1. Summary

This Report is concerned with the protection of individuals who may be exposed to radiation emitted by x-ray equipment and both sealed and unsealed radioactive sources in the practice of veterinary medicine. To the extent that the animal patient exposure is reduced, there is usually a proportional decrease in the occupational exposure to personnel.

The Report provides guidance for the development of an effective radiation safety program and recommendations for the design of radiological facilities and for the use of radiographic, fluoroscopic and therapeutic equipment in veterinary medicine. Included are recommendations for the use of radiopharmaceuticals in diagnosis and therapy, and for the use of lasers and ultrasonic equipment.

The National Council on Radiation Protection and Measurements (NCRP) provided recommendations for the limitation of exposure to ionizing radiation in Report No. 116 (NCRP, 1993). These recommendations are designed to achieve the objectives of radiation protection: (1) to prevent the occurrence of clinically significant acute radiation damage, and (2) to limit the risk of stochastic effects such as cancer and genetic effects. Radiation exposure to individuals from external radiation sources may be controlled and limited by any one or any combination of the following measures: (1) increasing the distance of the individual from the source (distance), (2) reducing the duration of exposure (time), and (3) using protective barriers between the individual and the source (shielding). For x- and gamma-ray equipment used by veterinarians, shielding and distance are the factors most readily controlled. Exposure to dispersed radioactive material from unsealed sources can be controlled and limited by using precautions in the handling of these materials.

Although x-ray machines are widely used in veterinary medicine, the workload, and thus the potential exposure of both the practitioner and the technical assistants is, on the average, low. However, because practices such as restraining animals and holding film cassettes introduce risks of unnecessary exposure of staff, special attention is given in this Report to proper practices.

Radiation safety program requirements are specified in Section 3. In summary, this radiation safety program *should* be commensurate with the hazards to personnel and to the general

public, *should* be well documented, and *should* be reviewed on a regular basis to determine whether it continues to meet the operational needs and is effective. All veterinary personnel *shall* receive training in radiation safety commensurate with the individual's anticipated risk from radiation exposure. Individual monitoring will be required for some staff. However, when the number of staff is small, it is reasonable to provide individual monitoring for all employees. It is not likely that the potential for exposure to dispersed radioactive material will be sufficient to require a bioassay program to assess internal exposure. However, at veterinary facilities where ^{131}I is used for radiation therapy, consideration *should* be given to instituting periodic thyroid counting of potentially exposed persons.

Surveys to evaluate the radiation safety characteristics of x-ray machines and gamma-ray irradiators are necessary and are especially required for all new installations. Radiation safety surveys *shall* be made when radioactive materials are administered to animals. Although unlikely to be necessary, air sampling *should* be performed when appropriate to determine whether individuals caring for the animals are subjected to airborne contamination and whether bioassay is indicated.

Warning signs, including instructions written in "plain" and unambiguous language, *shall* be used for radioactive material containers, radiation-producing devices, animal cages and pens, stalls, laboratories, and other areas in which radioactive materials or radiation-producing devices are used or stored.

Recommendations for the design of facilities that use fixed and portable radiographic and fluoroscopic equipment, therapy equipment, and radionuclides are detailed in Section 4. For radiographic and fluoroscopic facilities, the required shielding barriers *should* be an integral part of the building or permanently affixed to the equipment. In the event that movable or portable barriers are required due to multiple uses of the room or mobile applications, the operators *shall* receive specific training in the placement of the shields.

Structural shielding design for x- and gamma-ray equipment used for therapy and operating at energies up to 10 MeV is approached in a somewhat different way than the design for diagnostic x-ray equipment, although the same basic model is used. Leaded wallboard can be used to shield interior walls of diagnostic radiographic and therapy facilities operating at $\leq$150 kVp. For x-ray therapy facilities with operating potentials >150 kVp and for gamma-ray facilities, poured or precast concrete is generally the preferred shielding material. Under some circumstances lead and steel can also be used.

The models used to determine shielding requirements are discussed in Section 4. The basic concepts and terminology used in the design of shielding barriers include the *shielding design goals*, the *workload* for the x-ray unit, the *distances* to the areas to be shielded, *occupancy factors* for the areas to be shielded, and the *use factor*. These quantities are defined in the Glossary and examples of their use are given in Appendices A and B.

The selection of shielding design goals is based on the recommendations of NCRP (2004) for controlled and uncontrolled areas. It is clear that implementation of the shielding design goals requires that the management of each facility evaluate the use of its space relative to exposure of its employees and members of the public. A discussion on shielding design goals is presented in Section 4.1.5.1.

For diagnostic facilities, shielding requirements for barriers are given in Appendix A of this Report for lead, gypsum wallboard, and concrete. Typical workloads and operating potentials for veterinary facilities indicate that primary barriers would rarely exceed 3.2 mm (1/8 inch) of lead for both controlled areas and uncontrolled areas. For therapy facilities, shielding requirements for barriers are given in Appendix B of this Report for lead, steel and concrete.

Recommendations for the design features for facilities in which the handling and administration of unsealed radioactive materials take place are based on those unique aspects of the radioactive materials that will be used. Design considerations include preventing or facilitating the removal of contamination, minimizing exposure, preventing airborne and sanitary sewer contamination, and providing for safe and effective radioactive waste disposal.

When animals receive high administered activities of gamma-ray-emitting radionuclides, such as radioiodine for treatment of thyroid cancer, facility walls *should* be shielded to control radiation levels in surrounding occupied areas. In some instances, it would be acceptable to use mobile shields positioned close to the animals or their holding cells to protect areas of concern.

Individuals who handle radioactive materials for administration to animals *shall* be protected from unnecessary exposure. Shields shaped like an "L," with a lead base and a lead wall between the source and the radiation worker, can provide substantial reduction of potential doses to the worker and specific shields are indicated for syringes used to inject radioactive materials.

Almost all radionuclides used in veterinary practice have a half-life <120 d and lend themselves to decay-in-storage as an effective and safe method of disposal. However, waste radionuclides with half-lives >120 d might have to be processed for transfer to a

commercial disposal facility. Radioactive animal carcasses present a special problem as radioactive waste because there is not a shallow land disposal facility that will accept them. For disposal at a licensed radioactive waste disposal facility, animal carcasses are first incinerated at a licensed facility that has the capability of retrieving the radionuclides in ash and processing the ash in a manner that makes it acceptable for shallow land disposal. For those carcasses that can be processed *via* decay-in-storage, the carcasses can be disposed in the manner used for nonradioactive carcasses. However, steps *shall* be taken to ensure that animals used in radionuclide experiments are not subsequently consumed by human beings.

A qualified expert (see Glossary) *shall* evaluate the shielding and radiation safety requirements of any new or modified installation (*i.e.*, room redesigns or changes in shielding configurations) prior to the use of the facility (NCRP, 2004). The evaluation will normally involve direct measurements of the radiation transmitted through each of the shielding barriers. The measurement results *shall* be used to confirm that the shielding design goals have not been exceeded and therefore the respective annual values for effective dose recommended for controlled and uncontrolled areas (NCRP, 2004) have not been exceeded. Visual inspection during construction is important to verify that the specified type and thickness of shielding material and the safety systems are properly installed.

Sections 5, 6 and 7 present details of the design, performance and operation of radiographic [including computed tomography (CT)] (Section 5), fluoroscopic (Section 6), and radiotherapy equipment (including brachytherapy sources) (Section 7), that relate to radiation safety and the protection of staff and visitors. Quality-assurance procedures for radiographic applications (*i.e.*, x-ray equipment used for imaging) are given in Appendix C.

Section 8 covers radiation safety considerations, emergency response, and waste disposal related to the use of radiopharmaceuticals. Radiation safety includes exposure and contamination control, shielding and monitoring of personnel. Quality-control procedures for nuclear medicine components are given in Appendix C. The appropriate steps to control an emergency involving the release of radioactive materials are discussed. Section 8.3 on waste disposal includes a discussion of the types of waste that will be generated and their appropriate disposal. Also, recommendations are given for the use of radiopharmaceuticals in animals, and guidelines for an owner after treatment of an animal with radioiodine therapy are given in Appendix D.

Section 9 covers the nonionizing radiation safety and other associated safety concerns related to the use of lasers and ultrasound in veterinary medicine. For lasers, this includes eye damage and skin burns as well as electrical, fire and hazardous material precautions. With respect to ultrasound, both thermal and nonthermal biological effects are briefly discussed. Considerations are presented for the reasonable use of ultrasound for diagnostic and therapeutic purposes.