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

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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 large or small-scale operations that use radioactive substances. 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 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.

Three classifications of liquid waste exist 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 the 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 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. High-level waste, which may be hundreds or thousands of times more active than intermediate-level waste,[2] is the third type of liquid waste. Since only very small quantities of high-level waste are generated and since these are usually permanently stored or disposed of at the point of origin and do not enter the central disposal system, they will not be discussed here.

Gaseous waste is classified similarly to liquid waste. The Laboratory is served by a cell-ventilation system, which handles a large volume of air containing very small amounts of radioactivity, and an off-gas system, which has a much smaller volume capacity but which must deal with greater amounts of activity.

As the Laboratory has grown and expanded, so has the volume and activity of waste produced. In order to keep pace with this expansion the waste-disposal facilities have been enlarged and modified from time to time. 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 found necessary to reduce the volume by precipitating as much activity as possible directly in the tanks and then decanting the supernate to 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 settling basin was completed to serve as a collector and stilling pond for process waste. It also permitted settling of radioactive solids from the waste before discharge to White Oak Creek.

In 1949 the precipitation and decantation procedure for treatment of the highly active waste was discontinued and 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 to the creek. The first soil disposal pit was put into operation in 1952. This consisted of an excavation in the earth, 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. Since that time, the pits have been 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 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 a 250-ft stack, filters, and electrostatic precipitator were added.

In 1955 the lake which had been created behind White Oak Dam was drained. This was done to enable modifications to be made on 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 goal of radioactive-waste management here 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.[3]

2. Discharge the intermediate-level waste into the soil where the radioactivity is separated and retained by sorption. The partially decontaminated seepage eventually reaches the river.

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 ensure 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 Reactor Wastes, Appendix A), are discharged from hot sinks, glove boxes, and processing vessels into 17 underground stainless-steel monitoring tanks at the rate of 5,000 to 10,000 gal/day (see flowsheet, Fig. 1). This quantity of waste will contain from 75 to 100 curies of radioactivity. The capacity of the monitoring tanks varies from 500 to 2000 gal depending on the needs of the buildings served. To protect the tanks and other waste-disposal equipment against corrosion by some chemicals, especially chlorides, 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 into three 170,000-gal concrete holdup tanks. (These tanks were built in 1943 by the Gunite process. They are 50 ft in diameter, 12 ft deep, with 1-ft-thick walls. The inside walls were originally coated with an asphaltic material.) The choice between jets and pumps is determined by the elevation of the monitoring tanks and the length of the transfer lines.

The waste is temporarily stored in the holdup tanks to allow short-lived activity to decay and is then pumped to excavations in the earth approximately 1 1/2 miles from the Laboratory for final disposal. LaBour vertical-shaft, packless-type pumps are used for this transfer. Bellows-seal valves are used in the 2-in. cast-iron, mechanically joined transfer line and are located in concrete pits. The pumping is scheduled to take advantage of a maximum decay period while maintaining an adequate tank capacity to permit periodic repairs to the transfer equipment.[4]

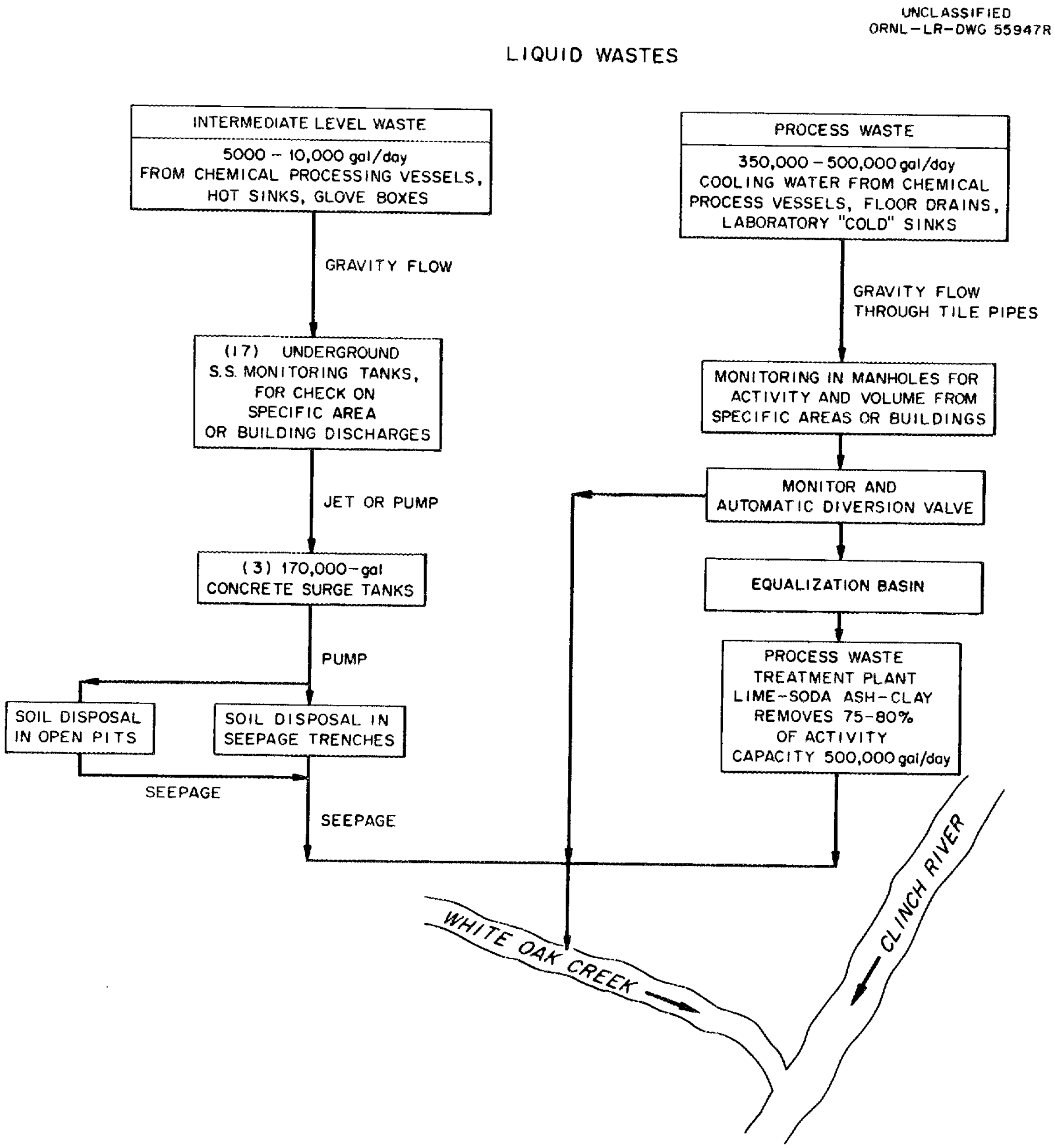

Fig. 1. Liquid Waste Flowsheet.

Two types of excavations are used for the disposal of intermediate-level wastes. Their locations may be seen in the aerial photograph, Fig. 2. Each of the three open pits has a storage capacity of approximately one million gallons. The covered trench is 300 ft long and has a capacity of 50,000 gal. A cross section of this trench may be seen in Fig.3.

The pits and trench are located in an area that was chosen for waste disposal because of the chemical properties of the Conasauga shale and clay which compose the soil, the fact that the natural soil drainage is toward the creek, and the remoteness of the location from the main Laboratory area. The waste pumped into the pits and trench seeps through the soil to the creek; and, as it does, all radioactivity except ruthenium and a small amount of cobalt is retained by the soil. The liquid passes into the creek and is released into the Clinch River.[5,6]

Until 1959 open 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. However, strontium retention was good; and, since Sr^{90} was the controlling contaminant in the MPC_w consideration for the river, there was little concern over the Ru^{106} release. Late in 1959 and early in 1960 large amounts of ruthenium were sent to the pits. During one month the ruthenium release increased by a factor of 100 over the normal monthly average, and at this time the river concentration began to increase. Radiation at the pit site also became a problem as the radiation became too high to send personnel into the area for sampling or other purposes (see Appendix A).

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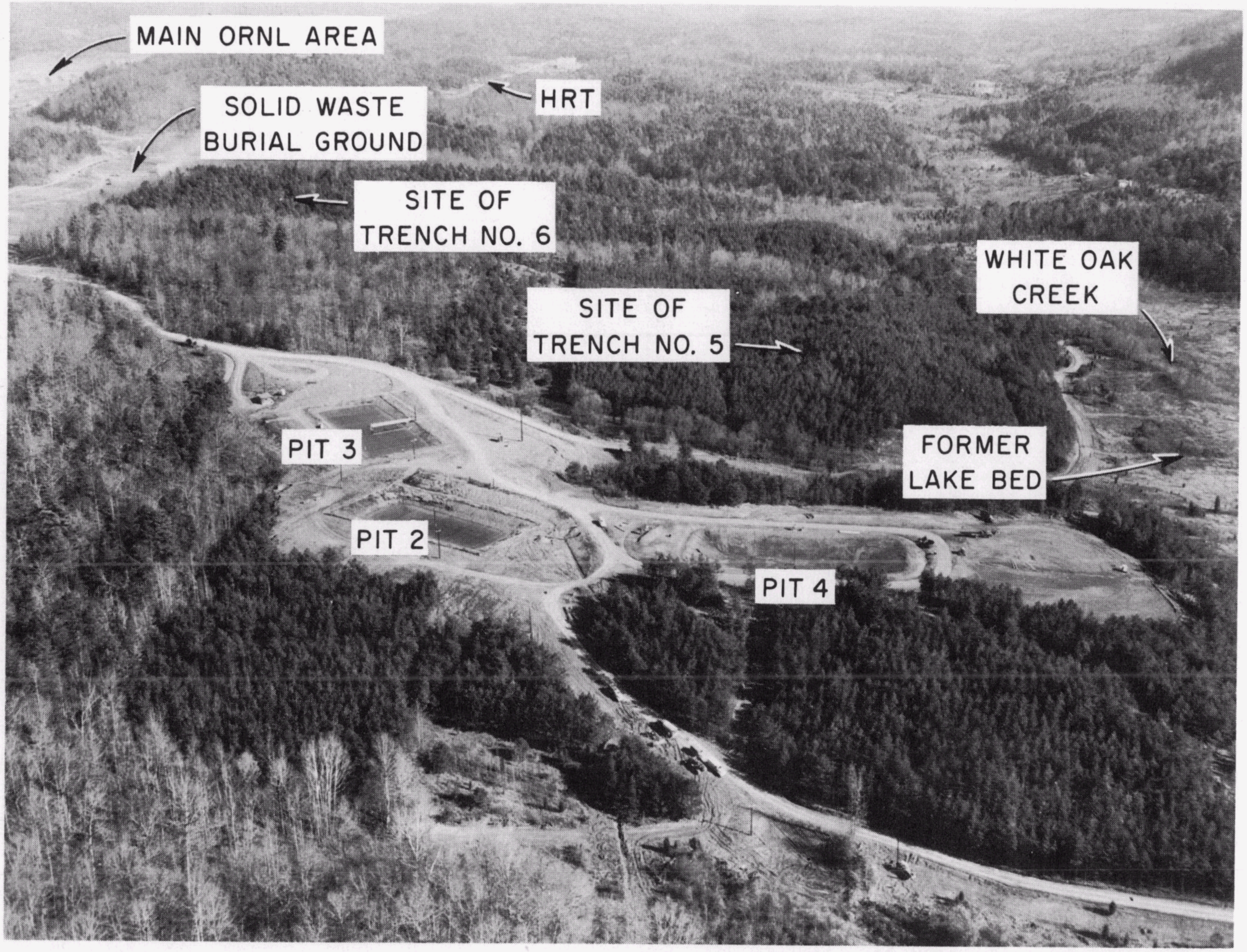

Fig. 2. ORNL Waste Disposal Area.

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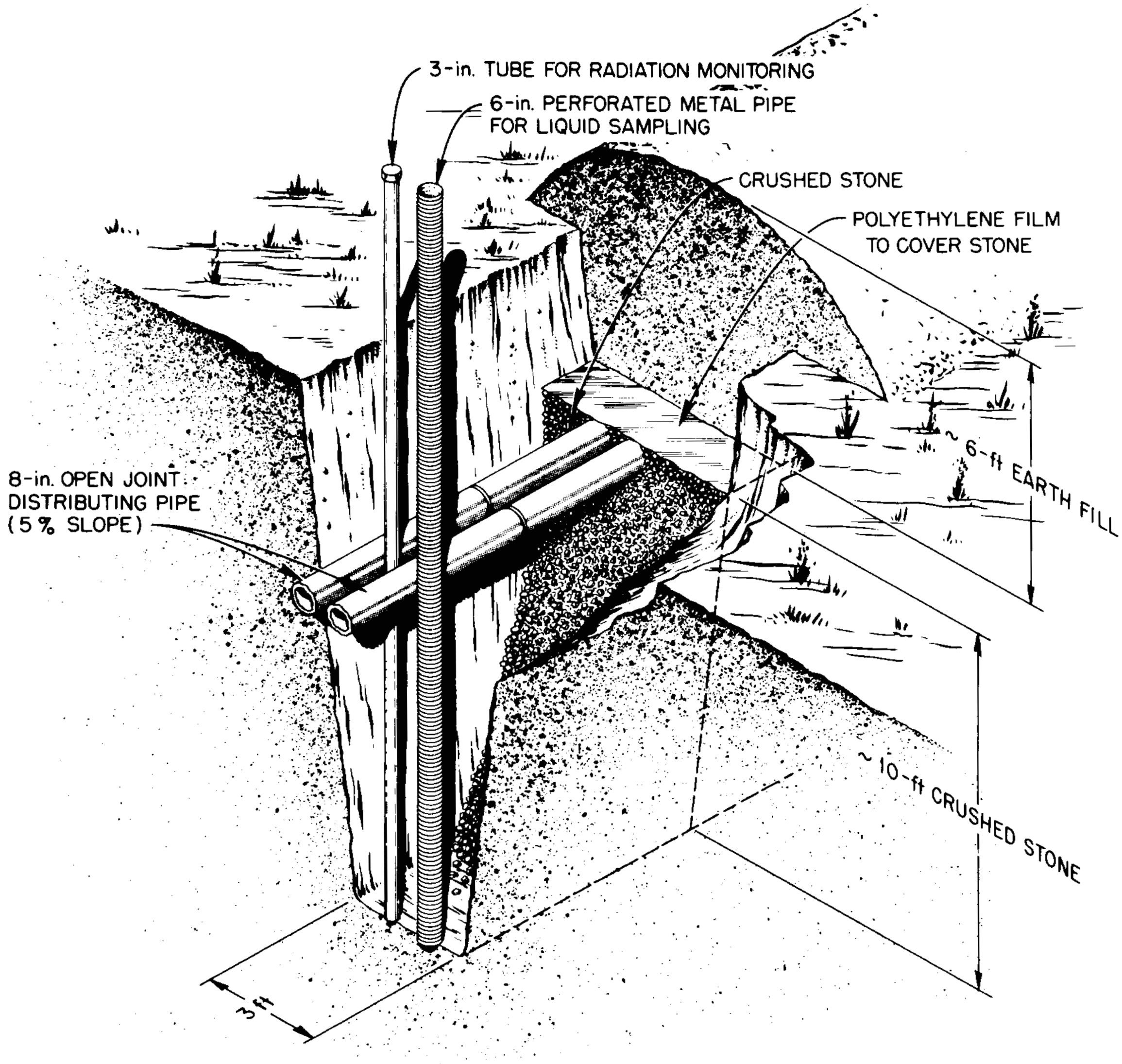

Fig. 3. Typical Waste Disposal Trench.

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 Ru^{106} would be considerably reduced by decay before it was released.

Unfortunately, it was found, soon after the trench was put into operation, that the seepage rate was lower than expected; and the trench could handle only about half of the intermediate-level waste generated by the Laboratory. To get the additional seepage capacity another trench (No. 6), similar in detail but longer (425 ft), was constructed and put into operation in September 1961.

The second trench was in operation for only a month when analyses of samples taken from a seepage stream several hundred feet away from the trench began to show radioactivity, including Sr^{90}. The indicated rapid movement of strontium immediately ruled out the continued use of the 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 first failure of this type, has not been definitely established.

The immediate plans are to construct a third trench. This trench will be made in several sections so that if a leak of radioactivity is detected from one section that section may be isolated while the others are kept in operation. Tests made at the location chosen for the new trench indicate that the seepage rates may be relatively high.

At present, both the first trench and the open pits are used. The use of the open pits must be continued until the third trench is put in operation, at which time the pits will be filled with earth. To reduce the ruthenium seepage problem during this period, wastes containing high concentrations of ruthenium are separated and permanently stored in underground tanks.

The Laboratory's long-term plan is to discontinue shallow ground disposal of liquid wastes. To that end, an evaporator is being designed for concentrating waste for storage. Its construction is scheduled for completion late in 1963. The final disposition of the concentrated waste is being studied.

The main problem in operating the intermediate-level system is the prevention of unnecessary dilution of the waste with water. The problem is most frequently created through the difficulty in gaining the cooperation of the large numbers of users of the waste system. Therefore, the operators of the waste-disposal system must constantly police the areas where wastes are generated and periodically re-educate the workers in these areas.

The volumes of waste received in the monitoring tanks are measured regularly to detect abnormal conditions in the various areas. The liquid level in every tank is telemetered and continuously recorded in one building, the Waste Monitoring Control Center. The tanks separate the wastes of the various operating and laboratory groups. After the waste-disposal operator becomes familiar with the normal discharges from the various areas and the habits of the users, he can detect abnormal releases and often go directly to the source of trouble.

PROCESS WASTE

Process waste is generated at a rate of approximately 400,000 gal/day. 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.

The waste is collected from the sources and flows by gravity to a common point, the diversion box (see flow sheet, Fig. 1). At the diversion box the waste may be routed to an equalization basin for processing through the Process-Waste Treatment Plant; or it may be sent directly to the creek, without processing, by means of a valve controlled automatically by the radioactivity in the waste. During the past year, 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 Appendix A). 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 Process-Waste Treatment Plant where approximately 75% of the activity is removed by a modified water-softening process using lime, soda ash, and clay.[7,8,9] 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 1 curie per month, with Sr^{90} accounting for about half the total. Although the quantity of Sr^{90} is small compared with the amount of other activity released into the creek (mainly Ru^{106} from the intermediate-level-waste pits), it is second in importance only to Ru^{106} from the standpoint of health in considering the contamination of the river. When the use of the intermediate-level-waste pits is discontinued, strontium will be the most important contaminant released to the river. Practically all the strontium in recent months came from the process-waste system, and the ruthenium came from the intermediate-level-waste pits.

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.

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 months has improved the effectiveness of the monitoring work and may make additional treatment of the waste unnecessary (see Appendix A).

There are nine 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 and activity) into the system. The data from the monitoring stations recorded at the Waste-Control Center leads 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 which otherwise might not be started until more dangerous quantities of activity were released into the process-waste system.

Proportional samples taken at the inlet to the equalization basin are analyzed for gross beta activity every 4 hours, 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.

Fig. 4. Typical Manhole Monitoring Station.

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. Some 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 more than two 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, 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.

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 Appendix B).

Fig. 5. Monitoring Station on White Oak Creek.

There are five stations such as this in use at present. The locations are shown in Fig. 6. Station 1 samples the activity discharged from the process-waste system only. Station 2 samples the activity from Burial Grounds 3 and 4, from the process-waste system, and all activity that may come from the sanitary and storm sewers. Station 3 samples activity coming from Burial Ground 5 and the Homogeneous Reactor Test site which is presently not in operation. Stations 4 and 5 sample the seepage from the open pits; no continuous sampler is provided for the seepage from the trenches since grab-samples have indicated that the activity is not significant. Station 6, located at White Oak Dam, samples the entire release into the Clinch River and is operated by the Health Physics Division.

The weakest part of the monitoring system at present is the lack of a station for the creek east of station 1, where storm sewers from the main part of the Plant flow into the creek. The combined activity from the storm sewers, Sewage-Treatment Plant, and the burial grounds may be obtained by subtracting the activity measured at station 1 from that measured at No. 2; but there is no way to separate activity releases from the storm sewer discharge. Another monitoring station is planned to correct this condition.

Samples normally taken at the creek monitoring stations cover an operating period of one month. They are analyzed for $Sr^{89,90}$, Cs^{137}, Ru^{106}, and gross-beta activity. A reasonably good material balance is usually obtained between stations 1 through 5 and station 6 for all activity except Ru^{106} which comes mainly from the open pits. The ruthenium discharge, measured at White Oak Dam, has always been lower than the total

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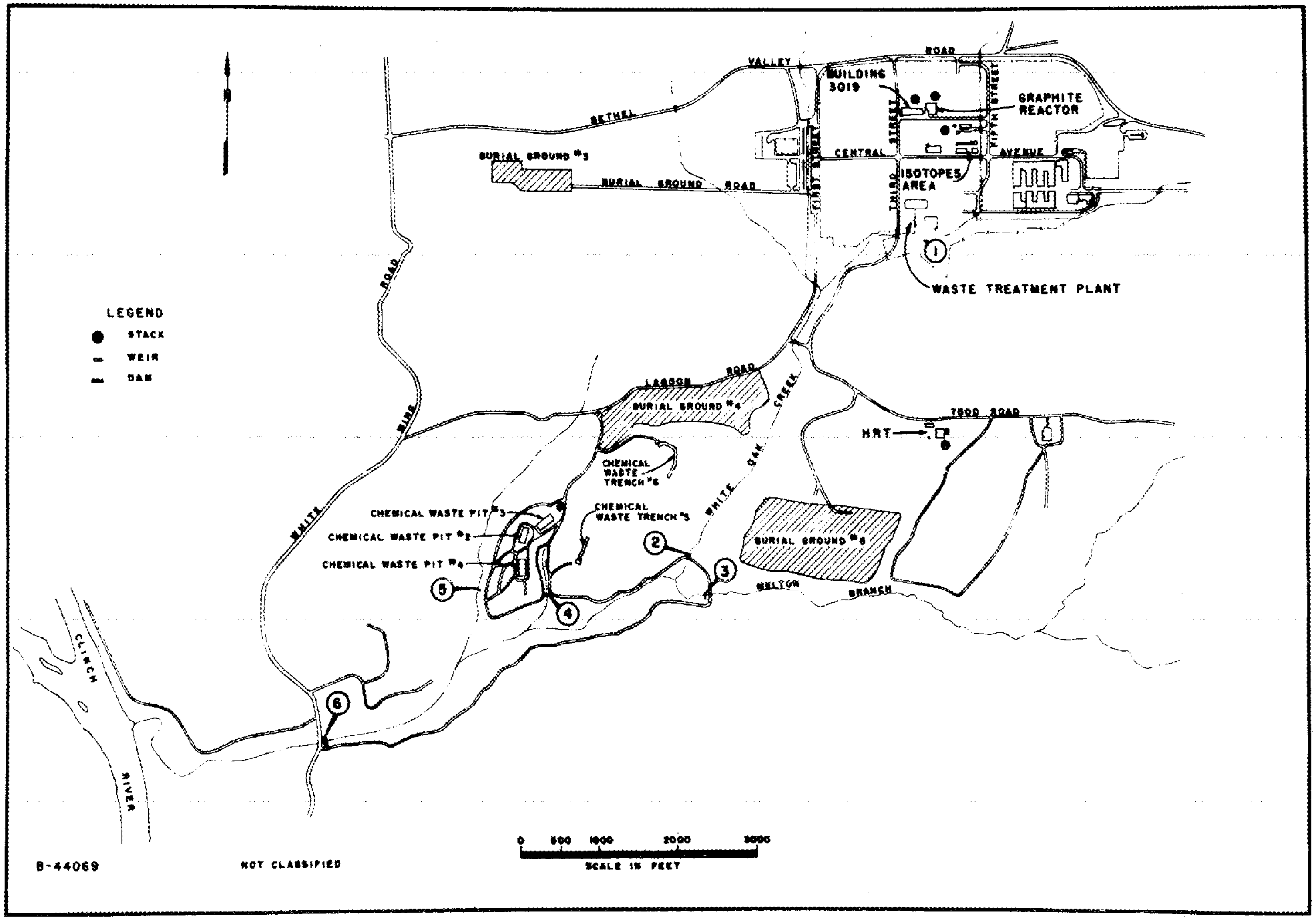

Fig. 6. Location Plan for Laboratory Waste Monitoring Stations.

of the ruthenium discharges from the individual sources. Holdup in the lake bed may account for this (see 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 instantaneously notify the operators of any significant amount of activity released through the sanitary and storm sewer systems.

GASEOUS WASTE

Radioactive gaseous waste produced by the Laboratory is derived from a wide variety of sources. Research and development groups are involved in experimental studies which include the reprocessing of reactor fuel, the disposal of high-level waste, purification and isolation of transplutonic elements, and basic research in many other fields. The ORNL Graphite Reactor (OGR), Low-Intensity Testing Reactor (LITR), and the Oak Ridge Research Reactor (ORR) are operated on a continuous basis and provide facilities for numerous experiments, including loops. The most extensive radioactive processing operation carried out at the Laboratory is in the irradiation and processing of numerous radioactive isotopes. Over one hundred different preparations are produced, ranging in quantity from millicuries to kilocuries.

The bulk of the gaseous waste generated by all but the reactor operations is released to the atmosphere through the 3039 Stack. This discharge 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; but, 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 is shown in Fig. 7. Cell-ventilation air, at the rate of about 152,000 cfm, is first filtered through roughing and absolute filters and then discharged by means of electric blowers to the 250-ft stack (see Appendix B).

Laboratory off-gas is handled at the rate of about 2200 cfm through a system of underground stainless-steel ducts from the point of generation where, in some cases, it is given an initial filtration, scrubbing, and/or charcoal cleanup treatment 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 likelihood of radioactivity in the off-gas, scrubbers are employed 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 reactive gaseous activity (primarily I^{131}) is removed. Filters then remove particulate activity, and the gas is delivered to the stack through an electric blower (see Appendix B). Although the principal activity found in the Laboratory gaseous waste is I^{131}, at least 24 other nuclides have been

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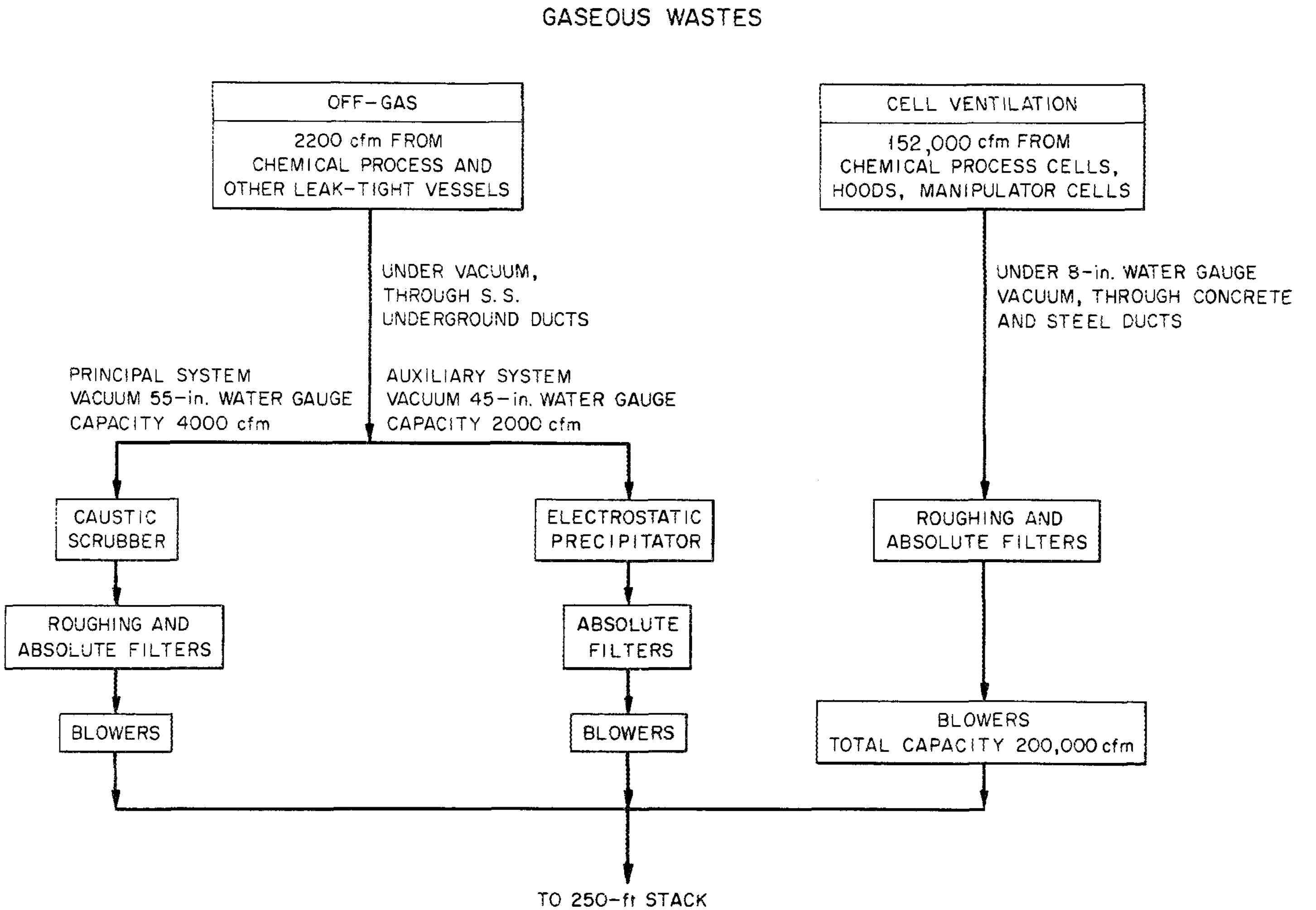

Fig. 7. ORNL Gaseous Waste Disposal System.

detected in stack emissions during the past year. It is estimated that 90% of the gaseous activity generated by the Laboratory is found in the off-gas, and for this reason every effort is made to ensure maximum decontamination prior to release to the environment.

The equipment just described was added to the system in April, 1961. The off-gas cleanup equipment in use prior to that date consisted of a filter unit and a Cottrell precipitator. No attempt was made to scrub out gaseous activity.[11]

Two other stacks, the 3018 and 3020, also contribute to the discharge of gaseous waste. The 3018 Stack discharges cooling air from the Graphite Reactor. Air from the OGR, at the rate of 120,000 cfm, is drawn through roughing and polishing filters similar in specifications to those in use in the cell-ventilation system. Particulate activity, usually I^{131} deposited on dust particles, is removed at this point. The remaining activity, largely A^{41} resulting from the irradiation of naturally occurring argon, is discharged into the atmosphere through the 200-ft stack. The activity emitted here (excluding the argon, which is not measured) comprises approximately 8% of the Laboratory discharge.

The 3020 Stack is located at the Chemical Pilot Plant and discharges ventilating air from operating cell areas in the pilot plant and hood-intake air from an analytical laboratory. The volume discharged from this area totals approximately 40,000 cfm; and, here too, the same type of filters are used as previously described to remove radioactive particles. The activity discharged from this stack amounts to only 1 to 2% of the measured total for the Laboratory and consists of small quantities of I^{131} with traces of the thoron daughters.

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 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, consists of a membrane filter followed by a charcoal-filled cartridge (see Appendix B). A 1-cfm pump is used to draw the sample stream through the collection assembly; metering of the flow is accomplished by use of a rotameter. Figure 8 shows a typical duct installation used for monitoring the various branches of the system. A probe extends into the duct to withdraw the sample; and, in operation, the filter and cartridge are changed after a 24-hr collection period. They 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. This type of sampler is also useful for back-checking to locate sources of known activity releases.

To provide continuous monitoring of the major flows discharging into the stack, moving-tape particle monitors are provided. Figure 9 shows the tape drive and detector unit. Radioactivity collected on the tape is measured by the detector tube and count-rate meter, not shown here (see Appendix B).

Figure 10 is a flowsheet showing the locations of these two types of activity monitors throughout the 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. Inventory samplers are located at the off-gas discharge and on the cell-

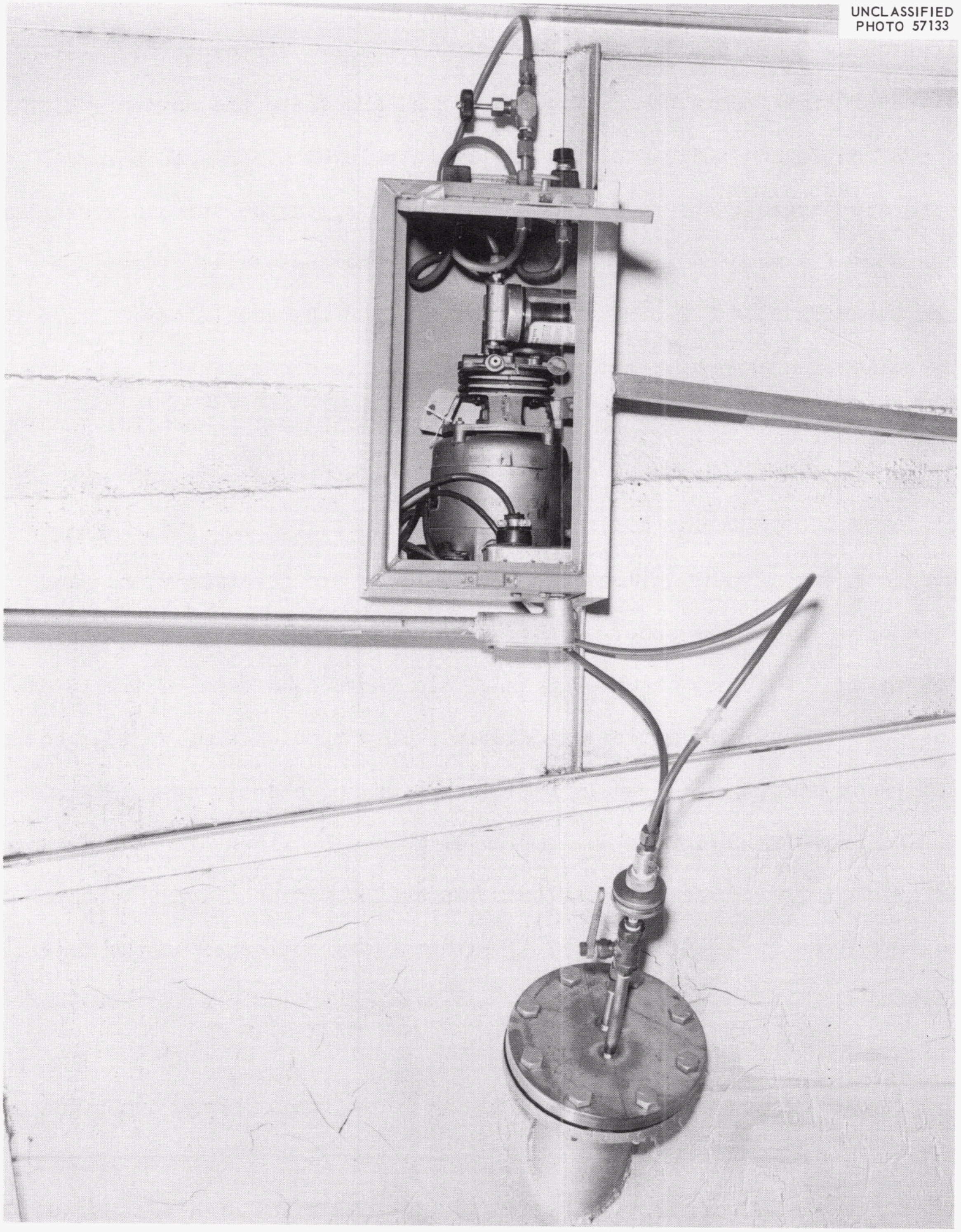

Fig. 8. Typical Duct Inventory Sampler.

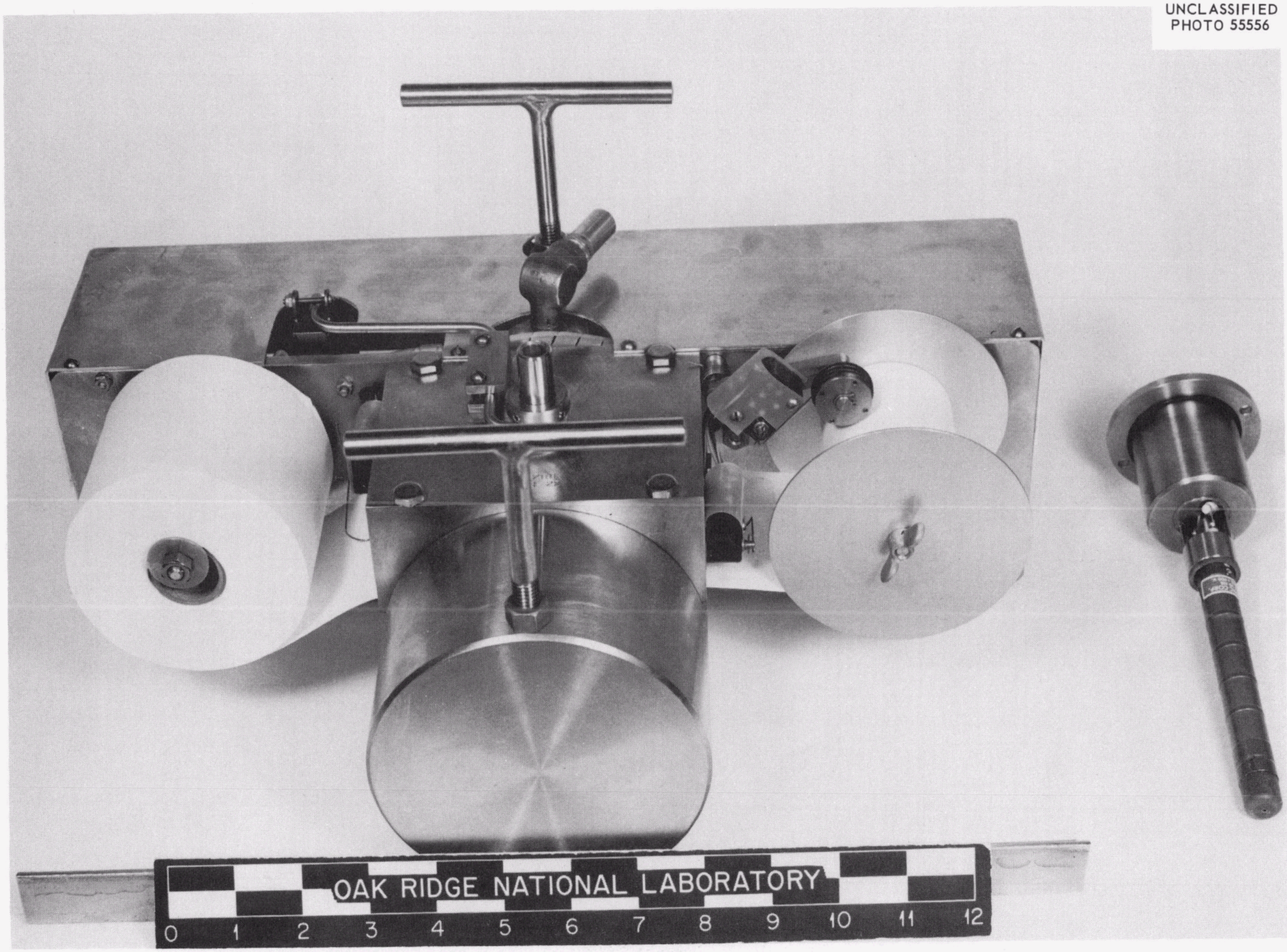

Fig. 9. Moving Tape Particulate Monitor, Q-2323 — Tape Drive and Detector.

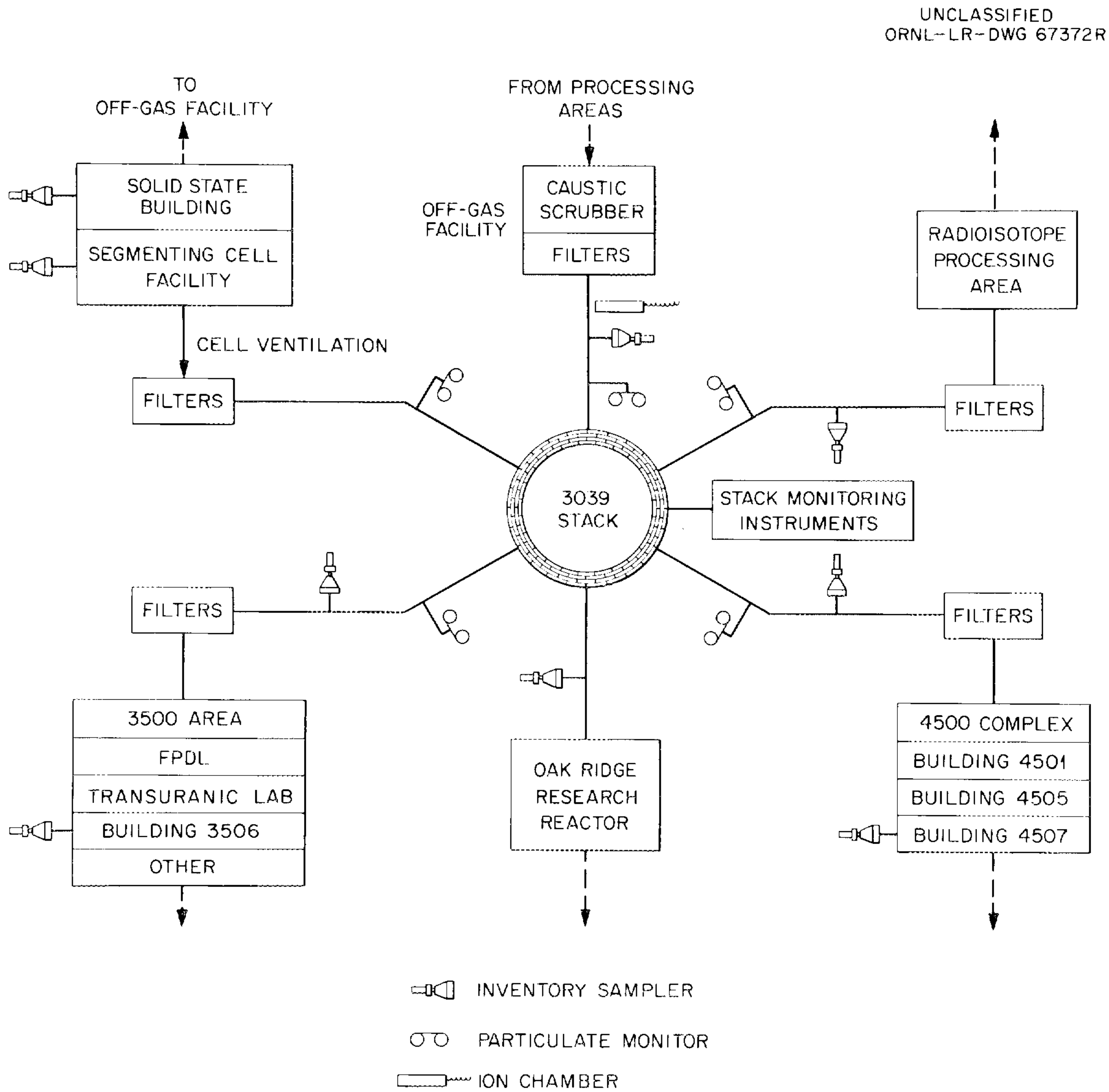

Fig. 10. ORNL Gaseous Waste Monitoring Flowsheet.

ventilation ducts serving the Isotopes Area; the 3500 Area, which includes the Fission Products Development Laboratory and the Transuranic Laboratory; and the 4500 complex. Inventory samplers are also located immediately adjacent to certain areas of particular interest such as the Segmenting Cell Facility, the Solid State Building, Building 4507, and the Isotopes Evaporator Facility. In the event of an activity release into the gaseous-waste system, detection would probably be made first by the tape monitors on the major ducts or by the stack-monitoring equipment. The upstream samplers would then be checked to ascertain the origin of the activity. The filters and cartridges in the outlying samplers are changed daily but need be analyzed only in the event of a suspected release. In view of the special hazard contributed by the off-gas system an additional detector was added there. It consists of an ion chamber inserted into the discharge duct from the off-gas facility (see Appendix B).

Shown also on this flowsheet is a block titled "Stack Monitoring Equipment". 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 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 connected to monitoring and sampling devices located on the ground. Four pieces of equipment were attached to this sampler and carried out the stack-monitoring function. They were: (1) a nonmoving-tape particle monitor; (2) a moving-tape particle monitor, similar in operation to the one mentioned above; (3) a charcoal-trap iodine monitor; and (4) an inventory sampler. The nonmoving-tape monitor (Figure 11), which is still in operation, collects a sample by drawing a measured volume of gas through a portion of filter tape. The tape is simultaneously monitored by a detector unit and is advanced manually. This instrument represents the first attempt at continuous monitoring of the 3039 Stack (see Appendix B). The moving-tape monitor seen in Figure 12 was thought to be a substantial improvement. In this device activity is collected on a tape which automatically advances on a preset time cycle. The activity on the moving tape is not "seen" by the detector tube, however, until after it is collected and advanced (see Appendix B).

The charcoal-trap iodine monitor (Figure 13) consists of an aluminum cylinder filled with charcoal, and monitored by an ion chamber. The stream of gas being monitored is drawn through the cylinder (see Appendix B).

These four devices used in conjunction with the perforated sampling probe represented major steps in the direction of reliable monitoring of the 3039 Stack. However, it was evident that certain modifications needed to be made if the system was to have the desired sensitivity for all types of airborne activity and if a more accurate picture of the total discharge was desired. The most obvious shortcoming was in the sampling probe with its 80 ft of associated piping. Such a sample withdrawal system is grossly inefficient for many types of activity found in a gaseous discharge and is particularly useless in sampling large particles (greater than 50 μ in diameter. The first move was to eliminate the downcomer and bring the detection equipment as near to the point of sampling as possible. This was accomplished by erecting a balcony on the 3039 Stack at the 50-ft

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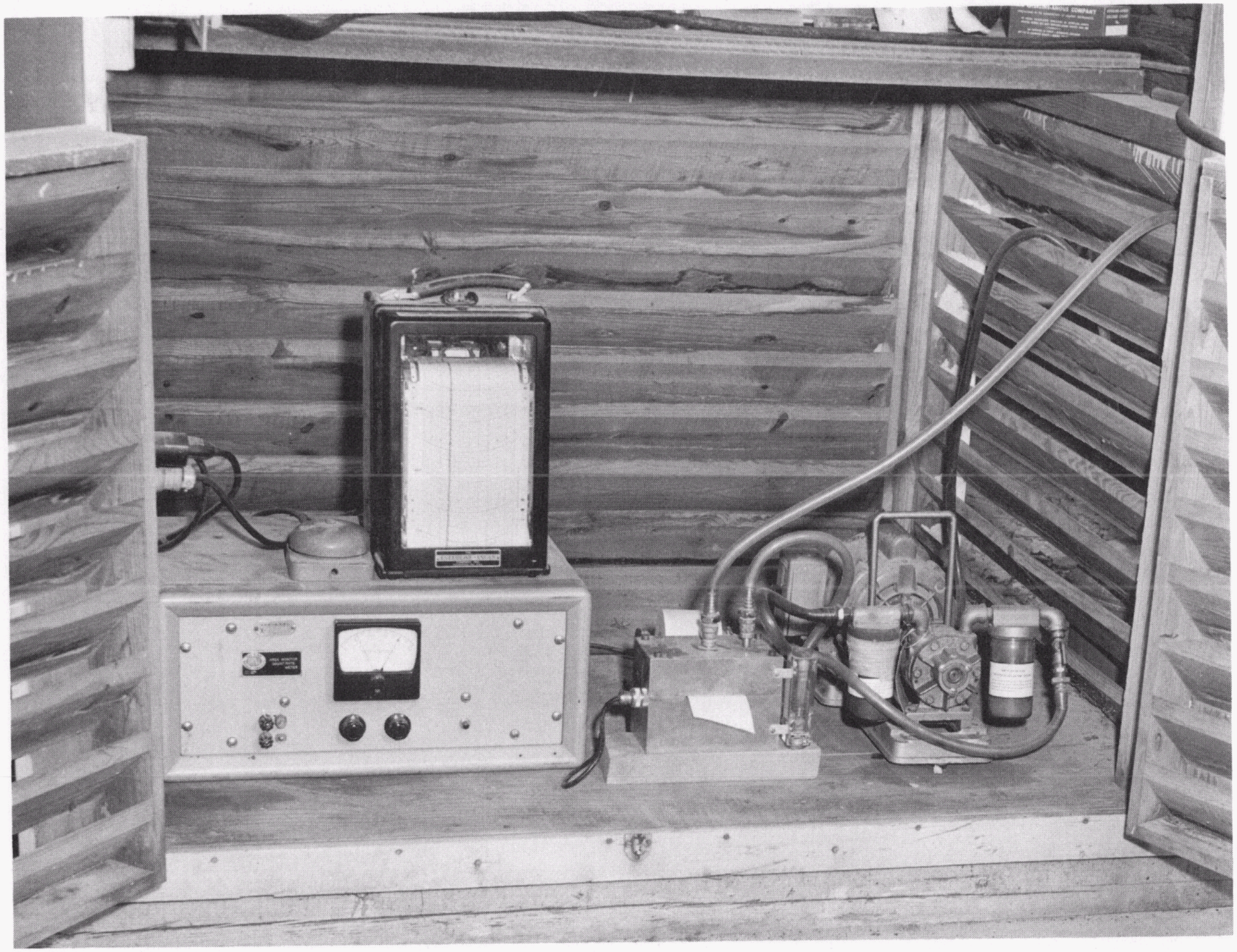

Fig. 11. Non-Moving Tape Particulate Monitor.

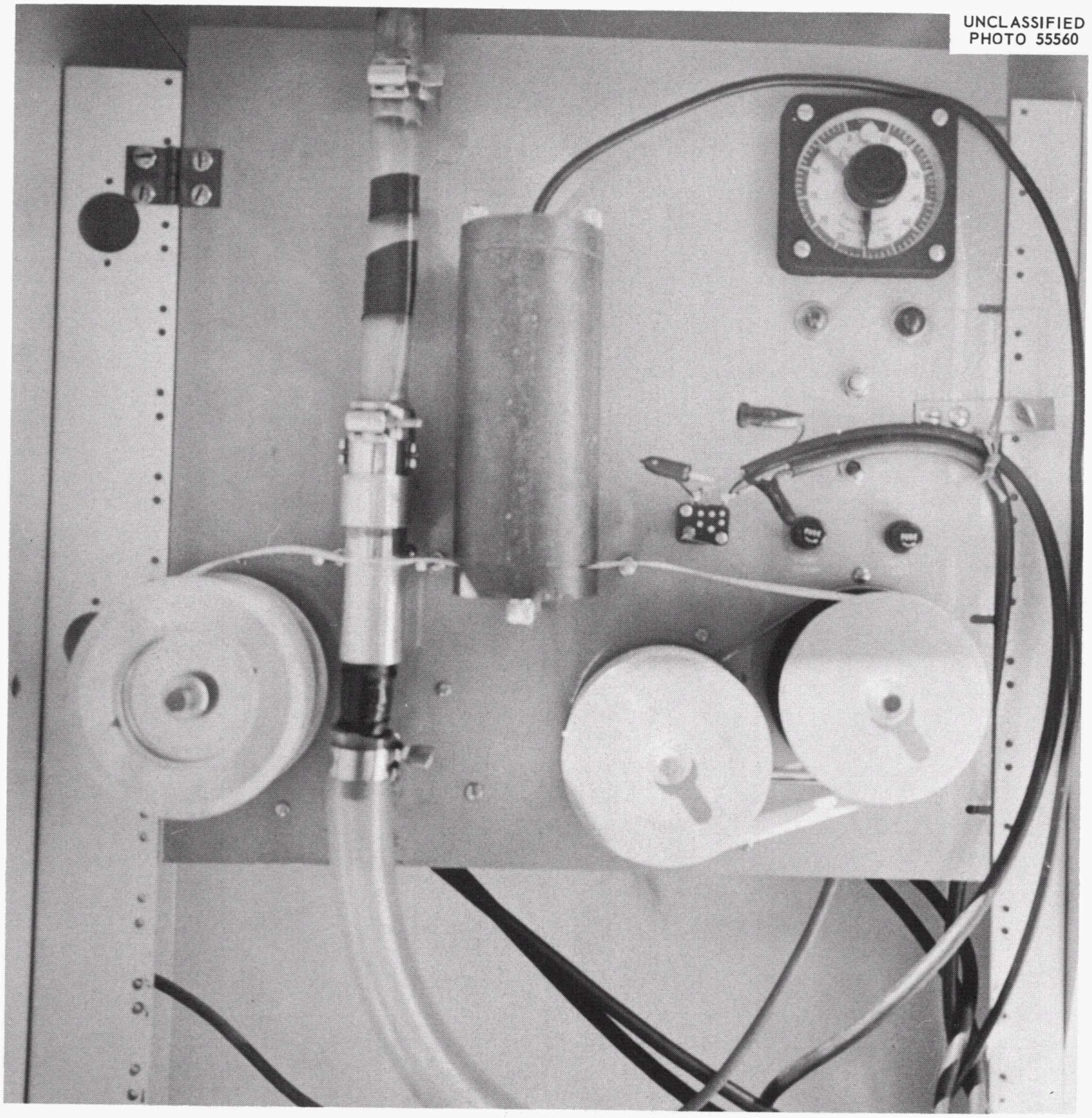

Fig. 12. Moving Tape Particulate Monitor, Q-1950.

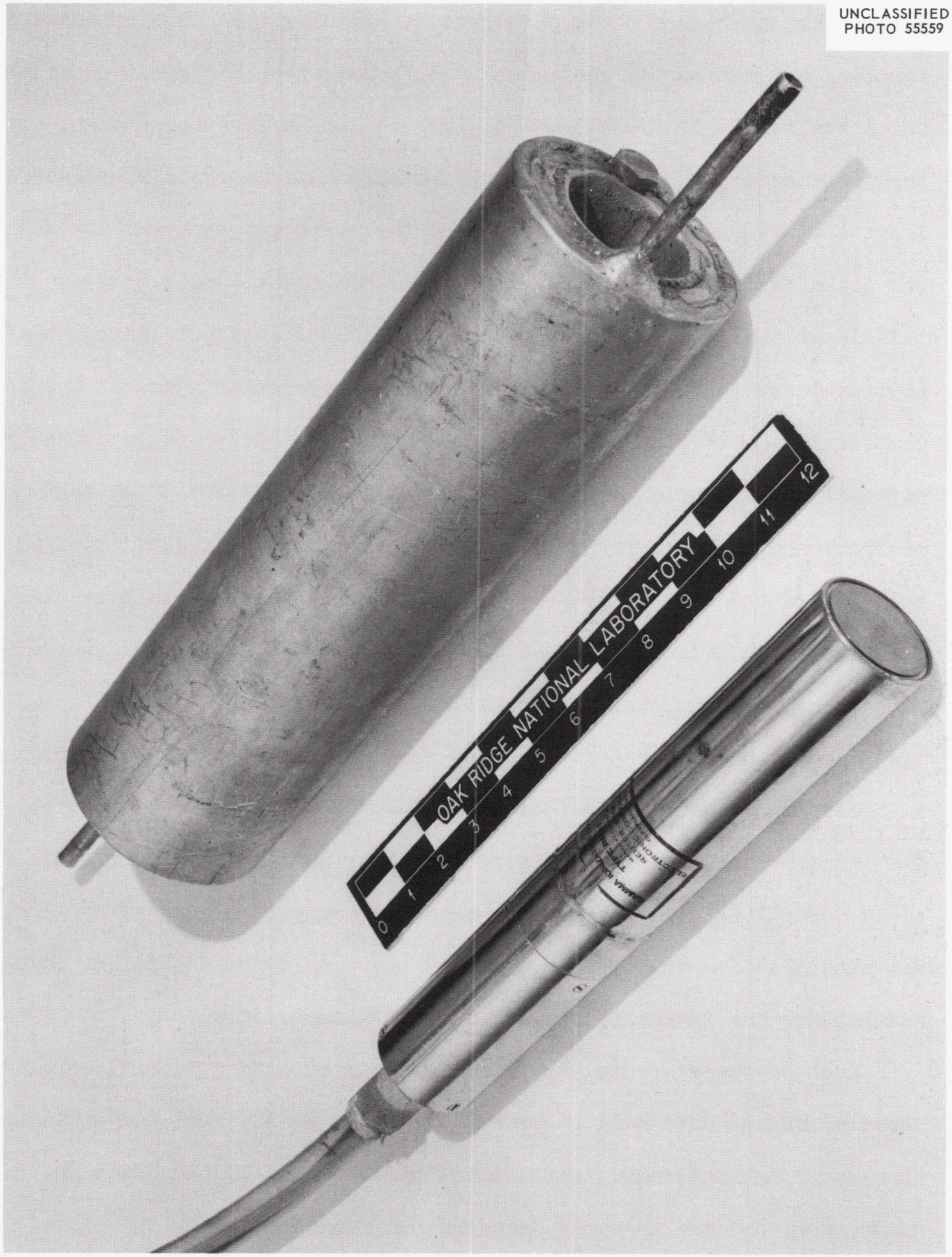

Fig. 13. Charcoal-Trap Iodine Monitor with Ion Chamber.

level where there are three penetrations available for the introduction of sampling and monitoring equipment. New probes were designed, fabricated, and installed in two of the holes. The equipment was then brought up to the 50-ft level, thereby shortening the sample transport distance by at least 60 ft. Numerous tests indicated that although the velocity within the stack is low (slightly above 500 fpm) mixing is sufficiently good at this level that a single withdrawal probe located anywhere within the stack (but at least 3 ft from the wall) will "see" essentially an average gas composition. Other criteria were also established: the curve at the probe tip must be as gentle as possible if sampling losses are to be kept to a minimum, and the velocity within the sample line should equal the stack velocity if the sample is to representative with respect to particles.

The probe assembly is shown in Figure 14. It consists of three probes and a flange mounting assembly. Two arrays such as this were installed with equipment attached as shown in Figure 15 (see Appendix B).

Tape monitors were installed on two of the probes: one containing a G-M tube for beta-gamma detection, the other a scintillation crystal for alpha detection. The charcoal-trap iodine monitor, described earlier, was attached to a third probe. Two of the probes are of special design and replace the inventory sampler for stack application.

Each of these special samplers is equipped with a rabbit, or sliding capsule, designed to hold a cartridge containing charcoal and a filter. When sampling, the rabbit with cartridge is pushed to the inner end of the guide tube; and the assembly is withdrawn completely when the cartridge is to be changed (see Appendix B). Two of these in-stack samplers are provided in order that duplicate samples may occasionally be taken and also to provide calibration for each of the sampling arrays.

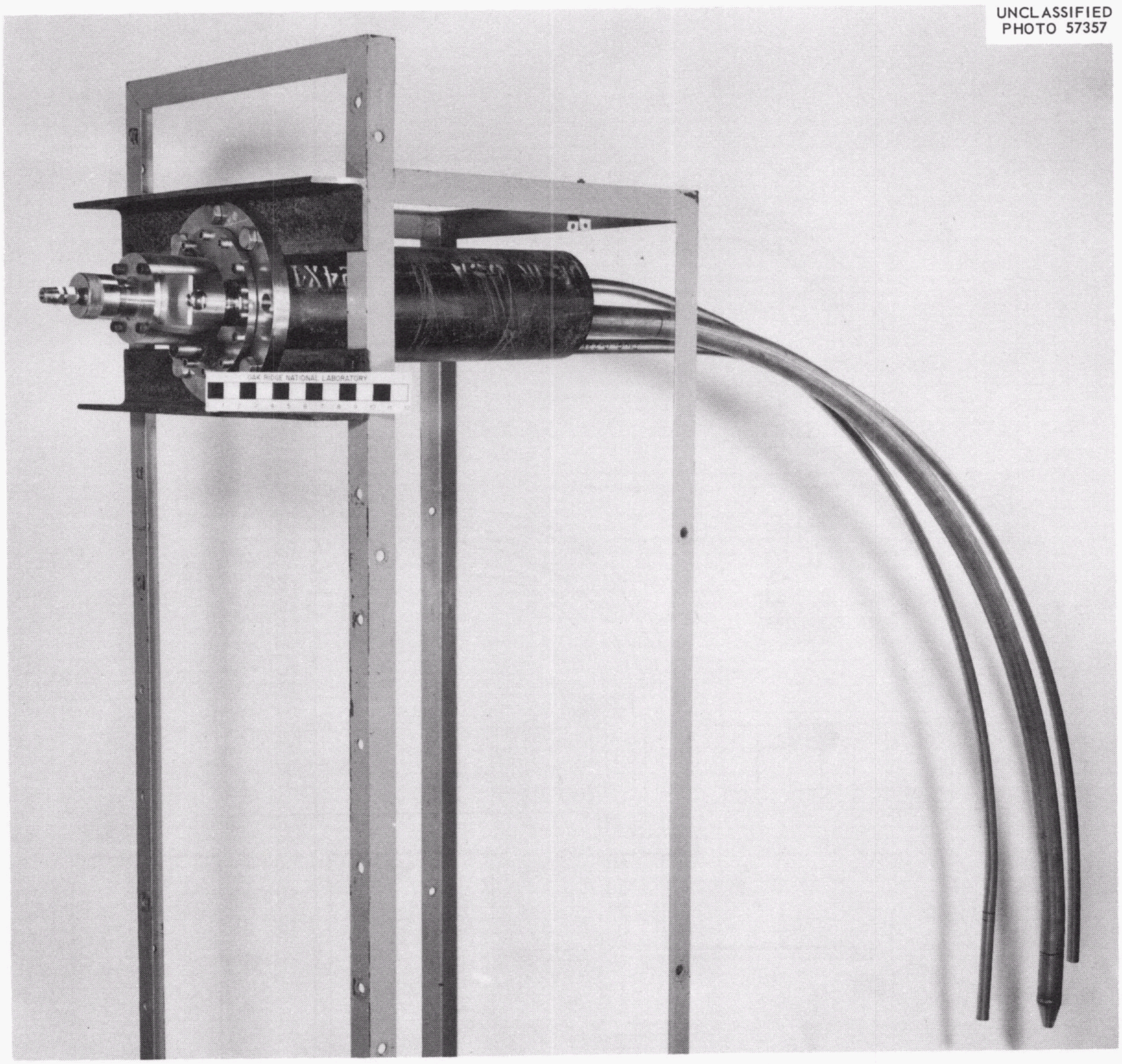

Fig. 14. Sampling Probe Assembly.

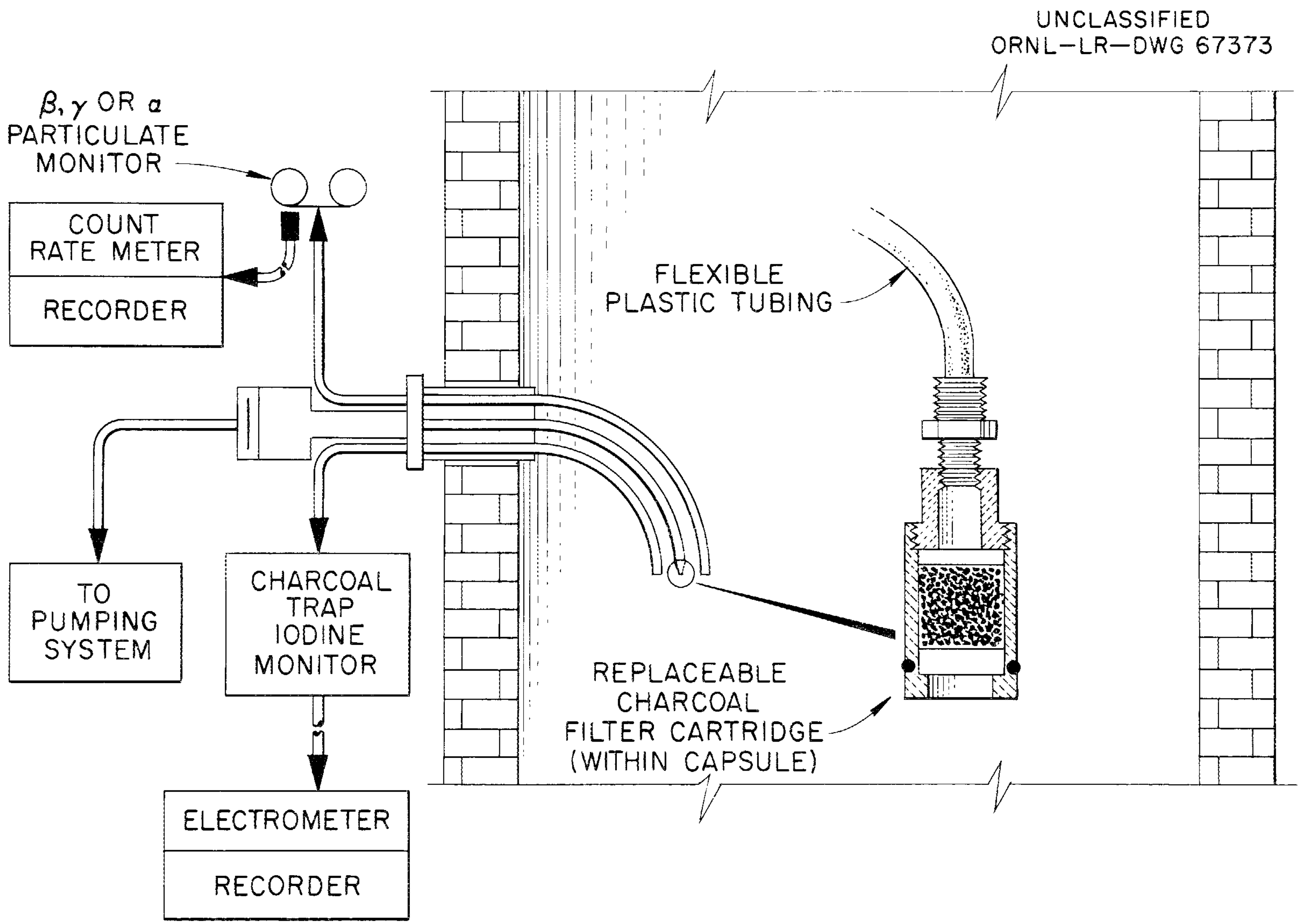

Fig. 15. 3039 Stack Sampler and Monitoring Equipment.

Of the six probes installed, five are being used. The sixth is reserved for special tests or for additional monitoring equipment which may be installed in the future.

A continuous record is kept of flow rates in the cell-ventilation ducts, off-gas discharge, and stack. 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 3018 and 3020 Stacks, mentioned earlier, have not yet been equipped with the variety of monitoring devices that are in service at the 3039 Stack since they do not discharge large amounts of particulate radioactivity. Inventory samplers and a number of other devices have been installed. These furnish data for estimating the daily activity emissions from the Graphite Reactor and the Chemical Pilot Plant. Since most of the gaseous activity generated by the Laboratory is routed to the 3039 Stack, it was originally felt that initial efforts at monitoring and control should be directed at that stack.

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.

Radioactive-waste disposal, monitoring, and control has been substantially improved at ORNL during the past 15 years. While initial efforts during that period 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 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 1500 gal/day of intermediate-level waste or about 15% 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 and ORR. From 90,000 to 110,000 gal/day of process waste comes from reactor operations. This is approximately 25% of the total for the Laboratory. 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 millicuries/day of radioactivity to the Process-Waste System. The systems are arranged to handle much larger quantities if the need should arise, however.

As noted in the text, cooling air from the OGR is released through the 3018 Stack. The ORR, however, is connected to both the cell ventilation and off-gas systems which discharge into the 3039 Stack. Approximately 6000 cfm of air from building ventilation and from cell cubicles pass through a caustic scrubber to the central cell-ventilation system. However, the caustic solution in the scrubber begins to flow only when the radioactivity level in the ORR building exceeds a preset limit and then its startup is automatic. 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. Samples of water taken from the creek and wells near the pits confirmed that Ru^{106} was the only nuclide moving in any significant quantity and that Sr^{90} 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 Ru^{106} was being released into the Clinch River, Sr^{90} 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 Ru^{106} to the pits in September. During that month, Ru^{106} 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 Ru^{106} 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 and recorder had been installed on the water intake.

At this time also, the growing inventory of other nuclides on the soil made it necessary to re-examine the soil disposal operation. By the end of 1959, a considerable inventory of Sr^{90} 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 and 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 leached and gradually move through the soil with some finally appearing 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.

Retention of Ruthenium in White Oak Lake Bed

The Ru^{106} measured at station 6 is always lower than the combined discharge from the pits 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 Ru^{106} to decay.

Process-Waste Control

Progress in the control of process waste has been accomplished in two ways: by the installation of the Process-Waste Treatment Plant in 1957 and by reducing discharges at the many sources. Two sources, the Graphite Reactor storage canal and the Isotopes Area, presently contribute about 75% of the activity carried by the process waste system; and corrective measures are being taken to eliminate the discharges from both of these areas. It is hoped that further reduction of radioactivity necessary to reach the goal set for the Laboratory will be accomplished by stricter control of releases into the system by the users. If this is found to be inadequate, plans are being made to remove the activity in the waste by additional processing. One method being developed uses a resin-bed ion-exchange process. Another method being considered is evaporation.

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 three stacks. This record is sent weekly to the main contributors, their supervisors, and the Radiation Safety and 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 among 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.

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, 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 totalizes 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.

A submersible pump, located in the pool above the weir, pumps a continuous stream of liquid through a shielded container housing a G-M tube detector. The count-rate meter, which receives and amplifies the signal from the detector, also actuates a pulse-type telemeter transmitter, sending a signal to the Control Center Building in the same manner as the flow measuring system.

The 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 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 over a year 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 site 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 three electrically 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 of the loss of cell-ventilation negative pressure. The capacity of the system is 200,000 cfm with the current usage being about 152,000. A minimum negative pressure of about 8-in. water gauge is maintained at the fan suction at all times.

Off-Gas Equipment(13)

The off-gas stream, on reaching the stack area, is first passed through a multi-cell, 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 rouging and absolute filters for particle removal and then is passed through silver-plated copper mesh for final removal of iodine. The roughing, or prefilter, is of fiber glass; the polishing filter is a pleated, Cambridge, absolute, paper 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. water gauge. Current usage of off-gas is about 2200 cfm. An automatically operated steam-driven blower is also installed 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 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. water gauge.

Inventory Sampler

A 2-in. Gelman-type Green-7 membrane filter is being used at present. The cartridge is 1 1/2 in. long, 3/8 in. in diameter and contains approximately 3 gm of coconut charcoal. A 1-cfm Gast pump is used to draw the sample stream through the collection assembly; metering of the flow is accomplished by use of a rotameter.

Moving-Tape Particle Monitor, Q-2323

An air sample stream is drawn through a 3-in. paper tape for a preset 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. After the preset time has elapsed, the tape automatically advances. The tape may also be advanced remotely, on demand, by the operator. Guard switches on the unit signal a tape break or a shortage of tape supply.

Off-Gas Discharge Ion Chamber

A Reuter Stokes Company, Type RSG-1, ion chamber is used here. This instrument, which is quite sensitive to gamma radiation, transmits a signal first to an electrometer and then to a recorder. Since its installation, this device has performed reliably and with a minimum of maintenance.

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 is drawn through a 2-in. filter tape located adjacent to a side window G-M tube. Buildup of activity, thus detected, is recorded and serves as a measure of stack behavior. The tape is changed daily by pulling through the collection block, and the deposited radioactivity is analyzed.

Moving-Tape Particle Monitor, Q-1950

The moving-tape particle monitor is an early model and employs a 1 1/2-in. filter tape which is normally advanced on a 30-minute time cycle. The detector used here is a 2 mg end-window, G-M tube which has a high sensitivity to beta-gamma activity.

Charcoal-Trap Iodine Monitor

The charcoal-trap iodine monitor consists of an aluminum cylinder 14 in. long x 4 in. in diameter, filled with about 750 g of 14-mesh charcoal. An ion chamber (Reuter Stokes Company, Type RSG-1) is inserted into a well through the center of the cylinder. Any absorbable activity is retained on the charcoal, and the accumulation is detected by the ion chamber. The signal is sent to an electrometer and recorder. This instrument is very sensitive and has required little maintenance.

3039 Stack-Sample Withdrawal Probes, Q-2285

The probes are of 1-in. stainless-steel tubing which 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 was 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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