ADMINISTRATIVE INSTRUCTIONS

to

RADIOGRAPHY PERSONNEL

Gordon P. Neumann
Metallurgical Engineer
Rev. 12 March 12, 1984

Control No. 70608

SCOPE

These instructions apply to license number 48-05395-01 granted to The Vollrath Company by the Nuclear Regulatory Commission and are subject to the limitations of that license. If any conflictions arise between these instructions and the Federal Regulations due to subsequent changes or additions to the latter, the latter will govern. This license and related data are for Cobalt 60 and Iridium 192 sources.

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A. Responsibility for Control of Sealed Sources -

Including Organizational Structure

The use and instruction for usage of sources will be under the supervision of Glenn A. Kurtz, Foundry Division, General Supervisor-Administration. In his absence, delegation will be to the alternate Radiation Safety Officer.

In case of emergency in "off hours", the following people will be notified by telephone:

R.L. Vandermus - Plant Maintenance Service Operations Manager
Home Telephone------467-6730
Vollrath Extension-------311

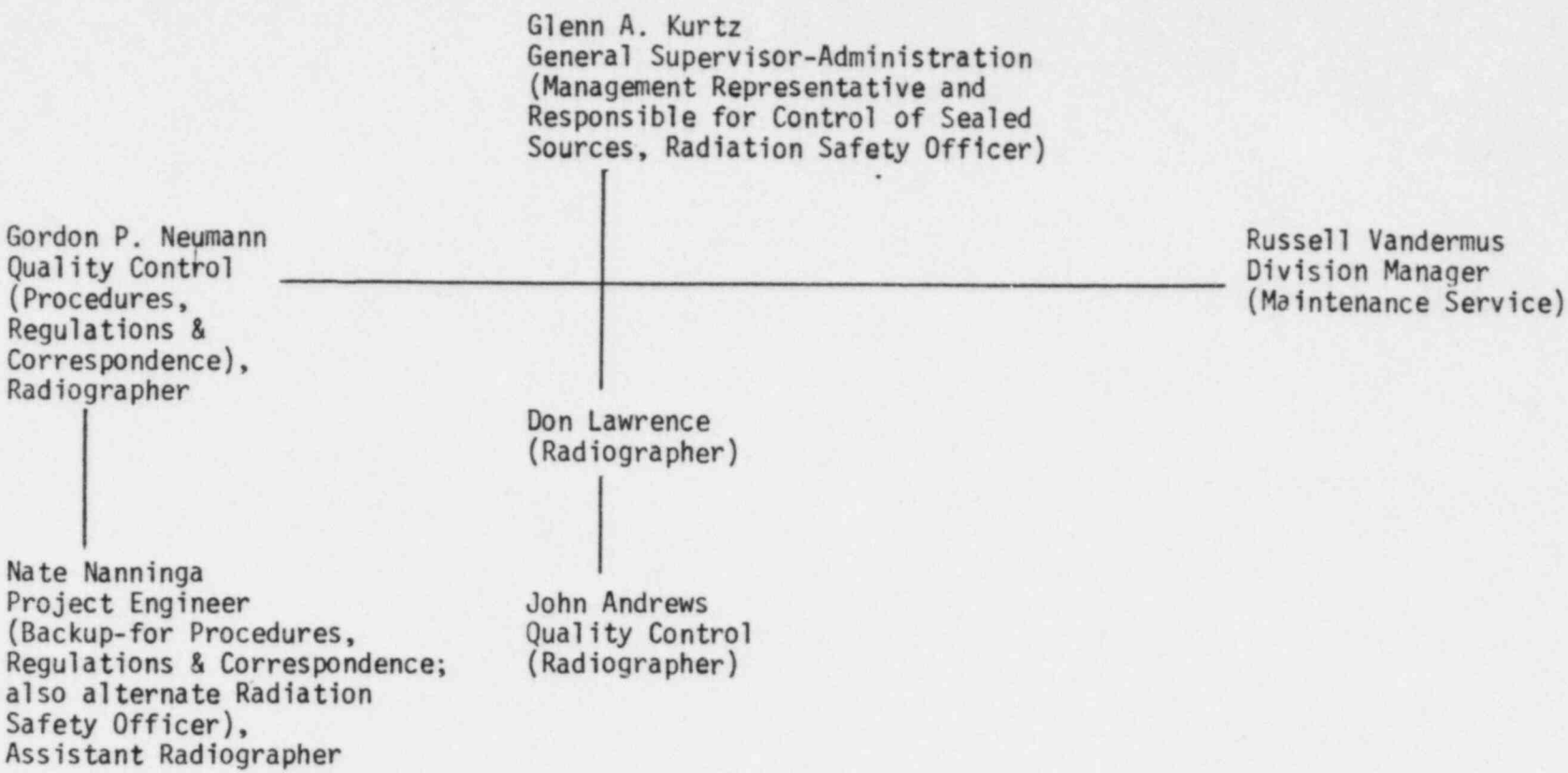
G.A. Kurtz - Foundry Division, General Supervisor-Administration
Home Telephone------452-0887
Vollrath Extension-------248

G.P. Neumann - Foundry Division, Quality Control
Home Telephone------458-5891
Vollrath Extension-------309

A sign bearing the above mentioned names and telephone numbers has been posted on the outside of the always-locked double door for the benefit of local authorities who have been so advised. A similar list is also posted at the entrance to the maze, at the foundry office and in the plant guard's gate house. In addition, the intra-plant telephone extension numbers of the above personnel are always included on the tabulation.

A.D.

RADIOGRAPHIC ORGANIZATIONAL STRUCTURE



NOTE: See following pages listing the duties and qualifications of all personnel in the gamma program.

A.D.

B. Duties of Personnel in Gama Radiography Program

1) Glenn Kurtz - General Supervisor-Administration - as the gamma radiation facility is an integral part of casting inspection employed for the maintenance of a high casting quality level in the foundry operations, he is responsible for the operation and use of the gamma facility. Also, as management representative in the gamma program, through his authority, new equipment which would improve the effectiveness of this facility is reviewed and taken through the company authorization process. He will also serve as program Radiation Safety Officer.

2) Russell Vandermus - Electrical Engineer - Plant Maintenance Service Operations Manager - is responsible for any maintenance needed to the gamma facility.

3) Gordon Neumann - Metallurgical Engineer - Radiographer - responsible for procedures, regulations and correspondence with the Nuclear Regulatory Commission.

4) Don Lawrence - Radiographer - under the direct supervision of Mr. Glenn Kurtz, is responsible for performing the daily operations.

5) Nate Nanninga - Foundry Project Engineer - in order to provide depth and backup capabilities in the areas of procedures, regulations and correspondence; also Assistant Radiographer. He will also serve as alternate Radiation Safety Officer.

6) John Andrews - Assistant Quality Control Manager - Radiographer - in order to provide backup capabilities for radiographer.

A D

C. Management Control Program

1) Glenn Kurtz

As head of all foundry operations, of which the gamma room is an integral part, the radiographer is directly accountable to him. He has a direct knowledge of the radiographer's daily work schedule, and he also reviews the films. This close contact to the gamma facility insures a safe operation. He also consults with all personnel and thereby maintains a free flow of information from the gamma room facility to upper company management. This direct line of communications insures that company management is kept well informed on all current gamma facility functions. He will also serve as program Radiation Safety Officer.

2) Russell Vandermus

As electrical engineer, Russ is the manager of plant maintenance services. Though there are only a few items of electrical and mechanical equipment in the gamma room, it is extremely important and necessary for this equipment to be operating properly. His management position in the company organization insures that when maintenance is required, a top level priority for repair is followed.

3) Gordon Neumann

As metallurgical engineer, he is in charge of casting quality, as related to gating and risering and internal casting integrity. Mr. Neumann spends considerable time in the gamma operation as compared to the rest of management personnel. Films are reviewed daily with the radiographer and new Nuclear Regulatory Commission regulations or regulation changes are discussed. He is also a qualified radiographer.

4) Nate Nanninga

He is a metallurgical engineer in charge of new processes and new product development in the Foundry Division. In this capacity, he works closely with the radiographer and is a valuable asset toward maintaining a safe operation. His efforts will be devoted toward NRC regulations, pending changes, and related radiography compliance, in addition will perform all duties of assistant radiographer. He will also serve as alternate Radiation Safety Officer.

5) John Andrews

Assistant Quality Control Manager, in this capacity, works full time on improving casting quality and is liaison to foundry production departments in initiating shop samples. In addition, he will perform all duties of radiographer.

A n

D. Qualification and Experience of Radiography Personnel

Name	
Glenn A. Kurtz (Management Representative and Responsible for Control of Sealed Sources)	-Gamma Industries Training Course held in Baton Rouge, LA, July 16th thru July 20th of 1979. No prior radiography experience, or industrial radiation exposure.
Russell Vandermus (Division Manager, Maintenance Service)	-Nuclear Systems Training Course in Philadelphia, PA, July 14-15-16 of 1959. In radiography program to date.
Gordon P. Neumann (Procedures, Regulations & Radiographer)	-Budd Company Training Course in Philadelphia, PA, March 22-23-24 of 1966. In radiography program to date.
Nate Nanninga (Backup responsibilities for Procedures, Regulations and Correspondence); Assistant Radiographer	-Gamma Industries Training Course held in Baton Rouge, LA, July 16th thru July 20th of 1979. No prior radiography experience, or industrial radiation exposure.
John J. Andrews (Assistant Quality Control Manager); Radiographer	-Gamma Industries Training Course held in Baton Rouge, LA, Sept. 8th thru Sept. 12th of 1980. No prior radiography experience or industrial radiation exposure to date.
Don Lawrence (Radiographer)	-Gamma Industries Training Course held in Baton Rouge, LA, Dec. 7th thru 11th of 1981. No prior radiography experience or industrial radiation exposure to date.

E. Responsibility for Radiation Protection Program

G. A. Kurtz will be responsible for radiation protection and reporting of any emergency condition to the Nuclear Regulatory Commission.

The established maximum permissible exposure limits for radiological and non-radiological personnel are as follows:

Restricted area:	1-1/4 Rem. per calendar quarter
Unrestricted area:	2 Millirem per hr., or 100 Millirem in any seven consecutive days.

Dosage rates in excess of those specified above must be reported to the Safety Officer immediately, who will notify Region III of the Nuclear Regulatory Commission. Always up-to-date addresses and telephone numbers are posted on the inside of the always-locked double doors and thus within arm's reach of the telephone.

F. Instruction of Personnel on Radiation Hazards

All new employees who will be working in industrial radiography, as well as those currently so engaged, will be thoroughly informed of radiation hazards and periodic "refresher" sessions will be held in accordance with The Vollrath Company's booklet titled "Training Program for Radiographers and Radiographers' Assistants".

Continual vigilance will be maintained to direct the radiography personnel's immediate attention toward:

a. Incoming correspondence from the N.R.C. as well as new regulations and amendments.

b. Magazine articles and books on related and current topics.

c. Non-Destructive Testing Society meetings.

Testing of the radiographers and radiographers' assistants continued ability, knowledge, retention, understanding of and ability to comply with N.R.C.,regulations, licensing requirements and these operating and emergency procedures are an important part of these instruction procedures.

G. Safe Operation of Radiographic Exposure Devices

1) Open-air radiography

No open-air radiography is to be done and none is allowed under this license.

2) Internal Inspection System

The radiographer will perform a daily inspection of all warning devices and security measures as are required in these instructions. The safety officer and the foundry operations manager will check on the radiographer periodically to make certain that this is being done.

In addition, the safey officer, or any other personnel listed in the management program, will check and be responsible for exercising sufficient management control, including inspections, to assure that all license provisions, N.R.C. regulations, and the "Operating and Emergency Instructions" are followed by the radiographer and radiographer's assistants.

Postings of current copies of these instructions, federal regulations, the license and form NRC-3 shall be maintained by the radiographer.

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H. Miscellaneous

1] Any employee who disregards these instructions or tampers with dosimeters, film badges, radiography records or any radiographic equipment is subject to disciplinary action, including discharge.

2] Annual physical examinations are to be arranged by the plant nurse for all personnel concerned with the radiography operation (those carrying film, badges and dosimeters). Suitable records are to be kept by the plant nurse. She will also notify the individuals of the date, time and place of their appointments and the name of the examining physician.

I. Revision of Protection Procedures

Procedures will be reviewed every six months and appropriate changes or additions made to incorporate additional radiation protection equipment and facilities and changes of responsibilities among personnel and changes in operation. When necessary, approval by the N.R.C. will be sought through an amendment before changes or additions are made.

J.

TRAINING PROGRAM

for

RADIOGRAPHERS AND RADIOGRAPHERS' ASSISTANTS

of

THE VOLLRATH COMPANY

SHEBOYGAN, WISCONSIN

Current License Number: 48-05395-01

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A.D.

INTRODUCTION

The following training programs, numbered i, ii, iii, iv and v are based on the federal government regulations outlined in:

U.S.N.R.C. Rules and Regulations, Title 10 - Atomic Energy, Part 34, paragraphs 34.11 and 34.31, and appendix A.

These program numbers (i, ii, iii, iv, and v) correspond to the prefix numbers of sub-paragraphs 1, 2, 3, 4 and 5 of the above paragraph 34.11.

Training-Program Instructors and Their

Qualifications

Program Number	Conducted By
i	Self-explanatory in text of Program Number (i).
ii	Conducted by, and under the direction of the safety director.
iii	Conducted by the radiographers. They have, by far, the greatest amount of practical radiographic experience of anyone at The Vollrath Company. They are each listed as an "individual user" and their academic, as well as practical experience, is on file with the N.R.C.
iv	Conducted by the safety director. (See program number ii, above.)
v	Conducted by the safety director. (See program number ii, above.)

A.D.

(i) INITIAL TRAINING

When more radiographers or radiographers' assistants are needed in our facility, the individuals considered for such work must first complete an "initial training" course. This course will not be given by Vollrath Company personnel, but will be conducted by an independent, disinterested third party whose program of curriculum and instructors meet the requirements of the N.R.C. This type of program in radiation health physics is offered by many companies for a low fee. Because the need for this type of personnel does not exist in the foreseeable future, no company or curriculum is here specified. When, and if, this need does arise, a thorough investigation must be made prior to the personnel's attendance of the course to assure that complete approval of the course is given by the N.R.C. based on whatever the requirements may be at that time.

In addition, the following manuals published by the N.R.C. will be used:

1) Industrial Radiography Manual

2) Industrial Radiography Manual - Student Guide and Laboratory Exercises

3) Industrial Radiography Manual - Instructor Guide

4) Working Safely in Industrial Radiography

(ii) PERIODIC TRAINING

Instructor's copy--may be read aloud by instructor or used as an outline.

Opening Statement

This portion of your training is required by Part 34, Title 10 of federal regulations, and is a semiannual "refresher" course covering material presented in your initial training. Your attention is called to the following federal regulations (instructor will read them):

10CFR34, paragraph 34.31, and
10CFR34, paragraph 34.11, and
10CFR34, appendix A.

Your attention is also asked while I read paragraphs 2.2 and 2.3 of NBS Handbook 54, "Protection against Radiation from Radium, Cobalt 60 and Cesium 137."

This material will be of minimum requirements and should not be construed that this is all that an individual should know: a review, as such, is not as thorough as the original course. Additional information can be gathered from books, pamphlets and other sources on file in the safety director's office and gamma building office, upon request.

It is also pointed out to you, that at this point in the training program, you have successfully completed the outside radiation and safety program as specified in section i and are starting in the observation phase of the training program. Two weeks time will be spent in this phase of the training program.

Areas to be covered include radiation properties, safety, detection, protection, equipment, federal regulations and operating procedures. Not included in this course will be the actual mechanics and techniques of making set-ups and exposures of processing radiographs. You have been made aware of the potential hazard involved with the application of radioisotopes and understand why it is imperative that only experienced and informed personnel be permitted to work with these materials.

At the end of this two week period, the trainee will complete a written 30 question test. Each question is listed with a specific point value. A grade of 80 percent will be considered acceptable, and the percentage correct will be calculated using the following formula:

$$\text{grade } \% = 100 - \frac{\text{total point values wrong}}{\text{total test point value}}$$

(ii) PERIODIC TRAINING (Cont'd.)

Opening Statement (Cont'd.)

The questions for this test will be selected from the Gamma Radiography Master List of Test Questions and graded by the safety director. Both radiographers and radiographers' assistants, whose job function it is to perform the actual radiography work, will review all of the material listed in phase ii on a yearly basis and also take the written 30 question test as specified in this section.

After phase ii, for a new trainee, is successfully completed, application will be made to the N.R.C., including a copy of the applicant's test, requesting approval for acceptance as an assistant radiographer. After approval is received, the trainee will progress to phase iii, on-the-job training as given.

Properties of Radiation

A - Radiation Penetrates Matter.

One of the useful characteristics of x-radiation and gamma radiation that is important to us is its ability to penetrate matter. When used with recording devices such as film, it enables us to study the internal structure of opaque materials. This then, would be a definition of radiography. The penetrating characteristics of radiation can also be harmful when the human body is exposed to its rays. This aspect will be discussed at length later.

B - X-Ray Radiation.

I have mentioned two types of radiation in connection with radiography, X-ray and gamma-ray. X-ray, the most commonly known of the two types, is produced by accelerated electrons striking a tungsten target. This action takes place in an x-ray tube, very similar in principle to an ordinary vacuum tube. A cathode emits an electron cloud when heated and an anode attracts the electrons. The cathode has a negative charge and the anode has a positive charge. It is a Physics law that unlike charges attract each other. By varying the potential difference between the anode and the cathode, we can control the acceleration of the electron.

The accelerated electron has stored up energy through movement. When this movement is suddenly stopped by the target, a transfer of energy takes place. This energy, that is given off, takes the form of heat and x-rays. This radiation can consist of many wavelengths. By varying the potential, we can vary the wavelength of radiation emitted. Increasing the potential will shorten the wavelength. The shorter the wavelength, the more penetrating power the x-rays have.

Properties of Radiation (Cont'd.)

The amount of radiation emitted from the x-ray tube can be controlled by adjustment of current on the cathode. This current is measured in milliamperes, or a shorter term, MA. The amount of current applied to the cathode determines the quantity of electrons freed from the element for use. A current of 10MA applied to the cathode would have twice the radiation output of an x-ray tube with 5MA applied to the cathode.

It naturally follows then that time also is a determining factor in how much radiation reaches the film. At a given technique, a film, body or other matter exposed for two minutes would have twice the radiation strike than it would in one minute. Since the density of a film depends upon the amount of radiation striking it, it, therefore, would have twice the density, also.

In order for the x-rays emitted from a tube to be useful in radiography, the radiation must be of certain geometric shape and projection. A bullet is of little use without the barrel to give it direction. This projected shape is accomplished by a focusing cup which focuses the electron beam at an angled target which projects the x-ray beam in a cone-shaped field or as 300° of radiation on some x-ray units.

C - Isotope Gamma-Ray Emitters.

Gamma-rays, like x-rays, are also part of the electro-magnetic spectrum. They differ from x-rays, not in nature, but rather in origin. Gamma-rays that you will work with emanate from artificially produced Isotopes. I say "artificially" because some elements produce gamma-rays naturally, such as radium.

Isotopes have the same atomic number of a particular element, but differ in number of neutrons and so have a different mass number. For a given element such as Cobalt, we can vary the number of neutrons and, hence, Isotopes, but we still have the basic element, Cobalt. Very simply speaking, the addition of neutrons in the nucleus of an atom is accomplished by putting an element into a nuclear reactor and bombarding it with neutrons. This addition of a neutron in the nucleus of the atom makes it unstable and it begins "to disintegrate," or another term - "a process of radioactive decay." The number of atoms affected depends upon the length of time in the reactor, type of material and physical size of the material. This form of energy that is given off, that we are concerned with, is gamma-ray.

(ii) PERIODIC TRAINING (Cont'd.)

Properties of Radiation (Cont'd.)

There are several types of Isotopes produced by N.R.C. licenses. The ones most commonly used for radiography are Cobalt 60, Iridium 192, Cesium 137 and Thulium 170. Because of certain disadvantages of Cesium and Thulium, we have in our possession only Cobalt and Iridium. The disadvantage of Cesium is its low specific activity and low radiation output per Curie, resulting in long exposure times. Also, Cesium comes in a powdered form and if the capsule is accidentally broken or it leaks, serious contamination problems could arise. Thulium has impurities which give off harder radiation, which predominates over the more useful soft radiation.

We have discussed two types of radiation used in radiography and some comparisons between the two. Review the following points:

1 - Both are electro-magnetic in nature, but differ in origin.

2 - X-rays produced electronically in an x-ray tube. Gamma-rays produced by disintegrating nuclei.

3 - X-rays can be shut off, but Isotopes are emitting gamma-rays at all times.

4 - Wavelengths of x-rays can be varied, but gamma-rays are emitted at characteristic wavelengths and cannot be varied.

5 - Quantity of radiation can be varied in an x-ray tube. For a given gamma-ray source, quantity cannot be varied.

6 - X-rays can be projected in a beam or up to 300°. Gamma-rays are given off in 360°, but may be columnated by a shielding material.

I have previously mentioned that X-rays and gamma-rays are electro-magnetic in nature. To enumerate some of these properties, they are (or do):

1 - Invisible.
2 - Travel in straight lines.
3 - Travel at the velocity of light.
4 - Affect photographic emulsions.
5 - Able to ionize matter.

(ii) PERIODIC TRAINING (Cont'd.)

Properties of Radiation (Cont'd.)

Another characteristic of radiation that is of great importance is what is known as the Inverse Square Law. This means that the radiation level decreases as the inverse square of the distance. As an example, a given amount of radiation at two feet would only be one-fourth of that measured at one foot. At four feet, one-sixteenth, at ten feet, one-hundredth, etc. The same would hold true if we used inches, or other units. From this characteristic, it is readily seen what a tremendous level of radiation is present--even from a small source--when measured at the surface of the source.

Energy of gamma-rays is usually expressed by the terms "Mev" or "Kev"...million electron volts or thousand electron volts. If we know the Mev or the Kev energy of an Isotope, we will have some idea of the penetrating abilities of that source. We learned in our discussion of x-ray that the shorter the wave-length, the more penetrating the radiation. The higher the electron volt characteristic, the shorter will be the wavelength and therefore, the more penetrating power. Unlike with X-ray tubes, the radiation wavelengths of isotopes cannot be varied and emit only the average wavelength throughout its unstable condition. Cobalt 60 has an average Mev of 1.2. Iridium has a rating of .375 Mev. It can be said then that Cobalt has more penetrating ability than Iridium, which is why Cobalt is used to radiograph heavy sections of steel and Iridium is used on thinner sections of steel.

The strength or amount of radioactivity in an Isotope is measured in Curies. One Curie of a radioisotope is the amount of material that disintegrates at the rate of 37 billion atoms per second. Do not let this fact upset you, as you will not be working with this cumbersome figure. Just keep in mind that a Curie is a unit of measurement, such as a volt, used in measurement of electrical potential. Two Curies of a given Isotope would produce twice the level of radiation as one Curie, but could be the same size physically. If they are of the same physical size, the former would be said to have twice the "specific activity" of the latter and, of course, would produce, at the same given distance, a radiation level twice as large as the latter. Isotopes of different elements do not necessarily emit the same amount of radiation Curie for Curie. As an example, one Curie of Cobalt produces almost three times the level of radiation of one Curie of Iridium. A Curie then is a quantity of radioactive nuclide that is disintegrating at a known rate.

D - Question and Answer Period.

Radiation Dose

A - Units of Radiation Dose.

As in every field or subject, there are certain terms, units and expressions that apply to that field and must be known and understood in order to convey certain ideas, functions, quantities and phenomenon of that particular field or subject. An example would be in the field of electricity where we have the terms "volt, ohm, ampere, impedance, resistance, etc.," with which everyone is familiar. The study of radiation also has its own particular terms and expressions. We have found out that the term "Curie" refers to a quantity of atoms that are disintegrating per second. This may be hard for most of us who are not physicists to visualize in our minds, so another way to remember and understand this term would be to think of it in terms of radiation production from an Isotope. That is to say that a Curie of radioactive material produces a certain quantity of radiation at a given distance. A millicurie is one-thousandth of one Curie. A thousand millicuries equals one Curie. One-fourth of a Curie is expressed as 250 millicuries or written .250 Curies. The abbreviations "C" and "MC" are sometimes used for these terms.

The radiation affect of a source is measured in Roentgens. One Roentgen is a unit of exposure based on the quantity of gamma or x-rays that produce a specific amount of ionization in a given amount of air under standard conditions. A milliroentgen would be one-thousandth of a Roentgen. Abbreviations are "R" and "MR."

Another term used for the measurement of radiation exposure is called the "Rem." This is the measure of amount or dose of radiation of any type in terms of that received by body tissue from any source. Practically speaking, one Rem equals one Roentgen.

B - Hazards of Radiation Dose.

As with many types of occupations today, radiography has certain hazards that could be harmful to individuals working in this field. I would like to point out now that the excellent safety record of radiation workers proves that these hazards can be overcome with proper equipment, thorough understanding of radiation characteristics and conscientious performance of the workers themselves.

Body components may be injured by overexposure to x-rays and gamma-rays, particularly the blood, skin and some internal organs. Unless exposure is kept at a minimum, the cumulative exposure may cause injury.

(ii) PERIODIC TRAINING (Cont'd.)

Radiation Dose (Cont'd.)

The following paragraphs are taken from the "National Bureau of Standards Handbook No. 73, Paragraph 2.22."

> "Injury to human beings may result from overexposure to beta and gamma-rays from sealed sources; should the sealed source be broken, there is a possibility of radioactive contamination of the skin by spilled material; of accidental ingestion or inhalation of these substances; or of other modes of entry of the substances, such as cuts, punctures and abrasions.
>
> "Overexposure may occur either from working with radioactive materials under unsuitable conditions or from habitual occupation of a position too close to the material in inadequately shielded storage. In the former case, the injury is likely to be local on the fingers and hands; in the latter it will probably be systemic.
>
> "Habitual or long-continued overexposure to the hands may result in dry reddened skin, which cracks easily and is very sensitive to heat and cold. The nails become brittle, keratoses form near them, small cracks may ulcerate. These ulcers, or any other sores, heal slowly. Cancer may develop in the keratoses or ulcers. (Of course, proper protective measures should be taken long before this stage is reached.) Overexposure of the entire body may lead to depression of bone marrow activity or leukemia. The occurrence of permanent sterility is extremely unlikely.
>
> "Contamination of the skin by intimate contact with radioactive material may produce a local reaction sufficiently intense to result in erythema and desquamation. The local effect would be due mainly to beta radiation, and healing would be expected to occur without sequelae if prompt and effective measures were taken to remove as much of the material as possible. However, repeated contamination of this type might well lead to irreversible damage.
>
> "Ingestion, inhalation or absorption of the material may give rise first to wholebody irradiation - followed by prolonged local irradiation if a long-lived substance is deposited in a particular region, as in the bones. Radium, mesothorium and possibly other alpha-particle emitters are most dangerous, because of the very intense local irradiation to their preferential sites of deposit, as for example to bone or lung. Some radionuclides that are not alpha-emitters are also "boneseekers," and not well eliminated. The result is

Radiation Dose (Cont'd.)

that even a small quantity of these materials retained in the body may lead to depression of bone marrow activity and to serious bone lesions. Other Isotopes generally are much more readily eliminated and, thus, do not constitute so great a hazard. Inhalation of radon from damaged radium containers may result in the deposit within the body of the decay products of the radon."

From these last two paragraphs, it can be seen why leak testing of Isotopes is of great importance. If the source is leaking, there is a possibility of spreading contamination in the work area and also in the air.

One of the most frequently asked questions by those anticipating working with radiation is just how much radiation does it take to injure a person. This varies from person to person, depending on one's present health and body structure, but average conditions have been set down. The following information has been taken from the "U.S. Dept. of Health, Education and Welfare Handbook on Radiological Health," September, 1960 edition.

Acute Dose (Roentgens)	Probable Effect
0-50	No obvious difficulty, except minor blood changes.
180-220	Vomiting and nausea for about one day, followed by other symptoms of radiation sickness - about 50 percent of personnel. No deaths anticipated.
400-500	Vomiting and nausea in all personnel on first day, followed by other symptoms of radiation sickness - about 50 percent deaths within one month; survivors convalescent for about six months.
1000	Vomiting and nausea in all personnel within 1-2 hours. Probably no survivors from radiation sickness.

These facts are presented to you, not to discourage you but to make you aware of the potential dangers in handling radioactive materials. We are not attempting to make you afraid of working with radiation, but to get you to respect its hazards if not properly handled.

Radiation Dose (Cont'd.)

C - Levels of Radiation.

In order to work with Isotopes, it is necessary to know how much radiation is present at all times. A Curie of any given Isotope is known to produce a given Roentgen level at a given distance. This factor remains a constant and, therefore, we can make reasonably accurate calculations using this constant and other factors which we shall discuss later.

The radiation output is usually expressed as RHM or RHF: Roentgen per hour at one meter or Roentgen per hour at one foot. Cobalt 60 has a value of 14.4 RHF per Curie. A Curie of Iridium has a value of 5.95 RHF. Therefore, if you wanted to know the radiation level of a 10 Curie source at one foot, you would multiply the given value by ten.

It can be seen that the radiation level present, therefore, depends upon the Curie rating or strength of an Isotope. This factor does not remain constant in an Isotope, but is changing continuously due to the decay of the Isotope. However, this decay process continues at a known rate and future strengths can, therefore, be calculated. This rate of decay of isotopes determines what is commonly called the isotopes' "half-life." The half-life of an Isotope is the time required to lose 50 percent of its activity by decay. At the end of one half-life, an equal time is required for half the remaining atoms to decay. As an example, Cobalt 60 has a half-life of 5.2 years. At the end of that time, the source will be half its original strength. In 10.4 years, it will be one-quarter of its original strength, after 15.6 years one-eight of its strength remains, and so on. Each different Isotope has its own half-life value. Another term, which is preferred over "half-life" but is less used, is "half-period." "Half-life" is a misleading term.

Iridium has a half-period of 75 days and, so, frequent adjustments to radiographic techniques are necessary.

Decay curves are usually furnished with the purchase of an Isotope, and the strength can be quickly found at any given time.

The inverse square law, which we discussed earlier, is another factor to be considered if we wish to calculate levels of radiation in air at any given point. This can be expressed by the ratio:

$$\frac{I_1}{I2} = \frac{D_2^2}{D_1^2}$$ Where I_1 and I_2 are the intensities at distances D_1 and D_2, respectively.

Radiation Dose (Cont'd.)

If we substitute our known values for I_1, D_1 and D_2, we can find I_2. Let's assume we are using a 2 Curie source of Cobalt 60 and we want to find the radiation level at two feet from the source. We know the intensity at one foot is 14.4 R/Curie/hour. For 2 Curies, it would be 28.8 R/hour. I_1 would equal 28.8, D_1 equals one foot, D_2 equals two feet. Substituting, we have the equation:

$$\frac{28.8}{I_2} = \frac{4}{1}.$$

Transposing, we get $4I_2 = 28.8$, $I_2 = \frac{28.8}{4}$. $I_2 = 7.2$, which proves out as we have doubled the distance and should get only one-fourth the radiation.

Scatter effect produced by radiation striking the floor, walls, ceilings and other objects has not been considered in arriving at the above figures, but for all practical purposes, the equation would be accurate enough except maybe when actually designing a radiography room or area. Absorption by air has not been considered either, but with gamma-rays the factor is small.

D - Method of Controlling Radiation Dose.

It is absolutely necessary to keep personnel radiation dose to a minimum, and there are certain methods we can use in order to accomplish this. They are: working time, working distance and shielding. The first, time, means the time spent in direct exposure to the radiation source. Obviously, the shorter time spent in an area, the less the exposure dose will be. If a set-up requires two minutes of direct exposure to the operator, and ways can be found to reduce this to one minute, the body will receive one-half the dose that it did at two minutes.

Distance sometimes is the only means of reducing exposure. It has been shown by the inverse square law that radiation falls off sharply with distance. Therefore, as much distance as possible should be between the source and any personnel.

The third method, shielding, is an excellent means of protection from radiation and should be used whenever possible. In a permanent installation, special rooms are usually constructed. In temporary locations, machinery, steel plating, or some such barrier that is usually found in shops that require radiography, should be utilized to reduce exposure. A combination of distance and this type of "barrier" can reduce the radiation level to a safe working condition.

Radiation Dose (Cont'd.)

Materials most commonly used for construction of gamma-ray rooms are concrete, stone, earth, sand and lead, or a combination of these materials and a few other materials of dense nature. Because of the penetrating ability of gamma-rays, lead in itself is not usually used because of the expense and construction problems.

The absorption capabilities of certain materials have been tested and calculated and is expressed as its Half Value layer. This is the thickness of any particular material necessary to reduce the intensity of an x-ray or gamma-ray beam to one-half its original value. Lead, as an example, requires one-half inch thickness in order to reduce the level about 50 percent.

E - Question and Answer Period.

Equipment and Techniques

A - Radiation Detection Instrumentation.

Since x-rays and gamma-rays are invisible, other than visual methods must be used in detecting them. Radiation detection instruments are available for this purpose and are a necessity in any laboratory engaged in radiation work. These instruments indicate the presence and level of radiation.

There are a variety of instruments on the market, but for radiography work an instrument that utilizes an ionization chamber and is calibrated in Roentgens and Milliroentgens should be used. The range of the instrument should be capable of detecting a level of a few milliroentgens per hour to at least one Roentgen per hour. In our laboratory, we use both the ionization and the Geiger-Mueller Tube instrument, but they are used in conjunction with each other. The importance of using these instruments at all times when engaged in radiography cannot be overemphasized. They are the only means of knowing whether a source is definitely in a safe position, protective barriers are adequate or if proper distance from sources is being maintained.

When using the survey meters, adequate warm-up periods are necessary before actual use of the units. This period also permits the operator to ascertain if the meter is functioning and if it is reading correctly. In case of doubt, two meters should be used as a check on one another.

Equipment and Techniques (Cont'd.)

Since these are delicate instruments, they should be handled with care. When operating outside, measures should be taken to keep them dust-free and waterproof.

Survey meters must be calibrated every three months. This is done by the company, using a source of Cobalt. The source has been calibrated and a very accurate decay curve drawn up to insure correct calibration of instrument. We have in our possession one type of meter that has its own calibration source built into the unit and can be calibrated very easily, but this calibration procedure is not acceptable to the N.R.C., so we use a specially developed procedure.

When entering a suspected radiation field, the finest scales on the meter should be used. This will detect the area at is furthest range and the safest distance. Our current license restricts radiographic exposures to the gamma building exposure room.

B - Survey Techniques.

Each permanent installation is to have a radiation survey made immediately upon start of radiographic operations to determine if walls or barriers are of adequate design. Particular attention should be made around doors, observation ports, ducts and other areas where protective barrier has been interrupted. Also, if concrete is used for shielding, it is essential to make a very complete scanning in order to detect cracks and air spaces.

The possibility of multiple scattering from walls and floors into other areas should not be overlooked and a survey should include those areas, as well as walls and barriers.

When taking a survey, the source should be placed at several positions to make sure proper protection is being maintained at various angles and positions that the source could be in under working conditions. A good practice is to take daily surveys after the initial survey for a while, just to make sure readings were accurate and to check scattering under working conditions. In any case, a survey is to be conducted at least every six months to ascertain that no leakage of barriers has developed.

Temporary radiographic areas are to be under constant surveillance during source exposure. When source is exposed for a temporary radiographic shot, a survey is to be made to make sure that ropes and barricades are placed at the proper distance so that no unrestricted area has a level of more than 2 MR/hr.

Equipment and Techniques (Cont'd.)

It is possible, through failure of exposure devices and/or handling equipment, accidents, etc., to be unable to retract a source back into its safe position. Either with the knowledge of the radiographer, or unknowingly, if the source should ever become disengaged mechanically and be left in the source tube, it could result in serious overexposure to personnel. Therefore, it is mandatory that a survey be made after each and every exposure to make sure that the source has been returned to its safe position. This is an N.R.C. regulation and is a condition of our license. Its importance cannot be overemphasized. Work sheets are provided to the radiographer and they must be filled in after these surveys have been done. Unabsorbed radiation from the exposure device should produce a reading on the survey instrument and is a good check to see if the instrument is functioning properly. If no reading is obtained, or it varies considerably from previous readings, the technician should immediately leave the area and use a different meter to make this survey.

When securing work area and exposure devices at the end of workday or job, a final survey is to be made of locked devices to make sure that the source is in the safe position. This survey is also to be recorded in the work sheet, after completion.

C - Use of Personnel Monitoring Equipment.

It is inevitable that people who work with x-ray units, radioactive materials and other sources shall receive various doses of radiation to their body. This is an occupational hazard similar to the hazards of other occupations such as construction workers, electricians, steeplejacks, etc. However, limits have been established for your protection on how much you may receive that will produce no injury. It is necessary then for us to know just how much the body has received...instantly, daily, weekly, yearly and as long as an individual works with radiation. Monitoring equipment is furnished for you to record this dose. They are: a film badge and a pocket dosimeter.

A film badge is a small piece of film enclosed in a packet and is worn on the outside of an individual's clothes. They are supplied to us by a commercial concern and are worn for a one-month period after which time a new one is issued. Radiation is recorded on the film and, after processing, the density of the film indicates the approximate radiation it has received in a one-month period. A report is then issued to the company of the findings and is kept on file. In a case of suspected overexposure, the film badge is immediately returned for evaluation.

Equipment and Techniques (Cont'd.)

The pocket dosimeter is a device that records a dose instantly and can be read at any time. It consists of a small ionization chamber and a scale usually read in milliroentgens. Before use, it is given a charge which returns the hairline indicator on the scale to zero. The amount of discharge due to radiation moves the hairline up the scale and is a measure of the quantity of radiation received. Dosimeters are charged daily and a record kept of the daily readings obtained.

The monitoring equipment is your only means of determining the radiation dose, so they must be handled with extreme care. They should not be left in work coats or clothing at the end of the day.

Film badges and pocket dosimeters will be worn at all times when inside the company gates.

D - Radiographic Equipment to be Used.

At the present, we are using only one type of exposure device: The Budd Co. Model 62 Multitron for both Cobalt and Iridium. This unit consists of three main components which are: the lead head that contains the sources when not in use, the control cable and source position indicator and the flexible source tube through which the sources travel to the point of exposure.

The following information is taken from the "Instruction Manual-Model 60 Multitron" provided by The Budd Co.

"OPERATION - By attaching the flexible source tubing to the Series 60 Multitron, it is used for internal, panoramic or difficult to reach exposures. Thus, the source may be positioned within a cavity in castings, valves, piping, tanks, etc., or in the center of a large group of specimens which can be radiographed in a single exposure.

To attach the flexible source tube, the aluminum plug is removed from the fitting in the base of the cone in the head shield and the source tube coupling is threaded into place.

The long control cable with the source position indicator is attached by removing the plug on the lock box of the source desired. With the machine locked, the small source cable should be pulled 1/4" to expose the disconnect. (NOTE: Pulling the source cable out with the machine unlocked may result in the source coming out of the head completely and exposing personnel to radiation hazard.) The disconnect on the control cable is then joined to the disconnect on the

source cable by bringing them together at right angles. The control cable is then straightened and the control cable adapter threaded into its proper position in the lock box. The Multitron is now ready for operation.

To set up for operation, the end of the source tube is placed in position where it is desired to have the source located during exposure. The end of the tube may be held in position by tape, test tube clamp, wooden blocks with a hole or in any other suitable manner.

The source tube should be as straight as possible for ease of operation. The control cable is then extended to its fullest length with the control handle as far away as possible from the end of the source tube where the source will remain for the exposure. It is preferable to have the operator with the control handle as far as possible from any point where the source is exposed, preferably behind a personnel shield.

After unlocking the Multitron with the key provided, the source is exposed by turning the control handle clockwise until it stops. The source position indicator on the handle shows the position of the source in the source tube at all times. No forcing of the handle is necessary.

After the exposure, the source is returned to the head by turning the handle counterclockwise until it stops and the source position indicator reads zero feet. A survey meter should always be used to make certain the source is properly shielded. The machine must be locked after each exposure to prevent inadvertent operation.

To use one of the other sources, the control cable is removed from the source then connected and attached to the source cable and hole of the desired source.

The pointer of the source position indicator has a tendency to drift slightly after a large number of operations. The pointer is reset to zero with the source in the head and the machine locked. The small screw on the pointer shaft is loosened slightly and the pointer reset at zero feet. The screw is then retightened."

E - Question and Answer Period

(ii) PERIODIC TRAINING (Cont'd.)

Federal Regulations

A - Federal Regulations.

Pertinent paragraphs of parts 19, 20, 21, 30 and 34 will be read verbatim and discussed.

B - Question and Answer Period.

C - Copies Of Regulations Are Available To Each Of You At All Times.

The Vollrath Company's Instructions

A - Administrative Instructions To Radiography Personnel and Operating And Emergency Instructions To Radiographic Personnel Will Be Read.

B - Question and Answer Period.

C - Copies of Administrative Instructions To Radiography Personnel and Operating And Emergency Instructions To Radiographic Personnel To Be Given Each Individual.

Closing

A - Review.

B - Question and Answer Period.

Oral Quiz

("Sample Questions and Answers" are identical with those used in training program numbers iv and v.)

THE END
(PERIODIC TRAINING)

A.D.

(iii) ON-THE-JOB TRAINING

A - For the Position of "Radiographer's Assistant."

This part of the training program is to be performed under the direct supervision of the radiographer and the safety director for a probationary period of three months minimum. In the event that the trainee has not completed the on-the-job training satisfactorily in all phases, at the completion of this probationary period, the trainee will not be permitted to continue on in the training program.

The radiographer and safety director will be responsible for the following items, in chronological order, for each on-the-job trainee:

1. The radiographer will not accept any personnel for on-the-job training as radiographer's assistant unless the individual has satisfactorily completed part (i) and part (ii) of this training program. This information can be obtained from the safety director.

2. The radiographer will issue personnel monitoring equipment and will begin by showing, explaining to and answering (the questions of) the trainee the multiple facets of radiographic work. This will be done in steps beginning with the phases farthest removed from actual work with by-product material (such as filing and photographic development) and culminating in making actual exposures. Each step, or phase, is to consist of two parts:

   a. Showing, explaining, teaching by the radiographer.

   b. Careful observation of the trainee by the radiographer as the trainee performs the step personally.

   The steps to be covered by the trainee are:

   a. Thorough familiarity with federal regulations, the company's license and the company's "Administrative, Operating and Emergency Instructions."

   b. Filing and record keeping.

   c. Darkroom equipment and procedures.

   d. Evaluation of radiographs.

   e. Monitoring equipment and safety equipment.

   f. Calculations for exposure times and shielding.

   g. Radiographic exposure equipment to be used.

(iii) ON-THE-JOB TRAINING

h. Set-up techniques, survey techniques.

i. Exposure of sources and production of radiographs.

j. Transfer of sources to and from shipping containers (source changers) and exchanging sources on S.P.I.

k. Calibration of survey meters.

3. Upon the trainee's completion of all the foregoing steps, the radiographer will so notify the safety director, as well as the general foundry superintendent, who will then observe the trainee in his work to be certain that the trainee is performing his tasks in a knowledgeable, alert and safe manner.

4. The safety director will then quiz the candidate in accordance with program number "v".

5. Finally, when the three month probationary period has elapsed, the safety director will meet with the general foundry superintendent and radiographer to determine the result of the on-the-job training. The trainee either will be accepted as a radiographer's assistant or will be returned to his former job (or other job opening) and have no affiliation with the radiography program.

B - For an Opening as "Radiographer."

The on-the-job training period, as listed in phase iii consisting of three months minimum, must be completed to the satisfaction of the safety director, general foundry superintendent and the radiographer. The candidate's experience and personnel record will be reviewed and unanimous agreement reached that the individual is qualified for the opening of radiographer. Of major importance in this consideration will be the result of a prior quiz administered by the safety director (see part iv, "Checking Radiographer's Understanding and Competence").

C - Quiz.

The "Sample Questions and Answers" for "on-the-job" training are (according to procedures outlined above) the questions and answers appearing in sections (iv) and (v) of this training.

(iii) ON-THE-JOB TRAINING

D - Written Test Required.

After the oral quiz is completed, as given in sections iv and v of this training program, the prospective radiographer will complete a written test of 50 questions covering aspects of the federal regulations, safety, operating and emergency procedures. This test will be administered and graded by the safety director. A passing grade will be considered to be at least 85%. If a passing grade is not attained, the trainee will be instructed in those areas found deficient, and a retest will be taken with a period of no more than two weeks. The trainee will be allowed one retest. If a passing grade is not reached at this point, training will be terminated and the prospective radiographer will have no further affiliation with the radiography program. After satisfactory test completion and unanimous agreement specified in section B above, application will be made to the N.R.C. requesting acceptance into the program as a radiographer. A copy of the trainee's test, showing a satisfactory grade was attained, will be sent along with this application.

E - Hiring a Radiographer Having Previous Industrial Radiography Experience.

In the event a trained radiographer is hired, this same Vollrath Gamma Radiography Training Program must be completed by the prospective candidate, with the following exceptions:

1) Phase i - The Initial outside training program will be waived, providing a comparable course has been previously completed. The fact that the course has been satisfactorily completed will be verified by the safety officer. Also, a record of the applicants past radiation exposure history will be verified.

2) Phase ii - The Periodic Training and observation phase will be of one week duration, rather than two weeks, as in the case of a new trainee. It should be noted, satisfactory completion of the written 30 question test, as specified in this phase, is required. A grade percent of 80 will be considered acceptable. Application will be made to the N.R.C. at this point in the training program to request acceptance as a "radiographer's assistant."

3) Phase iii - On-The-Job training is required but will be reduced from three months minimum to one month minimum.

(iii) ON-THE-JOB TRAINING

4) Phase iv and v - To be completed, as specified under the supervision of the safety director. After completion to the satisfaction of the safety director, the written test consisting of 50 questions is required. A passing grade will be considered to be 85 percent minimum, with the provision of one retest allowed. After satisfactory test completion and unanimous agreement between the safety director, general foundry superintendent and radiographer, application will be made to the N.R.C. requesting acceptance into the program as radiographer.

(iv) CHECKING RADIOGRAPHER'S UNDERSTANDING AND COMPETENCE

(Re: N.R.C. Regulations and Operating & Emergency Procedures)

The following are samples of the type of questions (with answers) to be asked of a candidate for a job opening as radiographer. The questions are to be asked of the candidate by the safety director before the personnel officer and safety director meets with the general foundry superintendent as outlined in part iii of the Training Program. By no means does the brevity of this list infer that the quizzing of the candidate shall be so limited. In addition to the type of questions below, the candidate shall be asked questions on the topics presented in the next part ("v"). See paragraphs 34.31 (a) and 34.11, b, 4 of Title 10, Part 34.

I. Sample Questions on N.R.C. Regulations & Licensing Requirements.

1. What is the maximum permissible dose to (the whole body of) an individual in a restricted area, as specified in Title 10 Part 20? Answer: 1-1/4 Rem per calendar quarter.

2. Define a "Curie." Answer: A Curie is a measure of radioactivity of a material which is experiencing decay at the rate of 3.7×10^{10} (37 billion) disintegrations per second.

3. What is the maximum permissible level of radiation in unrestricted areas? Answer: Except as might be authorized by the Commission upon special application, the maximum levels are two millirem per hour or 100 millirem in any seven consecutive days.

4. Which and where is the appropriate N.R.C. Operations Office and where may its address and phone number be found? Answer: The Chicago Operations Office, which is at Glen Ellyn, Illinois. Address and telephone numbers are found just inside the gamma building door on the door itself.

5. At what time should an application for renewal of our license be sent to the N.R.C.? Answer: At least 30 days prior to the expiration date of the current license. Send by first class mail, "return-receipt requested."

6. When may the radiographic exposure device be unlocked? Answer: Only when under the direct surveillance of a radiographer, his assistant or where the high radiation area is locked or equipped with a control device or alarm system approved by the N.R.C.

(iv) CHECKING RADIOGRAPHER'S UNDERSTANDING AND COMPETENCE (Cont'd.)

7. What must be the range of the survey meter? Answer: From two milliroentgens per hour through one roentgen per hour.

8. At what frequency must leak testing be performed, and of what sensitivity must the test be capable? Answer: Leak tests capable of detecting the presence of 0.005 microcuries of removable contamination must be performed every six months.

9. What must be done after each radiographic exposure and also prior to securing the exposure device? Answer: A physical radiation survey must be made to determine that the source is properly shielded.

10. What two basic types of licenses are there? Answer: Two, general and specific.

11. Is ours a general or specific license? Answer: Specific.

12. What must be specified in an application for an amendment to a license? Answer: Of what the amendment is to consist and the grounds for such application for amendment.

13. How may a license be transferred, assigned or disposed of? Answer: The inalienability of licenses prevents any such action except upon receipt of written consent from the N.R.C.

14. What is to be made available for inspection by the N.R.C. and when? Answer: At all reasonable times the N.R.C. shall be given opportunity to completely inspect the premises, facilities, equipment and records.

II. Sample Questions on the Operating and Emergency Procedures.

Same as those for radiographer's assistant. (Please see part "v" of the Training Program titled, "Checking Radiographer's Assistant's Understanding and Competence.")

(v) CHECKING RADIOGRAPHER'S ASSISTANT'S UNDERSTANDING AND COMPETENCE

(Re: Operating and Emergency Procedures)

The following are samples of the type of questions (with answers) to be asked of a candidate for a job opening as radiographer's assistant. The questions are to be asked by the safety director after item "4" of the candidate's period of on-the-job training (please see part iii of the Training Program). By no means does the brevity of this list infer that the quizzing of the candidate shall be so limited. See paragraphs 34.31 (b) and 34.11, b, 5 of Title 10, Part 34.

1. In case of emergency in "off hours," who must be notified? Answer: Vandermus, Kurtz, Reilly, Neumann.

2. Name two places where their names and telephone numbers are posted. Answer: (1) on always locked double door, (2) entrance to the maze, (3) foundry timekeeper's desk, (4) plant guard's gate house, and (5) directly below the bulletin board.

3. How shall the source tube and control tube be laid out? Answer: In as straight a line as possible, so nothing can happen to prevent easy retraction of source, and to provide maximum shielding and distance from the source (or provide minimum exposure to personnel).

4. When may open-air radiography be performed? Answer: Never.

5. When is the electric eye to be operating? Answer: Just prior to and during exposure.

6. What personnel monitoring equipment is to be worn, and when? Answer: Film badge and dosimeter, whenever inside company gates.

7a. How frequently are film badges exchanged? Answer: Monthly, normally. Immediately, if a dosimeter is discharged beyond its range.

7b. How frequently must survey meters be calibrated? Answer: Quarter-annually.

7c. How frequently must sources be inventoried? Answer: Quarter-annually.

(v) CHECKING RADIOGRAPHER'S ASSISTANT'S UNDERSTANDING AND COMPETENCE (Cont'd.)

8a. When the control cable crank is rotated counterclockwise as far as it will go, is the source exposed or retracted? Answer: Retracted.

8b. How many feet are then shown by the indicator on the control-cable-crank housing? Answer: "0" Feet.

9. After exchanging sources, what is done with the short source tube? Answer: It is returned with the source changer to the source vendor.

10. What is done monthly to the source tube and control cable? Answer: They are inspected for kinks or flattening.

Questions, of which the above are only samples, will be used "by the licensee to determine the radiographer's assistant's knowledge," and (in accordance with paragraph 34.11, b, 5) his "understanding of and ability to comply with" will be determined (by its nature) in actual practice, in his "on-the-job training," by the safety director and the radiographer.

THE END.

K. Distribution

2 copies	-	N.R.C.
1 copy	-	Foundry Manager
1 copy	-	Mr. G. Kurtz
1 copy	-	Mr. R. L. Vandermus
1 copy	-	Mr. N. Nanninga
1 copy	-	Mr. G. P. Neumann
1 copy	-	Plant Nurse
1 copy	-	Gamma Building File
1 copy	-	Mr. J. Andrews
1 copy	-	Mr. D. Lawrence

A.D.

OPERATING AND EMERGENCY INSTRUCTIONS

to

RADIOGRAPHIC PERSONNEL

including

Standard, Safe Procedures for Use and

Handling of, and Protection from,

Large Source Radioisotopes

Gordon P. Neumann
Metallurgical Engineer
Rev. 12, March 30, 1984

S C O P E

These instructions apply to license number 48-05395-01 granted to The Vollrath Company by the Nuclear Regulatory Commission and are subject to the limitations of that license. If any conflictions arise between these instructions and the Federal Regulations due to subsequent changes or additions to the latter, the latter will govern. This license and related data are for Cobalt 60 and Iridium 192 sources.

O.E.

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O.E.

O.E.

A. RESPONSIBILITY FOR RADIATION PROTECTION PROGRAM

G. A. Kurtz will be responsible for radiation protection and reporting of any emergency condition to the Nuclear Regulatory Commission.

The established maximum permissible exposure limits for radiological and non-radiological personnel are as follows:

Restricted Area:	1-1/4 Rems. per calendar quarter
Unrestricted Area:	2 Millirems per hr., or 100 Millirems in any seven consecutive days.

Dosage rates in excess of those specified above must be reported to the safety director immediately, who will notify Region III of the Nuclear Regulatory Commission. Always up-to-date addresses and telephone numbers are posted on the inside of the always-locked double doors and, thus, within arm's reach of the telephone.

O.E.

B. INSTRUCTION OF PERSONNEL ON RADIATION HAZARDS

All new employees who will be working in industrial radiography, as well as those currently so engaged, will be thoroughly informed of radiation hazards, and periodic "refresher" sessions will be held in accordance with The Vollrath Company's booklet titled, "Training Program for Radiographers and Radiographers' Assistants".

Continual vigilance will be maintained to direct the radiography personnel's immediate attention toward:

a) Incoming correspondence from the N.R.C., as well as new regulations and amendments,

b) Magazine articles and books on related and current topics,

c) Non-Destructive Testing Society meetings.

Testing of the radiographer's and radiographers' assistant's continued ability, knowledge, retention and understanding of and ability to comply with N.R.C. regulations, licensing requirements and these operating and emergency procedures is an important part of these instruction procedures.

C. SAFE OPERATION OF RADIOGRAPHIC EXPOSURE DEVICES

INCLUDING LEAK TESTING

1) In gamma ray building

a. The flexible source tube and flexible control cable of the remote handling device shall be kept in as straight a line as possible, and curved sections shall have as large a radius as practical, both when stored and when in use.

b. The source tube and control tube shall be located such that nothing can fall onto them and kink, choke or restrict them, or in any way prevent easy retraction of a source.

c. Instructions for operation of the remote handling device and storage container as supplied by the vendor have been re-written, and as such, are incorporated into our operating procedures. They are to be strictly followed.

d. Laboratory techniques in industrial radiography as they are developed are to be recorded and filed, including photographs or sketches of arrangements and/or setup, when applicable.

e. Cranking the source "in" or "out" is to be done by remote control at point "15" per drawing #D-1350 and the crank is to remain at this location during exposure of source. At times when the source is secured, the remote-control crank may be hung on the hook as indicated by position "14" per drawing #D-1350.

f. A light chain extending across the maze as shown by position "13" on drawing #D-1350 will be in place at all times that the source is exposed. The chain will also be in position while the source is secured except during radiographic setup or related work. Access to the gamma room is to be limited to the authorized personnel specified on a sign hanging from the chain. Immediately after each exposure, the lock box on multitron will be locked.

g. Leak tests shall be performed not less frequently than semi-annually in the following manner: A leak test kit (approved-for-use by the N.R.C. through issuance of a license for commercial use of their model #LT 100) is to be purchased with sufficient lead time to allow

for delivery schedules from The Instruments Division of Automation Industries, Inc. of Philadelphia, Pennsylvania. The kit is to be used by the radiographer in strict accordance with the instructions provided with the kit, and returned to the vendor for analysis after wiping has been done. The vendor will analyze the wiping and provide a report that the level of leakage of sources is either above or below that specified by current Federal Regulations as safe for continued use. These reports are to be kept on file by the radiographer. At any time an unfavorable report is received, (this will be via telegram from the vendor) the unit must be removed from service at once, and the safety director notified.

Results of "initial" leak tests of sources (performed by the vendor prior to shipment) will be provided by the vendor and kept on file in the gamma building with the reports of the analysis of the wipings made by the radiographer using the leak test kits.

It is to be particularly noted that a coarse check for contamination is to be made after the wipe has been made and the swab, or dauber, has been replaced in its tube and covered.

A complete set of leak testing procedures is furnished with each leak test kit. These procedures as applied to the Vollrath gamma facility are given as follows:

Model LT-100 Leak Test Kit Instructions

1.0 Preparing the unit for leak testing:

1.1 As sources are contained in the unit to be tested, a survey meter will be used to prevent exposure during all of the following procedures.

1.2 As the sources are contained in a remotely operated unit, disconnect the source tube from the shielded head after checking with the survey meter to make sure that the source is in a safe position within the head.

2.0 Taking the leak test sample:

2.1 Remove the lid from the cylindrical shipping container in the leak test kit. Take out the glass test tube and sampling swab.

2.2 Open the test tube and keep the cap in a convenient place where it won't be lost. Wet the swab by dipping it into the solution in the tube. Remove the excess liquid from the swab by moving it into a circular motion while pressing it against the side of the tube.

2.3 Insert the wetted swab into the outlet of the radiography unit. Push the swab in nearly as far as its handle will allow. Move the swab back and forth a few times to make sure that all internal surfaces of the source guide tube are contacted.

2.4 Remove the swab from the unit and place it in the test tube. Screw the cap on the test tube and tighten it.

2.5 Measure the radiation level <u>at the surface</u> of the test tube.

NOTE: The instrument that you use for this measurement must be accurately calibrated, and it must have a scale that permits accurate reading of the radiation value given in these instructions.

2.6 If a reading of <u>more</u> than 0.5 mr/hr. is observed, follow the procedure given in paragraph 3.0.

2.7 If a reading of <u>less</u> than 0.5 mr/hr. is observed, follow the procedure given in paragraph 4.0.

3.0 Handling procedures for samples reading more than 0.5 mr/hr.

3.1 If your test instrument shows a radiation level of more than 0.5 mr/hr. at the surface of the test tube, there may be gross contamination of the unit, and the following steps should be taken:

(1) Put the test tube back in its place in the cylindrical shipping container. Do not send it to Automation Industries.
(2) Immediately remove the radiography unit from service and notify the safety director. Keep the leak test sample and the contaminated unit together in a safe place until decontamination personnel can take care of them.
(3) As soon as possible, the safety director will call Region III of the N.R.C. Operations Office to inform them of the occurrence and

subsequent actions taken.

(4) Contact Automation Industries and provide them with the same information. Use the following address and telephone number:

Automation Industries, Inc.
Instruments Division
P. O. Box 245
Phoenixville, PA 19460

Attn: Radiation Safety Officer
Tele: 215/933-8961

(5) The contaminated unit will remain out of operation until corrective measures have been completed and approval is given by Region III of the N.R.C., and Automation Industries.

4.0 Handling procedures for samples reading less than 0.5 mr/hr.

4.1 If your test instrument shows a radiation level of less than 0.5 mr/hr, at the surface of the test tube, you can mail the sample to AII for further testing and certification. You are not required to return the sample by Railway Express. No radiation warning label need be affixed to the outside of the shipping container as Par. 173-391 of Dept. of Transportation Regulations now exempts small quantities of radioactive materials from specification packaging, marking and labeling.

Use the following procedure for preparation and mailing of the test sample:

(1) Put the test tube in its place in the foam shock-absorbing material in the shipping container. Make sure that the test tube cap is on tight and that the radiation warning label is on the tube. You will note that the tube has been pre-labeled for your convenience.

(2) Completely fill out the Leak Test Information Card included with the kit. Slip the card down between the foam material and the side of the cylindrical shipping container. This card will be kept at AII as a record which is available for inspection by the N.R.C.

(3) Put the lid on the shipping container and tighten it.

(4) Fill in the return address section of the shipping label supplied with the kit. Moisten the label and attach it to the shipping container. The container may be mailed to AII

by any method desired (first class, parcel post, etc.). The postage must be PREPAID.

4.2 When the sample is received by AII, they will test it and notify you of the results. If the test shows a contamination of greater than 0.005 microcuries, you will be notified immediately by telegram, telephone or teletype. In this case, you should remove the unit from service. If the test shows less than 0.005 microcuries, AII will mail you a certificate of leak test for your records.

h. A physical inventory of all licensed sources will be taken not less frequently than quarter-annually, and records kept on file by the radiographer.

2] Open-air radiography

No open-air radiography is to be done and none is allowed under this license.

3] Internal inspection system

The radiographer will perform a daily inspection of all warning devices and security measures as are required in these instructions. A complete list of the various duties of the radiographer are given in the following section "D".

Postings of current copies of these instructions, federal regulations, the license and form NRC-3 shall be maintained by the radiographer.

D. DUTIES OF THE RADIOGRAPHER

1) Daily responsibilities

   a. Attach film badge and dosimeter to clothing
   b. Read, record and charge dosimeters of all radiographers and assistant radiographers who are actively performing the radiography work schedule.
   c. Perform inspection and maintenance procedures:

      (1) Operational and Emergency Procedures Check List
      (2) Radiography Daily Inspection Chart
      (3) Automatic radiation activated warning and alarm system - system is electrically switched on at the beginning of the daily inspection. (System is then left on at all times during the entire radiography work shift schedule.)

   d. Radiographic procedure: Followed on all exposures

      (1) After the radiographic set-up is completed; and before the source is exposed, the lock box is unlocked
      (2) The chain across the maze is attached
      (3) The red flashing warning light and electric eye with sonic warning system is automatically activated by radiation when the source is exposed.
      (4) After the exposure cycle is completed, the source is retracted
      (5) (3) is automatically de-activated when the source is retracted into its safe storage position.
      (6) The chain across the maze is taken down
      (7) The source storage container and guide tube are checked with survey meter
      (8) The lock box is locked

   e. At the end of the work schedule, a physical inspection using the survey meter is performed
   f. A record of all work performed is entered on the utilization log
   g. Films are reviewed and catalogued by customer

2) Weekly responsibilities

   a. Weekly maintenance check with survey meter

3) Monthly responsibilities

   a. Change all film badges and submit previous month's badges to supplier
   b. Monthly inspection of projector and equipment

4) Quarterly responsibilities

   a. Complete "gamma facility inspection" form
   b. Calibrate survey meters and record data
   c. Complete quarterly physical inventory of radioactive sources and record data

5] Semi-annual responsibilities

a. Wall survey and record data
b. Perform leak test and record data
c. Attend semi-annual gamma room meetings and record

6] Periodic responsibilities

a. Order and maintain records of all operating supplies as needed
b. Order, receive and return radioactive sources and record information

E. OPERATIONAL AND EMERGENCY PROCEDURES - INSPECTION AND MAINTENANCE PROGRAM

1] Daily check list:

A. Check with meter after warm-up of at least one minute:

Source Safe - Multitron inlet
- Multitron outlet

B. Daily inspection of Multitron projector for:

1. Any impairment of locking mechanism.
2. Any physical damage to the device which may impair its operation.
3. Any dirt or sludge build-up at the two female threads and within the device.
4. Any damage to the source connector or cable.
5. Dust plugs in place.
6. Any abnormal radiation emanating from projector.

C. Daily inspection of Source Positioner and Indicator for:

1. Any physical damage to the handle and indicator assembly which may impair its operation.
2. Any physical damage to cable conduit which may prevent free movement of cable.
3. Proper operation of crank and indicator mechanism.
4. Any physical damage to connector of drive cable.
5. Any physical damage to male threads on conduit fitting.
6. Any dirt or sludge build-up on the cable that may impair its operation.
7. Any wear of connector.
8. Any change in shape of connector.

D. Daily inspection of source tube for:

1. Any physical damage that may prevent free motion of source through tube.
2. Any physical damage to fitting or end cap.
3. Any dirt or sludge build-up that may affect free motion of source through tube

E. Building and security inspection

1. Check doors, locks, and hinges for damage.
2. All warning signs in place.
3. All warning lights operating properly.
4. Electric eye working properly.
5. Automatic radiation activated safety monitoring system working properly.

F. Above items will be recorded on "Radiography Daily Inspection Chart"

2) Monthly inspection of projector and equipment for:

2.1 Wear or change in dimension of drive cable connector opening. Check screw type connector on drive cable and source pig tails for fit and wear.

2.2 Clearance in source tube. A steel ball 11/32" in diameter should pass freely through the entire length of the tube.

2.3 Any physical damage to projector and equipment that may impair its operation.

2.4 Adequate lubrication

(a) Source Cable Assembly
(b) Drive Cable Assembly

3) Maintenance and repair of projector and equipment:

3.1 Should be lubricated and kept clean of any dirt or sludge build-up after use.

3.2 Should have any damaged or malfunctioning components replaced before next use.

3.3 Determine and correct cause of any reported change in operating characteristics.

3.4 Correct any reported damage that may cause malfunction before use.

3.5 Maintain a standby set of controls and source tubes.

3.6 Maintain a supply of replacement small parts and fittings.

4) Periodic Inspection - not to exceed 3 months:

4.1 Daily Check List will be performed.

4.2 "Gamma Facility Inspection" will be performed.

4.3 Cleaning and lubrication of drive cable will be performed and the date will be recorded on the daily inspection chart.

5) Emergency Procedures

5.1 In the event of any electrical malfunction, contact the plant maintenance service operations manager for repairs.

5.2 In the event of malfunction of any radioactive isotope equipment, immediately contact the Radiation Safety Officer. Remain at "always locked door" until he, or other authorized gamma room personnel arrives.

6) General Instructions

6.1 The radiographer will read available literature relating to radiography.

6.2 Maintain, file and post NRC rules and rule changes.

O.E.

F. INSTRUCTIONS FOR USE OF RADIATION

SURVEY INSTRUMENTATION

1) a. A calibrated and operable survey instrument must be maintained in the gamma building. When not in use, it is to be placed conspicuously on a wall bracket installed for that specific use in the protected corner just prior to entering the maze. It is not to be removed from the gamma building except by the operator and then only when he is taking a survey on the outside of the walls of the building. No person is to pass the red light (whether it is turned "on" or not) without carrying and reading the survey meter all the way up to the safe. All radiation surveys must be taken with the meter located between the operator and the radioactive source (s).

   b. A description of the gamma facility radiation survey instruments is given:

      (a) Nuclear-Chicago Model #2588, range 0 to 2500 mr., 1 survey meter
      (b) Texas Nuclear, Model #2592, range 0 to 1000 mr., 1 survey meter

2) Radiation surveys will be taken not less frequently than every six months on the outside of the protective walls with the Cobalt 60 source exposed to assure adequate shielding, and weekly on the multitron, with both sources inside to maintenance, check the meter as well as the safe to insure that radiation levels do not exceed 10 mr/hr. measured at 1 meter.

   Records of the following shall be retained in a permanent file in the gamma building:

      a. Daily dosimeter readings of all radiographers and assistant radiographers.
      b. Monthly film badge reading.
      c. Weekly maintenance-check of survey meter.
      d. Semi-annual wall survey reading.
      e. Utilization Log and Post Exposure Survey Record.
      f. Quarterly inventory.
      g. "Semi-Annual Leak Test Reports" tabulation.
      h. "Quarter-Annual Calibration of Survey Meter" tabulation.

   A duplicate set of records "a" and "b", above, are kept in the Radiation Safety Officer's file.

3) A physical radiation survey of the multitron and source guide tube must be made immediately after each radiographic exposure to determine that all sources have been returned to their storage condition, and the reading must be entered in the "Utilization Log and Post-Exposure Survey Record", when the survey is the last survey prior to ending the days work operation. The lock box on the multitron must be locked immediately after each exposure.

4) The radiation survey instrument must be capable of measuring radiation levels of at least two milliroentgens per hour through one roentgen per hour. The survey meter must be turned on at least one minute prior to use, to insure adequate warm-up. The manufacturer's instructions must be followed.

   The meter is to be calibrated no less frequently than quarter-annually and after each instrument servicing. Records of calibrations and written procedures must be kept on file.

G. INSTRUCTIONS FOR RESTRICTING RADIOGRAPHIC AREAS

1) After the radiographic set-up is completed, the lock box is unlocked, and the chain is secured across the maze. The red flashing warning light and electric eye monitoring system is then activated by the presence of radiation when the source is exposed. A sign, "Caution, Radioactive Materials" and bearing radiation symbol must be located in a manner to be conspicuous to everyone immediately upon entering the gamma room. Posted at the entrance to the maze leading to the gamma room must be a warning sign, "Caution, High Radiation Area" and radiation symbol. On the locked door in the corridor leading to the high radiation area, "Caution, Radiation Area" and radiation symbol must be posted. The only door leading to the gamma building must be locked at all times whether operator is in the building or not and whether the source is exposed or not. The entrance to the maze must be under surveillance by the electric eye at all times when the source is exposed, so that an alarm in the immediate area, another in the foundry office, and a third alarm in the general foundry office, will sound if anyone enters the maze leading to the gamma room.

2) When the alarm sounds, it will be the responsibility of the personnel in the general foundry office to telephone the radiographer's office in the gamma building to determine the reason for the alarm sounding (i.e., an inadvertent motion by the radiographer, malfunction of the photo-electric cell, unauthorized personnel in the area). The individual will then, after placing the call to the radiographer (whether the call is answered or not), immediately notify the Radiation Safety Officer that the alarm sounded and state the reason, if known.

   If the Radiation Safety Officer is not in the plant, the individual will report immediately to one of the other men listed under "Emergency Procedures", section K, that the Radiation Safety Officer is not in the plant and notify him of the sounding of the alarm and the reason.

   The Radiation Safety Officer (or, in his absence, his alternate) will proceed to the gamma building and follow emergency procedures as given under section K of these instructions. If an alternate is called by the individual, the alternate will then see that the Radiation Safety Officer is informed upon his return to the plant. A list of these men's names and phone numbers and these instructions are posted at the foundry office bulletin board.

O.E.

The only exception to this procedure is: the call to the Radiation Safety Officer need not be made when the alarm is rung for the purpose of testing the alarm system.

3) Temporary radiographic areas and open-air radiography are not to be used.

H. INSTRUCTIONS FOR USE OF PERSONNEL

MONITORING EQUIPMENT

1) Type of equipment: To monitor personnel exposure, all personnel will wear film badges, additionally, 0-200 mr. pocket dosimeters will be worn by radiographers when in gamma building.

   A description of the gamma facility personnel monitoring equipment is given:

   a. Pocket dosimeters, Landwerk, Model L50 range 0-200 mr. and Victoreen, Model 541R range 0-200 mr.
   b. Film badges, Siemens, Model Standard Nuclibadge 11, supplied and processed by Siemens Gamma Sonics.

2) When, where and how personnel monitoring equipment must be used.

   a. Personnel monitoring equipment will be worn at all times while inside the gamma building.
   b. All dosimeters and film badges will be worn on the bearer's clothing where they can be conveniently and firmly attached at such point that registering radiation will not pass through the bearer's bodies or limbs prior to being recorded.
   c. Unexposed film badges will be issued monthly. Exposed personnel film badges, the control film and one monitor badge will be sent to the film badge service company:

      Siemens Gamma Sonics Inc.
      Health Physics Services
      Box 1367 Oakton St. Station
      Des Plaines, IL 60018

      (The above company is a re-organization of Nuclear-Chicago Inc.)

      At the beginning of each day, the radiographer will charge the dosimeters and return them to the bearers to whom they have been assigned. At frequent intervals during the day, dosimeter readings will be checked by each individual. At the end of each work day, the radiographer will read and record all dosimeter readings. In the event a dosimeter is found to be off scale, the individual will notify the radiographer and safety director immediately. The individual's film badge will then be sent to Siemens for reading and the individual will be witheld from gamma work until the exposure reading is

received. If over-exposure has indeed occurred, the safety director will notify Region III of the NRC at once. Unexposed film badges and reports will be received from, and exposed badges mailed to the film processing laboratory also by him, and the proper entries made on the records.

The radiographer will work with the safety director so that duplicate records will be maintained in the safety director's file as well as in the gamma office, as specified in F-2 of these instructions.

3) Dosimeter Calibration Procedure

All pocket dosimeters in use will be calibrated annually. The results of the calibration will be listed on the "Annual Dosimeter Calibration" table which shows the date, actual readings and dosimeter numbers. Meters found to be outside the designated acceptable range of plus or minus 30% will immediately be removed from use, then serviced or replaced.

The following formula, stating the calculated dose in milliroentgens is given:

$$MR = \frac{14400 \times C}{d^2} \times \frac{t}{60}$$

where
MR = calculated dose at a given distance
C = number of curies from the current Co^{60} decay curve
d = Distance in feet from source to dosimeter
t = Time of exposure in minutes

Example: Placing the dosimeters on petastal, at 10 feet, and exposure time of 5 minutes, Co^{60} source at 11.8 curies, the calculated MR will be

$$MR = \frac{14400 \times 11.8}{(10)^2} \times \frac{5}{60}$$

$$MR = 141.6 \text{ mr}$$

. . acceptable dosimeter readings will be:
+ 30% = 184 mr
- 30% = 99 mr

I. INSTRUCTIONS FOR TRANSPORTING SOURCES TO FIELD LOCATIONS

No transportation of sources to field locations will be done and none is permitted under the license to which these instructions are appended.

J. SECURITY OF SOURCES DURING STORAGE

1] After each exposure, the sources will be locked in Nuclear Systems Model 62 Multitron permanently labeled with a warning sign reading, "CAUTION, RADIOACTIVE MATERIALS". A survey on the machine and source guide tube will be made immediately after each exposure, as given in F-3 of these instructions. The gamma building will be locked at all times by automatic latch which locks the door as it is closed by the door closer. Permanent warning signs are posted in accordance with G-1 of these instructions. Signs will also have the names and telephone numbers of persons to call in case of emergency.

2] Other security measures to prevent accidental handling of radioactive sealed sources or devices include the visual and sonic systems as noted in G-1 of these instructions.

O.E.

K. EMERGENCY PROCEDURES

Definition of emergency: An emergency will be considered to exist at any time that --

a. The radiographer is unable to fully retract the radioactive source back into the multitron and lock it, or

b. the survey meter indicates that the source is not adequately shielded, or

c. the lock on the door or any of the other safety measures are inoperable or malfunctioning, or

d. anything in the discretion of the safety director or any of the individuals as listed in the subject license, represents any doubt of a possible existing or imminent hazard.

In an emergency as defined above, the radiographer or other person first noting the condition will immediately place a call for the safety director or, (if the safety director is not in the plant) one of the other men listed below:

Name	Phone Extension	Home
R. L. Vandermus	311	467-6730
G. A. Kurtz	248	452-0887
G. P. Neumann	309	458-5891

After completing the call, the caller will remain at the entrance to the gamma building until the individual called arrives and is acquainted with the nature of the emergency. Corrective measures will be initiated as soon as practical and complete security of the source and room will be maintained until the safety director (or individual called above) is convinced that radiography work may proceed in complete safety. Upon the return of the safety director to the plant, he is to be notified of the emergency, its nature, date and time, corrective measures taken and by whom and any other pertinent information. If plant corrective measures cannot be taken, the safety director, or his representative listed above, will call Region III of the NRC and inform them of the existing condition.

O.E.

A list of the names and telephone numbers shown above is posted in each of the following places:

1. On the radiation warning sign on the always locked double doors, and

2. On the high radiation warning sign on the wall at the entrance to the maze.

   NOTE: Other locations at which identical lists are found: guard's gate lodge and in general foundry office.

O.E.

L. INSTALLATION, REMOVAL OR EXCHANGE OF SEALED SOURCES IN EXPOSURE DEVICES

1) Equipment to be used when exchanging sources.

   a. Instruments Division of Automation Industries, Source Changer

   b. Instruments Division of Automation Industries, Source Changer Source Tube

   c. In-plant Instruments Division of the Budd Co. Model 62 Multitron

   d. In-plant Nuclear-Chicago Corporation approved and calibrated survey meter.

2) Procedure to be followed for installation, removal or exchange of sources: Complete written instructions are given later in these instructions.

M. MISCELLANEOUS

1) Do not step on, push or drive trucks over the flexible source tube or flexible control cable. Inspect tube and cable daily for kinks or flattening.

2) Any employee who disregards these instructions, or tampers with dosimeters, film badges, radiography records or any radiographic equipment is subject to disciplinary action, including discharge.

3) A sign with the text of M-2 above, has been placed on the locked door leading to the radiography room.

4) Annual physical examinations are to be arranged by the plant nurse for all personnel concerned with the radiography operation (those carrying film badges and/or dosimeters). Suitable records are to be kept by the plant nurse. She will also notify the individuals of the date, time and place of their appointments and the name of the examining physician.

O.E.

N. SPECIFIC MISCELLANEOUS INSTRUCTIONS -

OPERATING INSTRUCTIONS FOR AII SOURCE CHANGER

Any time a source is received or returned, make proper entry on "Receipt and Return of Sources" form.

For Installation of Source Into Empty Radiography Machine "S" Tube: When specified radiation surveys are to be made, the radiation level cannot exceed a reading of 10 mr/hr. at 1 meter.

1] Locate the source changer within 2 feet of the shielded head, on the outlet side (opposite the lock box), with "S" tube (of source changer) in which the source is located, aligned with the empty "S" tube of the machine into which the source is to be inserted. Be sure lock box of machine is fully locked.

2] Remove beamer plug or source tube from the machine outlet.

3] Connect the short source tube supplied to the machine outlet into which the new source is to be drawn.

4] Connect the remote-control cable to machine lock box at the point of entry to the "S" tube that is to be used for storage of the new source (in the event that the machine has more than one "S" tube). Extend control cable so that operator is positioned a full 25 feet from machine. Unlock the proper "S" tube passage.

5] Run control cable through machine and short source tube until cable disconnect is exposed. Check the area with a survey meter.

6] Remove the plug from the source changer "S" tube in which the new source is located, being careful not to pull out the source cable inside.

7] Carefully pull the source cable disconnect out of source changer outlet only enough to allow connection of disconnects.

8] Join disconnects on control cable and source cable.

9] Connect source tube to source changer outlet.

10] Pull source into machine by turning remote-control handle counterclockwise.

11] After a monitor check has been made with a survey meter, remove short source tube.

12] Replace the plug in source changer and replace beamer plug or reconnect standard length source tube to machine outlet.

13] Remove source number plate from inside of source changer and place in the proper plate holder on head of machine. Record this number on "Wall Survey" form (and on "Receipt and Return of Sources" form). Remove warning labels from changer.

14] Return short source tube with source changer to vendor, PREPAID.

15] Notify purchasing agent that source has been received and installed, and empty source changer is ready to be returned to vendor. Then write letter to vendor (see file for sample letter) and return key, if any, to vendor with letter.

NOTE: To remove a source from machine, follow instructions for exchanging sources (which follow) through step 8, and steps 15, 21 and 22. Make monitor check, attach lead seal to the proper source changer outlet, change source number plate from machine to source changer and attach Radiation Warning labels to changer and return to vendor with short source tube, shipping PREPAID.

For Removal of Spent Source and Insertion of New Source Into Radiography Machine "S" Tube: When specified radiation surveys are to be made, the radiation level cannot exceed a reading of 10 mr/hr. at 1 meter.

1] First, make certain that spent source is fully withdrawn into "S" Tube of machine:

a. Control cable crank will be rotated counterclockwise to maximum position.

b. Indicator showing number of feet exposed should read "0".

c. Make monitor check with survey meter.

d. Check to see if machine can be locked. If so, source is fully withdrawn.

NOTE: Be sure control cable is attached to spent source cable and all other "S" tubes are secured and locked if machine has more than one "S" tube.

2] Place the source changer within 2 feet of the shielded head of the radiography machine on the outlet side (opposite from the lock box), with empty (determine with survey meter) "S" tube of changer in line with spent source outlet.

3] Disconnect source tube from machine outlet of spent source or remove aluminum plug if unit was being used previously as beamer. Remove plug from empty "S" tube inlet of source changer.

4] Connect the short source tube (supplied with changer) to the correct machine outlet and to the empty "S" tube of source changer.

5] If not already done, extend control cable so that operator is positioned a full 25 feet from machine, and unlock spent source "S" tube.

6] Run control cable out by turning position indicator crank in clockwise direction, pushing spent source fully into source changer's empty "S" tube. Survey with meter upon re-entry to gamma room.

7] Carefully disconnect short source tube from source changer and slowly pull source cable out just far enough to disconnect control cable from source cable.

8] Disconnect control cable from source cable.

9] Remove plug from source changer "S" tube inlet where new source is located and place this plug in the source changer "S" tube inlet into which the spent source has just been placed.

CAUTION: Whenever removing the plug from source changer, be careful not to pull out the source cable inside the tube.

10] Carefully pull the new source cable disconnect out of source changer outlet only far enough to allow connection of source cable to control cable.

11] Join source cable to control cable.

12] Connect short source tube to source changer "S" tube in which new source is located.

13] Pull source into machine by turning control counterclockwise, as in "1" above.

14] After a monitor check has been made with a survey meter, lock the lock box and remove short source tube from source changer and the machine.

15] Reconnect standard length source tube to machine outlet or replace beamer plug. Insert source changer plug (removed in "3", above) into inlet of "S" tube of source changer.

16] Remove source number plate from inside of source changer. Record this number on the "Wall Survey" form and "Receipt and Return of Sources" form.

17] Remove the correct number plate in the machine where the transfer of sources has just been made and place this plate into the source changer where the spent source is located.

18] Place the number plate (removed previously from the source changer and which has been properly recorded as in "16" above) into the proper plate holder on the head of the machine, where the new source is stored.

19] Two (2) Lead Seal wires have been furnished with the new source. One (1) is to be used for resealing source changer cap plugs and attaching the old source number plate, and one (1) for sealing "U" Bolt Lock on the changer box.

20] Two D.O.T. style shipping labels are included in the envelope. These are to be pasted over the similar labels on the shipping box. The blank spaces should be filled in as follows:

Principal Radioactive Content--spell out: Iridium 192 or Cobalt 60.
Activity of Contents--Number of Curies.
Transportation Index--By radiation survey - mr/hr. at 3 feet.

21) For all outgoing radioactive shipments, the Bill of Lading Must State:

Radioactive Material, Special Form- N.O.S., Type B Container, Radioactive Yellow _____ label applies

Freight Rate Class 70
Declared value--less than $ .40/lb.
Transportation Index _____ N.A. 9182

Source (s) Contained:	Source Activity:
Iridium 192	_____ Curies
Cobalt 60	_____ Curies

NRC - Certified Package

"This is to certify that the above named articles are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation."

22) Notify purchasing agent that source has been received and/or installed, spent source is being returned to vendor in source changer and is ready to ship, and changer will be kept in gamma room until truck arrives to pick it up. Then write letter to vendor (see file for sample letter), and return key (if any) to vendor with letter.

23) When truck has picked up spent source, properly record this fact on "Receipt and Return of Sources" form.

24) The radiation survey meter reading, MR./HR., as performed in step 20 above, will be recorded and maintained on the "Receipt and Return of Sources" form. Also the surface reading of the shipping container will be taken and recorded on the "Receipt and Return of Sources" form.

O. 1) INSTRUCTIONS FOR ORDERING RADIOISOTOPES

Do not order more than 12 Curies of Cobalt 60 or more than 26 Cures of Iridium 192 because of the following tolerance and condition:

a. Cobalt 60: 12.0 Curies, maximum order
1.2 Curies, the 10% tolerance on reactor irradiation
5.0 Curies, spent source strength present at time of exchange of sources

18.2 Curies Total

Maximum of 20 Curies of Cobalt 60 present at sight at one time. Building designed for 20 Curies of Cobalt 60 (determining isotope).

License requested for 20 Curies of Cobalt 60.
Model 62 Nuclear Systems Multitron rated capacity is 15 Curies of Cobalt 60, which, from the above and the exchange procedures, will be the maximum it will ever contain, even during exchange of sources.

b. Iridium 192: 26.0 Curies, maximum order
5.2 Curies, for 20% tolerance
7.5 Curies, spent source strength

38.7 Curies Total

As shown above, the Cobalt 60, being the determining or strongest source handled in the gamma facility, our maximum order will be 12 Curies which is well within the design limitation of the building structure and the multitron unit. The design of our miltitron equipment makes it impossible to expose more than one source at a time.

2) RECEIPT OF SOURCE(S) AT PLANT CENTRAL RECEIVING OFFICE

a) Upon receipt of source(s) at Central Receiving Dept. receiving clerk will keep source changer segregated from other shipments in process.

b) Receiving clerk will immediately notify radiographer that source shipment has been received.

O.E.

c) Radiographer will survey source changer at central receiving dock location.

d) Radiographer will then transport source into gamma radiography facility

e) A notice stating the text of section 2 above, is on file at the plant receiving clerk's office.

f) Upon arrival into gamma room with source shipping container, the radiographer will visually inspect the container for damage that could be a potential safety hazard in shipment of the spent source and container back to Automation Industries. The visual check to the shipping container will include the following: broken walls, cracks in metal corners and edges, damaged latches or hinges, or any other physical condition that could impair safe return of spent source and container. A check-list titled "Source Container Inspection", (1 copy included in Section U), will be completed and this record will be kept on file in the gamma room. If in any event, a problem with the shipping container is noted, the source supplier, Automation Industries, will be advised of the noted condition and a new return shipping container will be supplied if acceptable repairs cannot be made to the damaged container.

3) MAXIMUM CAPACITY OF MODEL 62, NUCLEAR SYSTEMS, MULTITRON

a) If sources are contained separately:
30 Curies of Cobalt ^{60}, or
300 Curies of Iridium ^{192}

b) If sources are contained together:
15 Curies of Cobalt ^{60}, and
150 Curies of Iridium ^{192}

P. RADIOGRAPHY INSTRUCTIONS FOR LOCATION OF MONITOR FILM BADGE:

The monitor film badge is to be placed for a one-month period in each of the following places (refer to sketch on "Semi-annual Wall Survey Meter Readings" form):

A, C, E, F, G, H and one month on the wall cabinet door clearly marked in the darkroom and on entrance door to gamma room.

A complete cycle for the monitor badge will consume 8 months. When the monitor's entry is made on the film badge form, the location at which the exposure was made is to be prefixed to the magnitude, e.g., "A-15", "C-12", "H-5".

O.E.

Q. SPECIAL INSTRUCTIONS TO BE FOLLOWED

WHENEVER A NEW SOURCE IS RECEIVED

A wall survey is to be made immediately after the new source has been properly installed in the multitron, but the semi-annual wall surveys of the new source may be cycled in with the other semi-annual surveys (of the other source, if one is already in the Multitron), so that the wall surveys of both sources may thus be made thereafter on the same day. Consequently, the elapsed time between the initial wall survey with a new source and the first regular semi-annual wall survey thereafter may be less than six months.

When the initial wall survey is made, the following data must be recorded:

Source data: Type of Source (Cobalt, Iridium, etc.)
Number of Curies (on assay date)
Date of assay

Capsule date: Model number of sealed capsule.

Wall Survey data: Date of "wall survey" measurement Instrument used.

a. Manufacturer
b. Model Number
c. Serial Number
d. Latest Calibration Date
e. Survey reading taken by whom?

R. Instructions To Be Followed When The Source Cannot Be Kept In The Center Of The Gamma Room.

1) Since there is no practical need for moving the source tip from the center of the gamma building exposure room, all radiographic exposures will be made with the source tip located in the center of the room. Moving the source tip from the center of the room, thereby increasing the source to film distance would result in excessively long and impractical exposure times. Therefore, all radiographs will be taken with the source located in the center of the gamma room.

2) The source will be kept in the center of the gamma room except as specifically stated in Section T - Instructions To Personnel Performing Survey Meter Calibrations. In this case, when the source tip is moved for meter calibration purposes, the protective lead shield or collimator shield, must be placed around the source tip.

S. SAFETY PRECAUTIONS AGAINST RADIATION HAZARDS TO BE FOLLOWED BY MAINTENANCE MEN

At any time when construction, maintenance or other workers, whether employees of this company or of any outside contractor, must work above floor level in the southwest quarter of the old foundry, or on the gamma building, they must first follow the safety precautions as outlined below before beginning work.

In the event that the workmen are those of an outside contractor, they are to register at the Gate Lodge, at which time the gateman on duty will ask in which department of the plant they are going to work. If they are to work in or on the foundry or the gamma building, they must first get clearance from the radiographer before beginning work. In the event that workmen of an outside contractor are working in some department in the plant other than the foundry and wish to enter the foundry or gamma building at some time later that day to perform some work, they must re-register at the Gate Lodge, at which time the gateman will order that clearance be received from the radiographer before beginning such work. If the radiographer is not present, clearance to proceed must then be obtained from the safety director or the person doing the radiography work.

The Safety Procedures for Maintenance Men Are As Follows:

1] The radiographer is to be notified by the supervisor of the workmen.

2] At a mutually agreeable time between the radiographer and the supervisor of the workmen for work to be performed in the restricted area, the radiographer will check with the survey meter to be sure the sources are in the Multitron and locked in position before work is begun in the restricted area.

3] The radiographer will then place the warning sign (which states that neither source is to be exposed until proper clearance is given) on the Multitron so that it covers the lock box.

4] The radiographer will then notify the supervisor of the workmen that it is safe for them to proceed with their work in the restricted area and that he is to contact the radiographer upon completion of their work. The radiographer will also remind the supervisor that:

when the supervisor informs the radiographer that their work in the restricted area is completed, he (the supervisor) already shall have told his workmen not to re-enter the restricted area for any reason whatsoever. In case the workmen are those of an outside contractor, the supervisor of the crew must sign "out" at the Gate Lodge. Whether already signed "out" or not, re-entry into the area may be made only after going through this procedure again.

5) If the radiation collimator is being used, radiography work as well as inside shop maintenance work can be done simultaneously, after approval to proceed is given by the radiographer. It is pointed out here, that no radiography work is allowed when outside maintenance work in the restricted area on the gamma building roof is being done.

6) Radiography work can proceed when the above procedure has been followed and completion of the work has been acknowledged by the radiographer.

O.E.

T. INSTRUCTIONS TO PERSONNEL PERFORMING SURVEY METER CALIBRATIONS USING COBALT-60 SOURCE

Frequency: Meter calibrations must be performed at intervals of three months or less and after each instrument servicing, EXCEPT that in the event of future changes in federal regulations relating to frequency of calibrations (or to other pertinent factors) then the amended regulations will, of course, govern.

Location: Calibrations are to be performed in the exposure room of the gamma bldg., Foundry Division, of The Vollrath Company, Sheboygan, Wisconsin.

Personnel: Personnel performing the calibration function will be strictly limited:

1) One person alone may not perform the calibration; a team of not less than two individuals must be present (in the building) to:

   a) Provide additional safety
   b) Facilitate accurate measuring
   c) Substantiate meter indications to eliminate possibility of mis-reading the meter
   d) Co-initial the tabulated results

2) The team performing the calibration must be selected from the following list:

   a) Glenn A. Kurtz, General Supervisor-Administration
   b) Russell L. Vandermus, Electrical Engineer
   c) Gordon P. Neumann, Metallurgical Engineer and Radiographer
   d) Nate Nanninga, Foundry Project Engineer and Assistant Radiographer
   e) John Andrews, Assistant Quality Control, Radiographer
   f) Donald Lawrence, Radiographer

The only exception to the above limitation is that if and when other individuals are classified as radiographers or radiographer's assistants after satisfactorily completing the training program, they would then become eligible to assist. To avoid "the blind leading the blind" situation, however, both individuals performing the calibration may not be neophytes: at least one of the individuals must be a licensed radiographer from the above list.

O.E.

Purpose: The purpose of performing the calibration is to assure continued reliability of the meter. In keeping with this purpose, if at any time the meter operation appears peculiar, an emergency condition will be considered to exist and steps will be taken immediately to perform a calibration check. (Refer to emergency procedures.)

Safety: Calibrating personnel will adhere to normal radiographic safety precautions of preventing access to the gamma building via the always-locked door, and wearing personnel monitoring equipment (film badges and 0-200 mr. dosimeters).

Procedural Caution: When the source tip is moved from the center of the gamma room and located--no closer than--4 feet from the South and West walls, the protective source tip lead shield or collimator must immediately be placed around the source tip, with the tip located inside and centered (geometric center), of the 7" long shielding cylinder. This shield will reduce the radiation levels on the outside walls to well below the 2 mr./hr. limit for an unrestricted area. For example, actual readings taken using a 12 curie Co^{60} source are given:

Location Points on Outside Walls	Radiation Reading mr./hr.
A	0.1
B	1.0
C	0.2
D	0.2

Additionally, 1.0 mr./hr. was the maximum radiation level found at any outside wall location.

Equipment to be used: Calibration curve; gamma form 8; survey meters; lead shield for source tip (6½" OD x 3½" ID x 7" LG) or collimator; laboratory cart; model PC-33 Nuclear-Chicago 10 foot long flexible cable; crank on pedestal; control cable; source tube; stand for source tube tip positioning, stand for source tube tip lead shield; 100 foot tape; tubular lead shield for ionization chamber; lead blocks of proper thickness (as prescribed for use on calibration curve); Cobalt 60 source; slide rule; various wood blocks and wedges as required for blocking ionization chamber on the cart; a drum or other support on which to locate the main portion of the meter being calibrated; and the Multitron storage container with key for the lock box.

O.E.

Procedure:

1) Remove the calibration curve sheet and gamma form 8 from the calibration file.
2) Select the appropriate abacissa value on the curve sheet according to the current date and read ordinate values. (Draw a vertical line to assist, if you wish).
3) Record these values on form number 8 in the row labelled "graph" under the proper columnar heading.
4) Enter the date in the left column of form 8.
5) Check the survey meter for mechanical zero and turn the meter on per standard procedure to "zero set" and allow at least one minute for warm-up. (During this time, double-check that individuals present are properly wearing personnel monitoring equipment, that source position indicator on remote-control crank shows "0" feet of source are exposed and that the following items are all ready for use: laboratory cart, Model PC-33 Nuclear-Chicago 10 foot long flexible cable, drum for entrance to maze on which to rest the meter, 100 foot tape and slide rule. Since no radiography is done outside of the gamma building, all other items to be used will be in their usual location).
6) Set the meter's selector switch to the XI scale and with the meter held so that it would be subjected to radiation before the individual carrying it (meter precedes the bearer into maze and exposure room), and so that the bearer's body will not shield the meter from the energy source, check the maze and then the exposure room to assure that the source is in its shielded position. If the source IS shielded, as is certainly expected, the radiation level in the maze will be "0" mr./hr., and the level in the exposure room will likewise be "0" except when within 6" or so from the multitron. If the source is shielded, proceed to the next step (#7). If a level of anything other than "0" mr./hr. is noted in the maze, don't enter the exposure room at this point, for the source is exposed. A likely level in the maze (depending on location of the reading, and which source is exposed, and its strength) will be between 2 mr./hr. and 25 mr./hr. In this event, suspend further steps in the calibration, turn the meter off, declare an emergency to exist, and follow the emergency procedures immediately. When the reason for the source being exposed is known, and the source is safely returned to the shielded position and all equipment is completely normal and operable, repeat procedure from and including step 1,
7) TURN SELECTOR SWITCH OF SURVEY METER TO THE "OFF POSITION.
8) Place the laboratory cart approximately at the point where the maze exits into the exposure room, with the long dimension of the cart east to west so that the handles won't interfere with the calibration.
9) Place the lead cylinder (stored in the northwest corner of the exposure room) on the laboratory cart so that the cylinder's axis is horizontal and points approximately north to south. Accuracy of location and direction is not critical at this point. Block the cylinder in place with wedges to prevent it from rolling on the top of the cart.

10) Remove ionization chamber from the rest of the meter by firmly pulling axially (being careful that neither part will slip from your grasp).
11) Plug the 10 foot extension into the main portion of the meter and into the ionization chamber.
12) Place the fibre drum (upside down) at a safe location in the maze (radiation level usually averages 5 mr./hr. or less here while source is exposed): along the south wall of the maze, and just east of the chain.
13) Place the main portion of the meter on the over-turned drum's bottom (or equivalent) so that dial face may be easily read, and with the 10 foot extension cord issuing toward the west from the meter.
14) Being careful that the meter is not pulled off of the drum, insert the free end of the ionization chamber into the lead cylinder from the north. Insert it fully, until the plastic cover on the chamber is just flush with the south face of the cylinder.
15) Stand the first (thickest) lead block on edge against the south face of the lead cylinder so that it completely covers the hole of the cylinder and will shield the ionization chamber.
16) Measure the distance from the floor to the centerline of the ionization chamber, and adjust the source-tube-tip positioning stand so that the source-tube-tip is the same distance from the floor as is the ionization chamber centerline.
17) Move the source-tube-positioning stand to the southwest area of gamma room, but no closer than 4 feet from the South and West walls.
18) Re-arrange the source tube as necessary for this and other locations of the tube-tip so that only smooth and generous radii exist. Follow other instructions in this regard as given in the "Operating and Emergency Instructions", such as assuring that nothing heavy can fall onto the source tube, etc.
19) Measure the distance from the source-tube-tip to the midpoint (lengthwise) of the ionization chamber. Make allowance of approximately 5/16" from the tube-tip surface to the center of the source. Make any required adjustments in the distance or aligning the ionization chamber's centerline with the source-tube-tip by moving the laboratory cart, NOT the source-tube-tip. Final distance measured should be as specified for the thickest lead block on the calibration curve sheet.
20) If the Iridium source is attached to the remote-control system for cranking out the source, disconnect it and connect the cobalt source to the remote-control cable.

21) To minimize the length of the exposure times and the time for the overall calibration, tabulate the values of doserates in mr./hr. as read from the graph (and entered on form 8). Multiply each of these nine optimum levels by 90% and 110% to find the minimum and maximum acceptable levels (meter tolerance of ± 10%).

22) Turn the meter on (to "zero set") so that it can be warming up during the next step.

23) Adjust the "zero set" knob if necessary.

24) Unlock the lock box.

25) Both men performing the calibration will then position themselves in the vicinity of the remote-control crank while the radiographer cranks out the source.

26) The meter's selector switch will then be turned to the proper miltiplier.

27) Each of the two men will proceed to read the meter, and after agreeing on the measured level of radiation, will check that it lies between the maximum and minimum as determined from the graph and the applied 10%. If the reading does indeed lie between the two acceptable extremes, the calibration may continue with step 28. If the reading lies beyond either of the extremes, the calibration screw must be turned in the appropriate direction until the reading does lie in the acceptable range.

28) The meter's selector switch will then be returned to zero-set and checked for "zero".

29) With both men near the crank again, the radiographer will withdraw the source back to a shielded position. That this is accomplished will be checked by moving the selector switch to XI scale.

NOTE: AT ANY POINT IN THE CALIBRATION PROCEDURE that the calibration adjustment screw is moved, all readings already taken are void and calibration of all nine points must begin over with the first set-up. In other words, when the calibration is completed, all nine radiation levels read and entered on form 8 must have been achieved at a single setting of the calibration screw. If this can't be accomplished, check the batteries in the meter to be sure they are of sufficient strength, replace any weak ones and proceed again with recalibration beginning with the first set-up. If satisfactory results still can't be obtained, the meter will have to be serviced and recalibrated. If significant internal components (excluding batteries) are replaced in the meter, it is most likely that some degree of change will occur in the circuitry constants and it is conceivable, as a result, that a successful calibration using the "old" (current) calibration curve would be impossible to achieve. Again, if this occurs, a new calibration curve will be required. Also, when a new source is received, it will be necessary to prepare a new calibration curve sheet.

When preparing the new curve sheet for either of the above two circumstances, use the calibrated source

strength as basis in calculations. (Sample calculations follow.) If a new curve sheet is prepared, or calibration is delayed for any reason, it will be necessary to start over from the beginning of the calibration procedure.

30) With the source shown to be withdrawn into the shielded position, lock the lock box and make the next set-up in the exposure room. Turn meter to zero-set.

Repeat steps 23, 24, 25, 26, 27, 28, 29, and 30, until the complete calibration has been performed satisfactorily. Turn the meter "off".

Enter final results on form 8. Under "remakrs", include whether or not adjustment of calibration screw was necessary, as well as any other pertinent information. Both calibrators (the radiographer and his assistant) must initial the appropriate line on form 8.

Cautions: Double check that the meter is "off" before unplugging the 10 foot extension cord re-assembling the ionization chamber to the main portion of the meter to avoid damaging the instrument.

As mentioned earlier, the only acceptable locations for the source-tube-tip are:

1) In the center of the gamma exposure room (10 feet from each wall), and
2) No closer than 4 feet from either the South and West walls.

Return all equipment and materials to their original condition and locations.

Sample Calculations

For

Preparing Calibration Curve Sheet

Given:
1) Assume source calibrated strength is correct (actually, the vendor claims production radio-graphy sources are calibrated correctly to within ± 5%). This assumption places all error on the meter.
2) Absorption factors for lead are: 1.75 for 0.480"
   5.83 for 1.350"
   3.75 for 1.630"
   17.50 for 2.110"
3) Meter: Nuclear-Chicago Model 2586, serial 1193.
4) Cobalt 60 half-period: 5.2 years (Cobalt 60 will be used for calibration as well as for radiography).
5) Selected levels to use at left margin of graph sheet: 7.5, 13.0 and 20.0 mr./hr. (X1, X10, X100).
6) Cobalt emission rate: 14,400 mr./hr./curie at one foot.

For the sample calculation, let us select the 20.0 mr./hr. level on the X10 scale, or a level of 200. mr./hr.

(Although the exposure room is 20'-0" square, it is obvious that with the entrance to the maze (from the exposure room side) considered, an "L" shaped area exists which permits a source-to-ionization chamber distance of approximately 30 feet.)

Assume for this example that the vendor's decay curve for the source claims the source strength at calibration was 12.5 curies (this should then be within 5% of the true value), and the curve shows that on the day of the first calibration using the new curve sheet (and the day on which the curve is to be drawn), the strength has decayed to 12.0 Curies.

$$\text{Then: } 200 \text{ mr./hr.} = \frac{(14{,}400.)\ (12.0).}{d^2} \text{ and}$$

$$d^2 = \frac{(14{,}400.)\ (12.0)}{200.} = 864 \text{ ft.}^2;\ d = \sqrt{864.} \text{ feet}$$

$$= 29.45 \text{ feet.}$$

By the time we provide allowance for the laboratory cart, we exceed the 30 feet (approx.) available, and shielding will be required.

Try the thinnest of the four blocks available in order to maintain the greatest distance and thus minimize the % of error created by small measuring discrepancies. The thinnest block is 0.480 inches of lead. As given, the attenuation factor for this thickness is 1.75, and the equation then becomes:

$$d^2 = \frac{(14{,}400)\ (12.0)}{(200.)\ (1.75)} = \frac{864.}{1.75} = 494. \text{ ft.}^2$$

$$d = \sqrt{494.} \text{ feet} = 22.2 \text{ feet.}$$

This distance is available, and therefore the initial level read should be between (0.9) (200.) and (1.1) (200.) mr./hr. (due to ± 10% meter error), at 22'-2.4" using 0.480" of lead shielding (use 22'-2-3/8" distance.)

END OF SAMPLE CALCULATION

END OF CALIBRATION INSTRUCTIONS

U. Equipment and Techniques Including Summary of Safety Procedures

A. Equipment and Techniques

Radiographic Equipment To be Used.

At the present, we are using only one type of exposure device: The Budd Co. Model 62 Multitron for both Cobalt and Iridium. This unit consists of three main components which are: the lead head that contains the sources when not in use, the control cable and source position indicator, and the flexible source tube through which the sources travel to the point of exposure.

The following information is taken from the "Instruction Manual-Model 60 Multitron" provided by The Budd Co.

"OPERATION - By attaching the flexible source tubing to the Series 60 Multitron, it is used for internal, panoramic or difficult to reach exposures. Thus, the source may be positioned within a cavity in castings, valves, piping, tanks, etc., or in the center of a large group of specimens which can be radiographed in a single exposure.

"To attach the flexible source tube, the aluminum plug is removed from the fitting in the base of the cone in the head shield and the source tube coupling is threaded into place.

"The long control cable with the source position indicator is attached by removing the plug on the lock box of the source desired. With the machine locked, the small source cable should be pulled out 1/4" to expose the disconnect. (NOTE: Pulling the source cable out with the machine unlocked may result in the source coming out of the head completely and exposing personnel to radiation hazard.) The disconnect on the control cable is then joined to the disconnect on the source cable by bringing them together and locking firmly in place with the recessed set screw. The control cable is then straightened and the control cable adapter threaded into its proper position in the lock box. The Multitron is now ready for operation.

"To set up for operation, the end of the source tube is placed in position where it is desired to have the source located during exposure. The end of the tube may be held in position by tape, test tube clamp, wooden blocks with a hole, or in any other suitable manner.

"The source tube should be as straight as possible for ease of operation. The control cable is then extended to its fullest length with the control handle as far away as possible from the end of the source tube where the source will remain for the exposure. It is preferable to have the operator with the control handle as far as possible from any point where the source is exposed, preferably behind a personnel shield.

"After unlocking the Multitron with the key provided, the source is exposed by turning the control handle clockwise until it stops. The source position indicator on the handle shows the position of the source in the source tube at all times. No forcing of the handle is necessary.

"After the exposure, the source is returned to the head by turning the handle counterclockwise until it stops and the source position indicator reads zero feet. A survey meter should always be used to make certain the source is properly shielded. The machine must be locked after each exposure to prevent inadvertent operation.

"To use one of the other sources, the control cable is removed from the source then connected and attached to the source cable and hole of the desired source.

"The pointer of the source position indicator has a tendency to drift slightly after a large number of operations. The pointer is reset to zero with the source in the head and the machine locked. The small screw on the pointer shaft is loosened slightly and the pointer reset at zero feet. The screw is then retightened."

B. Summary of Safety Procedures For Radiographers

1. Attach personal monitoring equipment-dosimeters and film badge-described in Sections D and H.

2. Turn on cutie pie radiation survey meter to zero set warm-up position for a minimum of one minute before use-described in Section E.

3. After warm-up period, selector switch is turned to X1 position, then exposure device and gamma room radiation survey check is performed. Additionally, the entire Operational and Emergency Procedures inspection check, including the daily inspection chart is completed-described in Section E.

4. Perform daily radiography work schedule as described in Section D.

5. Weekly maintenance safety check of storage device is performed as given in Section D.

6. Monthly maintenance inspection of projector, source guide tube, remote control cables, and source position indicator is performed as given in Section E.

7. Quarterly periodic inspection (not to exceed 3 months) is performed as given in Section E. Also, quarterly survey meter calibrations are completed as given in Section T.

8. The semi-annual wall survey as given in Section D and semi-annual leak testing of the projector as given in Section C is performed.

9. In event of radiography emergency, procedures described in Section K are followed.

10. For use of source change equipment, Section N is followed. When ordering radioisotopes, instruction given in Section O are to be followed.

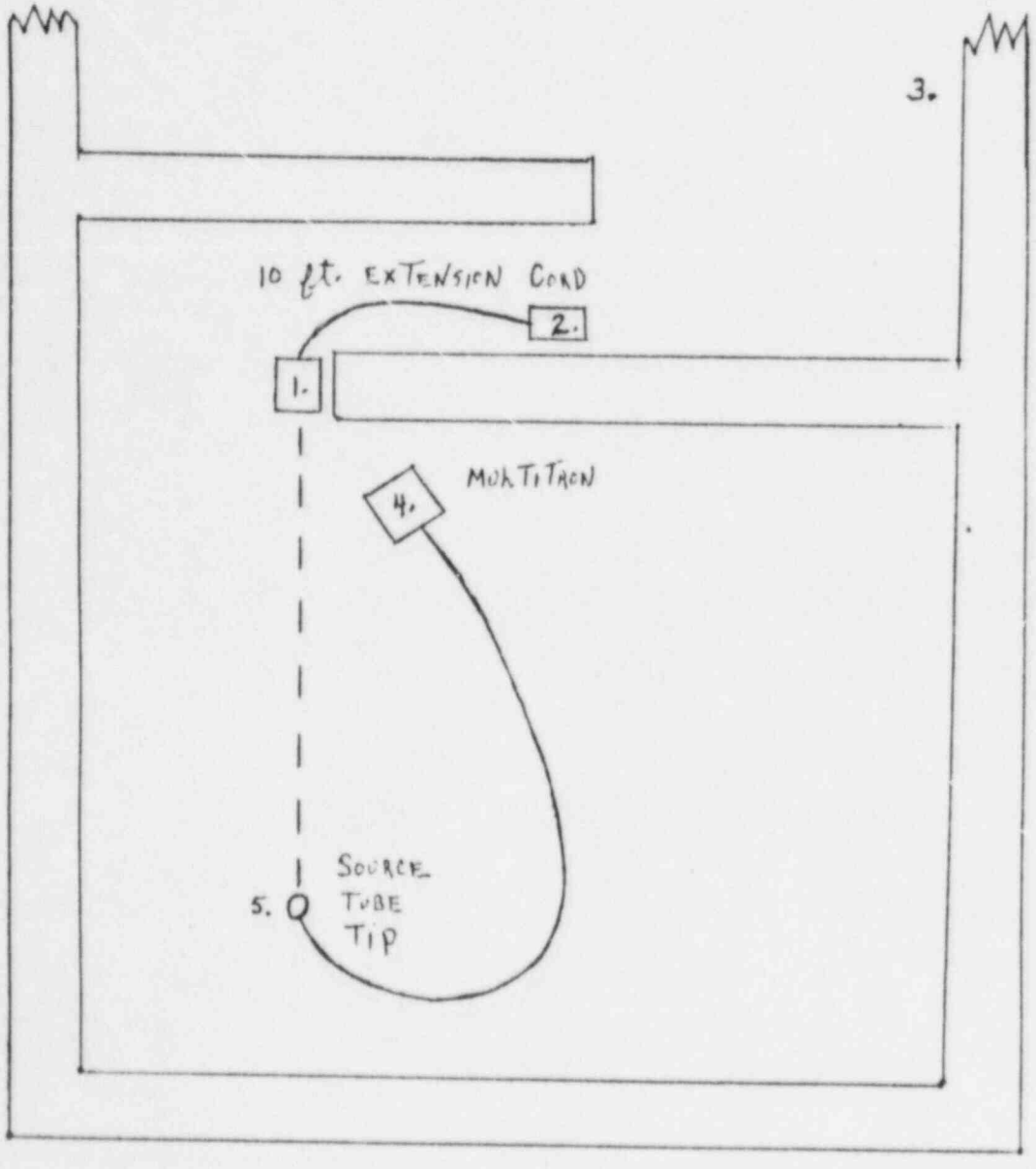
V. GAMMA ROOM LAYOUT AND RELATED GENERAL RECORD DATA FORMS

1. Equipment Layout to be Used for Survey Meter Calibration
2. Unscheduled Inspection of Gamma Building Facility
3. Quarter-Annual Calibration of Survey Meter
4. Receipt of Radioactive Sources
5. Return of Radioactive Sources
6. Advance Shipping Notice
7. Gamma Facility Inspection
8. Film Badge Monthly Tabulation
9. Tabulation of Leak-Test Reports
10. Radiography Daily Inspection Chart
11. Utilization Log and Post-Exposure Survey Record
12. Daily Dosimeter Readings in Milliroentgens
13. Quarterly Physical Inventory
14. Annual Dosimeter Calibration
15. Semi-Annual Wall Survey Meter Readings
16. Gamma Room Drawing Foundry Layout, #D-1350
17. Description of Symbols Found on Gamma Room Drawing #D-1350

EQUIPMENT LAYOUT TO BE USED

FOR SURVEY METER CALIBRATION

LOCATION #1-IONIZATION CHAMBER; #2-REMOTE READING INSTRUMENT BASE; #3-REMOTE CONTROL CRANK; #4-MULTITRON; #5-SOURCE GUIDE TUBE TIP



THE VOLLRATH COMPANY

INTRA-COMPANY MEMORANDUM

FROM: G. Neumann

DATE:

TO: G. A. Kurtz

REFERENCE:

COPIES TO: Foundry Manager
R. Vandermus
N. Nanninga
Gamma File

SUBJECT: UNSCHEDULED INSPECTION OF GAMMA BUILDING FACILITY

An inspection of the gamma facility, using the quarterly equipment inspection form has been performed. The status, defiencies (if any), and immediate corrective action taken are noted.

Inspection Date:

Signed:

Comments:

Radiographer (s) _____

were observed in use of equipment and survey instruments, and found to comply with procedure and safety regulations. Other listed radiographers did not perform radiography work during this quarter.

Control No. 76668

DATE _____

QUARTER-ANNUAL CALIBRATION OF SURVEY METER

Survey Meter:

Manufacturer
Model No.
Serial No.
Range

Source:

Manufacturer
Serial No.
Assay Date
Current Strength

Meter Scale	Graph	Actual	+ 10%	- 10%	% Error	Remarks

Distance _____

Meter Scale	Graph	Actual	+ 10%	- 10%	% Error	Remarks

Distance _____

Meter Scale	Graph	Actual	+ 10%	- 10%	% Error	Remarks

Distance _____

NOTE: X1 - 2 lead shields
X10- 1 lead shield
X100- No lead shields

Performed by:

_____

_____

Form 8

RECEIPT OF RADIOACTIVE SOURCES

IRIDIUM-192 AND COBALT-60

Control No. 76668

Date ceived	SOURCE Co	IR	Number	Curies	CONTAINER Number	Tag	Condition	CONTAINER SURVEY @ 3 Ft.	Surface	Date Installed	Remarks

All Sources Received from Automation Industries Inc.

RETURN OF RADIOACTIVE SOURCES

IRIDIUM-192 AND COBALT-60

Date eceived	SOURCE Co	SOURCE IR	SOURCE Number	SOURCE Curies	CONTAINER Number	CONTAINER Tag	CONTAINER Condition	CONTAINER SURVEY @ 3 Ft.	CONTAINER SURVEY Surface	Date Returned	Remarks

All Sources Returned to Automation Industries Inc.

ADVANCE SHIPPING NOTICE

Automation Industries, Inc.
P. O. Box 245
Phoenixville, PA 19460

Gentlemen:

Returning spent source _____, source

changer number _____. Shipped on _____.

Vollrath Company
Sheboygan, WI

Control No. 76668

GAMMA-FACILITY INSPECTION

Date: _____ Performed by: _____

Cutie-Pie survey meter in proper location? Yes____ No____

Photo-call operating properly? Yes____ No____

Warning bells (3) operating properly? Yes____ No____

Time of alarm: _____:_____:_____

Time of timekeeper's phone call: _____:_____:_____

Phone call, above, from whom? _____

Was he advised that ringing alarm was test only? Yes____ No____

If not, did he follow procedures & call Safety Director? Yes____ No____

Comments:

Phone operating properly? Yes____ No____

Rotating roof-light operating properly? Yes____ No____

Rotating inside light (at maze) operating properly? Yes____ No____

Chain across maze? Yes____ No____

Lock on always-locked door operating properly? Yes____ No____

Civil Defense meter operating properly & calibrated? Yes____ No____

Cutie-Pie meter operating properly? Yes____ No____

"Radiation Area" warning sign on always-locked door? Yes____ No____

"High Radiation Area" warning sign on wall at maze? Yes____ No____

"Radioactive Material" warning sign at maze exit? Yes____ No____

Names & phone numbers on above signs readable? Yes____ No____

Remote-control indicator at "0 feet?" Yes____ No____

Sources in storage condition? Yes____ No____

Lock-boxes locked? Yes____ No____

GAMMA-FACILITY INSPECTION

Date: _____ Performed by: _____

On Multitron:

Source plates in place?	Yes ____ No ____
"Radioactive material" tag in place?	Yes ____ No ____
Source inlets plugged or connected to source position indicator?	Yes ____ No ____
Can anything possibly fall onto source tube or remote-control cable?	Yes ____ No ____
Any kinks, dents, or sharp bends in source tube or remote-control cable?	Yes ____ No ____
"Caution---Men on roof" sign available, readable?	Yes ____ No ____
Is it in use at this time?	Yes ____ No ____
Calibration blocks & 10 ft. cord for meter in protected storage?	Yes ____ No ____
29" walls: Cracked on inside?	Yes ____ No ____
Cracked on outside?	Yes ____ No ____
Signs on roof in place and readable?	Yes ____ No ____
Form NRC-3 posted conspicuously?	Yes ____ No ____
Current license posted?	Yes ____ No ____
Current Administrative Instructions Posted?	Yes ____ No ____
Current Federal Regulations posted?	Yes ____ No ____
Current Training Program posted?	Yes ____ No ____
Doorbell & lighting operating properly?	Yes ____ No ____
Monitor badge in proper position?	Yes ____ No ____
Current letter position is _____	
Mirror in place?	Yes ____ No ____
Remote-control crank in correct location?	Yes ____ No ____

Date: _____ Performed by: _____

GAMMA-FACILITY INSPECTION

Records: _____	Records Current? Yes	Records Current? No	Entry on Time? Yes	Entry on Time? No
Dosimeters _____				
Post-Exposure _____				
Weekly Meter Check _____				
Film Badge _____				
Quarterly Inventory _____				
Quarterly Calibration _____				
Receipt & Return (Sources) _____				
Wall Survey _____				
Semi-annual meeting & insp. visits				
Leak-test _____				

Comments:

Date of last N.R.C. inspection _____

Remarks:

Sheet No. _____

Control No. 76668

FILM BADGE MONTHLY TABULATION

(In MR)

Period om Date rough Date	Film Badge Number & Bearer										
	3	5	7	8	11	13	14	15	16	17	18

itional Remarks:

TABULATION OF LEAK-TEST REPORTS

Wipe Date	SOURCE NUMBER		ANALYSIS			Wipe Done By Whom
	Cobalt 60	Iridium 192	Date	Result	By Whom	

REMARKS: All leak test wipings made at Vollrath Co. will be done with Budd Co. leak test kit No. LT-100 unless otherwise noted, under 1CC-29.

RADIOGRAPHY DAILY INSPECTION CHART

Date _____ Month _____
Year _____

ITEM	
1.	Check Meter
2.	Safe-inlet & outlet
3.	Source indicator SPI
4.	Doors
5.	Remote cables
6.	Source outlet tube
7.	Source safe
8.	S.P.I. crank
9.	Cable connection
10.	S.P.I. movement
11.	Warning signs
12.	Warning lights
13.	Electric eye
14.	Multiple alarm
15.	Inserts
16.	Ball 11/32
17.	Disconnect
18.	Gate house meter
	Clean & lubricate remote cables

Control No. 76668

UTILIZATION LOG (PER P.31.107) AND POST-EXPOSURE SURVEY RECORD (PER P.31.303, b, c, and d)

Sheet No.

(Enter highest reading found in room.
Check especially at source outlet of Multitron)

Date	SOURCE		TIME OF DAY		Survey Reading in mr./hr.	Net Time Exposed in Hrs. & Minutes	REMARKS: Customer name, part number "For survey reading" note, and suggestions or comments	Radiographer To Whom Source Is Assigned
	Cobalt	Iridium	Exposed	Secured				

ALL SEALED SOURCES ARE STORED IN, AND EXPOSURES MADE WITH, A BUDD COMPANY, INSTRUMENTS DIVISION, MODEL 62 MULTITRON, ONLY IN THE GAMMA ROOM, FOUNDRY DIVISION, OF THE VOLLRATH COMPANY, SHEBOYGAN, WISCONSIN.

Form 09255 - SPCo

Sheet No. _____

Month _____

Year _____

DAILY DOSIMETER READINGS IN MILLIROENTGENS

Date											
1											
2											
3											
4											
5											
6											
7											
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31											
TOTALS											

QUARTERLY PHYSICAL INVENTORY OF RADIOACTIVE SOURCES

SOURCE _____

Inventory Date	SOURCE		ASSAY		DATE		Remarks
	Number	Curies	Date	Curies	Rec'd	Ret'd	

All sources are located in the Gamma Room Building of The Vollrath Co., 1236 North 18th Street, Sheboygan, WI, unless otherwise recorded.

ANNUAL DOSIMETER CALIBRATION

	CALCULATED			ACTUAL READING									
DATE	DOSE*	+30%	-30%	1	2	3	4	5	6	7	8	9	10

*Calculated dose $mr = \frac{14{,}400 \times C}{d^2} \times \frac{t}{60}$

t = time in minutes

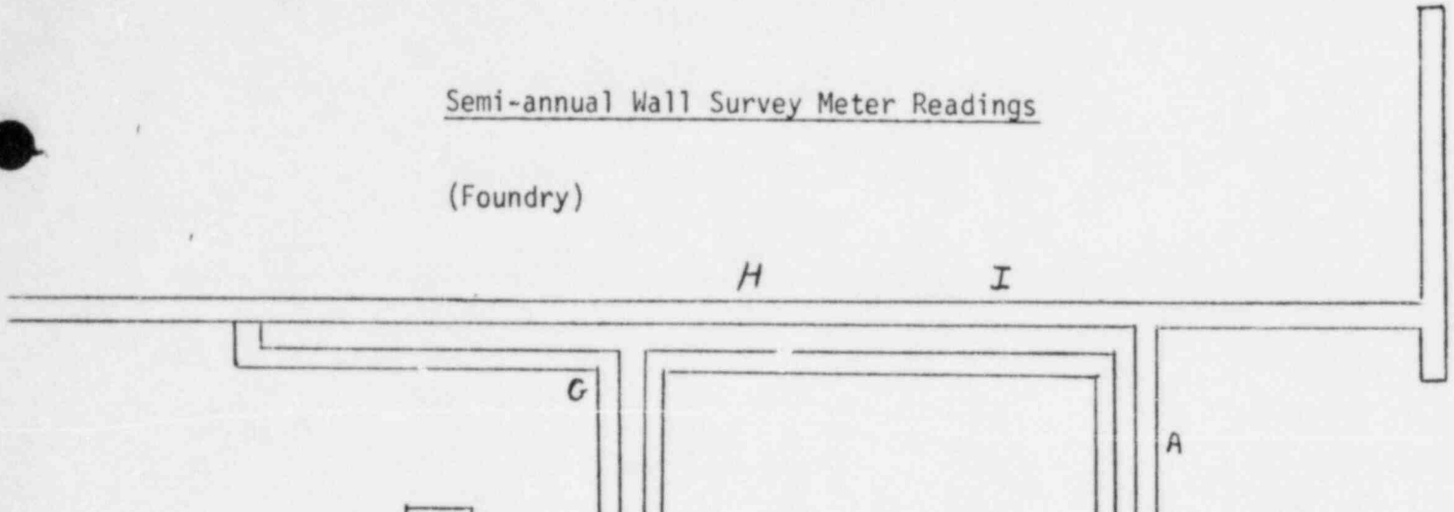
C = source strength of Co^{60} read from decay curve

d = distance in feet from dosimeter to source

Control No. 76668

Semi-annual Wall Survey Meter Readings

(Foundry)



Date	Survey Meter Readings in Milliroentgens/Hr. For Positions Shown In Sketch									
	A	B	C	D	E	F	G	H	I	Remarks

Additional Remarks:

ADDENDA TO FORM AEC-313-ITEM 13

Symbols Used On Gamma Room Drawing No. D-1350

1. Door (always locked).
2. Sign bearing radiation caution symbol and the words, "Caution, Radiation Area".
3. Sign bearing radiation caution symbol and the words, "Caution, High Radiation Area".
4. Sign bearing radiation caution symbol and the words, "Caution, Radioactive Materials".
5. Photoelectric cell warning device (rings alarm upon entry: at site "6", and in office area "7", and in metallurgist's office "12"). This photoelectric cell is energized by the same switch as the red flashing (revolving) light. They are used during exposures only.
6. Alarm at site.
7. Alarm in General Foundry Office.
8. Red flashing light *turned on during exposures).
9. Walls are solid, 29 inches thick; 2 courses of 8" concrete block (cores filled with rich grout) with space between courses filled with concrete.
10. Original 1'-0" thick brick wall has windows removed, and the openings closed with 12" concrete blocks (cores of blocks filled with rich cement grout), plus 1'-1" poured concrete and one tier of 8" concrete block (with cores also filled) to provide 33" solid wall.
11. Points at which radiation will not exceed 100 mr./week. By calculation, source exposure for a full 48-hour week will provide only 81.4 mr./week on the outside of the walls. Due to decay, usage, and ordering procedure in Administrative Instructions, actual radiation levels are much lower.
12. Alarm in Foundry Metallurgist's Office.
13. A light chain extended across the maze at waist height, with a sign thereon further restricting access to the Gamma Room to only certain authorized personnel.
14. Location where remote control crank may be placed when the source is secured.
15. Location of radiographer and crank while source is being cranked "in" or "out", and also location of crank during exposures.
16. Location of shelf where survey meter is kept during "off" hours.
17. Location of signs, "NO ADMITTANCE", and "THIS DOOR MUST BE KEPT CLOSED".
18. Sign with words found under Par. M-2 of Administrative Instructions.
19. Doorbell used to notify radiographer of delivery of castings to outside of locked door.
20. Revolving red light on roof over center of exposure room.
21. Fence along the edges of the gamma building roof.

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