

Exploration Radiation Safety Program Manual

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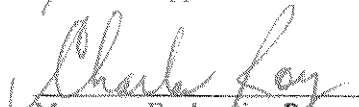
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1. RADIATION SAFETY PROGRAM

In exploration camps where uranium mineralization has been discovered, members of the workforce may work routinely with core samples containing uranium. Since uranium undergoes a spontaneous radioactive decay, the workforce has a probability of an exposure to radiation as a consequence of coming into close contact with, and handling, uranium mineralization and ores. In addition, there is a risk of a radiation exposure from the radioactive sources incorporated in certain items of equipment used in uranium exploration.

In recognition of the potential for radiation exposure to individuals working with uranium mineralization, this Radiation Safety Manual has been prepared for distribution to the Exploration Department and contractors. The manual details the types of radioactive materials that may be encountered, the relevant regulations, and the work practices to be adopted to minimize exposure.

2. RADIATION SAFETY PROGRAM POLICIES

The objective of the Radiation Safety Program is to minimize personal and environmental radiation exposures to levels that are as low as reasonably achievable (ALARA), economic and social factors considered. This is accomplished by the implementation of personal and area monitoring procedures and, where applicable, the use of personal protective equipment.

Though the level of radiation exposure resulting from exploration activities is generally minimal, Cameco is committed to the ALARA principle.

3. APPLICATION AND ADMINISTRATION OF RADIATION SAFETY PROGRAM

All applicable radiation safety principles and procedures will be applied at exploration sites where uranium mineralization is present. Once mineralization has been detected it is the responsibility of the project geologist to oversee the radiation protection program.

4. TRAINING

New hires and students will typically receive a short presentation on radiation protection at corporate office or attend the radiation protection training course offered at one of the Cameco sites in northern Saskatchewan.

4.1. INTRODUCTION TO RADIATION AND RADIATION PROTECTION

4.1.1. Types of Radiation

There are basically three types of ionizing radiation that emerge from radioactive substances such as uranium ores, namely, alpha, beta and gamma radiation. Alpha particles are relatively heavy charged particles, i.e., helium nuclei that are readily stopped by material, such as a sheet of paper or layers of dead skin. Beta particles are lighter charged particles, i.e., electrons or positrons, with slightly more penetrating power, typically up to 10 mm of body tissue. Gamma rays are electromagnetic radiation with high penetrating ability, such as being able to pass through steel pipes and body tissues.

4.1.2. Internal and External Exposure

An external exposure to radiation occurs if a person is subjected to radiation originating outside the body. External exposures primarily arise from gamma radiation emitted from a radioactive material, for example a high-grade core sample. Though alpha and beta particles have limited penetration into body tissues, beta radiation can result in exposures to both skin and eyes.

An internal exposure to radiation occurs if a person is subjected to radiation arising from a radioactive material that has entered the body. Intake routes for radioactive materials are by inhalation of dusts and gases, ingestion of particles, or through an open wound, for example dust from cuttings or radon progeny in an enclosed space with ore present. The internal exposure arises from alpha and beta particles that penetrate into sensitive body tissue before being stopped.

4.1.3. Radiation Protection Principles

The greatest potential of an external exposure to radiation during uranium exploration is from uranium mineralization and radioactive sources in exploration equipment.

Simple radiation protection is achieved by adhering to the three principles of Time, Distance, and Shielding:

- | | |
|------------------|---|
| Time | radiation exposure is reduced by minimizing your time spent close to a radioactive material; |
| Distance | radiation exposure falls off drastically as the distance between you and the radioactive material is increased; and |
| Shielding | radiation is absorbed by materials. External exposure is reduced by introducing thick steel sheeting, or concrete structures, between you and the radioactive material, i.e., operators of back-hoes, fork-lifts, |

etc, have some radiation protection provided by the metal components of the equipment.

Good radiation protection practice during uranium exploration is not to loiter in the vicinity of uranium mineralization and radioactive sources. Uranium mineralization and radioactive sources should be temporarily stored 5 m or more away from the current work area. If you have cause to approach any uranium mineralization, say, when undertaking core drilling, core inspection, core stacking, labelling, packing, or transporting, plan your work standing at least 2 m away from the material, carry out your task in close proximity to the material in minimum time, and then withdraw 2 m away to plan your next task. Minimize time in close proximity to, and maintain distance from, the radioactive material.

4.1.4. Good Housekeeping and Personal Hygiene

Since an internal exposure to radiation occurs from the inhalation or ingestion of radioactive materials, work practices should be adopted that restricts the amount of airborne dusts and contamination of hands, mouths, food utensils, etc. This is best achieved by handling materials in the wet state. When the radioactive material cannot be made damp, and airborne dusts occurs, then attempt to work up-wind of the dust source and wear respiratory protection. However, respiratory protection cannot filter out radon gas, and the best method of avoiding a radon intake when handling uranium mineralization is to work in a well ventilated area.

Radiation protection involves minimizing the external and internal exposures to radiation. To this end it is important that the uranium mineralization is kept in its correct storage locations. Any spillage or accumulation of the materials should be cleaned up immediately. A gamma radiation exposure will arise from small piles of materials while an internal exposure will occur from inhalation of airborne dusts. Prevention of ingestion of radioactive bearing material can be achieved by washing hands prior to smoking and eating. Attempt to leave the dust at the work place by wearing overalls while working and then showering and changing clothing prior to entering the kitchen/meals and living areas.

4.1.5. Personal Protective Equipment

While working with mineralization, there are a number of actions that each worker can take to protect themselves. When working with core samples, workers should wear coveralls and gloves to keep ore dust from their hand and clothes. This helps to limit the spread of contamination. Also, some people are not aware that safety glasses are mandatory when working with mineralized drill core to protect the eyes from beta radiation. Respiratory protection is also important for limiting exposure from dust and radon progeny, particularly when working in an enclosed area.

5. FACILITY RADIOLOGICAL HAZARDS AND SAFE WORK PROCEDURES

5.1. FACILITY RADIOLOGICAL HAZARDS

5.1.1. Field Camps / Core Shack

A radiation hazard will mainly be associated with uranium mineralization specimens taken by geologists in the field, and in certain drill core samples and chips from drilling programs. In such samples, the radiation hazards are external exposure from gamma radiation emitted from the uranium mineralization, internal exposure from inhaling or ingestion of the dusts arising from the uranium mineralization, and inhalation of radon progeny. Internal exposure can also occur from alpha and beta particles entering the body through open wounds.

Consequently the components of the radiation dose will be

- (i) external exposure from gamma radiation;
- (ii) internal exposure from inhaled airborne dusts;
- (iii) inhalation of radon and radon progeny;
- (iii) ingestion of dusts (minor source); and
- (iv) internal exposure from radiation entering open wounds (minor source).

In addition, radiation hazards may exist due to artificial radioactive sources, such as soil density gauges, down-hole logging equipment, spectrometers (with built-in sources) and calibration sources for scintillation detectors. The radiation hazards from these sources are external exposure from gamma radiation.

5.1.2. Corporate Office

Storage of radioactive materials in the corporate office is prohibited. Radioactive materials may be sent to Cameco's Cleveland Street warehouse for shipping to the material's final destination.

5.1.3. Saskatchewan Research Council (SRC)

Radioactive samples to be stored in Saskatoon will be stored at the Saskatchewan Research Council, which is licensed for radioactive materials storage. The Project Geologist will notify SRC of the impending arrival and departure dates of radioactive material shipments. The Project Geologist will be responsible for completing the log book entries and taking spot radiation readings.

5.2. SAFE WORK PROCEDURES

This section provides a summary of safe work procedures when dealing with both external and internal radiological hazards. For additional procedures for working with core samples, see Section 7.5.

5.2.1. Gamma Radiation (External)

The following general procedures are adopted when working with mineralized core:

- Be aware when working with mineralization,
- Store mineralized core in a "hot tent" at least 30 metres away from other structures,
- The hot core pile and other high gamma areas must have a placard noting a radioactive area with $> 25 \mu\text{Sv/h}$,
- Ensure good ventilation,
- Do not loiter in the vicinity of mineralization,
- Observe personal hygiene procedures,
- Always wear a TLD monitor badge,
- If available, wear a DRD when working with mineralized core, and
- Wear safety glasses to protect eyes from beta radiation and conventional hazards

5.2.2. Radon Progeny Exposure (Internal)

When working with uranium mineralization, it is important to work in a well ventilated area to minimize exposure to radon progeny. When working in an enclosed area, respiratory protection may be worn to further reduce any exposure to radon progeny.

5.2.3. Long Lived Radioactive Dust - LLRD (Internal)

Internal exposure from the ingestion or inhalation of contaminated dusts or particles is limited if the work procedure is 'wet'. The core cutting procedure, which is carried out using a power operated brick or rock cutting saw fitted with a circular diamond-tipped blade, is a 'wet' process, which utilizes water to cool the blade during cutting. Gloves are normally worn when handling the core whether wet or dry. If at any time dry core or samples are being handled and there is a risk of contamination then gloves and respiratory protection are worn.

Prevention of ingestion of radioactive bearing material is also achieved by washing hands prior to smoking and eating. Open wounds present a pathway for radioactive contaminants. Personnel must ensure that any such wound is covered by clothing or other means.

6. REGULATOR FRAMEWORK

The first stage of exploration activity is regulated by the province of Saskatchewan. The primary regulatory documents are the Saskatchewan Occupational Health and Safety Act and Regulations and the Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM). In addition, the Canadian Nuclear Safety Commission (CNSC) regulates exploration activities related to nuclear gauges and the transport of radioactive substances. Once a project has progressed to the stage of "evaluating" an ore body (as defined in the CNSC Draft Guidance for Uranium Mine Site Licence Preparation) the CNSC becomes the primary regulator.

Under the Canadian Guidelines for the Management of NORM, naturally occurring radioactive materials are radioactive elements found in the environment. This includes uranium, thorium, and potassium, and any of their radioactive decay products. By definition NORM is not part of the nuclear fuel cycle, therefore it is not under the control of the CNSC. It is the principle of these Guidelines, though, that workers exposed to NORM should be subject to the same radiation exposure standards that apply to workers exposed to CNSC-regulated radioactive materials.

The Guideline recommends that the annual effective dose of persons exposed to NORM as the result of a work practice be limited to the values given in Table 1. These dose limits are harmonized with the CNSC radiation dose limits. Occupationally exposed workers are those people who are exposed to NORM as part of the routine duties, and are officially classed as NORM Workers. Incidentally exposed workers are employees whose routine duties do not include exposure to NORM. These people are classed as members of the public.

Table 1: Radiation Dose Limits

Affected Group	Annual Effective Dose Limit (mSv)	Five Year Cumulative Dose Limit (mSv)
Occupationally Exposed Workers	20	100
Incidentally Exposed Workers and Members of the Public	1	5

6.1. THE NORM MANAGEMENT PROGRAM

In order to control doses to member of the public, as well as NORM workers, the Canadian Guidelines recommend a program of dose classifications/thresholds and reviews. These classifications determine the level and type of activities that must take place in order to effectively protect the workers. The classifications and program steps described below and illustrated in Figure 1. Note this program is based on an assessment of the maximum annual effective dose for members of the public and NORM workers, not the average. Addition information and standards for establishing radiation

protections programs is contained in the Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials

The underlying theme of all radiation protection programs and decisions, regardless of the classification is the ALARA principle. This means keeping doses As Low As Reasonably Achievable, social and economic factors taken into account.

6.1.1. NORM Program Classifications

6.1.1.1.Unrestricted Classification

The program classification used when the maximum effective dose to a member of the public is expected to be below 0.3 mSv/y and to a worker is expected to be less than 1.0 mSv/y. No further action is needed to control doses.

6.1.1.2.NORM Management Classification

The program classification when the assessed maximum annual effective dose to a member of the public or incidental worker is expected to exceed 0.3 mSv/y. Public access would need to be restricted, but worker access would be unrestricted. The NORM Management Program for this classification may include:

- restricting access to incidentally exposed workers
- introduction of material management procedures (see Section 7)
- changes in work practices

6.1.1.3.Dose Management Classification

The program classification when the assessed maximum annual effective dose to a worker is expected to exceed 1.0 mSv/y. For this classification, the Dose Management Program should include:

- worker notification of radiation sources
- consideration of work practices and protective clothing to limit worker exposures
- application of engineering controls where appropriate (see Section 7)
- training to control and reduce worker dose
- introduction of a worker radiation dose estimation program
- reporting of worker doses to the National Dose Registry

6.1.1.4.Radiation Protection Management Classification

The program classification when the assessed maximum annual effective dose to a worker is expected to exceed 5.0 mSv/y. In addition to the requirements of Section 6.1.1.3, the Radiation Protection Management Program for this classification should include:

- introduction of a formal radiation protection program
- place workers expected to exceed 5 mSv/y in a personal radiation dosimetry program meeting the requirements of the CNSC
- provide protective equipment, clothing, and work procedures to reduce the worker dose and spread of contamination.

When the actual measured dose of a worker is over 5 mSv/y, the following steps should be added to the program:

- use engineering controls and provide protective equipment designed to reduce worker dose as required
- ensure that workers do not exceed the five-year average occupational dose limit of 20 mSv/y.

6.1.2. Program Reviews

6.1.2.1. Initial Review

This is an initial assessment to determine if it is suspected that the maximum annual effective dose will exceed 0.3 mSv/y for either the public or workers. A radiation dose assessment is part of this review.

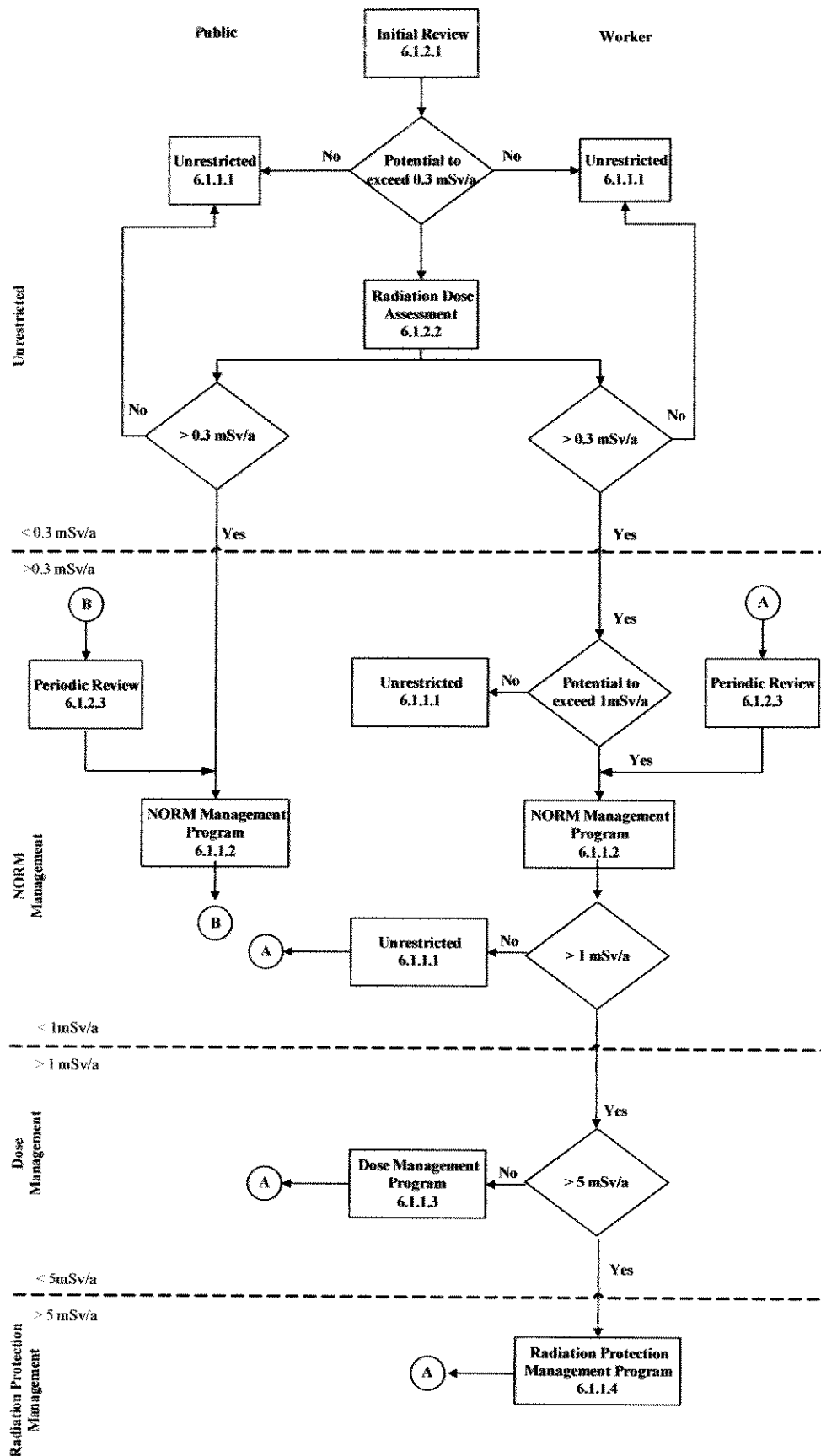
6.1.2.2. Radiation Dose Assessment

Estimate the doses to workers and members of the public by conducting a radiation survey of the workplace. This survey should include both gamma radiation and airborne radioactivity, as appropriate.

6.1.2.3. Periodic Review

Whenever a NORM Management, Dose Management, or Radiation Protection Management Program has been implemented, a periodic review is needed. The review is to determine if there are any changes to the system that might effect doses, to monitor the effectiveness of the program, and determine if any changes are needed. The frequency of the review depends on the program itself and the likelihood that conditions at the work site will change.

Figure 1: NORM Program Flowchart



7. EXPOSURE CONTROL AND MONITORING

The level of radiation exposure of personnel during all facets of the exploration activities can be expected to be minimal. However, to ascertain that radiation exposures are indeed minimal and to assist in implementing the ALARA principle, a certain amount of radiation monitoring is to be conducted. This will range from personal monitoring when working with mineralization to routine swipe surveys of the camp. Proper handling of core samples is also important to minimize exposure and comply with regulations. The various radiation monitoring and core handling procedures are outlined in the following sections.

7.1. GAMMA RADIATION

7.1.1. Personal Monitoring

For official dosimetry purposes, thermoluminescence dosimeters (TLD) are used. The Corporate Exploration Department rents the dosimeters from the distributor (Landauer or NDS) and distributes them to the appropriate personnel on a quarterly basis.

All Cameco or contractor personnel who will be working with or handling the core, working at the drill or in the hot core shack must have a TLD badge assigned to them which is changed every quarter. The badges are sent to the appropriate dosimetry service (e.g., Landauer or NDS, as appropriate) for reading when they are changed. Results must be reported to the workers.

Direct Reading Dosimeters (DRDs) such as the Canary IV units provide a daily reading the gamma dose. These units do not replace the TLDs, which provide the "official" gamma dose, but can be useful at tracking radiation doses on a daily basis. The use of DRD's is optional.

7.1.2. Area Monitoring

For general occupational and environmental monitoring, the gamma radiation levels at normally occupied locations and at 1 m above the ground should be measured. Core samples will also be measured as they are logged in or before transport.

It is important when using a gamma radiation meter or scintillometer to become familiar with the units in which the meter is calibrated and the range of each scale. The indicated units can be (i) roentgens (R), (ii) Rad (rad), (iii) rem (rem or r), (iv) grays (Gy), (v) sieverts (Sv), or (vi) counts per second for the scintillometer. When dealing with gamma radiation levels in air, then the relationship between the first four units is:

$$1 \text{ R} = 0.87 \text{ rad} = 0.87 \text{ rem} = 0.0087 \text{ Gy} = 0.0087 \text{ Sv}$$

These units are quite large quantities so it is common to use the metric prefixes for subunits, such as milli- (m) and micro- (μ). Thus the above relationships can be written as

$$1 \text{ mR} = 0.87 \text{ mrad} = 0.87 \text{ mrem} = 8.7 \mu\text{Gy} = 8.7 \mu\text{Sv}$$

While technically $1 \text{ R} = 0.87 \text{ rad}$, for simplicity the conversion between roentgen and rad is often given as $1 \text{ R} = 1 \text{ rad}$. The other units are simply converted $1 \text{ rad} = 1 \text{ rem} = 0.01 \text{ Gy} = 0.01 \text{ Sv}$. A useful conversion table is:

Table 2: Unit Conversion Table

μR	mrem	mSv	μSv
	100	1	1000
	10	0.1	100
1000	1	0.01	10
100	0.1	0.001	1
10	0.01	0.0001	0.1

The relationship between the number of counts per second for three common scintillometers and the unit of microsievert per hour is shown in Figure 2.

For actual operating instructions for any gamma radiation meter or scintillometer to be used refer to the manufacturer's manual. The meters should be calibrated annually by the appropriate authority.

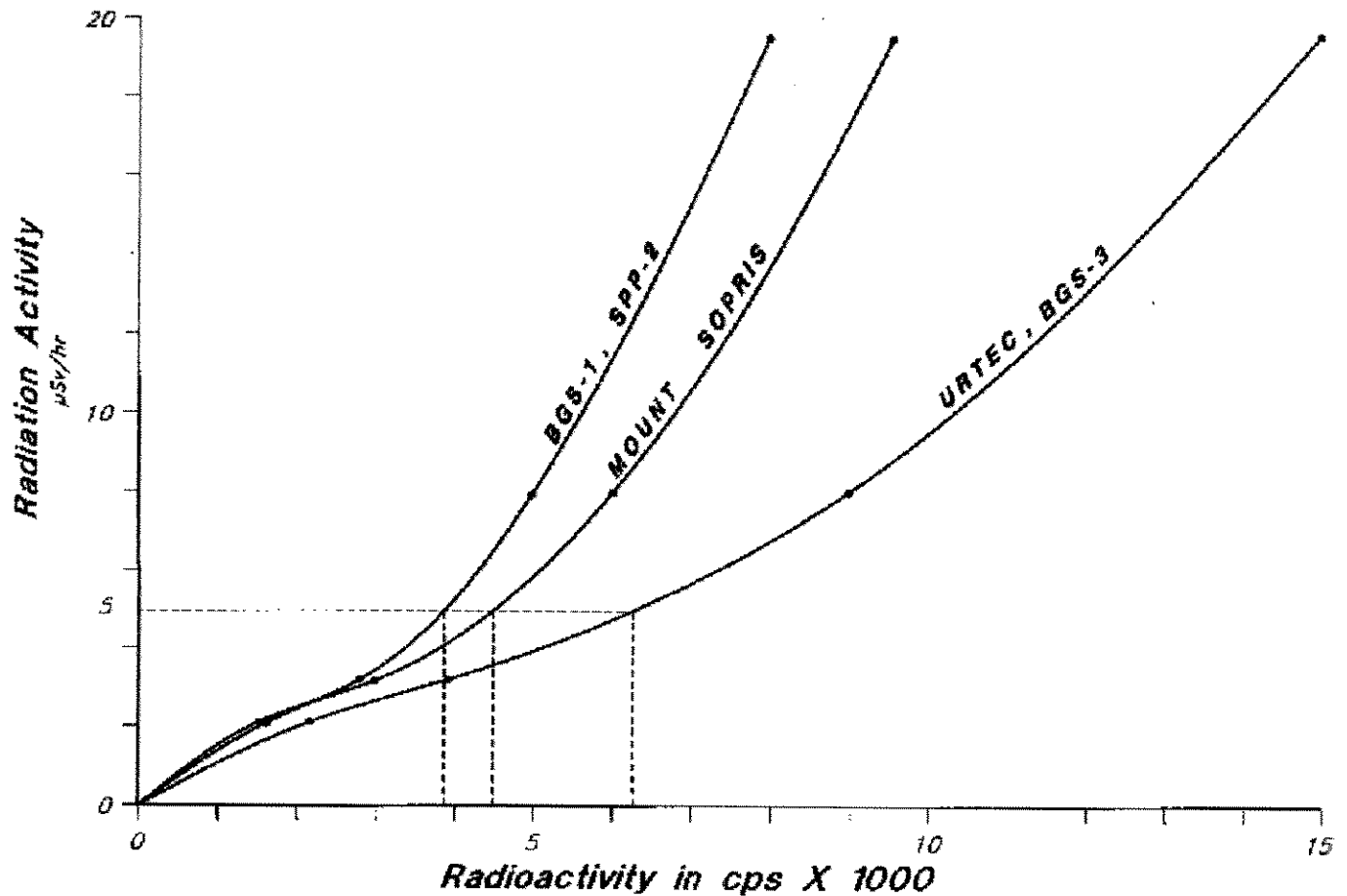
7.2. RADON PROGENY

One of the decay products of uranium is radon. Radon is a gas and, therefore, has the potential of escaping from the host particles. Consequently radon emanates from materials containing uranium. In still air conditions the levels of radon in the air in the vicinity of uranium materials can rise substantially and become a health risk from inhalation of the radon and its progeny. A natural breeze or forced ventilation quickly disperses airborne radon concentrations.

At uranium exploration camps potential radon problem areas are enclosed store sheds or tents. Such work places should be well ventilated prior to commencing work in them. Store sheds/tents can be ventilated by opening windows and doors to obtain airflow through the area.

Past monitoring has shown only trace background levels of radon progeny in the core tents. Either radon progeny monitors from Radiation Institute of Canada (RSIC) or radon track etch cups will be placed in the core shacks during the winter months to help assess the effectiveness of the ventilation.

Figure 2: Conversion Graph Between Counts per Second (cps) and Microsieverts per Hour for Common Scintillometers



**COMPARISON OF RADIATION ACTIVITY VS
SCINTILLOMETER READINGS (cps)**

Note: Data generated by M. Wilfrup 1984. Modified by C. Roy Feb. 1998

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7.3. LONG LIVED RADIOACTIVE DUST

The majority of work carried out on the core, where particulate matter is generated, is a wet process and therefore minimal dust is generated. It is important to ensure that machinery and work areas are cleaned after use. Dirty machinery and work areas can become dust sources when they dry. Personal hygiene is also important in preventing the inadvertent spread or ingestion of radioactive material. Food must not be consumed and no smoking allowed in areas where radioactive core is being stored or handled. When handling core, coveralls and gloves must be worn, and these must be taken off before entering uncontaminated areas.

7.4. CONTAMINATION MONITORING

Contamination monitoring is performed by assessing the loose contamination using a swipe. Data collection should begin once the camp is laid out to establish background levels in the camp. The results from these checks will be submitted, when an ore extraction permit is applied for.

Before drilling, swipe tests should be completed in your work area and around the camp. A swipe sample is taken by wiping the swipe over an area 100 cm². The following locations are recommended for routine swipe samples:

- 2 tests of each core shack floor.
- 2 tests of the core table in each core shack.
- 1 test of each office table in the core shacks.
- 2 tests of the floor in the dry. (If possible a dirty dry should be established for contaminated clothing, laundering of coveralls doesn't get done regularly in a drill camp.)
- 2 tests of the benches in the dry
- 3 tests of the kitchen floor.(people with dirty coveralls should not be allowed in the kitchen)
- 3 tests of the kitchen benches

If contamination starts showing up in the kitchen, then urine samples may be required. In addition, dust samples could be required if contamination levels are found to be unacceptable. Clean areas are to be maintained at less than or equal to 0.05 Bq/cm².

These tests should be completed every 30 days and at the end of the program. The swipes are sent out to the radiation department at one of the Cameco operations for counting.

7.5. DRILLING AND CORE HANDLING

Once mineralization has been intersected the drillers need to be instructed on how to minimize contact with the core and to store mineralized core at some distance from the core shack, prior it being transported into camp.

1. When drilling through mineralized zones, any recycled water should be collected into tanks or drums. Once the cuttings settle out, the water can be recycled. The container should then be sealed and shipped to a Cameco mine or mill for disposal.
2. Any spills of radioactive material should be collected in barrels, sealed and moved to a Cameco mine or mill for disposal.
3. Core is logged into the hot core shack. Date, time and the gamma level at 1 meter are recorded in a logbook. This requires a special meter; one with the lowest scale reading 0 to 1 $\mu\text{Sv/h}$ is preferred. The core is only allowed to remain in the core shack for 48 hours. The radiation level is recorded daily, while the hot tent is in use. A sign warning of radiation must be placed on the core shack door while core is inside. The date and time is recorded when the mineralization is removed. Each time the core is brought into the core shack you must record the entry and exit date and time.
4. If you can smell the uranium, then you have a problem with ventilation. Standard practice should be to have two fans set up in separate windows. One should force air into the tent and the other forcing it out. Before entering the core shack, the door should be fanned a few times to help flush the tent.
5. Before entering the hot core shack, a personal dosimeter should be obtained and activated. Your time in the hot core shack is recorded and your dosimeter reading. Sometimes these Canary Dosimeters can be rented from the mine sites.
6. Floor sweepings from the mineralized core tent and contaminated gloves and personal protective gear will be collected in a dedicated, sealed storage container or drum and disposed of at a licensed facility, typically a Cameco mine or mill.
7. Upon completion of drilling, the contractor's equipment must be decontaminated before being released. This may require the equipment being taken to one of our mines or mills. The floorboards may have to be replaced, to reduce the surface activity. The contaminated equipment must be disposed of at the designated radioactive disposal site at one of Cameco's facilities.
8. It is assumed that the projects are using the normal safety equipment when dealing with mineralized drill core. This would include coveralls, gloves, respirator and safety glasses.

Some people are not aware that safety glasses are mandatory when working with mineralized drill core.

9. After a drill hole is completed, drill mud, cuttings, soils, etc. with a uranium content greater than 0.05 % U_3O_8 must be disposed up down the drill hole. The upper 30 metres of bedrock or the entire depth of the hole, whichever is less, is then grouted. In addition, if mineralization greater than 1.0% U_3O_8 was encountered over a length of greater than one metre and with a metre-percent concentration greater than 5.0, grout the entire length of the mineralized zone and not less than 10 metres above and below the mineralized zone.

10. After moving off a mineralized drill hole the site must be scanned for contamination. Since the drilling fluid would have been collected during drilling, no contamination should be found. However, core chips and fluid from the tube may cause a problem. Sites must be cleaned to the Saskatchewan Environment clean-up criteria, which is 100 $\mu\text{R/h}$ (1 $\mu\text{Sv/h}$) measured at a height of one meter. No sample is to exceed 250 $\mu\text{R/h}$ (2.5 $\mu\text{Sv/h}$). This amount is about 500 CPS with a SPP2. The contaminated soil must be removed and disposed of at a licensed facility.

For the projects to meet these requirements, additional Eberline type scints and personal dosimeters (Canary IV) are required. Historically the cost of these items has been charged to the projects.

8. TRANSPORTATION OF RADIOACTIVE MATERIAL

8.1. CORE SAMPLES (URANIUM ORE)

The transportation of uranium mineralization and ores that have an average specific activity in excess of 70 kBq/kg conform to the requirements of the Packaging and Transport of Nuclear Substances Regulations. The procedure for the transport of uranium bearing material is contained in [Appendix A](#). All personnel shipping radioactive materials shall be certified to the standards required by the Transport of Dangerous Goods Regulations

The exploration camps have one exemption to the Transport of Dangerous Goods Regulations. Due to the remoteness of some exploration camps, we are permitted to transport core samples by air, providing they are less than 100 mm in diameter and are packaged in accordance with the Packaging and Transport of Nuclear Substances Regulations (section 12.11 of the TDG Regulations). This packaging requirement includes using IP-2 packaging if the sample averages more than 2% uranium.

8.2. RADIOACTIVE SOURCES

Radioactive sources need to be transported as per the Packaging and Transport of Nuclear Substances Regulation. The particular packaging and labeling required depends upon the source to be transported. Transportation of radioactive sources is not likely to be routine so each case needs to be considered separately. Reference to the Packaging and Transport of Nuclear Substances Regulations should be made at the appropriate time.

APPENDIX A

TRANSPORTATION OF RADIOACTIVE MATERIAL

TRANSPORTATION OF RADIOACTIVE MATERIAL

The standard unit of measure of the activity (number of atoms decaying per second) is the becquerel (Bq). Since 1 Bq is a very small quantity, larger multiples are used as follows:

1kBq	=	kilobecquerel	=	1000 Bq	=	1×10^3 Bq
1MBq	=	megabecquerel	=	1,000,000 Bq	=	1×10^6 Bq
1GBq	=	gigabecquerel	=	1,000,000,000 Bq	=	1×10^9 Bq
1TBq	=	terabecquerel	=	1,000,000,000,000 Bq	=	1×10^{12} Bq

Becquerels replace the curie (Ci) as the unit of measure of activity. The radiation dose-equivalent is expressed in units of sieverts (Sv). Smaller fractions are often used as follows:

1 mSv	=	millisievert	=	0.001 Sv	=	1×10^{-3} Sv
1 μ Sv	=	microsievert	=	0.000001 Sv	=	1×10^{-6} Sv

The sievert replaces the older unit for dose-equivalent, the "rem".

Following are procedures that can be followed for shipping many types of Class 7 materials and surface contaminated objects from Exploration Sites/Camps. These procedures are designed to help certified shippers of Class 7 radioactive material meet all regulatory and corporate requirements. These procedures do not apply to the air transport of radioactive material.

Other references you may require are:

- Packaging and Transport of Nuclear Substances Regulations, SOR/2000-208, May 31, 2000.
- IAEA Safety Series No 5: Regulations for the Safe Transport of Radioactive Material (as amended 1990).
- Transport of Dangerous Goods Clear Language Regulations, SOR/DORS/2001-286.

Radioactive material shipments are shipments of a known mass, grade, and type of radioactive substances, for example core samples, yellowcake, and tailings. Surface contaminate objects (SCOs) are pieces of equipment, scrap, etc. that have uranium embedded into the surface that can not be removed. The proper procedure should be followed for each type of shipment

If you are shipping material from a Cameco Mine or Mill Operation, site procedures must be followed.

Road Transport of Radioactive Materials

Step 1: Determine the specific activity of the material:

The specific activity is the number of Becquerels of activity per unit of mass of material (kBq/kg or Bq/g). Table 1 shows the specific activities of yellowcake, ore, and tailings. To calculate the specific activity for an ore/YC or tailings sample, multiply the appropriate specific activity from Table 1 by either the sample's grade or mill feed grade, respectively. If the grade is not known, it can be estimated using the following formula:

$$\% \text{ U3O8} = \frac{\text{Contact Gamma Reading } (\mu\text{Sv/h})}{45 \mu\text{Sv/h}}$$

Table 1: Summary of Specific Activities for Radioactive Material

Material	Specific Activity
Key Lake YC	42,000 kBq/kg
Rabbit Lake YC	35,000 kBq/kg
Uranium Ore	1500 kBq/kg per % U_3O_8
Tailings	1100 kBq/kg per % U_3O_8 of mill feed grade

If the specific activity is greater than 70 kBq/kg, the material is considered radioactive and TDG is required.

Step 2: Determine the total activity of the shipment:

To calculate the total activity, multiply the specific activity by the mass of the sample, as described below (note: the unit of MBq is used here instead of kBq because the total activity is usually a large value and the unit of MBq is more appropriate (1 MBq = 1000 kBq)).

1) Calculations for Total Activity for Yellowcake:

Total Activity (for **Rabbit Lake**) = (35 MBq/kg) * (mass of sample (kg))

Total Activity (for **Key Lake**) = (42 MBq/kg) * (mass of sample (kg))

2) Calculation for Total Activity for Uranium ore/drill core:

Total Activity = (1.5 MBq/kg per % U_3O_8) * (% U_3O_8) * (mass of sample (kg))

3) Calculation for Total Activity for Uranium Tailings:

Total Activity = (1.1 MBq/kg per % U_3O_8 of mill feed grade) * (% U_3O_8 in mill feed) * (mass of sample (kg)).

Step 3: Package the material:

The following instructions describe how to package both liquid and solid samples of radioactive material. As noted below, IP-2 packages (steel drums) are preferred where possible for shipment, but are a requirement if the material being shipped has an average grade of 2% U_3O_8 or greater. Below 2%, the material may be shipped in IP-1 packages (sealed plastic bucket).

Inner Packaging – Solid Samples

- 1) Place the sample in a bottle or a plastic bag. If the sample is in a bottle, tightly secure the lid using electrical tape.
- 2) Line the shipping drum using a shipping envelope or a large plastic bag. Ensure the plastic bag extends above the height of the shipping drum.
- 3) Place the prepared sample bottle/bag in the shipping drum and fill all empty spaces with suitable filler.
- 4) Secure the shipping envelope.
- 5) Add more filler if necessary then secure shipping drum lid.

Inner Packaging – Liquid Samples

- 1) Line the shipping drum using a shipping envelope or a large plastic bag. Ensure the plastic bag extends above the height of the shipping drum.
- 2) Place the prepared sample bottle in the shipping drum and fill with absorbent.
- 3) Secure the shipping envelope.
- 4) Add more absorbent then secure shipping drum lid.

Note: If the liquid volume is equal to or less than 50 ml, the package must contain absorbent (vermiculite) sufficient to absorb twice the volume of the liquid. If the liquid volume is greater than 50 ml the package must contain the absorbent and an inner and outer containment component. A plastic bucket is the best choice for the inner containment component.

Outer Packaging – Solid or Liquid Samples

Industrial packages IP are designed to meet general requirements in relation to mass, volume and shape therefore allowing for easy and safe handling and transport. Cameco is a leader in the uranium industry and strives to surpass the minimum standards therefore, use a steel drum (IP-2) when possible.

Step 4: Take gamma measurements and record Transport Index:

Once the material has been packaged, move the package to a low background area, and take gamma measurements on contact and at 1m on as many sides of the package as possible. Record the maximum contact and 1m reading in $\mu\text{Sv/h}$.

If there is more than one package (i.e. pail, drum, etc.), a gamma measurements must be for each package.

The next step is to determine the transport index (TI). The formula for calculating the TI is as follows:

$$TI = \left(\frac{\text{Max Gamma at 1m } (\mu\text{Sv/h})}{10} \right) \times \text{Multiplication Factor}$$

The Multiplication Factors are determined by the size of the package, as shown in Table 2.

This calculated TI should be rounded up to the first decimal place (e.g. 1.13 becomes 1.2). If the TI calculated from the formula above is less than 0.05, the TI is zero.

Table 2: Multiplication factors for use in TI calculation

Size of Load *	Multiplication Factor
Size of load < 1 m ²	1
1 m ² < size of load < 5 m ²	2
5 m ² < size of load < 20 m ²	3
20 m ² < size of load	10

* Use largest cross-sectional area of load being measured

Step 5: Determine Labeling Requirements and UN Number

Two pieces of information are required to determine the method of shipment: (1) the TI, and (2) the maximum radiation level on the external surface of package. Using these two numbers, first determine the label category from Table 3. Note that both conditions must be met for a category or you will need to choose the next label category. (e.g. If the TI is 0 but the maximum radiation measurement on the external surface is 7 $\mu\text{Sv/h}$ the label would be II-YELLOW)

If there is more than one package, each package must be labeled properly.

Table 3: Labeling requirements.

Transportation Index TI	Maximum Radiation Level on External Surface	Label Category
0	Not more than 5 μSv	I-WHITE
More than 0 but not more than 1	More than 5 $\mu\text{Sv/h}$ but not more than 500 $\mu\text{Sv/h}$	II-YELLOW
More than 1 but not more than 10	More than 500 $\mu\text{Sv/h}$ but not more than 2000 $\mu\text{Sv/h}$	III-YELLOW
More than 10	More than 2000 $\mu\text{Sv/h}$ but not more than 10000 $\mu\text{Sv/h}$	III-YELLOW and also under exclusive use

Next, determine the description / shipping name and the product identification number (PIN) from Table 4. The choices for shipping uranium are LSA UN2912, SCO UN 2913, Excepted Material UN2910. The PIN number UN 2913 is for SCO shipments and should not be used for radioactive material shipments. The following procedure may be helpful in deciding.

Is the label category II-YELLOW or higher?

If YES, then it should be shipped as LSA UN2912.

If NO, then determine whether the amount of uranium in the package is below the limit for an excepted package. An excepted material package must have less than 8.6g of 100% grade natural uranium ore; this is the same as 430g of 2% material ($8.6/0.02$) or 860g of 1% material ($8.6/0.01 = 860$), etc. Substitute the grade, as a decimal, into the following formula. If the mass of the package is less than the mass calculated below, it can be shipped as Excepted Material.

$$\frac{8.6 \text{ g}}{\text{Sample Grade (decimal)}} = \underline{\hspace{2cm}}$$

Note that for Excepted Material, the loose contamination on the outside must be less than 0.4 Bq/cm^2 .

When there is any doubt, sent the shipment as LSA UN2912.

Table 4: Classification of Class 7 (Radioactive) Material

Description & Shipping Name	Product Identification Number (PIN)	Definition
Radioactive material, low specific activity (LSA) N.O.S.	UN 2912	LSA- radioactive material which, by its nature has a limited specific activity. Yellowcake, tailings, ore, special waste are categorized as LSA
Radioactive material, excepted package, limited quantity of material	UN 2910	Excepted package – package containing radioactive that is designed to meet the general requirements in IAEA Safety Series No. 6. Limited quantity of material – must meet activity limits in Table IV of IAEA Safety Series No. 6.
Radioactive material, special form N.O.S.	UN 2974	An indispensable solid radioactive material or a sealed capsule containing radioactive material.
Radioactive material, surface contaminated object (SCO)	UN 2913	A solid object which is not itself radioactive but which has radioactive material distributed on its surface.

Step 6: Fill in the TDG paperwork

- 1) The name of the radioactive material or the symbol of the radionuclide or element and its atomic number; (U-natural)
- 2) A description of the physical and chemical form of the radioactive material or, where the material is a special form, a statement to that effect. Standard formats for exploration shipments are as follows:

When Shipping	Material Name	Physical Form	Chemical Form
Drill core	U-natural	Solid	U-natural
Tailings	U-natural	Solid or Liquid	Uranium Tailings

For SCO shipments a physical description is low specific activity material embedded on surface

Special form shipments may include “encapsulated instrument”, etc.

- 3) The volume (or mass) of the sample and the number of pieces (drums, barrels, etc.) in the shipment
- 4) The activity of the radioactive material in Bq, MBq, GBq, etc.
- 5) A statement indicating which of the labels is affixed to or printed on the package (“Radioactive White-I”, “Radioactive Yellow-II”, or “Radioactive Yellow-III”)
- 6) If the package displays a Radioactive Yellow-II or Radioactive Yellow-III label, the transport index of the package.
- 7) Where no special instructions are required indicate this with the statement “no special handling required”.

Refer to Example 1 at the end of this Appendix for an example of the completed paperwork

Step 7: Placard the transport vehicle

Place the appropriate placard for the class of radioactive material on the transport vehicle (Step 5, Table 4).

Transportation of Surface Contaminated Objects

If a beta/gamma meter is not available, equipment may need to be taken to one of the Cameco sites to be scanned for surface contamination. This procedure applies to a contractor's or employee's tools and vehicle after working with mineralization, as well as any other objects that were in contact with mineralization.

Step 1: Determine objects surface radioactivity (Bq/cm²)

Using a beta/gamma meter, measure the objects surface radioactivity in Bq/cm² to determine whether it requires shipment as a surface contaminated object (SCO). The contamination limits are as follows:

≤ 3.0 Bq/cm² – this item is not considered radioactive and can be sent without TDG paperwork
> 3.0 Bq/cm² – this item must be shipped as an SCO-I item

The following are the contamination limits to qualify as an SCO-I item:

- nonfixed contamination on accessible surfaces must not exceed 4 Bq/cm² averaged over 300 cm² for all radiation types,
- fixed contamination on accessible surfaces must not exceed 40,000 Bq/cm² averaged over 300 cm² for all radiation types, and
- non-fixed and fixed contamination on inaccessible surfaces must not exceed 40,000 Bq/cm² averaged over 300 cm² for all radiation types.

Items not meeting these SCO-I criteria can not currently be shipped.

Step 2: Check for non-fixed contamination

If the surface activity is greater than 4 Bq/cm² but less than 40,000 Bq/cm², do an alpha radiation swipe test on the surface of the object (100 cm²) to ensure that the activity measured is not due to non-fixed contamination. If the non-fixed activity from the swipe is above 4 Bq/cm², reclean item until the loose contamination is below 4 Bq/cm².

Step 3: Estimate the total activity

Shipping documents and labels for SCO-I require the total radioactivity present on the surface of the object to be recorded. Estimate the "Total Activity" on the object with the following calculation:

$$\text{Bq/cm}^2 \text{ (from step 1)} \times \text{surface area of the object (in cm}^2\text{)} = \text{Bq}$$

The surface area of the object will have to be measured or estimated.

The calculated total activity is used for the completion of the TDG paperwork (SCO-I) and is entered on the category labels for the object or package. The result can be converted to kBq or MBq if this is more convenient.

Step 4: Packaging and Shipment of an SCO

Options for shipping items that meet the SCO-I designation.

- A. Unpackaged (ie. an SCO-I item strapped to a pallet)
 - i) the objects can not be lost off of the conveyance (ie. the tailgate on the truck must be done up)
 - ii) the load shall be exclusive use for the SCO-I shipment, nothing else can be shipped with the unpackaged SCO-I item
 - iii) where it is suspected that non-fixed radioactive material exists on the inaccessible surface of the object (ie. inside a pump), measures must be taken to prevent this material from shaking loose and contaminating the truck box (ie. the bottom of the pump may have to be shrink wrapped)
 - iv) a transport index and two category labels must be done on each SCO-I item
- B. Packaged in an Industrial Package Type 1 (IP-1)
 - i) the shipping container must legibly indicate the maximum permissible gross mass allowed
 - ii) the container can not be used to ship non-radioactive items due to the potential of contamination on the inside of the container even when empty (exclusive use). It should be noted that the empty shipping container may have to be shipped as an "Excepted package" due to the internal contamination (outside category labels must be removed). The other option is to have the container fully cleaned ($\leq 4.0 \text{ Bq/cm}^2$) before being shipped empty.
 - iii) the external surfaces of the container can not exceed 4.0 Bq/cm^2 for non-fixed contamination
 - iv) only one transport index is needed for the package

Step 5: Take the Transport Index

Determine the transport index as per Step 4 of the Transport of Radioactive Material procedure.

Step 6: Determine Labeling Requirements and UN Number

Determine the labeling requirements and UN number as per Step 5 of the Transport of Radioactive Material procedure.

Step 7: Fill in the TDG paperwork

Fill in the TDG paperwork as per Step 6 of the Transport of Radioactive Material procedure. Refer to Example 2, below, for an example of the completed paperwork.

Step 8: Placard the transport vehicle

Place the appropriate placard for the class of radioactive material on the transport vehicle (Step 5, Table 4 of Transport of Radioactive Material procedure).



CLASS 7 - DANGEROUS GOODS
(GROUND TRANSPORT ONLY)

Example 1

SHIPPER: Cameco Corporation

ERP NUMBER: ERP-2-0453

CONSIGNEE:

CARRIER:

24-HOUR EMERGENCY
TELEPHONE NUMBERS:
PH: (306) 956-6204 (Cameco)
Ibrl
PH: (613) 996-6666 (Camtec)

PRODUCT SHIPPING NAME	CLASS	UN NUMBER	VOLUME	NO. OF PIECES
Radioactive material, low-specific activity (LSA), n.o.s. (U-natural)	7	UN 2912	20 kg	2 Steel Drums
U-natural (drill core), solid				
Activity – 30 MBq				
labels – Radioactive Yellow II				
T.I. – 3				
Radioactive material, low-specific activity (LSA), n.o.s. (U-natural)	7	UN2912	50 kg	4 Steel Drums
Uranium Tailings, solid				
Activity – 220 MBq				
labels – Radioactive Yellow II				
T.I. – 6				
ADDITIONAL HANDLING INFORMATION: No special handling required.				
This is to certify that the above-named articles are properly classified, described, packaged, marked and labelled, and are in proper condition for transportation according to the applicable regulations of the Canadian Transport Commission.				

PLACARDS: 4-Class 7

SHIPPERS NAME (PRINT):

DATE:

SHIPPER'S SIGNATURE:

TRANSPORT B/L NUMBER:

CARRIER'S SIGNATURE:



CLASS 7 - DANGEROUS GOODS
(GROUND TRANSPORT ONLY)

Example 2

SHIPPER: Cameco Corporation

ERP NUMBER: ERP-2-0453

CONSIGNEE:

CARRIER:

24-HOUR EMERGENCY
TELEPHONE NUMBERS:
PH: (306) 956-6204 (Cameco)
for
PH: (613) 996-6666 (Canutec)

PRODUCT SHIPPING NAME	CLASS	UN NUMBER	VOLUME	NO. OF PIECES
Radioactive material, surface contaminated objects (SCO)	7	UN2913		1 steel Container
Low specific activity embedded on surface (U natural)				
activity – 344 Bq				
labels – Radioactive White I				
T.I. -				
Radioactive material, surface contaminated objects (SCO)	7	UN2913		
Low specific activity embedded on surface (U natural)				
activity – Bq				
labels –				
T.I. -				
ADDITIONAL HANDLING INFORMATION: No special handling required.				
This is to certify that the above-named articles are properly classified, described, packaged, marked and labelled, and are in proper condition for transportation according to the applicable regulations of the Canadian Transport Commission.				

PLACARDS: 4-Class 7

SHIPPERS NAME (PRINT):

DATE:

SHIPPER'S SIGNATURE:

TRANSPORT B/L NUMBER:

CARRIER'S SIGNATURE: