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RADIOACTIVE WASTE MANAGEMENT POLICIES AND PRACTICES

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RADIOACTIVE WASTE MANAGEMENT POLICIES AND PRACTICESINTRODUCTION

The atomic energy industry effectively began with the production of plutonium for the first atomic bomb at the Hanford Engineering Works in 1944. Since that time, the development of atomic reactors for power production has progressed rapidly, and during the last few years sufficient commercial power reactors have become operational to justify the construction of several commercial fuel processing plants in the near future.

At the outset, it was apparent that a significant new source of pollution had developed in the by-products of the fission reaction. During the first 15 to 20 years of the new industry, the generation of wastes containing fission products was limited to a few Atomic Energy Commission production sites where the irradiated uranium fuels from production reactors were processed to remove the fission products and recover the plutonium product. Essentially all of the fission product wastes have been stored in underground tanks at the production sites. Small quantities of radioactive materials have been safely dispersed in the local environment under waste management programs established for each site by the operating contractor companies and the AEC. Over the years, continuous improvements of the radioactive waste management practices have evolved as advances in nuclear processing technology have occurred. Currently the major emphasis is being placed on long term radioactive waste control at these sites.

Concurrent with the development of atomic power reactors a program has been conducted by the AEC to develop nuclear fuel processing and radioactive waste management techniques to meet the needs of the nuclear power industry. Because the power reactor fuels were to differ considerably from the AEC plutonium production reactor fuels in many aspects, several different fuel processing schemes were developed through the pilot plant stage. However, in what currently appears to be an astute decision, the major development work in radioactive waste management was directed toward the treatment of waste from a solvent extraction uranium-plutonium separations plant similar to those at the AEC production sites. This development program was aimed at the solidification and packaging of the waste for interim storage and later disposal to a permanent, government-owned site.

As you might infer, the nuclear fuel processing and radioactive waste management programs for the power fuels industry do not exactly mesh with the AEC plutonium production site programs. However, the considerable experience gained at the production sites provides an excellent basis for the new power fuels industry and the AEC production technology has been very nearly duplicated in the first commercial power fuels processing plant, the Nuclear Fuels Service Plant near Buffalo, New York.

The purpose of this seminar is to discuss the radioactive waste management policies which guide the atomic energy industry today and the waste management practices currently being used. Experience at

Hanford will be emphasized but a brief view of the over-all industry will also be presented. Probable future trends in radioactive waste management will be discussed.

MAJOR ATOMIC ENERGY ESTABLISHMENTS

There are only a few major atomic energy establishments in the United States and in the world where irradiated nuclear fuels or reactor products are processed. There are many other locations where fission products and reactor products are used for research programs or specific applications but which are relatively unimportant from the standpoint of radioactive waste management. Radioactive wastes from the major sites are sufficiently high in radioactivity and of sufficient volume to require major waste management programs. The most important of these sites are the nuclear fuel processing centers. Of secondary importance are plutonium weapons fabrication sites and major research laboratories where significant quantities of radioactive materials are used in test programs.

United States

In the United States there are four nuclear fuel processing sites, three of which have associated research and development laboratories. There are two major plutonium fabrication sites and three national laboratories.

The Hanford site at Richland, Washington is the largest AEC plutonium production plant. Four reactors are operated for the AEC at the site by Douglas United Nuclear Company and there have been as

many as nine reactors in operation in the past. The complex includes a large fuel processing plant, a plutonium fabrication plant and uranium oxide preparation plant which are operated by Atlantic Richfield Hanford Company. A large research and development laboratory in which major AEC development programs are conducted is operated by Pacific Northwest Laboratory of Battelle Memorial Institute at the site.

The Savannah River Plant at Aiken, South Carolina is a large AEC production site which is operated by the E. I. duPont Company. It has three reactors in operation and has associated nuclear fuels processing, plutonium fabrication and uranium oxide plants. It also has substantial research and development facilities primarily to support the production operations.

The Idaho Chemical Processing Plant operated by Idaho Nuclear Corporation for the AEC is located near Idaho Falls, Idaho, on the same site as the National Reactor Test Station. This facility processes the majority of the United States test reactor fuels, particularly highly enriched uranium fuels. It also has an associated research and development laboratory.

The first commercial nuclear fuel processing plant for the power reactor industry is the Nuclear Fuels Services Plant at West Valley, New York. This plant processes power reactor fuels for recovery of plutonium and uranium for reuse in the industry.

Two major plutonium fabrication sites are Rocky Flats near Golden, Colorado, operated by Dow Chemical Company and Sandia Area Office near Albuquerque, New Mexico, operated by Sandia Corporation.

The three National Laboratories are Brookhaven National Laboratory located on Long Island, New York, and operated by Associated Universities, Inc.; Oak Ridge National Laboratory at Oak Ridge, Tennessee, operated by Union Carbide Company; and Argonne National Laboratory at Chicago, Illinois, and Idaho Falls, Idaho, operated by the University of Chicago. These laboratory complexes cover the broad spectrum of AEC research and development including reactor testing, fuel process development, isotope encapsulation, and biological studies.

Europe

In Europe there are several nuclear fuel processing plants outside of Russia. The three most important are in England, France and Belgium. In England, nuclear fuels from atomic power reactors are processed at Seascale in the Windscale Works operated by the United Kingdom Atomic Energy Authority. The major nuclear fuel processing site in France is the Marcoule Processing Plant Center at Baynols-Sur-Ceze. In Belgium several countries operate the Eurochemic Plant at Mol to process their power reactor fuels in a cooperative venture.

In addition to these sites Russia is known to have nuclear fuels processing facilities associated with the extensive atomic energy industry there, but little is known about their locations and functions.

RADIOACTIVE WASTE CLASSIFICATION

Radioactive wastes are generated at all of the atomic energy facilities but those generated at the nuclear fuels processing plants are by far the most diverse and highly radioactive. Essentially all

of the fission products and a major share of the plutonium wastes are contained in the process wastes generated at the processing plants. In addition, almost every type of contaminated material is handled at these sites. Since Hanford is the largest of the nuclear fuels processing sites, a description of the wastes generated there covers nearly all of the important waste types to be encountered in the industry.

Radioactive wastes are generally characterized by their physical and chemical properties and radionuclide content; all three factors are important in determining the method of disposal. Wastes are initially classified by their physical nature into solid, gaseous, or liquid. Further classification by radionuclide concentration is of primary importance with liquid wastes.

Solid Wastes

Solid radioactive wastes are radioactive materials that are essentially dry or contain sorbed fluids in sufficiently small amounts as to be immobile in the soil. Solid wastes are further classified by handling requirements that are determined by size, weight, and radiation intensity. Typical waste packages are:

Cardboard boxes

Steel drums

Wooden, concrete, or steel boxes

Major equipment pieces on expendable flat cars

Cardboard boxes are used for slightly contaminated wastes such as wiping tissues, rubber gloves, and contaminated clothing. Steel drums are used for grossly contaminated rags and small pieces of hardware. The drums may be shielded or transported in shielded containers.

Large pieces are placed in wooden, concrete, or steel boxes, depending on size, weight and radioactivity. Dose rates from packages of this size usually require remote handling during the filling, transport, and burial operations. Major equipment pieces may be too large for practical transport to burial grounds. These pieces are placed on expendable railroad cars for transport to rail tunnels adjacent to the operating plant.

Gaseous Wastes

Gaseous radioactive wastes are radioactive gases, vapors, and air. These wastes may contain particulate matter, which is contaminated, or volatile radionuclides. These wastes require treatment by air cleaning systems, chemical reaction, sorption, scrubbing and/or filtration to remove the contamination.

Liquid Wastes

Liquid wastes are solutions or slurries generated in the fuel processing facilities and contain the bulk of the radionuclides. These wastes are further categorized by the amount of contained radioisotopes. The categories are generally established by the method of waste treatment and have not yet been standardized in the industry. The categories established at Hanford are fairly representative of the industry and are as follows:

Low Level Wastes - are those which do not create a hazard when discharged to the ground surface. In general, the radionuclide concentrations are below the maximum permissible concentration in water (MPC_w). They contain less than 5×10^{-5} microcuries (μCi) per milliliter of combined alpha and beta emitters including less than

1×10^{-5} $\mu\text{Ci/ml}$ ^{90}Sr , which is the MPC_w for ^{90}Sr . These wastes are primarily condenser and other process cooling water which routinely has no direct contact with radionuclide-bearing solutions.

Intermediate Level Wastes - are those with radionuclide concentrations up to several times the MPC_w . They contain between 5×10^{-5} and $100 \mu\text{Ci/ml}$ of mixed radioactivity including less than $2 \mu\text{Ci/ml}$ ^{137}Cs , ^{90}Sr , and long lived alpha emitters or the combined total. Typical intermediate level wastes are process condensates, contaminated steam condensates, and water-immiscible organics such as process solvents.

High Level Wastes - contain greater than 99.9 percent of the fission products from the processed reactor fuels. Concentrations of the fission products in these wastes are significantly greater than the MPC_w , ranging from about $100 \mu\text{Ci/ml}$ to tens of thousands of curies per liter. Some of these wastes self-boil due to the fission product decay heat which can exceed 10 watts per liter.

WASTE MANAGEMENT POLICIES

Each country that has atomic energy programs has an atomic energy agency which has responsibility for the control of nuclear source materials, nuclear fuel materials, atomic reactors and the distribution and use of radioisotopes. The disposal of radioactive waste materials from atomic energy activities is also controlled by these agencies. Some of the agencies are: The Atomic Energy Commission (United States); the National Atomic Energy Commission (Argentine Republic); the National Council for Atomic Energy (Italy);

the Atomic Energy Council (Pakistan); the Atomic Energy Association (Spain); the Atomic Energy Committee (Sweden); Atomic Energy Board (Union of South Africa); and the Atomic Energy Authority (United Kingdom).

In 1946 the United States Atomic Energy Commission (AEC) was vested by law with the exclusive ownership of all atomic energy fissionable materials and all major facilities, including nuclear reactors, for the production of such materials. As a result, only the AEC or its contractors had the right to engage in the substantial production of fissionable material. The law also granted the AEC authority, for safety reasons, to control all users of the radioactive by-products of atomic energy, through licensing and regulation. A new law adopted in 1954 permitted the AEC to exercise control over nuclear reactors and other major atomic energy facilities primarily through a licensing and regulatory system rather than through exclusive and direct ownership. It then became possible for persons and organizations to own and operate major nuclear facilities, but only with the approval of the AEC. This situation prevailed until September, 1959, when the law was further amended authorizing the AEC to transfer to qualified states regulatory authority over radioisotopes, natural uranium and thorium, and small quantities of fissionable material (< a critical mass).

In the United States, the Code of Federal Regulations, Title 10 - Atomic Energy contains the rules and regulations pertaining to the Atomic Energy Commission's operations. Of particular interest to those who would plan to operate as a licensee are Part 20, Standards for Protection against Radiation, and the other parts listed in Figure 1 concerned with licensing, packaging of radioactive materials

FIGURE 1

CODE OF FEDERAL REGULATIONS

TITLE 10 - ATOMIC ENERGY

Part

- 20 Standards for Protection against radiation
- 30 Rules of general applicability to licensing of by-product material
- 31 General licenses for certain quantities of by-product material and by-product material contained in certain items
- 32 Specific licenses to manufacture, distribute, or import exempted and generally licensed items containing by-product material
- 33 Specific licenses of broad scope for by-product material
- 34 Licenses for radiography and radiation safety requirements for radiographic operations
- 35 Human uses of by-product material
- 36 Export and import of by-product material
- 40 Licensing of source material
- 50 Licensing of production and utilization facilities
- 55 Operators' licenses
- 70 Special nuclear material
- 71 Packaging of radioactive material for transport
- 100 Reactor site criteria
- 140 Financial protection requirements and indemnity agreements
- 150 Exemptions and continued regulatory authority in agreement States under section 274

for transport, reactor site criteria, financial protection requirements and exemptions in agreement states. Chemical separations plant site criteria are currently in preparation.

Individuals or companies planning to build reactors or chemical separations plants must submit detailed information concerning the site, the plant, the process, the equipment, analyses and description of the system including waste management, protection of the public, protection of plant personnel, the radiological safety plan, and the plant organization and startup plans. If the AEC is satisfied that all potential safety hazards have been identified and satisfactory controls can be established, a construction permit is issued; additional and more detailed information is required before an operating license can be obtained.

Formulation of policies for the management of radioactive wastes began about the time that awareness of the problems connected with disposal of other types of waste occurred. However, the problems of radioactive waste disposal have perhaps been given more attention than the disposal of any other forms of waste. Radioactively contaminated wastes can either be dispersed or confined depending on the quantity of radioactivity present. In the United States licenses are required to operate privately owned facilities within the provisions of the Code of Federal Regulations, Title 10, Part 20, for solid, gaseous and liquid wastes discharged to the environment.

Although AEC owned facilities are not licensed, policies and principles have been established by the AEC to guide Waste Management Programs at AEC contractor operated nuclear materials production and research and development sites. These guidelines have evolved over the 26 years since the startup of the first nuclear production

reactor. They reflect the broad operating experience and technological background developed during that time. The rapidly developing nuclear industry and increasingly stringent pollution control guidelines cause the following established policies and principles to be under continual review and evolution.

- . Personnel exposures resulting from waste management activities shall not exceed limits established in AEC Manual Chapter 0524, "Standards for Radiation Protection".
- . The total amount of radioactivity in wastes discharged to the environment within these limits should be minimized to the extent practicable.
- . All other liquid radioactive wastes, not suitable for routine release, should be suitably contained with adequate provision for control or recovery in the event of leaks or accidental spillage. Storage of such wastes as liquid in storage tanks shall not be regarded either as disposal or as an acceptable practice for long-term confinement. Rather, waste management programs should provide for reduction of wastes to solid form for long-term storage at sites designated by the AEC.

For the long-term, consideration should be given to transfer of radioactive wastes, either as liquid or solids, to storage in deep underground locations. Either approach should provide high assurance of waste isolation from the biosphere, be resistant to credible internal and external forces, and not be dependent upon mechanical cooling methods. Unless the Commission authorizes an exception, such long-term storage methods should not preclude removal of the wastes from such storage locations for relocation should this ever become necessary or desirable.

- . Using appropriate procedures in designated locations, ground burial of low-level solid wastes, contaminated materials and equipment on State or Federal government owned land appears to be an acceptable method of long-term storage and probably of disposal. Since burial grounds will require long-term land use restrictions and perhaps surveillance, burial should be restricted to as few sites as practicable. Adequate records of burial locations and other pertinent data should be maintained.

The foregoing guidelines resulted largely from a review of radionuclide waste management plans and recommendations of primary AEC contractors at Hanford, Savannah River, and Idaho Falls production and processing sites. They reflect the desire of the government to immobilize, contain, and isolate radioactive materials for the safety of the environs and population. Recommendations are sufficiently general so that contractors may conduct economical programs compatible with their particular situation and needs. A national policy for long-term radioactive waste disposal is still evolving. Accordingly, the AEC recommends for its own sites a program path which may be altered to coincide with national policies being adopted for commercial nuclear plants.

The policy of ARHCO for the management of waste chemicals and radioactive material is to ensure:

- . The long-term safety of the human population.
- . The preservation of off-site plant and animal resources.
- . The efficient use of disposal sites so that a minimum of land and water resources is relegated to restricted use. Releases of waste materials shall be held within applicable limits established by the AEC and other government regulatory bodies.

This policy is compatible with and based on AEC guidelines and is pointed toward operation well within these guidelines.

WASTE MANAGEMENT PRACTICES

Throughout the world waste management practices have been to isolate radioactive wastes of significant concentration from the environment and to safely disperse low level wastes. The storage of high level liquid wastes in tanks has been universal practice. Intermediate level liquid wastes have been treated by a variety of methods most of which result in the dispersal of a low level waste and the confinement of an intermediate or high level residue. Intermediate level wastes have been disposed to soil columns where radioactive residue is sorbed and held by ion exchange on minerals in the soil. Low level wastes have been dispersed through settling ponds or directly to rivers and the ocean as warranted. Solid wastes have been buried in various degrees of containment world-wide. Gaseous wastes have been treated by filtration and other gas cleaning methods to remove essentially all of the radioactivity prior to dispersal.

The waste management practices at Hanford encompass most of the practices throughout the world because of the large and diverse operations at the site. The following description of the Hanford practices can be viewed as typical of the current atomic energy industry practices.

Solid Waste Disposal

Solid wastes are buried by several techniques depending on the size, weight, and contents of the wastes.

Burial Trenches for small solid waste boxes or drums are about 12 feet deep. Boxes or drums are dumped into the shallow

trenches, and the trenches are back-filled with earth by bulldozers. The weight of the soil covering the boxes crushes them, compacting the waste.

Failed or obsolete process equipment is packaged in wooden, concrete, or steel boxes and buried in trenches about 16 feet deep (Figure 2). The boxes are transported to the burial trench by railroad using spacer cars to separate the train crew from the radiation field emitted by the burial container. Roads are barricaded during waste transfers to protect personnel from accidental radiation exposure. At the burial site the box is pulled into the trench by a bulldozer and a long cable. The trench is then back-filled with earth by the bulldozer. During trench filling the bulldozer operator maintains an earth shield between himself and the box. Several years ago a box broke open while it was being buried. As the box collapsed, contaminated air was released into the environs resulting in local contamination. This risk is now minimized by using stronger boxes and filling the box cavity with a filler material such as vermiculite.

Monitoring wells are sunk in the burial garden to maintain surveillance of the site; no evidence of migration of radioactive materials has ever been detected.

Burial trenches are in a fenced area to prevent unauthorized access. Waste is covered with a minimum of 4 feet of soil and any additional soil required to reduce surface readings to less than 1 milliroentgen (mR) per hour. No curie limits are imposed on the quantity of activity that may be buried in boxes or with failed

FIGURE 2

TRENCHES

FIGURE 3

CAISSONS

equipment. The intent is to decontaminate equipment as much as practicable prior to burial; in practice, the dose rates that can be safely handled by this technique set the quantities of activity that can be buried.

Caissons - Wastes that are small in volume but high in activity level may be packaged in 55-gallon drums and dropped into underground caissons (Figure 3). This arrangement permits ready transport in shielded containers that mate to the caisson during disposal so that personnel exposure to radiation is avoided. A portable concrete collar and plug are provided as a temporary top closure until the caisson is full of drums. When full, a concrete cap is poured and the drums are permanently isolated. Monitoring wells to ground water are located adjacent to the caissons to detect any migration of radioactivity. Again the dose rates set the quantities that can be handled.

Tunnels - Some very large pieces of processing equipment are too large for practical packaging and transport to burial trenches. These equipment pieces are placed on railroad cars and pushed into burial tunnels especially constructed for this purpose. These tunnels connect into the plant railroad system within the plant containment walls so that no external problems are encountered. The equipment is flushed and decontaminated before it is placed in the tunnel to minimize contamination problems.

Each of the solid waste disposal techniques has been completely successful from a confinement consideration, since the favorable climatic conditions preclude leaching of waste solids. The tunnel

approach makes reclaiming failed equipment a theoretical possibility. In practice the obsolescence rate of equipment makes this an unimportant consideration.

Gaseous Waste Disposal

Gaseous wastes are dispersed from controlled ventilation systems to prevent release of radioactivity. Ventilation air for process buildings is supplied from the atmosphere by fans through filters (Figure 4). After passing through the building the air is transferred through a rough filter and two stages of high efficiency filters before venting to the atmosphere through a 200-foot stack. The air is continuously monitored and sampled periodically to determine the quantity of radioactivity released to the atmosphere.

Treatment of off-gases from process equipment varies significantly depending on the history and gas composition. The vessel ventilation off-gases in the Purex reactor fuels processing plant pass through a condenser, a heater, a silver reactor for iodine removal and through two filters prior to stack entry. Ventilation and process off-gases from all other processing operations having potential for the release of particulate radioactive material are exhausted to the atmosphere through high efficiency filters in series to prevent radioactivity release. In addition, separators, demisters, scrubbers and absorbers are used as required to protect the high efficiency filters and retain noxious chemicals.

Low Level Liquid Wastes

Swamps - are used for the disposal of large volumes of low level waste (Figure 5). The swamps are formed by the discharge of waste to natural depressions. The area of the swamp increases until the amount

FIGURE 4

GASEOUS WASTE HANDLING - BUILDING VENTILATION

FIGURE 5
LOW LEVEL AQUEOUS WASTE
DISCHARGE FACILITIES - SWAMPS

Minimum travel time to river about 3 years.

of water lost by evaporation and percolation through the soil equals the rate of waste addition. A Hanford swamp will accommodate a flow of about 4 to 7 gallons per square foot per day.

Operational controls on swamps are minimal. The volume of waste entering the swamp is measured and the radionuclide content of the waste monitored by routine sampling and analyses. These controls are supplemented by in-line radiation detection instruments to ensure routine control of radionuclide concentrations below 5×10^{-5} $\mu\text{Ci/ml}$ of alpha and beta radioactivity. Wells adjacent to the swamps are also monitored to ensure complete control of the amount of radioactivity entering the ground water from this source. Capability is being installed to divert high volume, low level wastes to intermediate level liquid waste trenches should they inadvertently become contaminated above allowable limits.

Intermediate Level Liquid Wastes

Cribs - are used extensively for the disposal of intermediate level wastes and low level wastes that are judged to have a high potential for becoming contaminated. A crib is a sub-surface liquid distribution system. Cribs are long, narrow trenches about 10 feet wide at the bottom, filled with several feet of graded gravel as shown in Figure 6. A plastic membrane is placed over the gravel and the trench back-filled with earth. A single distributor pipe traverses the length of the crib within the gravel bed about 4 feet above the bottom of the excavation. For Hanford soils the design percolation rate is 10 gallons per square foot per day. Wells are drilled to various depths within the ground water adjacent (60 - 100

PLAN VIEW

CROSS SECTION—TYPICAL HANFORD
CRIB

FIGURE 6

yards) to the crib in the direction of ground water movement to permit monitoring of the crib effluent as it enters the ground water.

The long-lived isotopes of concern (^{90}Sr , ^{137}Cs and ^{239}Pu) sorb on the soil and are restricted from migrating to man's environment. Cribs are removed from service when long-lived radioactivity such as ^{90}Sr , ^{137}Cs , or ^{60}Co is detected in ground water beneath the crib site in concentrations approaching 10 percent of the maximum permissible concentration in drinking water.

Operating standards are imposed on cribs to ensure that the cribbed waste volumes and compositions are compatible with the soil to the extent that a reasonable crib life can be expected. These limits are responsive to the inherent degree of control the plant equipment affords over the waste composition and are based on laboratory soil adsorption studies with synthetic and actual plant waste.

Trenches - have been infrequently used for the disposal of intermediate level wastes with poor or unknown soil adsorption characteristics. This form of disposal relies on the sorption or blotter action of the soil to retain the liquid which may be either aqueous or aqueous-immiscible organics. Under the semi-arid climatic conditions existing at Hanford, there is no natural percolation to the ground water and the added liquids are held in the soil by capillarity. In practice, excavations 4 feet wide at the bottom, 20 feet deep and 200 feet long have been made with conventional earth moving equipment. Liquid wastes have been transported to the trenches in disposable drums, tank trucks or pipe lines. When the volume deposited in a trench reached 7 percent of the soil column volume beneath the trench, disposal was discontinued and the

trench was re-filled with earth. Additional facilities and modifications are being considered to eliminate this means of waste disposal. Currently this method of disposal is being terminated except for emergency backup for disposal of low level wastes which might become contaminated through process equipment failure.

High Level Liquid Wastes

In waste management processing high level liquid wastes are considered in two heat levels, self-boiling wastes and non-boiling wastes. Self-boiling wastes are wastes which contain the majority of the fission products and which normally self-boil in the storage tanks for several years after discharge. These wastes include currently generated concentrated solvent extraction wastes from the Purex chemical separations plant and stored self-boiling wastes generated earlier at the Purex plant and at the Redox separations plant which was shut down in 1966.

Non-boiling wastes are, stored and currently generated, salt wastes from the chemical dissolution of aluminum or zircaloy jackets from uranium fuel elements and stored well-aged process wastes from early separations plant operations.

Waste Storage - High level liquid wastes from the chemical processing plants at Hanford have been stored as alkaline slurries in underground tanks since startup. Currently, wastes in-process are being stored on an interim basis. The complex of waste storage tanks includes 149 tanks, ranging in capacity from 50,000 to 1,000,000 gallons. These tanks are constructed of reinforced concrete with a carbon steel liner on the

bottom and side walls. The first tanks were built for non-boiling wastes (Figure 7). These tanks are vented to the atmosphere, some through air-cooled reflux condensers. Instrumentation is provided to measure the sludge and supernatant temperature, and the liquid and sludge levels in the tanks. A grid of dry wells in each tank farm is used to monitor the soil for radioactivity, thus serving as a secondary leak detection system.

Later tanks were built to contain wastes with greater heat generating characteristics (Figure 8). These tanks are of the same general construction as those described for non-boiling wastes. Additional features have been provided, however, to permit self-concentration of waste, the vapors being routed through headers to cyclones and water-cooled condensers which are vented to the atmosphere after passing through a packed deentrainment vessel, filters and exhaust blowers. Condensate is routed to an underground crib or is returned to the waste tank to prevent over-concentration. The tanks are provided with airlift circulators for the agitation of the contents to prevent localized temperature buildup in the sludge and resultant bumping caused by sudden steam release. Each tank is closely encompassed by a complex of vertical and horizontal dry wells so that any leak may be detected by monitoring for radioactivity in the soil surrounding the tank. Some of the tanks have a drainage grid beneath the tank liner which connects to an associated leak detection well. A temperature element, liquid level instrumentation, and a radiation detector are located in each well. Any leakage which might be detected can be removed by pumping.

STORAGE TANK FOR NON-HEATING WASTES

FIGURE 7

FIGURE 8

CONTROL & SAFETY FOR HIGH LEVEL RADIOACTIVE WASTE STORAGE

Future waste tanks to be built at Hanford will be of a tank-in-tank design with the inner shell covering the dome and the secondary shell extending to the fill line of the primary tank.

HANFORD IMPROVEMENT PROGRAM

High level radioactive waste management practices at Hanford are currently in a transition period as a well defined waste management program is being implemented to improve long term safety. The goals of the program are to:

- . Assure isolation of hazardous radioisotopes from important life forms for centuries
- . Minimize the time to reach long term safety
- . Minimize the cost to develop and implement the program.

A schematic of the current waste management program for high level liquid wastes is presented in Figure 9. Self-boiling liquid wastes which have been generated and stored in underground tanks since about 1951 are now being processed in B-Plant for removal of ^{137}Cs and ^{90}Sr prior to solidification by evaporation and cooling of the residual bulk salts in the tanks. Removal of the cesium and strontium is necessary prior to solidification in order to limit the temperatures which are attained in the salt cakes. The isolated cesium and strontium will be doubly encapsulated as dry cesium chloride and strontium fluoride compounds for interim storage in a water-cooled basin prior to movement to a long-term disposal site. Currently generated self-boiling wastes will be treated

FIGURE 9
HIGH-LEVEL LIQUID WASTE MANAGEMENT PROGRAM

similarly to stored wastes except that an aging period of from 5 to 7 years, to permit short-lived fission products to decay, is required before the residual salt waste can be in-tank solidified. High level non-boiling wastes will be processed directly to salt cakes.

Waste Fractionization

Stored self-boiling liquid wastes and current Purex acid waste are processed in B-Plant for removal of ^{90}Sr and ^{137}Cs . An over-all flow scheme for processing these wastes is shown in Figure 10. The supernatants in the stored alkaline wastes are processed by ion exchange for removal of the cesium. The cesium product is concentrated and stored in B-Plant tanks prior to encapsulation. The stored alkaline sludges are sluiced from the tanks into the 244-AR Vault, acidified and transferred to B-Plant via the 244-CR Vault for processing. After head-end treatment using a lead-carrier, sulfate precipitation flowsheet with a carbonate metathesis step, the strontium is further purified by di-(2-ethylhexyl)phosphoric acid (D2EHPA) solvent extraction in four-pulse columns. The strontium nitrate product is concentrated and stored in B-Plant tanks prior to encapsulation.

Currently generated Purex acid wastes are transferred to B-Plant via lag storage in the 244-AR Vault. The solids are removed from the current acid waste and treated for removal of strontium, while the supernatant is processed for cesium recovery by precipitation with phosphotungstic acid (PTA). The recovered cesium is blended with alkaline tank farm supernatants and further processed by ion exchange. Strontium is recovered by campaigning the acid waste through the solvent extraction system. All B-Plant wastes from treatment of current acid waste

WASTE FRACTIONIZATION FLOWSHEET

FIGURE 10

are sent to interim boiling waste storage for 5 to 7 years to allow the short-lived fission products to decay prior to in-tank solidification.

In-Tank Solidification

Non-boiling wastes are solidified in existing tanks by evaporation with crystallization upon cooling. There are three types of evaporators in operation. One unit is a large electric immersion heater (4000 KW) installed in an airlift circulator in a storage tank. A second unit is a heated air unit in which about 3000 cfm of air at 1200 F is supplied to an airlift circulator in another waste storage tank. The third unit is a conventional steam heated tube bundle evaporator of about six million Btu/hr capacity. The evaporator units are operated on a recycle basis which permits solids to build up in air cooled bottoms receiver tanks and the supernatants to be returned to the evaporator.

The electric immersion heater is shown in Figure 11. The off-gas treatment facilities and operational mode are typical of the other units. The feed is pumped to the evaporator tank where it is concentrated to about 10 percent solids. The concentrate is pumped to a cascade of cooling tanks for further solids formation and deposition. The supernatant is recycled with fresh feed. The off-gas system includes a deentrainer, a condenser, a cyclone separator and high efficiency filters. The condensate is routed to a crib and the gases are vented to the atmosphere through a stack. The condensate's radioactivity is very near low level waste concentrations and the gases are well within release guide concentrations.

IN-TANK SOLIDIFICATION

FIGURE 11

Strontium and Cesium Encapsulation

The strontium and cesium recovered in B-Plant operations will be further purified, converted to dry salts, and packaged in high integrity containers for underwater storage until the method of ultimate disposal is determined. The conversion and encapsulation operations will be carried out in a new facility containing 5 shielded manipulator cells to be constructed adjacent to B-Plant.

The strontium will be precipitated as a fluoride in a sodium hydroxide-sodium fluoride solution (Figure 12). The resulting slurry will be filtered, dried, and then calcined at 1100 C. The powder will be ball-milled, and then step pressed into a liner which will be welded shut. The container will be leak-checked, roughly decontaminated and then further decontaminated by steam and ultrasonic cleaning. The liner will be inserted into an over-pack which will be welded shut and tested for leaks. The capsules then will be loaded out for storage in a water pool.

The cesium will be fed to a concentrator-converter where hydrochloric acid will be added to convert the cesium to a chloride. The concentrated chloride will be gravity fed to tantalum melt pots for final concentration, drying, and melting at 650 C. From the pots the melt will be poured into molds in a chilled casting wheel. The cast slug will be placed in its inner liner and capped by use of a cover press and welder. After leak checking and rough decontamination, the container will be cleaned by steam and ultrasonic techniques. The liners will be loaded in groups of four into a second container, or over-pack. After welding and nondestructive testing of the over-pack it will be loaded out for storage in a water pool.

FIGURE 12

STRONTIUM AND CESIUM ENCAPSULATION

FUTURE TRENDS

Even as major waste management programs are being implemented at atomic energy industry sites new technology and evolving waste management criteria are rendering parts of the programs obsolete. This continuing evolution has been recognized by both the AEC and firms in the industry. The emphasis is therefore on continued improvement of safety with the option for redirection of the programs with time. With the advent of commercial nuclear fuels processing plants, firm definition of waste management criteria for commercial firms is desirable because of the effect on fuel processing economics. The AEC is currently taking significant steps to provide such criteria.

The trends in radioactive waste management are toward a tightening of radioactivity release limits and increased safety of long-term waste disposal methods in cognizance of the rapidly expanding nuclear power industry and associated waste generation rates. The emphasis on the conservation of land, water and air resources is increasing. The waste form for long-term storage and the selection of storage sites is under intensive review.

Land burial of solid wastes will probably continue in the future; however, careful selection of burial sites will be required. Compaction of the solid wastes to conserve land is probable. Special vaults or other confinement facilities will probably be required. Development of new and better disposal methods will be pursued. England and European countries will probably develop sea burial because of the scarcity of suitable land burial sites.

Gaseous wastes will be treated to meet tighter radioactive and chemical pollution control limits. The use of more efficient nitrogen oxide recovery systems (e.g. absorption under pressure vice under vacuum), or oxygen deficient incineration are two methods for reduction of nitrogen oxide discharges to the atmosphere. Improved methods of trapping the radioactive gases will also be required.

Nuclear fuel processing plants being designed and constructed today will provide a significant reduction in volume of intermediate and low level liquid waste for disposal. Process streams will be recycled and re-used one or more times; however there will still be significant volumes of wastes for treatment. The radionuclides in the wastes will have to be below MPC_w before disposal.

Evaporation of these waste streams is a proven method for decontamination. The radioactivity content of the condensate stream, except for tritium, can be reduced by factors of 10^3 - 10^6 by a single stage of evaporation. Since evaporation is relatively expensive and since additional volumes of steam condensate and cooling water are generated in the process, alternative treatment methods are desirable.

The waste streams generated by nuclear fuel processing plants contain a mixed fission product spectrum, and removal of all of the radionuclides by a single treatment process is usually not possible. For example, zeolite ion exchange will effectively remove ^{137}Cs ; a polystyrene resin ion exchange column will effectively remove ^{90}Sr . Flocculation and filtration will remove several radionuclides but not ^{137}Cs or ^{106}Ru . Reverse osmosis and electrodialysis will also remove many radionuclides from these streams. Considerable development work

will be required before a nuclear processing plant operator can be assured that any one or a combination of treatments will provide an effluent stream which meets MPC_w limit for discharge.

High level liquid wastes will also be minimized in the future because of economics and the technical problems associated with disposal. Commercial nuclear fuel processing plants are currently using mechanical dejacketing which eliminates the liquid waste volume associated with chemical decladding. Alternative reductants are being developed for use in the process flowsheets aimed at minimizing the chemical salts in the wastes, especially iron and sulfate, to reduce the waste volume and simplify waste solidification processing. High level wastes with relatively low concentrations of chemicals and fission products will be concentrated prior to storage or treatment.

The high level liquid wastes will be processed to a solid form for disposal. The self-boiling waste will generally be stored for an interim period for decay of short lived fission products and reduction in the associated heat generation prior to solidification. The non-boiling wastes will be treated within a short time of generation to minimize storage costs.

Several methods for solidification of self-boiling wastes are in the final stages of pilot plant testing at the Pacific Northwest Laboratory of Battelle Memorial Institute and will be ready for industrial application within the next few years. These processes were developed on the bench scale at the National Laboratories of the AEC and were brought together at Hanford for the final development

and evaluation steps. The solidification methods being developed are spray calcination, pot calcination, fluidized bed calcination and phosphate glass formation. The best final form has not been decided; a trade off between solubility and physical properties is still in question. The costs of the processes appear to be relatively equal and will probably not be the major factor in the final choice. Any of the methods may be acceptable from the operational and safety standpoint.

Solidification of the non-boiling wastes has also been under investigation for a number of years and several methods are feasible. Fluidized-bed calcination has been demonstrated with aluminum nitrate and zirconium nitrate wastes at Idaho Falls and spray calcination is also feasible. Solidification of wastes with plastic, asphalt or cement has been demonstrated. Choice of the method to be used will depend on the waste characteristics, and economic and safety considerations.

The solidified high level wastes will be stored in or disposed to sites owned and designated to be safe by the government, either State or Federal. Abandoned salt mines have been proposed as the most probable storage sites but caverns in deep bed rock or vaults buried in desert areas are also being considered.

Considerable development work is being done to determine the suitability of such sites for radioactive waste disposal. A major development program on storage of radioactive wastes in salt mines is being completed by Oak Ridge National Laboratory. The storage of solid radioactive wastes in the desert is being demonstrated in the

Hanford program. Detailed investigation of the technology and safety of deep bedrock storage is being conducted at the Savannah River Plant. In addition, ARHCO is starting a program for the AEC to investigate the potential for deep disposal of waste in basalt beneath the Hanford site. At this time none of the methods have proven acceptable to all competent reviewers but on the other hand none have been shown to be hazardous. Development work is expected to continue for some years on the location of radioactive waste disposal sites.