GENERAL STANDARD

FOR

PROTECTION AGAINST RADIOACTIVE

SEALED SOURCES

ORIGINAL EDITION

MAY 1997

This standard specification is reviewed and updated by the relevant technical committee on Oct 2003. The approved modifications are included in the present issue of IPS.

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APPENDICES

0. INTRODUCTION

The use of sealed radioactive sources has become so widespread that a standard to guide the user is needed.

Safety is the prime consideration in establishing a standard for the use of sealed radioactive sources.

However, as the application of sources becomes more diversified, a Standard is needed to specify the characteristics of a source and the essential performance and safety testing methods for a particular application and, maintain the record of safe usage.

1. SCOPE

The group of engineering, material, construction and inspection standards for radioactive sources have been amalgamated and are compiled in one folder. The objective of this Standard is to provide guidance for the protection of persons from undue risks and harmful effects of ionization radiation. The standard include the following items:

a) Basic concept of radiation specifications.

b) Detailed information and requirements for apparatus, containers, tests, transportation, packaging and safety of sealed source.

c) Classification, identification and test procedures of sealed sources.

d) Site inspection, source exchange and source container maintenance service.

Note:

This standard specification is reviewed and updated by the relevant technical committee on Oct. 2003. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No 224 on Oct. 2003. These modifications are included in the present issue of IPS.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

BSI (BRITISH STANDARD INSTITUTION)

BS 5566-1992 “Installed Dose Rate Meters, Warning Assemblies and Monitors for Energy between 50 KeV and 7 MeV"

BS 3783 "X-Ray, Lead - Rubber Protective Obsolescent Aprons for Personal Use"

BS 5288 “Sealed Radio Active Sources”

DIN (DEUTSCHES INSTITUTE FUR NORMUNG EV.)

DIN 44425, DIN-6818 pt. 2

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

ISO 361 “Basic Lionizing Radioactive Symbol First Edition 1975”

ISO 3999 “Apparatus for Gamma Radiography Specification First Edition 1977”

ISO TR 4826 “Sealed Radioactive Sources Leak Test Method 1979”

ISO 2855 “Radioactive Materials Packaging Tests for Contents Leakage and Radiation Leakage”

IAEA (INTERNATIONAL ATOMIC ENERGY AGENCY)

Safety Series Nos. 6 and 37

3. DEFINITIONS AND TERMINOLOGY

For the purposes of this Standard, the following definitions apply.

3.1 Capsule

Protective envelope used to avoid any damage to actual source and for easy handling.

3.2 Container

General term designating any enclosure, which may surround the sealed source.

3.3 Device

Any piece of equipment designated to utilize sealed source(s).

3.4 Dummy Sealed Source

Facsimile of a radioactive sealed source the capsule of which has the same construction and is made with exactly the same materials as those of the sealed source that it represents but containing, in place of the radioactive material, a substance resembling it as closely as practical in physical and chemical properties.

3.5 Leakage

Transfer of radioactive material from the sealed source to the environment.

3.6 Model

Descriptive term or number to identify a specific sealed source design.

3.7 Non-Leach able

Term used to convey that the radioactive material in the form contained in the source is virtually insoluble in Water and is not convertible into dispersible products.

3.8 Prototype Source

Original of a model of a sealed source which serves as a pattern for the manufacture of all sealed sources identified by the same model designation.

3.9 Prototype Testing

Performance testing of a new radioactive sealed source before sealed sources of such design are put into actual use.

3.10 Quality Control

Such tests and procedures as are necessary to establish the ability of the sealed sources to comply with the performance characteristics for that sealed source designed as defined in Clause 7 of this Standard.

3.11 Radio toxicity

Of a radionuclide; the ability of a nuclide to produce injury by virtue of its emitted radiations, when incorporated in the human body.

3.12 Sealed Source

Radioactive source sealed in a capsule or having a bonded cover, the capsule or cover being strong enough to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed.

3.13 Simulated Source

Facsimile of a radioactive sealed source the capsule of which has the same construction and is made with exactly the same materials as those of the sealed source that it represents but containing, in place of the radioactive material, a sub-stance with mechanical, physical and chemical properties as close as possible to those of the radioactive material and containing radioactive material of tracer quantity only. The tracer is in a form soluble in a solvent which does not attack the capsule and has the maximum activity compatible with its use in a glove box.

3.14 Source Holder

Mechanical support for the sealed source. The following two terms apply to industrial radiography and gamma gages and irradiation sources:

a) Source in device

Sealed source, which remains in a device giving mechanical protection from damage during use.

b) Unprotected source

Sealed source which, for use, is removed from a device that would give mechanical protection from damage.

3.15 Radiation Output

Number of particles and/or photons of ionizing radiation emitted per time unit from the sealed source in defined geometry. This is best expressed in terms of radiation flounce rate.

3.16 Half-Life Period

Due to the radioactive decay the activity of a source decreases according to specific physical laws. The time in which a source loses half of its original activity (Ao) is referred to as the half-life of the source (HLT).

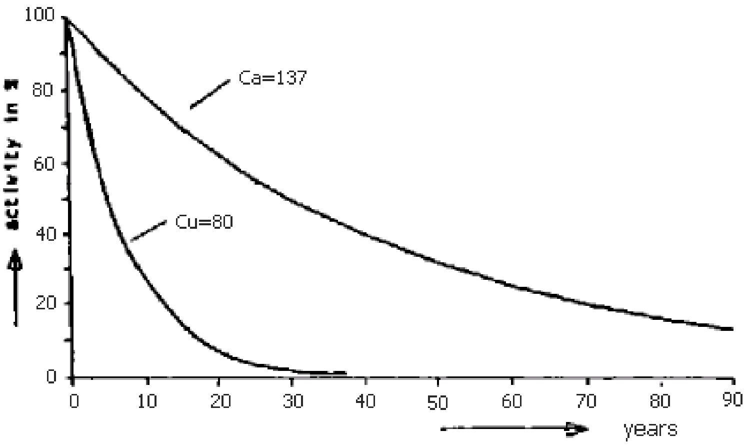


Fig. 1

The current activity (A) after a certain time period (t) is calculated as follows:

$A = Ao \times e^{-0.693 \times t/T}$

t = decay time hr

T = half life hr

For some of the more important sources the following half-lives can be given:

Co-60 - 5.3 years

Cs-137 - 30 years

Ir-192 74 years

3.17 Curie unit of activity equal to

3.7×10^{10} *Bq*

3.18 Kerma (K)

The sum of the initial kinetic energies of charged particles produced by the interaction of uncharged radiation (e.g., electromagnetic radiation or neutrons) per unit mass of the material in which the interaction takes place. Kerma is expressed in joules per kilogram or in rads. For electromagnetic radiation absorbed in air, the principal quantity in the relationship between kerma and exposure is the average energy required to produce an ion pair.

3.19 Apparatus for Gamma Radiography

An apparatus including an exposure container and accessories designed to enable radiation emitted by a sealed source to be used for industrial radiography.

3.20 Exposure Container

A shield in the form of a container designed to allow the controlled use of gamma radiation and employing one or more gamma radiography sealed sources. For the purpose of this I.P.S, an apparatus for gamma radiography is classified according to the mobility of the exposure container:

Class P: A portable exposure container, designed to be carried by one man alone.

Class M: A mobile but not portable exposure container, designed to be moved easily by a suitable means provided for the purpose.

Class F: A fixed installed exposure container or one with mobility restricted to the confines of a particular working area.

3.21 Maximum Rating

The maximum activity, expressed in becquerels followed by the value in curies in brackets, of a gamma radiography sealed source specified for a given radionuclide by the manufacturer and marked on the exposure container, and not to be exceeded if the apparatus is to conform to this

Standard.

3.22 Remote Control

A device enabling the gamma radiography sealed sources(s) to be exposed by operation at a distance.

3.23 Projection Sheath

A flexible or rigid tube for guiding the source holder from the exposure container to the working position and comprising the necessary connection between the exposure container and the exposure head.

3.24 Exposure Head

A device, which locates the gamma radiography, sealed source in the selected working position.

3.25 Secured Position

Condition of the exposure container and gamma radiography sealed source when the source is fully shielded and the exposure container is rendered inoperable by locking and/or other means.

3.26 Working Position

Condition of the apparatus for gamma radiography when the beam is emitted for radiography.

3.27 Activity, A

Activity of a radioactive nuclide in a particular energy state at a given time is the quotient of dN by dt, where dN is the expectation value of the number of spontaneous nuclear transitions from that energy state in the time interval of dt:

$$A = \frac{dN}{dt}$$

Units: s^{-1}

The special name for the unit of activity is becquerel (Bq), 1 Bq= $1s^{-1}$. The former special unit is curie (Ci)

1 Ci = $3.7 \times 10^{10} s^{-1}$ (exactly).

3.28 Absorbed Dose, D

The quotient of d by dm, where d is the mean energy imparted by ionizing radiation to matter of mass dm:

$$D = \frac{D}{dm}$$

Unit: $J.kg^{-1}$

The special name for the unit of a absorbed dose is gray (GY):

1 GY = 1 $J.kg^{-1}$

The former special unit is rad:

1 rad = 10-2 $J.kg^{-1}$

3.29 Absorbed Dose Rate, D•

The quotient dD by dt, where dD is the increment of absorbed dose in the time interval dt:

$$D^{\bullet} = \frac{dD}{dt}$$

Unit: $J.Kg^{-1}.S^{-1}$

3.30 Becquerel, Bq

The specific name of the unit of activity:

$IBq = 1s^{-1}$

3.31 Collimator

A device used for restricting the useful radiation beam to a specific direction and size.

3.32 Competent Authority

An authority appointed by the Atomic Energy Organization of Iran.

3.33 Contamination Radioactive

The presence of a radioactive substance or substances in or on a material or in a place, where they are undesirable or could be harmful.

3.34 Control Console

Panel having controls and indications for the potential, current, exposure time of the X-ray tube and any other parameter.

3.35 Dose Equivalent, H

The product of D and Q at the point of interest in tissue, where D is the absorbed dose, Q is the quality factor, which depends on the radiation type and energy:

$H = DQ$

The unit for both D and H is $J.Kg^{-1}$. The special name for the unit of dose equivalent is sievert (Sv):

$ISv = 1\ J.kg^{-1}$

In practice, the former special unit rem is still used:

$1\ rem = 10^{-2}\ Sv = 10^{-2}\ J.kg$

3.36 Half-Life, Radioactive

The time required for the transformation of one-half of the atoms in a given radioactive decay process, following the exponential law (physical half-life).

3.37 Level, Reference

The value of a quantity, which governs a particular course of action. Such levels may be established for any of the quantities determined in the practice of radiation protection; when they are reached or exceeded, all relevant information is considered and the appropriate action may be taken.

3.38 Licensee

Licensee means a person who has been issued a license by (AEOI).

3.39 Manipulator Rod

A rigid rod used for remote handling of a source pencil, normally of two meter length.

3.40 Non-Stochastic Radiation Effects

Radiation effects for which a threshold exists above which the severity of the effect varies with the dose.

3.41 Occupancy

Fraction of total time spent by radiation worker/members of the public in the radiation field.

3.42 Open Field Radiography

Radiography operations carried out on shop floors, erection sites or other such areas with provisions for adequate radiological safety for the radiography personnel and others including members of the public.

3.43 Radioactivity

The phenomenon exhibited by certain materials in which spontaneous emission of nuclear radiation occurs. Gamma radiation is the electromagnetic radiation emitted in such nuclear transformations.

3.44 Radiographer

A radiation worker who performs industrial radiography operations employing radiation sources and who possesses a valid certificate duly recognized or issued by the competent authority for this specific purpose.

3.45 Radiological Safety Officer (RSO)

A person who possesses valid RSO's certificate duly recognized or issued by the competent authority for this specific purpose.

3.46 RHM/RMM

RHM is exposure rate in air expressed in rontgen per hour at one meter from an unshielded gamma source of strength one curie. RMM is exposure rate in air expressed in rontgen per minute at one meter from an unshielded gamma source of strength one curie.

3.47 Rod Anode

Extended anode of X-ray tube for intricate exposures.

3.48 Rontgen

It is the special unit of the exposure of X or gamma radiation. The exposure, X, is the quotient of dQ by dm where the value of dQ is the absolute value of the total charge of the ions of one sign produced in air when all the electrons and/or positrons liberated by photons in air of mass dm are completely stopped in air:

$$X = \frac{dQ}{dm}$$

Unit: $C.kg^{-1}$

In practice, the former special unit rontgen (R) is still used:

$IR = 2.58 \times 10^{-4}\ C.kg^{-1}$ *(exactly)*

3.49 Site-in Charge

A person who is so designated by the employer and who possesses a valid certificate for site-in-charge duly recognized or issued by the competent authority for this specific purpose.

3.50 Source Drive System

Flexible cable system to drive the source pencil to the desired position.

3.51 Source Pencil

An assembly consisting of an encapsulated radioactive source and sometimes, a shield plug suitably encased with provision for attachment to a camera/flexible cable.

3.52 Stochastic Radiation Effects

Radiation effects, the severity of which is independent of dose and the probability of which is assumed to be proportional to the dose without threshold at the low doses of interest in radiation protection.

3.53 Transport Index

A number expressing the maximum radiation level at 1 meter from the surface of a package measured in mrem/h (1 mrem = 0.01 mSv).

3.54 Tube Potential

Potential difference applied across the electrodes of an X-ray tube. This controls the energy of the X-rays generated. This is normally expressed in kilo Volts (kV) or mega Volts (mV).

3.55 Work Load

Work load (known also as the weekly load) is expressed in terms of rontgen per week at one meter from gamma ray sources and in mA min. per week for X-ray sources.

3.56 X-Ray Cable

The cable connecting the control console and X-ray tube.

3.57 X-Ray Tube

X-ray tube is a vacuum tube in which X-rays are produced by a cathode ray beam incident on the anode (target).

Symbols and Abbreviations

a	Distance
A	Activity
Bq	Becquerel
Ci	Curie
D	Absorbed Dose
$\dot{D}$	Absorbed Dose Rate
dE	Mean Energy

Gy	Grey
H	Dose Equivalent
K	Kerma
K	Gamma Radiation Constant
Kev	Kilo electron volt
Hvl	Half Value Layer
m	Mass
N	Nuclear transition
rem	Rem
S	Second
t	Decay time
T	Half life
Sv	Sievert
Q	Quality factor
R	Rontgen
RHM	Exposure Rate
RMM	Exposure Rate
IR-192	Iridium-192
Co-60	Cobalt-60
W	Work Load
P	Authorized radiation level

4. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

5. SPECIFIC CONSIDERATIONS

5.1 General Radiation Protection Considerations

Any type of work involving ionizing radiation should be carried out in a manner such that the radiation exposure to the individuals (radiation personnel and members of the public) is As Low As Reasonably Achievable (ALARA), without exceeding the limits. This is because radiation exposure can cause harmful effects to the health of the exposed individual and in normal radiation work such effects may not be readily recognizable.

Accordingly, dose equivalent limits for radiation personnel and members of the public have been specified in Section 5. The risks associated with exposures within these limits are regarded as acceptable. While these dose equivalent limits should not be exceeded, it is recommended, that the dose received by individuals should be kept As Low As Reasonably Achievable (ALARA).

5.2 Types of Sources Used in Industrial Gamma Radiography

5.2.1 Radiography sources

Gamma emitting radio nuclides as well as X-ray generating equipment are used as radiation sources for industrial radiography work. The choice of a particular radiation source is decided on the basis of the material and thickness of the object to be radio graphed (Appendix F). Physical characteristics such as half-life, gamma energies and half value and tenth value thicknesses in different shielding materials of some typical radiation sources are given in Tables 2 and 3 of Appendix G.

5.2.2 Source pellets and source pencils

The isotopic sources used for gamma radiography are either in metallic form (^{60}Co, ^{192}Ir) or in metallic salt form (^{137}Cs, ^{170}Tm). These sources are sealed in stainless steel capsules to avoid any damage to actual source during use. These capsules are incorporated inside a source assembly, for easy handling, which in turn is loaded in a radiography camera. The source assembly may be a rigid one or a flexible one depending on the design of the radiography camera. The source assembly when rigid is called a source pencil and when flexible is called a "Pig Tail".

5.3 Selection of Radiography Site

5.3.1 An ideal site for radiography is one, which is away from any occupied areas, of storage of explosives and inflammable materials, and situated in one corner of minimum occupancy. In situations where there is little choice in selection of a site because of nature of thermal plants, for cross-country pipelines etc., it must be insured that the radiography work is carried out only during the time when there is no occupancy around.

5.3.2 Planning of the site must be done for a specific radiation source.

5.3.3 When radiography work is to be carried out for long duration, the radiography site should be in an area provided with suitable fencing such as with ropes and radiation symbols, to prevent unauthorized entry. Continued occupancy outside the fenced area must be restricted.

5.3.4 Temporary shielding can also be improvised by stacking heavy steel or concrete objects around the area.

5.3.5 The storage room for gamma radiography equipment and sources should be as close to the working site as possible.

5.4 Radiation Exposure of Human Beings

Whether the human body is exposed to radiation externally or internally, the damage to tissue depends on the type, strength and duration of the dose. The following types of radiation exposure may occur:

5.4.1 External radiation exposure

External radiation exposure can be expected when handling sealed radioactive substances in technical facilities. Protection against this type of exposure is possible if the equipment is handled properly and the radiation protection regulations are followed. In exceptional cases external exposure is also possible if skin or clothing are contaminated, but only if the source is leaking, or when handling open radioactive substances. In these cases special precautions must be taken.

Depending on the degree of occupational exposure, the personnel is classified in different categories. These dose rate values, recommended by international agencies, are the basis of the Radiation Protection Regulations.

5.4.1.1 Persons not exposed occupationally

The general public must not be exposed to an annual dose exceeding 5 mJ/kg = 5 MSv (0.5 rem).

5.4.1.2 Persons exposed occupationally-category B

Persons who are exposed to an annual dose of more than 5 mJ/kg = 5 mSv (0.5 rem) but less than 15 mJ/kg = 15 mSv (1.5 rem) belong to the category B. The body doses are recorded but medical examination is only required when handling open radioactive sources. During any quarter the body dose must not exceed fifty percent of the annual dose.

5.4.1.3 Persons exposed occupationally-category A

Persons who are exposed to an annual dose exceeding 15 mJ/kg = 15 mSv (1.5 rem) must be classified in category A. The maximum permissible radiation dose for these persons is 50 mJ/kg = 50 mSv (5 rem) per annum.

The person doses are to be determined by means of officially evaluated dosemeters. A medical examination once a year is mandatory. In this case, too, the body dose per quarter must not exceed fifty percent of the annual dose. Occupationally exposed persons of Category A must be examined by an authorized physician; occupationally exposed persons of Category B only if they handle open radioactive substances. This examination is repeated once a year. Further employment in the control area is only permitted after a certificate of authority has been granted.

TABLE OF ALLOWED DOSE

DOSE IN mSv PER YEAR	CLASSIFICATION		
	A	B	N
Whole body, head and trunk	50	15	5
Hands, forearms, feet and ankles	500	105	50

N = not classified people;

A = classified people category A;

B = classified people category B.

5.5 Biological Basics of Radiation

5.5.1 Dangers of radiation

If live-tissue is exposed to radiation, chemical and biological processes occur in the individual cells, which may change, damage or destroy the cells.

Alpha, beta and gamma-radiation interact with the electrons of the atom shell and neutrons are retarded by the nuclei. Thus, electrons may be separated and as a result the atoms will become ionized.

These ions are unstable and therefore react with adjacent atoms. Thus, undesired combinations may result, which can be harmful or even toxic.

a) Somatic Radiation Damage

Somatic radiation damage can occur as a result of short-term as well as long-term radiation exposure. Short-term exposure of the whole body will cause the following damage:

- Radiation hang-over;
- retardation of the blood formation;
- sterility;
- inflammatory diseases of the skin.

Depending on the dose the following effects may result when the whole body is exposed to radiation for a short term:

DOSE	EFFECT
Up to 0.2 Sv (20 rem)	No effect evident
Up to 1 Sv (100 rem)	Slight changes of the blood structure, but no serious damage is likely to occur
Up to 2 Sv (200 rem)	Radiation hang-over, vomiting,serious illness possible, good change of recuperation
2 - 6 Sv (200-600 rem)	Increase in mortality
More than 6 Sv (600 rem)	No chance of survival

Permanent exposure to radiation with even distribution will cause much less damage, due to the regenerative capacity of living organisms, but may nevertheless lead to chronic illnesses, such as leukemia or cancer. This is also the case if the body is exposed only once to a high dose of radiation.

b) Genetic Radiation Damage

Genetic radiation damage is caused by changes in the reproductive cells and can lead to mutations. A lower limit for the probability of mutations cannot be specified. In assessing this limit it is necessary to take into consideration the natural radiation (cosmic and terrestrial radiation) to which human beings are exposed, and which may be quite high in certain areas.

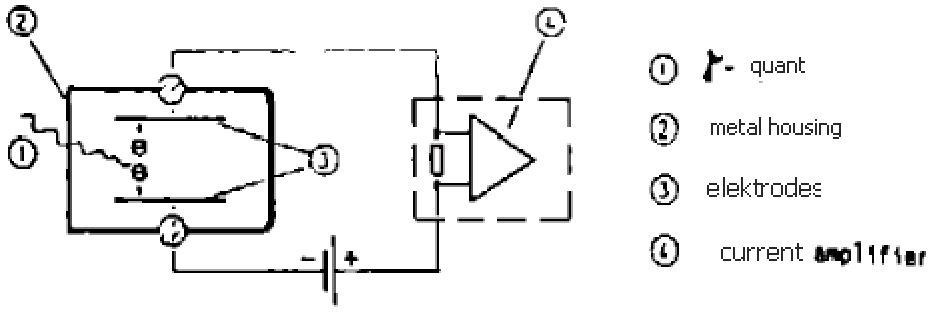
5.6 Radiation Measuring Techniques

5.6.1 Measuring systems for dose rate measurements

The human body cannot sense nuclear radiation. To detect radiation it is necessary to use suitable measuring instruments, with appropriate detectors for the different types of radiation. The most common detectors are ionization chambers, counter tubes (Geiger-Muller counter tubes or halogen counter tubes respectively) and scintillation counters.

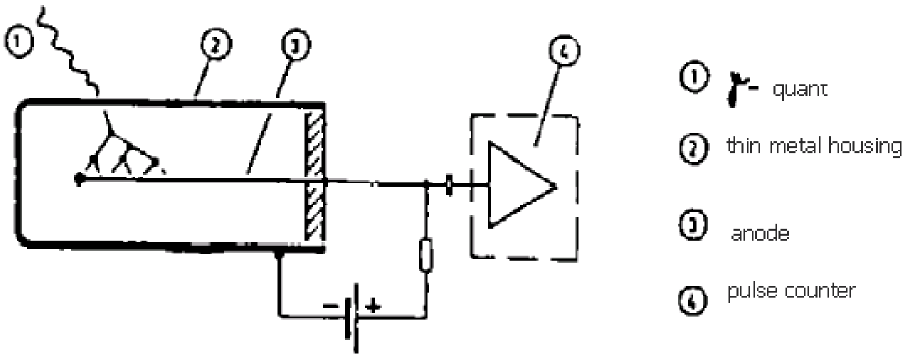
5.6.2 Ionization chamber

Basically a gas-filled plate capacitor in which the radiation received triggers positive and negative charge particles (ions and electrons), which generate an electric current directly proportional to the dose rate. Since this current is very small, it is necessary to amplify it substantially.



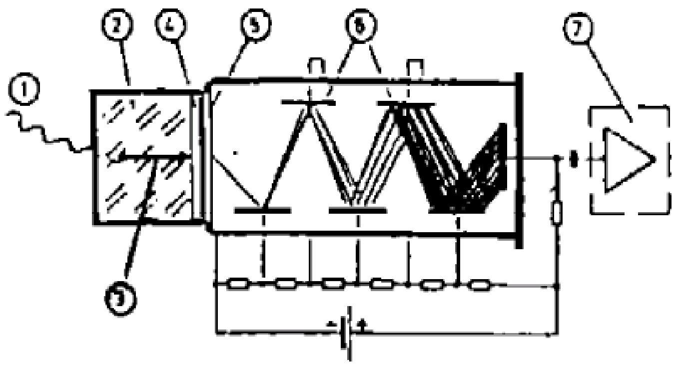
5.6.3 Counter tubes

Counter tubes (GM-tube) are built in such a way that the radiation received triggers a flow of electrons by means of ionization of the special gas filling (gas amplification effect). Thus, strong pulses are generated which can then be counted by simple means. The number of pulses per unit of time is a measure of the dose rate. Although the resolution and the energy independence are not very high, counter tubes are well suited for applications in certain ranges of the photon energy and are also preferred because they are economically priced. (This is also true for the associated electronics.)



5.6.4 Scintillation counter

With this detector flashes of light are generated in a crystal by the radiation received; these flashes are registered at the photo cathode of a photo multiplier and transformed into electrical pulses. The average of these pulses is a measure of the dose rate. Scintillation counters have high detection efficiency for radiation, but the technical expenses are quite high.



Construction and arrangement of the detectors for nuclear radiation have to be suited for the detection of the different types and energies of radiation with their individual characteristics.

Since the penetrative capacity of alpha and beta-radiation is low, the windows of the detectors have to be thin. Alpha and beta-radiation ionize the gas filling in the ionization chamber or the counter tube, or stimulate a scintillator to emit light. With gamma-radiation evidence is produced by secondary electrons being directly released across the detector walls, or by stimulating a scintillator. Exposure rate meters, warning assemblies and monitors for X and or gamma radiation of energy between 80 Kev and 3 MeV shall comply with BS 5566 standard.

5.6.5 Personal dose measurement

Personal dosimetry instruments have to be used to measure not only the intensity of a radiation field (dose rate), but also accumulated the resulting radiation dose while taking into consideration the duration of the reaction.

5.6.5.1 Film dosimetry

The darkening of photographic emulsion is utilized to determine the radiation dose. Film dosemeters contain film in a cartridge protected from the light; this cartridge contains numerous metal filters. From the darkening produced behind the filters, the exposure dose and the "radiation energy" can be determined. The advantage of film dosemeters is their robustness and their small dimensions (see Table 1).

5.6.5.2 Glass dosemeters

Contain a silver-activated phosphate glass enclosed in a capsule. Depending on the degree of radiation strongly fluorescent spots are generated which, upon evaluation, are stimulated by UV-light. The intensity of the fluorescent light is proportional to the dose received by the glass. Glass dosemeters are sensitive to dirt and therefore have to be protected (see Table 1).

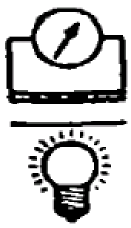
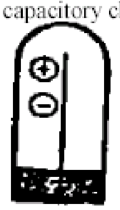
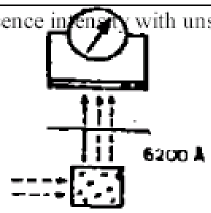
5.6.5.3 Pocket dosemeters

Provide direct reading of the dose received. They consist of a small electrometer whose cross-wire is made visible on a scale through a magnifying glass. Pocket dosemeters are charged by a brief connection to a voltage supply and discharged according to the radiation dose to which they are exposed. To prevent error caused by self-discharge, which is unavoidable, a daily reading of the pocket dosemeters is recommend (see Fig. 1 on figure section and Table 1).

5.6.5.4 Thermoluminescent dosimetry

Thermoluminescent dosimeter contains lithium fluoride (LIF), which is the commonly material used because of its negligible fading at room temperature at its low average atomic number. The TLD monitoring badge is composed a TLD holder with a clip, filters and TLD chip. Thermoluminescence is the emission of light from previously irradiated material after gentle heating.

TABLE 1 - THE DIFFERENT KINDS OF PERSONAL DOSE METER SYSTEMS

	MEASUREMENT	EVALUATION	CHARACTERISTIC FEATURES
Film	Translucency of film 	Evaluation only by official authority and only at fixed intervals. Measuring value is primarily used for subsequent dose balancing; useless for immediate measurement; info is available to user only after a long time (weeks).	Universally applicable; yields much information when evaluated properly. disadvantages: Subject to many uncontrollable error influences; limited measuring range; can not be stored.
Pocket	Discharge of capacitory chamber 	Read-out immediately and at any time by the user. Automatic evaluation systems with computer connection to the data evaluation system are being developed.	Fast, accurate information. Disadvantages: short measuring range; regular charging required.
Glass	Fluorescence intensity with unstimulation 	Evaluation any time and, due to storage of measuring values,as often as desired by the user and the official authority.	Ideal long-term dosemeter with high reproducibility, due to storage of measured values. Disadvantage:Too inaccurate in the low energy range(roentgen).Attempts to improve the measuring sensitivity and the energy dependence are being made.
Thermoluminescent	Measurement of the light photons emitted after heating the previously irradiated materials	The system provides sensitivity with a high degree of accuracy at low exposure levels, detecting 10 mrem (0.1 msv) with a standard deviation of 10 percent or less. Results are easily computerized.	There is no necessity for a development laboratory. TLDs may be reused many times. Relatively unaffected by moisture common solvents and minor physical abrasion.

Note:

The results of all measurements and calculation have to be recorded and kept on file for 30 years, and have to be submitted for inspection by the supervisory authority on request.

5.7 Radiation Protection Techniques

5.7.1 Basic principles of radiation protection

To avoid damage to the human body with near certainty, an annual dose for the persons classified in the different categories has been fixed internationally.

The aim of radiation protection is to adhere strictly to the specified permissible dose values and furthermore to avoid unnecessary radiation to keep the radiation dose for personnel as low as possible.

The formula for calculation of the radiation dose shows what kind of radiation protections can be carried out. The radiation dose (D) depends on the activity (A) of the source, its specific gamma radiation constant (k), the distance (a) from the source, the radiation time (T), and the weakening factor (s) of the available shielding.

$$D = \frac{A \times K \times T}{a^2 \times s}$$

The activity of a source and the corresponding specific gamma radiation constant are determined by the measuring task. When designing a measuring system, designer should try to keep the required source activity as low as possible by selecting suitable detectors and evaluation instruments.

From the above formula, the following radiation protection measures, which illustrate some important basic principles of radiation protection, can be derived:

a) Increasing the Distance

To the radiation source, i.e., the distance between the source and the body. Since the dose rate (just as light) follows the square law, doubling the distance means reducing the radiation intensity to a quarter. This is the most efficient as well as the easiest method of radiation protection. It is important, therefore to keep the largest distance possible when operating in the proximity of radioactive substances, especially those persons who are not involved with the operation. Even weak sources generate a substantial dose rate if the distance is short. Test sources with very low activities must not be touched by hand, but only with pliers or tweezers.

b) Shortening the Duration of Exposure

The time (T) has a linear effect, i.e., doubling the period of exposure gives twice the radiation dose. Operations close to the source should be well planned, so that the time of exposure in the immediate vicinity of the source is kept as short as possible.

c) Use of Shielding

With a high weakening factor (s), which depends in an exponential function on the product of thickness and density of the material. Apart from a few exceptions, radioactive substances used in industry already are installed in a suitable shielding when delivered. The shielding is effective only when the shielding functions properly and is handled safely.

d) Use Shielding Between Sources and Personnel if Possible

Dense, high atomic number materials, such as lead are preferred. Materials such as concrete must be much thicker to provide the same effective shielding. Table 2 below shows the thickness of lead required to reduce gamma radiation intensity by various transmission factors.

TABLE 2

RADIONUCLIDE	TRANSMISSION FACTORS: LEAD		
	0.5	**0.1**	**0.01**
Cobalt-60	15 mm	43 mm	86 mm
Iridium-192	3.5 mm	12 mm	28 mm
Thulium-170	0.8 mm	5 mm	19 mm
Ytterblun-169	0.8 mm	2.9 mm	8 mm

Table 3 below shows transmission factors for concrete:

TABLE 3

RADIONUCLIDE	TRANSMISSION FACTORS: CONCRETE		
	0.5	0.1	0.01
Cobalt-60 Iridium-192 Thulium-170 Ytterblun-169	165 mm 130 mm No Data Available	335 mm 245 mm	545 mm 390 mm

Transport containers alone do not normally provide sufficient screenage for permanent storage. A purpose built storage cell or container should be used.

5.7.2 Radiation protection areas

5.7.2.1 Restricted areas

Areas with a dose rate higher than 3 mSv/h (300 mrem/h) must be secure, so that nobody can enter unchecked with any part of the body. Access is only permitted under specific conditions and if there is an absolute need for it, the body dose should be calculated and the personal dose measured.

Note:

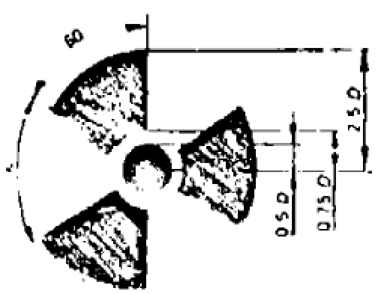
These areas are normally only the useful beam at the surface of the shielding. If it is possible for any part of the body to enter this area, it must be screened accordingly.

5.7.2.2 Control areas

These are areas with dose rates, which are equivalent to or higher than 7.5 µSv/h (0.75 mrem/h). Control areas must be marked off and provided with a radiation warning symbol and "Control Area". For these control areas the following warning signs shall be displayed.

1) The basic symbol shown below, which indicates the potential or actual presence of ionizing radiation;

2) Such additional inscriptions, colors or symbols as may be required to indicate in a manner understandable to all concerned the magnitude and particular nature of the exposure risk:



The symbol for ionizing radiation.

(See International Organization for Standardization,

International, Standard ISO 361-1975, ISO, Geneva 1975).

Entry to the control Areas is only permitted for persons carrying out specific operations. The body dose must be determined or the personal dose measured. The authority concerned may grant exceptions if it can be proved that the whole body dose will not exceed 15 mSv/year (1.5 rem/year).

5.7.2.3 Monitored areas

Plant Monitoring

The plant monitoring area commences from the control area with a dose limit of 15 mSv per annum (1.5 rem/year), if a person stays in the area for 40 hours per week (which is equivalent to a dose rate of 7.5 µSv/h or 0.75 mrem/h), and reaches to a dose rate of 5 mSv per annum. This will result in a dose rate of 2.5 µSv/h (0.25 mrem/h). Steps must be taken to ensure that persons will not be exposed to a higher dose than 5 mSv per annum (0.5 rem/year) taking into account the actual visits to this area.

5.7.2.4 General monitoring

The general dose rate limits are 0.3 mSv per annum (30 mrem per annum). Persons in this area must not be exposed to a higher annual dose than 1.5 mSv (150 mrem).

5.8 Classification Designation of Sealed Source

The classification of a sealed source shall be designated by the code ISO/followed by a letter and five digits.

The letter shall be either C or E.C designates that the activity level of the sealed source does not exceed the limit established in Appendices B and E designates that the activity level of the sealed source exceeds the limit established in Appendix B. The first digit shall be the class number, which describes the performance for temperature.

The second digit shall be the class number, which describes the performance for external pressure.

The third digit shall be the class number, which describes the performance for impact.

The fourth digit shall be the class number, which describes the performance for vibration.

The fifth digit shall be the class number, which describes the performance for puncture.

Example:

A typical industrial radiography source designed for use unprotected would be designated ISO/C 43515 (values are taken from Appendix C).

6. GENERAL REQUIREMENTS FOR RADIOGRAPHY EQUIPMENT

6.1 General Requirements

6.1.1 X-ray radiography equipment

X-ray equipment used in Industrial Radiography must be provided with adequate built-in safety features so as to minimize radiation hazards to its users and to the public. X-ray tubes are provided with lead lined to housing so as to reduce the leakage radiation below the level specified by the competent authority. In the case of conventional X-ray units, the leakage radiation at one meter from the target should not exceed one rontgen in one hour or 10 mGy in one hour. Further, the use of beam limiting devices is also recommended. For rod anode tubes which are used for panoramic exposure, and for which no tube shielding exists, this specification on leakage levels does not apply. The control console must have a locking provision to prevent the use of the X-ray machine by unauthorized persons. A red light must be provided on the control console as well as on the tube head to indicate the beam "ON" position. In the case of conventional X-ray units, the cable length between the tube head and the control console should not be less than 20 meters and the operator must make use of the full length of the cable while energizing the X-ray tube.

In case of linear accelerator the maximum leakage radiation at 1 meter from the target (other than the primary beam direction) should not exceed 0.1% of the primary radiation measured at 1m from the target.

6.1.2 Gamma radiography equipment

Each model of radiography camera is designed to house a particular source of specified maximum strength. Gamma ray sources of appropriate strength are used in radiography cameras. Depending upon the nature and strength of the source used and the type of radiography work, radiography equipment either of the stationary type or of the mobile type can be used. Higher source strengths of (i.e., more than 20 Ci of ^{192}Ir and 5 Ci of ^{60}Co) are permitted only for radiography cameras provided with remote handling mechanisms such as flexible cable operation or electrical or pneumatic operation so that all operations can be done from a safe distance thereby minimizing radiation exposure to the operator.

The source housing of gamma radiography equipment must have adequate shielding to restrict the leakage radiation within limits stipulated. The leakage radiation levels in the "OFF" position of industrial gamma radiography equipment stipulated by the competent authority are:

a) At a distance of one meter from the surface of the source housing when the source is in its fully shielded position:

i) The maximum radiation level in any direction must not exceed 0.1 mSv/h (10 mrem/h).

ii) The average radiation level must not exceed 0.02 mSv/h (2 mrem/h).

b) At a distance of 5 cm from any point on the surface of the source housing, in any direction:

i) The maximum radiation level must not exceed 1 mSv/h (100 mrem/h);

ii) the average radiation level must not exceed 0.2 mSv/h (20 mrem/h).

In the case of transport container (lead pots) used for temporary storage/transport, the leakage radiation levels in the full-shielded position of the source should not exceed:

a) 2 mSv/h (200 mrem/h) at a distance of one meter from the surface of the container.

b) 0.1 mSv/h (10 mrem/h) on the average of radiation level.

The cameras and containers must be provided with built-in locking arrangements so as to prevent unauthorized handling. Radiation warning symbol must be conspicuously visible on the camera/container.

6.2 Apparatus for Gamma Radiography

6.2.1 General requirements

An apparatus for gamma radiography shall be designed for the conditions which may be encountered in use, and which may adversely affect safe operation. Designers and manufactures shall give particular consideration to the following:

a) The durability and resistance to corrosion of components and their surface finishes, particularly where the functioning or moving parts may be affected;

b) the need to prevent the ingress of water, mud, sand, or other foreign matter into the controls or moving parts, or the facility with which the apparatus may safely be cleaned out using, for example, a hose and water;

c) the effect of temperatures which may be encountered in use;

d) the possibly damaging effects of gamma radiation on any non-metallic components such as rubbers, plastics, jointing, sealing compounds or lubricants in close proximity to the sealed source;

e) the provision of appropriate accessories designed for the secure mounting of the exposure container or exposure head in different positions of use;

f) the interchangeability of source holders and other replacement components;

g) the provision of instructions for use, periodic inspection and maintenance.

Where depleted uranium is used as the shielding material of an exposure container, it shall be clad with a nonradioactive material of sufficient thickness to attenuate or absorb the beta radiation. If the non-radioactive cladding is liable to react with the depleted uranium at elevated temperatures, then the depleted uranium shall be given a suitable surface treatment to inhibit this effect.

6.2.2 The sealed source capsule

a) Shall be free from surface radioactive contamination;

b) shall be leak-free;

c) shall be physically and chemically compatible with its contents;

d) shall not contribute significantly to the activity of the radioactive material in the case of a sealed source produced by direct irradiation.

6.3 Sealed Source Certificate

The manufacturer shall provide a certificate with every sealed source or sealed source batch. The certificate shall in every case state:

a) Name of manufacturer;

b) classification designated by the code established in 5.8;

c) serial number and brief description, including chemical symbol and mass number of the radionuclide;

d) equivalent activity and/or radiation output in terms of fluence rate, as appropriate, on a specified date;

e) method used and result of test for freedom from surface contamination;

f) leak test method used and test result.

An example of a certificate for a sealed radioactive source is given in the Appendix D.

Note:

In addition, the certificate may include, as appropriate, a detailed description of the source, in particular:

- For the capsule: Dimensions, material, thickness and method of sealing.

- For the active contents: Chemical and physical form, dimensions, mass or volume; percentage of undesirable radionuclides from the point of view of the use to which the sealed source is to be put.

6.4 Source Marking

Whenever physically possible, the capsule shall be durably and legibly marked with the following information, which is given in order of priority:

a) Mass number and chemical symbol of the radionuclide;

b) serial number;

c) for neutron sources, the target element;

d) manufacturer's name or symbol.

The marking of the capsule shall be done before the sealed source is tested.

6.5 Containers Marking

Each exposure container or a metal plate permanently fixed to the container shall be permanently and indelibly marked by engraving, stamping or other means with the following:

a) The basic ionizing radiation symbol, complying with ISO-361;

b) the word "RADIOACTIVE" in letters not less than 10 mm in height;

c) the maximum rating of the container:

- For a cobalt 60 source, shown as "Rating × Bq ^{60}Co (y Ci ^{60}Co)";

or;

- for a caesium 137 source, shown as "Rating × Bq ^{137}Cs (y Ci ^{137}Cs)";

or;

- for an iridium 192 source, shown as "Rating × Bq ^{192}Ir (y Ci ^{192}Ir)".

d) the ISO marking indicates the manufacturer's claim that the exposure container and its accessories conform to international Standard; this claim shall be stated in the manufacturer's literature;

e) the manufacturer's type and serial number.

6.5.1 Class M and F containers

A Class M or F exposure container shall be marked with the mass of the container without removable accessories.

6.6 Radiotoxicity and Solubility

Except as required by Appendix A radiotoxicity of the radionuclide shall be considered only when the activity of the sealed source exceeds the value shown in Appendix B. If the activity exceeds this value, the specifications of the sealed source have to be considered on an individual basis. If the activity does not exceed the values shown in Appendices B, and C the aforesaid specification may be used without further consideration of either radiotoxicity or solubility.

6.7 Quality Control

A quality control program is essential and shall be operated in both the design and manufacture of sealed sources, which are to be classified.

6.8 General Consideration of Exposure Container

6.8.1 Safety devices

6.8.1.1 Locks

On all exposure containers, a series of beam emissions of source projections shall be possible only after a manual unlocking operation.

An exposure container shall be provided either with an integral lock and key or with hasps through which a separate padlock can be fitted. The lock shall be either of the safety type, i.e., lockable without the key, or an integral lock from which the key cannot be withdrawn when the container is in the working position. The lock shall retain the sealed source in the secured position and shall not, if the lock is damaged, prevent the sealed source when it is in the working position from being returned to the secured position. If separate padlock is used, there shall be an additional device to provide a positive means of retaining the sealed source in the secured position.

6.8.1.2 Source position indicators

An apparatus for gamma radiography shall clearly indicate whether the sealed source is in the secured or the working position. If colors are used, green shall only indicate that the source is in the secured position and red shall indicate that the source is not in the secured position, but colors shall not be the sole means of indication.

6.8.1.3 System failure

A remote control system, which is not manually operated, shall either:

a) Be designed so that a failure of this system causes shutter closure or the return of the sealed source to the secured position, or;

b) be accompanied by a safety device, preferably manual, permitting shutter closure or the return of the sealed source to the secured position without unduly exposing personnel to radiation.

A remote control system, which is manually operated, shall be designed so that it is impossible for the sealed source to be withdrawn from the rear of the exposure container whilst operating, connecting or disconnecting the remote control cable.

6.8.1.4 Unauthorized operation

Where a remote control is incorporated, there should be provision to prevent its unauthorized operation when the operator is not in immediate attendance, for example by a removable winding handle.

6.8.2 Source holder security

The source holder shall be designed in such a way that it cannot release the sealed source accidentally, and shall provide it with positive retention and mechanical protection.

6.8.3 Exposure rate in the vicinity of the containers

An exposure container shall be made in such a way that when locked in the secured position and equipped with sealed sources corresponding to the maximum rating, the exposure rate, when tested as described in 6.10 does not exceed the limit in Column (4) and one or other of the limits in Columns (2) and (3) of Table 4.

TABLE 4 - EXPOSURE RATE LIMITS

1	2	3	4
	MAXIMUM EXPOSURE RATE, mSv/h (mR/h)		
Class	On external surface of container	50 mm from External surface of container	1 m from External surface of container
P	2(200) or	0.5 (50)	0.2 (2)
M	2(200) or	1(100)	0.05 (5)
F	2(200) or	1(100)	0.1(10)

See definition for different type of classes.

6.9 Handling Facilities of Exposure Container

6.9.1 Portability

A Class P exposure container shall be provided with a carrying handle. A Class M container shall be provided with a lifting device. Such a handle or device shall be adequate for its purpose and so secured that it cannot be accidentally parted from the container. (Such an adjunct is optional for a Class F container.)

6.9.2 Mobility

The equipment provided for moving a Class M exposure container shall have a turning circle of 3 m or less, and shall be fitted with an immobilizing device.

6.10 Manufacturing and Production Tests for Exposure Container

The manufacturers shall provide the necessary production quality control inspections and tests.

The program shall include at least the tests specified in the following standards:

a) Resistance to normal conditions of service covering the tests for:

- Vibration
- Shock
- Endurance
- Kinking, crushing tensile
- Accidental dropping

In accordance with standard ISO 2855.

b) Shielding efficiency test:

In accordance with standard ISO 3999.

c) Tests for Mechanical remote control devices:

In accordance with standard ISO 3999.

d) Production test:

In accordance with standard ISO 3999.

e) Leak test:

In accordance with standard ISO/TR 4826.

f) Testing procedures:

- Temperature test
- External pressure test
- Impact test
- Puncture test.

In accordance with standard ISO 3999.

6.11 Packing and Transportation of Radioactive Substance

6.11.1 Transportation

Transportation of radioactive substance on public transport is only permitted if approval has been granted by the supervisory authority. The transportation approval stipulates that delivery can only be effected if the following points have been considered:

a) Packing Type A;

b) marking of package;

c) marking of the shipping documents;

d) observe maximum permissible activity.

The transportation of radioactive material can take place only according the regulations for transportation of dangerous commodities. For transport regulation references is given in International Atomic Agency Safety series No. 6, No. 37.

6.11.2 Identification of the sealed source in the container

The user shall ensure that the following information is displayed in a durable form, which shall be attached to the exposure container:

a) Chemical symbol and mass number of the radionuclide;

b) activity and the date on which this activity was measured;

c) identification number of the sealed source.

6.11.3 Packaging

6.11.3.1 Packaging of radioactive materials is generally controlled by the International Atomic Energy Agency transport regulations (IAEA) (Safety Series No. 6, 1973 revised edition). There are two categories of packaging:

Type A:

Designed to retain the integrity of containment and shielding under the normal conditions of transport.

Type B:

Designed to withstand the damaging effects of a transport accident. Packages containing radioactive materials must conform to certain maximum external radiation levels according to the method of transport being used. Under IAEA Category III-yellow and exposure rate not exceeding 2 mSv/hr at any point on the surface of the package is allowed.

The package must also have a Transport Index (TI) within the limits prescribed for the particular method of transport. (The Transport Index is the number expressing the exposure rate in 2 mSv/hr at 1 meter from the surface of the package). For most passenger-carrying aircraft the TI must not exceed 3 or 4, but for freighter aircraft a TI up to 10 is generally allowed.

The IAEA transport regulations prescribe for each nuclide, maximum activities that may be transported in a type A package. The activity levels (A1 and A2 limits) depend on the toxicity, etc., of the nuclide and may vary according to whether or not the nuclide is contained in a capsule for which a "Special Form" certificate has been issued.

6.11.3.2 Exempt packaging

Packages are exempt from the packaging regulations if they conform to the following requirements:

a) The maximum activity of the contents is less than:

10^{-3} A1 (special form approval), or;

10^{-3} A2 (for other sources).

b) The exposure rate at any point on the surface of the package does not exceed 0.5 mrem/h.

Transport containers are designed for maximum safety and economy in transport and conform to the appropriate international regulations. Wherever possible lightweight non-returnable containers should be used but shipments requiring more shielding shall be packed in returnable containers. Some typical non-returnable and returnable containers are illustrated in Appendix E.

6.11.3.3 Non-returnable containers

These usually consist of a lead shield in a sealed can packed either in a cardboard box or in an expanded polystyrene casing. Packages of this type meet the IAEA requirements for Type A. Modified packaging to conform to Type B is also available. The sealed can may be opened with a domestic can opener. Refer to unpacking instructions where applicable.

6.11.3.4 Returnable containers

Returnable containers usually consist of a heavy lead shield inside a steel drum. In the steel drum there may also be a cork or fiber liner to give protection in case the container is involved in a fire. Specially designed containers should be used for loading high activity and high-energy gamma and neutron sources.

6.11.3.5 Customers' containers

Customers' own containers must meet the relevant transport regulations; formal evidence of this is required before shipments can be arranged.

6.11.3.6 Receipt of source package

a) The package should be inspected on arrival and if any damage is observed which could have resulted in damage to the product then it shall not be opened. Measure the surface dose-rate on the container. It should not exceed 2 mSv/h. A higher reading may indicate that the source is not in a safe position or that the shielding is damaged. The package must be made safe and the matter reported to the Atomic Energy Organization of Iran.

b) Check that the documentation and label description, agrees with the order acknowledgment. If there are differences notify Atomic Energy Organization of Iran as soon as possible.

c) Notify the Radiological Protection Supervisor that the package has arrived. Update the official record for radioactive substances accounting purposes, noting the identification, activity and date.

d) The shielding provided by transport containers is adequate to comply with the maximum dose-rate levels specified in the International Atomic Energy Agency Transport Regulations. However, these levels are normally too high to allow storage of the package in workplaces.

If the package is not opened immediately, a suitable and secure store must be provided. This store should be reserved for radioactive materials only and must be adequately shielded, correctly labeled and fully secured against intrusion by unauthorized persons. The external dose-rate should not normally exceed 2.5 Sv/h (0.25 mR/h).

6.11.3.7 Unpacking

a) Sources must only be unpacked in a Controlled Area by trained, competent and authorized personnel.

b) Radiation levels should be checked using a dose-rate meter at each stage of unpacking. The exposure rate at the outer surface of the package may be as high as 2 mSv/h and dose levels at each stage of unpacking will increase.

c) Various packing combinations are used depending on the type of sources. Steel drums are the most commonly used form of packaging. For these types proceed as follows:

- Remove steel closing band and lid;
- check the enclosed documents;
- remove cork lid and spacer, if fitted;
- lift the lead pot out of the drum, leaving the cork liner in place.

Caution:

- The lead pot is heavy. Use assistance if necessary.
- Place the lead pot on firm level ground.

Caution:

- The dose-rate on the lead pot may be as high as 15 mSv/h , so contact time should be minimized.

7. PROCEDURE TO ESTABLISH CLASSIFICATION AND PERFORMANCE REQUIREMENTS FOR SEALED SOURCE

7.1 Establish the radiotoxicity group from Appendix A.

7.2 Determine the amount of activity allowable from Appendix B.

7.3 If the desired quantity does not exceed the allowable quantity of Appendix B, an evaluation of fire, explosion,and corrosion hazard shall be made. If no significant hazard exists, the sealed source's classification may be taken directly from Appendix C. If a significant hazard exists, the factors listed in clause 6.10 shall be evaluated with particular attention to the temperature and impact requirements.

7.4 If the desired quantity exceeds the allowable quantity of Appendix B, an evaluation of fire, explosion and corrosion hazard and a separate evaluation of the specific sealed source usage and sealed source design shall be made.

7.5 After the required classification of the sealed source for the particular application or usage has been established, the performance standards can be obtained directly from Table 2.

7.6 Alternatively, the sealed source class can be determined from Table 5 and some suitable application may be selected from Appendix C. Since Table 5 is arranged in order of increasing severity from Class 1 through Class 6, sealed sources of an established classification may be used in any application having less severe specific performance requirements (classification numbers).

7.7 Identification of Sealed Sources

The classification designation in accordance with clause 5.8 shall be marked on the sealed source certificate and, where practicable, on the sealed source capsule and the sealed source container

7.8 Classification of Sealed Source Performance Standards Table 5

This is a list of environmental test conditions to which a sealed source may be subjected.

The tests are arranged in order of increasing severity. The classification of each sealed source type shall be determined by actual testing of two sources (sealed, prototype, dummy of simulated) of that type for each test in Table 5, or by derivation from previous tests, which demonstrate that the source would pass the test if the test were performed. Different specimens may be used for each of the tests. Compliance with the tests shall be determined by the ability of the sealed source to maintain its integrity after each test is performed.

A source with more than one encapsulation shall be deemed to have complied with a test if it can be demonstrated that at least one encapsulation has maintained its integrity after the test.

Leak test methods for sealed radioactive sources are given in ISO/TR 4826. When leak testing a simulated source, the sensitivity of the chosen method has to be adequate.

TABLE 5 - CLASSIFICATION OF SEALED SOURCE PERFORMANCE STANDARDS

TEST	CLASS						
	1	2	3	4	5	6	X
Temperature	No. test	-40°C (20 min) +80°C (1 h)	- 40°C (20 min) +180°C (1 h)	- 40°C (20 min) +400°C (1 h) and thermal shock 400°C to 20°C	- 40°C (20 min) +600°C (1 h) and thermal shock 600°C to 20°C	- 40°C (20 min) +800°C (1 h) and thermal shock 800°C to 20°C	Special test
External pressure	No. test	25 kPa absolute to atmospheric	25 kPa absolute to 2 MPa absolute	25 kPa absolute to 7 MPa absolute	25 kPa absolute to 70 MPa absolute	25 kPa absolute to 170 MPa absolute	Special test
Impact	No. test	50 g from 1 m	200 g from 1 m	2 kg from 1 m	5 kg from 1 m	20 kg from 1 m	Special test
Vibration	No. test	3 times 10 min 25 to 500 Hz at 49 m/g² (5 g)[1]	3 times 10 min 25 to 50 Hz at 49 m/S² (5 g)[1] and 50 to 90 Hz at 0635 mm amplitude peek to peek and 90 to 500 Hz at 98 m/S² (10 g)[1]	3 times 30 min 25 to 80 Hz at 1.5 mm amplitude peek to peek and 80 to 2000 Hz at 196 m/g² (20g)[1]			Special test
Puncture	No. test	1 g from 1 m	10 g from 1 m	50 g from 1 m	300 g from 1 m	1 kg from 1 m	Special test

1) Peek acceleration amplitude.

7.9 Sealed Sources Application and Exchange Procedures

7.9.1 Choice of sealed sources

A source used to produce radiation field should be sealed in a suitable container or prepared in a form providing equivalent protection from mechanical disruption. The following characteristics are desirable consistent with the work being carried out:

a) The activity of the source used should be a minimum.

b) The energy or penetrating power of the emitted radiation should not be greater than that necessary to accomplish the task with a minimum total exposure.

c) If possible, the radioactive material in the source should be of low toxicity and in such a chemical and physical form as to minimize dispersion and ingestion in case the container should be broken.

d) Sealed sources should be permanently marked to permit individual identification and facilitate determination of nature and quantity of radioactivity without undue exposure of the worker.

e) Sealed sources or appropriate containers should be regularly examined for contamination or leakage (smear tests, and/or electrostatic collection may be used). The interval between examinations should be determined by the nature of the source in question.

f) Mechanically damaged or corroded sources should not be used and should immediately be placed in sealed containers. They should be repaired only by a technically skilled person, using suitable facilities.

7.9.2 Methods of use of sources

7.9.2.1 Sources should always be handled in such a way that proper location is possible at all times. Inventories should be kept.

7.9.2.2 If any person has reasons for believing that a source has been lost or mislaid, he should notify the "safety officer" immediately. If the loss is confirmed, the designated authority should be notified without delay.

7.9.2.3 Sources should be handled in such a way that the radiation dose to personnel is reduced to a minimum by such methods as shielding, distance and limited working time.

7.9.2.4 Sources should be handled in such a way as to avoid hazards to all personnel including those not involved in the operations. Attention should be paid to people in adjacent areas including rooms above and below. Areas subject to high radiation levels should be clearly marked, roped off and evacuated if occupied.

7.9.2.5 Beams of radiation arising from a partially shielded source should be clearly indicated. Care should be taken to insure that such a beam is stopped at the minimum practical distance by suitable absorbing material. Monitoring procedures should be planned to take into account the sharp collimation of radiation fields, which may occur.

7.9.2.6 When practical, sealed sources should be used in enclosed installations form, which all persons are excluded during irradiation.

7.9.2.7 Sources should not be touched by hands. Appropriate tools should be used, for instance, long handled, lightweight forceps with a firm grip. If needed, even more elaborate means of protection have to be considered, such as master slave manipulation, etc.

7.9.2.8 Work with radioactive materials should be planned to permit as short an exposure as possible. The extent of protection provided by limiting working time can easily be lost if unexpected difficulties occur in the work, so that dummy runs should preferably be performed whenever it is possible.

7.9.2.9 Although work should be planned to limit exposure time to a safe figure, if sufficient shielding cannot be provided and time of exposure must be controlled, this should be carried out in a systematic way, preferably with time keeping and warning services outside the responsibility of the actual personnel.

7.9.3 Special use of sealed sources

7.9.3.1 Industrial gamma radiography

The controlled area should be clearly marked with easily recognizable signs. Such area should be made inaccessible to unauthorized personnel.

Light or audible signals, or both, should be provided to give adequate warning before and during irradiation. The radiographic setup should be completed before starting the irradiation. For radiography, which requires the removal of the sealed source from its shielding container, a clearly identifiable dummy capsule should be used during any preliminary adjustments that may be necessary.

If the sealed source must be handled outside the container, this should be done automatically or by remote means, so as to give adequate protection to all personnel concerned with the operation.

A radiation detection instrument should be used to verify that the radiographic source has been correctly returned to its shielding container at the end of radiographic exposure. When an industrial gamma radiography source is used away from the premises of normal use, notices consisting of diagrams and/or photographs with dimensions and identifying features of the radioactive source and the steps to be taken by any person finding such a source should be prepared. These notices should be displayed at the area where the source is being used until removal of it from the area has been verified.

7.9.3.2 Thickness gages, static eliminators and similar devices using sealed sources

Radioactive materials used for thickness gages, static eliminators and similar devices should be in the form of sealed sources conforming to the general provisions for sealed sources.

Whenever practicable, the normally unshielded portion of the sealed source should be protected against mechanical damage, and be provided with a cover plate, shutter or shield that can be readily secured so as to effectively intercept the useful beam.

Wherever possible, such devices should be installed or shielded so as to ensure that the levels of irradiation of all persons, including those installing or maintaining the sealed source or any machinery or plant in close proximity to it, should be in conformity with the allowed doses to the general public put up by competent authority (so avoiding the need for personnel monitoring procedures and special medical examinations).

Such devices should be conspicuously and permanently marked so as to warn personnel of the presence of radioactive material and the need to avoid unnecessary exposure. In case of a breakage of the source, the "safety officer" or other designated persons should be notified at once.

7.9.4 Source exchange procedure

Source changers are used to transport new sources from the manufacturer to the user. The changer is coupled to a source projector and the old source is transferred from the projector to an empty channel in the changer. (This allows an opportunity to service the projector if necessary). Then the new source is transferred from the changer to the projector. Finally the old source is returned to the manufacturer in the changer.

The general procedures described in this section must be read in conjunction with the specific procedures relevant to particular container types, which are described in Section 7.9. It is important that the complete procedure is thoroughly understood before any source unload is attempted. Fig. 9

7.9.4.1 Layout of equipment

Source exchanges must only be carried out in a Controlled Area. Use any available radiation shielding e.g. a wall, if possible.

a) Arrange the source changer (or lead pot) and the projector so that one length of guide tube will fit between them without any sharp bends or kinks in the tube.

Caution:

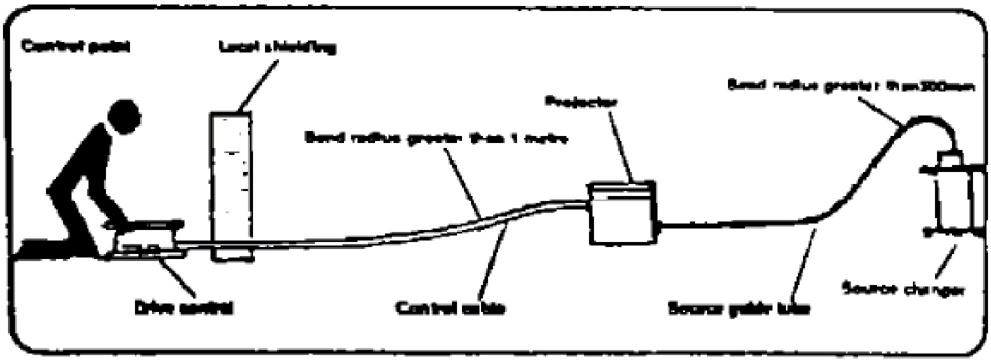
Any bends in the guide tube must have a radius of not less than 500 mm.

b) Lay out the drive cable between the projector and the drive cable control unit.

Caution:

Any bends in the control cable must have a radius of not less than 1 meter.

c) Locate the drive cable control unit as far away as possible from the projector and source changer. Preferably the control point will be outside the Controlled Area.



7.9.4.2 Equipment assembly

a) Connect the guide tube to an empty hole in the source changer, using an adapter as appropriate (if a clamp is fitted, lift lever).

Caution:

The source changer must remain upright at all times. Do not lay it on its side.

b) Connect the drive cable to the projector as per manufacturers instructions.

Caution:

Do not unlock at this stage.

c) Connect the other end of the guide tube to the projector as described in the manufacturers instructions.

Caution:

Minimize time spent near to the projector.

d) Position a dose rate meter close to the control point to continuously monitor dose rate to which the operator is exposed.

e) Check that any personnel remaining in the vicinity are wearing monitoring equipment as specified by the rules (film badge, TLD, dosimeter, QFE, etc.).

7.9.4.3 Transfer of decayed source into source changer

a) Set the radiography projector for exposure.

b) Sound and/or indicate visually the appropriate warning device(s) for imminent source exposure. Check area is clear of personnel and all access points are secure.

c) Crank the decayed source rapidly from the projector to the source changer.

Note:

The radiation intensity will increase greatly as the source is first exposed, decrease slightly as the source is cranked out, and then drop to background level when the source is correctly loaded in the source changer.

d) Check the dose rate meter reading.

Caution:

Do not move towards the projector or changer units if the reading remains high.

e) When satisfied that the source is located in the source changer, approach the equipment with a dose rate meter. The dose rate at 1 m should be about 0.75 mSv/h (75 mR/h) for a lead pot, or 100 Sv/h (10 mR/h).

Caution:

If significantly higher dose rates are measured as you approach the equipment, STOP, check the operations and return to a low dose area. Check with your supplier.

f) Check the dose rates on all sides of the projector, on the guide tube and on all sides of the source changer.

Caution:

The maximum dose rate at the surface of a source changer should be 15 mSv/h (1.5 R/h) for a lead pot, or 2 mSv/h (200 Mr/h).

7.9.4.4 Disconnecting the source

a) When satisfied that the source is properly loaded, uncouple the guide tube from the source changer. For a lead pot type, carefully unscrew the guide tube, taking care not to pull it away from the source changer as this may dislodge the source just transferred from its shielded position. For 650 units, open the latched source guide.

Caution:

Do not move the source more than 10 mm from its stored position. Monitor the dose rate during this operation to ensure that you are warned if the source becomes exposed.

b) Disconnect the drive cable from the source holder assembly taking precautions not to move the source. Amertest sources are disconnected by moving the lock pin of the connector towards the source and sliding the drive cable out through the keyway. Do not bend or twist. For other equipment, see appropriate manufacturers instructions.

Replace the closure nut on the source changer (if fitted) using firm finger pressure or close the clamp, disconnect the guide tube.

c) Wire the old source identity plaque to the source changer so that the position of the source can be traced.

7.9.4.5 Projector maintenance

The opportunity should be taken at this stage to inspect the empty projector. Routine maintenance work in accordance with the manufacturers recommendations may conveniently be scheduled to coincide with the source replacement.

To enable the drive cable to be disconnected from a projector, it is necessary to fit a test connector to the drive cable before withdrawing it into the projector. Test connectors (jumpers') are normally fitted in the drive connector dust cap of the projector. The drive cable connector should be checked for wear using a 'NO GO' gage.

7.9.4.6 Transfer new source into projector

a) Identify the position of the required new source. Each source position is shown by marker tape and a source identification plaque or by a loading chart.

b) Remove the appropriate closure nut (if fitted) and connect the drive cable to the source holder (lift clamp lever if fitted). Attach the guide tube.

c) Couple the source connector to the drive cable. Amertest sources are connected by depressing the lock pin with a thumbnail, sliding the drive cable connector into the keyway, then releasing the lock pin. Make sure that the connection is secure. Other equipment use equivalent methods see manufacturer's instructions.

Caution:

Do not move the source more than 10 mm from its stored position. Monitor the dose rate during this operation to ensure that you are warned if the source becomes exposed.

d) For the 650-source changer, close and latch the source guide after attaching the guide tube and the drive cable to the source holder as above.

e) Retire to the control point, sound warning devices and take precautions as for source unload.

f) Crank the new source rapidly from the source changer to its storage position in the projector.

Caution:

Observe the dose rate meter during the operation. The radiation intensity should increase as the source exits the source changer, increase as it approaches the projector and drop to a low level when the source is properly stored in the projector.

g) Survey the projector and the guide tube with the dose rate meter to ensure that the transfer has been properly completed the dose rate at the surface of the projector should be less than 2 mSv/h (200 mR/h) and less than 100 Sv/h (10 mR/h) at 1 meter.

h) When satisfied that the source is properly stored, lock the projector and remove all guide tubes and controls. Attach the new source identification plaque to the projector.

i) Remove the guide tube from the source changer. Replace the lock nut (close clamp if fitted) or hold down cap. Ensure adequate means of identifying loaded positions.

7.9.5 Specific container types

Specific features of 3 of the main source changer types are described in this section. Details of their construction and operation should be read in conjunction with the previous section on general methods of source exchange. Fig. 10

7.9.5.1 TEN650 source changer

a) To open, remove the cover from the TEN650 by unlocking the padlock, breaking the wire seal and removing the bolts.

Caution:

Monitor for radiation beams from the source position.

b) Remove the shielded source hold down cap from the top of the unit, by breaking the wire seal and unbolting. The loaded position will have the source identification plaque attached. The unloaded position will be unlabelled.

Caution:

Check visually that the position chosen for loading into, is empty.

c) Connect the guide tube extension to the fitting above the empty chamber of the TEN650 source changer. Close and latch the source guides to secure the tube.

Follow the general procedure for source transfers described in Clause 7.9.4.

d) To seal the container for returning sources, bolt down the source hold down cap in place and close with the seal and wire.

Caution:

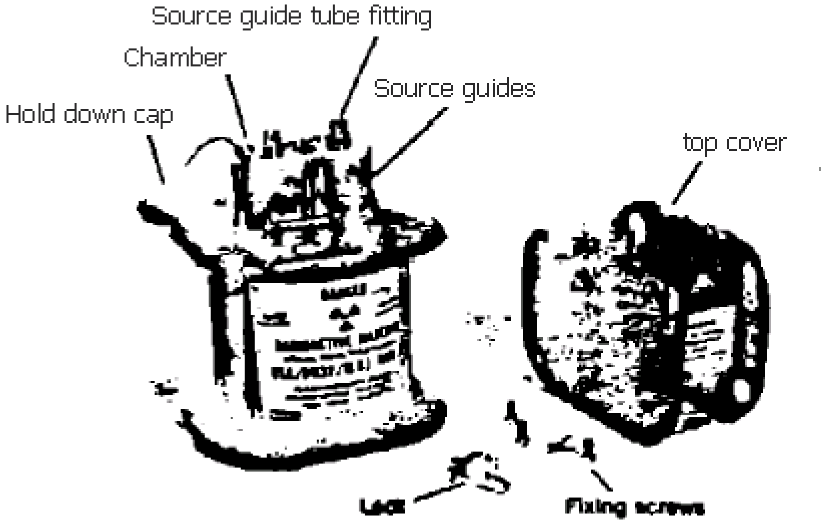
The cap must be bolted firmly in position over the source connectors.

e) Place the number 2 (red) copy of the 'Notification of Return' form in the top cover (see Clause 7.9.8). Bolt the TEN650 cover in place, padlock and wire seal.

f) Note the rated capacity of the unit is 8.9 TBq (240 Ci) as special form. Its size is 210 mm wide;

25 mm long; 337 mm high. The shipping weight is 32 kg.

TEN650 SOURCE CHANGER



7.9.6 Cable type source holders

a) Follow the general procedure for source transfers described in Clause 7.9.4.6.

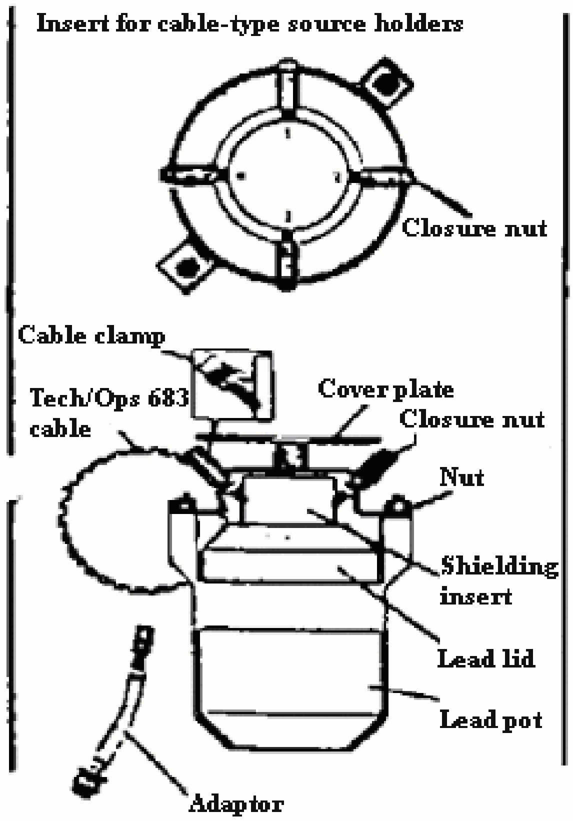
Caution:

Follow all the safety precautions and monitoring procedures, using a dose rate meter at every stage to check that the source is correctly located.

b) To open, unscrew the two nuts and remove the cover plate.

Caution:

The shielding insert containing the source holder is now loose. Do not remove the insert from the pot, this would give rise to very high dose rates 1 Sv/h (100 R/h).



c) Select an empty storage position in the pot-identified by not having "radioactive" label tape on the closure nut or a source identification plaque attached. Remove the closure nut (or clamp lever, if fitted).

Caution:

Monitor for radiation beams from source positions. Check visually that the loading position chosen is empty.

d) Connect the adaptor onto the source tube. If a clamp is fitted, connect the adaptor to the clamp and lift the lever. Connect the source guide extension tube (open at both ends) to the adaptor.

e) When the old source is fully wound into the lead pot, remove the adaptor and uncouple the drive cable, taking care not to pull the source out of the source storage tube. Replace the closure nut, using firm finger pressure only, or close the clamp and insert the wire seal.

f) Determine the position of the new source by reference to the loading chart. Remove the corresponding closure nut, connect the drive cable to the source holder and lift the clamp lever.

g) Move away to the drive control unit and wind the new source into the projector. Secure the source in the projector.

Caution:

Follow safety procedures and monitoring as in Clause 7.9.4.

h) Replace the closure nut or close the clamp. Replace the cover plate and tighten the nuts to clamp it securely in position. Replace the lead pot in the transport drum.

7.9.7 Back shielded source holders assemblies (Teletron, Gammamat)

a) Follow the general procedure for source transfers described in clause 7.9.4.

Caution:

Follow all the safety precautions and monitoring procedures, using a dose rate meter at every stage to check that the source is correctly located.

b) To open, slacken the two nuts securing the cross bar. Raise, turn and lift off the lid.

Caution:

The shielding insert containing the source holder is now loose. Do not remove the insert from the pot, this would give rise to very high dose rates > 1 Sv/h (100 R/h).

c) Remove any top shielding to reveal the shielded ends of the source holders.

Caution:

Monitor for radiation beams from source positions.

d) Select an empty storage position in the pot by monitoring for minimal radiation and then confirm by visual examination.

e) Connect the source guide extension tube (open at both ends) to the empty position, using an adaptor if necessary.

f) When the old source is fully wound into the lead pot, remove the adaptor and uncouple the drive cable, taking care not to pull the source out of the source storage tube. Replace the closure nut, using firm finger pressure only, or close the clamp and insert the wire seal.

g) Determine the position of the new source by reference to the loading chart on the back page. Remove the corresponding closure nut, connect the drive cable to the source holder and lift the clamp lever.

h) Move away to the drive control unit and wind the new source into the projector. Secure the source in the projector.

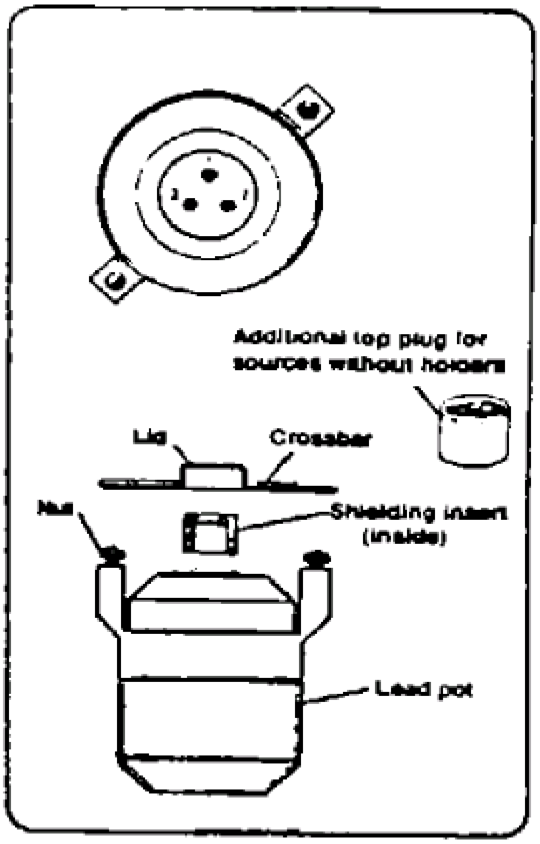
Caution:

Follow safety procedures and monitoring as per Clause 7.9.4.

i) Disconnect the guide tube, keeping any adaptor in a safe place.

Replace top shielding (if fitted). Replace the lid, turn until it drops into position and bolt securely.

INSERT FOR BACK SHIELDED SOURCE HOLDERS



7.9.8 Returning the container

7.9.8.1 General considerations

Before attempting to dispatch radioactive material the user should be familiar with IAEA Standards Safety Series No. 6. In particular the user must ensure that:

a) The container and any other packaging are fully approved for the radioactive material that the user intend to dispatch. Designated Authority approval certificates (Types A, B or Special Form) must be valid.

b) The container and any other packaging is undamaged and complete.

c) The description on the paperwork matches the material in the container.

d) Dose rate and contamination measurement have been carried out and recorded and that these comply with the statutory limits for transportation. The maximum surface dose rate must be less than 2 mSv/h (200 mR/h) and the T.I. must be less than 10. The maximum removable surface contamination must be <1 Bq/cm^2 averaged over 300 cm^2.

e) The outside of the container and/or package is correctly labelled.

f) The consignor’s certificate "Shipper’s Declaration for dangerous goods" is completed.

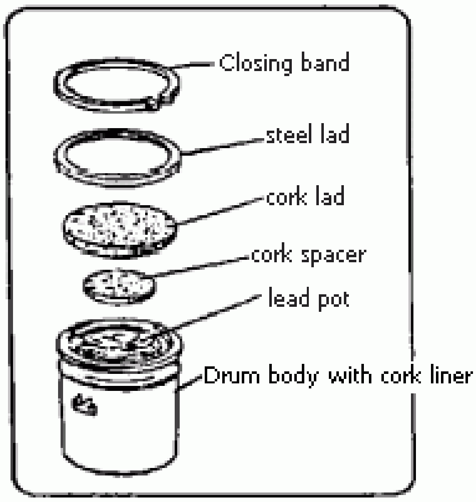
Caution:

Containers are designed for the shipment of specific types of sources. They must not be used for returning a source if the source, or any part of it or the package is damaged, modified or incomplete or if the source assembly being returned is not identical to the one received.

7.9.8.2 Repacking

Place the lead pot in the drum. Replace the cork spacer and lid. Place the steel lid on the drum and position the closing band so that it covers the joint between the drum body and lid. Tighten the closure until the lid is securely held on the drum. Tap the band gently all round with a rubber hammer or a block of wood. Retighten the closure. Repeat as necessary until the band is securely in position without any chance of working loose in transit.

Fit sealing wire to the closing band to ensure that the seal must be broken if the band is removed.



7.9.8.3 Monitoring the container

When the source has been loaded into the container, measure radiation dose rates to ensure conformance with Regulations:

a) Surface dose rate

Measure the radiation dose rate as close as possible to all surfaces of the container, including the base. It must not be greater than 2 mSv/h (200 mrem/h) at any point. Usually the source to be returned will be of much lower activity than the new one, so the surface dose will be well within this limit.

Caution:

If a high dose rate is detected anywhere on the surface of the container, check that the sources are correctly positioned in the lead pot or source changer and that all shielding components are properly in place.

b) Transport Index (TI)

Measure the dose rate at one meter from all surfaces of the drum. The maximum value found in millirem per hour (mR/h) is the Transport Index (TI). Where the dose rate is measured in units of microsieverts per hour (Sv/h), divide the value by 10 to obtain the TI. The TI value must be quoted on the labels and on the Consignor’s Certificate (Shipper’s Declaration for dangerous goods). For most passengercarrying aircraft the TI must not exceed 3 or 4, but for freight aircraft or sea or road transport, a TI of up to 10 is generally allowed.

7.9.8.4 Labelling the container

a) Remove all old labels.

b) Fill in the return address label and attach it to the container.

c) Attach two 'Radioactive' labels on opposite sides of the container.

Fill in the contents (e.g. Iridium-192), activity (e.g., 0.74 TBq, 20 curies) and Transport Index (e.g.,3.0) on both labels. Choice of label is described in table below:

MAXIMUM RADIATION LEVEL

	AT SURFACE	AT ONE METER
Radioactive white I 	5μSv/h 0.5 mR/h	none
Radioactive yellow II 	500μSv/h 50mR/h	10μSv/h 1 mR/h
Radioactive yellow III 	2mS/h 200mR/h	100μSv/h 10mR/h

7.9.8.5 Documentation for return

a) Notification of return form

A notification of Return of Radioisotope Transport Container form is enclosed in the package of documents sent with the container. It must be completed and the hard copy returned to manufacturer. Note that the customer is responsible for arranging transport.

b) Consignor's certificate

(Shipper's declaration for dangerous goods)

A consignor's certificate is required in addition to the usual shipping documents. For shipments by air the consignor's certificate must be in the form specified by the IATA. for other shipments, the certificate may be in any form providing it describes the radioactive contents and concludes with the signed declaration.

This is to certify that the contents of this consignment are fully described above, are safely packed in a proper condition for transport, and the container is properly marked and labeled, in accordance with applicable standard sign.

To complete the consignor's certificate, the following details must be given:

i) Shippers name and address.

ii) Consignees name and address.

iii) Description of the source (see the test report for details)- either.

- Special form material described as "UN 2974 Radioactive Material, Special Form, N.O.S Class 7" or,

- Other sealed sources, which are described as "UN 2982 Radioactive Material, N.O.S. Class 7".
- Nuclide.
- Activity on dispatch quoted in Bq (see decay chart, or calculated from source data).
- State Physical Form: SOLID or SPECIAL FORM.
- Designated Authority package certificate number (if Type B).
- Designated Authority Special Form Certificate number (if applicable).
- Category of radioactive label (e.g., yellow II, III etc.).
- Type of package (A, B, or Excepted).
- Container identification/serial number.
- TI (Transport Index).
- Signed declaration (see previous page).

Important:

If returning a container with radioactive material is legal responsibility,ensure that the container is properly packaged and labelled and ensure that all necessary paperwork is raised-in particular, the shippers or dangerous goods declaration.

To ensure that the assembly conforms with the Types A or B approval certificate and to assist in the tracking of the containers, the inner container must be returned in the original outer container.

7.9.8.6 Depleted uranium containers

For containers using depleted uranium as shielding (e.g. 650 source changer), special documents are required to describe the goods for transport purposes.

Complete a consignor's certificate as for a loaded container, but use the following descriptions:

a) Shipper's name and address.

b) Consignee's name and address.

c) Description, - either.

1) For surface dose rates less than 5 µSv/h (0.5 mR/h) state "UN 2910 Radioactive Material, Excepted Package, Class 7. Articles Manufactured from Depleted Uranium". Category and type are Excepted, TI not applicable, or,

2) For surface dose rate greater than 5 µSv/h (0.5 mR/h) states "UN 2912 Radioactive Material, Low Specific Activity, Class 7 LSA N.O.S.".

3) "Physical Form: Solid".

4) Group Notation: LSA-1.

5) Category is "Yellow II".

6) Type is "Industrial".

7) TI as appropriate.

8) Container number as appropriate.

9) Sign Declaration.

Attach two radioactive labels as described in the loaded container shipping instructions.

7.9.8.7 Returning empty containers

The following procedure should be used to return empty containers:

a) Remove all old adhesive labels.

b) Fill in the return address label and attach it to the container.

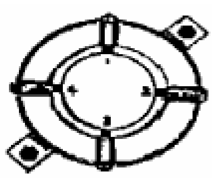
c) For empty lead shielded pots attach two 'Empty' labels ensuring that one covers over the metal 'Radioactive' label on the lid of the drum (if present).

7.9.8.8 Loading Chart

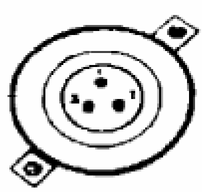
POSITION	SOURCE SERIAL NUMBER	SOURCE HOLDER NUMBER
1		
2		
3		

Different shielding inserts are used for the different types of source holders. The way sources are arranged in these inserts is shown below. The source positions are identified by numbers stamped on the inserts. The inserts can contain up to 10 individual source positions.

ADDITIONAL TOP PLUG FOR SOURCES WITHOUT HOLDERS



INSERT FOR CABLE-TYPE SOURCE HOLDERS



INSERT FOR BACK-SHIELDED SOURCE HOLDERS

7.10 Waste Disposal

Radioactive waste must be disposed of properly, i.e., it has to be deposited at the collection site for nuclear waste. This obligation must be observed strictly. It is illegal to dilute or reduce the concentration of radioactive substances, so that the radiation falls below the permissible limits, and therefore the regulations are no longer applicable. If the sealed radioactive substances are no longer contained,the designated authority must be notified immediately and steps taken to ensure that the contamination cannot be dispersed. Proper handling and disposal of possibly leaking sources or contaminated parts of the equipment must be coordinated with the designated authority.

Note:

Radioactive substances, which are no longer used, are not necessarily radioactive waste. These substances must be properly disposed of as well, e.g., by depositing them at the governmental collection site or by returning them to the manufacturer. In the latter case the manufacturer will fill out a certificate acknowledging receipt, which will also serve as proof that the substances have been disposed of properly.

8. SPECIFIC SAFETY PROCEDURES FOR RADIOGRAPHY

8.1 Work Practices

8.1.1 Radiography cameras must be operated only by certified Radiographers.

8.1.2 As far as possible, field radiography should be carried out during nighttime when there is little or no occupancy around.

8.1.3 Field radiography during daytime may be permitted on a restricted scale when the occupancy around is minimum, e.g., during lunch interval or on holidays.

If field radiography is carried out at the same location repeatedly, it is advisable to provide either wire fencing around or a temporary brick enclosure.

8.1.4 An appropriate area around the radiation source must be cordoned off during field radiography so that the radiation levels outside the area do not exceed the reference radiation levels for members of the public.

8.1.5 The distance to be cordoned off is determined by the type and strength of the radiation source used, the type of exposures given, the nature of occupancy and the total exposure time per week. The appropriate cordon-off distances may be selected from Table 4 of Appendix G, for Iridium 192.

8.1.6 The radiation levels along the cordon must be monitored by a suitable and calibrated radiation survey meter, so as to confirm that the cordon distance is indeed adequate.

8.1.7 Radiation warning symbols must be conspicuously posted along the cordon. Placards displaying the appropriate legend must be posted at the cordon. The placard and the radiation symbol should be readable from a distance of 6 to 7 meters under normal illumination.

8.1.8 Entry into the restricted area by unauthorized persons must be strictly prohibited during exposure.

a) When the radiography work is carried out at nighttime, the radiography site up to the boundary of cordon on all sides must be adequately illuminated throughout the duration of radiography work.

b) Red warning lights must be conspicuously displayed during night along the cordon and especially at the point of entry.

8.1.9 The concerned radiographer must be available at the site very near the cordoned area throughout the exposure.

8.1.10 Wherever practicable, field radiography work should be limited to collimated exposures.

Wherever collimated exposures would suffice but cannot be given with the available equipment, suitably improvised collimators should be used.

8.1.11 During collimated exposures the primary beam should be directed towards areas of minimum occupancy.

8.1.12 All panoramic exposures with the sources of activities greater than 20 Ci of ^{192}Ir, must be carried out using remote control system.

8.1.13 Manipulating devices must be used for handling the sources of activities up to 8 Ci of ^{192}Ir during panoramic exposures. While using X-ray machine, full length of the cable connecting the X-ray tube and control console must be used.

8.1.14 The full length of the manipulator rod should be made use of during panoramic exposures so that maximum possible distance is maintained between the radiation source and the operator.

8.1.15 The source pencil must never be touched or handled directly with hands.

8.1.16 Radiography work at elevated places and at locations where accessibility is restricted or limited should be carried out preferably by remotely operated cameras.

8.1.17 Suitable supporting and fastening devices must be used for hoisting and positioning the radiography cameras/Xray machines in order to avoid mishaps such as accidental fall etc.

8.1.18 The radiography equipment should always be operated by positioning oneself behind the camera/X-ray machine making use of the shielding provided by the body of the equipment.

8.1.19 All operations should be planned in advance and executed in minimum possible time.

8.1.20 The radiography work must be carried out only under the supervision and guidance of the designated authority.

8.1.21 After termination of each exposure, it must be verified by means of a radiation survey meter in proper working condition that the source has indeed returned to its safe position inside the camera.

8.1.22 After completion of each exposure, source pencil must be securely locked in the camera.

8.1.23 Prior to on-site transport of the camera with source from one place to another in a road vehicle/trolley it must be ensured that the source pencil is securely immobilized and locked in the camera. This would avoid any accidental opening of the shutter and falling of source pencil from the camera.

8.1.24 A log book must be maintained at every site to record the following details regarding the use of the source:

a) Date and Time of taking out the camera from the storage.

b) Model and Serial Number of the camera.

c) Nature and Strength of the Source.

d) Name of the Radiographer.

e) Location of use.

f) Type and total number of exposures given.

g) Duration of use.

h) Date and time of return of the source with the camera to the storage.

8.2 Additional Safety Measures in the Use of Teleflex Type Radiography Cameras During Field Radiography

8.2.1 Normal conditions

8.2.1.1 A wide range radiation survey meter must be available at the radiography site.

8.2.1.2 Coupling between the teleflex cable and the source cable and also between the camera and guide tube must be physically verified prior to the operation of the unit. Any sharp bend either in the driving cable or in the guide tube must be avoided in order to facilitate smooth and trouble-free movement of the source through the guide tube.

8.2.1.3 While operating the camera, the operator must make use of the full length of the cable so that maximum distance is always maintained between the operator and the source.

8.2.1.4 The smooth functioning of the driving system must be periodically inspected. Prescribed lubricating agents should be applied at periodic intervals in order to facilitate smooth functioning of the camera. Any defect, however trivial must immediately be attended to. A checklist may be prepared and used for such periodical inspection.

8.2.1.5 The source must never be driven under force. Should there be any obstruction to the smooth movement of the source through the guide tube during operation, the source must be immediately retrieved to the camera, the fault must be investigated and rectified before the radiography work with the camera is carried-out. The radiation survey meter must always be used during such occasions to verify the position and also its proper storage inside the camera. If the source is stuck in the guide tube and cannot be retrieved, radiography work must be suspended, and emergency procedures must be followed.

8.3 Radiation Protection Safety

8.3.1 Safety measures

When designing the installation of radioactive system, the possibility that a fire breaks out must be considered. Flammable substances must not be stored in the proximity of radioactive substances. They should be covered and protected properly, so that a possible spreading of the fire to the radioactive sources will be prevented. It is mandatory to coordinate all preventive measures against fire with the fire authorities. They must be informed about the type, scope and place of application of the radioactive substances used, in order to be prepared in the event of fire. When designing alarm plans, possible special features of the radiometric measuring system have to be mentioned; the safety officer to be notified in the event of an emergency.

8.3.2 Malfunctions and accidents

The Radiation Protection Regulations define malfunction as even which for safety reasons prohibits continuation of the operation of the facility. Malfunctioning means, that a device necessary to guarantee safe operation of the facility, e.g., the seal of the active radiation beam of the shielding, no longer functions properly. An accident is an event, which could expose persons to a radiation dose, which exceeds the permissible limits, or could cause contamination by radioactive substances. In terms of safety, malfunctioning and accidents are very serious events and appropriate steps must be taken immediately to prevent dangers for persons as well as for facilities, or to reduce them as much as possible. It is therefore important that the personnel is aware of preventive measures and is prepared for possible malfunctions of the facilities or accidents, so that dangerous consequences can be avoided as far as possible by a proper reaction of the personnel.

In any case, the safety officer, who checks the situation at site and takes all necessary steps to prevent unnecessary radiation exposure of the personnel, has to be notified immediately. All official authorities listed in the emergency procedure including local supplies shall be informed. The necessary steps should be taken in the following order:

- **a)** Locate the source.
- **b)** Measure the dose rate.
- **c)** Guard and mark the control area.
- **d)** Secure the source and shielding.
- **e)** Check the function and efficiency of the shielding.

f) Record the event and assess possible radiation exposure of the personnel concerned.

In case the source capsule is damaged, the following points have to be considered.

a) Avoid contamination.

b) Handle source with tools (e.g., tweezers) and put both in a plastic bag.

c) Stay behind an auxiliary shielding (e.g. concrete, steel, or lead plate).

d) Check if vicinity is free of contamination.

e) Secure the radioactive waste properly (deposit at designated collection site or return to manufacturer).

9. FIRE, EXPLOSION AND CORROSION

In the evaluation of sealed sources and source-device combinations, the manufacturer and user have to consider the probability of fire, explosion and corrosion and the possible results. Factors, which should be considered in determining the need for actual testing, are:

a) Consequences of loss of activity;

b) quantity of active material contained in the sealed source;

c) radiotoxicity;

d) chemical and physical form of the material and the geometrical shape;

e) environment in which it is used; and

f) protection afforded the sealed source or source-device combination.

10. HEALTH REQUIREMENTS

10.1 Health and safety rules (in conformity with this Standard) should be prepared for the areas in which radioactive material is to be handled.

10.2 All necessary operating instructions should be provided.

10.3 Suitable installation and equipment should be provided.

10.4 Provisions should be made for necessary medical supervision of the personnel and for suitable medical casualty service.

10.5 Only persons medically suitable and adequately trained or experienced should be allowed to work with radioactive material.

10.6 All personnel liable to exposure to ionizing radiation in the course of their work should be instructed about the health hazards involved in their duties.

10.7 Suitable training with reference to health and safety should be provided for all staff.

10.8 A person technically qualified to advise on all points of radiation safety should be available.

10.9 The authority in charge of the installation should consult on all points of radiation safety.

10.10 Procedures should be provided to handle persons who are exposed to radiation hazards.

10.11 Medical Casualty Service

The form of medical casualty service provided will depend on the availability of medical staff within the establishment.

First aid advice and equipment should be immediately available throughout the working area. The scope of first aid, treatment at tepted should be based on medical advice. Arrangements for referring casualties and personnel contamination problems to medical services at an appropriate stage should be clearly defined and known.

10.12 Personnel Monitoring

a) External Radiation Monitoring in which radiation measuring devices are worn by the personnel.

b) Internal Contamination Monitoring in which suitable instruments may be used or the body wastes may be sampled and analyzed, to determine the presence and quantity of radioactive material within the body.

10.13 Area Monitoring

The determination of radiation levels and air contamination in the working area.

a) Measurement by the use of radiation measuring instruments and devices.

b) Calculation based on the amount of radioactive material present, its form and the nature of the processes in which the workers will be exposed.

10.14 Determination by Personnel Monitoring

10.14.1 Monitoring for external radiation exposure with personnel dosimeters

This simple and convenient method should be used for the measurement of external radiation exposure of all personnel in the controlled area. The preferred device is the film dosimeter, which permits measurement of the accumulated radiation dose over a period. This film also provides a permanent means of checking the accumulated external radiation exposure record, which should be kept for each individual. Similar film dosimeters should be used on the hands, wrists or other extremities when these are exposed to higher radiation fields than is the trunk of the body.

Pocket ionization chambers, luminescent individual radiation detectors and thimble chambers supplement the above film dosimeters and are particularly useful where an immediate and sensitive measurement is needed in connection with a specific task. In the use of both film dosimeters and ionization chambers for personnel monitoring, serious errors may occur unless standard procedures are adopted.

11. INSPECTION

11.1 Site Inspection

Trained safety engineer should visit work site or equipment store to perform equipment inspection and overhaul.

11.2 Source projector maintenance service, gamma radiography source projector should be regularly inspected and maintained. The booklet radiation safety for site radiography recommends that this be carried out annually.

A complete inspection shall be made to check for any weakness in moving components or safety interlocks. Any maintenance that is required must be carried out by skill person. Repainting and provision of new labels will be included when appropriate. Certificate should be issued after each inspection and maintenance work is done. An inspection should normally be carried out during a source exchange.

Caution:

Source exchanges must only be carried out by a person who knows the precautions to be taken when working with radiation and is fully informed about the operations he is about to perform. A radiation monitor (dose rate meter) must be used at all times during source movements and particularly after each source movement (for source exchange or routine radiography) to check that the source is fully retracted and is in the fully shielded position.

11.3 Periodic Inspection and Maintenance of Radiography Equipment

The shielding integrity of radiography equipment must be regularly checked once in a month. The cameras and the associated accessories must be inspected periodically and any defect rectified immediately by a person duly authorized for the purpose by the designated authority.

The licensee must not undertake any repairs/modifications to radiographic cameras. However, some minor repairs such as mending hinges of the shutter, the source pencil arrester lock etc. Cameras must not be repaired with the radiography source in it. The source must be unloaded into a temporary source container prior to undertaking the repair. The details of the operational check procedures and radiography camera operation test procedures are given in Appendix H.

Radiography cameras with the source inside must never be taken out of an approved site without obtaining the permission from the concerned authority. However, the source/camera movement is permitted for urgent radiography jobs, provided all the relevant information is transmitted to the Division of Radiological Protection of AEOI simultaneously.

11.4 Service Instructions

When writing up service instruction, which should include the necessary rules of behavior, the following should be taken into consideration:

- Assembly and disassembly (the radiation path of the shielding must remain locked).
- Operations in the immediate proximity of the shielding.
- Ensure that the shutter of the shielding is locked if the vessel on which the source is mounted has to be entered or, with a density gage, removed from the pipe.
- Responsibility for the key of the lock of the shield incontainer.

11.5 Inspection and Testing

11.5.1 All guide tubes, cable connectors and other associated equipment must be inspected before use as described in the equipment Operating and Maintenance Manual.

11.5.2 Direct inspection of the source assembly is not possible (or safe) without specialized equipment. If normal source movements are difficult or impeded,damage can be inferred. Seek further advice from the local radiological protection service.

11.5.3 Leakage tests must be carried out at intervals as specified in local Regulations. A test to BS 5288 on the source itself is not possible unless shielded remote handling facilities are available.

To test for source leakage, the exit port of the projector or storage/transport container should be wipe tested and the result recorded:

source identity

method used

date of test

result (numerical)

pass/fail statement (limits)

reason for test

remedial action if failure

testing organization and signature.

11.5.4 Recommended working life

The "Recommended Working life" (RWL) is the period within which the source should be replaced. The period has been assessed on the basis of such factors as, toxicity of nuclide, total initial activity, source construction, half-life of nuclide, typical application environments, operation service experience and test performance data. Table 6 lists the RWLS for radiography sources.

TABLE 6

NUCLIDE		RWL
Iridium-192 Cobalt-60 Thulium-170 Ytterbium-169	(Portable unit, Fixed installation)	1 Year 15 Years 1 Year 1 Year

The assessment of the RWL is based on the assumption that the source is not used in adverse environments. It is the users responsibility to inspect and test the source regularly in order to assess at what point during the RWL the source should be replaced and sent for disposal.

Advise should be sought regarding the RWL for sources used in adverse environments or for sources that, having completed the RWL, appear satisfactory and, subject to full inspection by a competent laboratory, may be suitable for an extended period of use.

11.6 General Considerations

11.6.1 Explanation of Appendix A and Table 4

11.6.1.1 Classification of radionuclides according to radiotoxicity (Appendix A)

The above Appendix based on Internation commission for Radiation Protection ICRP Publication 5 classifies radionuclides into four Groups according to relative radiotoxicity.

11.6.1.2 Activity level (Appendix B)

This Appendix establishes a maximum activity of sealed sources,for each of the four radiotoxicity Groups in Appendix A below which a separate evaluation of the specific usage and design is not required. Sealed sources containing more than the maximum activity shall be subject to further evaluation of the specific usage and design. The activity level of a sealed source for purposes of classification according to Annex B shall be that at the time of its manufacture.

Appendix B also defines the physical, chemical and geometrical forms of the radionuclide used to determine these properties; they shall be the same as the physical, chemical and geometrical forms of the radioactive material within the sealed source.

11.6.1.3 Sealed source performance requirements for typical usage (Appendix C)

Appendix C is a list of some typical applications in which a sealed source or source-device will be used, together with an estimate of their minimum performance requirements.

This estimate takes into account normal usage and reasonable accidental risks but does not include exposure to fire or explosion. For sealed sources normally mounted in devices, consideration was given to the additional protection afforded the sealed source by the device when the Class number for a particular usage was assigned. Thus, for all usages shown in Appendix C, the Class numbers specify the tests to which the sealed source shall be subjected, except that for the category ion generators, the complete source-device combination may be tested.

Obviously, Appendix C does not cover all sealed source usage situations. If the particular usage or accidental risks are likely to differ from the values suggested in the estimate, or if the sealed source usage is not shown, the specifications of the sealed source shall be considered on an individual basis by the supplier, the user, and the regulating authority. The numbers shown in Appendix C refer to the Class numbers used in Table 4.

Attention is called to the International Atomic Energy Agency tests for special form radioactive material. These are not of general application but may be relevant when formulating special tests.

12. OPERATIONAL CHECK PROCEDURE FOR CAMERAS

See Appendix H.

13. X-RAY LEAD RUBBER PROTECTIVE APRON

13.1 This Section of Standard Apply to X-Ray Lead-Rubber Protective Aprons with or without back panel, used by personnel during medical X-Ray diagnostic examination with X-Ray Generated and voltage up to 150 Kev peak and intended to give to the body of the operator or patient a measure of protection against scattered radiation.

13.2 The aprons shall be designed to give the minimum protective value specified by the purchaser and in no case less than 0.25 mm lead equivalent for X-rays generated at a voltage of 150 kV peak. All joints or seams in the apron shall offer at least the same protection.

13.3 The protective material shall be either natural or synthetic rubber compound incorporating lead or a compound of lead. It shall comply with the test requirements specified in Clause 6.10, and together with its attached waterproof fabric shall be freely flexible.

13.4 The apron shall consist of an X-ray protective layer or layers covered on all exposed surfaces by a water proof fabric integral with the protective layer. The edges shall be protected by binding, and the binding shall be of such a nature as to remain flexible during the life of the apron.

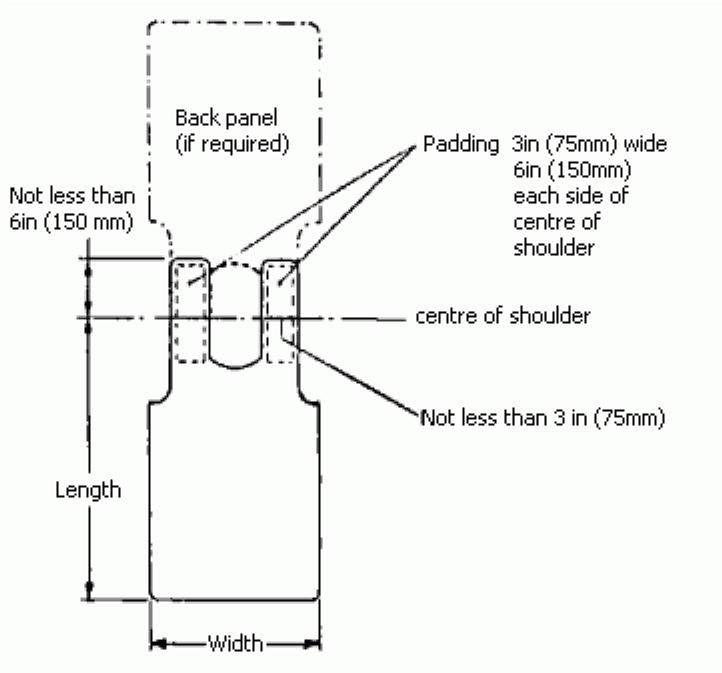
The fixings used for the supporting harness, and for attaching the back panel to the shoulder pieces, shall not reduce the life of the apron under normal conditions of use.

The apron shall be so designed that the width of the protective material on each shoulder should not be less than (76 mm), and the shoulder pieces shall extend over the back of the shoulder by not less than 152 mm as in sketch (1). When specified by the Purchaser, the shoulder pieces shall incorporate a suitably covered padding of soft resilient material 3 inches (76 mm) wide and extending a distance of 6 inches (152 mm) on either side of the center of the shoulder.

Note:

Urethane foam, 25 mm thick when uncompressed and of a density of 27 to 30 kg/m3 is one suitable material.

SIZE DESIGNATION	LENGTH (MEASURED FROM THE CENTER OF THE SHOULDER)	WIDTH
33 inch	33 ± ¼ in (83.8 ± 0.6 cm)	24 ± ¼ in (61 ± 0.6 cm)
36 inch	36 ± ¼ in (91.4 ± 0.6 cm)	24 ± ¼ in (61 ± 0.6 cm)
38 inch	38 ± ¼ in (96.5 ± 0.6 cm)	24 ± ¼ in (61 ± 0.6 cm)



SKETCH (1) GENERAL DIMENSIONS OF X-RAY PROTECTIVE APRONS

Note:
This illustration is diagrammatic only; it is given to define the essential dimensions but is not intended to indicate details of design.

APPENDICES

APPENDIX A

CLASSIFICATION OF RADIONUCLIDES ACCORDING TO RADIOTOXICITY (BASED ON ICRP PUBLICATION 5)

High toxicity

Group A

^{227}Ac	^{242}Cm	^{231}Pa	^{241}Pu	^{228}Th
^{241}Am	^{243}Cm	^{210}Pb	^{242}Pu	^{230}Th
^{243}Am	^{244}Cm	^{210}Po	^{223}Ra	^{230}U
^{249}Cf	^{245}Cm	^{238}Pu	^{226}Ra	^{232}U
^{250}Cf	^{246}Cm	^{239}Pu	^{228}Ra	^{233}U
^{252}Cf	^{237}Np	^{240}Pu	^{227}Th	^{234}U

Medium toxicity

Group B1

^{228}Ac	^{36}Cl	^{125}I	^{212}Pb	^{160}Tb
^{110m}Ag	^{56}Co	^{126}I	^{224}Ra	^{127m}Te
^{211}At	^{60}Co	^{131}I	^{106}Ru	^{129m}Te
^{140}Ba	^{134}Cs	^{133}I	^{124}Sb	^{234}Th
^{207}Bi	^{137}Cs	^{114m}In	^{125}Sb	^{204}Tl
^{210}Bi	^{152} (13y)Eu	^{192}Ir	^{46}Sc	^{170}Tm
^{249}Bk	^{154}Eu	^{54}Mn	^{89}Sr	^{236}U
^{45}Ca	^{181}Hf	^{22}Na	^{90}Sr*	^{91}Y
^{115m}Cd	^{124}I	^{230}Pa	^{182}Ta	^{95}Zr
^{144}Ce				

Group B2

^{105}Ag	^{64}Cu	^{43}K	^{143}Pr	^{97}Tc
^{111}Ag	^{165}Dy	^{85m}Kr	^{191}Pt	^{97m}Tc
^{41}Ar	^{166}Dy	^{87}Kr	^{193}Pt	^{99}Tc
^{73}As	^{169}Er	^{140}La	^{197}Pt	^{125m}Te
^{74}As	^{171}Er	^{177}Lu	^{86}Rb	^{127}Te
^{76}As	^{152} (9.2h)Eu	^{52}Mn	^{183}Re	^{129}Te
^{77}As	^{155}Eu	^{56}Mn	^{186}Re	^{131m}Te
^{196}Au	^{18}F	^{99}Mo	^{188}Re	^{132}Te
^{198}Au	^{52}Fe	^{24}Na	^{105}Rh	^{231}Th
^{199}Au	^{55}Fe	^{93m}Nb	^{220}Rn	^{200}Tl
^{131}Ba	^{59}Fe	^{95}Nb	^{222}Rn	^{201}Tl
^{7}Be	^{67}Ga	^{147}Nd	^{97}Ru	^{202}Tl
^{206}Bi	^{72}Ga	^{149}Nd	^{103}Ru	^{171}Tm
^{212}Bi	^{153}Gd	^{63}Ni	^{105}Ru	^{48}V
^{82}Br	^{159}Gd	^{65}Ni	^{35}S	^{181}W
^{14}C	^{197}Hg	^{239}Np	^{122}Sb	^{185}W
^{47}Ca	^{197m}Hg	^{185}Os	^{47}Sc	^{187}W
^{109}Cd	^{203}Hg	^{191}Os	^{48}Sc	^{135}Xe
^{115}Cd	^{166}Ho	^{193}Os	^{75}Se	^{87}Y
^{141}Ce	^{130}I	^{32}P	^{31}Si	^{90}Y
^{143}Ce	^{132}I	^{233}Pa	^{151}Sm	^{92}Y
^{38}Cl	^{134}I	^{203}Pb	^{153}Sm	^{93}Y
^{57}Co	^{135}I	^{103}Pd	^{113}Sn	^{175}Yb
^{58}Co	^{115m}In	^{109}Pd	^{125}Sn	^{65}Zn
^{51}Cr	^{190}Ir	^{147}Pm	^{85}Sr	^{69m}Zn
^{131}Cs	^{194}Ir	^{149}Pm	^{91}Sr	^{97}Zr
^{136}Cs	^{42}K	^{142}Pr	^{96}Tc	

^{*90}Sr has been re-allocated from Group A to Group B1 in accordance with the recommendations of ICRP Publications 5 and 6. **(to be continued)**

APPENDIX A - (continued)

Low toxicity

Group C

^{37}Ar
^{58m}Co
^{134m}Cs
^{135}Cs
^{71}Ge
^{3}H
^{129}I
^{111m}In
^{113m}In
^{85}Kr
^{97}Nb
^{59}Ni
^{15}O
^{191m}Os
^{193m}Pt
^{197m}Pt
^{87}Rb
^{187}Re
^{103m}Rh
^{147}Sm
^{85m}Sr
^{96m}Tc
^{99m}Tc
^{232}Th
Th (natural)
^{235}U
^{238}U
U (natural)
^{131m}Xe
^{133}Xe
^{91m}Y
^{69}Zn
^{93}Zr

Note:

The nuclides ^{125}I, ^{67}Ga, ^{87}Y, ^{111}In have been included although they are not in ICRP Publication 5.

APPENDIX B

ACTIVITY LEVEL

RADIONUCLIDE GROUP (FROM ANNEX A)	MAXIMUM ACTIVITY, TBq (Ci)	
	LEACHABLE [1] AND/OR HIGHLY REACTIVE [3]	NON-LEACHABLE [2] AND NOT HIGHLY REACTIVE [4]
A	0,01 (about 0,31)	0,1 (about 3)
B1	1 (about 30)	10 (about 300)
B2	10 (about 300)	100 (about 3000)
C	20 (about 500)	200 (about 5000)

Notes:

1) Leachable-greater than 0.01% of the total activity in 100 ml in still H_2O at 20°C in 48 hrs

2) Non-leachable-less than 0.01% of the total activity in 100 ml in still H_2O at 20°C in 48 hrs.

3) Highly reactive-highly reactive in ordinary atmosphere or water (metallic, Na, K, U and Cs, etc.).

4) Not highly reactive-not highly reactive in ordinary atmosphere or water (Au, Ir, ceramics, etc.).

APPENDIX C

SEALED SOURCE PERFORMANCE REQUIREMENTS FOR TYPICAL USAGE

Sealed Source Usage		Sealed Source Test & Class				
		Temperature	Pressure	Impact	Vibration	Puncture
Radiography – Industrial	Unprotected source	4	3	5	1	5
	Source in device	4	3	3	1	3
Medical	Radiography	3	2	3	1	2
	Gamma teletherapy	5	3	5	2	4
	Interstitial & interacavitary appliances [1)]	5	3	2	1	1
	Surface applicators	4	3	3	1	2
Gamma gauges (medium & high energy)	Unprotected source	4	3	3	3	3
	Source in device	4	3	2	3	2
Beta gauges & sources for low-energy gamma gauges or X-ray fluorescence analysis (excluding gas-filled sources)		3	3	2	2	2
Oil-well logging		5	6	5	2	2
Portable moisture & density gauge (including hand-held or dolly-transported)		4	3	3	3	3
General neutron source application (excluding reactor start-up)		4	3	3	2	3
Calibration sources - Activity greater than 1 MBq		2	2	2	1	2
Gamma irradiation sources	Unprotected source	4	3	4	2	4
	Source in device	4	3	3	2	3
Ion generators [2)]	Chromatography	3	2	2	1	1
	Static eliminators	2	2	2	2	2
	Smoke detectors	3	2	2	2	2

Notes:

1) Sources of this nature may be subject to severe deformation in use. Manufacturers and users may wish to formulate additional or special test procedures.

2) Source-device combination may be tested.

APPENDIX D

EXAMPLE OF CERTIFICATE FOR A SEALED SOURCE

[1] Manufacture's Name .... Certificate No.
and address ....

CERTIFICATE FOR SEALED RADIOACTIVE SOURCE

[1] Serial No...............
[1] ISO Classification Designated by Code No. ....
1) Radionuclide …………………........Mass Number and Chemical Symbol ....
Target Element (Applicable for Neutron Sources)
Equivalent activity[2] (Ci ±%) ....Measured on .... (Date)
and/or
[1] Radiation output (Fluence rate ±%) ....Measured on .... (Date)
of Specified kind of radiation
Actual/Maximum percentage of
Other radionuclides ....% Activity on ....(Date)
% Activity on .... (Date)
% Activity on... (Date)

Active contents:
Chemical and physical form [3] …..
Mass/Volume .... Dimensions...

Capsule:
Dimensions .... Minimum Thickness [4] ....
Material of construction …………………......... Method of Sealing ....
Number of encapsulations ....

[1] Freedom from surface contamination:
Method of test .... Date of test ....
Result of test ....

[1] Freedom from leakage:
Method of test .... Date of test ....
Result of test ....
We certify that this sealed source complies with the requirements of [ISO 1677 or relevant national standard] and that the above information is correct.
[5] We declare that we hold capsule approval certificate No. …..
in respect of this sealed source, issued on .... by ....
Date .... Signature ....

Notes:

1) Mandatory information.

2) See ICRU Report 10 c, Radioactivity (NBS Handbook 86).

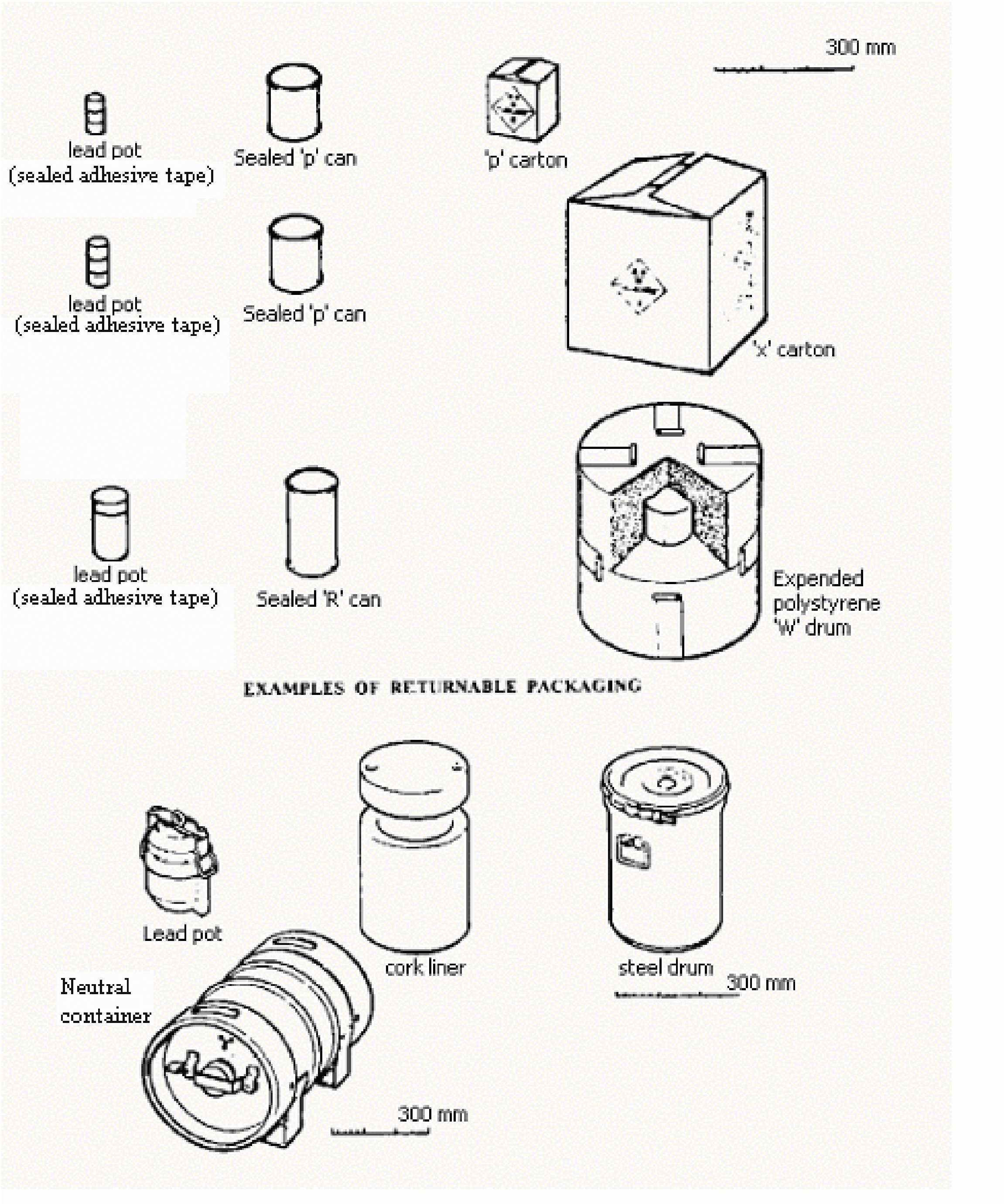
3) For example solid (metal, glass, ceramics powder), liquid, gas, etc.

4) Normally, this will be the thickness of the emitting surface (window).

5) This applies only to radioactive material in special form in accordance with the IAEA Publication Safety Series No. 6, regulations for the safe transport of radioactive materials, current edition.

APPENDIX E

EXAMPLES OF NON-RETURNABLE PACKAGING



APPENDIX F

STEEL THICKNESSES WHICH CAN BE RADIOGRAPHED WITH DIFFERENT ENERGIES OF X-RAY AND GAMMA RADIATION

X-RAY ENERGY	STEEL THICKNESS RANGE
Below 100 kV	Below 6 mm
110 kV	7 mm - 9 mm
130 kV	9 mm - 15 mm
160 kV	16 mm - 21 mm
200 kV	22 mm - 38 mm
400 kV	39 mm - 65 mm

GAMMA RADIATION

192 Ir	10 mm - 65 mm
137 Cs	15 mm - 100 mm
60 Co	50 mm - 150 mm

APPENDIX G

CALCULATION OF THE CORDON-OFF DISTANCE

The distances of cordon in a radiography site may be obtained from Table 4 of Appendix G. However, for combination of source strength and work load not specified in the table, the distance could be calculated as explained below:

Let the strength of the ^{192}Ir source be A Ci. The RHM value is 0.5 (Table 2) Appendix G. The radiation level at 1 m from the source = 0.5 A R/hour Let the period of operation be H hours/week.

The work load = W = 0.5 × A × H R/week at 1 m.

Let the occupancy factor around the site be T.

The proposed cordon distance = d in meters (m).

The radiation level along the cordon = $\frac{WT}{d^2}$ R/week.

The authorized (prescribed) radiation level along the cordon (= P) R/week.

Now the value of d should be such that:

$$P = \frac{WT}{d^2}$$

$$d = \left(\frac{WT}{P}\right)^{\frac{1}{2}} = \left(-\frac{0.5\ AHF}{P}\right)^{\frac{1}{2}}$$

Example 1:

An ^{192}Ir source of strength 8 Ci is to be operated for 10 hours/week Calculate the distance to be cordoned around the source if there is office area beyond the proposed cordon and non-occupational workers are present there.

Solution:

W = 8 × 0.5 × 10 R/week at 1 m.

T = 1

p = 0.01 R/week

$$d = \left(\frac{WT}{P}\right)^{\pm\frac{1}{2}}$$

= (40 × 100)½«

= 64 m (approximately)

Please check the Table 4.

Against 8 Ci for full occupancy corresponding to a work load of 10 hours/week, d = 65 m.

Example 2:

An ^{192}Ir source of strength 6 Ci, is to be operated for 12 hours/week. Calculate the distance to be cordoned around the source if there is open area beyond the proposed cordon, with occasional occupancy.

(to be continued)

APPENDIX G (continued)

Solution:

W = 6 × 0.5 × 12 R/week at 1 m

T = 1/16

p = 0.01 R/week

$$d = \left(\frac{WT}{P}\right)^{\pm\frac{1}{2}}$$

= (36 × 1/16 × 1/0.01)½

= 15 m.

Note:

In a given situation, the actual strength of the source and the period of operation may not correspond to the specific values given in Table 4, and yet this Table could be used if the quantity Ci-hours/week is obtained. In Example 2, above, this quantity was 6 × 12 = 72 Ci-hours/week. While T = 1/16. In the table for 5 Ci against a period of operation of 15 hours/week, we have 75 Ci-hours/week for which the cordon distance corresponding to T = 1/16 may be read as 17 m. This may be compared with the value of 15 m obtained in the Example 2.

DATA FOR SHIELDING AND CORDON-OFF DISTANCE CALCULATIONS

The data required for calculations of shielding and cordon-off distances are given in the following Table:

VALUES FOR OCCUPANCY FACTOR

PLACE	OCCUPANCY FACTOR T
Office/control room	1
Corridor, stair case	1/4
Open space	1/16
Above ceiling with no occupancy normally occasional occupancy	1/64
Storage room for unexposed radiography films	1

(to be continued)

APPENDIX G (continued)

PHYSICAL CHARACTERISTICS OF RADIATIONS SOURCES

NUCLIDE	PHOTON ENERGY (mev)	PROBABILITY OF EMISSION (%)	PHYSICAL HALF-LIFE	RHM (R HR AT 1 m FROM 1 Ci)
60_{CO}	1.17 1.33	100 100	5.27	1.3
137_{CS}	0.66	81	30 y	0.32
192_{Ir}	0.296-0.613	-	74.5 d	0.5
170_{Tm}	0.84 IC	3.3 19	127 d	0.0025
169_{Yb}	0.049-0.59 (thuliumk X-ray) 0.063 0.11 0.131 0.177 0.198 0.261 0.308	180 43.9 17.6 11.2 21.5 35.1 7 10.8	30 d	0.12

DATA ON HALF VALUE LAYER (HVL) AND TENTH VALUE LAYER (TVL) IN SHIELDING MATERIALS FOR BROAD BEAMS

NUCLIDE	THICKNESS IN cm							
	Concrete (2.35g/cc)		Steel		Lead		Depleted Uranium	
	HVL	TVL	HVL	TVL	HVL	TVL	HVL	TVL
^{60}CO	6.1	20.3	2.0	6.7	1.2	4.0	0.7	2.2
^{137}CS	4.9	16.3	1.5	5.0	0.7	2.2	0.4	1.2
^{192}Ir	4.1	13.5	1.3	4.3	0.6	1.9	0.3	1.1
X-rays (6 Mv)	10.2	33.8	-	10	1.54	5.1	-	3.5

(to be continued)

APPENDIX G (continued)

CORDON-OFF DISTANCES FOR OPEN FIELD RADIOGRAPHY (PANORAMIC EXPOSURE) Iridium-192

SOURCE	NATURE OF OCCUPANCY	5 hrs/wk	10 hrs/wk	WORK LOAD 15 hrs/wk CORDON OFF	20 hrs/wk distance (m)	30 hrs/wk
5 Ci	Full	37	52	66	74	93
	Partial	18	26	33	36	47
	Occasional	10	13	17	18	24
8 Ci	Full	47	65	80	94	122
	Partial	24	33	40	48	56
	Occasional	12	16	20	24	28
10 Ci	Full	53	74	90	100	126
	Partial	26	37	45	52	63
	Occasional	13	19	22	26	31

Note:

During collimated exposures the above cordon-off distances should be maintained in the direction of primary beam. The rest of the area should be cordoned at least up to a distance of 10 meters.

APPENDIX H

OPERATIONAL CHECK PROCEDURE (TECH/OPS)

(TO BE DONE PREFERABLY WITH A DUMMY PIGTAIL)

INSULATION:

1) Camera number	PRESENT/NOT PRESENT
2) Radiation symbol plate	PRESENT/NOT PRESENT
3) Shipping plug and its threading	PROPER/DEFECTIVE
4) Storage cover	PROPER/DEFECTIVE/NOT AVAILABLE
5) Locking device in locked condition:	
a) Key removal	POSSIBLE/NOT POSSIBLE
b) Selector ring rotation	POSSIBLE/NOT POSSIBLE
c) Pigtail projection	POSSIBLE/NOT POSSIBLE
6) Storage cover in position. Unlock. Selector ring can be turned only towards "CONNECT" position	YES/NO
7) Selector ring in "CONNECT" position:	
a) Dummy-source	PRESENT/NOT PRESENT
b) Dummy source held firmly	YES/NO
8) Drive cable and control device	PROPER/DEFECTIVE
9) Guide tubes	PROPER/DEFECTIVE
10) **a)** Couple drive cable to dummy source. Push connector collar into selection device. Turn selector ring to "OPERATE" position. Remove shipping plug. **b)** Drive out dummy source. Replace it with dummy pigtail. Retract. Put back the shipping plug. Decouple drive cable. Without coupling the drive cable to the pigtail is it possible to push the connector collar in and turn the selector ring? (During this check, do not remove the shipping plug. If the drive cable is drawn back without the pigtail, there would be problem).	YES/NO
11) Connection of guide tube assembly to source housing.	PROPER/DEFECTIVE
12) Repeat 10(a) with pigtail. Drive pigtail through guide tube assembly back and forth a few times. Operations.	SMOOTH & PROPER/DEFECTIVE
13) Control device operation	PROPER/DEFECTIVE
14) Operation of selector ring, when pigtail is in the exposed condition.	POSSIBLE/NOT POSSIBLE

Any other points. Checked on by

(to be continued)

APPENDIX H - (continued)

OPERATIONAL CHECK PROCEDURE

(TELETRON/GAMMAVOLT)

INSTITUTION:

1) Camera number	(see at the bottom)
2) Radiation symbol plate	PRESENT/NOT PRESENT
3) In locked condition operation of shutter knob	POSSIBLE/NOT POSSIBLE
4) Lock released-Guide tube not connected. Operation of shutter knob.	POSSIBLE/NOT POSSIBLE
5) Key removal in locked condition.	POSSIBLE/NOT POSSIBLE
6) Guide tube condition.	PROPER/DEFECTIVE
7) Lock released. Guide tube connected:	
a) Guide tube coupling	PROPER/DEFECTIVE
b) Operation of shutter knob.	PROPER/DEFECTIVE
8) Operation of safety flap and ring.	PROPER/DEFECTIVE
9) Operation of safety catch.	PROPER/DEFECTIVE
10) Coupling between the drive cable and the source pencil (Coupling should be possible when the angle between them is near 90).	PROPER/DEFECTIVE
11) Drive cable and control box.	PROPER/DEFECTIVE
12) Drive cable operation	PROPER/DEFECTIVE
13) Movement of Source pencil:	
a) Inside camera	PROPER/DEFECTIVE
b) Inside guide tube any other points.	

Checked on by

(to be continued)

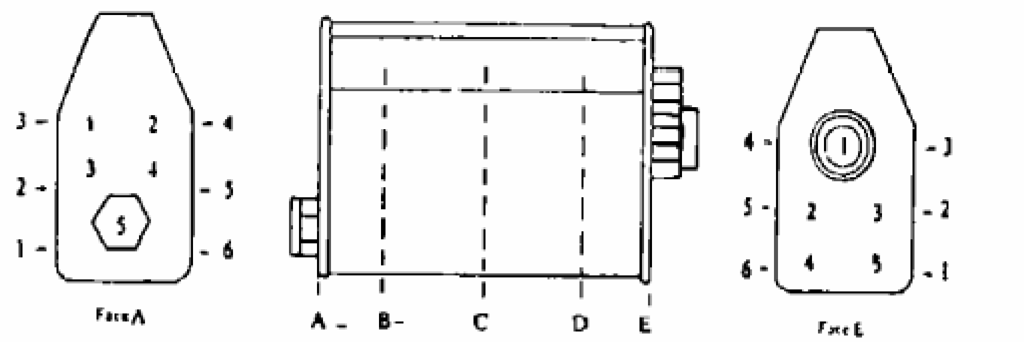
APPENDIX H - (continued)

TEST PER PORT ON TECHOPS CAMERA

INSTITUTION

ACTIVITY Ci:Ir-192 ON

TESTED ON BY



At 5cm FROM SURFACE

MONITOR USED

	mr/hr				
	A	B	C	D	E
1					
2					
3					
4					
5					
6					
OTHER POINTS					

	mr/hr	
	5 cm from surface	1 cm from surface
Avg.		
Max		

REMARKS

(to be continued)

APPENDIX H - (continued)

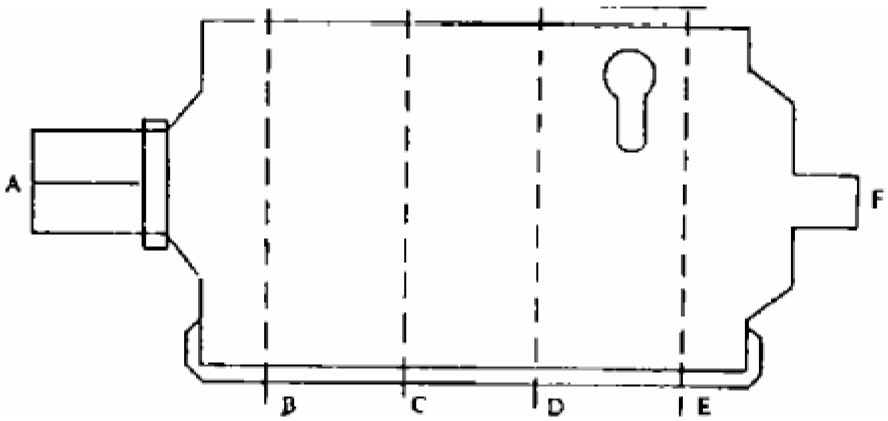
SU -

TEST PER PORT ON TECHOPS CAMERA

INSTITUTION

ACTIVITY Ci:Ir-192 ON

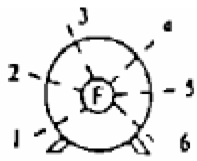
TESTED ON BY



5 cm FROM CENTER

	mr/hr			
	B	C	D	E
1				
2				
3				
4				
5				
6				
	A-		F-	
OTHER POINTS				

MONITOR USED



	mr/hr	
	5 cm from surface	1 cm from surface
Avg.		
Max		

REMARKS

APPENDIX I

TECHNICAL INFORMATION

SPECIFICATION

The strength of a radiation source may be specified either by its radiation output or by stating the radioactivity of its contents. For most applications the user is mainly interested in the source's radiation output, and requires information about content only for licensing or commercial reasons. For many sources the radiation output is not simply related to the activity content because factors such as self absorption, and attenuation by the capsule cause a non-isotropic output distribution. For this reason the radiation output in given direction, using the most appropriate method and do not rely on an estimate of the amount of radioactive material in the source.

A real source emits anisotropically, so it is necessary to specify the direction in which a measurement has been made, as well as the distance from the source. The distance taken from the center of the source and the direction is normally radial for cylindrical sources and axial for disc sources.

The relationship between equivalent activity and exposure rate is different for each radionuclide, depending on the type and quantity of radiation emitted in each nuclear transformation.

The accepted values for the most commonly used high energy gammaemitting nuclides are given in the table below. In the SI system, source strengths may be expressed in terms of air kerma rate at 1 meter in grays per hour. The equivalence between the old units and the new is shown below.

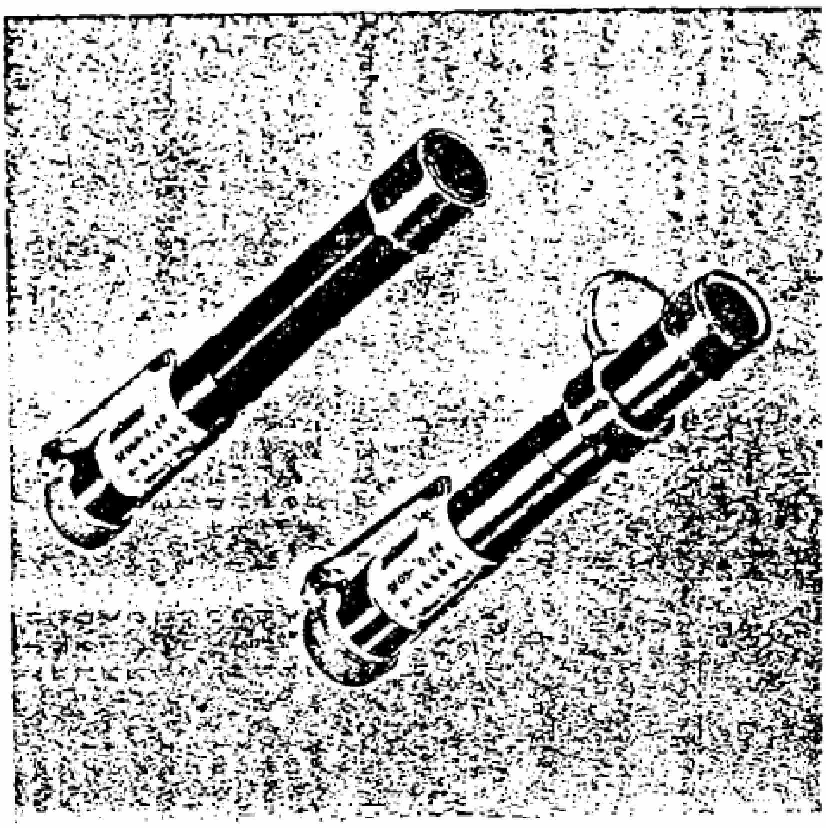
NUCLIDE	EQUIVALENT ACTIVITY	EXPOSURE RATE AT 1 METER	AIR KERMA RATE (K) IN AIR AT 1 METER (APPROX.)
137_{Cs} 60_{CO}	1 Ci 1 Ci	0.32 R/h 1.30 R/h	2.9 mGy/h 11 mGy/h

Where the source strengths are expressed in content activity, the curie values are given first with the becquerel values quoted alongside.

In cases where the sources strengths are expressed in terms of equivalent activity, the curie values are given first with the air kerma rate at 1 meter quoted alongside. The output of sources is sometimes expressed in terms of photons per second per steradian where this is appropriate for the application. The following SI Units have been recommended for radioactivity and absorbed dose.

PHYSICAL QUANTITY	SI UNIT	TRADITIONAL UNIT	RELATIONSHIP
Radioactivity	**Becquerel (Bq)**	**Curie (C)**	**1 Ci = 3.7 × 10^{10} Bq** **1 Bq = 2.70 × 10^{-11} Ci**
Absorbed Dose	**Gray (Gy)**	**Rad**	**1 rad = 0.01 Gy** **1 Gy = 100 Rad**
1 Bq= 1 nuclear transformation per second **Conversion factors:** **1 kCi = 3.7 × 10^{13} Bq = 37 terabecquerels (TBq)** **1 Ci = 3.7 × 10^{10} Bq = 37 gigabecquerels (GBq)** **1 mCi = 3.7 × 10^{7} Bq = 37 megabecquerels (MBq)** **1 μCi = 3.7 × 10^{4} Bq = 37 kilobecquerels (KBq)**			

FIGURES



PERSONAL DOSIMETER FOR RADIATION PROTECTION

Fig. 1

*** Ten indicating ranges, from 0.1 R to 200 R.**

*** Energy range can be:**

40 keV to 3 MeV

18 keV to 3 MeV.

*** Should be low self-discharge and vacuum-sealed metal-glass fusion.**

*** Rugged and drop-proof construction.**

TECHNICAL DATA

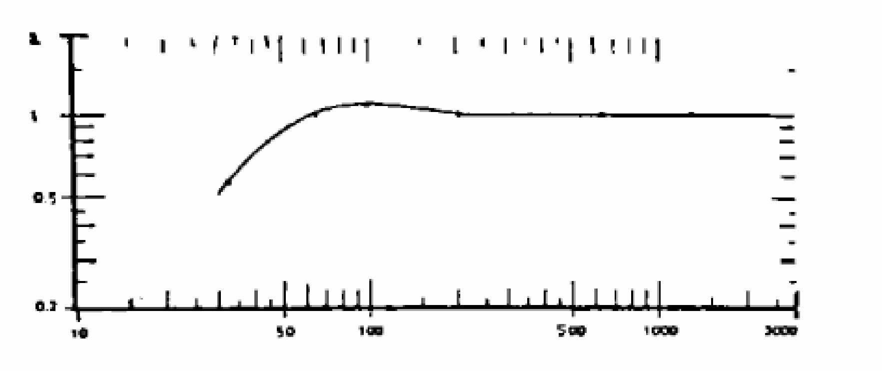
RADIATION DETECTOR	IONIZATION CHAMBER					
MEASURED VARIABL	STANDARD ION DOSE					
INDICATING RANGE	UP TO 200 R	- 0.1	R	RANGE 0-100	mR	(1 mSV)
		- 0.2	R	RANGE 0-200	mR	(2 mSV)
		- 0.5	R	RANGE 0-500	mR	(5 mSV)
		- 1	R	RANGE 0- 1	R	(10 mSV)
		- 5	R	RANGE 0- 5	R	(50 mSV)
		- 50	R	RANGE 0- 50	R	(500 mSV)
		- 200	R	RANGE 0-200	R	(2 mSV)
INDICATING RANGE UP TO 5 R		- 0.1	R	RANGE 0-100	mR	(1 mSV)
(CLASS II)		- 0.2	R	RANGE 0-200	mR	(2 mSV)
		- 0.5	R	RANGE 0-500	mR	(5 mSV)
		- 1	R	RANGE 0- 1	R	(40 mSV)
		- 5	R	RANGE 0- 5	R	(50 mSV)

ENERGY DEPENDENCE	RATED RANGE FROM 40 KV TO 3 mV (Fig. 1) RATED RANGE FROM 18 KV TO 3 mV (Fig. 2)	
REFERENCE POINT	PRESET MARKING RING (Fig. 3)	
PREFERRED DIRECTION	PERPENDICULAR TO DOSIMETER AXIS	
DIRECTIVITY	LESS THAN ±20% IN RANGE OF ±45% OF PREFERRED DIRECTION (Fig.)	
RELATIVE BETA DOSE INDICATION UP TO 5 R. WITH REFERENCE TO AZ 0.2 mm THICK LIF DOSI-METER	RADIATOR	RELATIVE DOSE INDICATION
	Ru 106/Rh 106	69%
	Sr 90/Y 90	37%
TEMPERATURE RANGE	- 20°C TO +60°C	
TEMPERATURE RANGE OF MEASURED VALUE	LESS THAN +5%	
EXTERNAL AIR PRESSURE	RATED RANGE 100 mbar TO 1300 mbar	
PRESSURE DEPENDENCE	LESS THAN ±5%	
HUMIDITY RANGE	0 TO 100 % RELATIVE HUMIDITY	
OPERATING POSITION	RATED RANGE ARBITRARY. READING ERROR LESS THAN ±5%	
SELF-DISCHARGE	LESS THAN 0.2% OF UPPER SCALE VALUE IN 24 h.	
PERSISTENCE OF SELF-DISCHARGE AFTER EX-POSURE TO 10 TIMES THE DOES OF THE UP-PER SCALE VALUE	1) DOSIMETER WITH MEASURING RANGES UP TO 5 R: AFTER 3 h < 2%. 2) DOSIMETER WITH MEASURING RANGES ABOVE 5 R: AFTER 7 h < 2%.	
CHARGING VOLTAGE	MAX. 195 V	
DIMENSIONS	LENGTH : SEE Fig. DIAMETER : 14 mm	
WEIGHT	APPROX. 25 g	

ROD-TYPE DOSIMETERS

The rod-type dosimeters are measuring instruments for determination of the standard ion dose of X-ray and gamma radiation and for evidence of beta radiation. Although primarily intended for determination of personal dose, they can also be used as local dosimeters.

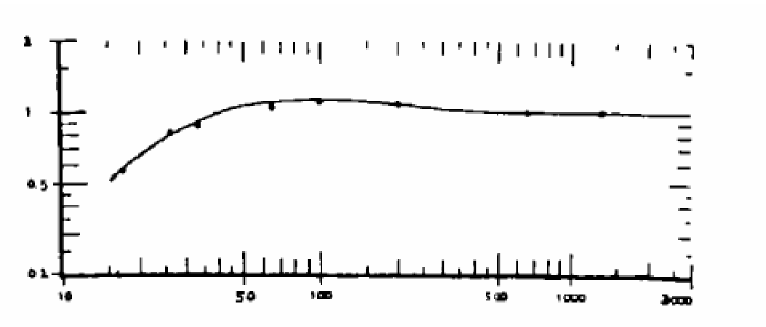
Up to 200 R dosimeters can be used in the energy range of 40 kV to mV. With an energy range from 18 keV to 3 mV, also detects very weak X-rays, thus enabling the use of these dosimeters for the protection of personnel working with X-rays (40 of the "Rontgenverordnung" -X-ray regulations).



$$\frac{\text{Indicated measured value}}{\text{Correct measured value}}$$

ENERGY DEPENDENCE CLASS I WITH REFERENCE TO Cs 137

Fig. 2



$$\frac{\text{Indicated measured value}}{\text{Correct measured value}}$$

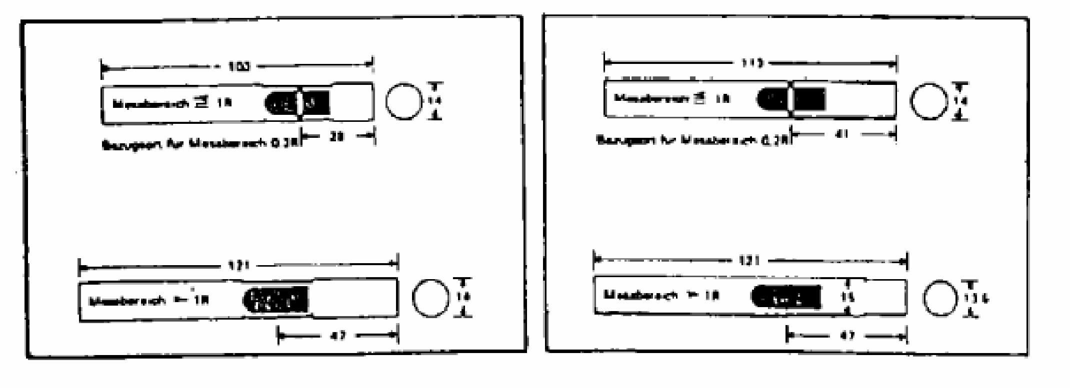
ENERGY DEPENDENCE CLASS II WITH REFERENCE TO Cs 137

Fig. 3

An ionization chamber serves as the radiation detector of the dosimeter, it must be charged to a specific voltage before commencing use. If the charged dosimeter is exposed to ionizing radiation, the ionization chamber will discharge itself to some extent. The voltage loss in this case is a measure for the total radiation dose accepted. The ionization chamber voltage is determined by a quarz-filament electrometer, the filament position of which can be directly read from a scale calibrated in roentgen.

In order to read, the upper end of the dosimeter is held directly in front of the eye and the lower end is aimed at a sufficient light source, e.g., daylight. The scale then appears, magnified by a lens, in the viewer and can be easily read.

CLASS I **CLASS II**

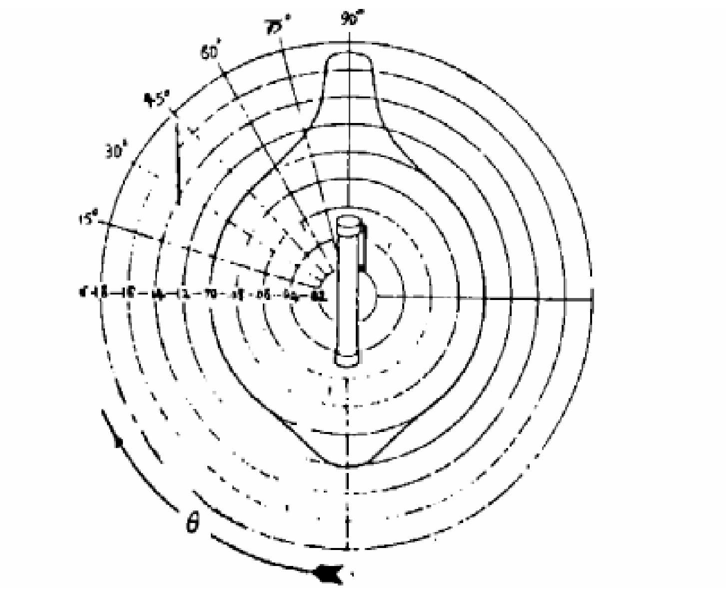


REFERENCE POINT OF DOSIMETERS SEQ 5 AND SEQ 6 R

Fig. 4

The connection for charging the dosimeter should complies with standard DIN 44 425. Any charging device that conforms to this Standard can therefore be used for charging.

In addition to DIN 44 425, the dosimeters should satisfy standard DIN 6818, Part 2, meaning that they can also be used for all corresponding problems within the scope of legal requirements for radiation protection.

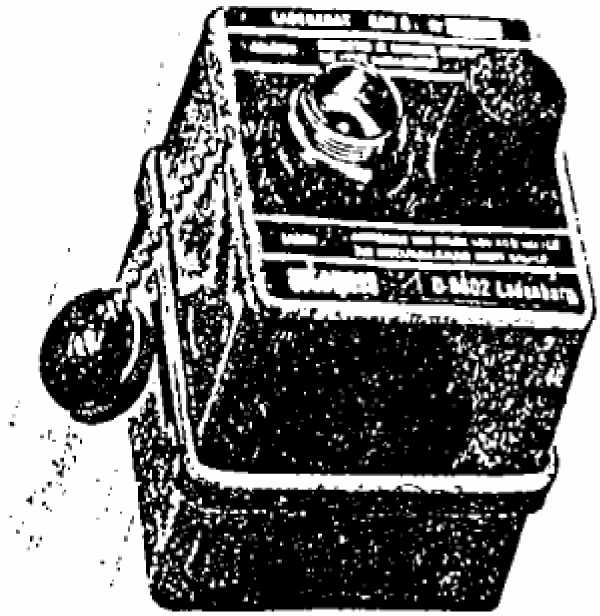


Dependence of the ratio of correct measured value to indicated measured value on the direction of incident radiation 0 for dosimeter class I in the case of Cs 137 Gamma radiation.

CHARGING UNIT

The battery-operated charging unit to standard DIN 44 425, it can therefore be used for charging dosimeters Class II and all other dosimeters conforming to standard. In order to charge the dosimeter, the protective cap is removed and the lower end is inserted in the charging receptacle of the charging unit and lightly depressed. This causes the charging unit to switch on, the dosimeter is illuminated and the scale can be observed.

The dosimeter should now be more forcefully depressed in order to connect the charging circuit of the ionization chamber to the charging voltage. At this time, the dosimeter filament can be set to zero by means of the regulator knob of the charging unit.



CHARGING UNIT

Fig. 5

CHARGING UNIT TECHNICAL DATA

Power supply	2 "C" batteries 1.5 V (R6 DIN 40863)
Adjustable range of charging voltage	100 V to 240 V
Dimensions	90 × 70 × 70 mm
Weight	approx. 280 g

TEST DEVICE 652.1

Capacity	max. 8 dosimeters
Dose rate	approx. 5 mR/h for Class I - 0.2 R approx. 4.5 mR/h for Class II- 0.2 R
Height	5.5 cm
Diameter	7.5 cm
Weight	1.2 kg
Radiation source	9.9 µCi Cs 137, with shield container

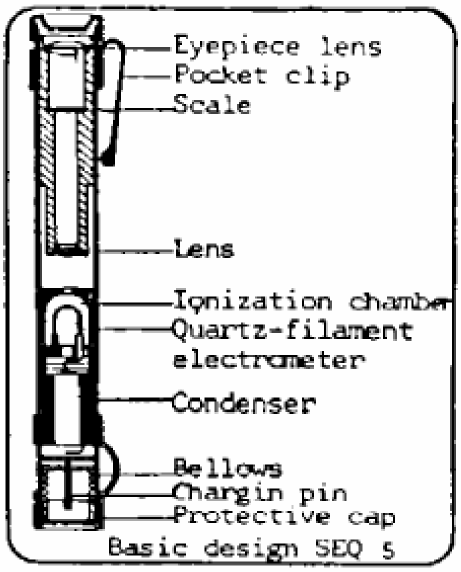
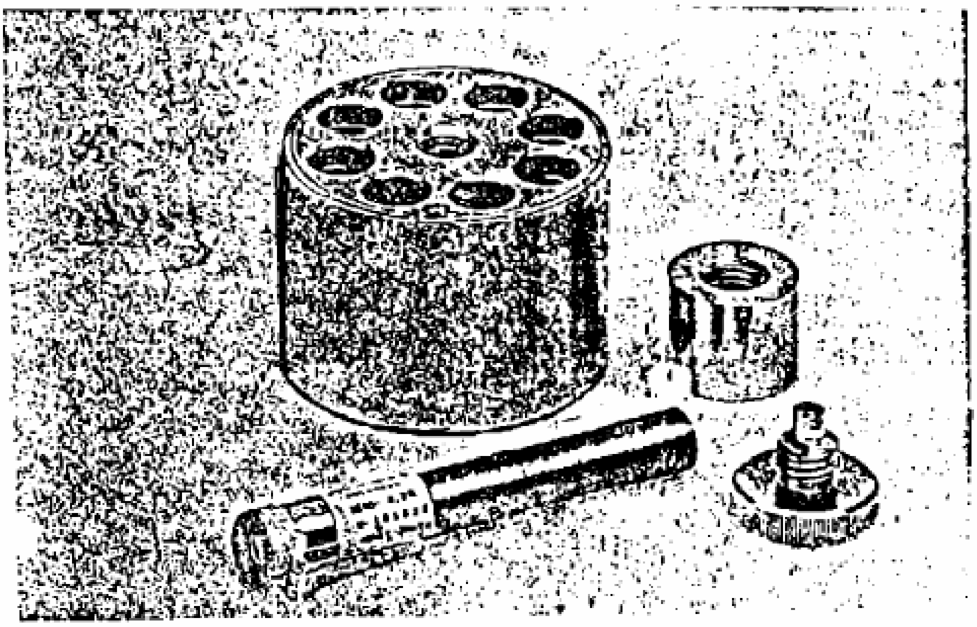


Fig. 6



TEST DEVICE WITH RADIATION SOURCE

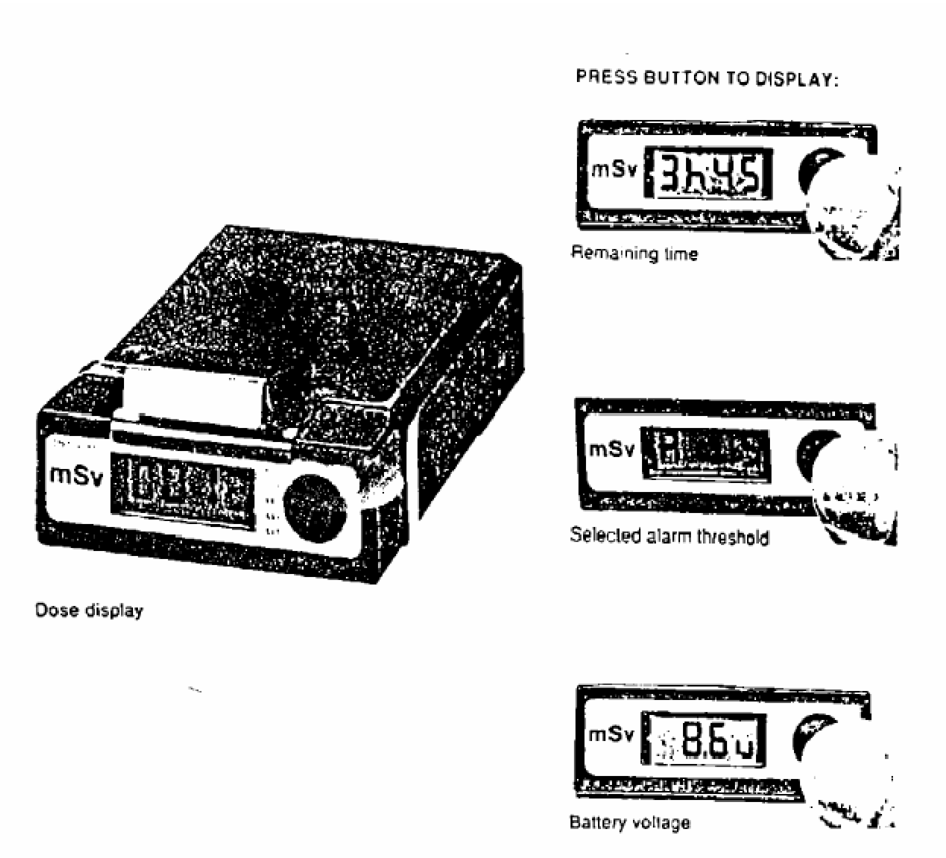
Fig. 7

TEST DEVICE

The test device should be used for checking the dosimeters for reliable operation; it should be accommodate a maximum of 8 dosimeters. The dosimeters should set to zero and then subjected in the test device to many hours of radiation with a known total dose which will cause a corresponding dosimeter indication.

In order to operate the test device, a separate radiation source, type Automess 6706, is required. This radiation source contains Cs 137 as the radioactive substance, with an activity of 9.9 µCi. This activity is less than ten times the free limit established in the "Strahlenschutzverordnung" (Radiation Protection Requirements) of October 13, 1976. Therefore, it is mandatory to register the procurement and utilization of the test device, but no approval is required.

The test device ,including the radiation source should be tested and approved for use in accordance with the "Eichgultigkeitsverordnung" (calibration validity requirements). The calibration validity period of 2 years for calibrated dosimeters can therefore be extended to 6 years when a test device is used, if test measurements are made at leas semiannually.



DIRECT READING ALARM DOSIMETER

Fig. 8

APPLICATION AND DESIGN

The Alarm-DOSimeter (ADOS) is a portable, battery-operated dosimeter for measuring photon radiation (gamma and X-rays). A GM tube is used as the radiation detector. The radiation values are processed by a microprocessor, and the digital, Liquid-Crystal Display (LCD) has four digits. Ten adjustable dose alarm thresholds and one fixed dose rate alarm threshold provide audible and visual alarms whenever a certain level of radiation is exceeded.

The ADOS is designed primarily for use as a personal dosimeter in all areas in which people are exposed to the hazards of increased photon radiation, for example, X-ray diagnostics, radiotherapy, nuclear medicine, technical applications and transportation of radioactive nuclides. The ADOS can also be used for local dose measurements.

The robust, waterproof housing made of diecast aluminum. Power is supplied by a commercially available 9 V battery; due to the low power consumption at low radiation levels, an alkaline battery gives a life of approximately 2000 hours continuous service.

All the necessary operations, such as switching the dosimeter on and off, setting the dose alarm threshold, resetting the dose and acknowledging alarms are effected with a single push-button. The device is thus completely autonomous, and no additional equipment or tools are required to operate it.

For special applications, the radiation values can be read and the dosimeter programmed automatically using an analyzer (optional). The data transfer between the dosimeter and the analyzer is contactless, and takes place via an inductive sensor inside the cover of the battery compartment.

DOSE STORAGE, DOSE RESETTING

The dose is displayed continuously and is stored in nonvolatile form. The term "non-volatile" means that the dose is not lost even if the dosimeter is deenergized, in otherwords it still remains stored when the dosimeter is switched off or when the battery is replaced. When the dosimeter is switched on again or a new battery is inserted, the dose which thereafter has accumulated will be added to the dose which is already stored.

The dose can only be reset directly after the meter is switched on (or optionally using an analyzer).

DOSE ALARM

The dose alarm threshold can be set to one of the fixed values when the dosimeter is switched on (see TECHNICAL DATA); it is set to 0.2 mSv as default. If the dose reaches or exceeds the alarm threshold, a dose alarm is output; the dose display flashes and an intermittent alarm tone begins. The dose alarm can be reset by pressing the push-button. If the dose rises still further by a a fixed amount. A new dose alarm is output as a reminder that the permitted dose has already been exceeded-a so-called "post-alarm".

This dose alarm method has been selected for the following reason: On the one hand it must be possible to reset the alarm, since a tone which cannot be reset is likely to annoy the wearer, yet on the other hand it is essential to ensure that an alarm which has been reset is not forgotten if the dose continues to rise. The wearer is thus given an opportunity to bring his work to some sort of conclusion before leaving the radiation field. Example: If he is working in a radiation field in which the first dose alarm is issued after one hour, a new dose alarm will be output roughly every minute. The currently adjusted dose alarm threshold can be displayed at any time by pressing the button.

DOSE RATE ALARM

The dose rate alarm threshold is permanently set to 1 mSv/h. If this value is reached or exceeded, an audible and visual alarms is issued and the dose rate is displayed as a digital value. The dose rate alarm can likewisebe reset by pressing the button; it is reset automatically when the dose rate falls below the alarm threshold again.

If a dose alarm and a dose rate alarm occur simultaneously, the dose alarm has priority. The dose rate alarm is not displayed until the dose alarm has been reset.

REMAINING TIME

The dosimeter continuously calculates the time remaining to the wearer up to the adjusted dose alarm threshold in hours and minutes, taking account of the current dose an dose rate values. If the dose alarm threshold is reached or exceeded, the remaining time is set to 0. The remaining time can be displayed at any time by pressing the button (maximum value 9 hours 59 minutes).

MAXIMUM DOSE RATE

The dosimeter remembers the maximum dose rate which has measure since the last time it was switched on or since the dose was last reset. This value cannot be read off directly on the dosimeter, but can only be read from the dosimeter and displayed with the aid of an optional analyzer.

GM TUBE MONITORING

The dosimeter continuously checks the GM tube with regard to the expected, minimum pulse rate, even if there is currently no external radiation. If no pulses are detected for a fixed period of time, the GM tube circuit is assumed to be defective an a resettable audible/visual alarm is output.

BATTERY MONITORING

The battery voltage is measured by the dosimeter at intervals of 5 minutes, and can be displayed by pressing the button. If the battery voltage falls below 5.0 V, a resettable audible/visual alarm is output.

ANALYZER

The dosimeter incorporates an inductive sensor, which enables data to be exchanged between it and an analyzer. Simply inserting the dosimeter in the slot in the analyzer permits the following functions to be activated:

- Readout and resetting of the dose and the maximum dose rate.
- Readout and programming of the dose alarm threshold, the dose rate alarm threshold and a personal identification number for the wearer.
- Readout of the serial number of the dosimeter.

It should be stressed again at this point that an analyzer is not essential for operating the ADOS. It merely offers an additional degree of sophistication and extra functions.

CHECK DEVICE

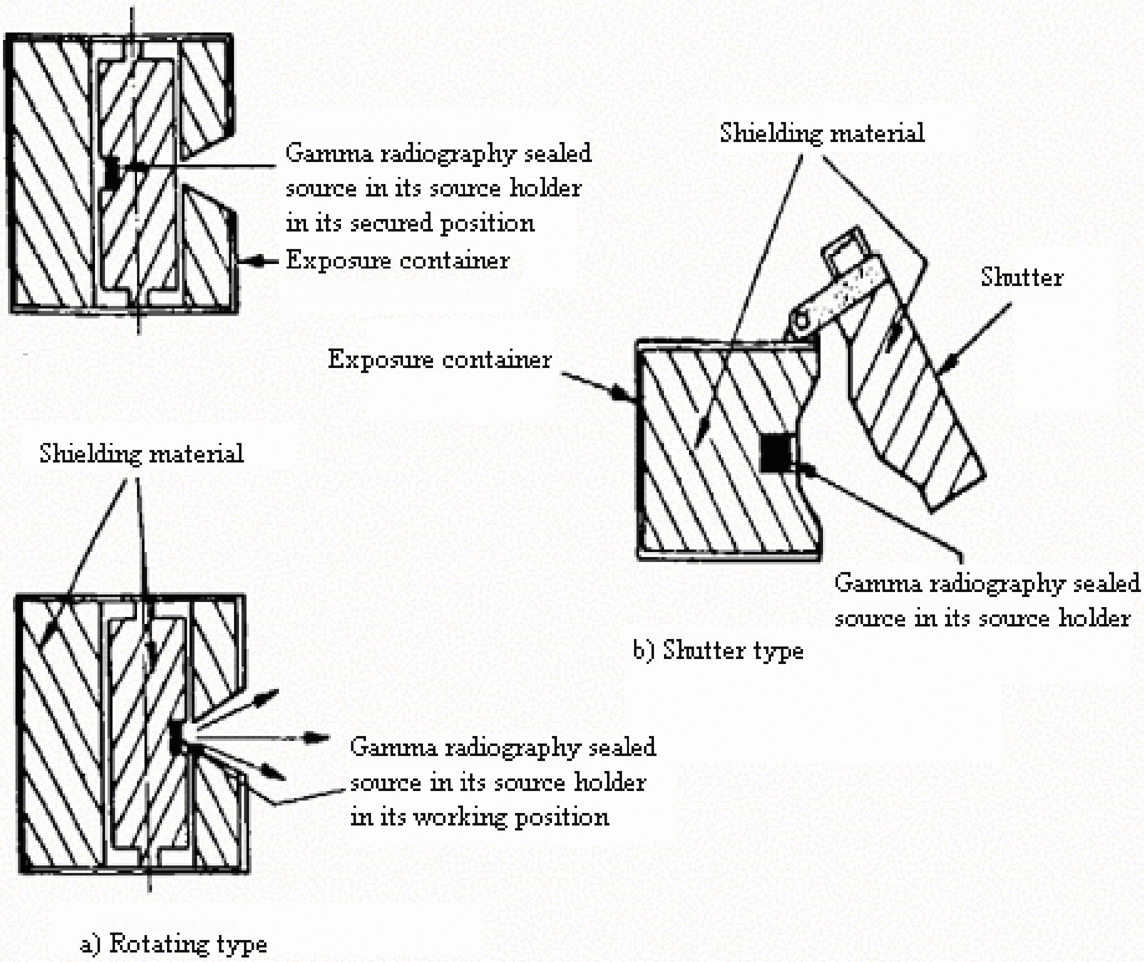
The check device 704.1 ADOS can be used for a quantitive check of the radiological functions of the dosimeter. The device is microprocessor-controlled and-apart from inserting the dosimeter and extending the Cs137 radiation sourceperforms all the necessary steps automatically, namely resetting the dose, selecting the radiation time, reading the dose at the end of the radiation time and printing out the results. A measurement process which simultaneously exposes 15 dosimeter to radiation takes 7 to 8 minutes using a radiation source with a rated activity of 37 MBq (1 mCi).

TECHNICAL DATA

Radiation detector:	GM counting tube ZP 1300 or equivalent type, for photon radiation, with energie filter.
Counting tube dimensions:	Inside diameter 4.8 mm, effective length 8 mm.
Dose sensitivity:	100 counting tube pulses correspond to 1 Micro-Sievert.
Photon energy:	Nominal range of use 0.07 MeV to 3 MeV.
Measured quantity:	Photon-equivalent dose.
Measuring accuracy:	±20% (typically better than ±10% calibration with Cs-137 gamma radiation.
Directional dependency:	±20% in nominal range of use of ±45°C with respect to

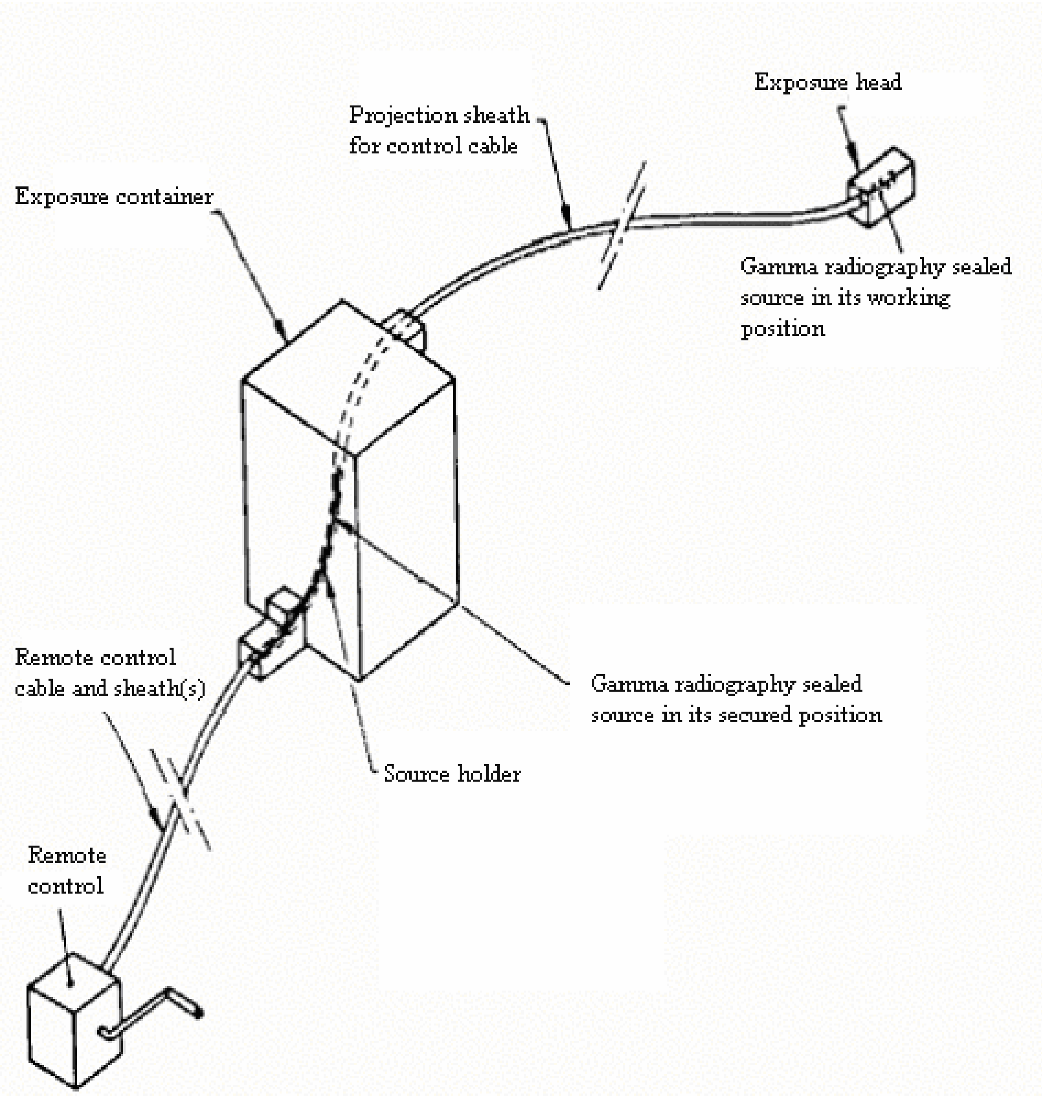
	preferred direction; 10%-30% - for all angles of incidence (complete solid angle) with Cs 137 gamma radiation.
Preferred direction:	Perpendicular to mark on large housing surface.
Display:	4-digit, 7-segment liquid-crystal display (LCD), with three decimal points between the four digits.
Dose measuring range:	0,001 mSv to 9999 mSv, no counting losses up to 5 Sv/h.
Dose display formats:	Four formats with autoranging:
	0.000 - 9.999 mSv
	10.00 - 99.99 mSv
	100.0 - 999.9 mSv
	1000 - 9999 mSv.
Dose memory:	Non-volatile, backup time at least 10 years.
Dose resetting:	Only possible after switching on dosimeter or with analyzer.
Dose alarm:	10 fixed alarm thresholds, one of which can be selected after switching on dosimeter.
Dose rate measuring range:	1 mSv/h to 999 mSv/h, with relative standard deviation of less than 5%.
	The dose rate is only displayed if the dose rate alarm threshold is reached or exceeded. Time constant of dose rate display: 8 seconds for dose rates less than 1 mSv/h, sliding between 8 seconds and 2 seconds for dose rates from 1 mSv/h to 3.5 mSv/h, less than 2 seconds for dose rates greater than 3.5 mSv/h.
Dose rate display formats:	Three formats with autoranging:
	h 1.00 - h 9.99 mSv/h
	h 10.0 - h 99.9 mSv/h
	h 100 - h 999 mSv/h.
	The flashing "h" (first digit) means per hour".
Dose rate alarm:	One fixed alarm threshold at 1 mSv/h.
Remaining time display:	Digital display after pressing button, in format x hyy for x hours and yy minutes.
Battery voltage display:	Digital display after pressing button, in format, 4.0 V to 10.0 V, automatic alarm if voltage falls below 5.0 V.
Overloading:	Meter can be overloaded with at least 25 Sv, no return up to at least 5S/v/h.
Radiological function:	Automatic monitoring of minimum pulse rate audible and visual alarm if this rate undershot.
Alarm tone:	Approx. 4 kHz, approx. 80 dB at a distance of 30 cm.
Temperature range:	-30 bis +60 degrees centrigrade (LCD) becomes increasingly inert below -10°C), temperature sensitivity of measured value over entire range: Less than 10% referred to +20°C.
Relative humidity:	Nominal range of use 0 to 100%.

External atmospheric pressure:	Nominal range of use 600 to 1300 mbar.
Positional dependency:	Any desired nominal range of use.
Battery voltage range:	5,0 to 10.0 Volt.
Power supply:	Standard 9 V battery, e.g., VARTA 6F22 or 6 LR 61 (Alkaline).
Service life:	Approx. 2000 hours with 6 LR 61 and radiation levels up to 0.2 mSv/h (without alarm tone).
Housing:	Diecast aluminum, degree of protection IP 67 as per DIN 40050 (protection against penetration of dust and when immersed in water), easily decontaminable.
Dimensions:	Height 97 mm, width 60 mm, depth 23 mm Approx.
weight:	145 g without battery, 190 g with battery.
Regular maintenance:	Not necessary, since no wearing parts (in particular, no separate round lithium cell or similar for memory backup).
Accessory:	Detachable stainless-steel clip.
Options:	Automatic analysis/logging with reader/printer, check device with radiation source Cs 137, 37 MBq (1 mCi).



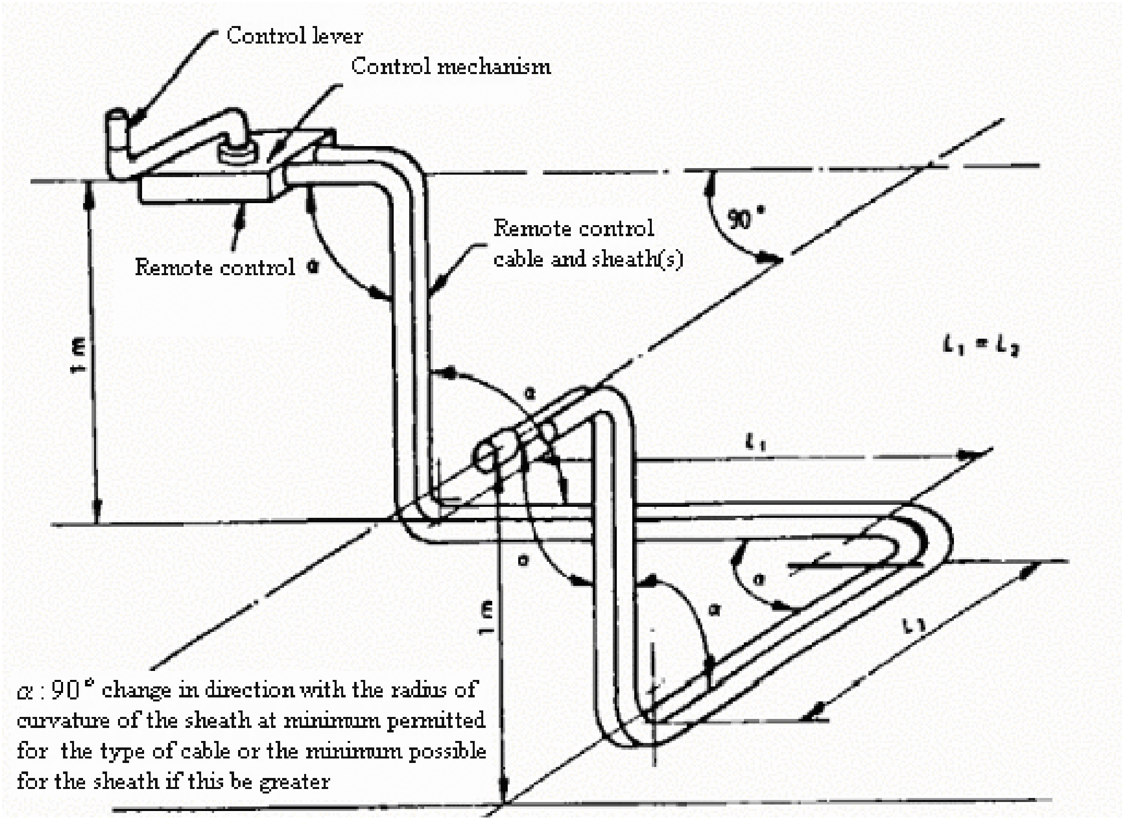
SKETCHES OF CATEGORY I APPARATUS FOR GAMMA RADIOGRAPHY

Fig. 9



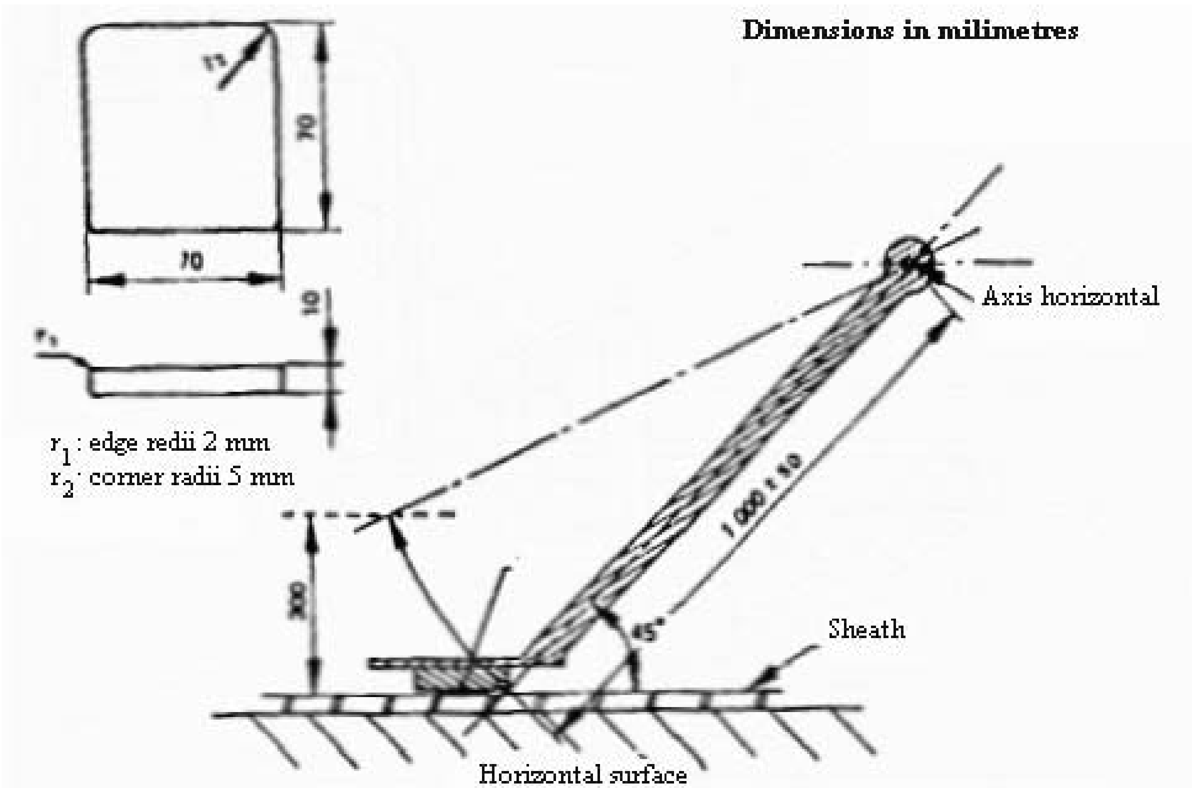
SKETCH OF CATEGORY II APPARATUS FOR GAMMA RADIOGRAPHY

Fig. 10



MECHANICAL REMOTE CONTROL DEVICE TEST GEOMETRY

Fig. 11



APPARATUS FOR CRUSHING TEST

Fig. 12