5.2 PHYSICAL HAZARDS

5.2.1 Heat

5.2.1.1 Hazard Location

The laundry, boiler room, and kitchen are known as hot environments. Other departments of the hospital may also be hot during the summer months, especially in older facilities that have inadequate ventilation and cooling systems.

5.2.1.2 Potential Health Effects

Heat-related health effects include heat stroke, heat exhaustion, heat cramps, fainting, and heat rash (NIOSH 1986b).

5.2.1.2.1 Heat stroke

Heat stroke is the most serious heat-related health effect; it results from a failure of the body's temperature regulating mechanism. The victim's condition may be characterized by hot, dry skin, dizziness, headache, thirst, nausea, muscular cramps, mental confusion, delirium, convulsions, or unconsciousness. Body temperature may exceed 105°F (41°C). Unless quick and proper treatment is rendered, death may occur.

Workers with any of these symptoms should be immediately removed to a cool area and attempts should be made to reduce body temperature by soaking the clothing thoroughly with water and fanning vigorously. A physician should be called immediately.

5.2.1.2.2 Heat exhaustion

Heat exhaustion is caused by the loss of large amounts of fluid and sometimes by the excessive loss of salt through sweating. The symptoms of heat exhaustion resemble those of heat stroke, but unlike the latter, the symptoms are milder and victims sweat and have a body temperature that is normal or only slightly elevated.

Victims of heat exhaustion should be removed to a cool place and given large amounts of liquids to drink. In mild cases, recovery is usually spontaneous with this treatment. Severe cases require the attention of a physician and may take several days to resolve.

5.2.1.2.3 Heat cramps

Heat cramps are painful muscle spasms that occur from salt loss through sweating and from the dilution of body fluids through drinking large quantities of liquids. The cramps usually occur in those muscles that are being used for work. Cramps may occur during or after work and may be relieved by drinking salty liquids. Workers on low sodium diets should consult a physician before beginning work in a hot environment.

5.2.1.2.4 Fainting

One mechanism for dissipating body heat is dilatation of blood vessels, which may cause fainting when blood pools in the legs and reduces circulation to the brain. This problem may affect unacclimatized workers who spend much of their time standing with little movement. Recovery may be hastened by placing the victim on his back with the legs elevated. Workers who must stand for long periods can prevent fainting by moving around.

5.2.1.2.5 Heat rash

Heat rash (prickly heat) results when the skin remains wet with sweat for prolonged periods and evaporation is reduced or absent. These conditions cause the sweat glands to become plugged and irritated, leading to development of a rash. Although it is not a health threatening condition, heat rash may be sufficiently irritating to impair the worker's performance. Heat rash can be prevented by keeping the skin dry and clean.

5.2.1.3 Standards and Recommendations

NIOSH has recommended an occupational standard for workers exposed to hot environments (Figures 5-1 and 5-2) (NIOSH 1986a). The standard includes recommendations for exposure limits, medical surveillance, posting of hazardous areas, protective clothing and equipment, worker information and training, methods for controlling heat stress, and recordkeeping. The recommendations consider both acclimatized and unacclimatized workers and the effects of clothing. The recommended exposure limits are based on the combined effects of metabolic and environmental heat (NIOSH 1986a). Table 5-3 provides data for estimating metabolic heat.

The values in Table 5-3 can be used to calculate the approximate total metabolic heat (H_t) consumed by a worker performing various tasks.

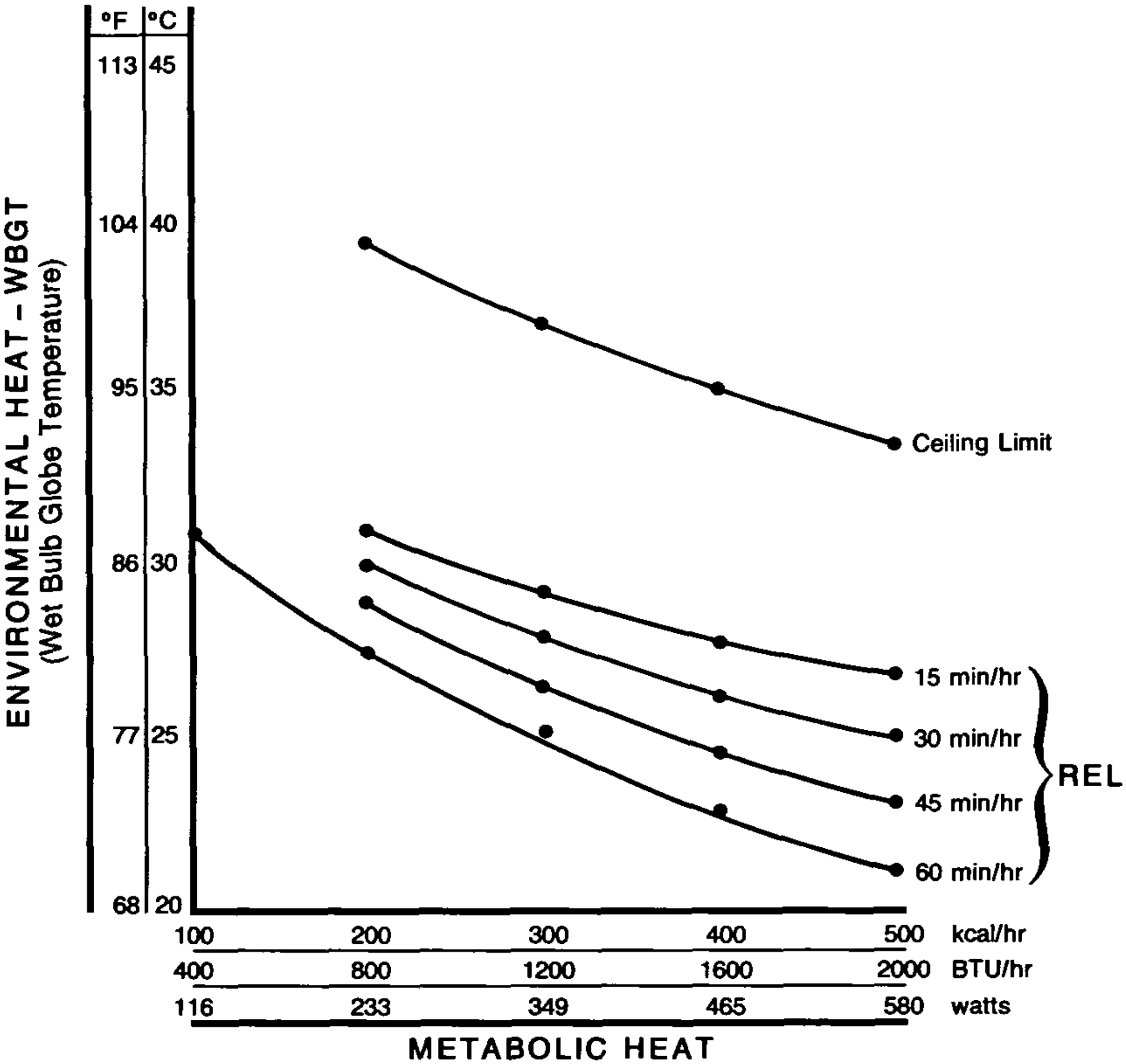

Figure 5-1. Recommended exposure limits (REL) for unacclimatized workers. Data assume a standard worker having a body weight of 154 lb (70 kg) and a surface area of 19.4 ft^2 (1.8 m^2). Adapted from NIOSH 1986a.

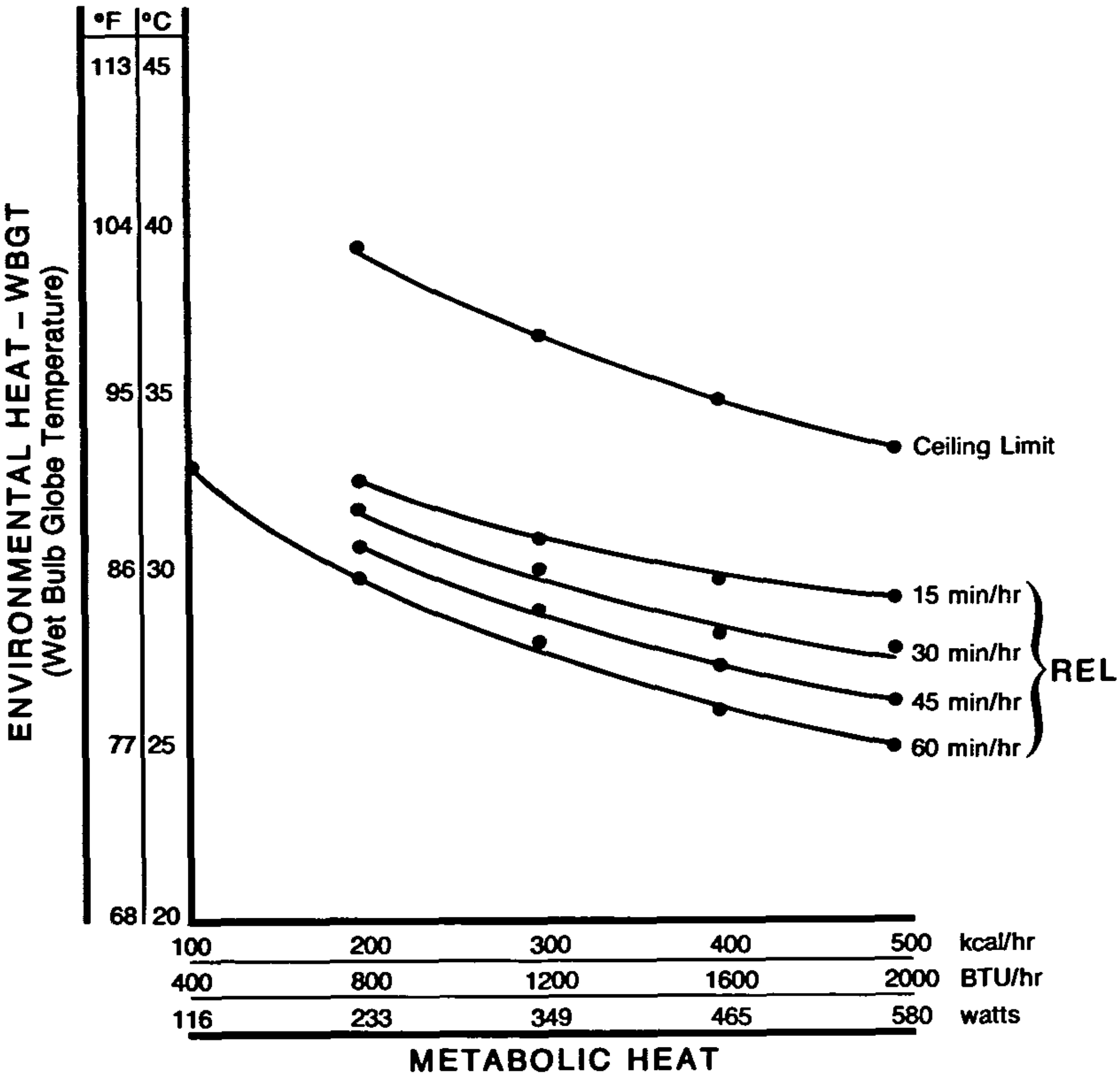

Figure 5-2. Recommended exposure limits (REL) for acclimatized workers. Data assume a standard worker having a body weight of 154 lb (70 kg) and a surface area of 19.4 ft^2 (1.8 m^2). Adapted from NIOSH 1986a.

Table 5-3. Approximate energy consumption of a standard* worker during various work tasks†

Activity or work task	Average kcal/hr
Body position and movement:	
Sitting	18
Standing	36
Walking on a level surface	150
Walking uphill	To 150, add 48 for every meter of rise
Type of work:	
Hand work:	
Light	24
Heavy	54
One-arm work:	
Light	60
Heavy	108
Two-arm work:	
Light	90
Heavy	150
Whole-body work:	
Light	210
Moderate	300
Heavy	420
Very heavy	540
Basal metabolism	60

*A standard worker is assumed to have a body weight of 154 lb (70 kg) and a surface area of 19.4 ft^2 (1.8 m^2).

†Adapted from NIOSH 1986a.

Total metabolic heat is calculated using the following formula:

$$H_t = H_m + H_w + M_b$$

where H_t = total metabolic heat (kcal/hr)
H_m = heat of movement (kcal/hr)
H_w = heat of work (kcal/hr)
M_b = basal metabolism (1 kcal/hr)

For example, a worker who is standing and using both arms to perform a task would be producing metabolic heat as follows:

H_m standing = 36 kcal/hr
H_w for two arms = 150 kcal/hr
M_b = 60 kcal/hr

Thus

H_t = 36 kcal/hr + 150 kcal/hr + 60 kcal/hr = 246 kcal/hr

The metabolic heat is used with the wet bulb globe temperature to determine exposure limits for work (Figures 5-1 and 5-2).

5.2.1.4 Environmental Monitoring

The most common and direct way of measuring heat exposure is with wet bulb and globe thermometers and the wet bulb globe temperature (WBGT) index. The WBGT index combines the effects of radiant heat and humidity with the dry bulb temperature. This method is inexpensive and simple (NIOSH 1986a).

5.2.1.5 Exposure Control Methods

A good source of general information on the health effects and control of occupational heat exposures is Criteria for a Recommended Standard: Occupational Exposure to Hot Environments (NIOSH 1986a). Listed below are some specific steps for reducing heat stress in hospital workers exposed to hot work areas (NIOSH 1986a; NIOSH 1986b):

- Schedule heavy work for the coolest part of the day and allow frequent rest breaks in cool areas.
- Isolate, enclose, and/or insulate hot equipment.
- Install exhaust ventilation to draw heat or steam away from the work area.
- Install reflective shielding where appropriate.
- Provide fans to increase sweat evaporation.
- Make cool water available.
- Provide cool areas for rest breaks and lunches.
- Train workers to recognize symptoms of heat stress.

- Permit workers who are new or returning from vacation or illness to become acclimatized to the hot environment. Heat acclimatization can usually be accomplished in 5 to 7 days while working in a hot job (NIOSH 1986a).

5.2.2 Noise

Noise is any unwanted sound; it is created by sound waves, which are rapid vibrations in the air. Sound has three characteristics: frequency (pitch), amplitude (intensity), and perceived loudness. Frequency is measured in cycles per second, or Hertz (Hz), and sound intensity is measured in decibels (dB). The decibel scale is a logarithmic measure of intensity. When a sound increases by 10 dB, it is 10 times as intense and is perceived as being twice as loud. Loudness, unlike intensity, is a subjective perception of sound and cannot be measured by instrument.

5.2.2.1 Hazard Location

Exposure to high levels of noise in the workplace is one of the most common job hazards, and despite the popular image of hospitals as quiet zones, they can be noisy places. In a 1979 survey of noise levels in 26 hospitals, five work areas were identified as noisy enough to reduce productivity (Seidletz 1981): the food department, laboratory, engineering department, business office or medical records department, and nursing units.

5.2.2.2 Potential Health Effects

The ear changes air pressure waves into nerve impulses that the brain interprets as sound. Hair cells in the inner ear stimulate nerves that carry the message to the brain. Loud noise damages these nerves and decreases hearing acuity. This decrease is called a temporary threshold shift. Such shifts can be reversed if there is enough rest from high noise levels, but exposure to loud noise for many years leads to irreversible hearing loss. Very loud noises of short duration, such as gunfire, can cause a permanent hearing decrement.

Noise may also trigger changes in cardiovascular, endocrine, neurologic, and other physiologic functions, all of which suggest a general stress reaction. These physiologic changes are typically produced by intense sounds of sudden onset, but they can also occur under sustained high-level or even moderately strong noise conditions. Whether repeated noise-induced reactions of this type can ultimately degrade one's physical and mental health is still uncertain. There are some reports that show that prolonged exposure to high-level noise may lead to physiologic disorders in animals (NIOSH 1972).

In addition to adverse health effects, work in high-noise areas makes it difficult for workers to communicate among themselves, either to relate socially or to warn others of impending danger (e.g., falling equipment or a slippery floor) or to concentrate on critical job functions.

5.2.2.3 Standards and Recommendations

The OSHA occupational exposure limit for noise is 90 dB measured on the A-weighted scale* (90 dBA) as an 8-hr TWA (29 CFR 1910.95). Because the noise exposure limit is time-weighted, the amount of time workers are permitted to spend in a noise exposure area varies according to the noise level, as follows:

Hours of exposure per workday	Permissible noise level (dBA)
8	90
6	92
4	95
3	97
2	100
1	105
0.5	110
0.25	115

For more detailed information on determining and complying with the OSHA noise standard, refer to 29 CFR 1910.95. This standard was amended in 1983 to require that employers document any worker exposures to noise levels equal to or greater than an 8-hr TWA of 85 dBA. If workers are exposed to higher noise levels, employers must administer a continuing hearing conservation program as cited in the OSHA standard. An important part of this program is the requirement for an audiometric testing program.

5.2.2.4 Environmental Monitoring

The OSHA publication Noise Control: A Guide for Workers and Employers (OSHA 1983) is a helpful guide for establishing a noise monitoring and control program. The standard sound level meter is the basic noise-measuring instrument; however, there are noise dosimeters that can measure the integrated (daily) noise exposure.

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*The A-weighted scale approximates the frequency response of the human ear.

5.2.2.5 Exposure Control Methods

5.2.2.5.1 Noise abatement programs

A noise survey should be made by trained personnel. If a worker's noise exposure exceeds the standard, a noise abatement program is required. Such a program should include periodic noise measurement, engineering and administrative controls, hearing protection for use while controls are being implemented, and annual audiometric testing.

5.2.2.5.2 Engineering controls

The goal of the hearing conservation program should be to develop engineering controls to reduce noise exposure. Engineering controls could include enclosure of noisy equipment, acoustical treatment of walls to reduce noise reflection, vibration damping of noisy machines, and replacement of metal-to-metal contact with synthetic material-to-metal contact. Administrative controls can also be used to limit a worker's exposure time to excessive noise.

5.2.2.5.3 Hearing protection devices

If engineering or administrative controls are not feasible, or if they are in the process of being implemented, hearing protection is required. Many forms of hearing protection are available, including ear muffs and ear plugs. Some are more effective than others depending on the noise level, frequency, and individual fit of the devices. Protection must be effective but reasonably comfortable.

5.2.2.5.4 Methods for reducing noise levels in various departments

5.2.2.5.4.1 Food department

The following methods can significantly reduce noise within the food department and still allow sanitary requirements to be met (Seidletz 1981):

- Mount table-top equipment on rubber feet or pads.
- Install sound-absorbent floor tiles.
- Isolate dishwashing areas when dishwasher noise cannot be reduced.
- Use acoustical ceiling tiles, wall hangings, and carpets to reduce cafeteria noise.

- Place rubber matting on landing tables (for scraping dishes) and in the steam table area.
- Install sealing around doors.

5.2.2.5.4.2 Office areas

Noise levels in office areas generally average 68 to 75 dBA. The use of padding under typewriters and sound-absorbing wall hangings reduced noise levels by 13 to 18 dB (Seidletz 1981).

5.2.2.5.4.3 Engineering department

In engineering departments, noise levels range from 78 to 85 dBA, with short bursts as high as 100 dBA. Noise levels around hospital generators may reach 110 dBA. Significant noise reduction can be achieved by isolating the generator area and installing mufflers and using sound-absorbing materials wherever possible (Seidletz 1981).

5.2.2.5.4.4 Nursing units and laboratories

Noise in nursing units and laboratories results from sources such as the ventilation system, intercom system, door closings, telephones, food service carts, radios, televisions, and conversations among staff, patients, and visitors. The results of a hospital noise survey showed that noise levels interfered with speech during the day and with sleep at night (Turner et al. 1975).

Most noise in nursing areas and laboratories can be simply and economically eliminated by the following methods (Turner et al. 1975):

- Decrease the volume of intercom speakers, televisions, and radios.
- Lubricate wheels, hinges, and latches.
- Adjust closers on doors to prevent slamming.
- Use sound-absorbent materials wherever possible.
- Make the staff aware of noise problems and secure their cooperation.

5.2.2.6 Medical Monitoring

As mentioned earlier, the OSHA noise standard (29 CFR 1910.95) requires audiometric testing (at least once a year) for all workers exposed to noise levels equal to or greater than an 8-hr TWA of 85 dBA.

5.2.3 Ionizing Radiation

5.2.3.1 Types of Ionizing Radiation

Ionizing radiation is part of the natural environment, and since the discovery of X-rays and radioactivity, it has become part of the work environment as well (NIOSH 1977d). Radiation is measured and defined as follows (SI units are given in the definitions):

Curie. . . . . A measure of a substance's radioactivity. 1 curie (ci) = 3.7×10^{10} disintegrations per second.

Absorbed Dose. . . . . . The amount of radiation that the body absorbs.

Exposure . . . . The amount of radiation to which the body is exposed.

Radioactive half-life. . The time required for the radioactivity of an isotope to decrease by 50%.

Rem (rem). . . . . Acronym for roentgen equivalent man--the dosage of any ionizing radiation that will cause biological injury to human tissue equal to the injury caused by 1 roentgen of X-ray or gamma-ray dosage. 1 rem = 0.01 sievert (SV).

Millirem (mrem). . . . . 10^{-3} rem. 1 mrem = 0.01 mSV.

Rad. . . . . Acronym for radiation absorbed dose--a unit that measures the absorbed dose of ionizing radiation. 1 Rad = 100 ergs/gm = 0.01 Gray (Gy).

Roentgen . . . . Unit of measure for quantity of ionization produced by X-radiation or gamma radiation. 1 Roentgen (R) = 2.58×10^{-4} coulomb/kg.

The different types of ionizing radiation vary in their penetrative powers as well as in the number of ions they produce while traversing matter.

Ionizing radiation is produced naturally by the decay of radioactive elements or artificially by such devices as X-ray machines. A radioactive element is one that spontaneously changes to a lower-energy state, emitting particles and gamma rays from the nucleus in the process. The particles commonly emitted are alpha or beta particles. X-rays are produced when high-energy electrons strike the nuclei of a suitable target, such as tungsten. When these fast-moving electrons approach the electrical field around the nuclei of the target material, the electrons are deflected from their path and release energy in the form of high-energy electromagnetic radiation (X-rays).

Alpha particles usually have energies of 4 to 8 million electron volts (MeV). They travel a few centimeters in air and up to 60 microns into tissue. The high energy and short path result in a dense track of ionization along the tissues with which the particles interact. Alpha particles will not penetrate the stratum corneum of the skin, and thus they are not an external hazard. However, if alpha-emitting elements are taken into the body by inhalation or ingestion, serious problems such as cancer may develop. Radium implants (radium-226 and radium-222) are examples of alpha particle emitters that may be used in hospitals.

Beta particles interact much less readily with matter than do alpha particles and will travel up to a few centimeters into tissue or many meters through air. Exposure to external sources of beta particles is potentially hazardous, but internal exposure is more hazardous. Examples of beta-particle emitters are the isotopes carbon-14, gold-198, iodine-131, radium-226, cobalt-60, selenium-75, and chromium-51.

Protons with energies of a few MeV are produced by high-energy accelerators and are quite effective in producing tissue ionization. The path length of a proton is somewhat longer than that of an alpha particle of equivalent energy.

X-rays generally have longer wavelengths, lower frequencies, and thus lower energies than gamma rays. The biologic effects of X-rays and gamma rays are better known than those of any of the other ionizing radiation. X-rays may be encountered during the use of electronic tubes and microscopes. Examples of gamma emitters are cobalt-60, cesium-137, iridium-192, and radium-226.

5.2.3.2 Sources of Radiation Exposure

In the United States, natural radiation results in an estimated average dose of about 125 mrem each year (Hamilton and Hardy 1974). In 1973, NIOSH estimated that medical and dental irradiation of patients in diagnostic and therapeutic procedures produced an average dose of 50 to 70 mrem per person per year in addition to natural radiation (NIOSH 1973c).

5.2.3.3 Hazard Location

Radiation exposure usually results from (1) the scatter of X-ray beams caused by deflection or reflection from the main beam, or (2) the emission of gamma rays by patients who are being treated with radionuclides or have therapeutic implants that emit gamma and beta radiation.

Ionizing radiation is used in the hospital for (1) diagnostic radiology, including diagnostic X-ray, fluoroscopy and angiography, dental radiography, and computerized axial tomography scanners (CAT scanners), (2) therapeutic radiology, (3) dermatology, (4) nuclear medicine in diagnostic and therapeutic procedures, and (5) radiopharmaceutical laboratories. A radiation hazard may also exist in areas where radioactive materials are stored or discarded. Radiation safety is usually well managed in diagnostic and therapeutic radiology units by the radiation protection officer. Staff in departments where portable X-rays are taken (operating rooms, emergency rooms, and intensive care units) are often inadvertently exposed and inadequately monitored for the effects of radiation exposure.

5.2.3.4 Types and Amounts of Radiation Exposure

The conditions presented by external radiation sources are entirely different from those presented by internal sources. Radiation can be deposited in the body as a result of accidental skin puncture or laceration and subsequent contact with radioactive material. Once inside the body, radionuclides can be absorbed, metabolized, and distributed throughout the tissues and organs. The extent of the effects of radiation on organs and tissues depends on the energy and type of radiation and its residence time in the body (biological half-life) and the radioactive half-life of the radioisotope. But the principal hazard presented by internal radiation sources is the continuous irradiation of cells.

The amount of external radiation received depends on the amount of radiation present, the duration of the exposure, the distance from the source to the worker, and the types of barriers between the source and the worker. The effects of radiation from external sources depend on the energy. Unless alpha and beta particles are inhaled or ingested, they are of little concern since they are low energy sources that do not penetrate the outer tissues. Gamma radiation is also rapidly attenuated.

Radiation workers in hospitals receive an annual average dose of radiation that ranges from 260 to 540 mrem. Twelve percent of dental personnel had an average annual exposure of 41 mrem, and 98% had exposures of less than 500 mrem (0.5 rem) (National Research Council 1980).

Nuclear medicine technicians who assist in many procedures during a single day may have higher exposures than others who handle radioactive materials. For example, technicians involved in nuclear cardiovascular studies can receive exposures of 2.5 mrem/hr (Syed et al. 1982). Radio-pharmaceuticals have been found contaminating the hands, wrists, lab coats, and urine of technicians and laboratory workers studied (Nishiyama et al. 1980).

Angiography is an activity of particular concern. Exposures during these procedures have ranged from 1 to 10 mrems inside the lead apron, and eye exposures have ranged up to 57 mrem (Santen et al. 1975; Kan et al. 1976; Rueter 1978).

5.2.3.5 Potential Health Effects

Radiation produces acute effects as well as delayed injuries. The degree of radiation damage depends on which organs and tissues are radiated. In general, the effects of radiation exposure are cumulative.

5.2.3.5.1 Acute effects

Occupational exposure to ionizing radiation is usually localized and can lead to erythema or radiodermatitis. An acute radiation syndrome episode occurs very rarely. Such an episode involves whole-body exposure exceeding 100 roentgens during a very short period. Persons with this syndrome usually suffer from nausea, vomiting, diarrhea, weakness, and shock. Following a latent period of 2 to 14 days, symptoms of fever and malaise occur and hemorrhagic lesions of the skin often appear. By the third week, epilation occurs. Internal and external ulceration may appear over the entire body, and bloody diarrhea may occur. Death may result from severe bone marrow depression if the radiation exposure level is high. If the person survives the toxic stage, recovery usually begins by the fifth or sixth week and is essentially complete after a long period (NIOSH 1977d).

A very high dose of radiation can produce symptoms of cerebral edema within minutes and death within 24 hr.

5.2.3.5.2 Chronic effects

Evidence continues to accumulate that low levels of radiation can cause biological damage. Researchers differ over the amount of radiation that is hazardous, but any amount of radiation is assumed to involve some risk. Workers should therefore avoid any radiation exposure. Variables such as age, sex, cigarette smoking, genetic makeup, state of health, diet, and endocrine status may modify the effects of ionizing radiation.

Ionizing radiation can cause gene mutation and chromosomal alteration; it can also delay or impair cell division and interfere with metabolic processes. Cells that normally divide rapidly (e.g., the blood-forming tissues, skin, gonads, and eye lenses) are usually more severely affected than the slower-dividing cells (e.g., the bones, endocrine glands, and nervous system).

Other somatic effects that result from irradiation include several types of cancers (myelogenous leukemia, bone, skin, and thyroid in children), lung and kidney fibrosis, lens opacities (cataracts), aplastic anemia, sterility, radiodermatitis, and shortened life span resulting from accelerated aging.

Prenatal radiation exposure may result in prenatal death from leukemia and morphological abnormalities in the developing nervous system or other organ systems. Sex-ratio changes have been noted. Doses of 10 to 19 rem received by human fetuses have been shown to produce small head size; doses above 150 rem have been associated with mental retardation (Beebe 1981; Meyer and Tonascia 1981).

5.2.3.6 Standards and Recommendations

OSHA has a standard for ionizing radiation (29 CFR 1910.96) that is intended to protect those workers not covered by the Nuclear Regulatory Commission (NRC) in 10 CFR 20. Several other agencies also have the authority to set and enforce standards and other measures to protect workers from radiation exposure (see Table 5-4). The National Council on Radiation Protection and Measurements (NCRP) was created by Congress in part to collect, analyze, develop, and disseminate information and recommendations about radiation measurements, quantities, and units. In 1971, the NCRP recommended maximum permissible dose equivalents of ionizing radiation during occupational exposure (NCRP 1975). The annual permissible dose for total body exposure is 5 rem per year, with 3 rem permitted within a 13-week period. The basic goals of the NCRP radiation dose limits are to prevent injuries such as cataracts and erythema and to reduce the probability of cancer. An exposure equivalent to 5 rem per year for the whole body or for certain organ systems is believed to permit a lifetime occupational exposure without reaching an injurious level. Specific limitations exist for dosages to various parts of the body such as the head, arms, hands, and trunk. In addition, the dose limit for the fetus of an occupationally exposed woman is 0.5 rem for the entire gestation period (NCRP 1977).

Under the Federal Food, Drug, and Cosmetic Act and other laws, the U.S. Food and Drug Administration (FDA) has the authority to regulate the manufacture and distribution of radiopharmaceuticals and medical devices containing radioactive materials. FDA shares this authority with the Nuclear Regulatory Commission (NRC), which has similar powers when the drugs or devices contain materials governed by the Atomic Energy Act. The two agencies have worked together in the development of regulations. The FDA's National Center for Devices and Radiological Health sets basic performance standards for X-ray machines and other radiation-emitting electronic products manufactured after 1974. The standards ensure that the products emit the smallest amount of radiation consonant with effective operation.

Table 5-4.--Standards for exposure to ionizing radiation*

Type of standard	Federal Radiation Council	National Council on Radiation Protection and Measurements (NCRP #39)	Nuclear Regulatory Commission (10 CFR 20)	OSHA (29 CFR 1910.96)
Radiation worker:+				
Whole body	5 rem/year, 3 rem/quarter, not to exceed the cumulative lifetime limit	5 rem/year, 3 rem/quarter, not to exceed the cumulative lifetime limit	5 rem/year, 3 rem/quarter, not to exceed the cumulative lifetime limit	3 rem/quarter
Cumulative life-time limit	5(N-18) rem§	5(N-18) rem	5(N-18) rem	5(N-18) rem
General population, individual, whole body	0.5 rem/year	0.5 rem/year	0.5 rem/year	---

*Adapted from ACGIH (1986), Documentation of the threshold limit values. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
+Workers in the radiation department or other job categories potentially exposed to ionizing radiation.
§N-18 = age of worker minus 18 years.

FDA also issues recommendations for the use of X-ray machines and other radiation emitters, conducts education programs, and assists the States with their activities. Title 10 of the Code of Federal Regulations contains the NRC rules on isotope sources (10 CFR Parts 20 and 34) and Title 21 for the FDA regulations on X-ray machines (21 CFR Parts 1,000 and 1,050). Many States have executed agreements with the Federal Government to assume responsibility for regulation of radiation sources in their States.

The JCAHO requires that a professional health physicist be available on the staff or as a consultant in any hospital with radiology equipment (JCAH 1979).

5.2.3.7 Exposure Control Methods

The amount of protection needed for a particular source of X-rays or gamma rays depends on the energy of the radiation and the length of time it will be in use (Parmeggiani 1983). The chief methods for reducing doses from external X-rays and gamma rays are to limit the time of exposure, increase the distance from the source of exposure, shield the source with protective material, and avoid unnecessary exposures. Improved equipment, knowledge, and reduced exposures have greatly reduced the risk for radiation workers.

5.2.3.7.1 Radiation protection officer

Reducing radiation exposure to personnel requires an integrated program directed by a radiation protection officer. This officer is responsible for all aspects of radiation safety in the hospital and should be available or on call at all times. The telephone number should be posted wherever radiation or radioactive materials are used. One of the functions of the radiation protection officer is to monitor workers and patients to ensure that applicable radiation exposure limits are not being exceeded. The officer must therefore devise a radiation monitoring program for both workers and patients to ensure that appropriate controls are implemented (NCRP 1976). The officer must also maintain an inventory and monitor the flow of radioactive materials entering and leaving the hospital. Training in the handling of radioactive materials is also the function of the radiation protection officer. This activity should begin with an intensive education program and should include information on equipment maintenance, personnel monitoring, and documentation. A successful program can reduce most personnel exposures to well below 0.5 rem per year (Laughlin 1981).

5.2.3.7.2 Recordkeeping

The following records should be kept:

- Personal radiation exposures
- Radioisotope inventory
- Receipt and disposition log
- Radiation survey reports

Recordkeeping requirements of the Nuclear Regulatory Commission are published in 10 CFR 20.401.

5.2.3.7.3 Protective equipment

No part of the body should be directly exposed to radiation. If there is a danger of exposing a body part, appropriate protection must be used. Lead aprons, gloves, and goggles should be worn by workers located in the direct field or in areas where radiation levels from scattering are high. All protective equipment should be checked annually for cracks in the lead and other signs of deterioration. For consistently elevated exposure (such as that occurring during angioplasty), a thyroid shield and leaded glasses are recommended.

5.2.3.7.4 General control measures for radiation exposure

The following measures should be taken to reduce occupational radiation exposure in hospitals:

- Properly mark any rooms housing radiation sources; allow only authorized personnel in the area.

- Enclose all radioactive materials.

- Maintain effective contamination control boundaries around all sources.

- Locate X-ray controls to prevent the unintentional energizing of the unit.

- Check all X-ray machines before each use to ensure that the secondary radiation cones and filters are in place.

- Keep X-ray room doors closed when equipment is in use.

- Equip treatment rooms with radiation monitors, door interlocks, and visual alarm systems.

- In therapeutic radiology settings, check system calibration periodically with lithium fluoride solid state dosimeters.
- Permit only the patient and trained personnel in the room where portable X-ray units and radioisotopes are used. Provide adequate warning to nearby workers when portable X-rays are about to be taken.
- Clearly identify patients who have received radioactive implants or other therapeutic radiology procedures.
- Follow correct decontamination procedures when control methods fail.
- Lead aprons, gloves, and goggles should be worn by workers located in the direct field or in areas where scatter radiation levels are high.
- Check all protective equipment annually for cracks in the lead.
- Use a thyroid shield and leaded glasses for consistently elevated exposure (such as that occurring during angioplasty).
- Prevent radiation exposure of pregnant workers.

5.2.3.7.5 Control measures for radioactive materials

Unlike X-rays, radioactive materials may be widely used throughout the hospital. They may be present in laboratories or in any place where patients are examined or cared for. Various precautions are needed when using radioactive materials--not only to avoid undue exposure to the radiation, but also to prevent these materials from contacting the skin or entering the body through cuts or injuries. To protect workers from radionuclides, attention must be paid to methods of handling them and to the laboratories where they are used. This section contains information to help minimize radiation exposure during diagnostic, therapeutic, and laboratory procedures.

5.2.3.7.5.1 Diagnostic procedures

The purpose of diagnostic procedures is to determine an organ's shape and how it is functioning. Most diagnostic procedures use small amounts of radioactive materials with short half-lives. Thus patients who are receiving such materials pose little risk of exposing others. Workers who must handle patients receiving diagnostic radioactive materials should observe the following precautions:

- The radiation protection officer should monitor all diagnostic procedures to ensure that radioactive materials (including radioactive urine or fecal material) are handled properly (NCRP 1976).

- Waterproof gloves should be worn during the collection or transfer of radioactive urine or fecal material and during the cleaning of bedpans, urinals, or other contaminated items (NCRP 1976).

- Urine and feces of these patients may be discarded through the sanitary sewer (Stoner et al. 1982).

- Materials that contact radioactive liquids (e.g., syringes) should be regarded as radioactive and disposed of accordingly (see Section 6) (Stoner et al. 1982).

- When small quantities of radioactive gases are administered to patients, the expired gases should be exhausted through a shielded duct system that is vented at the top of the building at a safe distance from the building's air intake (Stoner et al. 1982).

5.2.3.7.5.2 Therapeutic procedures

The proper control of radioactivity during therapeutic procedures depends on the class of radioactive procedure being used (NCRP 1976):

Class A -- Procedures in which radioactive materials are administered by mouth.

Class B -- Procedures in which radioactive materials are injected into body cavities.

Class C -- Procedures in which radioactive materials are injected into tumors and left there permanently.

Class D -- Procedures used to deliver radiation at distances of up to a few centimeters (brachytherapy).

Workers involved in the care of patients who have undergone any of these therapeutic procedures should receive a sheet of specific instructions on proper patient care (see NCRP 1970 for details). Workers should adhere to the following guidelines when caring for patients who have been treated therapeutically with radioactive material (NCRP 1976):

- The radiation protection officer should establish limits for the time that any individual should spend with the patient.

- A "radioactivity precautions" tag should be attached to the patient, the chart, and the bed.
- Workers should enter the patient's room to perform normal hospital duties, but they should not spend time visiting or performing nonvital personal services without authorization.
- Patients should be asked to care for themselves insofar as possible.
- Visitors may call, but they should stand at least 6 ft from the patient. Visits should be limited to 1 hr and should not include pregnant women or children.
- Pregnant workers should not be assigned to the routine care of radioactive patients.
- The radiation protection officer and the physician in charge should address all questions about the handling or disposal of contaminated clothing or instruments.

Patients who have undergone Class A procedures (radioactive material administered by mouth) may contaminate items such as linen, clothing, food utensils, and skin. In such an event, the radiation protection officer should be notified immediately. Patient care orders should provide special instructions for dealing with spilled urine, vomitus, excretion, or other body fluids. After a Class A procedure, the urine of patients may be collected during the first 24 to 48 hr for determination of radioactivity. If urine is not collected, the patient may use the regular toilet facilities (NCRP 1976).

Patients who have undergone Class B procedures (radioactive material injected into body cavities) may emit high energy gamma radiation or may be the source of contaminated surgical dressings or bandages. The latter should be changed only as directed by the physician in charge, and surgical gloves should be used to handle such materials. If the dressings are stained or bloody, they should be handled with forceps or tongs, and the physician in charge and the radiation protection officer should be notified immediately (NCRP 1976).

Patients who have undergone Class C procedures (radioactive material injected into tumors) may emit appreciable amounts of radiation for some time (NCRP 1976). The NCRP guidelines listed above in this subsection should be followed for such patients.

Patients who have undergone Class D procedures (brachytherapy) contain removable radioactive tubes or needles and present the greatest potential hazards. The exposure rate is likely to be considerable a few feet from the patient, and lead-impregnated aprons and gloves offer virtually no protection against high-energy gamma radiation. The NCRP has developed guidelines that should be followed for such patients (NCRP 1976):

- Nurses frequently assisting the physicians who implant radioactive tubes or needles should be designated as radiation workers. They should wear radiation monitors if the possibility exists for receiving one fourth of the permissible dose for radiation workers.
- Radioactive sources must be delivered to the operating room in lead-shielded containers by a worker responsible for proper handling and disposition of the material.
- No person should stand closer than necessary to the radioactive material either before or after its introduction into the patient.
- Any worker attending the patient after the operative procedure should stay as far as possible from the patient. Workers who attend such patients frequently may need to be classified as radiation workers.
- Nonhospital personnel should not be permitted to ride in elevators with such patients.
- X-rays of such patients should be completed as quickly as possible to avoid exposures of others in the area and to prevent fogging of X-ray film.
- These patients should remain in their own rooms unless other orders are issued.
- Linens, clothing, and bed pans should be checked regularly for radioactive tubes or needles that may have fallen out of the patient.
- If the patient's packing or dressing seems disturbed, the physician in charge should be notified, and the room should be checked for the presence of a tube, needle, or application device.
- If a radioactive capsule, needle, or other application device is loose or falls out, it should be picked up gently with forceps and placed in a container in the patient's room. Both the radiation protection officer and the physician in charge should be contacted immediately.

- Workers should limit the time they spend with these patients to that necessary for proper nursing care. The radiation protection officer should determine a work schedule and nursing assignments to minimize exposure.
- Bed baths should be omitted as long as the radioactive material is in place, and perineal care should not be given to gynecological patients.
- Only the attending physicians or their delegates should change dressings or bandages covering an area of insertion. Dressings should be safely stored while awaiting disposal.
- No special precautions are needed for vomitus, sputum, urine, feces, or eating utensils.
- When a radioactive source is removed from the patient, it should be returned to the worker who has been assigned the responsibility for its disposition.

5.2.3.7.6 Control measures for radiological procedures

5.2.3.7.6.1 Diagnostic procedures

Before X-ray equipment is used, the radiation protection officer should take the following steps (NCRP 1976):

- Conduct a complete radiation survey to ensure that walls and other barriers are sufficiently protective.
- Ensure that all equipment complies with applicable regulations and is in proper working order.
- Survey all adjacent floors and rooms.
- Designate certain areas as radiation areas with restricted occupancy.

Guidelines for general radiographic procedures (including mammography and dental radiology) are as follows (NCRP 1976):

- Only patients are allowed in unshielded areas when X-rays are generated.
- All X-ray technicians must be inside a shielded booth or behind a protective screen.

- Avoid using any person to hold or restrain a patient undergoing diagnostic radiology. If such restraint is necessary, efforts should be made to limit the number of times any worker performs this duty. A family member should be used if possible. Any such assistant should be provided with a protective apron and gloves and positioned to minimize direct exposure to the X-ray beam.

- When portable X-ray machines are used, the operator should be located at least 6 ft from the patient. Anyone assisting in the procedure should wear protective equipment.

Fluoroscopy and angiography require the presence of a number of personnel, all of whom should be aware of the basic principles of radiation protection and should take the following precautions (NCRP 1976):

- Protective devices supplied with the equipment (e.g., lead drapes, protective pull-up panels, etc.) should be used whenever possible.

- Special shielding devices should be devised when a number of patients are to be examined with the same physical set-up.

- Persons not required to attend the patient should stand back as far as possible or behind a protective shield.

All recommendations for control of radiological procedures should also be followed by radiation workers in animal laboratories.

5.2.3.7.6.2 Therapeutic procedures

No radiation is emitted from X-ray machines, linear accelerators, or betatrons until they are turned on. Workers may therefore enter treatment rooms without fear of exposure, but they must leave before the equipment is switched on. When radioactive cobalt or cesium is used for therapy, a low level of radiation is present at all times. When therapeutic procedures are performed, the following precautions should be implemented:

- The radiation protection officer must ensure that all workers are aware of the potential hazard and methods for minimizing exposures.

- Equipment used in radiation therapy should be checked for leaks at least once every 6 months and records should be maintained on the equipment's use, maintenance, and any malfunctions.

- Treatment rooms should be equipped with radiation monitors and an alarm system to indicate high levels of radiation and to prevent the door from being opened during treatment.

5.2.3.7.7 Control measures for laboratories

The following measures should be taken to control radiation exposures in laboratories (NCRP 1976):

- Accurate records must be maintained for radioactive materials used in the laboratories.
- All laboratory personnel must be trained in proper handling, use, and disposal of radioactive materials.
- Laboratory workers should not eat, drink, smoke, or apply cosmetics in the laboratory.
- Workers should remove any protective clothing, including laboratory coats, before leaving the laboratory.
- The radiation protection officer should conduct periodic surveys of the laboratory and keep records of the results.
- In addition to the surveys by the radiation protection officer, the laboratory worker should check counters, floors, and other work areas for contamination.
- The radiation protection officer should be called in the event of a spill of radioactive material.
- When radioactive materials are used in research with animals, any fluids or wastes should be handled and disposed of as radioactive materials.

5.2.3.7.8 Procedures following the death of a patient containing therapeutic amounts of radioactive material

The NCRP offers detailed procedures for handling the bodies of patients containing radioactive materials (NCRP 1970). General procedures are as follows (NCRP 1976):

- The radiation protection officer must be notified immediately when such a patient dies.
- The attending physician is responsible for the removal of brachytherapy sources and applicators.
- A report describing the nature and extent of the radioactive material used should accompany the body.

- The radiation protection officer should be contacted before an autopsy is performed on any body containing radioactive material.
- All personnel involved in such an autopsy should wear protective clothing.
- Tissues and fluids from such an autopsy should be disposed of as radioactive materials.

5.2.3.8 Environmental Monitoring

Dosimeters should be worn by all personnel exposed to sources of ionizing radiation. Two types of dosimeters are used to monitor ionizing radiation exposure--film and thermoluminescent dosimeters. Both are acceptable, but the thermoluminescent dosimeter is becoming more widely used because of the relative ease of processing. Wearing one film badge under the apron and one over the apron at the collar level will allow evaluation of both whole-body exposure and head and neck exposure. The pocket ionization chambers that can be worn and read daily are not acceptable for compliance purposes.

A dosimetry program should include:

- Regular analysis and recording of the results
- A program for informing workers of their measured exposure
- Laboratories that have a good quality control program

5.2.3.9 Medical Monitoring

All radiation workers should have preplacement and periodic examinations. These should include a complete blood count and differential white blood count, an eye examination, a history of previous radiation exposure, and a reproductive history.

The NRC regulatory guide entitled Instruction Concerning Prenatal Radiation Exposure may be helpful in assessing potential risks to women considering pregnancy (NRC 1975).

5.2.4 Nonionizing Radiation

Nonionizing radiation does not have enough energy to ionize atoms, but it vibrates and rotates molecules, causing heating. Nonionizing radiation is classified by frequency, which is stated in units of hertz (Hz). The following types of nonionizing radiation may be present in the hospital environment: ultraviolet (UV), visible (including lasers), infrared (IR), radiofrequency (RF)/microwave, and ultrasound.

5.2.4.1 UV Radiation

5.2.4.1.1 Hazard location

UV radiation may be emitted from germicidal lamps, some dermatology treatments, nursery incubators, and some air filters in hospitals.

5.2.4.1.2 Potential health effects

Over-exposure may result in the burning of exposed skin and serious eye effects. Eye exposure is especially dangerous because the results of over-exposure are not immediately evident. Damage is apparent only 6 to 8 hr after exposure. Although resulting conjunctivitis can be extremely painful, it is usually temporary. Long-term unprotected exposure can lead to partial loss of vision, accelerated skin aging, and increased risk of skin cancer (NIOSH 1977b).

5.2.4.1.3 Standards and recommendations

No OSHA standard exists for UV radiation exposure, but NIOSH has made recommendations for UV light in the spectral region of 200 to 400 nanometers (nm). For the spectral region of 315-400 nm, NIOSH recommends that the total amount of UV radiation allowed to strike unprotected skin or eyes (based either on measurement data or on output data) be no greater than 1.0 milliwatt (mW)/cm^2 for periods greater than 1,000 sec; for exposure times of 1,000 sec or less, the total radiant energy must not exceed 1,000 mW·sec/cm^2 (1.0 joule/cm^2) (NIOSH 1973b). For the UV spectral region of 200 to 315 nm, the total amount of UV radiation allowed to strike unprotected skin or eyes should not exceed the levels described in the NIOSH criteria document for UV radiation (NIOSH 1973b).

The following recommendations were developed by ACGIH (1987):

Duration of exposure per day	Effective irradiance, ($\mu W/cm^2$)
8 hr	0.1
4 hr	0.2
2 hr	0.4
1 hr	0.8
30 min.	1.7
15 min.	3.3
10 min.	5
5 min.	10
1 min.	50
30 sec.	100
10 sec.	300
1 sec.	3,000
0.5 sec.	6,000
0.1 sec.	30,000

5.2.4.1.4 Exposure control methods

The best preventive approach to UV exposure in hospital settings including newborn and intensive care nurseries is to provide a strong educational program and to issue protective glasses for potentially exposed workers. The use of shaded glass is usually sufficient to prevent damage to the eyes. Enclosures and shielding may also be used.

5.2.4.2 Visible Radiation

Sources of visible radiation in the hospital include incandescent and fluorescent lighting and lasers.

5.2.4.2.1 Incandescent and fluorescent lighting

5.2.4.2.1.1 Potential health effects

Constant exposure to glare from hospital lighting may result in visual fatigue and headaches. These effects are temporary and produce no known lasting physiological changes.

5.2.4.2.1.2 Standards and recommendations

No OSHA standard or NIOSH recommendation exists for exposure to visible radiation.

5.2.4.2.1.3 Exposure control methods

Glare from visible radiation sources can be reduced by properly positioning equipment, filters, or shields; routine rest periods are also helpful.

5.2.4.2.2 Lasers

Lasers (light amplification by stimulated emission of radiation) emit electromagnetic radiation in either the UV, IR, or visible spectrum. The wavelength and frequency of the emitted light depend on which spectrum is used. In the biomedical field, the laser has been used for microsurgery and for measuring immunoglobulins and other elements in the blood. Lasers are becoming increasingly popular in surgery.

5.2.4.2.2.1 Hazard location

The most typical locations for lasers in the hospital are in radiology departments where they are used to help align patients for radiographic treatment and surgical areas where they have a wide variety of applications.

5.2.4.2.2.2 Potential health effects and safety hazards

Lasers cause damage because they focus large amounts of light energy on a small surface area. The eyes and skin are the organs most susceptible to damage by lasers (NIOSH 1977b).

The cornea and lens of the eye can focus the light from a laser of visible wavelength so that the light energy may cause lesions because it is more concentrated when it strikes the retina. In some cases, the damage to the retina is not reversible. The light from UV lasers may also cause damage by heating the surfaces of tissues and denaturing proteins.

When lasers strike the skin, the effects may range from erythema to blistering and charring. The extent of the damage depends on the wavelength, power, and duration of exposure. Because lasers use voltages as high as 15,000 V, they present a potential electrocution hazard.

5.2.4.2.2.3 Standards and recommendations

No OSHA standards exist for exposure to lasers, but their performance is regulated by the U.S. Food and Drug Administration (FDA) Bureau of Radiological Health under 21 CFR 1040. This regulation should be consulted when lasers are used. In the regulation, FDA has identified the following four classes of lasers that have been summarized by Stoner et al. (1982) as follows:

Class 1: Lasers that are incapable of producing a damaging radiation level. (These are exempt from control measures.)

Class 2: Lasers that may be viewed directly under carefully controlled exposure conditions. (These must bear a precautionary label.)

Class 3: Lasers that require control measures to prevent direct viewing and subsequent eye damage.

Class 4: Lasers that must be controlled to prevent eye and skin damage.

ANSI also provides guidelines for the safe use of lasers (ANSI 1973), and ACGIH has published recommendations for occupational exposure to laser radiation (ACGIH 1986).

5.2.4.2.2.4 Exposure control methods

The primary means of worker protection is the use of effective eye protection and shielding of high-energy beams. When selecting eye protection, care must be taken to ensure that the filtering characteristics of the glass are appropriate for the laser being used. Protective glasses should be mounted in goggle-type frames to ensure that the eyes are protected from the side as well as the front. Each pair of goggles should be clearly marked to show the type of laser they are to be used for. Protective glasses should be checked regularly for cracks in the glass or deterioration of the frame. Hand protection should also be worn when working in or near the target area. Extreme care should be taken to ensure that the laser beam is not focused on any reflective surfaces. Special care should be taken with carbon dioxide lasers because of their invisible beams. In all cases, dry cloth, paper, or other flammable materials should not be located near the beam.

NIOSH recommends that a laser safety officer be appointed in facilities where lasers are used extensively. The laser safety officer should be responsible for developing the laser safety program and ensuring the proper maintenance of equipment.

5.2.4.2.2.5 Medical surveillance

Workers who are exposed to lasers should receive a periodic examination of the eyes and skin.

5.2.4.3 IR Radiation

5.2.4.3.1 Hazard location

All objects with temperatures above absolute zero (-273°C, or -459.67°F) emit IR radiation, which increases as a function of the object's temperature. In humans and animals, the major IR insult occurs as a result of a temperature rise in the absorbing tissue (NIOSH 1977b). Exposure to IR radiation in hospitals may occur during the use of heating or warming equipment in the kitchen and during procedures involving lasers or thermography.

5.2.4.3.2 Potential health effects

The hazards associated with exposure to IR radiation are acute skin burns, increased vasodilation of the capillary beds, and an increased pigmentation that may continue for some time. Continued exposure may result in eye damage. Where highly intense and compact sources of radiation are used, an injury may occur fractions of a second before the pain is evident.

5.2.4.3.3 Standards and recommendations

No OSHA standard or NIOSH recommendation exists for occupational exposure to IR radiation.

5.2.4.3.4 Exposure control methods

Eye protection with proper filters should be provided to workers for use in areas with IR radiation. Shielding and enclosures may also be used to control exposures.

5.2.4.4 RF/Microwave Radiation

5.2.4.4.1 Hazard location

Numerous applications exist in the hospital environment for RF/microwave radiation. These applications include heating in diathermy, cancer therapy, thawing of frozen organs for transplantations, sterilization of ampuls, and enzyme inactivation in tissues of experimental animals. Microwave ovens are also used to heat food.

5.2.4.4.2 Potential health effects

RF/microwave radiation may produce some adverse biological effects from the heating of deep body tissues (NIOSH 1979c). As a result of this heating, potentially damaging alterations may be produced in cells. Some concern also exists for nonthermal effects. Effects associated with RF/microwave radiation include neurological, behavioral, and immunological changes.

RF/microwave radiation effects that are due to heating have been well documented in animals, but evidence is incomplete and in dispute for those effects occurring without an increase in tissue temperature. Thermal effects are in direct proportion to the field strength or power density. When the amount of heat generated from the absorbed energy is too great to be released into the surrounding environment, the temperature of the body gradually increases and can lead to heat stress.

A large body of literature addresses the various aspects of animal and human exposures to RF/microwaves. Most of the animal studies have investigated the thermal effects of RF/microwave radiation. The reports of human effects consist of a series of clinical and epidemiologic investigations into the association between RF radiation and damage to the eyes, central nervous system, and reproductive capability. Firm associations between RF radiation and these effects have not been demonstrated. A complete discussion of this literature is beyond the scope of this document.

5.2.4.4.3 Standards and recommendations

The OSHA standard for exposure to microwaves is 10 mW/cm^2. Both ANSI and ACGIH have published guidelines for occupational exposure to RF/microwave radiation (ANSI 1981; ACGIH 1986). FDA's Bureau of Radiological Health has set a limit of 5 mW/cm^2 for leakage from microwave ovens during normal use (21 CFR 1030.10).

5.2.4.4.4 Environmental monitoring

Leakage from diathermy equipment should be monitored in the proximity of the applicator before each treatment. Microwave ovens should be checked at least every 3 months; leakage can be checked easily with a small, hand-held instrument.

5.2.4.4.5 Exposure control methods

Any area where RF/microwave radiation exposure exceeds permissible levels should be considered potentially hazardous. The area should be clearly identified, and warning signs should be posted. Interlocks may be used to prevent unauthorized entry. Basic protective measures include the provision of shields or absorbing enclosures for equipment. Personal protective equipment may be used (e.g., gonad shields, protective suits, and wire-netting helmets). Although special protective goggles have been developed, they may not provide sufficient protection.

5.2.4.5 Ultrasound

5.2.4.5.1 Hazard location

Ultrasound is the mechanical vibration of an elastic medium that is produced in the form of alternating compressions and expansions. The vibration may be produced by continuous or impulse sound in the form of a sequel of interrupted vibrations. The medical uses of ultrasound include therapeutic, surgical, and diagnostic procedures.

5.2.4.5.2 Potential health effects

Although exposure to ultrasound does not appear to pose a human health risk, exposure to audible high-frequency radiation above 10 kHz can result in a syndrome involving nausea, headaches, tinnitus, pain, dizziness, and fatigue. Temporary hearing loss and threshold shifts are also possible from high-frequency ultrasound radiation.

Low-frequency ultrasound radiation may produce local effects when a person touches parts of materials being processed by ultrasound. The hands are often involved in the area where ultrasound acts most strongly. Exposure to powerful sources of ultrasound may result in damage to peripheral nervous and vascular structures at the points of contact. Airborne ultrasound vibration may produce effects on the central nervous system and on other systems and organs through the ear and through extra-auditory routes.

5.2.4.5.3 Standards and recommendations

No OSHA standard or NIOSH recommendation exists for ultrasound. ACGIH has proposed the following TLVs for permissible exposure to airborne upper sonic and ultrasonic acoustic radiation (ACGIH 1987):

Mid-frequency of third-octave band (kHz)	One-third octave-band level in dB re 20 μPa
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115
50	115

5.2.4.5.4 Exposure control methods

Exposure to ultrasonic vibration can be reduced by the use of enclosures and shields. Sound-isolating panels on ultrasonic equipment should be free of any openings and should be isolated from the floor by rubber seals. Workers operating or repairing ultrasonic equipment should be provided with appropriate protective equipment that is selected based on the task being performed and the likelihood of exposure to radiation above 10 kHz or to contact with low-frequency sources.

5.2.4.6 Video Display Terminals

5.2.4.6.1 Hazard location

Video display terminals (VDT's) have rapidly replaced other word processing and data management systems in many hospital departments.

5.2.4.6.2 Potential health effects

VDT's are a frequent source of worker complaints. Eyestrain, back, neck, and arm discomfort, and symptoms of stress have all been associated with VDT work. These problems may be controlled or improved with ergonomic measures such as adjusting the position of the screen and keyboard, the chair, the lighting and glare, the color contrast, and the frequency of rest periods. Whether long-term VDT use causes significant visual dysfunction or degeneration is unknown. Extensive radiation measurements and health data have indicated that VDT's do not appear to present a radiation hazard to the operators (Pomroy and Noel 1984) or to the developing fetuses of pregnant operators (NIOSH 1984a). However, clusters of miscarriages and birth defects have been reported among VDT operators and warrant further investigation (NIOSH 1984a).

5.2.4.6.3 Recommendations

NIOSH studies have resulted in a report entitled Potential Health Effects of Video Display Terminals (NIOSH 1981h), which contains specific recommendations for the installation, maintenance, and use of VDT's. NIOSH recommends the following general guidelines for VDT work (NIOSH 1984a):

- Workstation design: VDT units, supporting tables, and operator chairs should be designed with maximum flexibility. VDT's should have detachable keyboards, and work tables should be adjustable for height. Chairs should be adjustable for height and should provide proper back support.

- Illumination: Sources of glare should be controlled through VDT placement (i.e., parallel to windows, and parallel to and between lights), proper lighting, and the use of glare-control devices on the VDT screen surface. For VDT tasks requiring screen-intensive work, illumination levels should be lower than those needed when working with hard copy, which may require local lighting in addition to normal office lighting.

- Work regimens: Continuous work with VDT's should be interrupted periodically by rest breaks or other work activities that do not produce visual fatigue or muscular tension. As a minimum, a break should be taken after 2 hr of continuous VDT work. Breaks should be more frequent as visual, mental, and muscular burdens increase.

- Vision testing: VDT workers should have visual testing before beginning VDT work and periodically thereafter to ensure that they have adequately corrected vision to handle such work.

5.3 MUTAGENS AND TERATOGENS

5.3.1 Introduction

Measures for locating mutagens and teratogens, controlling worker exposures, and conducting medical surveillance of exposed workers are also discussed by specific agent in Section 4 and in the other subsections of Section 5.

Health care workers may be exposed to a number of agents that are considered to be mutagenic or teratogenic. These agents include the following (Yager 1973):

- Biological agents
  - Rubella virus
  - Cytomegalovirus
  - Hepatitis B virus

- Chemicals
  - Ethylene oxide
  - Organic solvents

- Pharmaceuticals
  - Anesthetic gases
  - Antibiotics
  - Cytotoxic drugs

- Physical agents
  - Ionizing radiation