Book Outline

Health and Safety in Atomic Energy Activities

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Chapter 1

Radiation and Its Biological Effects

A. History of radiation injury

1. European pitchblende miners

    a. Miners with lung diseases known as early as 1500

    b. Problem acute at end of the 19th century at pitchblende mines at Joachimsthal

    c. High incidence of lung cancer related to radon concentrations in poorly ventilated shafts

        (1) Up to 1939 nearly one half of total miners' deaths resulted from lung cancer

        (2) Latent period for induction of lung cancer about seventeen years

2. Early scientists working with ionizing radiation

    a. Radiation injury dates back to 1896, the year that Becquerel discovered radioactivity

    b. First known injuries from ionizing radiation skin burns on hands of workers using X-ray machines

3. Radium dial painters around period of World War I

    a. Injuries came from ingesting radium used in luminous paint

    b. Death sometimes occurred within about three years after ingestion from severe anemia, hemorrhages and from infections, particularly of the bones of the jaw

c. Those who had ingested smaller quantities developed cancer of the bones. Such tumors usually developed more than fifteen years after first exposure to the hazard

d. Information from these cases subsequently provided valuable data in establishing maximum permissible radiation doses

4. Manhattan Project and AEC

a. Excellent safety record achieved by the contractors of the AEC and its predecessor, the Manhattan Engineering District

(1) Description of the safety record

b. Incidents at both AEC and private installations

(1) Description of several incidents resulting in discernible injuries

(a) Los Alamos decontamination accident (1957)

(b) Release of radioactive materials at a Texas plant with subsequent contamination (1957)

(c) Inadvertent plutonium criticality at Los Alamos (1958)

B. Basic nature of matter (understanding of the nature of radiation and its biological effects needed in order to comprehend how harmful effects take place and how they can be avoided)

1. Atomic structure

a. Nucleus constitutes nearly all the mass and contains protons and neutrons

(1) Protons have positive electrical charge and are heaviest of the particles

(2) Neutrons have no electrical charge

b. Electrons

(1) Move in orbit around nucleus

(2) Have negative charge

2. Atomic classification

a. Atomic number (number of protons in the nucleus determines the chemical properties of the element)

b. Atomic weight (total number of protons and neutrons in the nucleus)

3. Isotopes

a. Radioisotopes

b. Causes of radioactive emissions

C. Nature of radiation

1. Types

a. Ionizing radiation

(1) Alpha particles

(a) Helium nucleus

(b) Shorter range

(2) Beta particles

(a) Really electrons

(b) Somewhat longer range

(3) Gamma and X rays

(a) Not particulate

(b) Infinite range

(4) Neutrons

(a) Neutrons induce radioactivity

(b) Neutrons cause ionization through a secondary process

2. The chain reaction and nuclear reactors

3. Radioactive decay

a. Half life

b. Measuring radioactivity

(1) Curie

(2) Roentgen

(3) Rad

(4) Rep

(5) Rem

(6) Relative biological effectiveness

D. Biological effects of radiation

1. Mechanism of radiation injury to the cells

a. Ionizing radiations strike water molecules in the cell causing the formation of hydrogen dioxide and hydrogen peroxide

b. Hydrogen dioxide and hydrogen peroxide break down enzymes which control factors for cell division

c. Radiation causes protein damage in cytoplasm

d. Damage may also be done to the proteins in cell walls

e. Radiations sometimes split chromosomes in the cell

2. Effect of radiation on tissues and organs

   a. Tissues and organs basically collections of cells

   b. Individual cells reflect the degree of damage done

   c. Cells that make up the different tissues and organs of the body differ in their response to radiation

      (1) Intestines

      (2) Blood-forming organs

   d. Results of radiation damage to organs

      (1) Increase or decrease in organ's products

      (2) Alteration in organ's growth

      (3) Death of the tissue or organ

3. Radiation exposure

   a. Type of radiation a factor in biological effects (dose for dose, radiation of high specific ionization produces greater biological effects than radiation of low specific ionization)

   b. Type of dose as factor in biological effects

      (1) Acute dose (generally, single exposure to twenty-five roentgens or more)

      (2) Chronic dose (absorption of relatively small amounts of radiation daily over a long period of time)

      (3) Body's response to irradiation depends on the fraction of the whole body volume exposed

         (a) Whole body irradiation

         (b) Localized irradiation

(4) Location of radiation source as a factor

(a) External source

1) Alpha not harmful generally (certain high-energy alphas can produce skin burns)

2) Beta harmful in close proximity

3) Gamma and neutron most difficult to handle

(b) Internal source

1) Radioactive material that seeks particular organs most harmful

2) Biological half life of material (time it takes to eliminate through biological processes one half of total amount of ingested radioactive material)

4. Effects of radiation on specific parts of the body (it should be noted that these effects have been observable only after large doses)

a. Blood and bone marrow

(1) Effect of massive acute dose

(a) Decrease in white blood cells

(b) Changes in clotting mechanism

(c) Impairment in the formation of antibodies against infection

(d) Possibility of anemia

(2) Effects from chronic exposure

(a) Possibility of leukemia

b. Skin

(1) Similar effects noted with both massive, acute, and chronic low-level radiation exposure

(a) Reddening, swelling, pigmentation changes and loss of hair

(b) Ulcerations, atrophy, cancer

1) Development of skin cancer extremely unlikely with present safety precautions

c. Bones

(1) Threat from ingestion and/or inhalation of the "bone seekers"

(a) Strontium

(b) Plutonium

(c) Radium

(2) Bone cancer from long-term radiation bombardment by bone seekers

(3) Effect of external radiation on bone cells

d. Lungs

(1) Effects of radiation on lungs

(a) Damage to air sacs (alveoli)

(2) Hazard greatest from inhaled radioactive dusts and vapors

(3) Tendency of several radioactive elements, such as radon, polonium, uranium, and plutonium, to concentrate in the lungs

e. Eyes

(1) No replacement of lens cells

(2) On dying cataract forms

(3) Unlike other tissues, on damage by ionizing radiation only one or two cells can initiate cataract formation

(4) Neutron and gamma radiation chief producers of cataracts

(5) Susceptibility to radiation-induced cataract formation dependent on age

f. Reproductive organs

(1) Large single doses of radiation can lead to temporary sterility

(2) Chronic irradiation can lead to sterility but the doses have to be considerably in excess of present permissible maximum

g. Effect on life span

(1) Chronic irradiation may shorten the expected life span

(a) Damage to specific tissues

(b) Lowered immunity

(c) Damage to connective tissue

(d) Premature aging

(2) Correlation of shortened life span with radiation dose

h. Genetic effects

(1) Inherited characteristics controlled by genes

(2) Mutations in both dominant and recessive genes caused by radiation

(a) Only mutations occurring in reproductive cells affect heredity

(b) Number of mutations proportional to total amount of radiation reaching reproductive cells

(3) About 99% of all gene mutations undesirable

(a) Chromosome mutations from radiation

(b) Genetic effects of radiation statistically significant only on a total population basis

E. Summarizing biological effects

1. They may be direct or indirect
2. They may be immediate or delayed
3. They may be structural as well as functional
4. They may, depending on the amount of ionization, be reversible or irreversible.

Chapter 2

Codes and Regulations in the Control of Radiation Hazards

A. Role of National Committee on Radiation Protection

1. Organized in 1929 on the recommendation of the International Committee on Radiological Protection
2. The NCRP is not a federal agency
3. Recognized source of basic standards for radiation protection within the U.S.
4. NCRP's area of interest includes machine, and natural and artificial radiation
5. Prepared first recommendations on X-ray protection
6. One function is to recommend permissible radiation exposure levels

B. Factors influencing development of radiation codes

1. The assumption by some that any amount of radiation is harmful, no matter how small, has led to the "philosophy of risk"
2. Successive lowering of maximum permissible limits represents improvements between goal-zero and technical capability
3. Maximum permissible limits regarded as maximum levels - and not as normal operating levels
4. Need emphasized for working as far below maximum levels as circumstances permit
5. Latest recommendations show increased concern over possible genetic effects of radiation

C. Federal codes and regulations

1. Nine federal agencies have statutory responsibilities in regulating radiation hazards

   a. Atomic Energy Commission licensing regulations

      (1) General requirements

         (a) Qualifications by training and experience to possess and use the material or facility safely for the purpose for which it is licensed

         (b) Equipment and facilities of each licensee must be appropriate to protect health and minimize danger to life and property

         (c) Location of the proposed activity must be suitable for the purpose

         (d) Material or facility must be used only for purpose authorized in the license

         (e) Material or facility may not be transferred except to persons authorized to receive it

         (f) Inspections may be made to insure adherence

      (2) 10 CFR Part 20 - Standards for protection against radiation

         (a) Applies to persons who possess source, special nuclear or by-product material

         (b) Establishes maximum permissible limits for external exposure of employees to radiation

(c) Establishes maximum permissible concentration of radioactive materials in the body

(d) Establishes standards applicable to radiation and concentrations of radioactive materials released to the environment

(e) Prescribes requirements for:

1) Personnel monitoring

2) Protective equipment

3) Caution signs

4) Labels and signals

5) Radioactive waste disposal

6) Storage of licensed material

7) Instruction of personnel

8) Records

9) Reports of overexposure

(f) Requirements based primarily on recommendations of the NCRP

(3) 10 CFR Part 30 - Licensing of by-product material

(a) Before a license can be granted a review determines that User has:

1) Adequate, specialized training and experience

2) Proper physical facilities and equipment for proposed use

3) Adequate safety procedures

4) Properly labeled devices

5) Adequate restriction of work areas, and warning signs

6) Established administrative controls, which include line of responsibility for control and operating instruction

(4) 10 CFR Parts 40 and 70 - Control of Source Material and Special Nuclear Material

(a) Definition of source material

(b) Definition of special nuclear material

(c) Radiation safety review

(d) Prevention of accidental criticality

(5) CFR Part 50 - Licensing of Production and Utilization Facilities (Reactors and Critical Facilities)

(a) Health and safety of the public

(b) Construction

(c) Public hearings

1) Operating License

(6) 10 CFR Part 55 - Operator's Licenses

(a) Requirements for license to operate controls of a reactor or critical facilitiy

1) Written examination

2) Operating test

3) Physical examination

(7) 10 CFR Part 70 - Regulations to protect against:

(a) Accidental conditions of criticality in the shipment of special nuclear material

1) Companies or individuals licensed to own or possess special nuclear material must obtain prior approval for proposed shipping procedures for materials in excess of certain quantities

(8) Regulating AEC contractor operations

(a) AEC contractors not governed by licensee regulations

(b) Must maintain programs of radiation protection that meet requirements and standards of the AEC as published in AEC manuals for contractors

(c) Contractors have considerable freedom in establishing administrative and technical details of radiation programs

(d) Final approval rests with AEC

b. U.S. Public Health Service

(1) Agency responsible for conducting studies and assisting state health departments to protect public health

(2) Does not have regulatory responsibilities

(3) Has investigating and adjudicatory functions in connection with any water or air pollution affecting more than one state

c. Food and Drug Administration

(1) Agency has an interest in:

(a) The effect of radiation of foods and drugs exposed to radiation

(b) The effect on humans or animals of foods and drugs that may contain radioactive substances

(2) Regulatory jurisdiction over the use of "food additives" (all articles having or bearing any radioactivity that are defined as food additives)

(3) Prior approval of an additive is required

(4) Control over drugs containing radioactive substances. Approval of the Administration must be obtained before a new drug can be sold commercially

(5) Radioisotopes defined as carcinogens by FDA

d. Bureau of Mines

(1) Regulatory responsibility for radiation protection in connection with mining of uranium, thorium, and radium in mines located on public land

(2) Authority to undertake investigations and conduct research on mine safety hazards

(3) Conducts programs in cooperation with industry, state agencies, and Public Health Service to establish criteria for the protection of uranium and thorium miners from underground radiation hazards

e. Department of Labor

(1) Limited regulatory jurisdiction in the radiation protection field under Fair Labor Standards Act

(2) Hazardous occupations order covering employment of minors between sixteen and eighteen in occupations involving exposure to radiation

(3) Works with state occupational health agencies to develop standards for protecting workers

f. Department of Defense

(1) Regulatory control over facilities and special nuclear materials that are determined (by the President) to be necessary in the interests of national defense

(2) Other activities submit to regulatory control by AEC

g. Post Office Department

(1) Regulates shipments of radioactive materials through U.S. mails

h. Transportation agencies

(1) Responsibility for regulating the safe transport of radioactive materials rests with following

(a) Interstate Commerce Commission

1) Common carriers

2) Bureau of Explosives

(b) Civil Aeronautics Board

(c) U.S. Coast Guard

(2) AEC exempts carriers and warehousemen from its regulations

D. State Codes and Regulations

1. Control of industrial hazards traditionally a function of state government

2. Unusual circumstances surrounding origins of the atomic industry placed control of radiation hazards in the hands of the Federal Government

3. Atomic Energy Act of 1954 impetus to assume their traditional role

4. Present picture on radiation protection legislation in states is complex

5. Numerous departments in many states appear to have broad powers to promulgate regulations

6. State of New York has multiplicity of laws and codes

   a. Department of Health has developed an extensive set of radiation protection regulations

   b. Department of Labor has issued a set of regulations as part of the Industrial Code

   c. Public Service Commission has authority to establish health and safety standards for power plants

   d. Conservation Department and Water Pollution Control Board of the Department of Health have power to control waste disposal

e. Board of Pharmacy regulations can be interpreted to include radioisotopes used for medical purposes

f. State Building Commission has regulations for the installation of radiation generating equipment

g. State Traffic Commission has regulations for the transport of radioactive material over state highways

h. Public Service Commission has general powers to regulate transport by all common carriers in the state

i. Several New York City departments also have radiation protection regulations

j. New York State is a signatory to a number of interstate compacts dealing with water pollution problems

7. New Jersey -- simplified approach

   a. Radiation Protection Act of 1958 places authority for rules and regulations governing radioactivity in the hands of a committee on radiation protection

   b. The committee's regulations are administered by the State Department of Health

8. Council of State Governments recommendations:

   a. Statutes to regulate radiation exposure should be simple and minimal, leaving to administrative rule and regulation the establishment and enforcement of standards

   b. Regulations adopted should be in conformity with nationally accepted standards, such as those of the NCRP and AEC

c. Studies and recommendations of the various state agencies concerned with atomic development should be coordinated

d. Radiation sources should be registered

9. As of January 1959, thirty-two states have some sort of radiation protection regulations

a. Sixteen states require registration of radiation sources

b. Eight states have adopted comprehensive regulations of the type suggested by the NCRP's model state radiation protection regulation

c. Common features of comprehensive administrative rules include directions dealing with:

(1) Amounts of permissible exposure to radiation

(2) Monitoring of plants and their surroundings for radioactivity

(3) Systems of signs and signals warning of radiation danger

(4) Requirements for record-keeping of personnel exposure and radiation surveys

(5) Techniques of storing radioactive materials

(6) Shielding devices for installations where nuclear reactions are being produced

(7) Clothing to be worn and equipment to be used

(8) Rules frequently provide that one man in each plant or installation be given chief responsibility for the establishment's system of radiation hazard control

d. Differences between the regulations of various states result to some extent from differences between NCRP's recommended regulations and AEC "Standards for Protection Against Radiation"

(1) California

(a) No differentiation between exposure levels for various body organs, thus allows less exposure of the noncritical organs than NCRP

(b) Air concentrations are established only for alpha emitters as a class and beta and gamma emitters as a class. NCRP sets levels for each isotope. Thus California permits some higher concentrations than NCRP and insists on some lower concentrations

(c) No exceptions for persons under eighteen. The AEC permits only one tenth the adult exposure

(d) No exceptions for persons over forty-five. The NCRP would permit double exposure

(e) Registration of radiation sources not required

(2) New York

(a) Several separate regulations

(b) Permissible exposure levels essentially the same as recommended by the NCRP

(c) NCRP is followed with respect to waste disposal

(3) Pennsylvania and Texas adhere almost to the letter to NCRP recommendations

(4) Connecticut

(a) AEC regulations followed closely

(b) Stricter than the AEC in the area of thirteen-week exposure rule

(c) Yearly exposure formula suggested by NCRP adopted

(5) Massachusetts follows AEC regulations very closely but does not deal with problems of waste disposal

(6) Michigan

(a) Levels established by AEC generally adhered to

(b) Considerably lower permissible levels than AEC for radiographic activities

(c) Yearly exposure limit formula adopted

(7) Minnesota - the first state to require licenses for both the construction and operation of reactors and nuclear facilities

10. Other states have adopted some or partial, rather than comprehensive, regulations

a. Most incorporate weekly or daily exposure limits

b. Levels differ from NCRP

(1) Exposure limits for noncritical organs are more restrictive than those of NCRP

(2) Doses permitted over a long period are less restrictive than NCRP

c. Most of these regulations establish weekly permissible exposure

Chapter 3

Control of Radiation Hazards

A. Substitution - Use of a nonradioactive or less hazardous radioactive material for a highly hazardous radioactive material where possible

  1. Factors determining the choice of a radioactive material

    a. Short half life

      (1) Use of radioactive material with short half life reduces total time it is potentially dangerous

    b. Type of radiation

      (1) Considerations of effective range and ease of shielding

        (a) Substitute beta for gamma radiation

        (b) Substitute alpha for beta radiation

        (c) Except when ingestion is possible

    c. Energy of the radiation

      (1) Generally speaking, the lower the energy the less the external hazard

      (2) The isotope having the lowest total energy should be selected

      (3) When ingestion is possibility, select isotope with highest permissible body burden

  2. When ingestion is a possibility, alpha emitters are most hazardous, then beta, finally gamma

B. Shielding - Maintain effective barriers around a radiation source to render it biologically ineffective

1. Two methods of shielding

   a. Proximate or close method

   b. Remote or barrier method

2. Factors affecting selection of shielding material

   a. Energy and type of radiation

   b. Problem of weight

   c. Cost of shielding material

   d. Structural considerations

3. Alpha shielding

   a. Alpha blocked in most cases by sheet of paper

   b. Ordinary clothing provides effective means of shielding against total body exposure

   c. Rubber gloves to protect hands

4. Beta shielding

   a. Beta particles are more penetrating than alphas - require special shielding

   b. Selection of shielding material is based on completely absorbing all the particles

   c. Range or distance traveled within the shield is inversely proportional to density of the shielding material

   d. Secondary gamma rays are produced by the beta particles impinging on heavy materials

   e. Low-density materials such as aluminum or plastic preferable for beta shielding

f. Plastic or glass shielding permits operator to view work

5. Gamma and X rays

   a. Theoretically, this radiation cannot be absorbed completely by shielding

   b. Shield that will pass only a nonhazardous fraction of the original radiation should be objective

   c. Effective materials for gamma shields are elements having high densities

   d. Compromises must be made, however, on cost and weight

6. Neutrons

   a. Neutrons present the most difficult shielding problems

   b. Thickness of shield depends on composition and energy of neutrons

   c. Gamma rays are produced in the attenuation of neutrons and in the fission process - materials used to fabricate the shield must guard against both types of radiation

   d. Hydrogenous materials are excellent for neutron shielding

7. Positrons emitted from cyclotron require beta and gamma shielding

C. Distance from source of radiation

1. Distance may be used as a means of control

2. Distance from alpha and beta particles where no exposure is received can be ascertained

3. Gamma and X-ray exposure decreases with distance in the same manner that the intensity of light is never completely eliminated

4. Combination of distance and shielding can be used to decrease cost of shielding
5. Remote handling equipment

D. Time - Total radiation exposure in given field of radiation will depend on the length of time in field

1. Limit on time in which an operation may be done may be necessary to keep within maximum permissible weekly exposure
2. Jobs requiring large exposures are accomplished by rotating workers so as to keep individual exposures within allowable limits
3. Speed in operation is important

E. Group protective devices

1. Area monitoring devices
   a. Portable surveying
   b. Appropriate instrumentation for the exposures involved
      (1) Ionization chamber - measures gamma, X-ray and presence of beta
      (2) Proportional type monitor - measures alpha and beta radiation
      (3) Geiger-Mueller monitor - low and moderate radiation intensities
      (4) Electroscope monitor - measures X-ray and gamma - gives total accumulated dose - measures radiation from intermittent sources

c. Instruments stored in areas free from contamination for emergency uses

d. Stationary and continuously operating instruments

e. Air samplers

f. Smear tests

g. Ventilating systems

    (1) Generally necessary wherever loose radioactive materials, vapors, or gases are involved

    (2) Local exhaust ventilation

    (3) Building-wide air systems

    (4) Prevention of release of radioactive materials to the environment

    (5) Hoods

    (6) Glove boxes

h. Personal measuring devices

    (1) Dosimeters

        (a) Film badges

            1) Most common personnel radiation monitor

            2) Detection X-ray or gamma radiation

            3) Neutron detection

            4) Cumulative radiation exposure recorded

        (b) Pocket ionization chambers

            1) Self-reading type

            2) Machine-read type

(c) Hand and foot counters

(d) Protective coverings

1) Coats and coveralls to prevent contamination from loose radioactive materials

a) laundered in special facilities

2) Respiratory devices - to prevent inhalation of radioactive particles or vapors

3) Gloves

4) Shoes

F. Medical examinations

1. Pre-employment examinations

a. Routine blood count

b. Skin examination

c. Chest X-rays

d. Urinalysis

2. Periodic re-examination

a. Chronic exposure injury

b. Checks capability of the body to respond to radiation damage

G. Plant construction and housekeeping

1. Philosophies of operating procedures determines design of nuclear laboratory

a. Contamination control

(1) Movement in the laboratory is from "cold" to "hot" areas passing through intermediate zones

(2) Helps prevent spread of contamination

(3) Excludes all but those persons most directly concerned from dangerous areas

(4) Air flow in building design from positive pressure halls to offices to still lower pressure laboratories

b. Concentrate radiation zones

(1) Control radiation by total enclosure of the radioactive material

(a) Dry boxes

(b) Hot cells

c. Total control assures personnel protection and minimizing contamination

Chapter 4

Company Radiation Safety Practices

A. Administrative control of radiation hazards

1. Establishing company policy on radiation safety

    a. "Just another industrial hygiene problem"

    b. Radiation hazards unique and require special policy

    c. Type of policy may depend on whether company is AEC contractor or licensee

    d. State company operates in may make a difference in developing a policy

2. Establishing responsibility for personnel radiation safety

    a. Rests with the individual worker

    b. "Individual must be protected against himself"

        (1) Supervisor responsibility

        (2) Separate safety group

3. Organization responsible for radiation health and safety

    a. Medical department

    b. Industrial hygiene department

    c. Separate and autonomous group

4. Company practices on radiation exposure

    a. Exposures kept to absolute minimum

    b. Minimum exposures consistent with performance of operation

    c. Simply abiding by federal and state codes

    d. Setting arbitrary company limits lower than limits in codes

e. Taking advantage of quarterly exposure limit

f. Rotating jobs

5. Getting expert advice

a. Utilizing technical people within organization

b. Engaging outside consultants

6. Establishing work procedures

a. Operating within broad standards

b. Work procedures spelled out in detail

B. Physical control of radiation hazards

1. Location and design of radiation installation

a. Type of operation dictates location and design

b. Consideration of future use or expansion of radiation on premises

c. Consideration of future changes in operations

2. Adequate radiation instrumentation

a. Portable survey instruments

b. Area monitoring

c. Personnel monitoring

d. Placement of instrumentation

3. What information is to be obtained

a. Personnel monitoring

(1) Film badge results

(a) Frequency

(b) Who gets reports

(2) Pocket dosimeters

(a) Usage

(b) Recording results

b. Radiation surveys and monitoring

(1) External radiation

(a) Methods

(b) Frequency

(c) Records

(2) Contamination

(a) Methods

(b) Frequency

(c) Records

c. Radiation inventory

(1) Controlling hazards by controlling source location

d. Occupational health records

4. Design engineering

a. Approval of new designs by health-safety department

b. Establishing standards for engineering department

Chapter 5

Health and Safety Departments

A. Size and organization varies with

   1. Company philosophy toward radiation protection

   2. Degree of radiation hazards

   3. Number of employees working with radioactive material

B. Place in company organization chart

   1. Staff

   2. Line

C. Philosophy of department's role

   1. Police force

   2. Advisory capacity

   3. May determine relationships with operating personnel

D. To whom does it report?

   1. Top management

   2. Operating manager

   3. Other departments

E. Membership

   1. Professional

   2. Technicians

      a. Unionization

      b. Nonunion

   3. Auxiliary (clerical, etc.)

F. Qualifications of staff

G. Functions

1. Aiding plant site selection
2. Aiding design of plants, laboratories, and equipment
3. Establishing radiation exposure standards
4. Establishing safe operating procedures
5. Area monitoring
6. Personnel monitoring
7. Surveying environmental hazards
8. Supervising waste disposal
9. Instrument calibration and maintenance
10. Orientation and educational programs
11. Record keeping
12. Visitor control
13. Planning for emergencies, such as fires, explosions, sudden releases of radioactivity

H. Budget

1. Capital equipment
2. Personnel salaries
3. Department overhead
4. Supplies and materials

I. Public relations role

1. Before start-up
2. Routine
3. In an emergency

J. Consultant's or advisor's role in health and safety program

Chapter 6

Waste Disposal

A. The problem of handling and disposing of radioactive wastes

B. Plant investment for radioactive waste handling and disposal in AEC facilities is on the order of $200 million, with annual operating costs of $6 million

C. Fundamental waste disposal concepts

1. "Dilute and disperse approach"
    a. Applicable to small concentrations of radioactive materials, where concentration is reduced to small quantities by treatment
    b. Waste discharged to environment provides little or no direct control by man over the effects of wastes following discharge
2. "Concentrate and contain" technique
    a. Applicable to wastes containing more radioactive material than can be safely assimilated by environment
    b. Method permits continuing long-term control by man

D. Types of radioactive wastes and methods of treatment

1. Low-level liquid wastes - susceptible to direct disposal to nature or to disposal following minimum treatment
    a. Normal laboratory operations
    b. Ore and feed material processing
    c. Normal operation for nearly all reactors

d. Routine operation of chemical processing plants

2. High-activity liquid wastes - serious and expensive disposal problem

   a. Chemical processing of reactor fuel wastes

   b. Specially designed tanks generally necessary for storage

   c. Future approaches to high-level liquid waste handling

      (1) Fixation in inert media

      (2) Special separation of specific radioisotopes

      (3) Direct discharge to selected geologic formations

3. Gaseous (and particulate) wastes

   a. Operations radioactivity levels ranging from the very low to high

   b. Airborne particulate wastes treated through filtration and air scrubbing

   c. Gaseous wastes handled by air-treating units or atmospheric diffusion and dispersion through tall stacks

   d. Extremely small permissible concentrations of various radioactive materials in atmosphere necessitate highly efficient filtration and dispersion systems

4. Solid wastes

   a. Includes contaminated laboratory trash, nonrecoverable scrap and contaminated equipment

   b. Levels of radioactivity range from a few times background to quantities requiring substantial shielding and remote handling

c. Generally buried at established burial grounds at AEC installations

d. Methods of reducing waste volume

(1) Compressing and baling widely practiced

(2) Incineration of combustible solid wastes

E. General waste disposal procedures

1. Radioactive waste that cannot be released to the environment buried at AEC facility or disposed of at sea

2. Packaging and shipment of waste handled by individual organization or by commercial waste disposal firm

3. Liquid wastes must generally be incorporated in solid material

4. Evaporation of waste to obtain minimum quantities

5. Permit for shipment of radioactive wastes must be obtained from the Bureau of Explosives

F. Economics of waste disposal

Chapter 7

Nonradioactive Hazards and Their Control

A. Toxic materials

1. Beryllium

   a. Beryllium possesses useful nuclear properties

   b. Beryllium an extremely toxic material - has caused a number of fatalities

   c. Two forms of beryllium disease

      (1) Respiratory illness

         (a) From inhalation of excessive quantities of air-borne beryllium dust, fumes, or mist

         (b) Appears in both an acute and chronic form

            1) Acute form observed only among industrial workers

            2) Chronic form observed among industrial workers and residents close to beryllium processing facilities

            3) Illness can be caused by extremely small concentrations of beryllium

      (2) Skin reactions or tumors and dermatitis

         (a) Cases of ulceration and benign tumors from beryllium fragments imbedded in skin

         (b) Dermatitis most important skin reaction in beryllium processing

(c) Dermatitis results only from direct contact

(d) Amount of beryllium dust deposited on skin from heavy suspension in air will cause skin reaction

(e) Material accumulated in work clothes and at contact surfaces of dust respirators

(f) Dermatitis disappears after an individual is removed from exposure

d. Maximum permissible air concentrations are very stringent

(1) Average in-plant concentrations

(2) Out-of-plant concentrations

e. Controlling beryllium hazards

(1) Plant design and operation

(a) Wet processes

(b) Operations designs

(2) Ventilation and air cleaning

(a) Local exhaust ventilation

(b) Air is cleaned before entering exhaust stacks

(3) Personal hygiene of employees

(a) Special clothing and respirators

(b) End-of-shift showers

(c) Frequent washing

(4) New employees indoctrinated in company rules for safe working practices

(5) Frequent air sampling

2. Uranium

   a. Uranium is a chemically toxic element

   b. Uranium is absorbed into body only with difficulty

   c. Effect on body is determined in part by solubility of airborne uranium compound

      (1) Insoluble oxide is largely retained in lungs and produces injury by irradiation

      (2) With soluble uranium compound, may cause severe chemical injury to kidneys

         (a) Uranium produces a characteristic histological injury in the kidney

         (b) Good evidence that concentrations of soluble uranium of 50 micrograms per cubic meter of air will not cause significant injury over the normal working lifetime of a man

            1) This figure has been accepted for all uranium exposures

            2) No reported injuries from uranium toxicity

         (c) Dust control techniques

3. Plutonium

   a. Plutonium is some 200,000 times more radioactive than uranium

   b. Although toxic chemically, plutonium, because of its radioactivity is, like radium, dangerous within body in amounts far less than would produce a chemical hazard

c. Absorbed with difficulty through gastrointestinal tract

d. Greatest part absorbed is eventually deposited in skeleton

e. Controlling plutonium hazard

(1) Working-glove box enclosures

(2) Maintaining negative pressure within box

(3) Prevention of laboratory contamination when insetting or removing materials from glove box

4. Other toxic materials

a. Lead

(1) Neurological disorders

(2) Gastrointestinal disorders

b. Mercury

(1) Effect on kidneys

(2) Dental disorders

(3) Skin reactions

c. Chlorinated hydrocarbons

(1) Necrosis of liver

(2) Kidney disorder

(3) Intoxication

d. Manganese

(1) Neurological disorders

e. Tellurium

(1) Gastrointestinal pains

(2) Transient headaches

5. Protective measures necessary for toxic materials

    a. Operations in closed systems

    b. Good ventilation

    c. Protective clothing

    d. Good personal hygiene practices

B. Pyrophoricity

1. Pyrophoric materials capable of igniting spontaneously

2. Uranium, plutonium, thorium, zirconium, sodium, and potassium are used in atomic energy industry

3. Spontaneous ignition of massive metal is very rare

4. Most severe pyrophoric problems arise when metal is in powder form

    a. Powders have much greater surface area on which to generate heat

    b. Powders have much smaller mass of metal in which to dissipate this heat

    c. Powders have much smaller percentage of total surface area available for loss of heat to external surroundings

5. Moisture increases pyrophoricity

    a. Some metals react violently with water

    b. Uranium high termperature reaction with steam is much more violent than with oxygen

    c. Only common factor involved in all pyrophoricity accidents investigated is hydrogen

6. Stress increases pyrophoricity

   a. Stress can be physical or chemical

   b. Uranium lathe chips more susceptible to spontaneous ignition than annealed metals of same dimensions in sheet form

7. Ruptured fuel elements in a nuclear reactor present a very real fire hazard

   a. Chalk River incident

   b. Windscale reactor incident

8. With fissionable materials, fires are limited by criticality considerations

9. Methods used to handle pyrophoric materials

   a. Finer the material the smaller the quantities handled

   b. Layers of pyrophoric material are kept thin

   c. Initial surface treatment (slow exposure of pyrophoric materials to dry oxygen)

   d. Keeping pyrophoric materials under an inert atmosphere

   e. Fires fought with graphite powders

10. Serious pyrophoric incidents that have occurred and corrective measures taken

    a. Y-12 area (1956)

    b. Uranium rolling operation (1956)

    c. Sylvania plant (1956)

Chapter 8

Safety and Health in Radioisotope Applications

A. Radioisotope applications represent the most widespread use of atomic energy

B. Health and safety problems vary with type of application and form in which radioisotopes are used

1. Sealed sources
    a. Gaging and radiography are primary uses
    b. Shielding and distance used as protective measures
    c. Gaging sources present minor external hazard
    d. Hazards
        (1) Rupture
        (2) Leakage
        (3) Radiation
    e. Wipe tests detect leakage of sources
        (1) For specific sources
        (2) Frequency of tests
    f. Radiography sources kept in shields until ready for use
    g. Radiography can be done in heavily shielded room where admission is prohibited (warning bells, labrynths, etc.)
    h. When radiography is done on shop floor, barriers are set up to take advantage of distance concept
2. Unsealed sources - definition of unsealed source
    a. Industrial research makes wide use of unsealed sources

b. External hazard present

c. Shielding used to prevent external exposures

d. Shielding arranged so as not to hinder experiments

e. Major hazard from unsealed sources is contamination and threat of ingestion

3. Contamination problem

a. Not easily seen as such

b. Presence detected or verified through instruments

c. Radioactive contamination easily transferred and spread on contact or through ventilation

d. Variables considered in dealing with radioactive contamination

(1) Extent of contamination

(2) Location

(3) Chemical and physical form

e. Laboratory contamination limits set by following:

(1) Employee health

(2) Community health

(3) Technical requirements - need to keep radiation below background

4. Methods of preventing contamination

a. Building and laboratory design with following factors considered

(1) Nature of radioisotope programs involved

(2) Types and quantities to be used

(3) Access control planning

(4) Personnel and equipment shielding

(5) Laboratory interiors and equipment to be easily decontaminated or replaced

(6) Floors to withstand high loads necessary for equipment and shielding

(7) Complexity and cost of equipment required for safe handling and storage of radioisotopes

b. Good housekeeping procedures

c. Use of hoods and dry boxes

d. Frequent monitoring and wipe tests

e. Storage of radioisotopes when not in use

f. Areas of radioactive spills marked off

g. Contamination checks when moving equipment from one area to another

h. Good safety practices

5. Preventing ingestion

a. No foods permitted in laboratories

(1) Hand and foot monitors

(2) Decontamination facilities

b. Smoking prohibited or curtailed

c. Pipetting never performed by mouth

C. Company organizations for safety and health

1. Varies depending on following:
   a. Type of radioactivity and frequency of use
   b. Number of employees engaged in radioisotope work
   c. Type of AEC license held
2. Laboratory supervisor or individual responsible for radiological safety
3. Company industrial hygiene or safety department assumes responsibility for radiological health and safety
4. Authority vested in radioisotopes committee
   a. Membership
   b. Responsibilities
      (1) Purchases and distributes radioactive materials
      (2) Approves all proposed radioisotope experiments based on following:
         (a) Experience of experimenter
         (b) Potential hazards of experiment
         (c) Safeguards taken
      (3) Checks on safety of work as it progresses
      (4) Keeps records to determine location of all radioisotopes on premises
         (a) Economics
         (b) Systems

D. Personnel protective devices
   1. Degree of radioactivity hazard determines type needed

2. Film badges commonly used

3. Pocket dosimeters

4. Hand and foot counters

5. Special protective clothing

    a. In most cases an ordinary laboratory coat

    b. Rubber gloves commonly used

    c. Shoe coverings

6. Physical examinations

    a. Customary company physical amended to include blood tests and X-rays

    b. Urinalysis performed in the event of the possibility of ingestion of radioactive material

E. Waste disposal

1. Generally of a low level of radioactivity

2. Handling of wastes

    a. Commercial service

    b. Laboratory handles its own

        (1) Placed in special shipping drums

        (2) Permission for shipment by common carrier from Bureau of Explosives

        (3) Sent to approved AEC burial grounds for disposal

Chapter 9

Safety and Health at Irradiation Facilities

A. Highly radioactive sources are used in various research studies

   1. Initiation of chemical reactions

   2. Food and drug sterilization

   3. Radiation effects on materials

B. Potential personnel hazard from intense external exposure to gamma radiations

C. Pool-type facilities

   1. Shielding by water against radiation

   2. Water in pool constantly purified

D. Radiation Caves

   1. Shielding provided by thick concrete walls and lead-glass windows

   2. Viewing operation

      a. Lead-glass windows

      b. Zinc-bromide windows

      c. Periscopes

      d. Mirror systems

   3. Taking advantage of natural shielding to reduce construction costs

   4. Labyrinths

   5. Interlock systems

      a. Personnel prevented from entering cave when source is out of storage walls

b. Guarding against removal of radioactive source from storage while personnel are in the cave

E. Transportable irradiation facilities ("Hot Pots")

1. Lead shielding

2. Fail-safe design

F. Periodic monitoring

1. Area monitoring

2. Source leakage checks

G. Projects utilizing irradiation facility approved by safety supervisor

1. Competence of experimenter

2. Assurance that project won't damage radiation source

H. Personnel protective devices

1. Film badges

2. Dosimeters

I. Waste disposal

1. Only in event of source leakage

Chapter 10

Safety and Health at Hot Laboratories

A. Handling of highly radioactive materials

B. Potential radiation hazards

1. Extremely high external radiation fields
2. Danger of radioactive contamination

C. Construction features of hot cells

1. Thick, high-density concrete shielding
2. Special lead-glass windows
3. Remote handling equipment
4. Special access doors to hot cells
5. High-velocity ventilating systems
6. Interior surfaces easily cleaned
7. Decontamination facilities

D. Permanently mounted alarm systems

1. Airborne contamination
2. High radioactivity levels
3. Failure of ventilating system

E. Restricted laboratory entry

1. Persons not connected with the work forbidden to enter unless escorted by laboratory representative
2. Persons allowed to enter made familiar with safety rules and regulations

F. Regulated cell entry

G. Operational procedures

1. Radiation work permit

a. Specifies required protective clothing and respiratory equipment required

2. Lists radiation levels and working time

a. Cask handling

b. Desirability of "cold" preparatory runs

H. Emergency procedures

I. Health safety organization

1. Staff

2. Functions

a. Routine surveys of areas to detect radiation and contamination hazards

b. Monitoring "hot" operations such as waste removal and decontamination of equipment

c. Recording of radiation readings, personnel exposure, contamination surveys

d. Checking radiation instruments for accuracy

e. Continual check of laboratory and hot cell atmosphere for airborne contamination

f. Audit of operating methods and procedures

J. Physical controls

1. Personnel measuring devices

a. Film badges

b. Pocket dosimeter

c. Hand and foot counters

d. Friskers

2. Protective clothing

a. Coveralls

b. Head coverings

c. Shoe coverings

d. Lead aprons

e. Gloves

f. Respirators

g. Face masks

h. Discardable clothing

K. Decontamination

1. Personnel

2. Equipment

L. Personnel training

M. Medical examination

1. Pre-employment physicals

2. Periodic re-examinations

a. Urinalysis

b. Other tests as deemed necessary

N. Waste disposal

1. Liquid

2. Solid

Chapter 11

Safety and Health at Research and Test Reactors and Critical Facilities

A. Number of reactors for research and testing have increased greatly since 1954

1. A wide variety of reactor types are used for testing and research purposes

    a. Test reactors for examining properties of materials exposed to radiation

        (1) Unenriched test reactors

        (2) Enriched test reactors

    b. Research reactors for basic and applied research also produce radioisotopes

        (1) Unenriched research reactors

        (2) Enriched research reactors

        (3) Training facilities at universities generally have very low power

2. Flux level will depend on purpose of use

    a. Industrial interests

        (1) Test reactors

        (2) Research reactors

        (3) Critical facilities

    b. University interests

        (1) Research reactors

B. Critical facilities

1. Continuous change of fuel geometry changes power levels

2. Criticality effectively unpredictable due to nature of use

3. Prompt criticality

C. Experimental nature of work in research and tests creates new situations on a continuing basis

D. Location

1. Location of reactor depends on many factors

a. Reactors located in populous areas

b. Reactors located at isolated sites

2. Location of critical facilities

E. Potential radiation hazards from research and test reactors and critical facilities

1. Radiation from experimental beam holes for experiments outside reactor or from beam holes accidentally uncovered

a. Ionizing radiation

b. Neutrons from reactor core

(1) Fast

(2) Slow

(3) Different methods required for handling fast and slow neutrons

2. Radioactivity from experimental materials taken from reactor

3. Catastrophe incidents

4. Prompt criticality

5. Fuel storage areas

6. Decontamination and radioactive waste areas

F. Methods for safeguarding against radiation hazards

1. Administrative controls

a. Reactor committees to pass on operations and procedures

(1) Reactor safeguards committees to examine physical controls

(2) Experiments-review committees to consider feasibility of work before it is performed

(3) Excess exposures committees to examine causes of overexposures and recommend changes

(4) Maintenance committees to advise on reactor repairs

(5) Instrumentation committees

(6) Criticality committees

b. Operation procedures

(1) Operator's responsibility

(2) Supervisory controls

(3) Rules and regulations for operations

(a) Decontamination

1) Equipment

2) Personnel

(b) Start up

(c) Shut down

(d) Emergency

(e) Check lists

(f) Other

c. Restricted area control

(1) Reactor floor during operations

(2) Experiment set-up rooms

(3) Auxiliary laboratories

(4) Control room

(5) Instruments room

(6) Control-rod area

(7) Heat dissipation area

2. Physical controls

a. Personnel measuring devices

(1) Who wears them

(a) Film badges

(b) Pocket dosimeters

(c) Neutron badges

b. Area monitoring devices

(1) Ventilating systems

(2) Air alarm systems

(3) Ionization chambers

(4) Warning devices within reactor itself

c. Personnel protective devices

(1) Coveralls required in certain areas

(2) Special shoes worn where contamination is a problem

(3) Hats

(4) Respirators

d. Decontamination facilities

3. Health and safety group

a. Membership

(1) Professional

(2) Technicians

(3) Auxiliary

b. Organization

(1) Responsibility

(2) Industrial hygiene

c. Duties

(1) Monitoring

(a) Personnel

(b) Equipment

(2) Bio-assays for certain workers

(3) Environmental controls

(4) Record-keeping

(5) Other

d. Budget for operations of health safety department

e. Public relations role

(1) Visitor control

G. Nonradioactive hazards

1. Experimental material placed in reactor may present unexpected hazard

a. Beryllium

b. Liquid metals generally in test loops

c. Explosive material

d. Fire is always a problem

(1) Not always advisable to call on fire department

H. Waste disposal procedures

1. Types of waste

a. Solid

b. Liquid

c. Gaseous

2. Method of disposal

a. Storage

b. Removal from site

I. Employee education programs

1. Program will depend on whether organization is industrial or university type

a. University personnel periodically changes, requiring frequent training sessions

b. University personnel generally better informed on hazards

2. Employee indoctrination

a. Informal on-the-job training

b. Formal training courses

3. Training programs

a. Nature will depend on work to be performed by individual

b. Length varies from one institution to another

c. Frequency varies

(1) Difficult to get professional personnel to refresher courses

J. Medical examinations

1. Pre-employment physical

a. To whom

(1) Radiation workers

(2) Nonradiation workers

b. Extent will depend on type of work

(1) Full physical

(2) Special examinations

2. Periodic physical examination

a. Type of employees

b. Frequency

c. Nature of examinations

(1) Chest X-ray

(2) Urinalysis

(3) Blood count

(a) Not taken by all companies

K. State and federal controls

1. Inspections

a. AEC

b. State agencies

(1) Sanitary Engineering Department

(2) Labor or Industries Department

(3) Health Department

(4) Fisheries Department

(5) Departments of Labor and Industries

(6) Other control agencies

c. Municipal

(1) Sewer Department

(2) Health Department

(3) Other

Chapter 12

Safety and Health at Power Reactor Facilities

A. Power reactor systems operations

B. Potential radiation hazards in power reactor operations

   1. To employees

      a. Reactor area during operations

      b. Fuel loading and unloading

      c. Reactor maintenance operations

      d. Waste storage

   2. To general public

      a. Disaster

      b. Chronic environmental contamination

         (1) Atmosphere

         (2) Water

         (3) Soil

C. Primary radiation control

   1. Reliance on shielding and denial of access

   2. Containment and isolation to protect public in event of disaster

   3. Safety built into reactor

D. Methods for controlling radiation exposures

   1. Administrative controls

      a. Operations procedures

      b. Restricting entry

c. Formal work permits

d. Delegation of responsibilities

(1) Centralized control

(2) Supervisory control

e. Safeguards committees

(1) Membership

(2) Functions

(a) Advisory

(b) Control

2. Physical controls

a. Personnel measuring devices

(1) Film badges

(2) Pocket dosimeters

(3) Hand and foot monitors

(4) Neutron detectors

b. Protective clothing (change from skin out)

(1) Coveralls

(2) Shoes and shoe covers

(3) Gloves

(4) Head coverings

(5) Respirators and air packs

(6) Plastic suits with portable air supply

c. Group measuring and protective devices

(1) Air filtering systems

(2) Mounted radiation alarm systems

d. Environmental monitoring

e. Medical examinations

(1) Pre-employment physical

(a) Regular company examination

(b) Blood counts

(c) Urinalysis

(d) Slit-eye examination

(2) Periodic examinations

(a) Type of worker examined periodically

(b) Extent of examinations

E. Employment practices

1. Indoctrination procedure

a. Formal group lectures

b. Informal talk with member of radiation safety group

2. Education for radiation protection

a. On-the-job training

b. Training programs

(1) Nature

(2) Extent

(a) Personnel engaged in fuel loading and unloading

(b) Maintenance personnel

(c) Radiation safety monitors

c. Safety meetings

d. Publications

F. Organization of radiation protection groups

1. Position in company organization

    a. Autonomous group

    b. Within company industrial hygiene and safety department

    c. Under medical department

2. Size of staff

    a. Conservative approach

    b. Liberal approach

3. Staff composition

    a. Professionals

    b. Technicians

    c. Auxiliary

4. Functions of staff

    a. Assist in site selection

    b. Routine monitoring

        (1) Area

        (2) Personnel

    c. Establishing work procedures

    d. Supervising hazardous operations

    e. Instrument calibration and maintenance

    f. Sample analysis of wastes before release

    g. Record keeping

5. Budget

G. Organization and operation maintenance services

1. Dry runs

2. Equipment and decontamination

3. Rotation of personnel to keep within dosage limits

H. Public relations

1. Visitor controls

I. Waste disposal

J. Incidents at power-reactor facilities

1. Meltdown of cases

a. Company experience

2. Other incidents

a. Company experience

Chapter 13

Safety and Health at Chemical Processing Plants

A. Objectives of chemical processing

1. Separation of radioisotopes
2. Separation of fissionable material
3. Decontamination of fuel and refabrication

B. Brief description of various processing methods

1. Solvent extraction processing
2. Volatility processing
3. Batch processing (precipitation or scavenging)

C. Potential radiation hazards in chemical processing operations

1. Fission product radioactivity
2. Accidental criticality
3. Spillage contamination
4. Atmospheric contamination
    a. Noncondensable gases
    b. Condensable gases
    c. Particulate matter
        (1) Plutonium
        (2) Uranium
        (3) Other matter
5. Waste removal procedures and storage areas
    a. Solid
    b. Liquid

D. Potential nonradioactive hazards in chemical processing operations

1. Explosive materials

   a. Ammonium nitrate

   b. Solvents

2. Fire hazards

   a. Use of inflammable substances for solvent extraction processes

3. Toxicity

   a. Particulate matter

   b. Gases created in process operations

   c. Other substances

E. Radiation areas

1. Separation plant canyons

2. Hot cells for processing samples

3. Waste disposal sites

4. Reservicing facilities for protective devices

   a. Clothing

   b. Respirators

5. Analytical and research laboratories

6. Other areas

F. Methods for controlling radiation

1. Administrative controls

   a. Establishing standards

   b. Establishing work procedures

c. Committee on criticality

    (1) Establishes technical basis for operation

    (2) Procedures for separate sites

d. Designation of radiation areas or zones

    (1) Special entry permits

e. Methods of operation

f. Delegation of responsibility

    (1) Centralized

    (2) Decentralized

g. Nuclear committees to consider special situations

    (1) Membership

    (2) Functions

h. Engineering design practices

    (1) Approval by health-safety group

    (2) Each component responsible for own design

    (3) Radiological engineering departments

2. Physical controls

    a. Personnel measuring devices

        (1) Film badges

            (a) Read every two weeks to one month

        (2) Pocket dosimeters

        (3) Hand and foot monitors

        (4) Whole body counters

    b. Protective clothing

(1) Status board at entrance to each zone indicates type of clothing to be worn

(2) Clothes

(a) Cloth

(b) Plastic

(c) Rubber

(3) Gloves

(a) Rubber

(b) Leather

(c) Cotton

(4) Shoes

(a) Rubber

(b) Canvas

(5) Respirators

(6) Face masks

(a) Filter-type

(b) Free air-type

(7) Head covering

3. Group measuring and protective devices

a. Air filters

(1) Selected-site filters

(2) Whole-room filters

b. Alarm systems

c. Ventilation systems

(1) Pressure systems

(2) Free-air systems

4. Environmental monitoring

a. Public safety

b. Types of monitoring

(1) Atmospheric monitors

(a) Location of monitors

(2) Water monitoring

(a) Ground water

(b) Effluent

(3) Vegetation monitoring

5. Medical examinations

a. Pre-employment physical

(1) Type of examination

(a) In some cases optional

(b) Age a factor

(c) Work a factor

b. Periodic examinations

(1) Urinalysis for plutonium every three months

(2) Blood counts primarily for other than radiological purposes

c. Special examinations if possible overexposure

G. Employee practices

1. Indoctrination procedures

a. Training rests with line organization

b. Supervisor has prime responsibility for training lectures

c. Formal

d. Informal

(1) On-the-job training

(2) Talks with health-safety personnel

2. Education for radiation protection

a. Training programs

(1) Periodically for supervisors

(2) On "as-needed" basis for others

3. Safety meetings

4. Pamphlets or brochures

5. Other methods

H. Organization of radiation protection groups

1. Position in company organization

a. Reports to director of technical services division

b. Reports to general manager for administration

2. Size of staff

a. Range from 3% to 5% of total work force

3. Staff composition

a. Professional

(1) Health physicists

(2) Industrial hygenists

b. Technicians

(1) Union affiliation

(2) Nonunion

c. Auxiliary

4. Functions of staff

a. Pre-start-up role (site selection)

b. Monitoring

(1) Areas

(2) Personnel

c. Establishing procedures

d. Other duties

5. Budget

a. Very high for chemical processing operations

(1) Operating

(2) Other

I. Incidents with radiation exposures

1. Experience with spillage contamination

2. Experience with criticality incidents

3. Air pollution incidents

4. Equipment contamination incidents

5. Other incidents

J. Waste Disposal

1. Large amount of liquid and solid wastes encountered in chemical processing plant operations

a. Solid Waste

(1) "Cold" run with mock-up before removal

(2) Heavy material removed by flat cars

(3) Use of lead pigs

(4) Burial ground

b. Liquid waste

(1) High level

(a) Stored in containers

(b) Evaporation

(c) Seepage ponds

(d) Other

c. Gaseous waste

(1) Removal

(2) Storage

Chapter 14

Safety and Health at Fuel Fabrication Facilities

A. Description of fuel element fabrication facilities

   1. Research and development

   2. Manufacturing operations

B. Hazards in fuel fabrication are greater from nonradioactive substances used than from radioactivity

   1. Except when working with recycled uranium

C. Potential radiation hazards

   1. External exposure to ionizing radiation

      a. Uranium

      b. Thorium

      c. Plutonium

   2. Ingestion and/or inhalation of radioactive materials

      a. Uranium

      b. Plutonium

   3. Criticality (fissioning) will occur under certain conditions with uranium 235, uranium 233 and plutonium 239

      a. Conditions for criticality

         (1) Sufficient mass

         (2) Sufficient enrichment

         (3) Proper geometry

         (4) Proper environment

D. Radiation Control Procedures

   1. Administrative controls

a. Responsibility

(1) Employee

(2) Supervisor

(3) Management

b. Rules and regulations

(1) Permissible limits and work standards

(2) Controlled areas

(3) Eating

(4) Smoking

(5) Protective clothing

(6) Personal cleanliness

(7) Movement of critical materials

(8) Others

2. Physical controls

a. Personnel monitoring devices

(1) Film badges

(2) Pocket dosimeters

(3) Finger rings

(4) Neutron badges

b. Group monitoring devices

(1) Ventilation

(a) Local exhausts

(b) Room and building exhausts

(c) Filters

(d) Stacks

(e) Criticality monitoring

c. Environmental monitoring

(1) Very little hazard

E. Organization of health and safety department

1. Position in organization chart

2. Memberships

a. Professional

b. Technician

c. Auxiliary

3. Functions

a. Monitoring personnel

b. Monitoring areas

c. Standards and procedures

d. Special reports

e. Training programs

f. Maintain records

F. Potential hazards from nonradioactive sources

1. Toxic materials

a. Beryllium

(1) Produces pulmonary disease

(2) Skin diseases

b. Mercury

(1) Dental damage

(2) Kidney damage

(3) Skin diseases

c. Chlorinated hydrocarbons

(1) Intoxication

(2) Necrosis of liver

(3) Kidney damage

d. Lead

(1) Gastro-intestinal disorders

(2) Neurological disorders

e. Manganese

(1) Neurological disorders

f. Tellurium

(1) Transient headache

(2) Gastro-intestinal pains

G. Protection against nonradioactive hazards

1. Beryllium

a. Protective clothing

b. Personal hygiene

c. Good housekeeping

d. Decontamination

e. Hoods

f. Ventilation

2. Mercury

a. Temperature control

b. Atmosphere-measuring devices

c. Ventilation

3. Chlorinated hydrocarbons

   a. Ventilation

   b. Gloves

   c. Face shields

   d. Proper storage

H. Hazards and controls of pyrophoric materials

   1. Types of pyrophoric materials

      a. Uranium

      b. Thorium

      c. Zirconium

      d. Titanium

   2. Controls of pyrophoric materials

      a. Approval of work procedure by safety director

      b. Storage rules

      c. Fire-protection equipment

I. Criticality controls

   1. Criticality engineer

   2. Approval of health safety department before moving fissionable materials

   3. Approval of health and safety department of procedure for using fissionable materials

   4. Approval of health safety department of storage areas for fissionable materials

5. Compliance with work standards

J. Scrap recovery

K. Waste disposal

1. Absolute control of all waste essential for the protection of plant environs and the public

2. Methods of controlling waste

   a. Separation of waste by radiation level

   b. Wastes above established levels recovered

   c. Combustible waste is burned in special facilities and ashes saved for disposal

   d. Waste disposal services are used - few companies store waste on site

3. Cost of waste disposal

   a. Waste disposal considered expensive

L. Personnel indoctrination

1. Informal

   a. Supervisor generally gives instructions with on the job training

2. Formal

   a. Lectures

   b. Courses as required for job

   c. Special courses

3. Monitoring of employee by health-safety officer as he moves through job functions. Information on protection given at this time

4. Periodic training

    a. Selected employees

    b. Employees shifting responsibility

    c. New supervisors

M. Medical department

1. Relation to health-safety department

2. Communications between health-safety and medical department

3. Examination of new employees

    a. Normal physical for industrial worker

    b. Periodic physicals 6-18 months

    c. Weekly urine samples

    d. Weekly breath samples

    e. Blood counts

4. Special examinations

Chapter 15

Safety and Health at Uranium Refining Plants

A. Description of refining process

  1. Digestion

  2. Recovery

B. Potential radiation hazards in uranium refining plants

  1. Enriched uranium

  2. Radium and daughter products

  3. Criticality

C. Methods for controlling radiation hazards

  1. Administrative controls

    a. Standards and procedures

    b. Responsibility

      (1) Supervisor controls

      (2) Individual responsibility

    c. Safety committees

      (1) Membership

      (2) Functions

    d. Special work permits

  2. Physical controls

    a. Personnel measuring devices

      (1) Film badges

      (2) Pocket dosimeters

      (3) Hand and foot counters

b. Protective clothing

(1) Coveralls

(2) Gloves

(3) Shoes

c. Respirators

3. Group measuring and protective devices

a. Local air-filtering systems to main stack

b. Whole-room systems

4. Environmental monitoring

a. Public safety

D. Potential nonradioactive hazards in uranium refining operations

1. Explosive materials

2. Fire hazards

a. Uranium is pyrophoric

3. Toxicity

a. Uranium dust

b. Many chemicals used in processing are toxic

E. Controls of nonradioactive hazards in uranium refining operations

1. Ventilation

a. Special ventilation systems near workers

b. Whole-area ventilation

c. Special procedures for handling uranium

d. Good personal hygiene practices

e. Other methods of control

F. Medical examinations

   1. Pre-employment physical

   2. Periodic examinations

      a. Nature of examination will depend on job

      b. Blood tests given every six months in some cases

      c. Clerical workers also examined as a control group by some companies

      d. Periodic examination important because of problems inherent in a chemical plant

      e. Urinalysis for some workers as frequently as every two months

      f. Chest X-ray

      g. Slit-eye examination

G. Employment practices

   1. Indoctrination procedures

      a. Formal

         (1) Lectures

      b. Informal

         (1) Supervisor

   2. Follow worker through job to get integrated exposure

   3. Education for radiation protection

      a. On-the-job training

      b. Talks with health-safety personnel

      c. Monthly safety meetings

d. Bulletins

H. Organization of health-safety groups

1. Position in company organization

2. Size depends on whether contractor or licensee operation

3. Staff composition

a. Professionals

b. Technicians

c. Auxiliary

4. Budget

I. Radiation incidents at refining plants

Chapter 16

Safety and Health in Uranium Mining and Milling

A. Uranium mining

1. There are about 1,000 uranium mines employing more than 5,500 miners in the U. S.
2. Principal uranium producing areas include the states of Utah, Colorado, Arizona, and New Mexico
3. Safety record to date
    a. Over half the domestic uranium mines have atmospheric concentrations of radioactive contaminants far above the levels considered reasonably safe for industrial exposures
    b. 55% of the mines employing 64% of the miners have concentrations more than five times the recommended maximum permissible levels
4. Radioactive hazards
    a. Chief source of radiation in underground uranium workings is daughter products of radon, a radioactive gas, as well as radon itself
    b. Radon is emitted from the ore and water seepages and disperses throughout the atmosphere of the mine
    c. Radon and its daughter products deposit in the lungs and bronchial tubes and emit alpha particles
    d. Harmful effects of overexposure may lead to cancer of the lungs

(1) Results from chronic overexposure

5. Nonradioactive hazards

   a. Toxic effects may result from inhalation of uranium dusts

      (1) Toxic effects depend upon the physical characteristics of the dust as well as the chemical nature of the uranium

   b. Uranium miners may also develop silicosis in uncontrolled mines

      (1) Most of the uranium ores in the Colorado Plateau contain 30% to 70% free silica

6. Precautions necessary to control hazards

   a. Radioactive and nonracioactive hazards essentially controlled by same methods

      (1) Adequate mechanical ventilation

      (2) Dust control practices

         (a) Wet drilling

         (b) Watering down muck piles during loading

         (c) Wetting down of working places

      (3) Delay entry to mine after blasting to allow for decay of radon and daughter products released in blast

      (4) Personal hygiene

         (a) Frequent baths and clothing changes for underground miners

         (b) Eating and storing of foods outside of mines

(5) Personnel measuring and protective devices

(a) Film badges

(b) Respirators

B. Uranium milling

1. Twenty-six mills employ about 4,000 people

2. Mills process about 20,000 tons of ore daily

3. Operations and associated hazards in the milling of uranium ore

a. Crushing

(1) Extremely dusty operation

(2) Very difficult to achieve 100% control of dust

(3) Radon and daughter-product concentrations

b. Grinding

(1) Relatively dust free operation

(2) Possibility of radon and daughter products released from grinding mill

c. Leaching process

(1) Acid leaching

(a) Potential nonradioactive hazard from generation of arsine, phosphene, and hydrogen sulfide

(2) Carbonate leaching

(a) Carried out at high temperatures

(b) Only hazard is possibility of thermal burns

d. Recovery of uranium

(1) Ion exchange

(a) Resin columns may present external radiation hazard because of radium concentrations

(2) Solvent extraction

(a) Solvents used are chemically toxic

(b) Reassignment of personnel allergic to solvents

e. Drying of final uranium product (yellow cake)

(1) Most severe radiation problem area in milling

(2) Uranium is so concentrated that dust levels must be kept very low

(3) Drying methods in general use

(a) Double-drum, steam-heated dryer - dust problem is severe

(b) Tunnel type dryer - relatively dust-free

(c) Multiple hearth dryers - dust problem

f. Uranium ore stockpiles

(1) May present fairly high radiation field

(2) Personnel don't spend much time in this area

g. Tailings piles

(1) Presents a high radiation field

(2) Men working a 40-hour week in this area can receive 100-150 mrem

4. Physical control of radiation hazards

a. Dust control

(1) Mechanical ventilation

(2) Hooding

(3) Wetting down operations

(4) Enclosing yellow-cake area

(5) Dust sampling

b. Shielding of resin columns

5. Personnel protective devices

a. Respirators in dusty areas

b. Film badges

c. Very few mills provide protective clothing

d. Emphasis on personal hygiene

(1) No eating or smoking in dusty areas

(2) Wash up before eating

e. Physical examinations

(1) Pre-employment including chest X-ray

(2) Not many mills give followup physicals

f. Rotation of personnel to keep individual dosages down

6. Waste disposal

a. Liquid effluent and spent solvents contain high radium concentrations

b. Mills on rivers discharge directly into water

(1) Volume of water regulates whether there is compliance with maximum permissible concentrations (dilution concept)

(2) Animas River incident

(3) Reducing radium content by neutralization of effluent

c. Remotely located mills place effluent in ponds

d. Chemical pollution

(1) Pollution of water supply by Anaconda mill

(2) Switch to different process

Chapter 17

Workmen's Compensation

A. Workmen's compensation traditionally a state responsibility

1. Workmen's compensation laws in effect in all fifty states, District of Columbia, and Puerto Rico

2. Two federal laws also cover workmen's compensation

   a. The Federal Employees Compensation Act

   b. Longshoremen's and Harbor Workers' Compensation Act

B. Analysis of existing legislation relating to coverage of radiation injuries

1. Type of law

   a. First test is type of coverage provided

   b. Compulsory coverage requires every employer within scope of act to accept its provisions (29 laws)

   c. Elective coverage

      (1) Permits employer and employee to accept or reject provisions of law

      (2) If elective, radiation injury may or may not be covered (25 laws)

2. Three methods for guaranteeing payment of benefits

   a. Insurance with authorized insurance company

   b. Self-insurance requires proof of qualifications

   c. Insurance with state fund

3. Extraterritorial coverage

a. When an employee hired in one state is injured in another, it sometimes is clear that he is covered by the law of the state where he was hired

b. Employee is sometimes specifically covered by the law of the state where the injury occurred

c. State where remedy should be sought is often difficult to determine

d. Extraterritorial provisions affect primarily the coverage of radiation injuries for workers engaged in the servicing, installation, and construction of atomic energy facilities and in the transportation of materials with a radiation hazard, where such workers cross state lines in their activities

4. Injuries and diseases covered

   a. Accidental injuries

   b. Occupational diseases are covered in two ways

      (1) Full coverage (32 laws)

      (2) Schedule coverage

         (a) Eighteen state laws include specific language for coverage of radiation disease

         (b) In eight of these state laws, it is questionable whether language used is adequate to cover all radiation diseases

5. Waiver

a. Handicapped workers permitted to "waive" their rights to benefits for an injury caused, or contributed to, by a previous disability

b. Waiver may overcome employer reluctance to hire previously injured workers

c. Waiver for radiation injuries still permitted under fourteen state laws

6. Subsequent injury fund provisions

a. Special fund to insure that an employer who hires a handicapped worker will not, in the event such a worker suffers a subsequent injury on the job, be responsible for the payment of compensation for a greater disability than that actually resulting from the subsequent injury by itself

b. A means of overcoming employer resistance to hiring of previously injured workers

c. Thirteen states have broad-type coverage under subsequent injury fund

7. Time limits for filing claims

a. Major problem affecting coverage of radiation injuries is requirement relating to time limit for filing claim

b. Under present federal and state laws there is variation in time limits

(1) Fifteen states require filing within specified period from date of disablement

(2) Four states base time limit on date of last exposure to the hazard

(a) Varies from one to three years after last exposure

(3) Thirteen states set times from date of injury

(a) In cases of occupational disease this is usually not spelled out and is a matter for interpretation

(4) Four states date from first manifestation of symptoms

(5) Six states fix time limit from date of worker's knowledge that he has an occupational disease

c. Only California and New York to date, meet the standards recommended by the International Association of Industrial Accident Boards and Commissions -- that the time limitation for radiation diseases runs from the date on which the employee has knowledge of the nature of his disability and its relationship to his employment

8. Medical and rehabilitation benefits

a. All state and federal laws provide that injured worker shall receive medical benefits

(1) Seventeen state laws provide medical benefits without limit as to time or amount

(2) Sixteen state laws specify that administrative agency is authorized to provide indefinite medical aid

(3) Sixteen state laws have definite limitations on medical benefits for radiation injury

b. Worker who has suffered a serious permanent radiation injury or has received the maximum permissible lifetime dose and cannot return to his former job will often require vocational rehabilitation

(1) Fifteen states have positive provisions for rehabilitation

(2) Thirteen states provide maintenance during vocational rehabilitation

(3) Seven state laws place on administering agency responsibility to see that worker gets such physical restoration service as he needs and vocational rehabilitation when necessary

c. Conclusions drawn from analysis of present workmen's compensation laws

(1) More than 95% of employed persons now work in states where there is some form of compensation for radiation disease

(2) There are wide variations in the provisions of the various state laws

(3) There are gaps in coverage of radiation injuries

(4) The extent of protection for workers who suffer a radiation injury will often depend not only on the law but on its administration

(5) One of the most serious problems for the future is the question of proving causal relationship between a radiation injury and the job

d. AEC contractor requirements to overcome deficiencies in state workmen's compensation laws

(1) Initially, AEC contractors authorized to establish special benefit plans for employees

(a) Would permit contractor to pay up to $10,000 for death or disablement from certain hazards

(b) Payments were in addition to any workmen's compensation rights an employee might receive

(c) Still in effect at a number of installations

e. Substantial modification of special payments plan for contracts drawn after 1952

(1) Compulsory law - requires AEC contractors to accept liability for workmen's compensation payments

(2) Extraterritorial coverage

(a) No specific AEC action

(b) Voluntary insurance coverage will probably apply

(3) Full coverage of occupational diseases

(a) When state law fails to provide occupational disease coverage for all radiation disability, AEC authorizes contractors to purchase extra insurance

(4) Time limits

(a) Where voluntary insurance is purchased, it may carry an extended time limitation

(5) Broad-type coverage under subsequent injury funds

(a) AEC feels it can assure nondiscrimination by contractors

(6) Unlimited medical benefits

(a) Deficiencies in payments for medical care overcome by authorizations contractors to obtain outside insurance, which provides excess medical treatment up to $100,000

(7) Maintenance benefits during rehabilitation

(a) Has been taken care of by contractors

Chapter 18

Insurance

A. Insuring radioisotope users against radioactive contamination

1. Through endorsements to basic fire policy

2. Endorsement A - limited form

   a. Limited coverage provided against direct loss resulting from perils insured against by basic policy

   b. Contamination must arise out of material used or stored on premises described in policy

3. Endorsement B - broad form

   a. Policy extended to insure against loss by sudden and accidental radioactive contamination without being limited by phrase "directly resulting from any perils insured against by this policy"

   b. Contamination must arise out of material used or stored on premises described in policy

4. Coverage of both endorsements subject to proviso "at the time of such loss there is neither a nuclear reactor nor any new or used nuclear fuel elements on the described premises"

5. Insurance company method to extend basic fire policy to include coverage against radioactive contamination

   a. Attach nuclear clause and required nuclear exclusion clauses to all policies relating to subject property

b. If coverage is immediately necessary it is provided by binder or by attaching endorsement to basic policy on a "subject-to-rate" basis

c. Local rating bureau is requested to recognize additional coverage by adjusting fire rate applicable to subject property through application of a special schedule

B. Insuring against damage to nuclear installations

1. Insurance coverage for physical damage to installation is available

2. Nuclear Energy Property Insurance Association and Mutual Atomic Energy Reinsurance Pool offer combined coverage up to about $50 million per installation

3. Installations eligible for coverage

a. Reactor installations

b. Nuclear fuel plants

c. Nuclear fuel in transit

d. Other installations using substantial quantities of radio-isotopes or spent fuel elements

4. Standard policy offered is an all-risk type but excludes:

a. Perils of war

b. Floods

c. Earthquakes

d. Certain customary inland marine and boiler and machinery features

5. It is deductible type policy

   a. $\$5,000 + 1/2\%$ of total amount of insurance coverage (not to exceed $75,000) for power reactor installations and nuclear fuel plants

   b. $\$2,500 + 1/4\%$ of total amount of insurance coverage (not to exceed $25,000) for all other NEPIA coverage

6. NEPIA will write following policy endorsements, generally at additional premium

   a. Earthquake assumption

   b. Premium adjustment endorsement to provide for fluctuations in property value

   c. Extension of policy to include coverage for property of reactor owner off described premises of reactor installation

      (1) Such contamination must result from incident involving insured reactor

7. Business interruption coverage

   a. Provided in conventional situations by rider to physical damage policy

   b. Covers loss of profit and necessarily continuing expenses

   c. Coverage not available at present to operators of power reactors

8. Rates for nuclear installations established by Nuclear Insurance Rating Bureau

   a. Nuclear power installations

(1) Plan of rating uses as a base the fire, extended-coverage and vandalism rates produced under nation-wide schedule for electric power plants

b. All other eligible risks

(1) Basic fire, extended-coverage and vandalism rates as calculated under regular rating plans

c. To these figures are added charges for following:

(1) Conventional boiler and machinery exposures

(2) Charge for the nuclear perils

(3) Increment for all-risk exposure not measured by any of the other rate charges

(4) Composite rate, used by syndicates in issuing all-risk policies (only policies that either syndicate will issue)

C. Liability insurance

1. Public liability represents most serious aspect of the nuclear industry's insurance problem

2. Methods of meeting problem of liability

a. Private insurance represents basic method of meeting problem of liability

(1) Liability coverage up to $60 million per installation is available

(a) Nuclear Energy Liability Insurance Association

(b) Mutual Atomic Energy Liability Underwriters

(2) Will cover only liability resulting from radiation hazards

    (a) For full coverage, a conventional liability policy will also have to be purchased

(3) To avoid pyramiding of coverage, single policy will cover liability of operator of nuclear facility and all suppliers up to limit of policy

(4) If operator purchases full amount offered by syndicate, no other insurance against liability for radiation damage available

(5) $60 million private insurance available should cover all but most serious accidents

(6) Total far short of amount of liability which might result from catastrophic accident

b. Indemnity provisions of Atomic Energy Act

(1) Licensees subject to financial protection requirements of Act required to furnish financial protection for public liability arising out of a nuclear incident

    (a) For research reactors with thermal power ratings from 0 kilowatts to 10 megawatts, amount of financial protection required ranges from $1 million to $2.5 million

    (b) For research reactors with thermal power levels above 10 megawatts and all power and testing reactors, financial protection requirements range from \$3.5 million to \$60 million

(c) Formula based principally on thermal power level of reactor at rate of \$150 per thermal KW

(d) Recent feature adds to formula a factor which takes account of population density of area surrounding reactor

(e) Financial protection in amount of \$1 million shall be furnished by holders of construction permits authorized to store nuclear fuel at site of a reactor under construction

(f) Financial protection can be furnished in following forms

1) Liability insurance

2) Adequate financial resources

3) Any other type of financial protection approved by AEC

(g) Federal agencies and nonprofit educational institutions exempt from financial protection requirements

(2) AEC will furnish indemnity protection in amount of \$500 million over and above required liability coverage per installation