BC Centre for Disease Control
AN AGENCY OF THE PROVINCIAL HEALTH SERVICES AUTHORITY

Non-Medical X-ray Radiation Survey Guide

- for use by owners and operators -

Prepared by the Radiation Protection Services, BC Centre for Disease Control
Re: WorkSafeBC, Occupational Health and Safety Regulation, Part 7.24, "Radiation Survey"

Introduction

Non-medical x-ray equipment refers to all types of x-ray equipment using an x-ray generator operating at energies up to 1 MeV (million electron volt), but not those used for medical, dental chiropractic or veterinary purposes. Some examples are x-ray diffraction and spectrographic equipment and equipment used to examine material. This guide was developed to help owners carry out a radiation survey measuring radiation levels in the occupied work areas around the equipment.

This survey is different from and is not a substitute for the more thorough Safety Code radiation protection surveys referred to in the *WorkSafeBC Regulation*. The relevant Health Canada Safety Codes are available free of charge in "PDF' format on the Health Canada web site at: http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/index-eng.php#codes.

Radiation Survey

The intent of a "radiation survey" is to detect and measure radiation that is emitted from energized x-ray equipment and directed into occupied areas. The radiation survey determines whether or not the radiation emitted is resulting in workers getting more radiation exposure than expected.

Injuries from analytical x-ray equipment have occurred in the past to the hands and fingers of operators from the intense, localized primary x-ray beam(s), and the diffracted or scattered portions of the primary x-ray beam. If a person conducting the radiation survey of occupied work areas needs to survey close to x-ray unit, they must be competent and knowledgeable of the safety systems and safe survey procedures so that unintended hazards to themselves and others are not created.

Suitability of Instrument

The validity of a survey ultimately depends upon the survey instrument. There are a number of commercially available instruments that may be used for a radiation survey. Three of the more common instruments are the Geiger-Muller (GM) survey meter, the ion chamber survey meter and the sodium iodide (NaI)Tl scintillator. These survey meters, as well as detecting radiation leakage, can be calibrated to provide an indication of a worker's dose from exposure to the leaking radiation. The two most commonly used meters are the GM survey meter and the ion chamber survey meter. The GM meter can have excellent sensitivity for detecting low levels of radiation. The ion chamber meter is preferred for measuring the amount of radiation emitted principally because of its accuracy. Equipment manufacturers can be helpful in choosing the correct meter. When discussing the purchase of a meter, be as specific and detailed as possible about your intended use of the meter. The specifications of the survey meter are important. **Not all radiation-measuring survey meters measure all types and all energies of radiation!** GM meters are highly energy dependent and their use should be restricted to the **detection** of radiation only, not an **assessment** of the exposure or dose rate, unless the GM meter has been calibrated for the radiation energies expected.

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Before Conducting the Survey

☑ Have a survey meter able to measure the x-rays with the energies that your x-ray equipment produces. Check the detectable x-ray energy range listed in the specifications for the meter and make sure it is comparable to the energy range of the x-rays emitted by the x-ray equipment.

Note: X-ray machines produce x-rays with a range of energies from almost 0 keV (kiloelectron volt) to a maximum keV. "keV" is a unit of energy. This is not the same thing as the kV (kilovoltage) or kVp (kilovoltage peak) setting on the x-ray unit. kV and kVp are measurements of voltage on the x-ray tube, not the energy of the x-rays emitted.

However, the highest energy (keV) x-rays emitted by an x-ray machine is numerically equal to the voltage (kV) setting on the machine. The average (or effective) energy of the x-rays that will be emitted from the x-ray machine is numerically equal to about 1/3rd of the kV or kVp setting. An x-ray tube operating at 150kVp emits x-rays with an average (effective) energy of ~ 50 keV.

Example: Your x-ray equipment is currently set to run at 60 kV (or kVp). Which survey instrument below should you use?

A. XYZ Products 2000 Geiger-Muller survey meter with specifications that state that it will "detect gamma and x-rays with an energy response from 80 to 1500 keV".

B. ZXY Products 3000 ion chamber survey meter with specification that asserts that it will detect gamma and x-ray above 35 keV.

Do not use either of them! The average energy of the x-rays coming from the x-ray equipment is 1/3 rd of 60 kVp = 20 keV. Neither of the meters can detect x-rays of this low energy. If you used one of these meters, while it might appear to be working normally by indicating background radiation, it will not detect most of the x-rays emitted from the x-ray unit.

☑ Choose a survey meter that is able to indicate the WCB OH&S regulation Action level for workers, of 1 milliSievert (mSv) per year.

Note: It is easier to detect the presence of radiation than it is to estimate effective dose of an exposed worker. The survey meter must be calibrated for the x-ray energy being measured before it can be used to make an accurate estimate of worker effective dose. Also the action level is on a per year basis whereas survey meters usually indicate the radiation levels on a "per hour" basis.

Example: A survey meter indicates a reading of 0.003 mSv per hour (3 μSv/h) at a workers normal work location. Does this level exceed the action level of 1 mSv per year?

Since the action level is an annual exposure level, it depends upon how long the worker is exposed. A worst-case estimation may be made by assuming that the worker is constantly exposed while working. For a worker working 8 hours per day, 5 days per week and 50 weeks per year, the action level would be 1 mSv per year divided by the total number of hours in a year or 1/ (8 x 5 x 50) = 1/2000= 0.0005 mSv/hr or 0.5 μSv/hr (microSievert per hour). In the worst case then, this worker could exceed the action level. At this point one should make a more realistic estimate of the worker's exposure time and redo the calculation. Further reduction of the estimated effective dose value due to partial body exposure should not be made without expert assistance.

Instrument Check and Background Radiation

A practical way to check that your survey meter is operating as expected is to measure a known source of radiation each time you use your meter. It is useful to have a small radioactive "check source". One can sometimes be purchased from a survey meter supplier. Some survey meters come with a check source attached. A thorium based lantern mantle or other radioactive source will also work for GM survey meters and some ion chamber survey meters.

When the survey meter is new or immediately after the meter has been calibrated, measure the radiation from the "check source" at one or two fixed distances and record the readings on the survey meter along with the distances. A normally functioning meter should continue to indicate the same amount of radiation at each of these distances. This is an operational check; **not a calibration.** Follow the manufacturer's instructions on how often to have your meter calibrated.

Practice using your survey meter to measure the check source and background radiation. Background radiation is a random process. It averages less than approximately 0.1μSv/hr (0.01mR/hr) in BC. The background level will be higher for areas of higher altitude and wherever radium, uranium or other radioactive elements are found in the soil. Some ion chamber meters cannot measure this low level. Try to get a "feel" for measuring background radiation and use the check source to increase your skill at detecting radiation.

Survey of Worker Occupied Areas

- Do not assume that your x-ray machine does not leak. Occasionally shielding has been inadvertently left out during assembly and when the x-ray machine was modified or serviced. Satisfy yourself that the equipment is not presenting a radiation hazard to you or others.

1. If you have a personnel dosimeter assigned to you, place it at your waist or chest level.
2. Turn on your survey meter.
    - Check the battery and replace batteries if indicated.
    - If there is an audio switch turn it to "ON."
3. With the x-ray equipment off, practice measuring background radiation with your survey meter if it is designed to do so. If your survey meter normally reads background radiation but this time it is not, then do not use it. Check for old batteries in the battery compartment.
4. Next measure the "check source" at one of the distances chosen previously and note the readings on the meter. Do not use the survey meter if it does not read within about 10 - 20% of the expected reading.
5. With the survey meter on, turn on the x-ray equipment and set the x-ray machine for the highest kV (or kVp) normally used, but choose a very low current (mA). Immediately make a broad sweep around the just to see if there are any high fields. If nothing is found survey the areas that are normally occupied by workers. If you do measure levels significantly above the reading equal to the Action Level, move back from the x-ray unit immediately until you find a position where the readings are equal to the Action Level value. Record this level and location. Ensure that you do not spend more than an hour in levels that are up to a hundred times the hourly rate equivalent of the Action Level value. If measured levels exceed one hundred times the Action Level equivalent value,

immediately terminate the survey, and have the x-ray unit turned off and taken out use. Do not bring the unit back into use until repaired.

Note: In some situations workers are free to move about around the x-ray equipment so that the area normally occupied can be all around the x-ray equipment. In this case it may be more efficient for you to scan the x-ray equipment for leakage rather than all possible worker areas. If so, place the meter about 5-cm away from the surface of the equipment and move the survey meter slowly over all external surfaces of the x-ray unit. A scan rate of about 2-3 cm per second should allow detection of leaks from the equipment above the normal background rate. Survey all sides of the x-ray equipment including areas you suspect could not leak and pay particular attention to seams and joints. Include the top of the equipment in your scan. The bottom can be ignored if the unit is not located above an occupied area. If the space between the undersides of the x-ray unit is inaccessible for the survey meter, go to the floor below and survey the ceiling.

6. Remember that the survey meter only indicates radiation incident upon the detecting area and some detectors are directionally dependent. During the x-ray survey pay close attention to the audio indication and/or visual indicator of your survey meter.
7. If nothing is found with low mA, slowly increase the mA in a series of steps and repeat the survey in areas that are normally occupied by workers to check whether there are leaks at higher mA settings. Continue this way until you reach the highest kV (or kVp) and mA settings normally used.

Note: x-rays of higher kV penetrate through shielding more easily than low kV x-rays. Higher mA settings create more radiation than lower mA settings at the same kV (or kVp) setting.

8. If the meter indicates levels of radiation above normal background, record the indicated level so that a determination of a worker's effective dose and/or equivalent dose can be made. (See item 5 above where excessive levels are observed, for your protection).
9. Always ensure that the instrument is turned OFF when not being used. This will preserve the batteries.
10. Report the findings to the responsible owner/operator.

When should a Survey be Conducted?

Some workers briefly survey their work location and the x-ray equipment at the start of every use. A survey must be conducted every 2 years and immediately after damage, maintenance, alterations or repairs, when there is an indication of an unusually high exposure of a worker to ionizing radiation, or when specified in the equipment manufacturer's instructions.

Radiation Survey

Date of Survey:_____ Surveyor Name: _____

X-ray Unit: Manufacturer: _____

Model #: _____ Serial #: _____

Maximum Test kV (or kVp): _____ Maximum Test mA: _____

Survey Meter

Model: _____ Serial #: _____

Survey Meter Reads in Unit of: _____

Date of Last Calibration: _____

Background Reading: _____ Check Source Test OK? _____

Sketch the layout of the x-ray unit and areas of maximum reading on the back of this sheet.

Maximum Reading at Worker 1 Area: _____

Describe Location of Worker 1 Area: _____

_____

Maximum Reading at Worker 2 Area: _____

Describe Location of Worker 2 Area: _____

_____

Maximum Reading at Worker 3 Area: _____

Describe Location of Worker 3 Area: _____

_____

Exposure/Effective Dose Calculation: _____

_____

Recommendations: _____

_____

_____

_____

Sketch