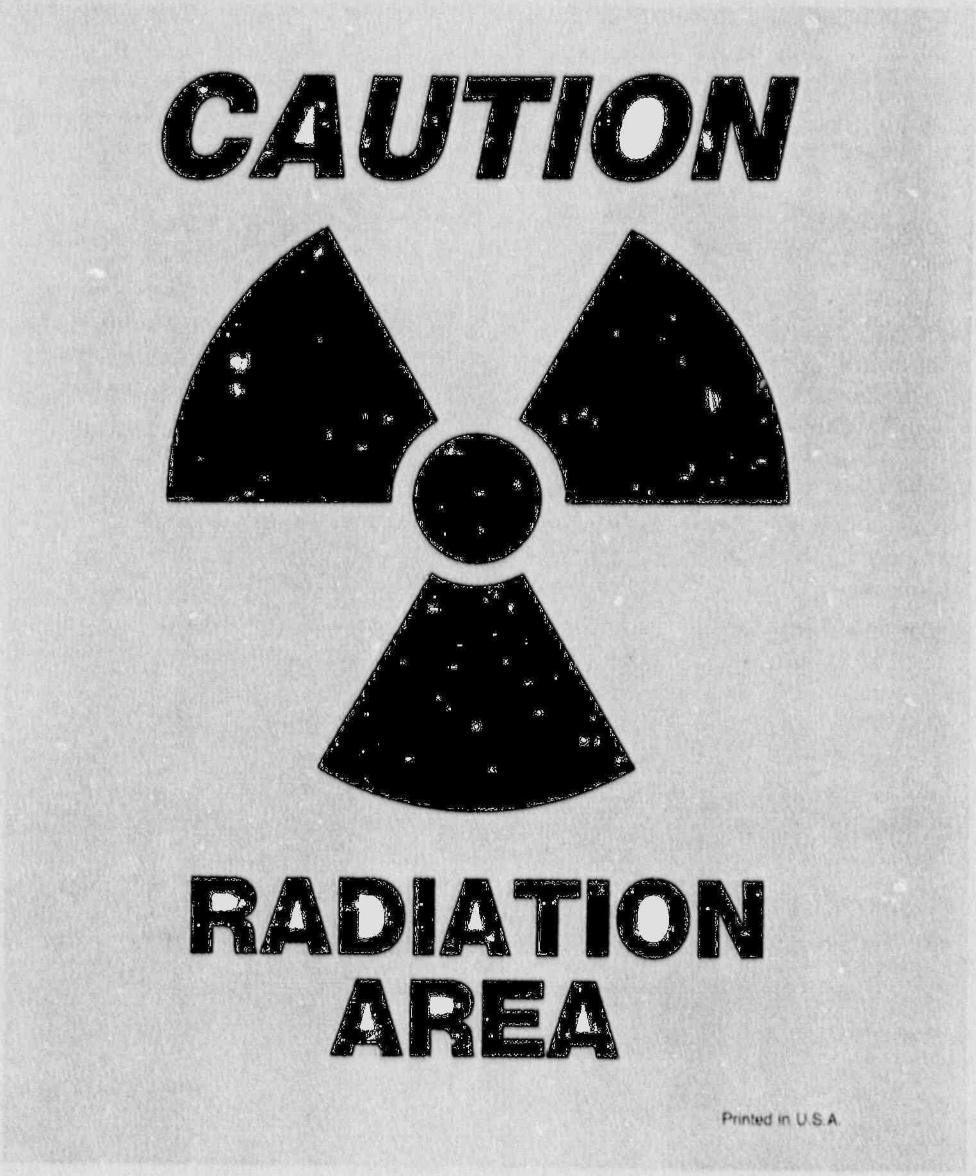


Figure 7
BLANK COPY

OK TRACERS, INC.
SHIPPING PAPER
for
MOVEMENT OF MATERIALS BY COMPANY VEHICLE
(As specified in Code of Federal Regulations 49, Sec. 177.817)

The driver of each motor vehicle transporting hazardous materials must have in his possession the following information*

LOCATION ______________________

IN CASE OF EMERGENCY CONTACT:

UNIT #(s) ______________ DATE ______________

NAME ______________________

DRIVER ______________________

TELEPHONE ______________________

Number & Type of Containers	HM* RQ	DOT Proper Shipping Name* – DOT Hazard Classification* – DOT I.D. Number* as per 49CFR 172.101	Quantity*	Halliburton Name	Part Number

Figure 8

EXAMPLE ONLY (For All Tracer Material)

OK TRACERS, INC.

SHIPPING PAPER
for
MOVEMENT OF MATERIALS BY COMPANY VEHICLE

(As specified in Code of Federal Regulations 49, Sec. 177.817)

The driver of each motor vehicle transporting hazardous materials must have in his possession the following information*

LOCATION Somewhere, USA

UNIT #(s) 01000 DATE 5-5-86

DRIVER John Doe

IN CASE OF EMERGENCY CONTACT:

NAME Dan G. Kelly

TELEPHONE 405/255-0242

Number & Type of Containers	HM* RQ	DOT Proper Shipping Name* – DOT Hazard Classification* – DOT I.D. Number* as per 49CFR 172.101	Quantity*	Halliburton Name	Part Number
1-A	X	Radioactive Material, n.o.s., UN2982,	50 mCi	tracing sand	n.i.s.
		Iridium-192, Solid Coated on Sand,			
		50 mCi			
		Radioactive Yellow III Label,			
		Transport Index - 4.5			
		Type A Shipping Container			

FORM 2069 Rev.

Figure 9
EXAMPLE ONLY (For Empty Containers)

OK TRACERS, INC.
SHIPPING PAPER
for
MOVEMENT OF MATERIALS BY COMPANY VEHICLE
(As specified in Code of Federal Regulations 49, Sec. 177.817)

The driver of each motor vehicle transporting hazardous materials must have in his possession the following information*

LOCATION Somewhere, USA

UNIT #(s) 01000 DATE 5-5-86

DRIVER John Doe

IN CASE OF EMERGENCY CONTACT:

NAME Dan G. Kelly

TELEPHONE 405/255-0242

Number & Type of Containers	HM* RQ	DOT Proper Shipping Name* – DOT Hazard Classification* – DOT I.D. Number* as per 49CFR 172.101	Quantity*	Halliburton Name	Part Number
1-A	X	Radioactive Material, n.o.s., UN2982	Residual	Tracing	n.i.s.
		Iridium-192, Solid coated on Sand,	Quantities	Sand Containers	
		Residual Quantities,			
		Radioactive Yellow II Label,			
		Transport Index - .8,			
		Type A Shipping Container			

FORM 2069 Rev.

RADIOACTIVE TRACER STORAGE RECORD

Location: ______________________ Inventory Dates ______________ to ______________

Radioactive Isotope	Quantity Received mCi	Quantity Removed mCi	Date	P.O. or P.C. Number	Container Serial No.	Customer-Well County & State	Signature

When page is complete; keep original on file at District Office and provide a copy to the Radiation Safety Officer.

Figure 10

Figure 11

LIQUID RADIOACTIVE MATERIAL RECEIVING SURVEY

Purchase Order Number ______________________ . Supplier & Invoice No. ______________________ .

Isotope __________________ Activity __________________ mci Background __________________ MR/hr.

Date & Time Received ______________________________ District ______________________________

Survey Meter: Model ____________________ Serial No. ____________________ Calib. Date __________

A. Meter reading 1 meter from package surfaces ______________________________ MR/hr.

B. Transport index from radioactive yellow III label ______________________________ MR/hr.

C. Meter reading at package surface ______________________________ MR/hr.

If readings A & B are the same, it is unlikely that inner containers are leaking and if C is 200 MR/hr or less, the survey is complete.

____
Signature

D. If reading A is significantly higher than B, proceed as follows:

1. Remove inner containers temporarily and place about 30 ft. from the outer container.

2. Take geiger counter reading at the inside center of the outer container ____________________ MR/hr. If the reading is the same as background, no leakage has occurred. If above background, leakage could exist.

E. In the event that **C is greater than 200 MR/hr** or that **leakage could exist** (D. 2), notify the Radiation Safety Officer immediately for further instructions.

Action taken if leakage or high surface reading found:

____
Signature

NOTE: File this report with Radioactive Material Receiving Records.

Figure 12

PERIODIC STORAGE FACILITY SURVEY

(Perform Whenever the Storage Configuration Changes)

Date	Survey Meter Type & S/N	Background	Max Exposure At Perimeter	Signature of Person Performing Survey and Comments

FIGURE 13

RADIOACTIVE MATERIAL HAS BEEN REVERSED AND ABANDONED AT THE FOLLOWING LOCATION

Company ______________________________

Well Name ______________________________

County/Parish ______________ State ______________

Isotope ______________________________

Estimated Total Volume of Material Tagged (Cement, Proppant, Etc.) ______________

____

Estimated Activity in Total Volume Material Reversed ______________

____

Disposition of Well Returns (Waste Pit, Dug Pit) ______________

Date of Well Returns ______________

Reported By: ______________

District ______________

Date ______________

Sketch In Location of Waste Pit or Dug Pit (Direction and number feet from well)

SURVEY RESULTS

	Before Reversal	After Reversal	Bkg. ______ mR/hr
Waste Pit	______ mR/hr	______ mR/hr	Meter Model No. ______
Dug Pit	______ mR/hr	______ mR/hr	Meter Serial No. ______
Other ______	______ mR/hr	______ mR/hr	Last Calibration ______

461306

11-3-86
Final Draft
for Approval

INDEX

Copy sent to DCS

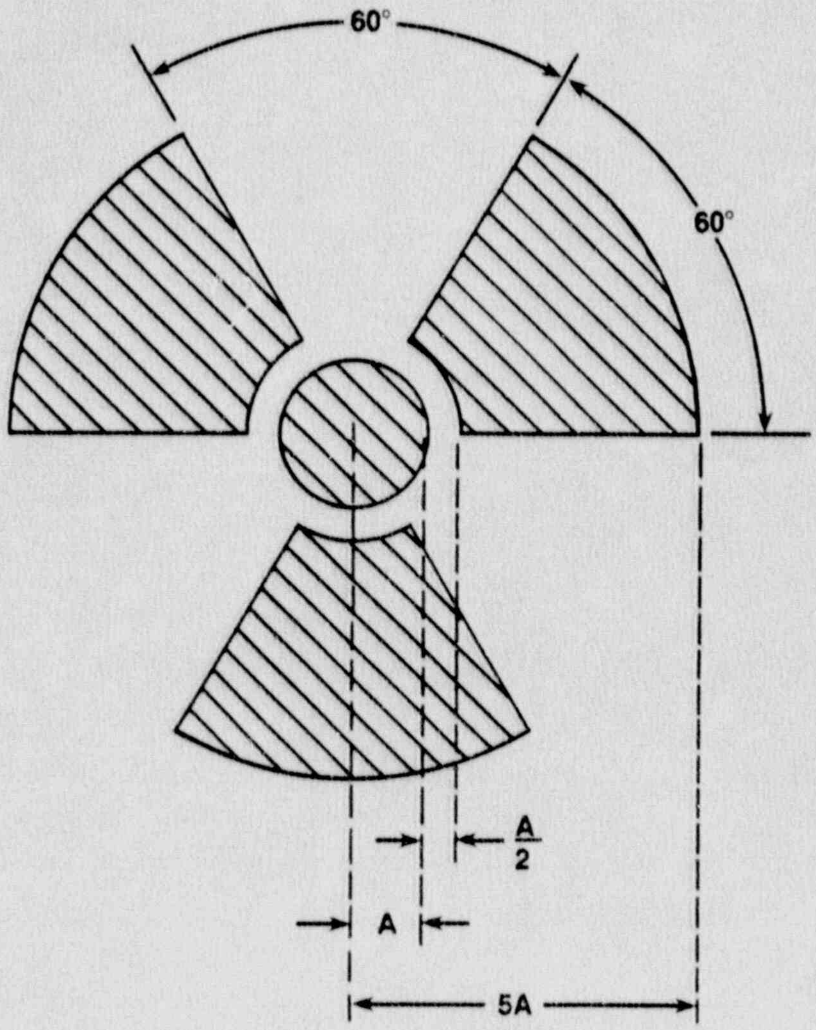
461306

Charts and Figures

RADIATION SYMBOL

1. CROSS-HATCHED AREA IS TO BE MAGENTA OR PURPLE.

2. BACKGROUND IS TO BE YELLOW.



GLOSSARY OF TECHNICAL TERMS

The terms listed below are in common use in the literature on radioisotopes. In many cases the definitions given are those of the Glossary of Terms used in Nuclear Science, published by the British Standards Institution as B.S. 3455:1962.

Absorption

1. The retention, in a material, of energy removed from radiation passing through it.
2. The removal of radiation or the reduction of its energy on passing through matter.
3. The process whereby a neutron (or other particle) is captured by a nucleus.

Activity

Of a quantity of radioactive material, the number of nuclear transformations which occur in this quantity in unit time. (See also curie, below).

Alpha particle

A fast-moving helium (^{4}He) nucleus.

Annihilation radiation

The electromagnetic radiation resulting from the mutual annihilation of two particles of opposite charge. In the case of a collision between a positive and a negative electron the annihilation radiation consists of two photons, each of energy about 0.51 meV, emitted in directions opposite to each other.

Atom

A unit of matter consisting of a single nucleus surrounded by one or more orbital electrons. The number of electrons is normally sufficient to make the atom electrically neutral. Adding or removing one or more electrons turns the atom into a negative or positive ion, but this is regarded as a state of the same atom. The atom is characterized by its nucleus; to change this requires very much more energy than changing the state of the atom.

Atom mass unit (amu)

One-twelfth of the mass of a neutral atom of carbon-12.

Atomic number

Of an element, denotes the number of protons in the nucleus, the number of positive charges in the nucleus, and the number of orbiting electrons.

Atomic weight

For a given specimen of an element, the mean weight of its atoms, expressed in either atomic mass units (physical scale) or atomic weight units (chemical scale).

Atomic weight unit (awu)

One-twelfth of the mean mass of the neutral atoms of naturally occurring carbon.

Beta particle

An electron, of positive or negative charge, emitted in the beta transformation. (See also electron).

Curie (Ci)

The unit of activity. One curie (1Ci) is $3{\cdot}7 \times 10^{10}$ nuclear transformations per second.

Daughter

Of a given nuclide, any nuclide that originates from it by radioactive decay.

Decay

Of a radioactive substance, the gradual decrease of its activity; its transformation into its daughter products.

Disintegration

Any process in which a nucleus emits one or more particles either spontaneously or as a result of a Collision.

Dose equivalent

A unit of biologically effective dose, defined as the absorbed dose in rads multiplied by the Quality Factor (QF). For all X-rays, γ-rays, β-particles and positrons likely to be encountered from radioisotopes the QF is 1. For α-particles it can be taken as 10.

Electron

The negatively charged particle (charge $e = 1 \cdot 60 \times 10^{-19}$ coulomb, mass $m = 9.11 \times 10^{-28}$g) which forms a constituent of all atoms, its positively charged counterpart of equal mass and charge being called the positron. However, the word electron is often used to include both negative electrons (negatrons) and positive electrons (positrons).

Electron volt (eV)

A unit of energy equal to the kinetic energy acquired by an electron when accelerated through a potential difference of 1 volt ($1\ eV = 1 \cdot 60 \times 10^{-12}$erg).

Element

Matter consisting of atoms having the same atomic number.

Enriched material

Material containing an element in which the abundance of one of the isotopes has been increased above that which it normally possesses.

Equivalent activity

Of a radiation source, the activity of a point source of the same radionuclide which will give the same exposure rate at the same distance from the center of the source.

Excitation

The addition of energy to a system, transforming it from its ground state to an excited state.

Fission

A nuclear reaction in which a heavy nucleus splits into two (or very rarely three or four) approximately equal parts.

Fission products

The stable and unstable nuclides resulting from fission.

Flux

The product of the number of particles or photons per unit volume and their average speed.

Gamma radiation

Electromagnetic radiation emitted by atomic nuclei. Also called gamma rays.

Ground state

The state of lowest energy of a system.

Half-life

The time in which the amount of a radioactive nuclide decays to half its initial value.

Ionization

Any process by which ions are formed; in particular, ionization of a gas by the passage of fast charged particles.

Isotopes

Nuclides having the same atomic number but different mass numbers.

Isotopic abundance

The number of atoms of a particular isotope in a mixture of the isotopes of an element, expressed as a fraction of all the atoms of the element.

keV

Thousand electron volts = 10^3eV.

Mass number

Of a nuclide, the integer A which is nearest to its atomic mass; it is the number of protons plus neutrons in the nucleus.

Metastable states

In a nucleus, isomeric states with energies above that of the ground state.

MeV

Million electron volts = 10^6eV.

Neutron

One of the particles of which nuclei consist; it is the zero charge and slightly heavier than a proton.

Nucleus

The positively charged central portion of an atom, with which is associated almost the whole mass of the atom, but only a minute part of its volume.

Nucleon

A proton or neutron.

Nuclide

A species of atom characterized by its mass number, atomic number and nuclear energy state, provided that the mean life in that state is long enough to be observable.

Parent

Of a nuclide, that radioactive nuclide from which it is formed by decay.

Photon

A quantum of electromagnetic radiation, possessing the energy hv (h being Planck's constant and v the frequency).

Positron

See Electron.

Proton

A nuclear particle of mass number 1 having a charge equal and opposite to that of an electron and having a mass of 1.0076 amu.

Quality factor (QF)

See Dose equivalent.

Rad

The unit of absorbed dose. One rad is equal to 100 ergs per gram.

Radiation source

A quantity of radioactive material used as a source of ionizing radiation.

Radioactive concentration

The activity per unit quantity of any material in which a radionuclide occurs.

Radioactivity
The property of certain nuclides of emitting radiation by the spontaneous transformation of their nuclei.

Radioisotope
An isotope which is radioactive.

Radionuclide
A nuclide which is radioactive.

Rem (Roentgen equivalent man)
The unit of dose equivalent. The absorbed dose in rads multiplied by the Quality Factor of the type of radiation.

Roentgen
The unit of exposure dose of X or γ-radiation. One roentgen is an exposure dose of X or γ-radiation such that the associated corpuscular emission per 0.001293 grams of air produces, in air, ions carrying 1 electrostatic unit of quantity of electricity of either sign. (1.61×10^{12} ion pairs per gram.)

Specific activity
The activity per unit mass of an element or compound containing a radioactive nuclide.

Specific gamma ray constant (or emission)
Of a radioactive nuclide, the exposure dose rate produced by the gamma rays from a unit point source of that nuclide at unit distance. (Unit: Roentgens per millicurie hour at 1 cm).

Stable isotope
An isotope which is not radioactive.

Thermal neutrons
Neutrons in approximately thermal equilibrium with their surroundings. At room temperature their mean energy is about 0.025 eV. Neutrons of higher energies are referred to as fast neutrons.

Transformation
The change of one nuclide into another.

X-rays
Electromagnetic radiation resulting from extra-nuclear loss of energy of charged particles (for example, electrons) and having shorter wavelength than ultra-violet radiation.

CHAPTER 1
THE STRUCTURE OF MATTER

1.1 Atomic Number and Weight

The nuclei of atoms are made up of protons and neutrons (with the single exception of the simplest hydrogen atom). The charge on the nucleus of an atom is determined by the number of protons in the nucleus. The 92 elements found in nature have been numbered from 1 to 92. Number 1 is hydrogen and number 92 is uranium.

Symbols for the elements are commonly written with subscripts and superscripts. Example:

hydrogen	$_1H^1$	oxygen	$_8O^{16}$
helium	$_2He^4$	uranium	$_{92}U^{238}$

The subscript is called the atomic number and denotes the nuclear charge or number of protons in the nucleus. The superscript refers to the sum of the neutrons and protons in the nucleus and is called the nucleon number. Also, this superscript is approximately the atomic weight.

The weight of one carbon atom has been arbitrarily set as 12 units of mass. On this basis, the atomic weights of other elements have been determined. Examples:

hydrogen	1.008	cobalt	58.9
helium	4.003	lead	207.1
nitrogen	14.0	uranium	238

Note that these are very nearly whole numbers.

Dalton's atomic theory came early in the nineteenth century. It motivated a search for elements which by the middle of the century resulted in the discovery of some 75 elements. Study of these showed that they differed in atomic weight and that, furthermore, they could be placed in serial order. Also noted was the fact that some groups of elements seemed to have similar properties. For example, lithium, sodium, and potassium were soft shiny metals, easily tarnished in air. Their compounds were similar. Sodium chloride, table salt, is a salty tasting white crystal which dissolves easily in water. Lithium chloride and potassium chloride have the same properties.

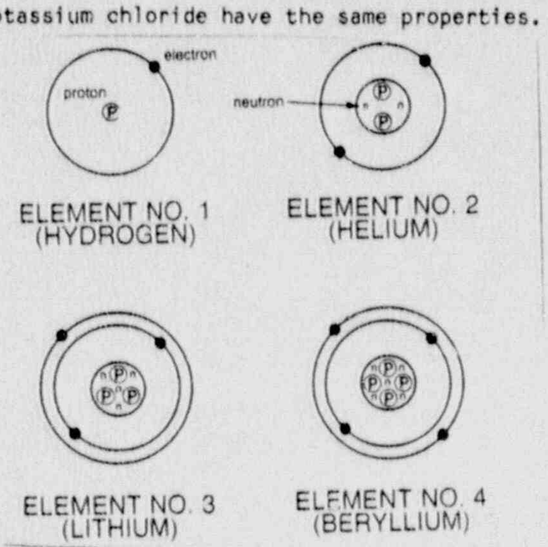


FIGURE 1.1. - Atoms of First Four Elements

Mendeleev, in 1869, arranged elements in a pattern called the Periodic Table (see Table 1.1). This grouped together similar elements and enabled the prediction of new elements and even the properties of new elements which were then unknown. Using this table, the structure of the nucleus and the electron shells for an atom may be visualized. Also the atomic number and weight may be found.

1.2 Isotopes

Atoms of an element are composed primarily of electrons, protons, and neutrons. The protons and neutrons are particles having approximately the same mass, and they make up the nucleus of the atom. The electrons are arranged in shells about the nucleus and at a relatively long distance from the nucleus. The number of protons in the nucleus (the atomic number) equals the number of electrons in shells about the nucleus. This number determines the chemical properties of an element. The total number of protons and neutrons in the nucleus (the atomic weight) primarily determines physical properties of an element.

Thus, all atoms with one proton in the nucleus are hydrogen. All atoms with 8 protons are oxygen and all atoms with 27 protons are cobalt. If the number of protons in the nucleus of an atom is changed, the resulting atom will be a different element. The number of protons in atoms varies from one in hydrogen to 92 in uranium. Work since World War II has resulted in producing several new elements which have atoms with more than 92 protons.

The number of electrons in orbit about the nucleus of an atom ordinarily equals the number of protons in the nucleus of the atoms. By a process called ionization, the number of electrons may be changed but not the nucleus. It remains an atom of the same element as it was originally.

The number of neutrons in the nuclei of atoms ranges from zero for the hydrogen atom to 146 for uranium. In Figure 1.1 it may be seen that the nucleus of a hydrogen atom contains one proton and no neutrons. The next element, helium, has an atom containing 2 protons and 2 neutrons. Thus, it is said that hydrogen has an atomic weight of one and helium has an atomic weight of four. Is there anything with an atomic weight in between these?

Scientists found what was thought to be a sample of a pure element containing identical atoms. This was really a mixture of atoms with different atomic weights. The atoms had the same number of protons in their nuclei but had different numbers of neutrons. The atoms retained the same chemical properties while differing in atomic weight. These atoms of the same element having different numbers of neutrons were called isotopes of the element.

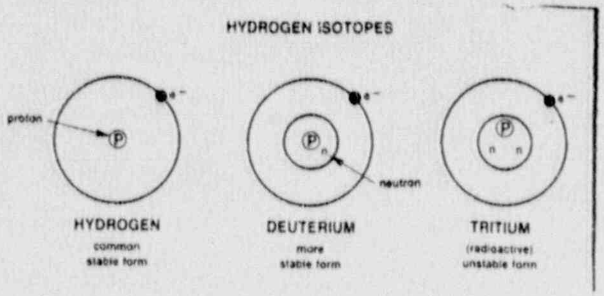


Figure 1.2 - Isotopes of Hydrogen.

Hydrogen was found to have two isotopes other than the ordinary hydrogen atom. By cooling hydrogen gas to a liquid and allowing it to evaporate, a concentration of heavier atoms remained. The nucleus of the "heavy" hydrogen (deuterium) atom contains a neutron as well as the usual proton. Heavy hydrogen atoms combine with oxygen to form "heavy" water. Only about one hydrogen atom in 6700 is a heavy atom. More recently a still heavier hydrogen atom (tritium) has been discovered.

The number of isotopes for each element varies. While hydrogen has three isotopes, tin has 25 isotopes. Uranium has several isotopes. One is called uranium-238. Its nucleus has 92 protons and 146 neutrons for a total of 238 particles. Another isotope, uranium-235, has 92 protons and 143 neutrons, or 235 particles. Both of these react chemically in the same way. In all, more than 1,500 isotopes have been found. About 900 of these isotopes are radioactive. This means they are unstable and they will change in some way to attain a stable condition.

Table 1.1--Periodic Table of Elements

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	INERT GASES
1 Hydrogen H 1.008																	2 Helium He 4.003
3 Lithium Li 6.94	4 Beryllium Be 9.01											5 Boron B 10.8	6 Carbon C 12.0	7 Nitrogen N 14.0	8 Oxygen O 16.0	9 Fluorine F 18.9	10 Neon Ne 20.1
11 Sodium Na 22.9	12 Magnesium Mg 24.3											13 Aluminum Al 26.9	14 Silicon Si 28.0	15 Phosphorus P 30.9	16 Sulfur S 32.0	17 Chlorine Cl 35.4	18 Argon A 39.9
19 Potassium K 39.1	20 Calcium Ca 40.1	21 Scandium Sc 44.9	22 Titanium Ti 47.9	23 Vanadium V 50.9	24 Chromium Cr 51.9	25 Manganese Mn 54.9	26 Iron Fe 55.8	27 Cobalt Co 58.9	28 Nickel Ni 58.7	29 Copper Cu 63.5	30 Zinc Zn 65.3	31 Gallium Ga 69.7	32 Germanium Ge 72.5	33 Arsenic As 74.9	34 Selenium Se 78.9	35 Bromine Br 79.9	36 Krypton Kr 83.8
37 Rubidium Rb 85.4	38 Strontium Sr 87.6	39 Yttrium Y 88.9	40 Zirconium Zr 91.2	41 Columbium Cb 92.9	42 Molybdenum Mo 95.9	43 Technetium Tc (99)	44 Ruthenium Ru 101.1	45 Rhodium Rh 102.9	46 Palladium Pd 106.4	47 Silver Ag 107.8	48 Cadmium Cd 112.4	49 Indium In 114.8	50 Tin Sn 118.6	51 Antimony Sb 121.7	52 Tellurium Te 127.6	53 Iodine I 126.9	54 Xenon Xe 131.3
55 Cesium Cs 132.9	56 Barium Ba 137.1	57 Lanthanum La 138.9	72 Hafnium Hf 178.4	73 Tantalum Ta 180.9	74 Tungsten W 183.8	75 Rhenium Re 186.2	76 Osmium Os 190.2	77 Iridium Ir 192.2	78 Platinum Pt 195.1	79 Gold Au 196.9	80 Mercury Hg 200.5	81 Thallium Tl 204.3	82 Lead Pb 207.1	83 Bismuth Bi 208.9	84 Polonium Po 210	85 Astatine At (211)	86 Radon Rn 222
87 Francium Fr (223)	88 Radium Ra 226	89 Actinium Ac 227															

Lanthanum Series	58 Cerium Ce 140.1	59 Praseodymium Pr 140.9	60 Neodymium Nd 144.2	61 Promethium Pm (145)	62 Samarium Sm 150.3	63 Europium Eu 151.9	64 Gadolinium Gd 157.2	65 Terbium Tb 158.9	66 Dysprosium Dy 162.5	67 Holmium Ho 164.9	68 Erbium Er 167.2	69 Thulium Tm 168.9	70 Ytterbium Yb 173.0	71 Lutetium Lu 174.9
Actinium Series	90 Thorium Th 232	91 Protactinium Pa 231	92 Uranium U 238	93 Neptunium Np (237)	94 Plutonium Pu (242)	95 Americium Am (243)	96 Curium Cm (245)	97 Berkelium Bk (249)	98 Californium Cf (249)	99 Einsteinium Es (254)	100 Fermium Fm (252)	101 Mendelevium Md (256)	102 Nobelium No (253)	103 Lawrencium Lw (257)

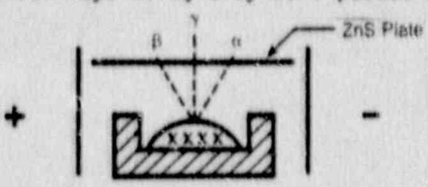
CHAPTER 2

RADIATION

2.1 Radioactivity

In 1895, Roentgen discovered emissions from the anode target of a Geissler tube that passed through glass and caused a zinc sulphide screen to fluoresce. He called the emissions X-rays. Becquerel, in 1896, found that minerals containing uranium gave off radiation which could pass through ordinary materials and fog photographic plates. The Curies found that pitchblend (uranium ore) gave off rays more penetrating than those from uranium alone and subsequent refining of the ore produced radium.

In order to discover what these rays were, they were passed between electrically charged plates as shown and



the beam splits into three beams. One attracted to the (+) plate, one to the (-) plate and one is not affected. The three "particles" are called alpha (α), beta (β) and gamma (γ) rays. Subsequent analysis showed that:

1. the alpha ray is a helium nucleus with an electrical charge of +2,
2. the beta ray is an electron with an electrical charge ±1, and
3. the gamma ray has zero charge and the characteristics of x-rays.

The high energies of α, β and γ rays is evidence that large amounts of energy reside in the atomic nucleus.

2.2 Kinds of Radiation

It should be clear now that there are two main types of radiation. One type is composed of tiny particles which move through space and is called "particulate" radiation. The other type consists of very short waves called "electromagnetic" radiation. Both of these kinds of radiation may be given off by radioactive atoms. Radioactivity refers to the disintegration of unstable nuclei of atoms. Both kinds of radiation convey energy through space.

Particulate radiation is the movement of tiny subatomic particles through space. The particles have mass (or weight) and, in most cases, an electrical charge. They transfer energy from one point to another. These particles traveling at a very high speed may strike and be deflected by other particles such as orbital electrons or nuclei of atoms, or they may be stopped and captured by nuclei. As these particles change speed, they change in energy. When they are slowed or stopped, they release energy. When particles carry an electrical charge, electrical or magnetic forces affect their motion. When these fast moving particles transfer energy to atoms, they may cause heat and light to be given off and they may cause ionization to take place. The particulate radiation of concern to isotope applications includes alpha and beta particles and neutrons.

Electromagnetic radiation consists of very short electromagnetic waves of energy having no mass or weight. The radiation moves with the speed of light (186,000 miles per second). Actually, electromagnetic radiation has been described as small packages of energy called photons or quanta. In this respect, such radiation has some properties of particles. However, electromagnetic radiation has a characteristic wave motion and wavelength, and its frequency can be determined. Frequency is measured in number of waves per second and wavelength is the distance between similar points on the waves. For all electromagnetic radiation, the product of frequency and wavelength is constant. This constant is the speed of light. Also, the energy possessed by the photons or quanta depends on the frequency or wavelength of the radiation. High frequency radiation has high energy, while low frequency radiation has low energy. Thus gamma radiation, which has very high energy (high frequency or short wavelength), penetrates matter much farther than does lower frequency ultraviolet radiation. The kinds of electromagnetic radiation of concern to us include X- and gamma radiation.

Electrical charges and energy levels are given in descriptions of radiation. An electron is said to have a unit negative electrical charge (This has been measured to be 4.80×10^{-10} electrostatic units.) A proton has a unit positive charge. The energy of radiation is expressed in ev's (electron volts). This is the energy (equivalent to 1.6 X 10 erg) acquired by a particle carrying a unit charge when it falls through a difference in potential of one volt.

Alpha radiation consists of relatively heavy particles, which are identical with helium nuclei. When an alpha particle slows down in its passage through matter, it acquires two free electrons and becomes an atom of helium. An alpha particle has an atomic weight of 4.00277 and carries two unit positive electrical charges. Alpha particles are emitted from radioactive materials at speeds of 2,000 to 20,000 miles per second. Because of their size and relatively low speeds, they travel only a few centimeters in air and may be stopped by a sheet of paper. These particles are emitted with an energy ranging from 4 to 10 million electron volts (Mev).

Beta radiation consists of high speed electrons. They carry one unit negative charge and have a mass about 1/1,840, that of a proton. They are emitted at very high velocities approaching the speed of light. They have a range of several feet in air but may be stopped by a thin sheet of aluminum or a few sheets of paper. The energy of beta particles ranges up to 3.15 Mev, with most particles having about 1 Mev.

Gamma radiation consists of very short electromagnetic waves having no mass or weight. It has very short wavelengths of about 10 centimeters and extremely high frequencies and high energy. The radiation travels at the speed of light. These rays are highly penetrating and may be detected after passing through several inches of steel. The energy of gammas rays is measured in Mev. Gamma rays emitted by natural radioactive elements have energies from about 0.04 to 3.2 Mev.

X-rays and gamma rays are similar in that both are electromagnetic radiation. However, they differ in their origin. When the nucleus of a radioactive atom emits an alpha or beta particle, the daughter nucleus frequently is left in a high energy or excited state and the excess energy is emitted as gamma radiation to bring the nucleus to a more stable condition. Thus, gamma radiation originates in the nucleus of an atom.

X-rays, on the other hand, are produced when any stream of fast-moving (high-energy) electrons is slowed down upon striking a suitable target. Electron transitions between orbital shells give rise to the photons or quanta of energy called characteristic X-rays.

The neutron is another type of particle which accompanies certain types of nuclear reactions. It is not found in natural radioactive decay, however. The neutron particle has about the same mass as a proton but is neutral so far as electrical charge is concerned. It was found that when alpha particles bombarded light elements such as beryllium and lithium, they emitted neutrons. Because neutrons have no electrical charge, they make good "bullets" to bombard the nuclei of elements. The positively charged nuclei do not repel the neutron as they do other particles. Neutrons play an important role in nuclear fission, since the capture of a neutron by nuclei of atoms of certain elements causes the nuclei to split apart and form atoms of different elements.

A number of particles and radiation have been identified. A list of the properties of some particles and radiation is presented in Table 2.1.

2.3 Properties of Radiation

X-rays and gamma rays are similar in that they are both electromagnetic radiation but they differ in origin. X-rays are produced when high energy electrons are accelerated when striking a target. Electron transitions between inner orbits produce photons or quanta of energy called characteristic X-rays.

Gamma rays on the other hand are produced by nuclear processes. When a nucleus emits a beta or alpha particle, the daughter nucleus is frequently left in an excited state and the excess energy is emitted as gamma radiation to bring the nucleus to a more stable state.

The neutron is the product of certain types of nuclear reactions; however, it is not found in natural radioactive decay. Since they have no charge, they do not react electromagnetically with electrons or protons. They play an important role in nuclear fission and they are of great importance in the generation of radioisotopes from stable isotopes.

Radiation	Kind	Mass	Charge	Description	Energy	Range in Air
Alpha	Particle	4	+2	Helium Nucleus	3-10 MEV	5 cm
Beta	Particle	a/1840	°1	Electron	0-3.2 MEV	Several Feet
Gamma	Wave	0	0	Electro-Magnetic Wave	0.04-3.2 MEV	Indefinite
Neutron	Particle	1	0	Uncharged Particle	.025 ev and up	

Table 2.1 The Properties of Nuclear Radition

2.4 The Electromagnetic Spectrum

The speed of light, radio waves, and other electromagnetic radiation in empty space is approximately 186,300 miles per second (3×10^{10} centimeters per second). There are electromagnetic radiations with wave lengths both longer and shorter than light. At one extreme of the spectrum are long radiowaves with wave lengths of hundred of meters (low energy) and at the other extreme are gamma and X-rays with wave lengths shorter than 10^{-} centimeters.

The electromagnetic spectrum is a continuous spectrum with no sharp division between "kinds" of electromagnetic radiation. In fact, ultra violet, X-rays, and gammas rays which are determined by origin may overlap in the spectrum. See Figure 2.2.

46/306

Figure 2.3 shows the relation between frequency, wave length and speed.

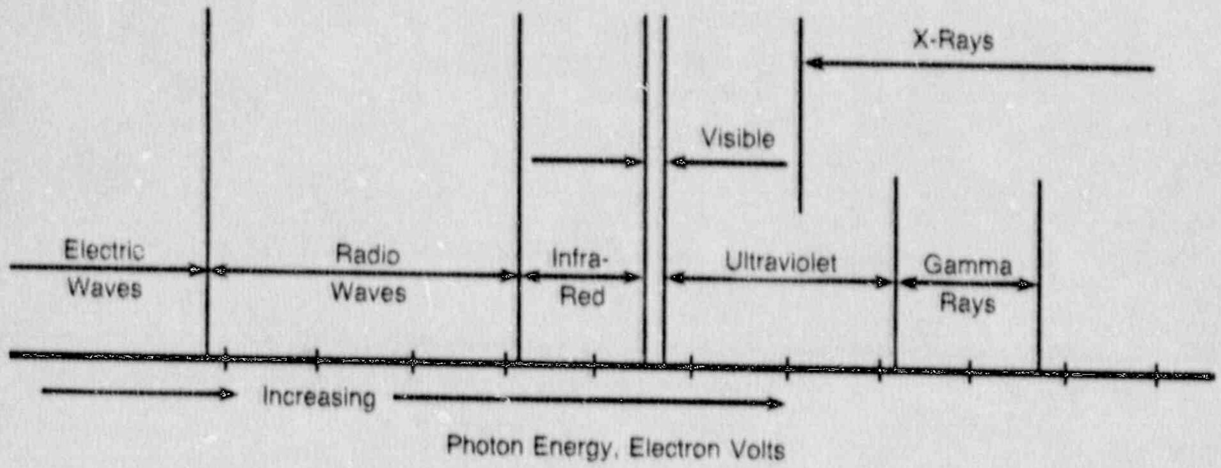


Figure 2.2 - The Electromagnetic Spectrum.

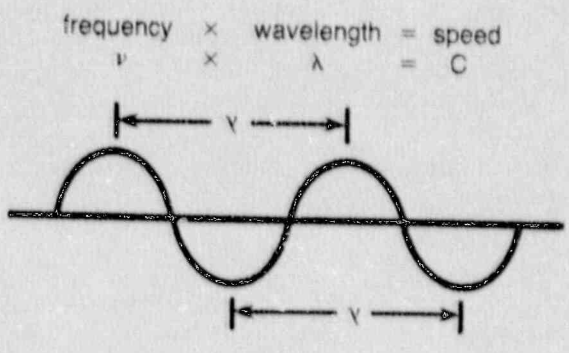


Figure 2.3 - Wave Motion and Wavelength (λ).

CHAPTER 3
NUCLEAR REACTIONS

3.1 Nuclear Reactions

Changes in the physical properties of the nucleus in concert with other particles or by a spontaneous isolated change is termed a nuclear reaction. An example is given for the spontaneous alpha decay of a U nucleus.

$$_{92}U^{238} \rightarrow {_2He^4} + {_{90}Th^{234}} + \text{ENERGY} \quad (1)$$

Some radioisotopes decay in one reaction to a stable state while others may involve a number of steps to reach a stable state. The resulting isotopes are called daughter products. Figure 3.1 follows the decay chain whereby U goes through a series of disintegrations to reach the stable daughter product Pb (lead).

Symbolic reactions are given for alpha and beta decay as well as the decay of a neutron.

$$_ZX^A \rightarrow {_2He^4} + {_{(z-2)}Y^{(A-4)}} + \text{ENERGY} \quad (2)$$

$$_ZQ^A \rightarrow {_{-1}e^0} + {_{(z+1)}R^A} + \text{ENERGY} \quad (3)$$

$$_0n \rightarrow {_1H^1} + {^-e} + (\text{neutrino} + \text{ENERGY}) \quad (4)$$

The reaction (4) is the mechanism of beta decay where a neutron changes itself into a proton. It is also the reaction which has taken place in (3) where a neutron in Q changes to a proton resulting in a different chemical element. It is possible that a positive beta (positron) may be emitted in some cases in which case the parent (Z) changes to a daughter (Z-1).

The number of portons plus the number of neutrons must be the same before and after, as must be the total charge before and after, the reaction. Look at Eg. (1) where the subscripts and superscripts are respectively.

	before		after
Subscripts	92	⟶	2 + 90 = 92
Superscripts	238	⟶	4 + 234 = 238

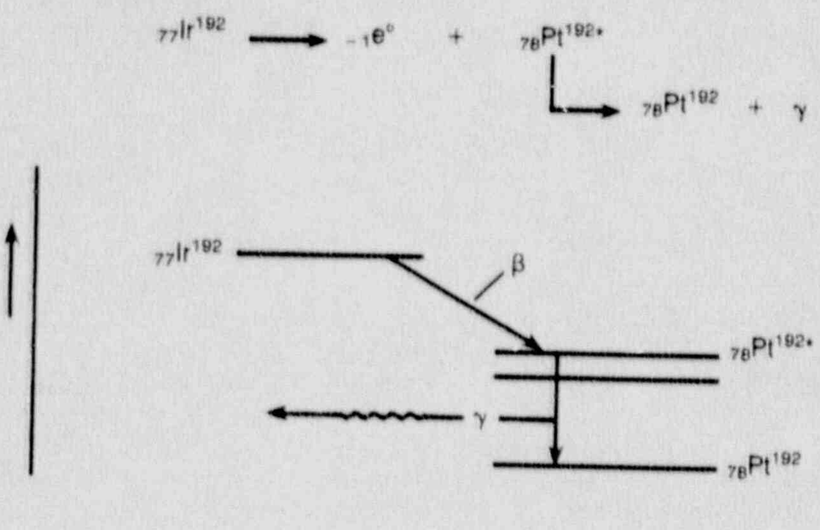
For equation 3 in symbolic form:

Subscripts	Z	⟶	Z + 1 - 1 = Z
Superscripts	A	⟶	0 + A = A

The activation reaction makes it possible to change stable isotopes into radioisotopes through neutron absorption in nuclear reactors. This process and the nuclear reactor, which provides the neutrons, have given us virtually all the radioisotopes so important to nuclear medicine and our tracer work. The reaction is given below for Iridium and takes place in a nuclear reactor.

$$ {}_0n^1 + {}_{77}Ir^{191} \rightarrow {}_{77}Ir^{192} \qquad (5) $$

Iridium 192 (${}_{77}Ir^{192}$) decays at a rate such that in about 74 days half of the original amount will decay. Each radioisotope has a characteristic decay time called the half life.



3.2 Activity and the Curie

The activity of an isotope is the number of disintegrations a given amount of an isotope undergoes in a given length of time. The unit of activity is the curie. By definition the curie is 3.7 X 10 disintegrations per second. (Historically this is about the activity of Radium 226 which was isolated by the Curies.)

3.7 X 10 d/Sec	= 1 curie
3.7 X 10 d/Sec	= 10^{-3} curie = 1 millicurie
3.7 X 10 d/Sec	= 10^{-6} curie = 1 microcurie

3.3 Radioactive Decay

Radioisotopes are in an excited state (contain excess nuclear energy). The excess energy is usually emitted as or particles or gamma rays. Naturally occurring radioisotopes at the high atomic weight part of the periodic table fall into three distinct series. The uranium, thorium and actinium nuclei each follow a distinct series of disintegrations which produce as an end result three different stable daughter isotopes of lead (Pb). The uranium series is shown in Figure 3.1

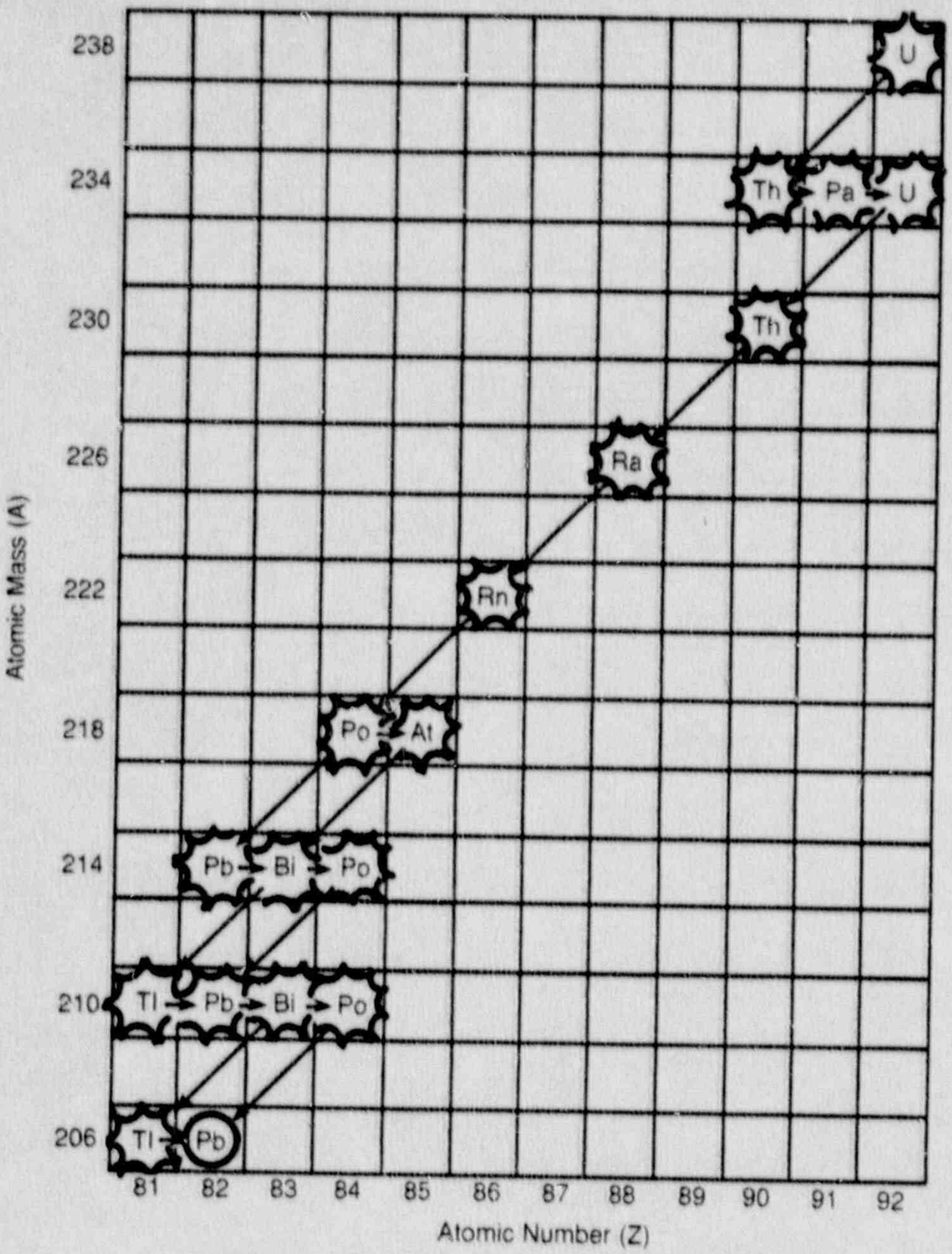


Figure 3.1
Uranium-238 decays to lead-206 through a series of alpha and beta decays.

It is found experimentally that the number of nuclei of a radioisotope which decay in a unit time is proportional to the total number of nuclei present at that time. Since the number of nuclei of the particular radioisotope changes continuously, the rate of decay is changing. The calculus develops the following equation for random processes which describes the decay:

N = Noe (1)

where No = Number of nuclei present at t=0

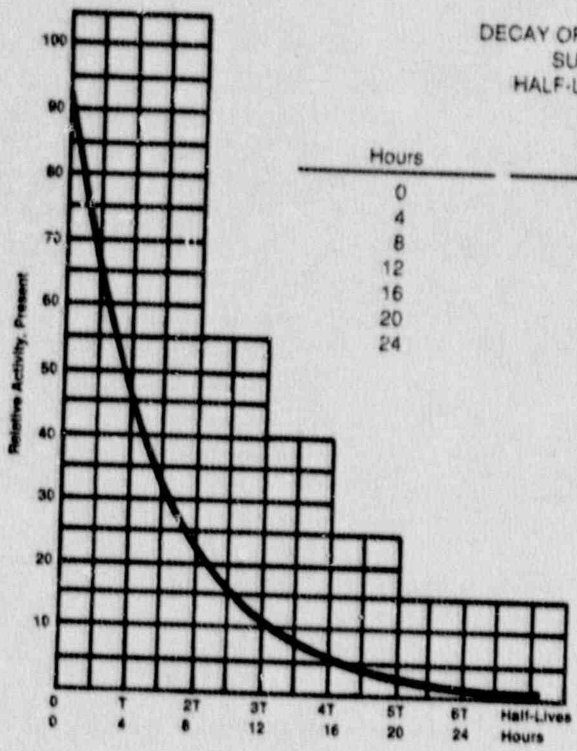
e = base of natural logarithms (2.718...)

= decay constant of the radioisotope

t = time since t = 0

N = number of nuclei remaining after time "t"

Figure 3.2 is a graph of equation (1).



DECAY OF A RADIOACTIVE SUBSTANCE
HALF-LIFE 4 HOURS

Hours	Half-Lives	Relative Activity,%
0	0	100
4	1	50
8	2	25
12	3	12.5
16	4	6.25
20	5	3.125
24	6	1.562

Figure 3.2 - Decay of Radioisotopes.

The decay constant is related to the half life of the radioisotope.

$$\text{half life} = \underline{0.693} \qquad (2)$$

There are no environmental factors such as temperature, pressure, state of the matter, etc. which we can exert to change and thus the half li·· ($t_{1/2}$).

After about six half lives ($6t_{1/2}$) the fraction of radioactive nuclei left is less than 2%.

An alternate formulation gives for the fraction remaining:

$$N/No = (1/2)^n \qquad (3)$$

Where n is the number of half lives. For n = 6 this gives
$N/No = (1/2)^6 = 1/2 \times 1/2 \times 1/2 \times 1/2 \times 1/2 \times 1/2 = 1/64$

Half-life values for commonly used isotopes

I131 = 8 days
Ir192 = 74 days
Sc46 = 85 days

Tables to provide for ½ life correction are included in Charts 1, 2, 3 and 4. To use; determine number of days since time 0 and read off the fraction of residual activity remaining.

SCANDIUM 46

Half-life - 85 days
Radiations:
Beta - 0.36
Gamma - 1.12, .88

	DAYS				
	0	10	20	30	40
0	-	.92	.85	.78	.72
50	.66	.61	.56	.52	.48
100	.44	.41	.38	.35	.32
150	.29	.27	.25	.23	.21
200	.20	.18	.17	.15	.14
250	.13	.12	.11	.10	.094
300	.087	.080	.074	.068	.063
350	.058	.053	.049	.045	.042
400	.038	.035	.033	.030	.028
450	.025	.023	.022	.020	.018
500	.017	.016	.0145	.014	.012
550	.011	.011	.010		

IODINE 131

Half-life - 8.14 days

Radiations:

Beta - 0.608 *87%), 0.335 (9%), 0.250 (3%)

Gamma - 0.638 (8%), 0.364 (80%),
0.284 (7%), 0.080 (4%)

	DAYS				
	0	1	2	3	4
0	-	.92	.84	.77	.71
5	.65	.60	.55	.51	.46
10	.43	.39	.36	.33	.30
15	.28	.?6	.24	.22	.20
20	.18	.17	.15	.14	.13
25	.12	.11	.10	.092	.085
30	.078	.071	.066	.060	.055
35	.051	.047	.043	.039	.036
40	.033	.030	.028	.026	.024
45	.022	.020	.018	.017	.015
50	.014	.013	.012	.011	.010

IRIDIUM - 192
Half-life - 74 days
Radiations:
Beta - 0.67
Gamma - 0.605, 0.588, 0.485, 0.468, 0.316
0.308, 0.296, 0.206, 0.201

DAYS

	0	5	10	15	20
0	-	.95	.91	.87	.83
25	.79	.75	.72	.69	.66
50	.63	.60	.57	.54	.52
75	.50	.47	.45	.43	.41
100	.39	.37	.36	.34	.32
125	.31	.30	.28	.27	.26
150	.25	.23	.22	.21	.20
175	.19	.19	.18	.17	.16
200	.15	.15	.14	.13	.13
225	.12	.12	.11	.11	.10
250	.096	.091	.087	.083	.079
275	.076	.072	.069	.066	.063
300	.060	.057	.055	.052	.050
325	.048	.046	.044	.042	.040
350	.038	.036	.035	.033	.031
375	.030	.029	.028	.026	.025
400	.024	.023	.022	.021	.020
425	.019	.018	.017	.016	.016
450	.015	.015	.014	.013	.013
475	.012	.011	.011	.010	.010

CHAPTER 4
INTERACTION OF RADIATION WITH MATTER

4.1 Ionization and Ions

Atoms, molecules, and various subatomic particles which carry either a positive or negative electrical charge are called ions. Free electrons, not attached to any parent atom, are called negative ions. Other particles having negative electrical charges are also negative ions. The alpha particle, a helium nucleus, carries two positive charges and so is referred to as a positive ion.

Any action which distrubs the electrical balance of the atoms which make up matter is referred to as ionization. Radiation, either particles or electromagnetic, has the ability to ionize. A highspeed particle or a photon of energy which passes through matter will disrupt the atomic arrangement of the matter. For example, an alpha particle may strike an orbital electron in an atom and cause the electron to leave its orbit. The electron may attauh itself to an atom. The first atom then has a positive charge and the latter atom a negative charge, and these are referred to as positive and negative ions. Also they may be called an ion pair.

The charge on a particle moving through matter also affects ionization. Thus the moving matter also affects ionization. Thus the moving particles may attract or repel an orbital electron. Dislodged electrons may, themselves, cause other electrons to be driven from their orbits in what is called secondary ionization. This may continue, in fact, until the energy of the dislodged electron is below that necessary to drive other electrons from their orbits.

The ionization process described here is the principal reason behind the various biological effects of radiation. The ionization of atoms which make up the cells of the body have very serious effects on these cells and body tissue. These are described in more detail later.

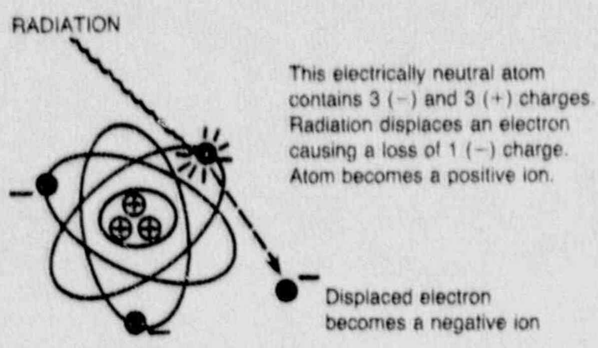


Figure 4.1 - Ionization

4.2 Ionization by Particles

In ionization by a particle there is an energy transfer from the particle to the orbital electrons of atoms. In this process the moving particle is slowed down. When the energy of the particle falls below that needed to ionize (dislodge orbital electrons), the particle still may impart some energy to, or excite, electrons. The speed, mass, and charge of a particle all affect the transfer of energy to an electron. In turn the amount of energy received by the electron determines the amount of secondary ionization caused by the electron.

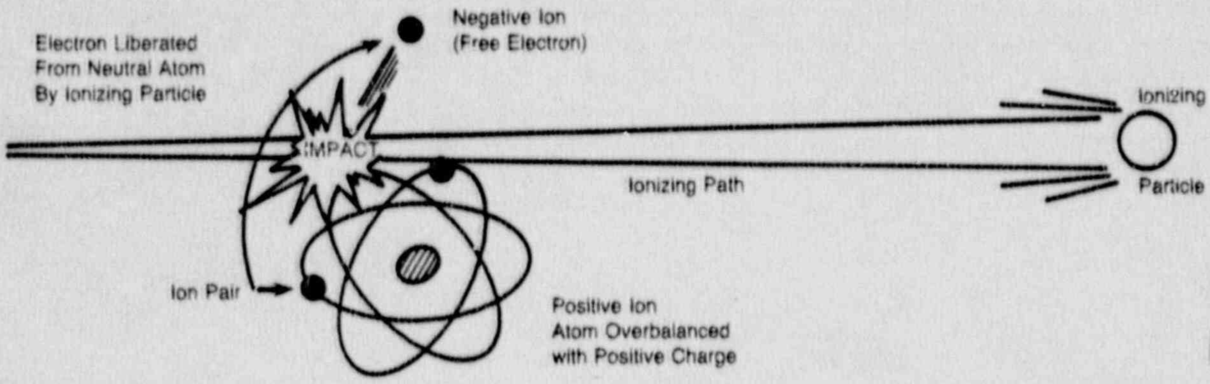


Figure 4.2 - Ionization by Particle Radiation

The number of ion pairs produced per centimeter along a particle's track is called the specific ionization of the particle. This is generally stated as the number of ion pairs produced per centimeter of track in air. Differences in speed, mass, and charge greatly affect the specific ionization of particles. The total number of ion pairs produced by a particle, regardless of length of track, is called total ionization.

Alpha particles travel only about two inches in air and may be completely stopped by a sheet of paper. Thus high-energy alpha particles lose their energy rapidly. This means that they have a high specific ionization which ranges from 20,000 to 80,000 ion pairs per centimeter of air traveled. Alpha particles have energies ranging from about 4.0 to 10.6 million electron volts (Mev). The alpha particle is relatively large and slow moving. These factors cause it to have a high ionizing effect. Also, its positive charge causes it to dislodge nearby electrons due to coulombic attraction when there is no direct collision.

A beta particle travels much farther in matter than an alpha particle of the same energy. This is true because the beta particle is very small, moves at a very high rate of speed, and has less electrical charge than the alpha particle. Being light in weight, the beta particle is easily deflected so that distance from point of origin is not a good measure of distance traveled. Beta particles have a low specific ionization of 50 to 500 ion pairs per centimeter of air, they may travel several meters in air. Beta particles may have speeds up to 99 percent of the speed of light. Beta particles have energies ranging from 0.025 to 3.15 Mev. Both the speed and the range of the beta particle are proportional to its energy.

The neutron has no charge and does not ionize directly. A neutron passing matter has a negligible effect upon orbital electrons in atoms of the matter. However, the neutron may strike the nucleus of an atom and cause reactions which will ionize. The

46/306

nucleus may absorb the neutron and then emit particles which cause ionization. It may fission and the resulting fragments may emit ionizing particles, or the nucleus which is a charged particle itself may recoil and produce some ionization.

4.3 Ionization by Electromagnetic Radiation

Gamma and X-rays are not particles and have no mass or weight. Therefore they do not produce ionization directly by collision as do alpha and beta particles. Since these rays or photons of energy travel at the speed of light, they do not lose their energy as readily as do the particles. Gamma and X-rays lose their energy at atoms by three processes known as photo-electrical absorption, Compton scattering, and pair production. When an atom absorbs energy by one of these three processes, it emits an electron. The emitted electron then may produce ionization in a manner similar to that of other ionizing particles. (Figure 4.3)

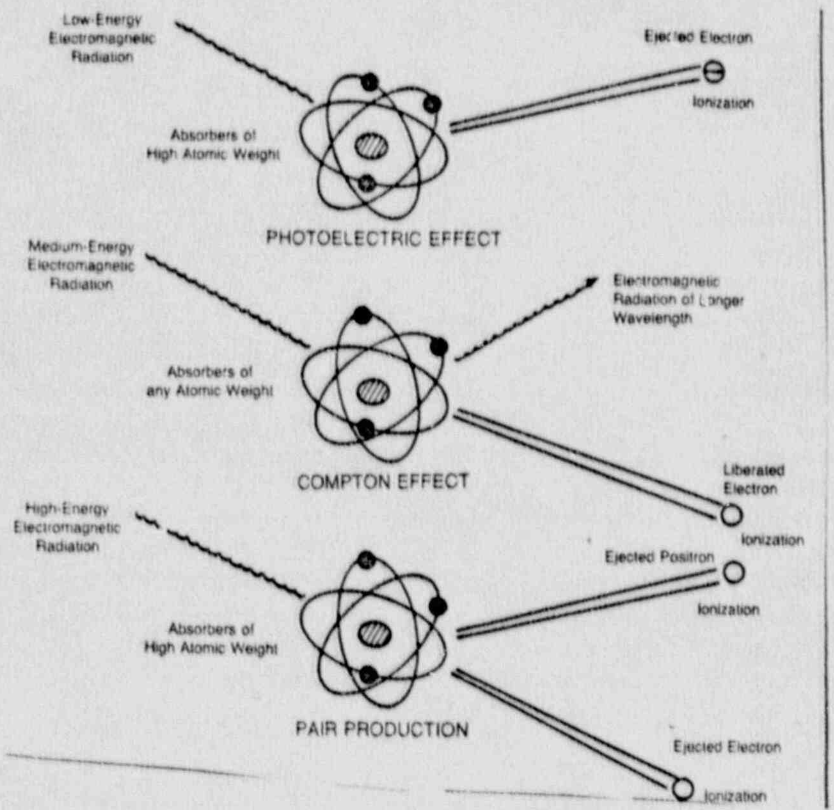


Figure 4.3 - Ionization by Electromagnetic Radiation.

Gamma and X-rays are very penetrating. It is not practical to measure the penetration of these rays in feet or meters. Instead, it is measured by the thickness of materials needed to reduce the rays to half their original intensity. The process by which the direction of incident radiation is changed is called scattering. This may occur in several ways and scattering is of prime concern.

4.3.1 Photoelectrical Absorption

When gamma or X-ray photons of low energy penetrate matter, the photon energy may be transferred to an orbital electron. Some energy will dislodge the electron from its orbit and the remainder will give the electron kinetic energy or a velocity. These are

TABLE 4.1 - Dose Rate of Commonly Used Radioisotopes

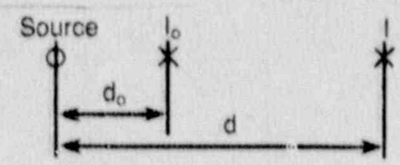
	R/hr/mCi at 1 Cm	mr/hr/mCi at 1 ft.
I 131	2.2	2.4
Ir 192	4.8	5.16
Co 60	13.2	14.2
Sc 46	10.9	11.7
Zr 95	4.1	4.4
Nb 95	4.2	4.5
Cs 137	3.3	3.55
Br 82	14.6	15.7
Au 198	2.3	2.48
La 140	11.3	12.2
Ag 110m	14.3	15.4
Na 24	18.3	19.8
Fe 59	6.4	6.9

Charts 7, 8, and 9, at the end of this chapter indicate radiation levels of various commonly used isotopes at one foot, three foot and hand exposure when handling the isotope container.

4.5 Radiation Attenuation

When a source of radiation is confined to that it may be considered a point source, the intensity of radiation is inversely proportional to the square of the distance from the source. The so-called "Inverse Square Law" is a follows:

$$\frac{I}{I_o} = \left(\frac{d_o}{d}\right)^2$$

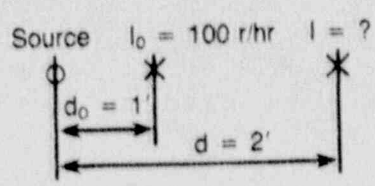


where: I = Radiation intensity at distance d
I_o = Initial radiation intensity at distance d
d = Initial distance from source
d_o = Distance at which intensity is I_o

It is possible to calculate the dosage rate at any point where emission constants are known.

Example: Suppose the emission of a source of radiation is 100 roentgens per hour at 1 foot. What is the dose rate at 2 Feet? At 4 feet?

If
I_o = 100 r/hr
d_o = 1 ft.
d = 2 ft.



Then: $I/_{100} = (1/2)^2$ or, $I = 100 \times (1/2)^2 = 100 \times 1/4 = 25$ r/hr

If I_o = 100 r/hr
d_o = 1 ft.
d = 4 ft.

Then: $I/_{100} = (1/4)^2$ or, $I = 100 \times (1/4)^2 = 100 \times 1/16 = 6.25$ r/hr.

called photoelectrons, and the transfer of energy is called the photoelectric process. Only about 30 to 50 electron volts are needed to dislodge an electron so the remainder of the energy of the photon give the electron a high velocity. The moving electron then loses its energy producing ion pairs through ionization as previously described. The photoelectric effect usually occurs with low energy gamma or X-photons of 0.1 Mev or less.

4.3.2 Compton Scattering

When photon has energy of 0.1 to 1.0 Mev Compton scattering occurs. The photon does not lose all its energy to an orbital electron, part of the energy is transferred to an electron emitted at an angle to the path of the original photon and a lower energy photon is scattered at an angle to the original photon path. This may be repeated until the original photon is completely absorbed by the previously described photoelectric effect.

4.3.3 Pair Production

Photons of 1.02 Mev or more cause ionization by a method called pair production. In this process a high energy photon approaches the nucleus of an atom and converts from energy into an electron-positron pair. A positron has the same mass as an electron but carries a positive charge. By Einstein's famous equation, $E = mc^2$, it has been found that the mass of one electron is equivalent to 0.51 Mev of energy. This explains the need for photons of 1.02 Mev to form the electron positron pair. Energy above 1.02 Mev causes the pair of particles to have kinetic energy or speed. The electron may then cause ionization. The positron may cause ionization, but has an extremely short life. It combines with an electron and disappears with the emission of two gamma photons of 0.51 Mev each. These will act as other low energy gamma photons and may cause ionization by the photoelectric effect or by Compton scattering.

4.4 The Roentgen

An amount of radiation is not measured directly. Rather, the amount of ionization produced by passage of the radiation through some medium is used to measure radiation. The roentgen (r) is a measure of ionization in air due to passage of gamma or X-radiation. One roentgen, or one r is that quantity of gamma or X-radiation that will produce 2.083×10^9 ion pairs per cubic centimeter of air at standard temperature and pressure (0°C and 760 mm mercury). This is equivalent to 1.61×10^{12} ion pairs per gram of air and also is equal to one electrostatic unit (esu) of charge. In standard measures of energy one roentgen equals 83 ergs.

The roentgen is a rather large amount of radiation. Therefore a subunit is used for convenience in measuring small amounts of radiation. This is the milliroentgen (mr), or one thousandth of a roentgen. Thus one roentgen equals 1000 milliroentgens.

The roentgen measures a definite amount of gamma or X-radiation in terms of their ionizing effect on air. Dosimeters measure a dose or number of roentgens or milliroentgens. Also useful is a dose rate concept. Ionizing rates are expressed in terms of roentgens per hour (r/hr) or milliroentgens per hour (mr/hr). Emission or dosage rate constants are useful to the operator when expressed as roentgens per hour per curie at a unit distance from the source (See Table 4.1). This term is called emissivity and has units-r/hr/ci @ 1 ft. or mr/hr/mci @ 1 ft.

Example: A 10-curie source of Co-60 is to be used at 10 feet from a group of workmen. What dose rate will they receive? What dose would they receive in 8 hours?

Note that the dosage rate for Co-60 is 14.2 r/hr/c at 1 ft.

If $I_0 = 10 \times 14.2 = 14.2$ r/hr
$d_0 = 1$ ft.
$d = 10$ ft.

Then: $\frac{1}{144} = (\frac{1}{10})^2 = 1 = \times(\frac{1}{10})^2 = 144 \times \frac{1}{100} =$

1.44 r/hr or
1440 mr/hr

In 8 hours the men would receive 8 X 1440 mr/hr = 11,520 mr

Occasionally a known dosage rate is given and the distance from the source must be calculated.

Example: In the above example at what distance would the group of men receive only 2 mr/hr?

If = 2 mr/hr
= 144 r/hr = 144,000 mr/hr
= 1 ft.

Then find the distance d in the equation:

$$\frac{I}{I_0} = \left(\frac{d_0}{d}\right)^2$$

$$\frac{2}{144{,}000} = \frac{1}{d^2}$$

$2d^2 = 144{,}000$
$d_2 = 72{,}000$
$d = \sqrt{72{,}000} = 268$ ft.

The variation in the intensity with distance from source may be plotted (Figure 4.4).

Example: Suppose a radioisotope source has an emission of 6 mr/hr/mc at 1 foot. If an 800 mc source is used, determine the dosage rates 2 ft., 3 ft., 4 ft., 5 ft.

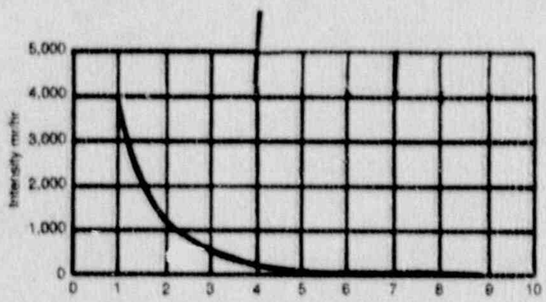
$$\frac{I}{I_o} = \left(\frac{d_o}{d}\right)^2 \text{ or } I = I_o \times \left(\frac{d_o}{d}\right)^2$$

$$I = 6 \times 800 \times (1/2)^2 = 4800 \times 1/4$$

$$= 1200 \text{ mr/hr (Figure 4.4)}$$

Results of Calculations

Distance From Source Feet	Intensity mr/hr
1	4,800
2	1,200
3	533
4	300
5	192



Distance from Source, feet

Figure 4.4 - Variation of Radiation Intensity with Distance from Source

Chart 5 can be used to determine the dose rate at distances from one inch to twenty feet, when the dose rate at one foot is known.

4.6 Absorption of Radiation

Alpha rays are completely stopped by a few centimeters of air or a sheet of two paper. Beta rays are stopped by a few meters of air or a few millimeters of lead. Gamma rays, however, can penetrate the most dense materials.

Gamma rays are diminished in number by any given absorber, but are not wholly stopped. If the number of monoenergetic gamma photons traversing an absorber is plotted against the thickness of the absorber, an exponential curve results. The intensity of the gamma rays after passing through an absorber may be calculated by the formula:

$$I = I_0 e^{-\mu t}$$

where

I_0 = initial intensity of gamma rays
e = base of natural logarithms
μ = linear absorption coefficient of absorber for given gamma rays
t = thickness of absorber in centimeters

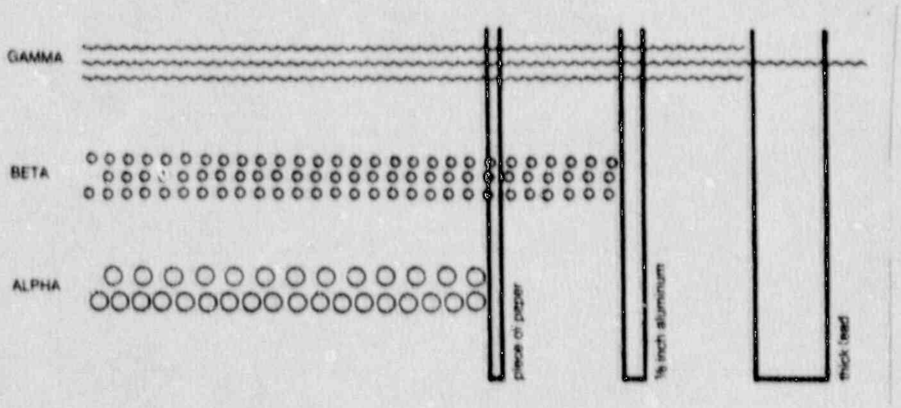


Figure 4.5 - Absorption of Radiation

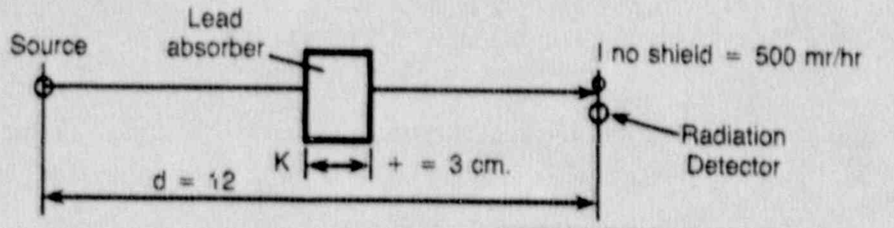
Absorption Coefficients per cm

E (Mev)	Pb	Fe	Al	H_2O
0.2	5.0	1.06	0.33	0.14
0.6	1.7	0.63	0.23	0.090
1.0	0.77	0.44	0.16	0.067
1.5	0.57	0.40	0.14	0.057
2.0	0.51	0.33	0.12	0.048
2.5	0.48	0.31	0.10	0.042
3.0	0.47	0.30	0.090	0.033
4.0	0.48	0.27	0.082	0.033
5.0	0.48	0.24	0.074	0.030

Table 4.2 - Linear Absorption Coefficients.

Example: An unshielded point source emitting 1 Mev gamma rays produces an emission of 500 mr/hr at 1 ft. What will be the dosage rate if there are interposed lead shields 1 cm. thick, 2 cm. thick, 3, 4, 5, and 10 cm. thick?

To compute intensity of radiation for the 3 cm. thickness of lead shielding, note that the linear absorption coefficient for lead at 1 Mev is 0.77 (Table 4.2).



$I_o = I_o e^{-\mu x}$

$= 500\ e^{-.77 \times 3}$

$= 500\ e^{-2.31}$

= 49.5 mr/hr at 1 ft.

Results from calculations of radiation intensity passing through other thicknesses of lead are tabulated on Figure 4.6.

Results of Calculations

Lead Shield Thickness Centimeters	Intensity mr hr
1	225
2	107.2
3	49.5
4	23
5	10.6
10	0.227

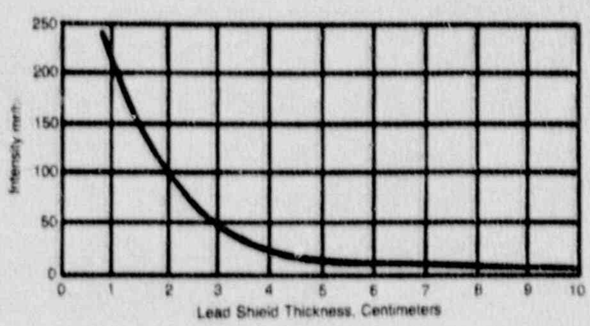


Figure 4.6 - Variation of Radiation Intensity with Lead Shielding; Cartesian Coordinates.

When the same data are plotted on semi-log paper, note that the exponential curve become a straight line. One advantage of using semi-log paper to plot such data is that only two points are needed to determine the straight line. (Figure 4.7)

4.7 Half-value Layers

There is little use in trying to compute the amount of shielding necessary to stop gamma or X-radiation, since a point is never reached when all such radiation is stopped. A convenient measure is that amount of shielding when will stop half of the radiation of a given intensity. This measure is called the half-value layer. The half-value layer of an absorber is related to the linear absorption coefficient by the following equation:

$$HVL = \frac{0.693}{\mu}$$

where

HVL= half-value layer (centimeters)
μ = linear absorption coefficient (in reciprocal centimeters)

Example: Suppose there is a 1.0 Mev source of gamma radiation. The linear absorption coefficient of lead for 1.0 Mev radiation is 0.77. What is the half-value layer of lead?

$$HVL = \frac{0.693}{0.77} = 0.90 \text{ cm}$$

Therefore, nine-tenths of a centimeter of lead will reduce gamma radiation of 1.0 Mev energy to one-half its intensity.

Example: A 10-curie source of Co-60 is to be used at 10 feet from a group of workmen. How much lead shielding would be needed to reduce the dose rate to 2 mr/hr? (Figure 4.8)

Source	Lead ½	Iron ½	Concrete (147 lbs. cu. ft.) ½
I-131	0.15	0.25	0.7
Co-60	0.49	0.87	2.7
Ra-226	0.56	0.91	2.9
Cs-137	0.25	0.68	2.1
Ir-192	0.19	0.52	1.9
Sc-46	0.35	0.62	2.3

*The thicknesses for half-value layers provide shielding protection from the scattered radiation resulting from deflection of the primary gamma rays within the shield as well as protection for primary radiation from the sources.

Figure 4.8 - Half-value Layers

Since the energy of emission of Co-60 is approximately 1 Mev, the half-value thickness of lead would be .90 centimeters. From a previous example it was found that the dosage rate for the workmen was 1440 mr/hr.

1 HVL reduces 1440 mr/hr to 720 mr/hr
2 HVL reduce 1440 mr/hr to 360 mr/hr
3 HVL reduce 1440 mr/hr to 180 mr/hr
4 HVL reduce 1440 mr/hr to 90 mr/hr
5 HVL reduce 1440 mr/hr to 45 mr/hr
6 HVL reduce 1440 mr/hr to 22 mr/hr
7 HVL reduce 1440 mr/hr to 11 mr/hr
8 HVL reduce 1440 mr/hr to 5.5 mr/hr
9 HVL reduce 1440 mr/hr to 2.75 mr/hr
10 HVL reduce 1440 mr/hr to 1.375 mr/hr

Ten half-value layers of lead shielding would be required to reduce the dose rate to a value less than 2 mr/hr.

This would result in a shield thickness: 10 X .90 centimeters = 9 centimeters. Since 1 centimeter = .4 inch, then the lead shielding would need to have a thickness of 9 X .4 = 3.6 inches (not including buildup).

As radiation passes through materials there will be some radiation "scattered". The result is that more radiation will pass through an absorber than is indicated by the absorption equation. This increase has been named "buildup". It depends upon the radiation energy (Mev) and the atomic number (Z no.) of the absorber. Calculations involving buildup factors may become quite complicated. For this reason, the acceptable calculations can be made using half-value layers and reduction factors.

If buildup had been given consideration in the preceding example, the results would have been:

Example: One lead HVL for Co-60 radiation is 0.49" (refer to Figure 4.8).
10 HVL X 0.49" = 4.9" lead required

This clearly indicates that buildup is an important factor in shielding design.

Material having a high atomic number absorb more gamma radiation than materials having a low atomic number. Some frequently used shielding materials are lead, iron, concrete, and water. (Figure 4.9)

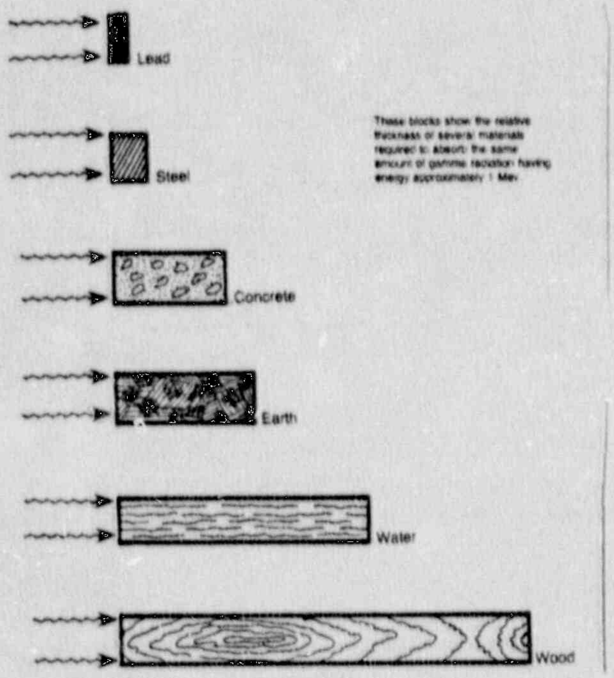


Figure 4.9 - Relative Efficiency of Shielding Materials.

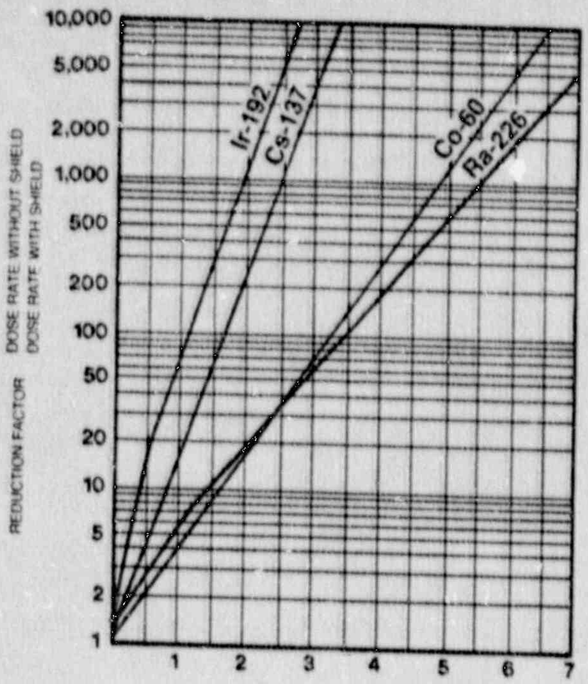
Radioisotope	Lead Thickness
Ir-192	1.9
Cs-137	2.6
Co-60	4.8

4.8 Reduction Factors

The concept of a reduction factor is useful in computing the amount of shielding needed. The reduction factor is the dose rate of gamma radiation reaching a point at some distance from a source with no shield divided by the dose rate reaching the same point with some shield interposed. This reduction factor depends upon the radiation energy (Mev) and the shield's atomic number, thickness, and density.

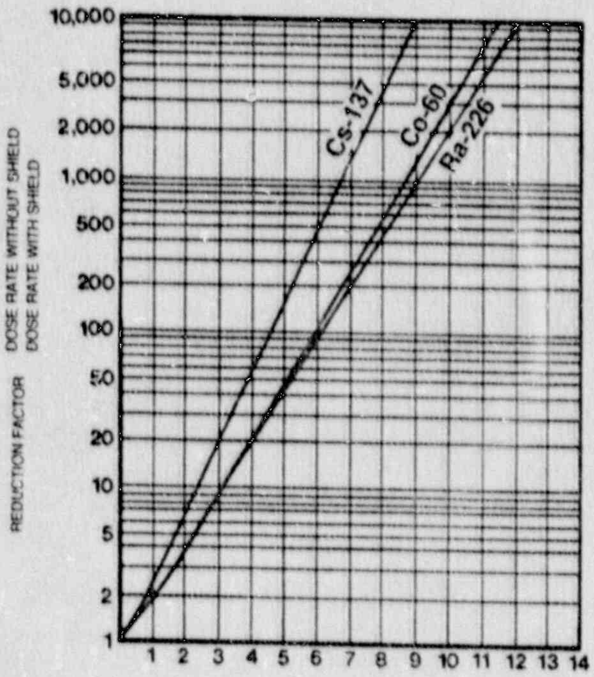
$$\text{Reduction Factor} = \frac{\text{Dose Rate Without Shield}}{\text{Dose Rate With Shield}}$$

Figures 4.10, 4.11 and 4.12 show the reduction factor for gamma radiation from Co-60, Ra-226, Cs-137, and Ir-192 plotted against shield thickness for lead, iron, and concrete. The data on these graphs include buildup.



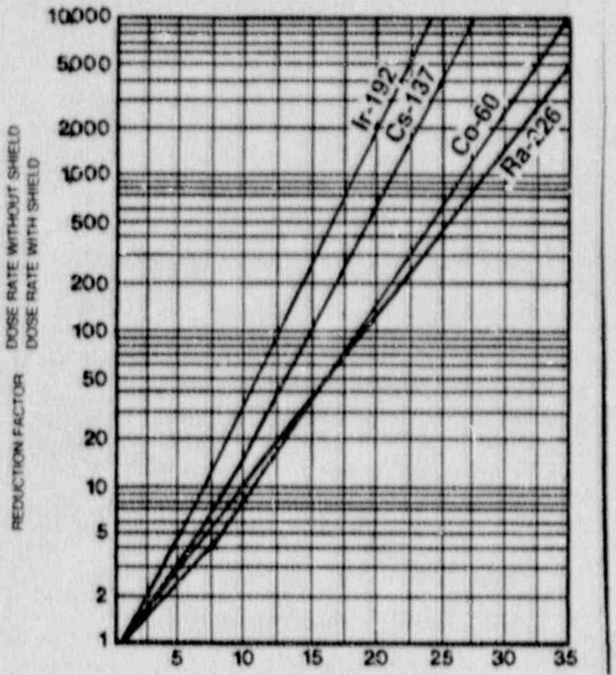
Lead Thickness Inches

Figure 4.10 - Broadbeam Shielding for Absorption of Gamma Rays in Lead



Iron Thickness Inches

Figure 4.11 - Broadbeam Shielding for Absorption of Gamma Rays in Iron



Concrete Thickness Inches (147 lbs./cu. ft.)

Figure 4.12 - Broadbeam Shielding for Absorption of Gamma Rays in Concrete

Example: A Co-60 source has an exposure of 2,000 mr/hr at a distance of 10 feet. Workmen need to be at that distance from the source but should receive only 4 mr/hr. How much lead shielding should be used? Iron? Concrete?

$$\text{Reduction Factor} = \frac{2,000}{4} = 500$$

Lead - 4.4 inches
Iron - 7.8 inches
Concrete - 24.5 inches

It is very important to remember that the interaction of radiation with matter depends upon (1) the gamma ray energy (Mev) and (2) the atomic number (related to density). By referring to Figure 4.8, it is possible to consider the half-value layer thickness variations with no change in gamma ray energy. For example, observe that:

(1) The atomic number and density decrease while reading across the table columns from lead to iron to concrete.
(2) For a selected radioisotope, e.g., Cs-137, the half-value layer thickness increases as one reads across the table - 0.25" for lead to 0.68" for iron to 2.1" for concrete.

This is acceptable for calculations using heavy shield materials for high energy gamma rays. Similar conclusions can be drawn from data in Figures 4.10, 4.11 and 4.12.

Example: To demonstrate the thickness variation of a selected shielding material when using energies from several radioisotopes, determine the lead thickness at a reduction factor of 1,000 to shield Ir-192, Cs-137, and Co-60.

Example: An Engineer plans to use tracer in a location where it is necessary for people to work periodically as close as 10 ft. to a 500 mc source of Ir-192, He plans to reduce the dose rate to 6.45 mr/hr by placing a portable lead shield between the tracer material and the work area. What thickness shield would be needed to attenuate the gamma radiation to the required level?

Find the exposure rate at 10 feet from the 500 mc source of Ir-192. One curie of Ir-192 has an exposure rate of 5160 mr/hr at 1 foot. Therefore, 500 mc would have an exposure rate one-half this amount, or 2580 mr/hr at 1 ft. From the equation:

$$\frac{I}{I^o} = \left(\frac{d_0}{d}\right)^2$$

the exposure rate at 10 ft. may be found

$$I = I_o \times \left(\frac{d_0}{d}\right)^2$$

$$= 2580 \times \frac{(1 \text{ ft.})^2}{(10 \text{ ft.})^2}$$

$$= 2580 \times \frac{1}{100}$$

$$= 25.8 \text{ mr/hr}$$

The 25.8 mr/hr dose rate must be reduced by the lead shielding to 6.45 mr/hr.

$$\text{Reduction Factor} = \frac{25.8 \text{ mr/hr}}{6.45 \text{ mr/hr}} \quad 4.$$

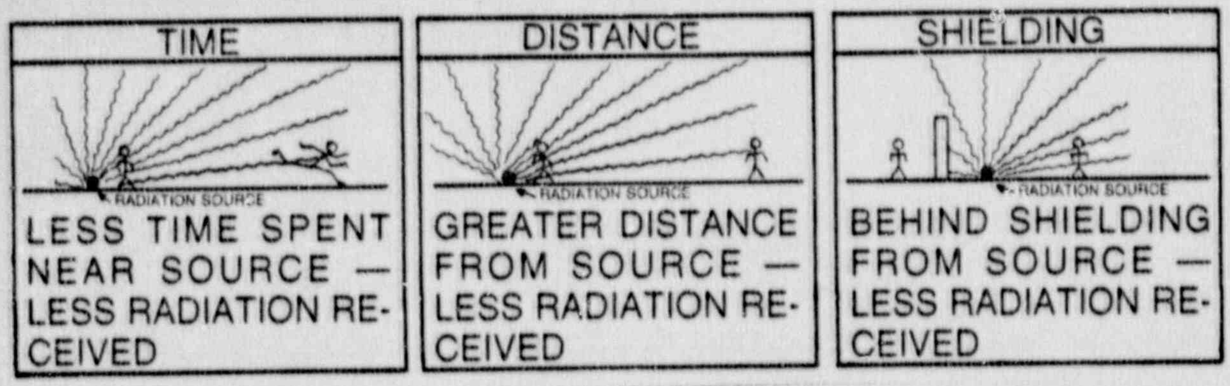
A reduction factor of 4 for Ir-192 in lead from Figure 4.11 indicates that a lead shield about .38 inch thick is necessary to reduce the radiation to 6.45 mr/hr.

Chart 6, "Reduction of Radiation by Shielding" is used to determine the amount of shielding required to reduce radiation to safe levels.

4.9 Principles of Radiation Safety

All industrial operations require the use of radiation sources having high energy, kev or Mev, and frequently sources having high emission rates. Adequate radiation safety precautions must be well understood, organized, and utilized, to avoid overexposures to personnel.

This chapter provides the basic concepts for using radiation sources. When properly trained persons use sources there is no more reason to be afraid of the radiation hazard than to be overconcerned with safety problems when working with electrical systems or toxic chemicals.



Three principles must be applied for controlling body exposure to sources. These are (1) time, (2) distance, and (3) shielding.

All installation and techniques should be designed using these principles. All operations should be frequently inspected to assure that the planned conditions associated with the source exposures are maintained.

4.9.1 Personnel Exposure Time

Personal dosage received depend directly upon the time a person remains in the radiation field. He would receive only 3 mr in 2 minutes at a given point where he would receive 15 mr if he had remained 10 minutes. Limiting the working time in a radiation field requires using suitable instruments, paragraph 5.5, for detecting and measuring the radiation intensity and applying the equation:

$$\text{Allowable working time in hr/week} = \frac{\text{permissible exposure in mr/wk}}{\text{exposure rate in mr/hr}}$$

Chapter 6 lists personnel exposure limits. An operator may use the more convenient limit of 100 mr/week for his "radiation protection guide". The work shall be organized in such a way that no radiation workers could receive more than 100 mr/wk.

4.9.2 Working Distances

Lower personnel exposures will be received greater distances from radiation sources. The inverse square law, paragraph 4.5, and the examples, give information and methods that permit one to calculate the radiation intensities at various distances from a source. Survey meters should be frequently used to verify the calculations. Table 4.3 tabulates useful data that verify the importance of working at various distances from gamma sources.

4.9.3 Radiation Shielding

In the event that working time is too long, and operating conditions prevent sufficiently long exposure distances, shielding material may be placed in the radiation beam to protect personnel. Shields will not stop all of the radiation, but adequate shielding will attenuate the radiation to a value that will permit operations without excessive personnel exposures. Using the absorption equation, half-value layers, or reduction factor methods for shielding calculations, will be adequate.

In many industrial situations there will be requirements to use high intensity sources and limited space will be available. In these cases, shielding will be necessary. Suitable protection will require the operator to use time, distance, and shielding.

This can best be illustrated with an example.

d	$\frac{I_0 = I(if)}{I_0}$
d	I_0
$(_2d_0)$	$I_{0/4}$
$_3d_0$	$I_{0/9}$
$_4d_0$	$I_{0/16}$
$_5d_0$	$I_{0/25}$
$_6d_0$	$I_{0/36}$
$_{10}d_0$	$I_{0/100}$

Table 4.3

Example: A densometer technician opens 50 densometers a week and for each the 20 mCi Cs 137 source is exposed for 6 minutes. It is only a small shop and he must work 1 foot from the exposed source. Determine the lead shield thickness that must be provided to prevent the technician from receiving more than 20 mr/week.

Step 1. The source is exposed:
50 X 6 minutes = 300 minutes = 5 hours

Step 2. Calculate personnel exposure rate in mr/hr so that worker receives less than 100 mr/week.

$$\frac{100 \text{ mr/week}}{5 \text{ hr/week}} = 20 \text{ mr/hr} = \text{Max Exposure Rate allowed.}$$

Step 3. Determine gamma exposure 1 ft. from 20 mCi Cs 137 source.

Exposure = 20 mCi X 3.55 mr/hr/mCi = 71 mr/hr

Step 4. Use half value layer concept to determine lead thickness to reduce Exposure below 20 mr/hr.

1 HVL reduces 71 mr/hr to 35.5 mr/hr.
2 HVL reduces 35.5 mr/hr to 17.75 mr/hr.

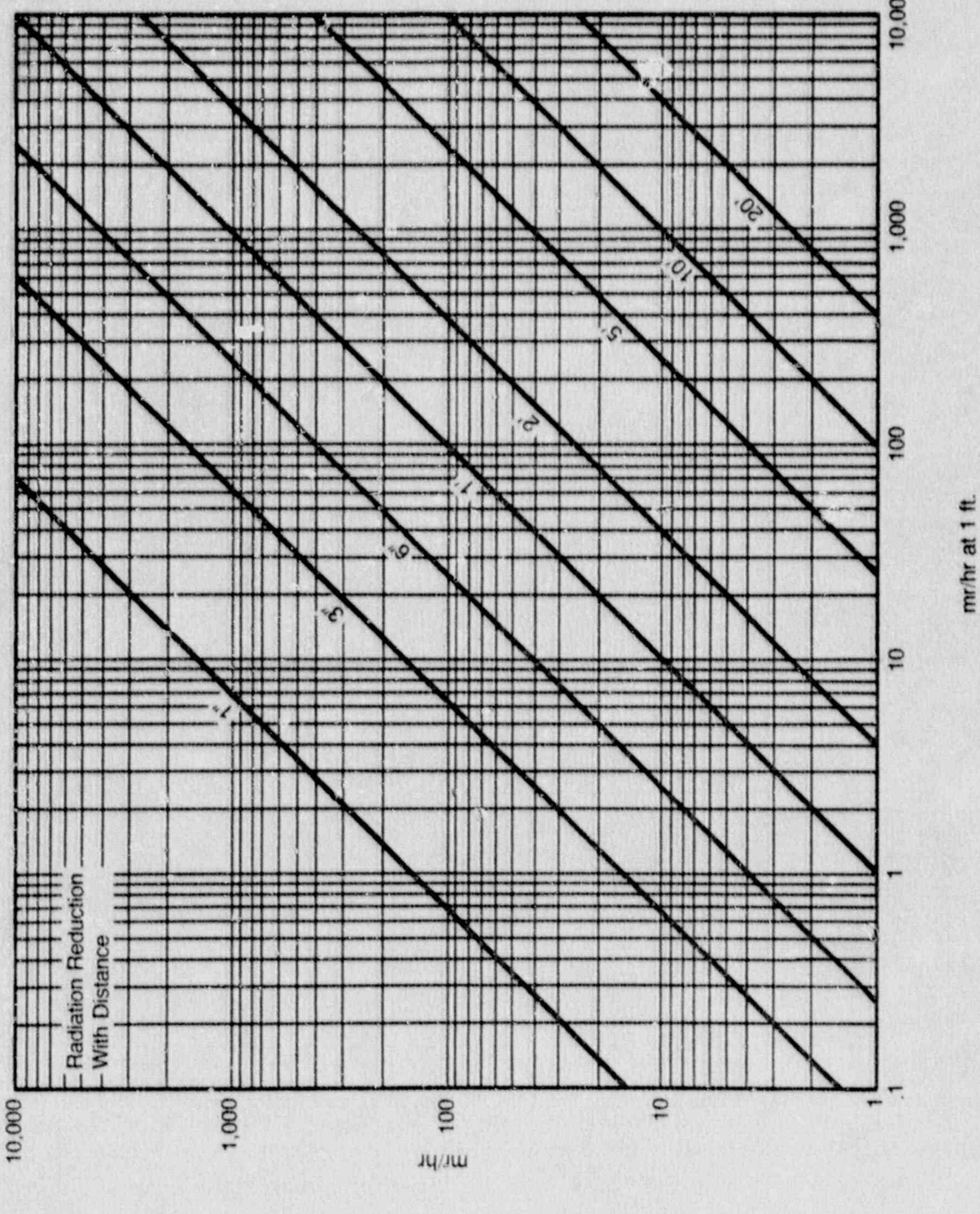
HVL for lead for Cs 137 is 0.25 inches,
2 X 0.25 in = 0.5 in lead.

For comparison, determine the thickness using the reduction factor and Figure 4.10.

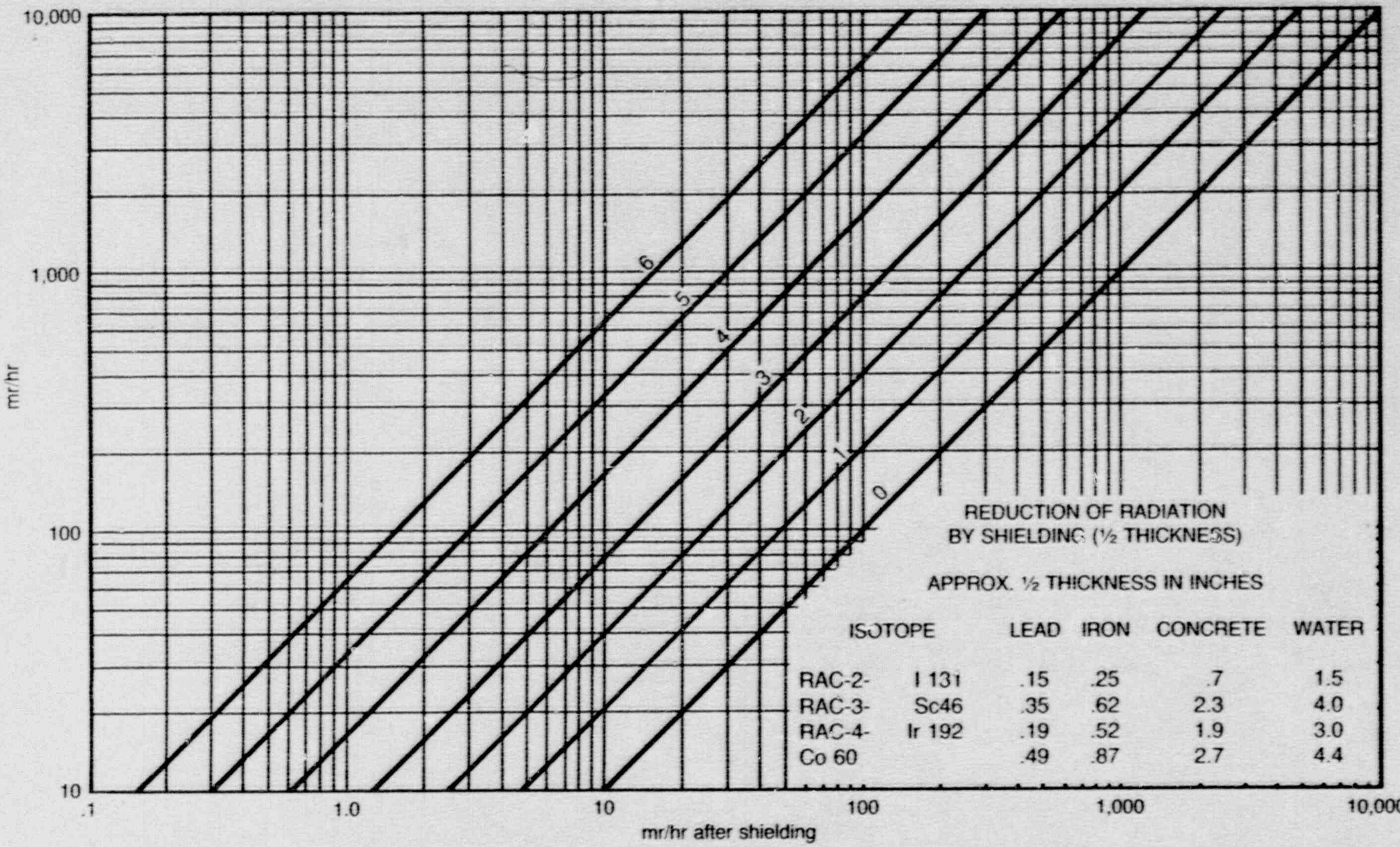
$$\text{Reduction Factor} = \frac{71 \text{ mR/hr}}{20 \text{ mR/hr}} = 3.05$$

Figure 4.10 gives about .4 in lead.

Chart 5



461306



REDUCTION OF RADIATION
BY SHIELDING (½ THICKNESS)

APPROX. ½ THICKNESS IN INCHES

ISOTOPE		LEAD	IRON	CONCRETE	WATER
RAC-2-	I 131	.15	.25	.7	1.5
RAC-3-	Sc46	.35	.62	2.3	4.0
RAC-4-	Ir 192	.19	.52	1.9	3.0
Co 60		.49	.87	2.7	4.4

Chart 6

Chart 7 — RADIATION LEVELS AT ONE FOOT FROM UNSHIELDED RADIOACTIVE TRACERS

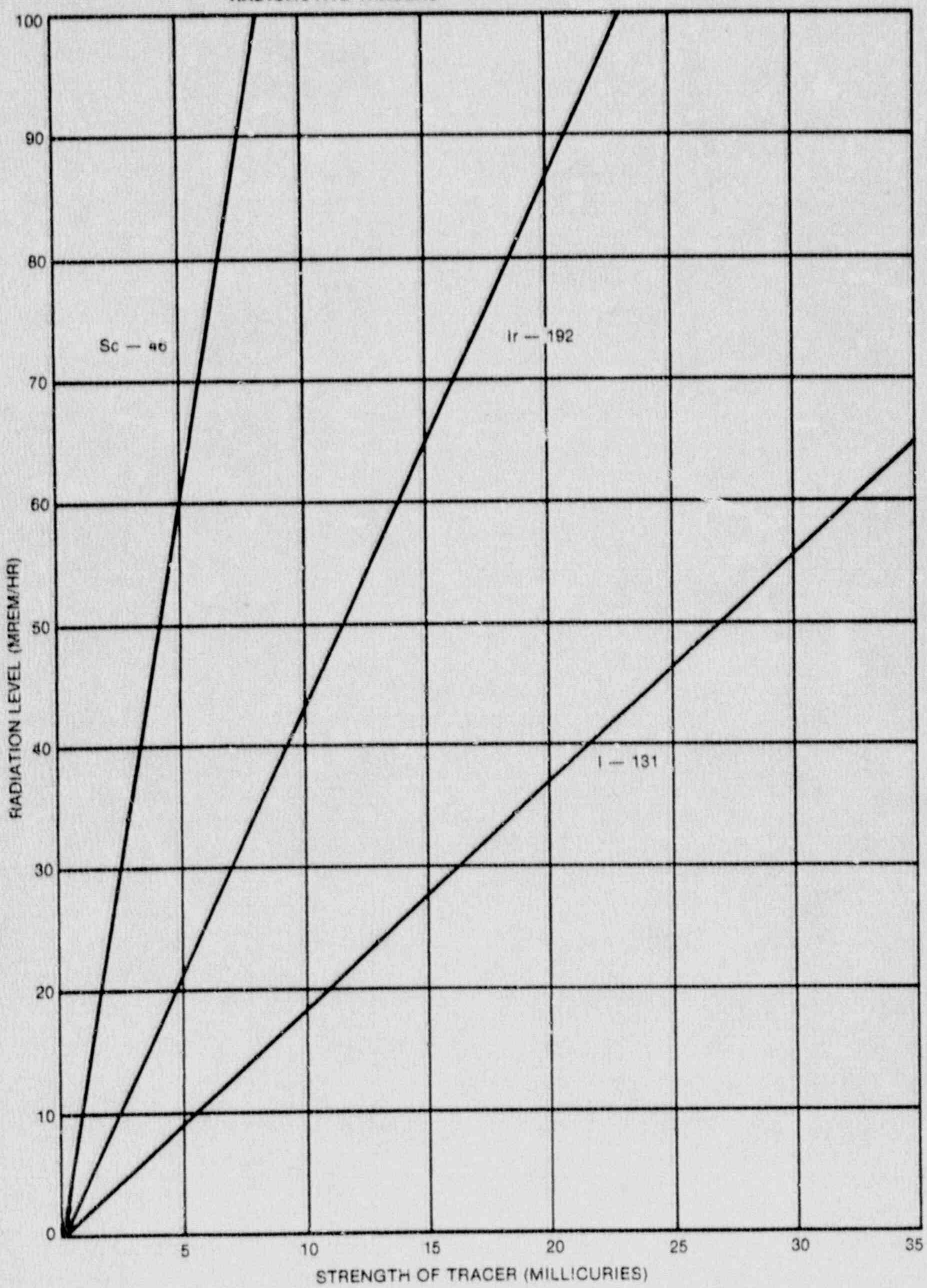


Chart 8 — RADIATION LEVELS AT THREE FEET FROM UNSHIELDED RADIOACTIVE TRACERS

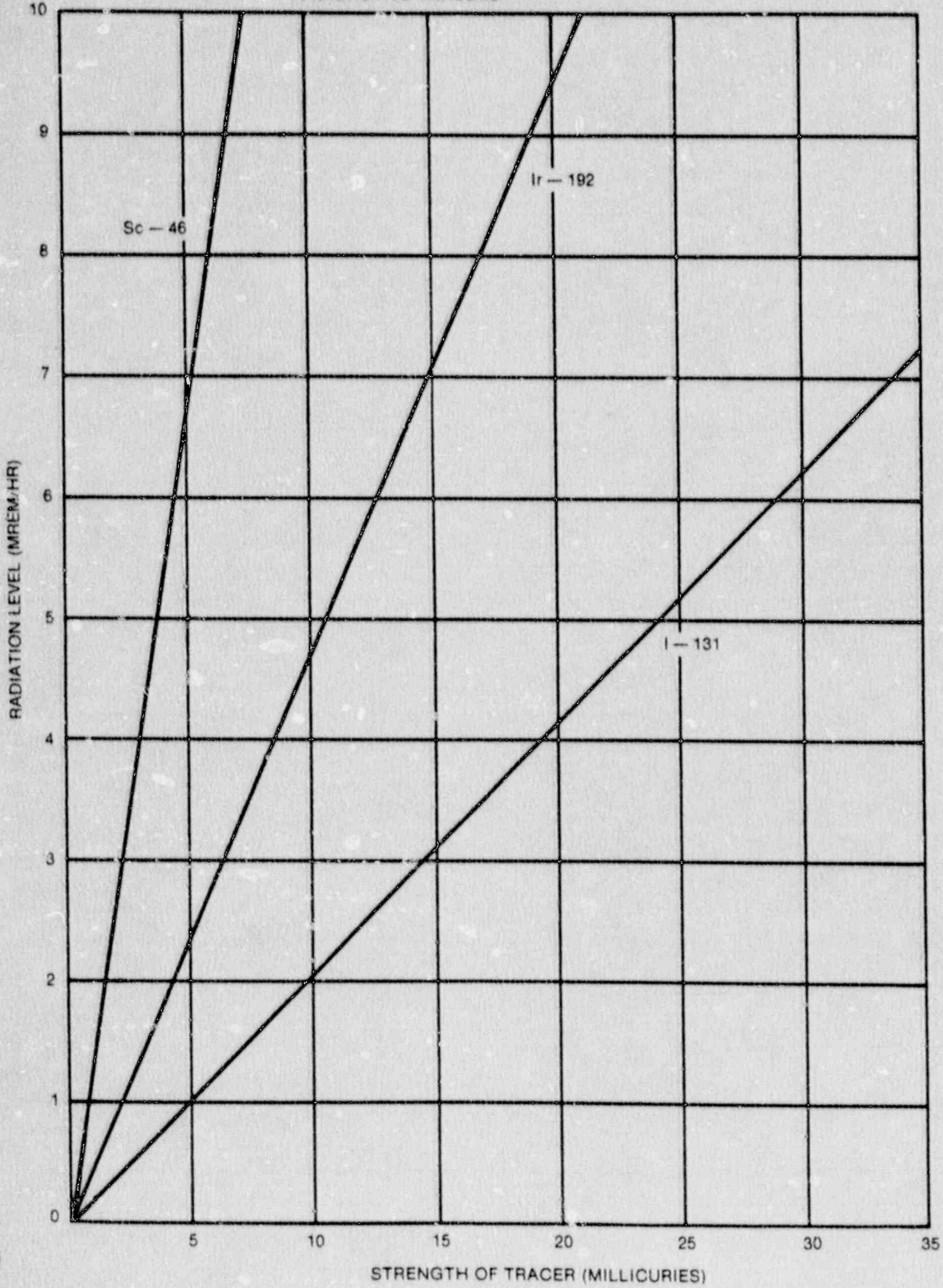
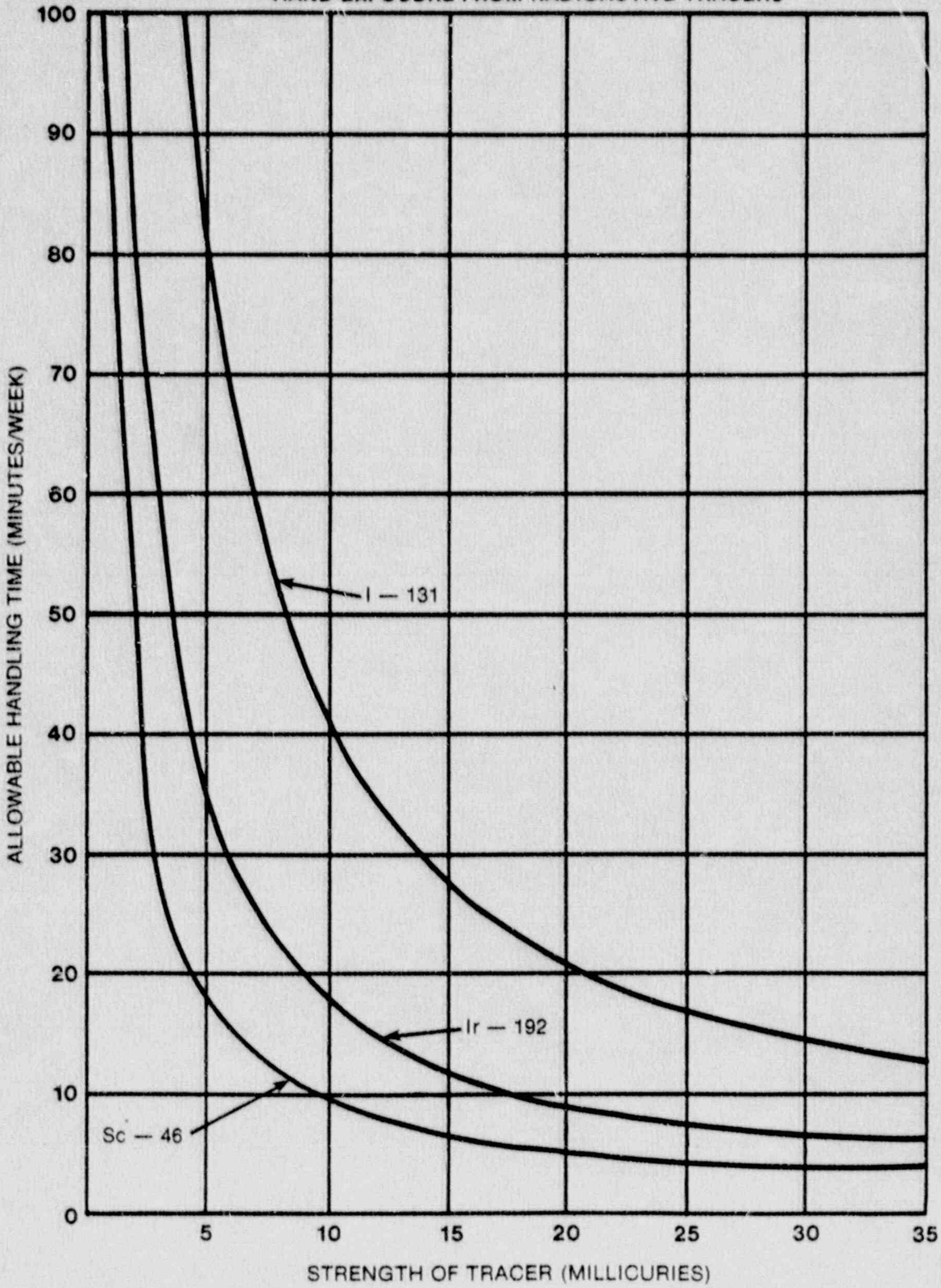


Chart 9

— HAND EXPOSURE FROM RADIOACTIVE TRACERS



CHAPTER 5
RADIATION DETECTION AND MEASUREMENT

5.1 Radiation Detection and Measurement

Man cannot detect with his senses radiation coming from radioactive materials. The body may be penetrated by high intensity radiation and feel no pain, even though it may be severely injured by the radiation. This is similar to the reaction of man to ultraviolet and radio waves. A person may be exposed to the ultraviolet rays in sunlight and feel pain from over exposure several hours later. Likewise, a person receiving an overexposure of radiation may not be aware of it until some time later when radiation sickness develops. Man must, therefore, depend on some kind of instrument to detect nuclear radiation that may be of danger to him.

The term "detection" usually includes only a determination of the presence of radiation, whereas "measurement" includes both the detection and some measure of the amount of radiation present. Radiation detection or measurement instruments detect the interaction of radiation with some type of matter. Some instruments are based on the ionization produced in the instrument by the passage of the radiation; in other instruments the excitation of materials is used to detect radiation. These are the scintillation-type monitoring instruments. Chemical and photographic detection techniques are also used.

5.2 Radiation Measurement

Radiation measuring instruments usually provide a measurement of dose or of dose rate. The first measurement refers to the accumulated dose of radiation over a period of time. The second measurement refers to an immediate measure exposure rate or radiation intensity.

The unit of radiation exposure is the roentgen, which is based on the effect gamma or X-radiation has as it passes through air. This is a rather large unit for measuring occupational exposures, so the milliroentgen is frequently used for measuring small doses of exposure (1 roentgen = 1,000 milliroentgens).

Instruments which measure total dose exposure are called dosimeters. If a workman is to be in an area where he is exposed to radiation, he may want to know his total dose exposure. A dosimeter would be used to tell him his total dosage upon completion of his work in that area. Examples of dosimeters include the Lauritsen electroscope, the pocket dosimeter, the R-meter, film & TLD badges.

Instruments used to measure dose-rate exposure or radiation intensity are called survey meters. A workman may know that an area has radiation, but may not know the intensity of the radiation. A survey meter will tell him the exposure rate and hence whether it is safe to enter the area or not. Examples of exposure-rate instruments include the Geiger counter and the ionization chamber.

Except for photographic film techniques and a few special methods, all radiation-detecting devices are based upon the ionization produced in a gas by the radiation. When a high-speed particle or a photon enters a gas, it may act on an atom or molecule with a force large enough to remove an electron and form an ion pair.

5.3 Dosimeters

Several types of total exposure instruments are of interest to the person working where radiation is present.

5.3.1 The Pocket Dosimeter and Pocket Chamber

Useful quartz fiber instrument is the pencil-type, or pocket, dosimeter (Figure 5.2) which is essentially a Lauritsen electroscope modified so that it is about the size of a large fountain pen. The electrode in the dosimeter consists of two quartz fibers, one fixed and one movable, but each bent into a U shape. The two fibers are fused together at the ends of the U, and a microscope is focused on the opposite end of the movable fiber. As with the Lauritsen electroscope, the dosimeter is charged from a separate source with a high enough voltage to deflect the movable fiber to the zero

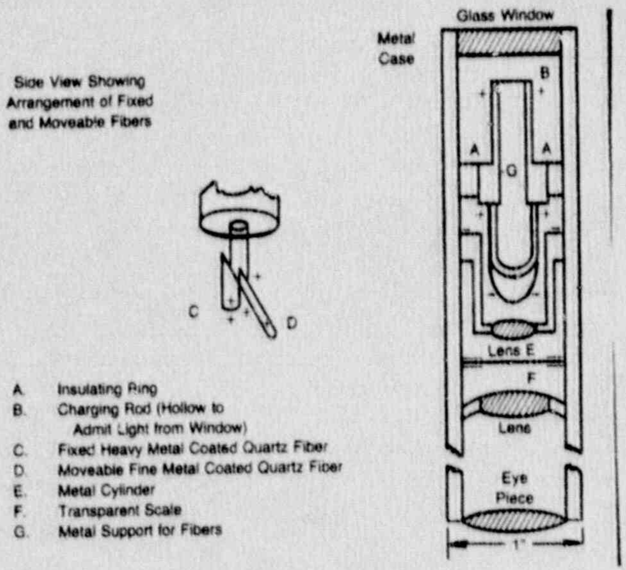


Figure 5.1 - The Pocket Dosimeter.

point on the scale. The presence of radiation then produces ionization, neutralizes the charge, and allow the movable fiber to return toward the fixed fiber, a distance proportional to the quantity of radiation absorbed. Dosimeters can be made sufficiently rugged to withstand the shocks of normal human activity, are small enough to be worn comfortably, and are useful for measuring total exposure. Their sensitivity can be made such that 100 mr will produce about one-half full scale deflection.

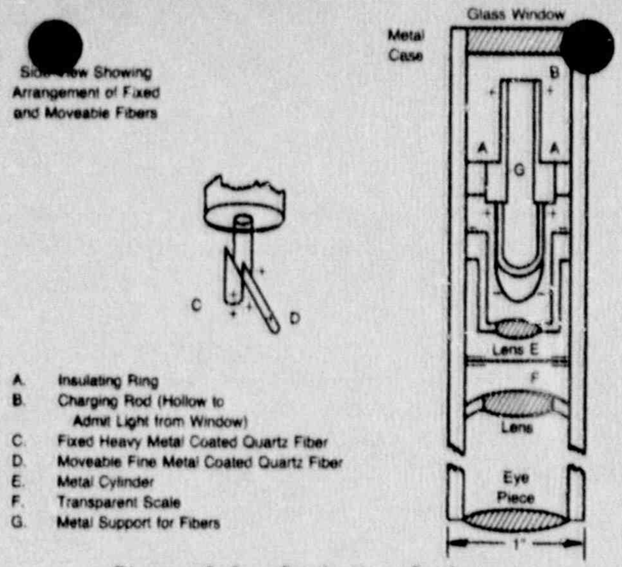


Figure 5.2 - Dosimeter Scales.

To prepare a pocket dosimeter for measuring radiation, it is charged to about 150 volts to bring the image of the quartz fiber to zero on the scale (Figure 5.3). A pocket dosimeter is charged by an external source of voltage. The ionization chamber is held at ground potential and the metal frame and quartz fiber are charged to the potential of the charger. The fiber and metal frame repel each other since they are at the same potential. The position of the fiber then varies with the voltage difference between the ionization chamber and the fiber. The variance is linear over the range covered by the scale. Dosimeters with scales such as those shown are called direct-reading dosimeters. Other types require a reading device and are called pocket chambers (Figure 5.4).

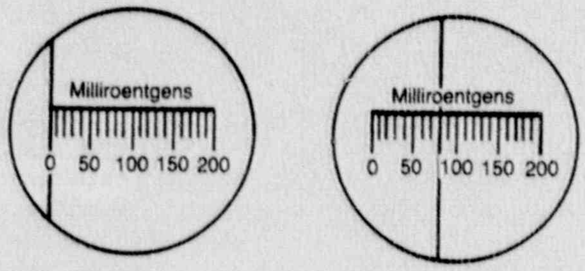


Figure 5.3 - Dosimeter Scales.

5.3.3 Film Badges

A film badge consists of a small piece of X-ray film inserted in a metal holder. It is worn on the outer clothing and is the most common type of total dose exposure measuring devices. It is used mainly to detect gamma and X-ray radiation and high energy beta radiation. The film does not react to alpha radiation.

The badge consists of a metal or plastic jacket in which : photograph or nameplate may be inserted. Inside the jacket are a front and rear filter composed of lead, cadmium, or some other shielding material. Between these are inserted one or more bit of film with varying sensitivities. In one portion of the jacket there is a window to admit low energy gamma rays or beta rays.

After the film badge has been worn for a period of time, several days or weeks, the film is removed and developed by controlled photographic techniques. The film will be darkened in proportion to the amount of radiation received. The darkened film may be compared with a set of control films of the same type which have been exposed to a known amount of radiation. A densometer is used to measure the density of the image on the film. This measure is then compared with densities of known quantities of radiation of given energies. In this way an estimate can be made on the amount of radiation received by the person wearing the film badge. Obviously, the badge should always be worn by the person when in a radiation area, and it should not be exposed to radiation when not being worn by the person.

5.3.4 TLD (Thermoluminesent Dosimeter)

When a crystal (such as CaF ;Mn) abosrbs an X or -Ray, electrons in the crystal are raised to higher energy levels and are trapped there. Thus the crystal retains in its memory data about the number of photons it has absorbed. At some time, the crystal may be heated at a uniform rate and as the temperature increases the crystal annels and the electrons are released from the trap so when they drop to their ground state, they give up their excitation energy as visible light photons. In effect a "glow curve" is produced as these photons are defected by a photon multiplier tube. The area under the "glow curve" is produced as these photons are detected by a photon multiplier tube. The The area under the "glow curve" is a measure of the total radiation absorbed since it was last annealed. The TLD crystals are reversable in contrast to film badges which are one time dosimeters.

TLD service is available from a number of sources. OK Tracers, Inc. utilizes TLD's and they are "read" quarterly to provide personnel exposure data for all OK Tracers personnel concerned with radioactive material handling and usage. Contact your Radiation Safety Officer for further information. See Chapter 11 for TLD badging instructions.

5.4 Survey Meters

Although all instruments of the types previously described measure radiation exposure, they cannot be utilized effectively in making a survey of a large area since too many such instruments and too much time would be required. To make a rapid survey of an area another type of instrument is needed, one that instantly measures radiation intensity. Three such instruments are available-ionization chamber instruments with amplifier systems, Geiger counters, and scintillation counters. All survey meters must be calibrated at time intervals not to exceed 6 months or after repair.

5.4.1 Ionization Chamber Instruments

In an ionization chamber, when ionization occurs in a gas in the presence of an electric field, the ions will move in opposite directions, each going to the electrode having the charge of opposite sign. If the electrodes are connected to a battery, or other source, the ions reaching the electrodes will give up their charge and become neutral again, but at the expense of removing charge from the battery. This results in a current flow through the battery and the external circuit. This current flow, though extremely small, can be measured and interpreted in terms of the radiation intensity required to produce the ionization. Instruments of this type can be made small and portable, and are used for health monitoring and survey work. Their accuracy is plus or minus 15% of fullscale and they are therefore not suitable for accurate measurements. At the point of measurement, this type of instrument indicates intensity of radiation, an instantaneous measurement.

5.4.2 Geiger Counters

In areas where the radiation intensity is low, ionization chamber type instruments are not satisfactory, for they do not provide sufficient amplification of the ionization current to indicate it accurately on a meter. Low intensity measurements are made with Geiger counters which attain their greater sensitivity by taking advantage of all possible amplification within the Geiger tube itself (gas amplification) as well as that provided by electronic amplifier circuits.

In the Geiger counter ionizing radiation creates ions by interacting with neutral atoms. These ions strike other atoms and molecules, and if the ions move slowly their collisons are elastic; that is, they impart some of their energy to each of the gas molecules with which they collide, speeding them up somewhat, but producing no ionization. Another disadvantage of ions with slow speed is the fact that it takes them a long time to reach the electrodes, and they have many opportunities on the way to collide with oppositely charged ions, neutralize each other, and decrease the total ionization within the area. If ions created by radiation move rapidly, however, they in turn strike atoms and molecules with sufficient force to knock electrons out and create other ions, thus increasing the total amount ionization within the area. Such collisions are called inelastic collisions.

Since it is the ionization that is measured by most of the instruments used for measuring radiation, the greater the ionization, the easier it is to measure the radiation. One of the means of speeding up the ions is increasing the voltage difference between the electrodes and thereby making the attraction of the ion for the electrode greater. It is advantageous, therefore, to secure as high voltage as possible between the terminals in order to gain sufficient speed to produce a large amount of ionization. Another way to speed up ions is to reduce the pressure. This increases the time between collisons and gives the ions enough momentum to make collisions inelastic and produce more ionization. Geiger tubes have these high voltages and low pressures to gain gas amplifications within the ionization chamber itself, and each particle or photon entering the chamber produces an avalanche of ions. This process requires only a fraction of a thousandth of a second then the system is "quenched" to prepare the instrument for another ray and the resulting avalanche. With further electronic amplification circuits, each avalanche can deflect a needle, produce a click, light lamps, or make any convenient record desired.

Instruments using Geiger tubes as detectors can be made small and portable for safety surveying. Their accuracy is plus or minus 15 percent of full scale and they are not intended to make accurate measurements. These meters indicate exposure rates.

5.4.3 Scintillation Detectors

In a scintillation counter the ionization produced by the passage of a charged particle or gamma ray is detected by the emission of weak scintillations (light flashes) as the excited atoms of the detector crystal return to their lowest energy state. The Sodium Iodide crystal is most commonly used to detect gamma rays. The light output of the scintillater is proportional to the energy lost by the particle that traverses the detector; thus, by coupling it to an analyzer through a photo multiplier tube the energy of the gamma ray obsorbed may be determined.

The scintillation detector is much more sensetive than the Geiger-Mueller counter. Its high efficiency enables it to find small sources and monitor small charges in background. An important fact which must be borne in mind is that the scintillation detector measures the number of events, i.e., counts per minute whereas the Geiger counter uses a different process which matches the rate of ionization in the detector to an exposure in Roentgen or MiliRoentgen per hour. In other words they are measuring different quantites.

Scintillation Detector - Measures absolute number of events
Geiger counter - Is calibrated to reflect a given R/hr for a certain ionization current established in the detector.

As an example of the relative sensitivity, a scintillation detector may indicate a significant reading above background when 40 feet from a radioactive densometer and the Geiger counter will not indicate a significant reading above background until the detector is about six feet away.

5.5 Instrument Characteristics

The radiation measuring devices, previously described, all measure gamma or X-radiation. Since particulate radiation is much less penetrating, the particles cannot pass through the walls of most of the devices, except those designed with a thin window. Such detectors usually have a shutter that can be opened to admit particles. If the shutter covering the detector is opened, particulate radiation is admitted along with gamma radiation. Measurements made with the shutter both opened and closed allow a computation of the amount of intensity of particulate radiation. Also, film badges and TLD's have an opening in the jacket and filter to admit beta radiation.

Since both alpha and beta rays present a minor external radiation hazard, and usually cannot penetrate the skin, their measurement is not of much importance. However, Rayfrac operators should be familiar with the characteristics of instruments and the type of radiation they detect or measure.

Instruments should have suitable ranges for the radiation intensities to be measured. The NRC specifies that instruments used by Rayfrac operators should measure as low as 1 mr/hr and as high as 1000 mr/hr. Geiger counters are usually low level instruments and read only to about 50 milliroentgens per hour. The ionization chamber type instrument measures high levels of radiation. Commonly used types of such instruments read up to 500 R/hr.

Geiger counters have a tendency to "block-out" in a high radiation field. This means the needle on the dial will not move above zero. Ordinarily, Geiger counters show a small reading above zero due to background radiation. The person using this type of instrument should be careful not to accept a blocked Geiger counter reading of zero as meaning no radiation is present. Special circuits may prevent this blocking. Ionization chamber type survey meters will not block-out. If they are used in a radiation field whose intensity is greater than the instrument's range, the needle will go beyond the highest scale reading.

Several important characteristics of survey meters should be considered in selecting an instrument. These are summarized as follows:

(1) Instruments must detect the desired radiation. Survey meters for radiography must detect X-ray and gamma radiation.
(2) Survey meters must cover a suitable range of radiation dose rate.
(3) Instruments should be stable and hold calibration.
(4) Instruments should have an acceptable time constant. A short time constant is desirable; however, the time constant should not be such that the needle fluctuations would prevent making measurements. (Time constant is an expression of the time required for an instrument to respond to changing signals.)
(5) Batteries must be replaced and therefore should be readily available.
(6) The survey meter manufacturer should maintain a repair and calibration service.

46/306

CHAPTER 6
THE NATURE AND CONSEQUENCES OF RADIATION EXPOSURES

Part I dealt with certain technical aspects of radiation physics. It was brought out in a general way that radioactivity was harmful to man under certain circumstances. This chapter proposes to acquaint the reader with (1) common types of radiation exposure, and (2) how they are measured. (Also, refer to Chapter 5.) A short statement designed to place the matter of radiation health in proper perspective serves as an introduction to these topics.

6.1 Radiation Health in Perspective

It was only a short time after the discovery of X-rays and of radioactive substances that radiation was identified as a potential health hazard.

The reports (usually dramatized) of illness and body damage sustained by persons handling, or otherwise exposed to, radioactive materials had created a vivid impression on the popular mind even before the Nagasaki and Hiroshima bombs. Since that time there has been so much publicity on the after-effects on the Japanese who were exposed that it is not strange that many laymen tend to regard radiation with awe and fear and to have an exaggerated concept of radiation hazard.

It is true that the biological effects of radiation can be serious, depending on various factors and conditions. However, it is just as true that radiation can be handled in a safe manner and can be made to perform useful services for mankind. Since an atomic era has been launched, it behooves all persons to develop at least a degree of familiarity with radioactivity. Gross ignorance generally results in one of two attitudes, both of which can be undesirable. The first is a blind fear of radioactivity, and the second is complete lack of appreciation for radiation hazards.

In the first instance the individual may be reminded that daily living involves many health hazards as great or greater than radiation. A person hit by an automobile, overcome by a disease germ, or shocked by electricity may experience a biological effect ranging from slight discomfort to death. To harbor a morbid fear of these possibilities is foolish, because they have become a part of everyday life. At the same time, the potential hazard of automobiles, disease germs, and electricity are recognized and proper safety measures are taken. This is precisely the attitude which should be assumed toward radiation hazard.

The purpose of this chapter is to acquaint the reader with the effects which radiation produces on the body, so that a proper attitude may be developed.

It may be observed that all people are continuously exposed to natural radiation. Cosmic radiation from outer space is ever present. At the same time, the earth's crust contains many radioactive elements which find their way into building materials, foods, clothing, and many other items for human use. When radiation for medical reasons is included (X-rays, etc.), it can be seen that humans can and do tolerate considerable radiation during the course of lifetime. See Table 6.1 for average annual gonad (testes and ovaries and sex organs) exposures in the United States.

TABLE 6.1.—Estimated Average Annual Gonad[1] Exposures in the United States.

1. 98 mrad/year in Berkley, California to 425 mrad/year in Florida to 48,201 mrad/year in Iran.
2. BEIR panel average 182 mrad/year (1980).
3. The natural radiation environment is not a physical constant. It is a wide range of from 10 to 10000 times higher than the regulatory preference.

Refer: Luckey, T. D.: *Hormesis with Ionizing Radiation*,CRC Press Inc., Boca Raton, Fla. (1980)

Gessel, T. F. and Lowder, W. M.: (editors) Symposium, *Natural Radiation Environment III*, TIC/US DOE, Conference - 780422 (2 Vol), NTL Service, Springfield, Va. 22161.

Table 6.1 - Estimated Average Annual Gonad Exposures in the United States

Since man lives within an environment which has a natural background of radiation, exposure hazard must be considered in terms of degrees. A parallel may be drawn to exposures from more familiar radiations, such as heat and light. Excessive heat results in severe burns (often fatal), and overexposure to direct sunlight produces, at the least, painful sunburn. Yet both heat and light have extremely beneficial effects in proper dosages. Injuries from ionizing radiations differ in nature from heat and light radiation (they may penetrate beyond surface layers) but, likewise, are harmful only to the extent of overexposure.

Radiation hazards are thus much like all natural and man-made hazards. They must be considered in terms of the goals or objectives sought. Hardly anyone refuses to work in a building because it is wired for electricity. This is true because an unquestioning faith is held that proper measures have been taken to control or harness this source of energy. By the same token, there is no reason why one should be reluctant to work in a building housing radioactive material which is under proper control. In fact, control measures for individual and group protection are likely to be considerably more stringent for radiation hazards than for electrical or fire hazards.

6.2 Measurement Units of Radiation Doses

It is impossible to measure a quantity of radiation directly since it can bring about a change in matter only to the extent of the energy actually absorbed by this matter. A given biological effect may also depend on the type and energy of the radiation, making possible different effects from equal energy absorption. For the above reasons, it is more convenient and practical to measure exposure in purely physical terms, and then use an additional factor to allow for the relative biological effectiveness of different types and energies of radiation. The terms used in measuring radiation exposure are the following.

6.2.1 Roentgen

The unit for measuring the penetrating external radiation exposure is the roentgen, which is abbreviated r (named in honor of the man who discovered X-rays in 1895). The roentgen measures gamma or X-ray radiation in air only, and is defined as the quantity of X- or gamma radiation that will produce one electrostatic unit (esu) of charge, either negative or positive, in one cubic centimeter of dry air at standard temperature and pressure (0°C and 760 mm Hg.). One roentgen of radiation has the ability to produce an amount of ionization which represents the absorption of approximately 83 ergs of energy from radiation per gram of air. The roentgen can be subdivided into a smaller unit called the milliroentgen, abbreviated mr, which is one thousandth of a roentgen.

6.2.2 Rem

Since the roentgen measures radiation in air only, it cannot be used to measure the biological effects on man. The reason for this is that the amount of energy required to produce an ion pair in animal tissue differs from the energy needed to produce an ion pair in air. The term used for these purposes is called the rem (roentgen equivalent man). The rem can be sub-divided into a smaller unit called the millirem and abbreviated as mrem, which is one thousandth of a rem. A rem is defined as the quantity of ionizing radiation of any type which, when absorbed by man or any other mammal, produces a physiological effect equivalent to that produced by the absorption of one roentgen of X- or gamma ray.

6.2.3 Rad

The rad (radiation absorbed dose) has recently been accepted as a unit of measurement for radiation absorbed locally by a person. It is defined as the amount of radiation energy imparted to matter per unit mass of irradiated material. The dose unit, the rad, represents an absorption of 100 ergs of energy per gram of irradiated material at the place of exposure. It has been estimated that a rad results in the ionization of approximately one tissue atom in twenty billion. Obviously, this is a very small amount of energy. One rad can be sub-divided into a smaller unit called the millirad, abbreviated mrad, which is one thousandth of a rad.

6.2.4 RBE

Knowledge of the biological effectiveness of radiation has considerable practical importance since it determines permissible exposure rates for medical uses and industrial radiation exposure. For example, although both gamma and neutron radiation can produce cataracts, neutrons are approximately ten times more effective than gamma rays. Values of RBE (relative biological effectiveness) have been worked out by the National Committee on Radiation Protection based on the X-ray as the RBE of one.

The actual practice, the total biological dose for several types of radiation (i.e., when a person receives radiation from several sources) is converted to rem. The dose in rem equals absorbed dose in rads times RBE. This procedure may be illustrated as follows: Assuming an individual received mixed radiation comprising 0.4 rad of gamma, 0.1 rad of alpha, 0.3 rad of thermal neutrons, and 0.2 rad of fast energy neutron irradiation, his total exposure would be calculated in this matter:

Example:

Radiation	Dose in Rad		RBE	Dose in Rem
Gamma	0.4	X	1	0.4
Alpha	0.1	X	10	1.0
Thermal neutron	0.3	X	5	1.5
Fast Neutron	0.2	X	10	2.0
Totals	1.0			4.9

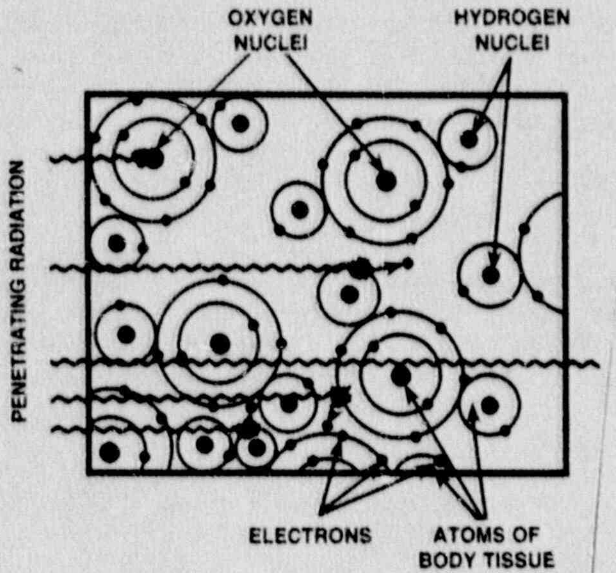


Figure 6.2 - Ionization Produced by Radiation Effect on Atoms.

6.3 The Effects of Ionizing Radiation on Health.

The biological effects of ionizing radiation are influenced by several factors other than the amount of radiation exposure.

6.3.1 Dose Rate Effects

The rate at which a radiation dose is received is an important factor because living tissue is not inert. As soon as damage is produced the healing process begins. When a particular dose is delivered over a long period of time, it is possible that repair may keep pace with the damage so that no detectable change is produced. Coversely, the same dose delivered all at once may produce a noticeable reaction.

The knowledge of the effects of radiation has generally been developed from data on large doses received in a short time. These sources include Hiroshima survivors, victims who received acute doses in radiation accidents and patients who receive acute doses in radiation therapy treatment. However; most human exposure is in the form of low doses and low dose rates. The biological effects of this type of radiation can only be observed by observation of large groups of people over many generations. This difficulty has led to the general practice of predicting the results of low doses and low dose rates on the basis of high dose and high dose rate data.

In addition, in order to present conservative estimates of radiation effects, it is generally assumed that some injury occurs for any exposure to radiation. It should be stressed that this is not known to be the case. There are certainly levels of radiation that produce no detectable effects - background radiation and routine X-rays, for example. However; to insure maximum protection for the population the most conservative estimates are used.

6.3.2 Age

The sensitivity of an individual to radiation is greatly influenced by his age. Before birth when organs are developing the sensitivity is high because differentiating cells and cells in the process of rapid division are more easily damaged than mature cells. In a like manner the period of growth between birth and maturity when high rates of cell division and possible further cell differentiation render a child more sensitive to radiation exposure than an adult would be. In addition, this exposure may give rise to genetic effects in children that would not be important in a person beyond the productive age. Similarly, for older people whose life expectancy is short, radiation effects which might appear only after a long time (example: tumor induction) would not be as significant as with younger people.

6.3.3 The Body Part Irradiated

The radiation effects are more severe for irradiation of the upper abdomen than if a body area of similar size elsewhere were exposed to the same dose. The presence of vital organs in the upper abdomen makes this region more sensitive. The recommended dose limits for the general population vary for different body parts. They range from a low of 500 mrem/year to the reproductive organs and red bone narrow to a high of 7500 mrem/year for hands, forearms, feet and ankles.

6.3.4 Extent of the Body Irradiated

Irradiation of a small part of the body surface has much less general effect than an equal dose per unit area delivered to the whole body, since the unirradiated portion of the body can aid in the recovery of the affected part.

6.3.5 Biological Variation

It is possible to determine an average dose which produces certain effects, however; individual responses will vary from those of the average. For example, it required a dose of about 600 rads in a single exposure to kill half a group of rats within 30 days. On the other hand, some of the rats died after 400 rads and some still lived after 800 rads. This is the result of biological variations.

6.3.6 Location of the Radiation Source

The person who works around or othewise comes in contact with radioactive materials may be exposed in two entirely different ways. Radiation from a source outside the body is <u>external radiation</u> and is the most frequently encountered radiation. The second type of exposure is from radioactive material introduced into the body through ingestion, through abrasions or cuts, and by absorption through the skin. The exposure is <u>internal radiation</u>.

It is clear that these two types of exposure consitute separate radiation safety and health problems. Precautions taken against one type will not necessarily be effective against the other. For this reason external and internal radiation will be treated separately in some detail.

6.3.6a External Radiation

There are two commonly known types of external radiation hazards. Both have already been described. The first are the long-range, highly penetrating gamma or X-rays which, consist of very short waves of electromagnetic energy having no mass or weight. The second are the short-range, less penetrating alpha and beta particles, which are tiny particles of matter. Because of their low penetration, alpha and beta particles contribute very little (except skin damage) to the total body effect of external radiation.

It is common to illustrate the waves of energy from gamma or X-rays as a continuous shower of tiny invisible bullets which may penetrate the body to some depth before causing damage. (See Figure 6.2) Such an illustration is an oversimplification of course, but it helps to emphasize the point that it is possible for a gamma or X-ray to penetrate various distances into substances (or all the way through) before it hits anything, because of the empty space between atom particles. When a ray hits one of the electrons which is spinning around the nucleus of an atom, a transfer of energy results (the ionization process). (See Figure 6.2) Ionization can be the cause of complex changes in the body chemistry which results in varying degrees of sickness or death, depending on the amount of exposure.

Neutrons may also produce an external hazard. Neutron logging processes and nuclear reactors are the main neutron sources encountered by Halliburton personnel.

3.3.6b Internal Radiation

The internal radiation exposure problem comes principally from alpha particles. The particles do not present an external radiation hazard because they have relatively short range and cannot penetrate beyond the outer layer of skin. The greatest risk thus comes when such materials are taken into the body.

There are four common ways in which it is possible to get radioactive materials into the body: (1) by breathing; (2) by swallowing (3) through breaks in the skin; (4) by absorption through the skin.

After radioactive elements get into the body the first question to consider is, "How long will they stay in the body?" A high percentage of everything which is inhaled is exhaled immediately. Materials which are swallowed and which are not soluble in the body's digestive system may be discharged rather quickly through the feces. However, if a material is soluble and goes into the blood stream, it will be carried around the body to the various organs. Since the organs are chemical machines, they chemically respond to the materials. If the radioactive materials are rejected chemically by one organ, the blood stream takes them along to another organ where they may or may not be taken in. If no organ accepts the material, the blood takes it to the kidneys and the kidneys dispose of it through the urinary system. When an organ has use for the material, or if the chemicals of the organ react to the radioactive substances as a material, harmful results may come about. The point to remember is that the organs of the body, initially, are reacting chemically to the element which is carrying the radioactivity, and not to the radioactivity itself.

With external radiation, the dose to an individual can be reduced with shielding, distance or shortening of the exposure time. When the radioactive source is inside the body, reduction of the dose is not so simple. Also, the amount of internal radiation necessary to bring about a given effect is much smaller than that required from a external source. This is because that internally radioactive material actually becomes a part of the living tissue.

The effect of internal radiation depends on several factors besides the activity. One of these is the sensitivity to radiation of the organs or tissue to which the material goes. Another factor is the type of energy of the radiation being emitted. This determines the quality factor. The physical and chemical form of the radioactive material also helps to determine its effects. A major factor in the effect of internal radiation is the effective half life (T_E) of the radioactive material. This is the time it takes a person to reduce the amount of radioactive material to one-half the original amount. The effective half life is in turn determined by the biological half life (T_B), which is the time it takes the body to remove one-half of the radioactive material; and the physical half life (T_p), which is the half life of the radioactive material. These three terms are related by the expression

$$1/T_E = 1/T_p + 1/T_B$$

Thus a long-lived radionuclide emitting alpha particles and deposited in bone would be more harmful than an equivalent amount of short-lived radionuclide emitting gamma rays which are not readily absorbed into tissue and do not concentrate in any organ.

6.3.6c Radiation Effects

Biological effects of radiation are divided into two general classes. Somatic effects are those observed only in the person who has been irradiated. Genetic effects are those seen in the offspring of the person who has been irradiated.

Somatic Effects

Cellular response:

The first event in the absorption of ionizing radiation is the production of excited atoms and ion pairs. When these are produced in the chemical systems of a cell, new and possibly harmful chemicals are produced as the original chemical structure of the cell is disturbed by their radiation. Thus toxic materials may be produced. Furthermore, if the radiation affects chromosomal material within the cell nucleus, cell division may be affected. Thus a cell may respond to irradiation by chromosomal changes, cell death before division, failure to specialize, failure to divide completely or slowing of the division rate. In addition, some cells will be unaffected by the radiation.

The cellular response to radiation is determined by a number of factors. Among these are the stage of specialization of the cell, its activity and its division rate. These factors would partially account for the sensitivity to radiation of the embryo as compared to an adult. In the embryo, a small group of cells eventually will specialize or form an organ, so these cells are especially radionsensitive.

The factors also help to make radiation therapy possible. A patient with cancer, for example, receives a number of exposures giving him a large total radiation dose. Through the phenomenon of repair following radiation exposure, the cells begin to repair the radiation damage between exposures. However, the rapidly dividing cancer cells have a greater chance of being destroyed because they are more frequently in the radiosensitive stages of cell division.

Organ sensitivity:

The radiosensitivity of organs and tissues depends on cell multiplication. In the lining of the gastrointestinal tract, for example, some of the cells are mature. These are continuously being discarded and replaced by new cells produced nearby. If a high dose of radioactivity is received, these rapidly dividing cells will be severely decreased in number. If the dose is not too high, the cells still living will be able to replace those destroyed.

If a large dose is given to a small area of the body, the general and local effects will depend on which organ was irradiated. For instance, a large radiation dose to an arm will very likely cause detectable changes in the arm. But it will not result in death or severe damage to the blood-making system because the majority of this system was not exposed to the radiation. On the other hand, a moderate dose of only 30,000 mrads to the small reproductive organs can result in temporary sterility.

Total body doses:

The effects of large sudden whole body doses of radiation are called the acute radiation sickness syndrome. This syndrome consists of nausea, vomiting, general aches and pains and possibly a decrease in the number of white cells. Localized phenomena such as reddened skin or loss of hair may be produced. Larger doses cause weakness, drastic depression of all blood elements and possibly sterility. Exposure of the eyes may cause cataracts. At still higher dose levels, death will probably occur.

Table 6.2 shows the probable results of various massive whole body doses of radiation received over a short time period.

Table 6.2
Effect of Large Whole-Body Doses of Radiation

10,000,000 mrem	Death within hours due to damage to central nervous system
1,200,000 mrem	Death within several days due to damage to gastrointestinal system
600,000 mrem	Death within several weeks due to damage to blood-forming organs
450,000 mrem	50-50 chance of death within 30 days
100,000 mrem	Possible temporary impairment, but probable recovery

It has been shown in animals that high radiation doses cause bodily changes that lead to effects similar to the aging process. It is obviously difficult to obtain such data for humans, but it is probable that some degree of life shortening may occur following high dose exposure.

The effects of long-term, low dose rate exposure must be predicted, since data on such exposure and its effects are nearly impossible to obtain. The problem is complicated because of such low dose effects generally develop years after the exposure and, the same effects may be caused by something other than the radiation. For examples, cancer and leukemia may be long-delayed consequences of a single large exposure and they may also follow chronic exposure. But they are by no means an inevitable result of any form of human exposure to radiation.

Genetic Effects

The term genetic effects refers to the production of mutations, which are permanent transmissible changes in the characteristics of an offspring from those of its parents.

Mutations occur in all living organisms. They may occur of their own accord, apart from any known alternation in the environment. Whatever their origins, most mutations are undesirable. Every individual has some of these undesirable mutations.

Radiation-induced mutations are divided into two classes: gene mutations and chromosomal abnormailities. Most radiation-induced alterations are gene mutations. These tend to be recessive. In other words, the effect of the mutation is not seen in the offspring unless the altered gene is carried by both parents.

Chromosomal abnormalities include chromosome loss and chromosome breaks. These effects are more severe, and the result is usually death of the embryo before birth. This type of genetic effect happens much less frequently than does gene mutation.

6.4 Levels and Symptoms of Radiation Injury

A person receiving radiation injury exhibits symptoms according to the severity of his exposure. Certain terms have come into common usage to designate the "gross" condition of injury and to describe the levels of exposure. Although these terms represent arbitrary groupings and classes, they make up a useful vocabulary for describing the level of injury received and the overall condition of the person irradiated.

Doses of radiation are classified accordingly:

6.4.1 Mild Dose

A small dose of radiation which produced no detectable clinical effects on the body is considered extremely mild. Such a dose would hardly ever exceed 25 rem, although it might range to 50 rem. Slightly higher doses may produce some changes of temporary nature in certain body cells, and may possibly produce delayed symptoms. However, it is improbably that serious effects would result to the average individual, and this is the criteria used for classifying such dosages as mild.

6.4.2 Moderate Dose

Acute exposure with doses ranging from 50 to 200 rem are classed as moderate. When this dose is received there are almost always observable phenomena, although the injury may vary from very slight to serious. The important criterion in classifying a radiation effect as moderate is that there be some but not excessive permanent damage. At the lower limit of moderate exposure, symptoms include blood cell changes, swelling, increased acidity and granularity of the protoplasm, crumbling of chromosomes, and halting of cell division. At the upper limits of moderate exposure symptoms include nausea, vomiting, malaise, and possible changes in the blood. When dosages approach 200 rem, symptoms increase to include epilation (loss of hair), loss of appetite, sore throat, pallor, diarrhea, and moderate emaciation. These symptoms occur after a latent period of about one week (sometimes longer).

Recovery from moderate doses of radiation is likely unless complications related to poor health, injuries, or infections set in. However, delayed effects of moderate doses may shorten life expectancy as much as one percent and a few individuals may die within two to six weeks after exposure.

6.4.3 Strong Dose

When acute exposure results in a dosage from 200 to 600 rem it is classified as a strong dose. The median lethal Dose, the dose for which 50% are expected to die, is 450 rem. Injury and disability are certain at higher exposures. Symptoms include nausea and vomiting in one to two hours, followed by a latent period of perhaps as long as a week. After this period epilation, loss of appetite and general malaise accompanied by fever, are characteristic. Severe inflammation of mouth and throat usually occurs near the third week. The fourth week brings on a pallor, petechiae, diarrhea, nose bleed, rapid emaciation, and related symptoms. At the level of the body cell, reproduction (cell division) is permanently affected. General disability may be accompanied by drastic changes in the blood picture, including abnormalities in the red and white cells, platelets, and hemoglobin. It is also probable that intractable anemia will develop, that sterility will result, and that cataract formation will take place. Epilation will be permanent, and many skin changes will take place, with the possible malignant degeneration of some cells accompanied by cancer formation.

6.4.4 Lethal Dose

An acute exposure of 600-800 rem or more to the whole body of man is considered a lethal dose. Symptoms are nausea and vomiting in one to two hours, then a short latent period of about a week following which there is diarrhea, vomiting, and inflammation of mouth and throat. As early as the second week, fever and rapid emaciation occur with the probability of death.

6.5 Common Terms of Reference for Gross Effects of Radiation Injury

6.5.1 Radiation Sickness

This is a condition produced when a massive overdose of penetrating external gamma radiation is received. Its symptoms are nausea, vomiting, diarrhea, malaise, hemorrhage, and a lowering of the body's resistance against disease and infection. If the irradiation is serious enough it can cause death.

6.5.2 Radiation Injury

Radiation injury is the second term commonly used to describe symptoms of radiation exposure and consists of localized injurious effects. Injury is most often to the hand because contact is usually made with the hands. This type of sickness is recognized when injuries not unlike burns occur along with loss of hair and skin lesions. Genetic damage is also a form of radiation injury which is usually permanent in nature.

6.5.3 Radioactive Poisoning

Radioactive poisoning is illness resulting when dangerous amounts of certain types of radioactive materials enter the body. Alpha emitters are termed radiopoisons.

6.5.4 Chemical Poisoning

Results when radioactive materials enter the body.

6.6 Summary of Biological Effects of Radiation (See Table 6.3)

The biological effects of radiation were summarized by the Federal Radiation Council in a report to the President dated May, 1960. It is apropos to quote the nine points made in this report as a summary of the levels and symptoms of effects of radiation on man.

(1) Acute doses of radiation may produce immediate or delayed effects, or both.
(2) As acute whole body doses increase above 25 rems, immediate observable effects increase in severity with dose, beginning with barely detectable changes to biological signs clearly indicating damage or death at levels of a few hundred rem.
(3) Delayed effects produced either by acute irradiation or by chronic irradiation are similar in kind, but the ability of the body to repair radiation damage is usually more effective in the case of chronic rather than acute irradiation.
(4) The delayed effects from radiation are, in general, indistinguishable from familiar pathological conditions usually present in the population.
(5) Delayed effects include genetic effects (effects transmitted to succeeding generations), increased incidence of tumors, lifespan shortening, and growth and development changes.
(6) The various organs of the body differ in their sensitivity to radiation.

(7) Although ionizing radiation can induce genetic and somatic effects (effects on the individual during his lifetime other than genetic effects), the evidence at the present time is insufficient to justify precise conclusions on the nature of the dose-effect relationship at low doses and dose rates. Moreover, the evidence is sufficient to prove either the hypothesis of a "damage threshold" (a point below which no damage occurs), or the hypothesis of "no threshold" in man at low doses.

(8) If one assumes a direct linear relation between biological effect and the amount of dose, it then becomes possible to relate very low dose to an assumed biological effect even though it is not detectable. It is generally agreed that the effect that may actually occur will not exceed the amount predicted by this assumption.

Table 6.3
Effects of Whole-Body Doses of Radiation

Term	Range	Type Damage	Symptoms	Recovery
Occupational Dose	0 - 5000 mrem	none	none	definite
Mild Dose	25,000 - 100,000 mrem	minor body cell changes	undetectable	definite
Moderate Dose	100,000 - 300,000 mrem	blood cell reduction, swelling of tissue, protoplasm acidity & granularity, chromosome aberation	nausea, vomiting, malaise, epilation sore throat, pallor,	most probable
Strong Dose	300,000 - 600,000 mrem	Same as Moderate Dose, more severe	Same as Moderate Dose, more severe	50 -50 chance of death
Lethal Dose	600,000 + mrem	Same as Moderate Dose, more severe	Same as Moderate Dose, more severe	Very probable

Table 6.4
RULE OF THUMB MEDICAL RADIATION EXPOSURES
(Values will vary widely with Hospital/Doctor)

Complete GI Series	2 RADS/REMS	2,000 mREM
Typical Chest X-ray	.1 - .2 RADS/REMS	100-200 mREM
Cobalt treatment for lung cancer	500 RADS/REMS each	500,000 mREM

6.7 Personnel Monitoring

The human senses-hearing, seeing, tasting smelling and touch cannot detect ionizing radiation. Radiation penetrating the body causes no pain and a person can be injured severely without realizing he is in danger. To overcome this condition it is necessary to provide radiation detecting and measuring devices to determine body exposures. To prevent undue body damage the exposure must be limited. Permissible exposure limits have been established by regulatory agencies such as the Nuclear Regulatory Commission and certain State health departments. These limits are rigidly enforced.

NRC Exposure Limits

Whole Body	1.25 rem/qtr. year *3.0 rem/qtr. year (if whole body exposure is complete, over 18 years of age, and not exceeding 5 (N-18)
Skin of Whole Body	7.5 rem/qtr. year
Extremities	18.75 rem/qtr. year

*Individuals less than 18 years old are not to exceed 10% of the above specified limits.

The hands and forearms logically are likely to be exposed to more radiation than other parts of the body in an occupational situation. It is permissible for the hands and forearms to receive considerably more radiation under NRC regulations because of their known resistance to radiation injury.

Occupational exposure may not start before age eighteen. At any age beyond 18 years, the exposure limit is equal to five times the number of years over age 18, provided no annual increment exceeds 12 rems. Thus, exposure of personnel in restricted areas = 5(N - 18), where N = a person's age in years.

Bank Account (rems)

	Age	Deposits (Permissible Dosage Accumulation)	Withdrawals (Dose Received)	Balance
1. a. 5yrs. x 5 rem/yr.	23	25		25
2. a. 1st year at work			-12	13
b. 6th year over Age 13	24	+5		18
3. a. 2nd year at work			-12	6
b. 7th year over Age 18	25	+5		11
4. a. 3rd year at work			-12	-1
b. 8th year over Age 18	26	+5		4
5. a. 4th year at work			-12	-8
b. 9th year over Age 18	27	+5		-3
6. a. 5th year at work			0	
b. 10th year over Age 18	28	+5		+2

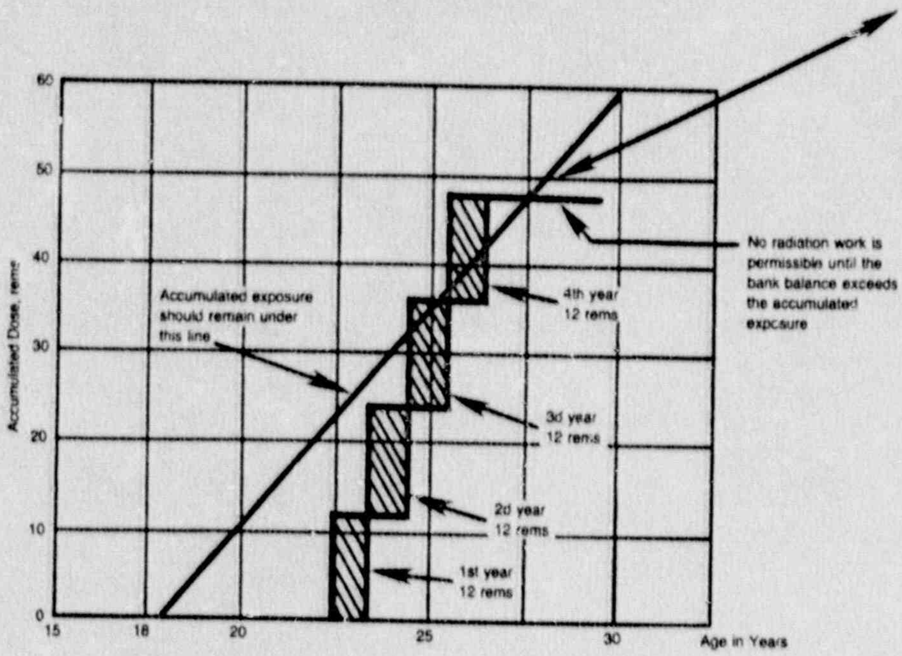


Figure 6.3 - Radiation "Banking" Concept for Radiation Workers

6.8 Instrumentation

The common types of personnel monitoring instruments currently used to measure accumulated gamma radiation exposures are the film badge, TLD, the pocket chamber, and the direct reading dosimeter. These types of monitoring devices have been described in Chapter 5.

Survey meters, paragraph 5.4, are used to survey the radiation fields to determine the radiation intensities. These measurements will give information required for calculating personnel residence time in radiation areas.

MS-16

T2

Route 3, Box 247Q
Duncan, Oklahoma 73533

July 25, 1987

RECEIVED
AUG - 5 1987

United Stated Nuclear Regulatory Commission
Region IV
Nuclear Materials Licensing Section
611 Ryan Plaza Drive
Suite 1000
Arlington, Texas 76011

ATTENTION: Mr. Charles L. Cain, Chief

Re: Control No. 461306; Response to correspondence dated June 15, 1987.

Dear Mr. Cain:

This correspondence is in response to your above referenced correspondence and will assume the same format as the referenced correspondence.

Prior to preparing this response, it has been evident that all correspondence and mailing received from U.S. NRC has been addressed to "Oklahoma Tracers, Inc.". It is requested that "OK Tracers" also be approved for this license.

1. Training program for "Logging Supervisors" and "Logging Assistants" as defined in 10 CFR 39.2.

   a. The individual that will be conducting all of the training, both classroom and on-the-job will be Dan G. Kelly. A resume' for him is presently on file with NRC. Mr. Kelly worked for Halliburton Services from 1955 to 1986. During that time he worked with research and field activities performed by the Company under Radioactive Materials Licenses 35-00502-02, 35-00502-03 and 35-00502-04G, and earlier license numbers. From 1965 to 1974 Dan Kelly supervised the same activities and in 1974 was named Radiation Safety Officer under these license and coordinated all activities under these licenses until retirement in 1986.

   b., c. & e. The course outline will be followed for instruction to "Logging Supervisors", "Logging Assistants" and individuals with previous well logging training (not provided by OK Tracers). The training will consist of a minimum of 40 hour classroom instruction. Verification of competency by written examination will be the same for all three categories. See Attachments #1 and #2 for the course outline and course written examinations.

Copy sent to DCS

461306

d. See Attachment #3 for the "Field Performance Evaluation". It is a check list used by the RSO observing the performance of the Logging Assistants and Logging Supervisors. The field evaluation will be repeated until all points are performed correctly. No individual (Logging Supervisor or Assistant) will be permitted to perform tracer injections without the presence of the instructor until they have successfully completed the classroom and field performance evaluation.

f. Attachment #3 "Field Performance Evaluation" will be used as a guide for an Annual Safety review of all Logging Supervisors and Logging Assistants. The review will be conducted by the Radiation Safety Officer, Dan G. Kelly.

2. a. The radioactive waste to be held for decay will come from both the tracer operations and manufacturing process. All concentrated liquid of solid waste will be held indefinitely and separate from all other waste. There will be no commercial waste collection, only what is generated by OK Tracers. It is not fully understood what is meant by "inventory of waste", but no more than licensed quantities of any or all licensed isotopes will be held in stock or as waste simultaneously. If at any time the estimated inventory exceeds this figure it will be reduced by shipping the excess to a commercial facility.

b. Controls for Environmental Pollution, Inc. will perform assays for all isotopes on randomly selected weight percentage portions of a drum of rad waste, only if the rad waste exceeds background surface readings as measured or surveyed by a Ludlum Model 14C using a Ludlum Model 44-7 GM probe and confirmed with a Model 14C using a Ludlum Model 44-2 NaI probe. Controls for Environmental Pollution, Inc. will analyze for all licensed isotopes and provide the results in microcuries per gram. These figures will be used to compute the total isotope content of the drum. If nothing unusual is found the drum will be held for further decay. If necessary the drum of waste will be disposed of by shipping to a licensed disposal or holding facility.

At the end of the holding period (10 half life minimum) the drum of rad waste will be surveyed by taking surface readings, completely covering the entire outer surface of the drum and through the center of the drum (see response 2.c.). The survey will be performed using a Ludlum Model 14C survey meter with a Model 44-7 GM probe and confirmed using a Model 14C with a Model 44-2 NaI probe. Survey meter readings equivalent to background will be considered non-radioactive and be treated as trash. Any drum having readings exceeding background will be retained in storage for further decay or sampled and submitted to Controls for Environmental Pollution, Inc. as described in the preceding paragraph.

c. The drums used for waste storage will be ring-sealed and of fifty-five gallon capacity. The drums will be plastic lined to help control contamination. A thin walled plastic tubing, having a diameter sufficient to accept a survey meter probe, will be placed in the center of the drum. The tubing will extend from the bottom to the top of the drum. This open-ended tubing will be used to permit interior surveys at the end of the holding period.

Rad waste will be physically dumped by hand into the drum from the container in which it was temporarily stored or transported. A heavy headed, long handled steel mallet will be used to compact the waste within the drum. No mechanical compaction will be used without future NRC approval. When the drum is full it will be ring-sealed, labelled and dated for storage.

The operator performing the rad waste transfer and compaction will wear protective clothing consisting of disposable gloves and apron or coveralls. A respirator will be worn to prevent dust inhalation.

d. The following record or records will be maintained for each drum placed in rad waste storage and ultimately disposed of. These records will be kept on file until NRC permits their disposal.

1. Numbered as indicated on drum and lid.
2. Date placed in storage.
3. Complete list of all radioisotopes. The radioisotope having the longest half life will be used for determining the holding period.
4. The approximate weight of the drum and the contents.
5. An estimate of the quantity (microcuries) of each isotope.
6. The initial survey performed on the outer surface and interior of the drum.
7. The final and any intermittent surveys performed on the drum.
8. A description of the instrumentation and the calibration date used for each survey.
9. The date of disposal of the waste.
10. An accurate description as to where the disposal was made.
11. Each and every document pertaining to the drum will be dated and signed by the Logging Supervisor or RSO.

3. It is our understanding that well-to-well injections for secondary recovery operations such as well flooding require individual license amendments based on pertinent data and characteristics. OK Tracers will not perform such injections without amendments and permission of NRC and/or local Agreement State.

4. The following survey instruments will be used for monitoring and physical surveys at each temporary well site where tracer is used.

a. Model 14C, Ludlum Measurements, Inc., Sweetwater, Texas.
b. Model 44-7 GM probe, Ludlum Measurements, Inc., Sweetwater, Texas.

c. Model 44-2 NaI probe, Ludlum Measurements, Inc., Sweetwater, Texas will be used as a backup.
d. Model 2, Ludlum Measurements, Inc., Sweetwater, Texas.

These instruments are presently ready for use and will be used at every temporary well site. However, several manufacturers make comparable instrumentation and OK Tracers has no desire to be confined to a single manufacturer.

The survey meters will be calibrated by one of the following licensed firms.

a. Ludlum Measurements, Inc., Sweetwater, Texas (Texas license).
b. Gulf Nuclear, Inc., Houston, Texas (Texas license).
c. Nuclear Sources and Services, Inc., Houston, Texas (Texas license).
d. W. H. Henken Industries, Arlington, Texas (Texas license).

5. The annual inspections of the job performance for each Logging Supervisor will be performed by the RSC, Dan G. Kelly and will include all items on Attachments #2 "Radiation Training Quiz Questions" and #3 "Field Performance Evaluation". These documents will be dated and signed by the RSO and maintained on file for at least three years to maintain compliance with 10 CFR 39.13(d).

6. The NRC emergency telephone numbers in Section 10.1 of the OK Tracers draft of the "Operations and Procedures Manual" have been corrected as indicated in your referenced correspondence. The final publication will show the correct numbers.

7. The word "Halliburton" in Section 8.1(c) of the manual has been corrected to "Oklahoma Tracers" and will be reflected in the final draft.

8. Licensed material will be stored and used only at the facility in Duncan, Oklahoma. If additional locations become necessary in the future, an amendment request will be made prior to establishment and use of the location.

9. Please amend the original application for amendment dated November 12, 1986, Section 8.7.14(A) to read; "No disposal of any material for which there is detectable activity, as measured by a survey meter, will be made".

Sincerely,

Dan G. Kelly

DGK/cdo
Attachments

ATTACHMENT #1
TRAINING COURSE OUTLINE

I. Structure of Matter — 2 hours

A. Atomic number of the elements

B. Isotopes of the elements
1. Protons
2. Neutrons
3. Electrons
4. Non radioactive isotopes
5. Radioactive isotopes

C. Periodic Table of the Elements

II. Radiation — 2 hours

A. Units of Radioactivity

B. Kinds of radiation
1. Alpha
2. Beta
3. Gamma
4. X-ray
5. Neutron

C. Properties of Radiation
1. Mass
2. Change
3. Description
    a. Particle
    b. Electromagnetic
    c. Electron
    d. Helium Nucleus
4. Energy ranges
5. Travel speeds
6. Travel distances

D. Electromagnetic spectrum
1. Frequency
2. Wavelength
3. Speed
4. Wave motion

III. Nuclear Reactions — 2 hours

A. Nuclear reactions
1. Alpha decay
2. Beta decay
3. Gamma ray

B. Units of Activity
   1. Curie (Becquerel)
   2. Disintegrations
   3. Subdivisions

C. Decay
   1. Uranium-238
   2. N=Noe
   3. Half Life
      a. Decay constant
      b. Various isotopes

IV. Interaction of Radiation with Matter — 4 hours

A. Ionization of Ions
   1. Electrical changes
      a. Positive
      b. Negative
      c. Electrical balance

B. Particles causing ionization
   1. Ionpairs
   2. Electron volt
   3. Effects of speed, mass and charge

C. Ionization by Electromagnetic Radiation
   1. Gamma
   2. X-ray
   3. Penetration
   4. Energy transfer
      a. Photo-electrical absorption
      b. Compton scattering
      c. Pair production

D. Roentgen (coulomb/kg) (c/kg)
   1. Measures effects on air
   2. Ion pairs per cc
   3. Electrostatic unit
   4. Dose rate
      a. r/hr
      b. Subdivisions
   5. Dose rate Constants
   6. Inverse Square Law

E. Radiation Absorption
   1. Alpha particles
   2. Beta particles
   3. Gamma ray
   4. X-ray
   5. $I = Ioe^{-ut}$
   6. Absorption coefficients

F. Half-Value layers (HVL)
1. $HVL = \frac{0.693}{\mu}$
2. Thickness
3. Density
4. Scattering
5. Buildup
6. Reduction factors
7. Reduction by shielding

G. Principles of Radiation Safety
1. TIME
2. DISTANCE
3. SHIELDING
4. Personnel exposure time
5. Working distances
6. Use of shielding

V. Radiation Detection and Measurement — 8 hours

A. Detection
1. No human sensors
2. Instruments

B. Measurement (Instruction and Hands-on)
1. Dose
2. Dose rate
3. Roentgen
4. Dosimeters
5. Film Badges
6. Thermoluminesent Dosimeter (TLD)
7. Survey meters
8. Ionization Chamber Instruments
9. Geiger Counters and probes
10. Scintillation detectors
11. Instrument characteristics

VI. The Nature and Consequences of Radiation Exposure — 4 hours

A. Radiological Health
1. Visual display of body injury from mishandling
2. Exposure in U.S. from natural sources
3. Background radiation

B. Measurement units of radiation doses
1. Roentgen
2. Rem
3. Rad
4. RBE

C. Effects of ionizing radiation on health
1. Dose rate effects
2. Age
3. Body part
4. Extent of body irradiated

5. Biological variation
6. Location of radiation sources
    a. External radiation
    b. Internal radiation
    c. Radiation effects
7. Somatic effects
    a. Cellular response
    b. Organ sensitivity
    c. Total body doses
8. Genetic effects

D. Levels and symptoms of radiation injury
1. Mild dose
2. Moderate dose
3. Strong dose
4. Lethal dose
5. Radiation sickness
6. Radiation injury
7. Radioactive poisoning
8. Chemical poisoning

E. Summary of effects
1. Acute
2. Chronic
3. Latent effects
4. Damages
5. Type damage
6. Symptoms
7. Recovery

F. Personnel Monitoring
1. NRC Exposure limits
2. Administrative limits
3. ALARA
4. Back account concept
5. Instrumentation

VII. Tracer Services — 4 hours

A. Introduction

B. Radioactive propping agents

C Tracer sand and other props

D. Iodine-131

E. Scandium-46

F. Iridium-192

G. Gold-198

H. Lanthanum 148

I. Zirconium-Niobium 95

J. Sodium 24

K. Silver 110^m

L. Iron 59

M. Cobalt 60

N. Zinc 65

O. Miscellaneous isotopes

P. Applications
   1. Cementing
   2. Fracturing
   3. Fluid tracing
   4. Downhole markers
   5. Formation markers

VIII. Standard Procedure for Handling Radioactive Materials 4 hours

A. Assignment of responsibility
   1. RSO
   2. Logging Supervisor or Logging Assistant
   3. Qualification
      a. Classroom - 40 + hours
      b. On-job - Approximately 3 months

B. Procedure for performing radioactive services
   1. Part 19
   2. Part 20
   3. Part 39
   4. Operating procedures
   5. Emergency procedures
   6. Licenses and license conditions

C. Personnel monitoring procedures
   1. Survey meter
   2. TLD
   3. Radioactive treatment report entries

D. Records (maintained at office)
   1. Radioactive treatment reports
   2. Personnel exposure reports
   3. Parts 19, 20 and 39 of 10 CFR
   4. License and amendments
   5. Notices to employees
   6. Operating and emergency procedures
   7. Radiation survey instrument calibration records
   8. Physical inventory
   9. Storage records
   10. Radioactive treatment reports (utilization records)

11. Inspection records
12. Training records
13. Survey records
14. Violation records
15. Violation notice response
16. Occupations external radiation exposure histories
17. Shipping documents
18. All related correspondence

E. Field handling of radioactive material
   1. Determine nuclide needed
   2. Order isotope
   3. Receiving procedures
   4. Storing procedures
   5. Removal from storage
   6. Transporting isotope
   7. Transport surveys
      a. Pre transport
      b. Post transport
      c. In transit
   8. Shipping document
   9. Pre-use survey at job-site
   10. Operator protection
   11. Establishing radiation area
   12. Injection
   13. Control of waste and contaminated materials
   14. Post-use survey
   15. Transportation to office and storage
   16. Disposition of waste and unused isotope
   17. NO SMOKINC, EATING OR DRINKING
   18. Preparation of waste for storage handling

F. Job-site decontamination procedures
   1. Isolation of area
   2. Containment or abatement procedure
   3. Survey, physical
   4. Personnel clothing
   5. Prevention of cross contamination
   6. Clean up procedures
   7. Waste containment and disposition
   8. Verification by survey
   9. Verification by assay when necessary
   10. Reporting
   11. Follow up procedures

IX. Packaging, Transporting and Storing Tracers 4 hours

A. Receipt of package containing isotope
   1. Pickup
   2. Securing
   3. Monitoring during opening
   4. Liquid receipts
   5. Wipe tests and physical surveys
   6. Records

B. Packaging requirements
   1. DOT 7A containers
   2. Markings
   3. Labels
   4. Shipping papers
   5. Storing in containers

C. Vehicle placarding

D. Security during transport

E. Storage facilities
   1. Design
   2. Security against unauthorized entry
   3. Proper signs
   4. Inventory control records
   5. Periodic surveys
   6. Wipe tests as necessary
   7. Reports

X. Emergency Instructions — 2 hours

A. Emergency assistance
   1. RSO
   2. NRC

B. Procedures to be followed in case of spillage

C. Procedures to be following in case of fire

XI. TLD Badge Monitors — 1 hour

A. RSO will assess need and order

B. Transfers

C. Terminations

D. Exchanging insert

E. Return used insert

F. Control badge

G. Exposure report

H. Lose of TLD

I. Instruction for wearing TLD

XII. Record Maintenance 8 hours

A. License

B. Operating and emergency procedures

C. Regulations for control of radiation
1. Title 10 CFR Part 19
2. Title 10 CFR Part 20
3. Title 10 CFR Part 39
4. Part 39.61 (6 hours)

D. Notice of violations

E. Corrective action letters

F. Personnel training records

G. Personnel exposure records

H. Employee termination or transfer notice

I. Employee over exposure reports

J. Lost/damage TLD reports

K. Radioactive treatment reports

L. Disposal records

M. Storage records

N. Material transfer reports

O. Physical Inventory records (6 months)

P. Inspection records

Q. Survey records

R. Annual employee testing and evaluation results

S. Survey meter calibration records

T. Bioassay records

XII. Bioassays 1 hour

A. Iodine 131 50 mCi level

B. Precautions

C. Urine sampling

D. Sample handling and shipment

E. Bioassay results

F. Response

XIII. Radioactive Treatment Report (RTR) 2 hours

A. Must be taken in transport to job-site

B. Prior to job-site
1. Well information
2. Material record
3. Survey meter data
4. Vehicle survey
5. Passenger area survey
6. Badge (TLD) number and identity

C. Emergency information

D. Isotope used

E. Isotope quantity

F. Isotope procurement

G. Disposition of unused material

H. Type of service performed

I. Exposure data

J. Pre job survey

K. Post job survey

L. Vehicle survey (post job)

M. Physical radiation survey of delivery vehicle

N. Survey of job area during injection

O. Signature and TLD badge number

P. Date of injection

ATTACHMENT #2
RADIATION TRAINING QUIZ QUESTIONS

1. The unit of activity is:

   A. millroentgen
   B. millirem
   C. millirad
   D. millicurie

2. Iodine 131 emits what type(s) of radiation:

   A. Gamma Rays and X-Rays
   B. Beta and Gamma
   C. Alpha and Gamma
   D. Beta and Alpha

3. Iridium 192 emits what type(s) of radiation:

   A. Gamma and Alpha
   B. Neutron and Gamma
   C. Protons and Electrons
   D. Gamma and Beta

4. The half-life of Iodine 131 is approximately:

   A. 75 days
   B. 8 days
   C. 84 days
   D. 30 years

5. The half-life of Iridium 192 is approximately:

   A. 75 days
   B. 8 days
   C. 84 days
   D. 30 years

6. The half-life of Scandium 46 is approximately:

   A. 75 days
   B. 8 days
   C. 84 days
   D. 30 years

7. Which of the following isotopes can be used by OK Tracers for tracer studies:

   A. Iridium 192
   B. Iodine 131
   C. Scandium 46
   D. All of the above

8. If at one foot the reading from an unshielded can of Iridium 192 tagged sand was 59 mR/hr, how far would you need to retreat to be at the 2 mR/hr level?

   A. 4 feet
   B. 5 feet
   C. 5.3 feet
   D. 7.1 feet

9. The inverse square law proves that if you increase your distance from a radioactive source your exposure will decrease substantially.

   True or False

10. What is the quarterly allowable whole body dose?

   A. 3 Rem
   B. 1.25 Rem
   C. 5,000 mRem
   D. 400 mRem

11. The instrument used to detect an ionization radiation exposure rate is the:

   A. Geiger Counter
   B. TLD
   C. Pocket Dosimeter
   D. None of the above

12. Beta particle radiation is denoted as a skin dose on the personnel monitoring reports.

   True or False

13. Gamma radiation is denoted as a whole body dose on the personnel monitoring report.

   True or False

14. Personnel monitors (TLD) are exchanged:

   A. quarterly
   B. monthly
   C. semi-annually
   D. annually

15. The three principles of radiation protection are ______, ________ and __________.

16. When using liquid Iodine 131 at what activity level would a bioassay be required?

    A. 10 mCi
    B. 25 mCi
    C. 50 mCi
    D. 5 mCi

17. What type of sample must be given for a bioassay?

    A. urine
    B. feces
    C. blood
    D. none of the above

18. Gamma rays are energy packets known as photons.

    True or False

19. Geiger counters must be calibrated at what frequency?

    A. annually and after servicing
    B. quarterly and after servicing
    C. monthly and after servicing
    D. semi-annually and after servicing

20. Name two sources of naturally occurring radioactivity. __________ and __________

21. Sealed sources are to be leak tested every

    A. six months
    B. year
    C. 18 months
    D. 3 years

22. The storage location should be posted with signs that state "________________________".

23. What type of protective clothing must be worn when handling tracer radioactive material (bare minimum)?

24. Empty containers may be disgarded at the job-site in the waste or reverse pit.

    True or False

25. A radioactive Yellow II label may have a maximum exposure rate at 3 feet of:

    A. 1 mR/hr
    B. 10 mR/hr
    C. 100 mR/hr
    4. none of the above

26. The radioactive treatment report must be completed "as you go" or as readings are taken.

True or False

27. The source of radiation in the instrument calibrater is:

A. Iridium 192
B. Iodine 131
C. Cesium 137
4. Radium 226

28. When radioactive material is on something, that item is said to be ____________.

29. The unit of exposure (radiation dose) is the

A. Roentgen
B. Rem
C. Rad
D. Curie

30. Liquid spills should be cleaned by:

A. blotting
B. wiping
C. diluting
D. evaporation

31. All spills must be cleaned to a removable exposure rate of:

A. 0.1 mR/hr
B. 2 mR/hr
C. below background
D. none of the above

32. Readings from naturally occurring sources of radiation constitute ____________.

33. If you are involved in an accident on the highway and transporting radioactive material you should:

A. check for injuries
B. check the radioactive material container
C. send someone for assistance if it is needed
D. secure the area if a radiological hazard exists
E. all the above

34. Radiation damage to the body is accumulative.

True or False

35. When "Yellow III" labeled containers are transported it is necessary to use "Radioactive" placards on all 4 sides of the transporting vehicle.

True or False

36. Tongs or other handling tools do not need to be used when only handling 1 or 2 cans of Iridium 192 tagged sand.

True or False

37. MATCHING

___	Iodine 131 (liquid)	A. Substitute to Iridium 192
___	Iridium 192 (tagged sand)	B. Used to tag frac proppant
___	Scandium 46	C. Good for cement squeeze tag
___	Iron 59	D. Cement Plug Marker
___	Cobalt 60	E. Collar Markers
___	Iodine 131 (tagged sand)	F. Used to tag formation
___	Iridium 192 (liquid)	G. Used in minifracs

38. Radioactive placards are required on the transport vehicle when transporting containers having the following Label(s).

    A. Radioactive White I
    B. Radioactive Yellow II
    C. Radioactive Yellow III
    D. All of the above

39. Survey instrument calibration records must be retained on file for what period of time?

40. Physical inventories to account for all licensed material received and possessed must conducted at what frequency?

    A. Monthly
    B. Quarterly
    C. Semiannually
    D. Annually

41. Personnel monitoring records must be retained on file for what period of time?

    A. Six Months
    B. Three Years
    C. Five Years
    D. Indefinitely

42. Documents and records required at temporary job-sites when performing a tracer study include:

    A. Operating and emergency procedures
    B. The latest survey instrument calibration records
    C. The latest survey records of transport and job-site
    D. Shipping papers
    E. Any reciprocity agreements
    F. All of the above
    G. None of the above

43. The Logging Supervisor can leave a temporary job-site once it is known that the pumping operation is proceeding safely.

True or False

44. Physical radiation surveys and monitoring at the temporary job-site (well location) are required as follows:

    A. Before the job is started
    B. During the job
    C. After the job
    D. All of the above
    E. None of the above

45. Physical inventory for accounting for the receipt, possession and use of licensed material must include:

    A. Quantity of isotope
    B. Identity of isotope
    C. Location of isotope
    D. Date of inventory
    E. Name of person doing inventory
    F. None of the above
    G. All of the above

46. The OK Tracers Material License permits the injection of licensed isotopes into fresh water aquifers.

True or False

47. Tell in your own words what "ALARA" means.

48. Which of the following protective clothing are required when transferring waste to a drum for storage?

A. Apron or Coveralls
B. Gloves
C. Respirator
D. None of the above
E. All of the above

50. A survey meter must be capable of measuring 0.1 to 50 milliroentgens per hour.

True or False

51. Match the following:

A.	Curie	A.	Coulomb/kg
B.	REM	B.	Becquerel
C.	Roentgen	C.	Sievert
D.	RAD	D.	Gray

52. Units of radioactivity are measured in terms of:

A. Rad
B. Rem
C. Roentgen
D. Curie

53. Licensed materials can be disposed of by incineration.

True or False

54. Any loss or theft of licensed material must be reported by telephone immediately and by written report within 30 days to U.S. NRC.

True or False

55. Form NRC-3, "Notice to Employees" must be posted in an obvious place along with a copy of the license, operating and emergency procedures, notices of violations, and licensees violation response:

True or False

Fifty of the above fifty-five questions must be completed corre[illegible]ly for qualification as a Logging Supervisor.

Signature of Trainee

Signature of RSO

Date:

RADIATION SAFETY QUIZ ANSWERS

1. D. millicurie
2. B. Beta and Gamma
3. D. Gamma and Beta
4. B. 8 days
5. A. 75 days
6. C. 84 days
7. D. All of the above
8. C. 5.3 feet
9. True
10. B. 1.2 Rem
11. A. Geiger counter
12. True
13. True
14. A. Quarterly
15. Time, Distance, & Shielding
16. C. 50 mCi
17. A. Urine
18. True
19. D. Semiannually & after servicing
20. Thorium & Uranium
21. A. Six months
22. Caution Radioactive Materials
23. Gloves
24. False
25. A. 1 mR/hr
26. True
27. C. Cesium-137
28. Contaminated
29. B. Rem
30. A. blotting
31. D. None of the above
32. Background
33. E. All of the above
34. True
35. True
36. False
37. C., B., A., D., E., G., F.
38. C. Radioactive Yellow III
39. 3 years
40. C. Semi-annually
41. D. Indefinitely
42. F. All of the above
43. False
44. D. All of the above
45. G. All of the above
46. False
47. Exposure & rad levels must be kept as low as possible within economic reason.
48. E. All of the above
49. Omitted
50. True
51. A.-B., B.-C., C.-A., D.-D.
52. C. Roentgen
53. False
54. True
55. True

ATTACHMENT #3
FIELD PERSONNEL EVALUATION

1. Removal of tracer material from storage
   a. Use of protective disposable gloves
   b. Make appropriate entries on Storage Inventory
      i. Quantity of isotope
      ii. Identity of isotope
      iii. Date
      iv. Signature
   c. Secure storage

2. Preparing shipment for transportation
   a. Survey of transport vehicle before loading
   b. Secure cargo
   c. Apply placards
   d. Perform transport vehicle surveys
      i. Exterior surface readings
      ii. Passenger area readings
      iii. Make appropriate data entries
   e. Make proper disposal of gloves after loading

3. Transport to well location
   a. Prepare "Shipping Paper"
   b. Security during transportation
   c. Security during stops
   d. Security at well site

4. Prejob radiation surveys
   a. Job area
   b. Well head
   c. Waste pit
   d. Personnel/clothing
   e. Equipment
   f. Make appropriate data entries

5. Setting up for Injection
   a. Proper protective clothing
   b. Connection of Injection device
   c. Checking for leaks prior to adding isotope
   d. Preparing isotope for injection

6. Injection
   a. Communication with Service Company Supervisor
   b. Check for leaks
   c. Perform area surveys periodically
   d. Record data
   e. Isotope transfer and containment at end of job

7. Post job Radiation Surveys
   a. Job area
   b. well head
   c. waste pit
   d. Personnel/clothing
   e. Equipment
   f. Appropriate data entries

8. Transport for return to camp
   a. Load and secure unused isotope if necessary
   b. Load and secure injection equipment
   c. Perform vehicle survey
   d. Perform survey in passenger area
   e. Connect or make new shipping papers
   f. Contain disposable clothing
   g. Make appropriate data entries
   h. Security of isotope during trip

9. Return to Storage
   a. Return unused isotope to storage
      i. Use appropriate clothing
      ii. Disposal of clothing
      iii. Enter data on storage inventory sheet
   b. Decontaminate injection equipment if necessary
      i. Use appropriate clothing
      ii. Disposal of dry wipes and clothing
      iii. Secure against unauthorized removal

10. Complete "Radioactive Treatment Report".

11. Comments of Logging Supervisor or RSO:

____
Signature of Trainee

Date:

____
Signature of RSO

OK indicates all was well
X indicates advise necessary
I.P. indicates inadequate performance

The individual trainee must perform all functions with everything indicated OK by the RSO before permitted to perform tracer studies without supervision.

The same form will be used and completed by the RSO for annual performance evaluations of the "Logging Supervisors".

The individual undergoing annual evaluation must be advised that their performance is being evaluated and that incompetency will require dismissal.

RECEIVED
NOV 24 1986

November 12, 1986

Mr. Jack Whitten
Nuclear Materials Safety Section
United States Nuclear Regulatory Commission
Region IV
611 Ryan Plaza Drive
Suite 1000
Arlington, Texas 76011

RECEIVED
'86 NOV 26 A10:45
U.S. NRC FEE MGMT. BRANCH

Re: Amendment request to Radioactive Materials License Number 35-21353-01.

Dear Mr. Whitten:

The above referenced license is strictly for the manufacturing, processing and distributing of radioactive materials as stated in Item 9, Authorized Use. The purpose of this correspondence is to request that Item 9, Authorized Use be amended to include the actual use of the licensed isotopes for tracer studies in oil and gas wells at any location within the United States where the U.S. Nuclear Regulatory Commission has jurisdiction.

To support this amendment request an operational and emergency manual, which is also used for personnel training, is attached for your examination and filing. The procedures within the manual will be strictly adhered to in all operations. Also in support of this amendment request is over thirty years of experience in coordinating and supervising an identical radiation safety and management program with Halliburton Services from 1955 to date.

It is requested that the following nuclides be added to the license with the same authorized uses.

a)	Lanthanum-140,	any form,	500 millicuries
b)	Zirconium-95 (Nb-95),	any form,	1 curie
c)	Sodium-24,	any form,	500 millicuries

It is also requested that the license be amended to include a holding facility for radioactive waste generated by the licensee. This is to include all licensed isotopes having 100 day or less half life. The waste by specific nuclide will be partially compacted in ring-sealed 55 gallon drums, properly labelled, dated and stored for a time lapse of twelve half lives, assayed, then treated as normal trash at a local landfill. Controls for Environmental Pollution, Inc. of Santa Fe, New Mexico or similar laboratory will perform the necessary assays.

The rad waste will be stored in building similar to a pole barn, but access controlled by lockable gates and also fenced for complete enclosure. It will be properly designated with "Caution - Radioactive Materials" and "Caution - Radiation Area" signs.

Copy sent to DCS

License Fee Information on next p.

461306

The "Central Interstate Low Level Radioactive Waste Compact Commission" will very obviously not have a disposal facility within the next few years, and disposal costs are escalating rapidly.

A check in the amount of $170.00, made payable to the U.S. Nuclear Regulatory Commission, referencing license number 35-21353-01 is enclosed to cover the amendment request fee.

If you have questions or require additional information please contact me at:

OK Tracers, Inc.
Route 3, Box 247Q
Duncan, Oklahoma 73533
(405) 255-0242

Respectfully submitted,

Dan G. Kelly

Dan G. Kelly

DGK/cdo

Nov-3-IV
2264 2139
$170 530
3A 5A
Apr 11/20/86

deposited by RM 1/16/87

461306