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THE DISPOSAL OF RADIOACTIVE LIQUID AND GASEOUS WASTE
AT OAK RIDGE NATIONAL LABORATORY

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AUGUST 1967

OAK RIDGE NATIONAL LABORATORY

Oak Ridge, Tennessee

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ABSTRACT

This report, which describes the ORNL radioactive waste disposal systems, is a revision of a similarly titled report (TM-282) issued in 1962. Since that date, growth of the Laboratory has extended the waste disposal systems and the accompanying monitoring nets to the new facilities in Melton Valley. The whole concept of intermediate-level waste disposal has changed with the elimination of soil disposal pits and trenches in favor of deep-well injection of an evaporator concentrate. Increased demand on the systems has resulted in continual upgrading and replacement of equipment and changes in operating procedure. In this report an effort has been made to include the significant changes seen in the area of waste disposal at ORNL during these years.

INTRODUCTION

The Oak Ridge National Laboratory, functioning as a research center for the Atomic Energy Commission, is engaged in a wide variety of activities, most of which involve operations that use radioactive materials. Research and development groups are involved in experimental studies that include the chemical processing of many highly active substances, ranging in quantity from millicuries to kilocuries. There are at the Laboratory eight nuclear reactors of different types, three of which operate continuously and provide facilities for numerous experiments. One of these, the High Flux Isotope Reactor, operates at a power of 100 Mw. This reactor will be used to irradiate plutonium targets and to produce, over a period of years, gram quantities of ^{252}Cf . The transplutonium program is already well under way at the Laboratory with gram

quantities of curium and americium isotopes being processed routinely.

Such operations invariably produce radioactive gaseous and/or liquid wastes which must be disposed of. Large volumes of this waste may be generated; and, depending on the processes involved, hazardous quantities of a wide variety of nuclides may be present. It is the function of a central waste system at the Laboratory to collect and remove this material in a manner which will present the least hazard to the environment outside the AEC controlled area or to the personnel and operations within that area.

Two classifications of liquid waste are used at the Laboratory--the division being made according to the radioactivity level present. Low-level process waste water constitutes the largest volume and contains only trace amounts of radioactivity. The process waste water comes from equipment cooling systems, floor drains, laboratory sinks, and discharges from other low-activity operations. It is the least radioactive of the liquid wastes except for sewage and storm water, yet it is the most difficult to manage because of its combination of low radioactivity and large volume. Intermediate-level waste is produced in a much smaller volume and originates in process vessels in the laboratories and "hot" cells. Other possible sources of this waste, such as laboratory hoods or decontamination areas, may be equipped with "hot" drains which connect to this system. The volume of intermediate-level waste comprises only 2-5% of the total liquid waste generated by the Laboratory; however, its radioactivity level may be 100,000 times higher than that of the process waste.

Gaseous waste is classified in a similar manner to the liquid

waste and is handled by two systems. A cell-ventilation system handles a large volume of air containing very small amounts of radioactivity. An off-gas system deals with greater amounts of activity in a smaller volume.

As the Laboratory has grown and expanded, so has the volume and activity of waste produced. In order to keep pace with this growth, the waste disposal facilities have been enlarged or have undergone major modifications from time to time.¹ When the Laboratory was established in 1943, the first construction included the Graphite Reactor, a chemical-separations pilot plant, and a number of large underground concrete storage tanks. The tanks were soon filled with highly radioactive chemical waste and liquid uranium waste, and it was necessary to reduce the volume by precipitating as much activity as possible directly in the tanks and then decanting the supernate into White Oak Creek.

In that same year a dam was built across White Oak Creek and an impoundment area created for possible holdup of discharged waste. In the summer of 1944 a 1,500,000-gal basin was completed to serve as a stilling pond for process waste. It also permitted settling of radioactive solids from the waste before discharge into White Oak Creek.

In 1949 the precipitation and decantation procedure for treatment of the highly active waste was replaced by an evaporation step, which produced a concentrate that was permanently stored in the concrete tanks and a low-level condensate which was discharged into the creek. The first soil disposal pit was put into operation in 1952. This consisted of an excavation, which, after being filled with waste, would permit

seepage through, and decontamination by, the soil through sorption. The evaporation process was discontinued two years later. From that time and until very recently, the pits were used to dispose of what is now termed intermediate-level waste.

In 1950 further expansion of the Laboratory called for more drastic revisions of the disposal system. A tributary-monitoring system that provided flow rates and proportional sampling was added to the process-waste system. Stainless-steel tanks for the collection of intermediate-level waste were added throughout the area to provide better segregation and volume control. For gaseous wastes an additional 250-ft stack, filters, and an electrostatic precipitator were added.

In 1955 the lake which had been created behind White Oak Dam was drained. This was done to permit modification of the dam, to provide additional emergency impoundment volume as an added safeguard, and to drive out the fish and wild fowl that had been attracted to the lake.

A water treatment plant for the decontamination of process waste water was completed and put into operation in 1957 and has been in continuous operation ever since.

The disposal of intermediate-level waste came under critical study again in 1961 and the decision was made to resume concentration of the waste by evaporation and then to ultimately dispose of the concentrate by using the shale-fracturing method developed at ORNL. Construction of a new waste evaporator was completed in 1965 and by late spring of 1966 the facility was in continuous operation. The shale fracturing process went into routine operation in 1966, and the first injection of waste concentrate was successfully carried out in December of that year.

The goal of radioactive-waste management at ORNL is to dispose of wastes as safely and as economically as possible. The present approach is as follows:

1. Chemically treat the low-level liquid waste and remove the greater part of the radioactivity prior to discharge into the stream and river system. Dilution in the river then reduces the concentration of radioactivity to levels well below the maximum permissible concentrations set by the National Committee on Radiation Protection and the International Commission on Radiological Protection.²
2. Concentrate the intermediate-level waste by evaporation and then finally dispose of the concentrate by injection, as a concrete grout, into shale beds lying approximately 900 ft below the surface.
3. Filter and/or chemically treat all gaseous waste before discharge to the atmosphere. Final discharge to the atmosphere is made through stacks of sufficient height to insure the dilution of the released radioactivity to levels below the maximum permissible concentration.
4. Monitor all waste streams before and after discharge to verify safe operation.

INTERMEDIATE-LEVEL LIQUID WASTE

Intermediate-level wastes, generated in many areas where radioactive materials are handled (see "Wastes From Reactor Operations", Appendix A), are discharged from hot sinks, glove boxes, and processing vessels into 22 underground stainless-steel monitoring tanks at the rate of 5,000 to 10,000 gpd (see flowsheet, Figure 1). This quantity of waste will contain from 75 to 100 curies of radioactivity. The capacity of the monitoring tanks varies from 500 to 2,000 gal depending on the needs of the buildings served. To protect these tanks and other waste-disposal equipment from chemical corrosion, especially chloride attack, the liquid in the monitoring tanks is kept basic while the tanks are being filled.

The waste in the monitoring tanks is transferred by pumps and steam jets through 2-in. stainless steel lines to a 170,000-gal concrete holdup tank. (Six of these tanks were built in 1943 by the Gunitite process. They are 50 ft in diameter, 12 ft deep, with 1-ft-thick walls. The inside walls were originally coated with an asphaltic material³). The choice between jets and pumps is determined by the elevation of the monitoring tanks and the length of the transfer lines.

The waste, temporarily stored in the holdup tank, is pumped in batches to the Evaporator Facility, Building 2531, where it is concentrated by a factor ranging from 10 to 30:1. The concentrate is returned to another of the Gunitite tanks for storage. The condensate, after polishing by ion exchange to remove last traces of activity, is released to the process waste system. Final disposal of the concentrate is by

ORNL DWG 67-3510

Fig. 1. Intermediate-Level Waste System

injection, via a deep well, into underlying shale formations located in Melton Valley approximately 1 1/2 miles from the main Laboratory area.^{4,5}

An isometric view of the hydrofracture facility is shown in Figure 2. At the site, three tanks with a total capacity of 40,000 gal will be used to store the waste during the injection operation. Four bulk storage bins are available for storage of the cement and other dry components used in the grout formulation. The injection pump and other transfer pumps; mixing and blending equipment; and control and monitoring devices comprise the remainder of the equipment located at the wellhead. Prior to each injection a grout sample is prepared and tested for setting time and other pertinent characteristics. The solid constituents of the mix are then blended and stored and the injection well is slotted at the desired depth. Water is pumped into the well and the pressure is increased until the formation fractures. At this time pumping of waste to the mixer is begun, simultaneously with the addition of the blended solids. The resultant slurry is pumped down the well and into the fracture continuously until the end of the run. Injection rates are such that the facility only needs to operate two or three times each year and then for only two or three days at a time.

Until 1959 open seepage pits were used exclusively for the disposal of all intermediate-level waste; and the operation was considered safe, simple, and economical. It had been determined that ruthenium was not completely retained by the soil. Still, strontium retention was good; and, since ^{90}Sr was the controlling contaminant in the MPC_w consideration for the river, there was little concern over the ^{106}Ru release. Late in 1959 and early in 1960, however, large amounts of ruthenium were

Fig. 2. ORNL Hydrofracture Disposal Plant

sent to the pits, and the river concentration began to increase. (See "Conditions Affecting the Operation of the Intermediate-Level Waste Disposal Pits", Appendix A). At the same time radiation at the pit site became too high to send personnel into the area for sampling or other purposes.

To cope with these growing hazards a covered trench (No. 5) was put into operation in June 1960 as a temporary expedient to eliminate the open-pit operation. This trench, being covered, eliminated the problem of a high radiation background. It was placed in an area where seepage to the surface was expected to take a much longer time so that the ^{106}Ru would be considerably reduced by decay before it was released.

An additional trench (No. 7) was constructed and put into operation in the fall of 1962 to provide needed extra capacity. This trench was made in two sections with a total volume of 50,000 gals. The sections were alternately filled so that if a leak was detected the faulty section could be taken out of service. Trench No. 7 gave good service and many thousands of gallons of waste were disposed of there; however, when the decision was made to discontinue seepage disposal, both trenches were taken out of service. (See "Difficulties Encountered in Covered Trench Operations", Appendix A).

The main problem in operating the intermediate-level system is the prevention of unnecessary dilution of the waste with water. The difficulty in gaining the cooperation of the large numbers of users of the waste system is, at times, a problem. Therefore, the operators of the waste-disposal system must constantly inspect the areas where wastes are generated and periodically call the attention of the workers in these

areas to the waste problems at hand. As noted earlier, intermediate-level waste is received in a number of monitoring tanks which segregates the discharges of the various operating and laboratory groups. The volumes of these discharges are regularly measured to detect abnormal conditions in the areas. The liquid levels are telemetered and continuously recorded in one building, the Waste Monitoring Control Center. After the waste disposal operator becomes familiar with the normal discharge levels from the various areas and with the habits of the users, he can detect abnormalities very quickly and can often go directly to the source of the trouble.

PROCESS WASTE

Process waste is generated at a rate of approximately 400,000 gpd. It is water from process-vessel cooling systems and drains in laboratory and operating areas and may become contaminated with radioactive materials through malfunction of process equipment, spills, or other accidents. Under ideal conditions, process waste should contain little or no radioactivity.

Waste from the Bethel Valley area is collected from the sources and flows by gravity to a common point, the diversion box (see flowsheet, Figure 3). At the diversion box the waste may be routed to an equalization basin for processing through the Waste Treatment Plant; or it may be sent directly to the creek, without processing, by means of a valve controlled by the radioactivity in the waste. Since 1964, because of a reduction in volume, all process waste has been sent through the treatment plant and use of the diversion valve in the future is not anticipated. (See "Diversion Box", Appendix B). In Melton Valley a series of ponds is

provided to segregate the waste generated by the HFIR and other facilities located in that area. Tributary monitors automatically divert waste containing excessive radioactivity to a "hot" pond from which it is pumped to the equalization basin; uncontaminated waste is collected in "cold" ponds and, after final sampling, is discharged directly to Melton Branch. The equalization basin serves to level out fluctuations in pH and volume of waste received. From the equalization basin, the waste is fed into the Waste Treatment Plant where approximately 70-90% of the activity is removed by a modified water-softening process using lime, soda ash, and clay.^{6,7,8} The waste is then released to the creek, and the activity that is removed is transferred with the sludge to a pit in the solid-waste burial ground.

Current discharges of radioactivity from this system into the creek average about 1 curie per month, with ^{90}Sr accounting for less than one-third the total. Although the quantity of ^{90}Sr is small compared with the amount of other activity released into the creek it is now the most important nuclide from the standpoint of health in considering river contamination.

While the dilution of the river provides a considerable reduction in concentration, the Laboratory's goal is to reduce the activity in the creek so that at the point of its discharge into the river the activity will be within the maximum permissible concentration for the exposure of the residents in the neighborhood of an atomic energy installation. Much progress has been made thus far toward reaching this goal. As the permissible concentrations have been lowered, the releases of radioactivity over the past 14 years have also been greatly reduced.

Fig. 3. Process Waste System

Controlling releases into the process waste system involves persuading the users to eliminate unnecessary discharges of water into the system so that the total volume of waste does not exceed the capacity of the Process Waste Treatment Plant and eliminating, insofar as possible, all but accidental releases of activity into this system. Users are encouraged to keep the volumes of radioactive waste to a minimum and to discharge it into the intermediate-level waste system. The success in reducing the releases to date is due mainly to intensive monitoring of the flows through the process waste system tributaries and to prompt identification of the releases with the facilities responsible. New improved equipment installed in the system in recent years has enhanced the effectiveness of the monitoring work.

There are 14 monitoring stations in the process waste system. One is located at the inlet to the equalization basin where all tributaries join, and the rest are in the main tributaries of the system. Each station is equipped with continuous-flow and radioactivity-measuring devices with telemetering connections to the Waste Monitoring Control Center where the data is recorded. A proportional sampler is also installed at each station. A typical monitoring station is shown in Figure 4.

One of the waste disposal operator's most important duties is to locate the source of abnormal discharges (volume or activity) into the system. The data from the monitoring stations, recorded at the Monitoring Control Center, lead him to the general area where the discharges occur. Knowledge of the normal releases from each area and the type of work being done often enables the operators to identify a release with a specific operation. Information thus obtained is immediately referred to those

responsible for the releases. Corrective measures may, therefore, be initiated promptly--measures which otherwise might not be started until more dangerous quantities of activity were released into the process waste system (see "Reporting of Information", Appendix A).

Proportional samples are taken every four hours at the inlet to the equalization basin and analyzed for gross beta and alpha activity, mainly to be sure that the monitor at that point is in good working order and to give a better estimate of the total activity passing through the system. Samples taken at the tributary monitors may be analyzed when abnormal discharges occur and there is need to know what nuclides are present in order to determine the source of the material; otherwise, analyses are made only monthly for inventory purposes.

CREEK AND RIVER MONITORING

Normally, all the radioactivity discharged to the creek comes from the intermediate-level and process waste systems. However, there are other routes which bypass both systems through which activity may accidentally get into the creek. One of these is the sanitary sewer system which discharges its effluent from the sewage treatment plant into the creek, and another is the storm sewer system which collects ground surface drainage and discharges it at several points into the creek. Activity has gotten into both systems on several occasions by seepage into their loosely joined underground pipes from leaking intermediate-level waste lines, and by improper use of the systems. An incident occurred several years ago when a leak from an underground radioactive waste line channeled through the soil to the sanitary sewer. This was not detected immediately; and, consequently,

Fig. 4. Typical Process Waste Manhole Monitoring Station

the sewage treatment plant became contaminated. The solid-waste burial grounds present another potential source of activity for the creek, although the seepage from them has thus far been insignificant and is not likely to become a serious problem.⁹

To detect accidental releases from the potential sources just mentioned and to maintain a complete inventory of activity releases to the creek from these sources, from the intermediate-level waste pits and trenches and from the Process Waste Treatment Plant monitoring stations have been installed along the creek. A typical monitoring station is shown in Figure 5. These stations measure the total flow and provide a proportional sample. Results of the monthly analyses of these samples are used to calculate the total radioactivity discharge for the period (see "Stream Monitors", Appendix B).

There are seven stations such as this in use at present. The locations are shown in Figure 6. Station 1 samples the discharge from the process waste system only. Station 2 samples the White Oak Creek flow from the east end of the Bethel Valley area (many storm sewers discharge into the creek in this area). Station 3 samples White Oak Creek and the flows from Burial Grounds 3 and 4, from the process waste system, and from the sanitary and storm sewage systems. Station 4 samples Melton Branch and flows from Burial Ground 5 and the Melton Valley facilities. Stations 5 and 6 sample the seepage from the pit area; no continuous sampler is provided for the seepage from the trenches since grab-samples have indicated that the activity there is not significant. Station 7 located at White Oak Dam, samples the entire release into the Clinch River and is operated by the Health Physics Division.

Samples normally taken at the creek monitoring stations cover an operating period of one month. They are analyzed for total Sr, ^{137}Cs , ^{106}Ru , ^{60}Co and gross beta activity. A reasonably good material balance is usually obtained between Stations 1 through 6 and Station 7 for all activity except ^{106}Ru which comes mainly from the pit area. The ruthenium discharge, measured at White Oak Dam, has always been lower than the total of the ruthenium discharges from the individual sources; holdup in the lake bed may account for this (See "Retention of Ruthenium in White Oak Lake Bed", Appendix A).

In addition to the sampling stations just mentioned, direct radiation monitors are now installed in the Sewage Treatment Plant effluent line and in the creek between the burial ground in Melton Valley and the main Laboratory area. The signals from these monitors, which measure radiation only, are also telemetered and recorded at the Waste Monitoring Control Center. Their purpose is to notify the operators of any significant amount of activity released through the sanitary and storm sewer systems.

GASEOUS WASTE

The same sources which produce radioactive liquid waste at the Laboratory usually generate quantities of gaseous waste. The greater part of this waste is discharged to the atmosphere from six stacks. (Some buildings release small quantities of ventilation air from roof exhausts; however, the amounts of radioactivity involved are small and such systems will not be discussed here. It should be pointed out, however, that any operation at the Laboratory which proposes to release gaseous wastes directly to the atmosphere in this manner is scrutinized very carefully and the safety of the operation must be assured beforehand).

Fig. 5. Monitoring Station on White Oak Creek

Fig. 6. Location Plan for Laboratory Stream Monitoring Stations

In the Melton Valley area of the Laboratory are located the newest research facilities: the High Flux Isotope Reactor (HFIR), the Transuranium Facility (TRU) where the targets from the HFIR will be processed, and the Thorium-Uranium Fuel Cycle Development Facility (TUFCDP). Gaseous wastes from these areas consist mainly of off-gas from reactor coolant degasifiers and chemical processing equipment and ventilation air from cells and containment areas. The off-gas streams, being the most radioactive, are passed first through charcoal beds where adsorbable activities are removed and then through absolute filters before discharge to the stack. Cell-ventilation air is only filtered. A common stack serves all these areas. Although the HFIR is now operating at its rated power level (100 Mw), little activity has been found in its waste streams. Likewise, the TRU facility has, at this time, only small amounts of activity present in the cells and the discharge of gaseous activity from this area is negligible at the present time.

The Molten Salt Reactor Experiment (MSRE), also located in this valley, has the capability of producing radioactive gaseous waste. Off-gas from the fuel pump and the reactor cell and ventilation air from other cells and containment areas is treated, as at the HFIR, either by filtering alone or by both filtering and exposure to charcoal. This facility is served by its own stack. Activity releases from this area have been found to be very low, consisting mainly of ^{131}I and rare gases.

Most of the Laboratory's operations are located in Bethel Valley, and it is from this area that most of the gaseous activity originates. The oldest contributor to the gaseous waste system in this area is the Graphite Reactor, now out of service. The fuel channels are still ventilated

however, and the exhaust air is filtered before it is released through the stack. No significant amount of activity can be detected in the release.

The Pilot Plant stack discharges ventilation air from cells and operating areas where several species of alpha emitters are processed and also from an analytical laboratory in the same building. The gaseous waste from this area passes through absolute filters but is found to contain ^{131}I and traces of the thoron daughters when it is discharged to the atmosphere.

A recently completed analytical laboratory, designed and equipped to carry out analytical procedures on very highly active substances, is also considered a potential source of gaseous particulate activity. The exhaust air from this building is filtered before release to the environment.

A sixth stack, designated as the 3039 Stack, serves most of the chemical and research facilities of the Laboratory; and about 99% of the total gaseous activity generated at ORNL is discharged through it. Principal contributors of activity to this stack are the radioisotopes processing areas, the Oak Ridge Research Reactor (ORR), and the large complex of buildings which houses the research and development groups. Although a wide variety of operations is tied into this stack, the predominant activity here, as elsewhere, is and has always been ^{131}I . However, during recent years, at least 24 other nuclides have been identified in the stack emissions.

The discharge from the 3039 Stack is divided into two streams in a manner analogous to that used in classifying liquid waste. Cell-ventilation air, originating in areas such as laboratory hoods and cells which may contain process equipment, is high in volume but low in activity. The off-gas system, handling a much smaller but much more radioactive stream, is connected directly to the operating equipment in instances where venting is

required or a reduced pressure is desired. Both systems are normally used in a processing area; in the event of an off-gas failure, the cell-ventilation system will provide secondary protection since it usually vents the area around the equipment.

A schematic diagram of the cell-ventilation and off-gas systems at the 3039 Stack is shown in Figure 7. Cell-ventilation air, at the rate of about 160,000 cfm, is first filtered through roughing and absolute filters and then discharged by means of electric blowers to the 250-ft stack (see "Cell Ventilation Equipment", Appendix B).

Laboratory off-gas is handled at the rate of about 3000 cfm through a system of underground stainless steel ducts from the point of generation to the 3039 Stack area where it enters the final treatment facility and is exhausted to the stack. In certain areas, such as the Fission Products Development Laboratory where there is greater likelihood of radioactivity in the off-gas, filters, scrubbers, and/or charcoal may be used to give an initial decontamination.¹⁰ On reaching the stack area the off-gas is passed through a caustic scrubber, where the bulk of the remaining reactive gaseous activity (primarily ^{131}I) is removed. Filters then remove particulate activity, and the gas is delivered to the stack through an electric blower (see "Off-Gas Equipment", Appendix B). It is estimated that >99% of the gaseous and airborne particulate activity generated by the Laboratory is found in the off-gas and for this reason every effort is made to insure maximum decontamination prior to release to the environment.

The off-gas equipment just described was added to the system in April, 1961. The cleanup equipment in use prior to that date consisted of a filter unit and a Cottrell precipitator. No attempt was made to scrub

ORNL-DWG 65-2253R

Fig. 7. Central Gaseous Waste Disposal System,
3039 Stack Area

out gaseous activity.¹¹

As noted earlier, there are, throughout the Laboratory, processing areas and laboratories which may be served by the off-gas system but are not connected to the cell-ventilation system. Such locations, in nearly every instance, provide individual filtering and/or scrubbing at each hood, dry box, or cell before its discharge is released to the atmosphere. If there is any doubt as to the complete decontamination of the gaseous discharge, provisions are made for venting to the Laboratory off-gas system.

It is felt that the gaseous waste disposal system for the Laboratory has sufficient capacity to accommodate any reasonable demand which may be placed on it. It is necessary, however, that users exercise care and judgment. The user is responsible for keeping activity releases at levels which will not overtax the cleanup facilities. He must also be kept informed of the volume restrictions which differentiate the cell-ventilation system from the off-gas system. The former may be used as a standby for the off-gas in emergencies, but its normal function is to dispose of large volumes of air at low activity levels.

In order to provide information for control and efficient operation of the disposal system and in order that the users of the system may always be aware of the activity which they are discharging to the gaseous waste, a monitoring system has been installed.¹² This monitoring system provides, first, continuous surveillance of the activity being discharged through the system and, second, a continuous indication of

the various characteristics of operation, such as flows, pressures, mechanical reliability of the various blowers, etc. Inasmuch as the monitoring of activity in gaseous waste presents problems unique to the nuclear industry and of special interest in waste disposal, this aspect of the Laboratory monitoring system will be emphasized.

Monitoring devices used at the Laboratory fall into two broad classifications. There are devices which simply collect radioactivity over a period of time from a sample stream of gas, and there are devices which give a continuous indication of the activity level of the gas stream being discharged. The first of these types, called the inventory sampler, uses a charcoal filled cartridge containing a paper filter. (See "Inventory Sampler", Appendix B). A pump is used to draw the sample stream through the collection assembly and measurement of the flow is accomplished by use of a rotameter or an integrating flow meter. This type of sampler may be installed on off-gas or cell-ventilation ducts for monitoring the various branches of the system or it may be inserted within a stack for monitoring a total discharge. After the collection period the cartridge is disassembled and the filter and charcoal are separately analyzed by means of the gamma spectrometer; and, when the sampling rate and the flow through the duct or other passage are known, the total activity discharge for the period may be calculated.

To provide continuous monitoring of the major flows discharging into the stack, moving tape particle monitors are provided. Figure 8 shows the tape drive and detector unit of such a monitor. Radioactivity collected on the tape is measured by the detector tube and count

Fig. 8. Moving Tape Particulate Monitor, Q-2323-Tape Drive and Detector

rate meter, not shown here (see "Moving Tape Particle Monitor, Q-2323", Appendix B).

Figure 9 is a flowsheet showing the locations of these two types of activity monitors throughout the central gaseous waste disposal system. Each of the four main cell-ventilation ducts in the 3039 Stack area and the discharge from the off-gas facility is equipped with a tape monitor. Included at each of these monitor stations is a collection or inventory sampler. The filter, which is usually a part of the cartridge assembly, is not used here since the cartridge is located in series with and downstream from, the tape monitor. Occasionally during special operations it is desirable to sample a duct continuously, perhaps for inventory purposes; or, if an increase should be seen in the activity detected by the tape monitor, it may be necessary to sample with a cartridge in order to pinpoint the source of activity. The ORR is served by two systems which employ charcoal in addition to filters. These systems are monitored by ion-chamber detectors attached to the duct work.

Shown also on this flowsheet is a block titled "Stack Monitoring Instruments". Since the stack is obviously the last point of possible radioactivity detection prior to release, every effort is made here to provide the most complete and efficient monitoring array. The first sample withdrawal probe to be installed in the 3039 Stack was a perforated, 1-in. stainless steel pipe inserted across the diameter of the stack at the 50-ft level. This pipe continued down the side of the stack and was connected to monitoring and sampling devices located on the ground. Originally these consisted of an inventory sampler for

ORNL-LR-DWG 67372RAR

Fig. 9. ORNL Caseous Waste Monitoring Flowsheet

collecting a daily sample and a very simple nonmoving tape monitor (Figure 10). This tape monitor, the forerunner of the one described earlier, collected a sample by pumping a measured stream of gas through a portion of paper filter tape. The tape was simultaneously monitored by an adjacent detector unit; and, if the collected activity exceeded preset limits, an alarm sounded.

Over the years the stack monitoring system has been expanded and improved many times. At the present time the monitoring equipment for the 3039 Stack, as well as for all other stacks, is located on a balcony at the 50-ft level. At that point withdrawal probes are inserted within the stack and the sample gas is pumped to the nearby monitoring devices through a minimum length of piping. Each probe array (Figure 11) consisted of two smaller sampling pipes and a larger pipe which is of special design and is used as an inventory sampler. Figure 12 is a schematic of the probe array at the 3039 Stack showing the various types of monitors in use at that location. To one probe is attached a beta-gamma tape monitor. On the other, smaller probe is an alpha sensitive tape monitor, an iodine monitor, and an inert-gas monitor connected in series. The iodine monitor consists of a container of charcoal surrounded by a cluster of G-M tubes, all within a lead shield (Figure 13). The sample gas, after leaving the alpha monitor, passes through the charcoal where iodine or any other adsorbable activity is trapped. The G-M tubes detect such a build-up of activity (See "Charcoal Trap Iodine Monitor", Appendix B). The inert gas monitor which then receives the gas stream is similar to the iodine monitor except that charcoal is not used (Figure 14). The incoming sample stream impinges directly on an end-window G-M tube in

PHOTO 55558

Fig. 10. Non-Moving Tape Particulate Monitor

PHOTO 57357

Fig. 11. Sampling Probe Assembly

Fig. 12. 3039 Stack Sampler and Monitoring Equipment

Fig. 13. Charcoal-Trap Iodine Monitor

Fig. 14. Inert Gas Monitor

this monitor and traces of inert activities such as ^{55}Kr or ^{133}Xe can readily be detected.

The center probe of the sampling array is used as an inventory sampler. This sampler is equipped with a rabbit, or sliding capsule, designed to hold one of the charcoal filter cartridges mentioned earlier. During sampling, the rabbit with the cartridge is pushed to the inner end of the guide tube; and the assembly is withdrawn completely when the cartridge is to be changed. This operation is carried out on a daily basis and the information derived from this sample is used to calculate the total stack discharge for the day. Five of the stacks discussed earlier are equipped with this type of sampler, and each is continuously monitored by at least one of the other instruments described above.

A continuous record is kept of flow rates in the cell-ventilation ducts, off-gas discharge, and stacks. The data from these instruments is not only necessary for calculating integrated discharges but is also a valuable check on the over-all condition of the system.

The proper assembly of data for final recording and evaluation is of great importance in gas monitoring. The Waste Monitoring Control Center serves this purpose for the gaseous waste system as it does for the liquid waste system. Information from the various instruments just described is telemetered to the center, recorded or indicated, and kept under close surveillance. An annunciator system alarms in the event of an abnormal occurrence.

THE STATUS OF WASTE DISPOSAL AT ORNL

Radioactive waste disposal, monitoring, and control has been substantially improved at ORNL over the years. While initial efforts were aimed at providing facilities and devising techniques for the handling of increasing volumes of waste and levels of activity, more recent emphasis has been placed on better monitoring and control and the reduction of the amount of activity released to the environment (see "Reporting of Information", Appendix A). The risk of an undetected release of any magnitude to the river system or to the atmosphere has been reduced. Likewise, the Laboratory is better able to audit its discharges to the environment. Continuing research in the field of waste disposal, both liquid and gaseous, will undoubtedly bring about further improvements in the Laboratory's disposal methods and procedures. Advance in these areas and constant effort on the part of the processing groups to reduce their activity releases will eventually eliminate the problem of radioactive waste disposal at ORNL and its associated hazards to our environment.

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APPENDIX A - OPERATIONS

Wastes From Reactor Operations

Reactor operations produce from 500 to 1,000 gpd of intermediate level waste or about 9% of the total volume at the Laboratory. This waste usually contains about 1 curie of radioactivity and is derived primarily from the regeneration of resin in the cooling water demineralization systems at the LITR (Low Intensity Testing Reactor) and ORR (Oak Ridge Research Reactor). From 75,000 to 110,000 gpd of process waste, approximately 25% the total for the Laboratory, comes from reactor operations. Cooling water used in experiments and overflow water from the OGR storage canal make up the bulk of this waste, and these sources contribute approximately 30 mc/day of radioactivity to the Process Waste System. The systems are arranged to handle much larger quantities if the need should arise, however.

The ORR is connected to both the cell-ventilation and the off-gas systems which discharge into the 3039 Stack. Approximately 6,000 cfm of air from building ventilation and from cell cubicles pass through a charcoal filter bed and absolute filters before entering the central cell-ventilation system. Normally, no radioactivity is released to this system and only trace amounts are ever detected; however, the possibility of a release from experiments or from the reactor does exist.

The ORR is served by two off-gas systems. The central off-gas system provides a capacity of 500 cfm and a second "pressurizable" system is rated at 500 cfm. The pressurizable off-gas discharges through filters and a charcoal bed before being released to the 3039 Stack. This

system has its own blower and is completely independent of the central off-gas facility which serves the remainder of the Laboratory. This is to prevent accidental releases into other areas or buildings due to pressurization of a common system in the event of equipment failure. Normally, only small amounts of radioactivity are released through these off-gas systems; however, potentially large quantities could be released if an experiment failed.

Conditions Affecting the Operation of the Intermediate-Level Waste Disposal Pits

Until late in 1959, open pits were used exclusively for the disposal of all intermediate level waste.^{1,2} Samples of water taken from the creek and wells near the pits confirmed that ^{106}Ru was the only nuclide moving in any significant quantity and that ^{90}Sr was being retained in the soil near the pits with no apparent danger of its moving into the seepage. The operation was simple and appeared to offer economy as well as safety. Although some ^{106}Ru was being released into the Clinch River, ^{90}Sr released from the process waste system and other sources (not the pits) was still the controlling contaminant in MPC_w considerations. Late in 1959 and early in 1960, however, several large releases prompted a critical reappraisal of the waste disposal practices. One of these was a very high discharge of ^{106}Ru to the pits in September. During that month, ^{106}Ru transfer to the pits was more than one hundred times greater than the monthly average for the previous four years. This caused a significant increase in the ^{106}Ru concentration in the river.

Although the increase in ruthenium contamination of the river water did not create a health problem to the users downstream, the increase

was detected at the AEC's Oak Ridge Gaseous Diffusion Plant, the first user of the river water downstream from the Laboratory, where a continuous gross activity monitor had been installed on the water intake.

At this time also, the growing inventory of other nuclides in the soil made it necessary to re-examine the soil disposal operation. By the end of 1959, a considerable inventory of ^{90}Sr had been placed in the open pits. None of the samples taken from seeps and wells gave evidence of any significant movement of strontium activity; however, there appeared to be no way to account for the location of every portion of the activity or to predict with certainty its future behavior. If, for example, local changes should cause the soil to become acid in a region containing radioactivity it is possible that the radioactivity might be "eluted", gradually move through the soil, and finally appear in the surface streams.

High radiation background in the vicinity of the pits also became a problem. Exposure of personnel during normal operations had been minor; it became more serious after the high release of ruthenium. A proposal to drill sample wells adjacent to the pits could not be considered because the background was as high as 1500 mr/hr.

Difficulties Encountered in Covered Trench Operation

As noted in the text, the use of covered trenches was resorted to as a consequence of the exposure hazards which existed in the vicinity of the open pits. Two trenches were constructed and functioned well. A third trench, No. 6, was constructed and put into operation in September 1961. It was similar in design but longer (425 ft) than trench No. 5. Trench No. 6 was in operation for only a month when analyses of samples taken from a seepage stream several hundred feet away began to

show radioactivity, including ^{90}Sr . The indicated rapid movement of strontium immediately ruled out the continued use of this trench for waste disposal. Fortunately, only a small amount of strontium had been put into the trench so that it did not present a problem of river contamination. The reason for the leakage of the trench, the only failure of this type, has never been definitely established.

Retention of Ruthenium in White Oak Lake Bed^{3,4}

The ^{106}Ru measured at Station 6 is always lower than the combined discharges from the pit area measured at Stations 4 and 5-- the average difference over a long time being roughly a factor of two, with peak variations as high as 125. The greatest discrepancies occur during dry seasons. There is no sharply defined stream between the waste pits and White Oak Creek so the liquid seeping from the pit must move toward the creek through a wide swampy area. During the dry weather periods, the retention time by the soil and vegetation in this area is greatest. Measurements made by the ORNL Health Physics Division indicate that the subsurface activity in the swampy area is moving toward the creek very slowly, so that the swamp area serves as a long-term storage area which permits a large portion of the ^{106}Ru to decay.

Reporting of Information

To complement the daily monitoring and contacts with the users, a daily record is kept of the significant volumes of intermediate-level waste received in the monitoring tanks, the volume of process waste generated by each area, and the total release from each of the six stacks. This record is sent weekly to the main contributors, their supervisors, and the Safety and Radiation Control Office. Each month a

complete summary of this information is prepared, together with data on discharges to the creek and to the river. Comparison with past performances is made, and abnormalities in operation are discussed. This report is for the information of Laboratory management and is distributed to all those interested in waste disposal.

Wide dissemination of this information aids in keeping all levels of operation and management constantly aware of waste disposal problems and in holding the discharged waste volume and activity to a minimum.

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APPENDIX B - EQUIPMENT

Diversion Box

The diversion box, which routes the process waste water flow either through the Waste Treatment Plant or around it, is equipped with flow measuring equipment, a proportional sampler, a pH monitor, and radiation detection devices. Flow is measured by means of a weir and bubble-type level sensing device.

This level is recorded as flow on a circular chart, and an integrator totals the volume passing over the weir. The integrator also actuates the power supply for a systolic-type sampling pump so as to provide a sample which is proportional to the flow being measured. At the same time, a current pulse is telemetered to a receiver at the Waste Monitoring Control Center, where the flow is again recorded.

Submersible pumps, located in the pool above the weir, pump continuous streams of liquid through two monitors, one of which measures the alpha activity present, the other the beta-gamma activity. The count rate meters, which provide readout of the detected activity levels, also telemeter this information to the Control Center building.

The beta-gamma radiation signal also controls the action of the diversion valve. By presetting a radiation limit, the diversion valve can be made to change position in case of a radioactivity rise thereby channeling the process waste through the Waste Treatment Plant. When the radiation level drops below the limit, the valve automatically changes to its first position and the waste is sent directly to White Oak Creek. By use of a "manual" setting, the flow can be permanently

set in either position. For a number of years the volume of process waste received at the diversion box has been low enough to permit continuous flow through the treatment plant, and the valve has been manually held in that position.

Stream Monitors

Flow in the streams is measured by either V-notch weirs or Cipolletti trapezoidal weirs used in conjunction with bubble-type level sensors. This equipment is similar to that found at the manhole monitoring stations and described earlier. Instrumentation at the sites provides a continuous recording of the flow and also indicates the total flow passing over the weir. This integrator also operates a sampling pump thus providing a sample proportional to the flow in the stream. The sample container is emptied daily into a large vessel; and, at the end of each month, the resulting composite sample is analyzed. When the total volume flowing by the station during the month and the sample to flow ratio are known, the total radioactivity discharge for the period can be determined. No radiation detection is provided in these stations, nor is information telemetered.

Cell-Ventilation Equipment

Cell-ventilation air is carried through a network of underground concrete and steel ducts to the 3039 Stack area where it reaches the blowers. These discharge through three 4- by 6-ft breeches into the 250-ft stack. Filters are installed in branches of the cell-ventilation system. These consist of glass fiber roughing filters followed by absolute filters that have a removal efficiency of 99.95% for 0.3 μ particles. The air is moved through the ducts by means of four elec-

trically driven, high capacity, low-vacuum exhausters. Two steam-driven units are available as standbys and are put into service automatically in the event of a power failure or the loss of cell-ventilation negative pressure. The capacity of the system is 200,000 cfm with the current usage being about 160,000. A minimum negative pressure of about 8-in. H_2O is maintained at the fan suction at all times.

Off-Gas Equipment¹

The off-gas stream, on reaching the stack area, is first passed through a multicell, absorber-type air washer where it is scrubbed with a 0.5% caustic solution. The temperature of the gas is then raised to 110°F, and it is filtered through roughing and absolute filters for particle removal. The roughing or prefilter is a stainless steel Neva-Clog unit; the polishing filter is a pleated, Cambridge, cellulose-asbestos unit having an efficiency rating of greater than 99.95% for 0.3 μ particles. The over-all efficiency is estimated at about 50% for gaseous activity and 99% for particulate activity. The off-gas is exhausted to the stack by means of an electrically-driven, Roots-Connersville, positive-displacement blower with a total capacity of 4000 cfm at a negative pressure of 55 in. H_2O . Current usage of off-gas is about 3000 cfm. An automatically operated steam-driven blower is also available for emergency use during electric power failure.

This system is new, having been placed in operation in April, 1961. The system it replaced consisted of blowers, filters, and a 75-kv, Cottrell, electrostatic precipitator. This equipment is still operable and is maintained as an auxiliary in the event of a forced shutdown of the new equipment; however, the capacity of this system is only 2000 cfm

at a negative pressure of 45 in. H₂O.

Inventory Sampler

A charcoal-filled cartridge containing a paper filter is used as the collection device in the stack and duct inventory samplers. The cartridge consists of a plastic (celluloid) cylinder $1\frac{1}{4}$ -in. in diameter and $1\frac{1}{2}$ -in. long containing approximately 5 g of coconut charcoal. Adsorbable gaseous activities passing through the cartridge are stopped by the charcoal and particulate matter is collected by an HV-70 filter located at one end of the cartridge. After a collection is made the cartridge is disassembled in the analytical laboratory and the charcoal and filter are separately gamma scanned. With the information derived here and a knowledge of sample and flow rates, the discharges of gaseous and filterable activities through a particular stack or duct may be calculated.

Moving-Tape Particle Monitor, Q-2323

An air sample stream is drawn through a 3-in. paper tape for a pre-set period of time; the accumulating activity, primarily particles, is monitored during this time by a side-window G-M tube or other type of detector held in a shielded enclosure. The activity "seen" by the detector and its count rate meter is recorded. The tape is advanced remotely, on demand, by the operator. Guard switches on the unit signal a tape break or a shortage of tape supply.

Nonmoving-Tape Particle Monitor

The nonmoving-tape particle monitor was the first continuous monitor to be developed for an ORNL stack. A measured stream of sample gas was drawn through a 2-in. filter tape located adjacent to a side-window

G-M tube. The buildup of activity, thus detected, was recorded and served as a measure of stack behavior. The tape was changed daily by pulling it through the collection block, and the deposited radioactivity was analyzed.

Charcoal Trap Iodine Monitor²

Basically, the iodine monitor is a monitored container of charcoal. The sample gas passes through the charcoal and adsorbable activities are retained and detected by the monitoring devices.

Several designs have been tried in this monitor; however, the most recent employs an 8-oz polyethylene, wide-mouth bottle half-filled with charcoal and closed with a perforated cap (Figure 13). Attached to the cap is a plastic centrifuge tube with holes in the end. With the bottle in the inverted position, the sample gas is introduced through the centrifuge tube, passes through the charcoal, and out the perforations in the cap. This arrangement is situated within a cluster of G-M tubes and the entire assembly is enclosed within a lead shield. The G-M tubes operate in parallel for maximum sensitivity and telemeter a signal to a count rate meter located in the control building.

3039 Stack Sample Withdrawal Probes, Q-2285

The probes are of 1-in. stainless steel tubing, extend 4 ft into the stack and curve downward on a 4-ft radius. The collecting ends are bevelled to a sharp edge. A set of probes is installed in each of two holes, spaced 45° apart.

Operation of In-Stack Sampler

When the in-stack sampler is operating, the "rabbit" carrying the filler and charcoal cartridge seats firmly against the inner tip of the

probe and is connected to a pumping system with flexible plastic tubing. When the cartridge is changed, as it is daily, the tubing is freed from the pump by means of quick-disconnect couplings; and the rabbit is drawn outside the probe assembly. The used cartridge is replaced with a new one and is pushed back down the guide tube, after which the flexible tubing is reconnected and sampling started once again. During the removal operation, seals at the exit end of the guide tube prevent the release of contaminated air to the outside.

This device, with the withdrawal probes previously described, makes up the complete sampling array.

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