Title
A NEW METHOD OF CONTROLLING RADIOACTIVITY IN LABORATORY WASTE WATER

Author
Eno, Eugene

Publication Date
1972-04-01

LBL-998
UC-70 Waste
Disposal and Processing
TID-4500 (59th Edition)

A NEW METHOD OF CONTROLLING RADIOACTIVITY IN LABORATORY WASTE WATER

Eugene Eno, Robert J. Walker, and Paul Salz

April 17, 1972

AEC Contract No. W-7405-eng-48

DISCLAIMER

CONTENTS

A NEW METHOD OF CONTROLLING RADIOACTIVITY IN LABORATORY WASTE WATER*

Eugene Eno, Robert J. Walker and Paul Salz

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

April 17, 1972

ABSTRACT

A novel method of monitoring and controlling radioactive water from active waste sewers is presented. This method, developed to handle large flows, costs less, requires less space, and is more effective than the conventional "holding tank" method. Advantages, equipment details, and comparative economics are discussed.

Introduction

Despite the rigorous controls exercised by personnel working with radioisotopes, accidents occasionally occur whereby radioactive materials are released as liquid waste. Consequently, buildings housing radiochemical laboratories are generally equipped with separate "active waste" sewers. These sewers collect all liquid wastes from the laboratory sinks and deliver them to a monitoring and control system.

Most control systems use the "holding tank" method to prevent the release of radioactive waste water. This method requires that all water from active waste sewers be collected and held in tanks until proven free of high-level radioactivity. The method is simple, direct and effective. It has, however, some significant drawbacks:

1. When the waste water flows are large, the storage capacity required may make the system quite expensive and may demand more space than is available.

2. The analysis of the water in a storage tank only shows what the average level of waste water radioactivity was during the period required to fill this tank. Although this level may be within acceptable limits (thus allowing the release of the stored water), adequate control of radioactivity may be lacking. If the tank volume is large, the total quantity of radiochemicals released can be significant. This is particularly true where these chemicals tend to concentrate in a metabolic chain or tend to persist in the environment.

3. It is often difficult to dispose safely of the large volumes of collected waste water if this water is highly radioactive.

4. In the event of natural catastrophes such as earthquakes, large volumes of possibly radioactive fluid could be released into the environment.

We have designed and placed in operation a control system using the "monitor and treat" method. This method relies on in-line instrumentation and ion exchange units to detect and remove the radioactivity from waste water. Briefly, the method is as follows:

The level of radioactivity in the waste water is continuously monitored by means of an electronic network. If the radioactive content is below a predetermined level, the water is automatically diverted directly to the sanitary sewer. If the radioactive content is above this level, the water is automatically cycled through nuclear grade ion exchange resins to remove the radioactivity. The effluent from the ion exchange unit is kept in a closed system, recycling through the unit, until the monitoring instrumentation shows it to be free of radioactivity. It is then released by manual control. (This release can be automatic if so desired.) We feel that the advantages of this method over the "holding tank" method are:

1. For large flows, it costs less.
2. It requires less space.
3. It requires less mechanical equipment maintenance.
4. The waste water is cleaned as it flows, thus eliminating the need for a large storage of possibly radioactive fluid.
5. Through instantaneous control, it prevents the release of water whose level of radioactivity exceeds any predetermined maximum value, generally, less than the maximum permissible concentration (MPC). Thus it effects a positive reduction of the total amount of radiochemicals released.
6. It measures and records the flow rate and the instantaneous level of radioactivity of the waste water. This permanent record is often of value.
7. It removes the radiochemicals from the waste water and concentrates them into a nearly solid form in a relatively small container. This container is disposable and can serve as a shipping container.

MECHANICAL FEATURES

The mechanical features described below were designed for our system to accommodate our particular problems. A different set of problems may require a different design. However, the general approach presented here could be applied to any set of conditions.

Special Construction Materials

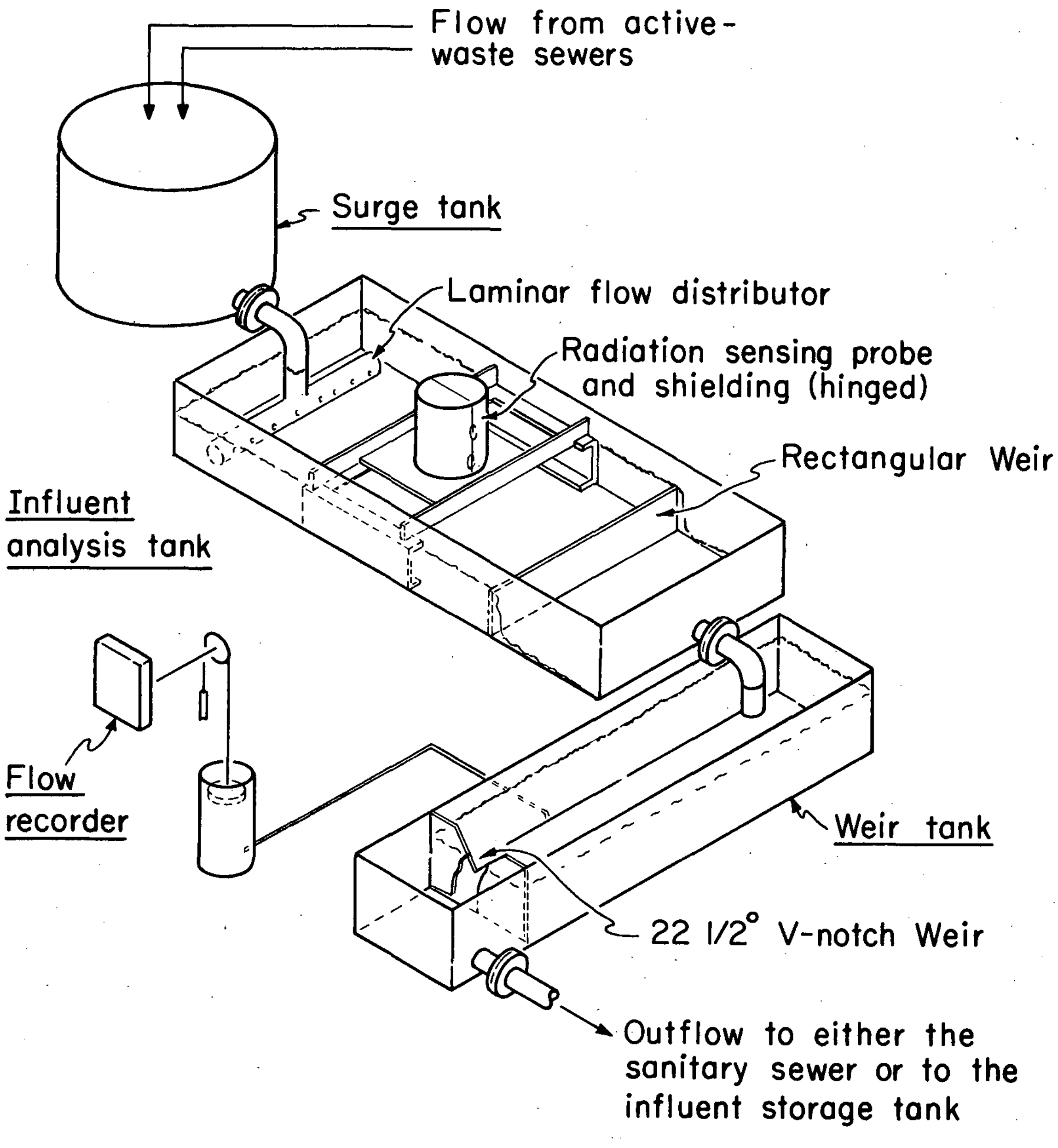
The monitoring station receives active waste water from two radiochemistry buildings. Since this water contains low-level concentrations of many combinations of chemicals, we have constructed the station of materials resistant to chemical attack. All piping handling untreated waste water is made either of high-silicon iron ("Duriron") or stainless steel. All pumps are made of stainless steel, and all tanks are coated with a baked phenolic resin ("Bisonite 957").

Surge Tank

Approximately 50,000 gallons per day of water from the active waste sewers of the two building flow into the "surge" tank. This tank reduces flow surges and prevents the backflow of waste water from one building into the other.

Influent Analysis Tank

The water from the surge tank flows into the "influent analysis" tank through a laminar flow distributor located at the bottom of this tank (see Fig. 1). This tank is used to analyze the water for radioactive content and is, accordingly, equipped with a support to hold the radiation sensing probe and its shielding. In addition, it contains a rectangular weir designed to maintain the depth of probe immersion at 0.3" ± 0.1" from maximum to minimum water flow. The entering water, passing across the bottom of the tank in a laminar flow, scrubs out the volume adjacent to the weir. This eliminates any non-circulating region which could hold residual radioactivity after the main flow has cleared. There is a waste-water flow retention of eighty gallons behind the weir. This particular retention quantity was established to accommodate possible future liquid sampling.



XBL725-2929

FIG. 1. Isometric schematic of surge tank, influent analysis tank, and weir tank.

Weir Tank

The water from the influent analysis tank flows into the "weir" tank. The weir tank, used to measure the water flow rate, is equipped with a $22\frac{1}{2}°$ V-notch weir and is connected to a float tank and flow recorder (Stevens 51-R). The flow recorder records the instantaneous water flow rate and indicates the integrated flow. In addition, it is equipped with electrical contacts which close each time eighty gallons of water pass through the weir. (These contacts may be used to accomplish possible future liquid sampling.)

Influent Diverting System

The path of the water flowing out of the weir tank is determined by the radioactivity of the water. This control is carried out by means of an electro-pneumatic system as follows:

1. If the amount of radioactivity sensed by the probe in the influent analysis tank is below a predetermined level, an electronic network causes a solenoid air valve to be energized. This valve distributes the air flow and exhaust to and from the operators of two glass-lined, Saunders-type, diaphragm valves, so that one of these valves is open and the other is closed. The waste water then flows through the open valve directly to the sanitary sewer.
2. If the amount of radioactivity in the water is above the predetermined level, or if there is a loss of electrical power, the solenoid air valve is de-energized. This causes the first air-operated valve to close and the second to open. The waste water then flows through the second valve to the "influent storage" tank.

Influent Storage Tank and Controls (See Fig. 2)

The "influent storage" tank has a capacity of 5000 gallons and is equipped with a conventional bubbler. (A bubbler is a device for measuring the liquid level within a tank. It consists of a tube that has an open end near the bottom of the tank and extends vertically the height of the tank. Air is forced through this tube, bubbling out through the water in the tank. The rate of air flow through the tube is kept constant by a purge meter-differential pressure assembly. Accordingly, the air

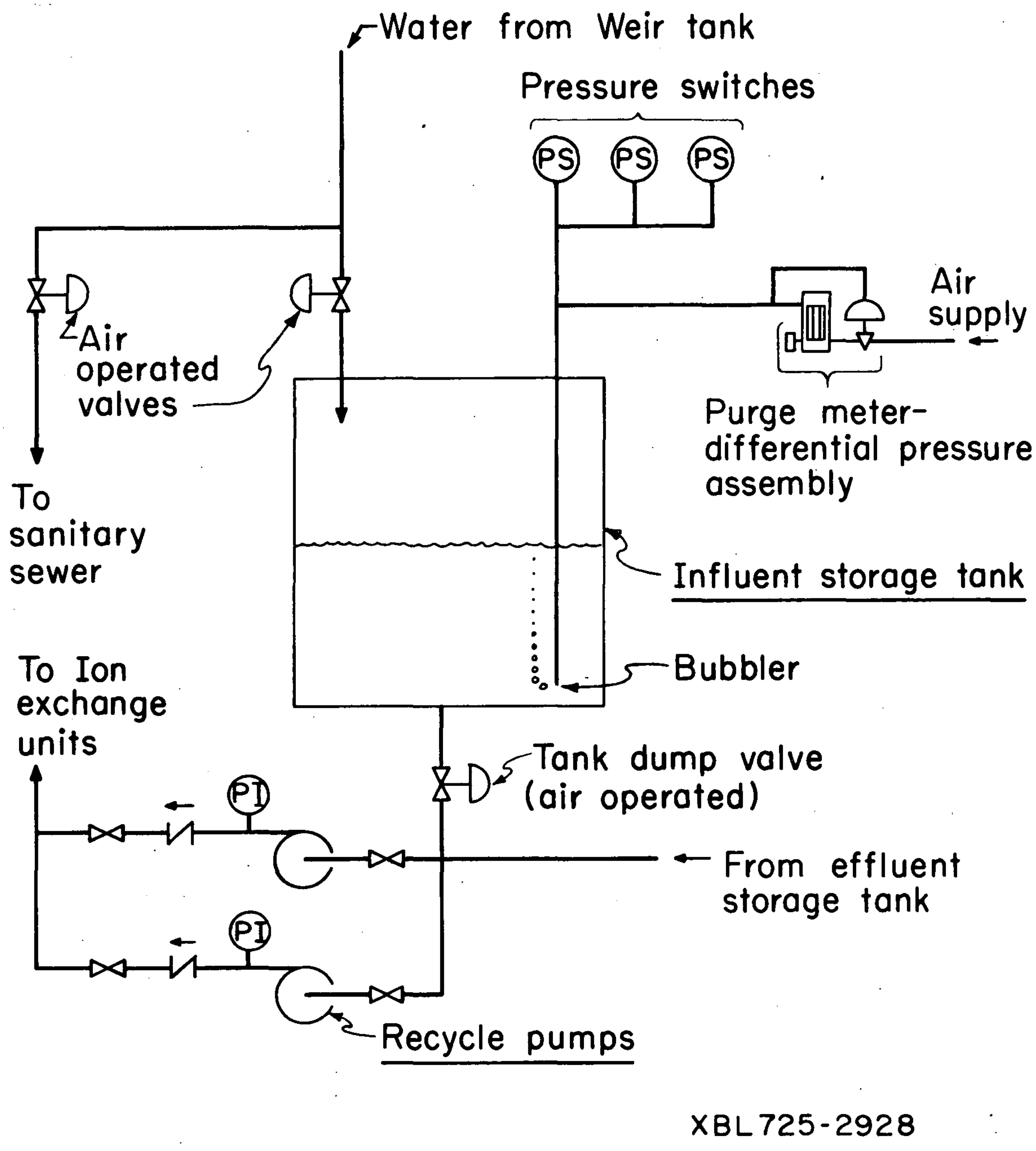


FIG. 2. Schematic drawing of influent storage tank and recycle pumps, including related processes and air piping.

pressure within the tube varies directly with the height of water in the tank. Pressure sensing devices, including switches, are connected to this tubing.)

When the waste water flowing into the tank has risen to a predetermined level, the pressure developed within the bubbler tubing closes the electrical contacts of one of the pressure switches. This energizes a solenoid air valve, which in turn causes the air-operated tank dump valve to open; the contacts also energize the motor starters for the recycle pumps.

When the level of the water in the tank has been pumped down to another predetermined level, the decrease in air pressure within the bubbler tubing closes the contacts of a second pressure switch. This de-energizes the solenoid air valve (and thus closes the tank dump valve), and also stops the recycle pumps.

A third pressure switch actuates an alarm when the water level in the tank has risen too high (i. e. when there is a malfunction either of the tank dump valve or of the recycle pumps).

Recycle Pumps

The recycle pumps pump the water from the storage tank to the ion exchange units. Only one pump is required, the other serving as a standby. These pumps (Moyno CDQ) were selected to be resistant to chemicals, to handle sedimentary materials such as coffee grounds, and to maintain nearly the same discharge flow with varying line pressure (i. e. to be positive displacement pumps).

Ion Exchange Units and Controls (See Fig. 3)

The waste water from the influent storage tank is pumped to the two ion exchange units. These units are used to remove ionized chemicals from the water. They were designed to be disposable and to serve as shipping containers. They contain nuclear grade, mixed bed, ion exchange resins (Rohm and Haas Amberlite IRN-150).

The water flows through only one unit at a time. When one unit has been exhausted, the water flow is automatically directed through the other unit. This is accomplished as follows:

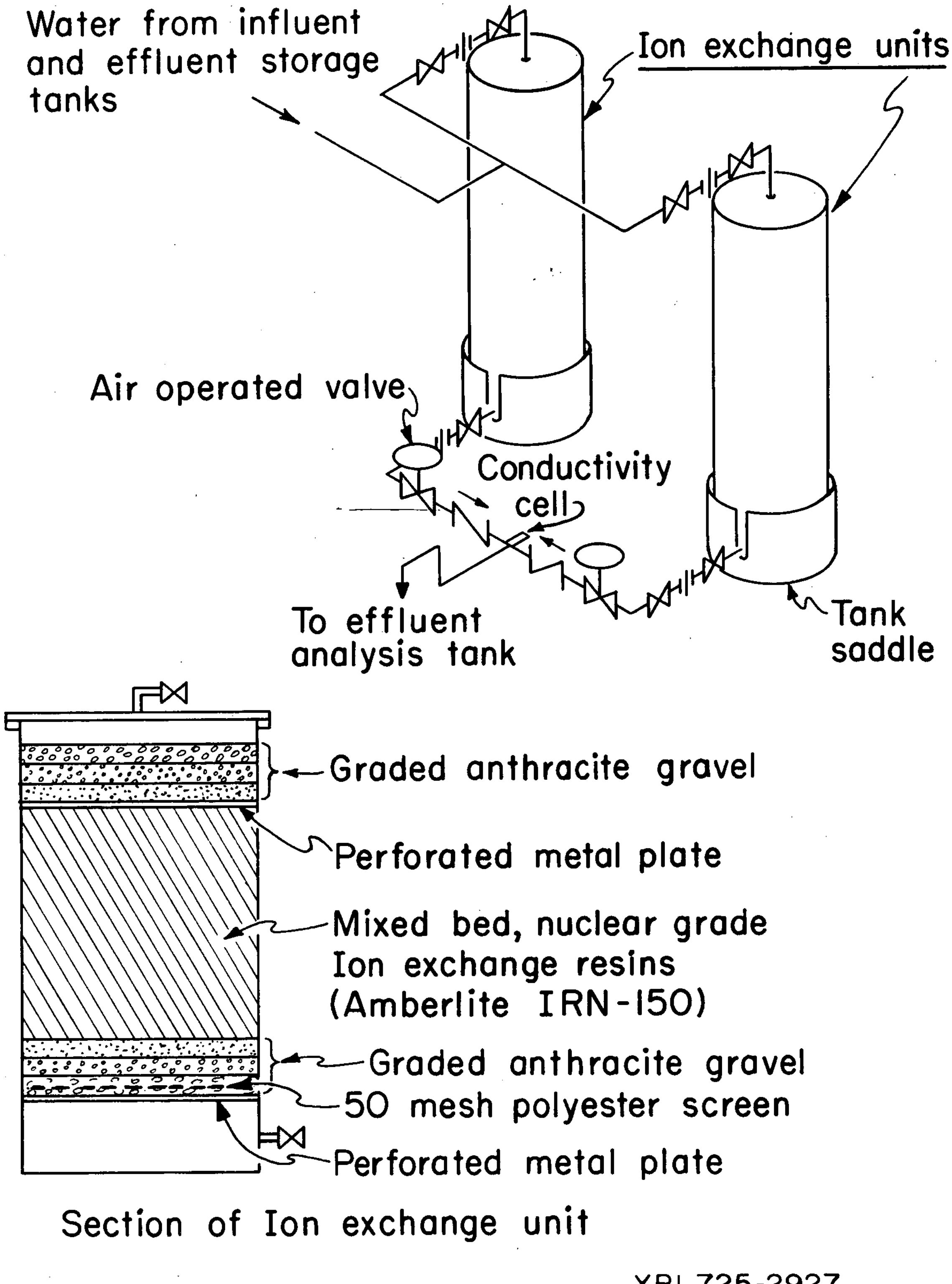


FIG. 3. Section view of an ion exchange unit and an isometric schematic of ion exchange units and associated piping.

A temperature-compensated conductivity cell (Beckman CEL VS-01-SK) measures the conductivity of the effluent from the ion exchange units. If this conductivity is above a predetermined level, the conductivity controller (Beckman RE-194-H1-K) causes the energizing (or de-energizing, depending upon the sequence of a stepping relay) of a solenoid air valve. This in turn causes the air operated valve in the discharge line of one of the units to close and the other to open. The switching from one unit to the other can be accomplished independently of the conductivity controller by simply moving the stepping relay one step.

Effluent Analysis Tank (See Fig. 4)

The effluent from the ion exchange units flows into the "effluent analysis" tank. This tank is essentially of the same construction as is the influent analysis tank.

Effluent Diverting System

When high-level radioactivity is sensed in the influent analysis tank, the water from the effluent analysis tank is automatically diverted to the effluent storage tank. This occurs regardless of the radioactivity sensed in the effluent analysis tank.

After the high-level radioactivity has cleared from the influent water and after evaluation of the effluent water radioactivity has shown this water to be safe, the discharge from the effluent analysis tank is diverted to the sanitary sewer by manual control. The controls for the effluent diverting system are essentially the same as those for the influent diverting system with the exception that the solenoid air valve is energized manually rather than automatically.

Effluent Storage Tank and Controls

The "effluent storage" tank and its controls are essentially the same as the influent storage tank and its controls.

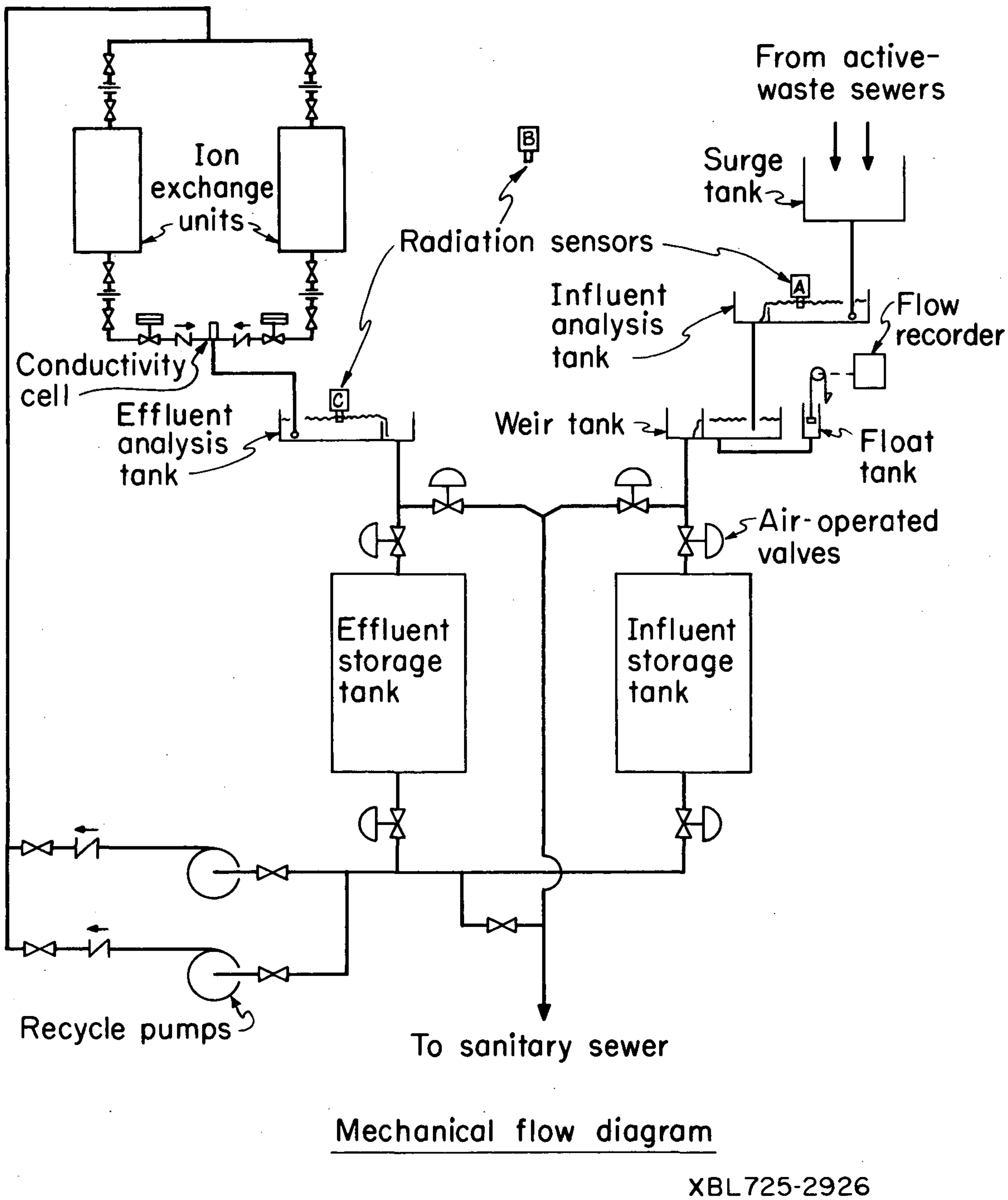


FIG. 4. Process flow diagram of active waste monitoring system.

MONITORING SYSTEM

Detectors

The radiation activity in the "monitor and treat" system is detected by a 0.063 in. thick, 5 in. diam NaI(Tl) scintillator coupled to an RCA 8055 photomultiplier tube.

Three detector units, all similar in construction, are used at different locations within the system.

The sensing head of unit 'A' is protected by a mylar sheet and is partially immersed in the waste stream. It is exposed to the background and to the waste stream.

Unit 'B' detects the background radiation, both natural and that due to nearby accelerators.

Unit 'C' is exposed to the effluent stream.

Electronics

The amplified pulse output of each detector is routed to a single channel pulse height analyzer. The range of accepted pulse energy is set between 10 keV and 100 keV, as seen by the detector.

The pulse output of each of the analyzers is transmitted over signal lines from the sampling site to counting equipment located at a monitor station.

The pulse information 'A' (activity and background) and 'B' (background) are each routed to pulse rate circuits. The analog output of these circuits is indicated by panel meters M(A) and M(B). The outputs are also routed to a subtracting circuit which produces the net output of C(A) minus C(B) (counts/unit time). A panel meter indicates this output.

The three meters, M(A), M(B), and M(A-B), each registering pulses per minute, are shown in Fig. 6.

Counts originating at the three detectors are also accumulated by digital count rate scalers. The accumulated information is periodically printed out for a historical record. Figure 5 shows the detections, conversion, and alarm actuation system in block diagram form. Figure 7 is a photograph of the station alarm panel. Figure 8 is a view of the influent analysis tank, showing the probe and shielding, and Fig. 9 shows the ion exchange tanks.

Alarm Settings

The statistical variation of background counting causes the difference meter to fluctuate between +100 and -100 counts per minute. Whenever 400 counts/minute are reached or exceeded, an alarm condition exists, and the waste stream is diverted to a temporary storage tank.

Sensitivity and alarm threshold studies are still in progress. The present alarm threshold is set for a ^{241}Am concentration of 10 disintegrations per minute per cubic centimeter. The maximum permissible count rate for ^{241}Am is 220 d/m/cc, calculated from data given for a similar detector.[2]

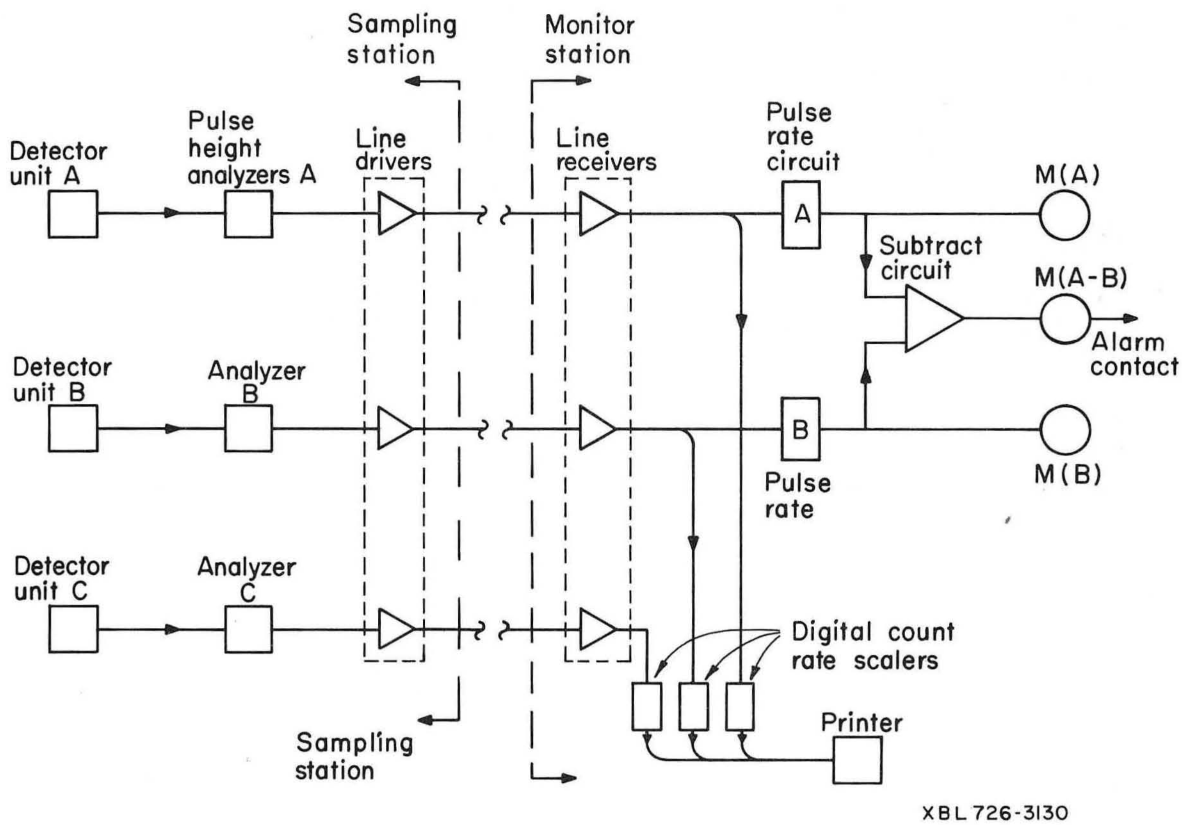
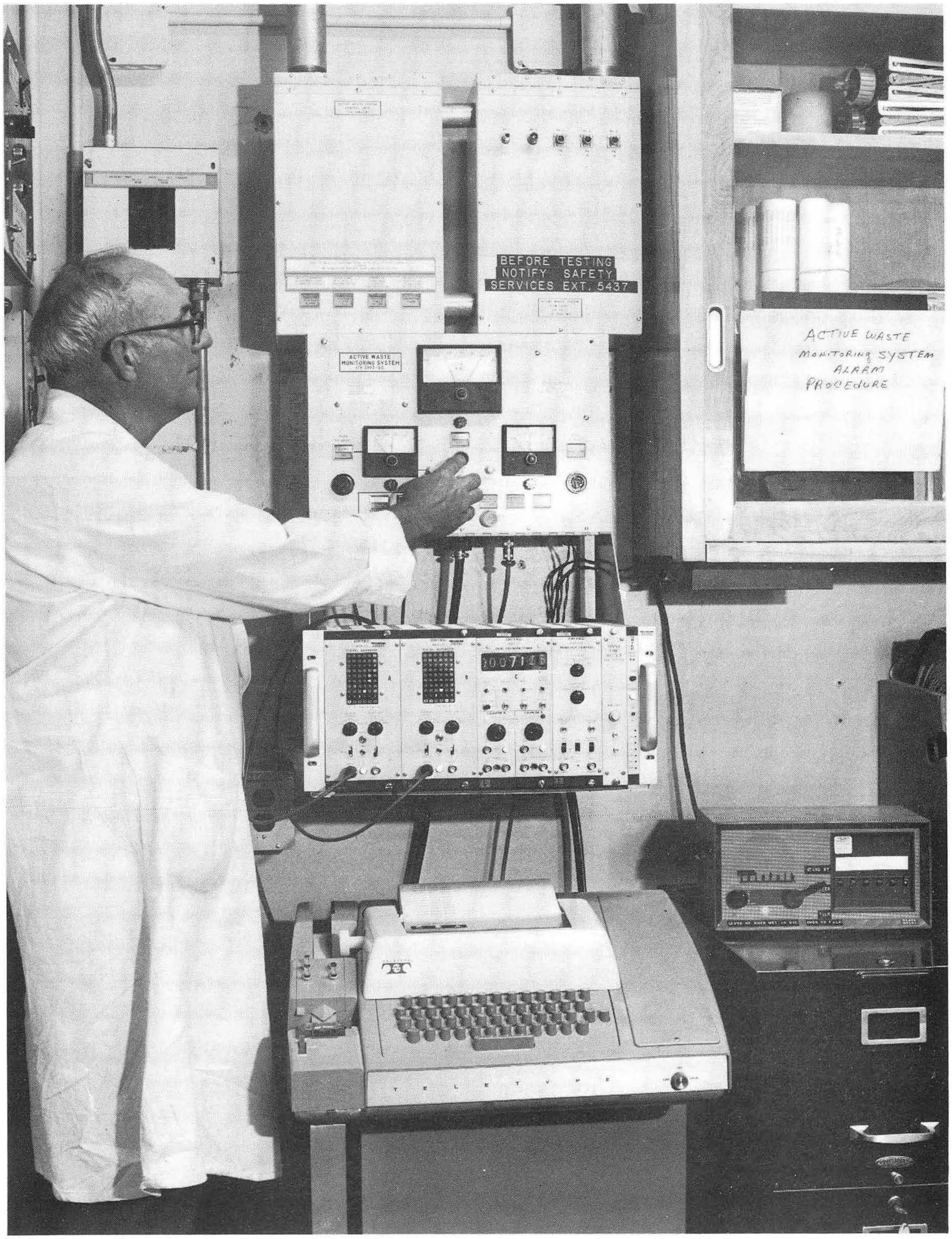
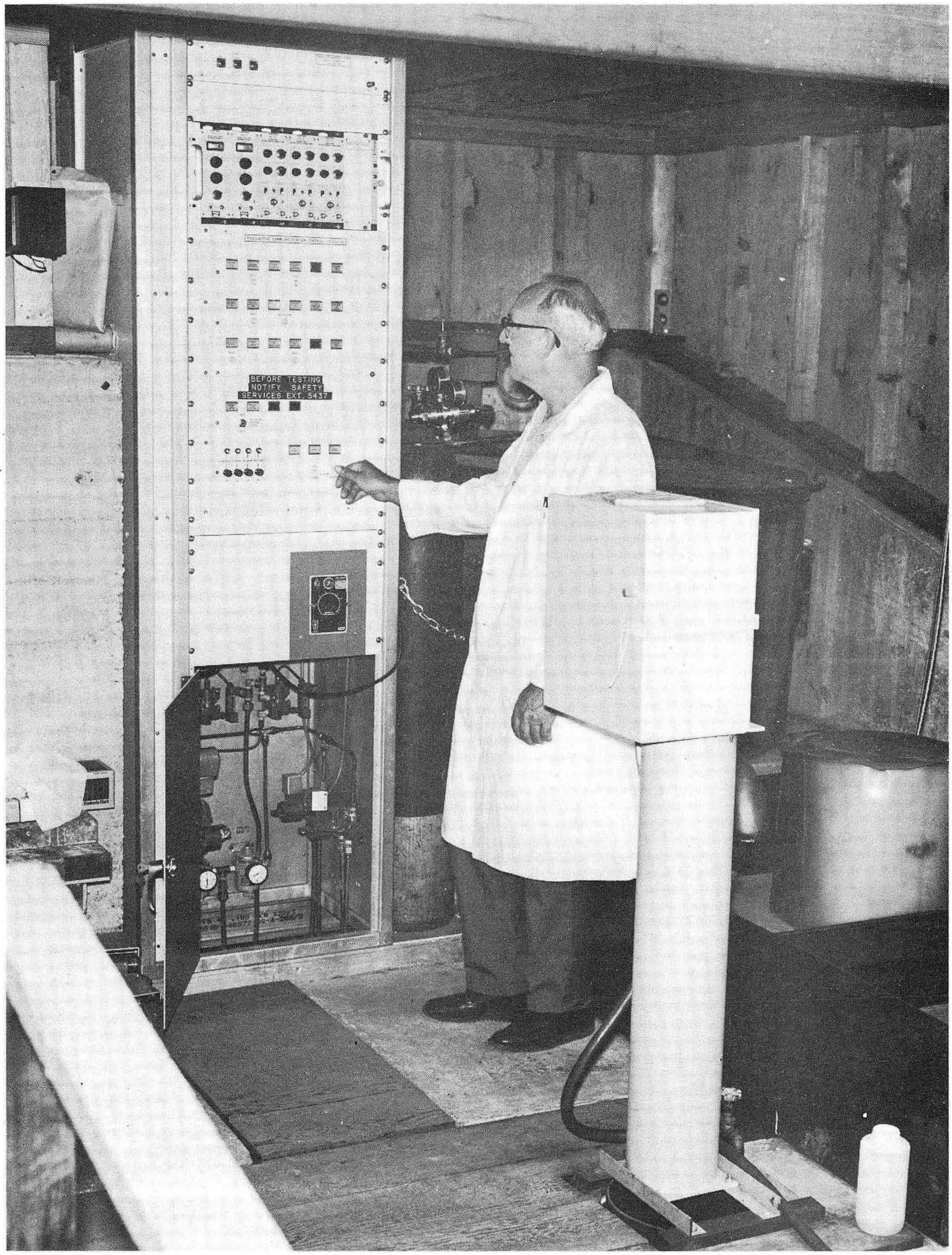


FIG. 5. Block diagram of detection system.



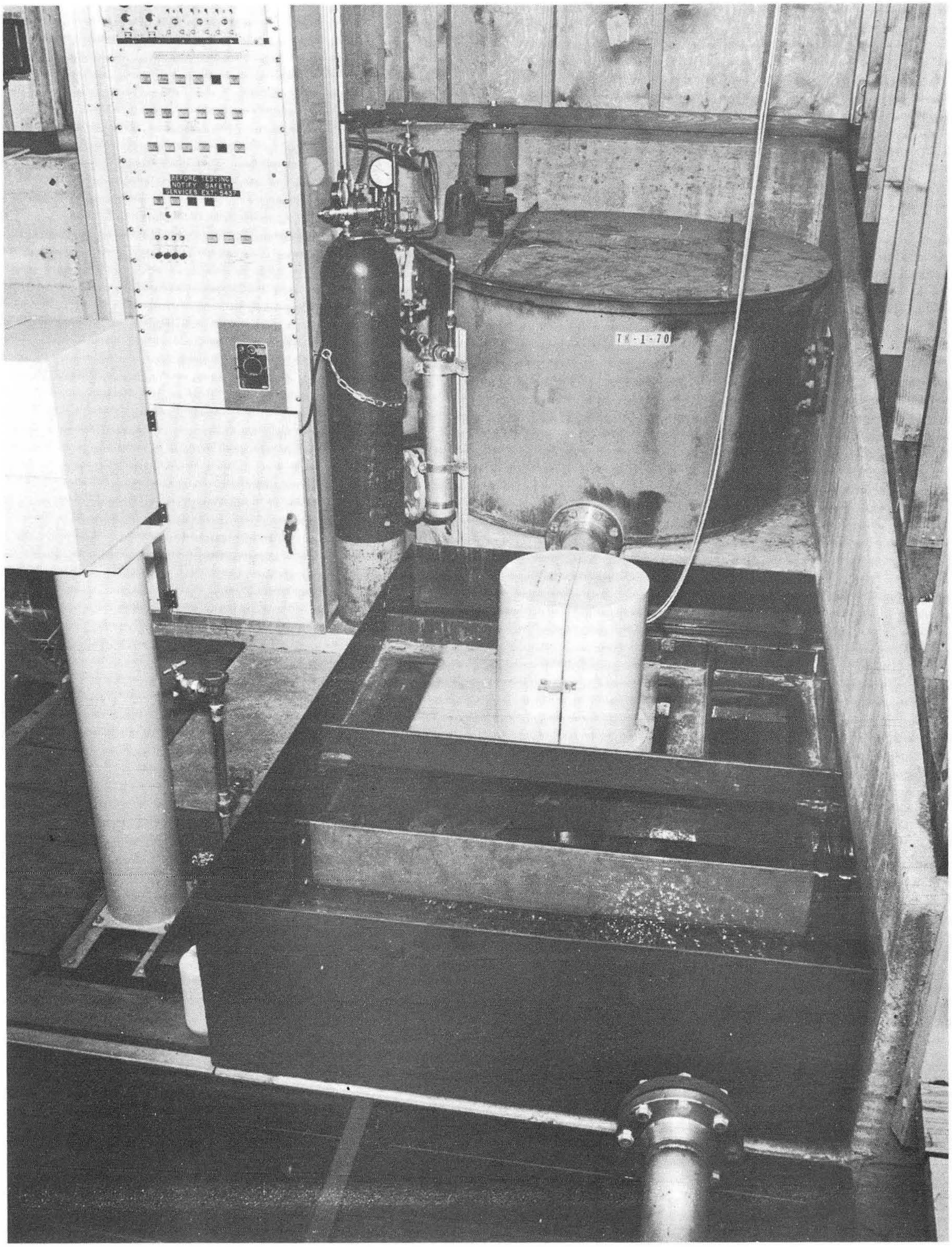
XBB 725-2709

FIG. 6. Photograph of remote alarm panel and radioactivity readout equipment.



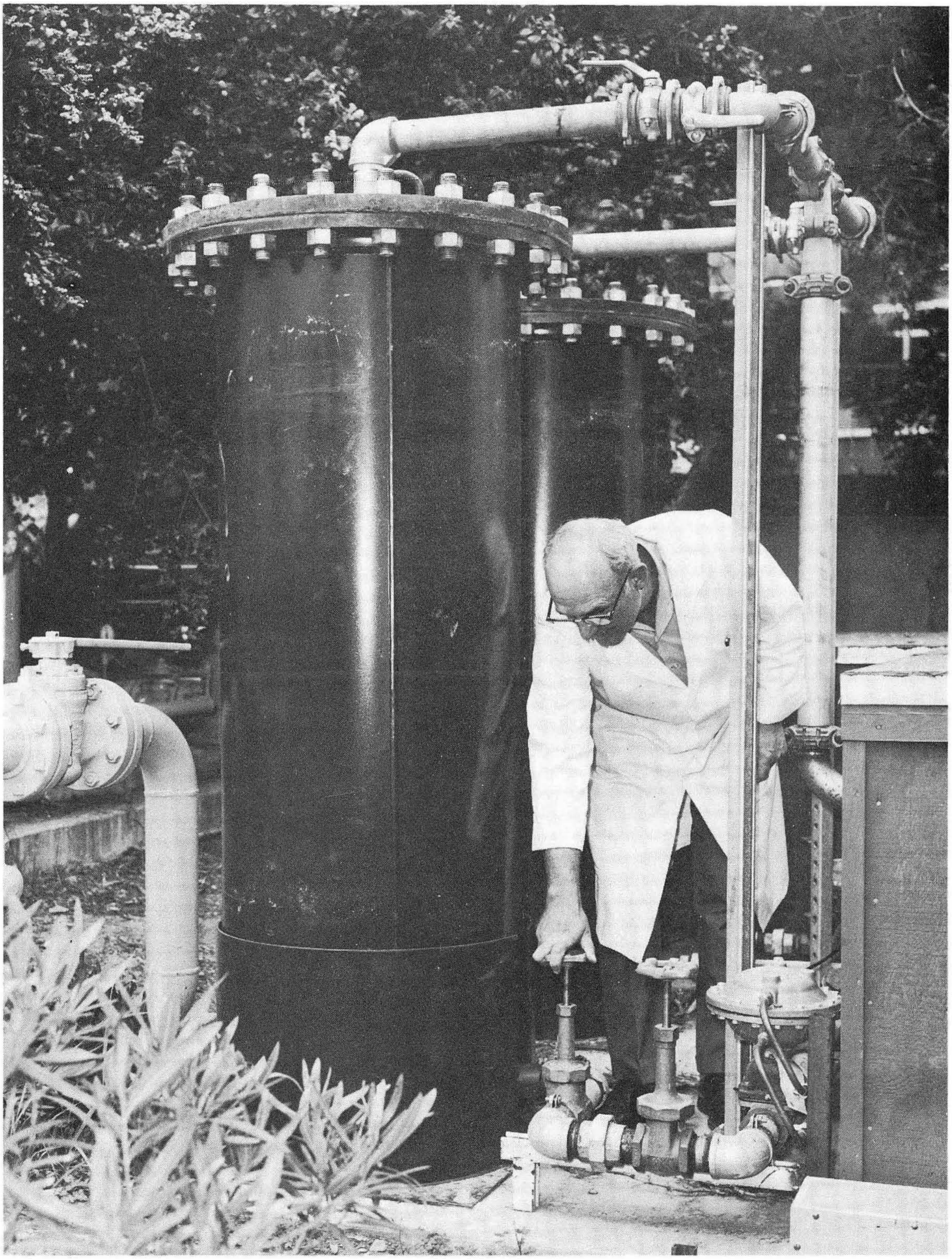
XBB 725-2710

FIG. 7. Photograph of station alarm panel. Air solenoid valves are seen through open door at bottom of panel.



XBB 725-2712

FIG. 8. View of influent analysis tank, showing probe and shielding.



XBB 725-2711

FIG. 9. View of ion-exchange tanks.

COMPARISON OF "HOLDING TANK" AND "MONITOR AND TREAT" METHODS

The "holding tank" method requires at least 150,000 gallons storage capacity to accommodate an influent waste water flow of 50,000 gallons per day. (This capacity is required to allow for weekends and holidays.) The storage should be divided into not less than three tanks, preferably more. Assume the storage is distributed among six 25,000 gallon capacity tanks:

1. The area required for a "holding tank" station is about six times that required for a "monitor and treat" station.
2. The cost of the "holding tank" station is about double that of the "monitor and treat" station.
3. Three times as many air-operated valves, solenoid air valves, bubblers, and other controls are required for the "holding tank" station.
4. If the analysis of the water in a holding tank shows it to be highly radioactive, we must somehow dispose of 25,000 gallons of dangerous liquid.

   Using the "monitor and treat" method, the radiochemicals are removed from the waste water and concentrated in the resins within an ion exchange unit. This unit is comparatively small, is disposable and is designed to serve as a shipping container. It is easily removed for disposal, and there is little danger of radioactive contamination.
5. In the event of an earthquake or other catastrophe, the "holding tank" method presents the possibility of releasing large volumes of stored waste water, possibly radioactive.

   Using the "monitor and treat" method, the waste water is analyzed and treated as it flows so that there is seldom any storage.
6. A short duration flow of radioactive water through a "holding tank" station could be so diluted by the remainder of the 25,000 gallons in a storage tank that the tank water analysis could show

the level of radioactivity to be within acceptable limits. Accordingly, the water in the storage tank would be released without treatment.

Using the "monitor and treat" method, the radioactive water would immediately be treated to remove the radioactivity. Thus, there would be a positive reduction of the total amount of radiochemicals released. This could be quite significant if the radiochemicals were those which tended to concentrate in a food chain or tended to persist in the environment.

7. Using the "monitor and treat" method, the rate of flow and the level of radioactivity of the waste water are immediately monitored and recorded. These permanent records are of value in determining the origin of radioactive "releases". The sensitivity of the monitoring instrumentation is such that we can now detect "releases" which would have gone unnoticed when the "holding tank" method was in use.

ACKNOWLEDGMENT

The authors want to thank Eugene Powers for the design of the electrical and electronic circuitry.

REFERENCES

*Work supported by the U. S. Atomic Energy Commission.

1. AEC Handbook SRP Chap. 0524, Sec. II, B.2 and II, E.1.
2. Lawrence Livermore Laboratory Report UCRL-50007-69-2, Hazards Control Progress Report No. 34, May-August, 1969.

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720