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INTERIM REPORT

SURVEY OF RADIOACTIVITY - MONITORING PRACTICES AT A BOILING WATER NUCLEAR POWER STATION

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INTRODUCTION

Late in 1976, Brookhaven National Laboratory undertook a Technical Assistance Program with the U. S. Nuclear Regulatory Commission to survey radioactivity monitoring practices in liquid and gaseous effluent streams from nuclear power reactors. It was subsequently supplemented to include the consideration of the capability of existing effluent monitoring to assess radiological releases under accident conditions.

Specifically, the objectives of this program are to obtain sufficient information from field surveys to characterize the currently employed practices and procedures to compare typical effluent monitoring and sampling systems with the apparent state-of-the-art, to recommend needed improvements in the state-of-the-art, with regard to assuring reliability of the isolation function of monitoring systems and the adequacy of monitoring data to establish compliance with as low as reasonably achievable (ALARA) design objectives (10 CFR 50, Appendix I).

An additional objective, included by the supplement, is to obtain information so as to characterize the capability of existing systems under accident conditions to accurately reflect releases of radioactive materials through anticipated releases points, using criteria established in Regulatory Guide 1.97.(1) Additional guidance on essential performance parameters and monitor placement under emergency conditions was obtained from a proposed ANSI Standard.(2)

This interim report summarizes information obtained from the site visit made on April 13-14, 1977 by Brookhaven (along with staff of the Division of Operating Reactors) at a multiple unit boiling water reactor nuclear power station, which is herein referred to as "Station A". Additional information obtained from the plant operator, the vendor (General Electric Company), and from pertinent reports subsequent to the site visit is also included.

I. GENERAL DESCRIPTION

Station "A" consists of three identical boiling water reactors, each with a power capacity of 3,297 Mw(t), or 1,065 Mw(e). The startup of Unit 1 was made in 1973, of Unit 2 in 1974, and of Unit 3 in 1976. All were operating at the time of the site visit.

The three reactors, each with associated fuel handling area and turbine building, are housed in contiguous structures. Each has an identical set of off-gas and building ventilation air monitoring instrumentation. Originally designed for 30 minute delay off-gas holdup, each reactor unit off-gas system is now equipped with advanced off-gas treatment which provides an estimated 9.7 hour delay for radiokryptons and 7.3 days for radioxenons, as well as essentially containing the radioiodine from this pathway. The station is provided with one 600' stack and one radwaste treatment facility.

II. INSTALLED MONITORS AND SAMPLING ARRANGEMENTS

For the most part, the station's air and liquid effluent monitors and sampling arrangements correspond to those customarily installed in BWR process systems.[3] With the exception of the continuous gas, particulate and radioiodine monitors for the ventilation air from the reactor building refueling area, turbine building and radwaste areas, all the monitors were provided by the reactor vendor (General Electric Company).

The locations and types of the installed off-gas and stack monitors and samplers are shown schematically in Figure 1; those of the installed reactor building, fuel handling area, and turbine building ventilation air monitors are shown schematically in Figure 2; and those of the installed liquid waste and service water effluent monitors in Figure 3. Since the types and locations of

the installed monitors and samples are identical for each unit, only one has been shown in these figures.

III. AIR AND LIQUID EFFLUENT MONITORS AND SAMPLING

1. Off-Gas and Stack

A list of the off-gas system air monitors including their manufacturers, types and principal features, is shown in Table 1. These monitors read out and alarm in the control room of their respective units (the stack monitor in Unit 1). Additional pertinent comments follow, in the order of listing.

a) Pre-Treatment Off-Gas Monitor: Two gamma-sensitive ion chambers are installed immediately adjacent to a six inch diameter vertical sample chamber which is a section of the line containing an aliquot of the flow just downstream from the recombiners (see Fig. 1). Flow in this line is established by ΔP to the SJAE inlet. The position of these ion chambers relative to the sample chamber, as located in a shielded room, is shown in Figure 4. A manual sampling station, as shown in Figure 5, is located in an adjacent room. The ion chamber indications are compared with the concentrations and types of gases in the line on at least a quarterly basis. However, weekly analyses are made of the gas mixture, and the calibration factor revised whenever a non-conservative change becomes apparent. This monitor has alarms but has no isolation function. They are provided to warn the operator of increased off-gas rate, indicative of fuel failures.

b) Post-Treatment Monitor: The charcoal bed effluent gas sampling system consists of a vacuum pump, two shielded gas sample chambers containing Na-I scintillation detectors, and associated flow control features. As shown in Figure 6, it is installed in a rack which is situated in the

advanced off-gas system house (underground adjacent to the plant stack). Any one upscale "high" radiation trip which is set to occur at a release rate of 7,300 μCi/sec (0.5% of Technical Specifications) closes the charcoal bed bypass valve (if open), and directs the flow through the beds. The "high-high" alarm is set to occur at a release rate of 2.19×10^4 μCi/sec (1.5% of Technical Specifications), in order to provide time for corrective operator action before the system isolates. Two upscale "high-high-high" radiation trips, which are set to occur at a release rate of radioactive gases of 0.146 Ci/sec (10% of Technical Specifications) produce a signal to isolate the off-gas system. The chamber indications are compared with types and concentrations of gases in this line on at least a quarterly basis. As with the pre-treatment monitor, its calibration factor is adjusted whenever significant changes are found from weekly analyses of post-treatment gas mixtures.

c) Stack Monitor and Sampling: All of the primary system off-gas streams (air ejector, vacuum pumps, gland seal leakage) from the three reactors, the ventilation from the exit filter cubicle, and the effluent air from the standby gas treatment system, are discharged to the atmosphere through a 600' stack. An aliquot of this effluent airstream is drawn using a probe which is isokinetic for maximum stack flow and which is installed at the 75' level, through a heat traced line (set to maintain a temperature of 110 - 134°F). The sampling system consists of a vacuum pump, two shielded gas sample chambers containing Na-I scintillation detectors, preceded by fixed particulate and charcoal filters and associated flow control features. As shown in Figure 7, it is installed in a rack, which is located within the base of the stack. The inlet sampling line, with the halogen and particulate

filter holder in place is shown in Figure 8. This monitor is set to give a "high" alarm at a gaseous release rate of 0.146 Ci/sec, or 10% of Technical Specifications for the release of radioactive gases, and a "high-high" alarm at 0.291 Ci/sec or 20% of Technical Specifications. It has no isolation function. The chamber indications are compared with types and concentrations of gases in this line on at least a quarterly basis. As with the preceding off-gas monitors, the calibration factor for the stack gas monitor is adjusted whenever significant changes are found in weekly analyses of the stack gas mixture. Fixed filters are changed on at least a weekly basis, for subsequent analysis of halogens and particulates with a half-life > 8 days on a GeLi system. Spot 24 hour samples are obtained at least monthly for analysis to establish the concentrations of the short-lived radioiodines, ^{131}I - ^{135}I. Analysis of monthly composite samples are made for gross alpha emitters, and quarterly analyses of composite samples are made to establish the concentration of ^{90}Sr in particulates in the stack effluent air.

2. Building Ventilation Air Monitors

The building ventilation effluent airstream is normally released to the atmosphere from roof stacks on the reactor building, about 175' above ground level. As shown in Figure 2, the turbine building is also provided with supplementary fans, which are employed in hot weather, and which discharge to vents on the roof of the turbine building, about 120' above ground level.

A list of the building ventilation air monitors, including their manufacturers, types and principal features, is shown in Table 2. All these monitors are provided with readout and alarm, both at their location and in the control room of the affected unit, with the exception of the reactor zone ventilation

monitor, which reads out in the control room. Additional pertinent comments follow in the order of listing.

a) Reactor Zone Ventilation Monitors: Two GM detectors are installed immediately adjacent to each reactor secondary containment ventilation 6' x 6' duct, as shown in Figure 9. A similar set is located next to each refueling pool on the refueling floor. These monitors have a warning alarm at 10 mR/hr. An upscale trip from any channel, set at 100 mR/hr, will produce a signal which will shut down the ventilation of the affected unit, as well as initiate the Standby Gas Treatment System and closure of the primary containment purge and exhaust paths. Neither the operator nor the vendor could furnish a rationale for this isolation set point. Our calculations suggest that it would correspond to a concentration of about 1.3×10^{-2} $\mu Ci/cm^3$ (for an effective energy of 1 MeV), or to a release rate of about 1.3 Ci/sec (10 times Technical Specifications).

b) Plant Ventilation Monitors: The plant ventilation monitoring systems were selected by the operator, who acted as A & E for the station. It consists of several subsystems. As indicated in Figure 2, for each reactor there is a monitor which collects a composite sample of the normal ventilation exhaust of the reactor zone, refueling zone and turbine building. One of these monitors is shown in Figure 10, in which the joining of the sample lines from the three zones is apparent. Flows are split and orifices sized so that sampling from each vent is isokinetic. Another monitor obtains a composite of the upper air near the roof vents in the turbine building of each reactor. These vents are utilized only in hot weather. A characteristic installation, showing the manifolding of sample lines from several roof vents, is shown in Figure 11. Another individual ventilation monitor is provided for the radwaste building.

All of the plant ventilation monitors consist of identical cart-mounted room air monitors, adapted for in-line sampling. Each includes a fixed particulate filter with associated 2" diameter beta scintillation detector, a halogen collecting charcoal cartridge viewed by a 2" x 1" sodium iodide detector, and a gas monitor consisting of a 5/8" diameter GM tube with a 30 mg/cm^2 wall, in a 900 cm^3 volume and 3" thick lead shield.

The alarm levels of <u>each</u> ventilation effluent monitor (including the radwaste building) are set as follows:

Gaseous Activity - 0.013 Ci/sec (10% of Tech. Spec.)

Particulate Activity - 0.066 μCi/sec (20% of Tech. Spec.)

Iodine Activity - 0.066 μCi/sec (20% of Tech. Spec.)

As indicated previously, none of these monitors have an isolation function.

At the present time, the plant operator utilizes the vendor's calibration factor for the gaseous channel of these units. An initial independent calibration of the particulate and iodine channels was made by the plant operator. The particulate channels of the several monitors averaged 15% lower efficiency than that specified by the vendor, and the iodine channel a 10% lower efficiency (for ^{131}I). An independent verification of the sensitivity of the gas channel is planned. All channels are checked at least quarterly against several solid disc sources.

These constant air monitors were originally supplied with a moving tape particulate collector (Nuclear Measurements Corporation Model AM331F). They have subsequently been modified to a fixed filter arrangement due to excessive in-leakage (now corresponding to NMC Model AM221F). Problems were also experienced with sticking check sources, as well as in-leakage through the source channel. To remedy this, the shield opening for the source was

plugged and the source strength increased. Sampler motor failures have also been experienced on the order of once a year, but down time minimized by the interchangability of the monitors and the provision of spare units. The location of monitors on the floor of the reactor refueling level and on the turbine building necessitates long sampling lines (50-100'), as shown in Figure 12 (for the secondary containment exhaust).

3. Liquid Waste and Service Water Effluent Monitors

The liquid process, liquid waste and service water effluent monitors at the station are characteristic of most boiling water reactor installations for which the vendor (GE) has supplied the instrumentation. They consist of γ-scintillation detectors mounted in a shielded sleeve in contact with the process or discharge line. As shown in Figure 3, these are installed in the radwaste discharge line, the reactor building closed cooling system service water discharge, and the reactor heat removal service water discharges.

As is the case with on-line monitors, they are not sufficiently sensitive to detect releases in concentrations at or approaching licensed liquid effluent release limits (1×10^{-7} µCi/ml, after dilution, for unidentified isotopes), and are subject to artificial increases in background due to plate-out in the monitored lines. Planning is underway to replace them with off-line monitors in order to achieve greater sensitivity (in the order of 1×10^{-7} µCi/ml), as well as to provide a sample chamber which can readily be decontaminated.

A list of the currently installed liquid waste and service water effluent monitors, including their principal features, is shown in Table 3. Additional pertinent comments follow in the order of listing.

a) Radwaste Monitor: The radwaste monitor is installed in a shielded "pot", as shown in Figure 13. The flow rate in this discharge line is

variable between 16-150 gpm, depending on whether the discharge is to the cooling tower blowdown (50,000 gpm) or to the once through cooling discharge canal (500,000 gpm), so as to maintain the effluent concentration after dilution to $< 1 \times 10^{-7}$ μCi/ml. Releases from this system are by preanalyzed batch. A "high" alarm, corresponding to 2×10^{-4} μCi/ml, will cause termination of the discharge flow and thus assure that this effluent stream will not exceed 1×10^{-7} μCi/ml after dilution. The calibration factor for these monitors is regularly compared with the known discharge concentration from the batch analysis. Additionally, a check of the monitor's response to an external ^{137}Cs source is made at least quarterly.

b) Service Water Effluent Monitors: The reactor building closed cooling water system service water is monitored just prior to release to the condensor cooling water discharge canal. The reactor heat removal service water effluent lines are monitored just prior to their discharge to the river on which the plant is located. Each line has a γ-scintillation detector installed in a shielded sleeve, as shown in Figure 14 (for a RHRSW line). It should be noted that these monitors are not installed for the purpose of establishing the concentrations of activity in these discharge lines, but rather to provide an alarm in the event that they contain radioactivity, which would indicate a leak across a heat exchanger (from an in-plant closed system). Accordingly, they are set at a small multiple (2x - 3x) their normal background reading. They are calibrated against an external ^{137}Cs source at least quarterly. They are also compared against grab samples which are obtained weekly from the closed cooling water service water, and periodically from the reactor heat removal system (which has flow only when the reactor heat removal systems are in use).

IV. INSTRUMENTATION FOR THE ASSESSMENT OF RELEASES OF RADIOACTIVITY UNDER ACCIDENT CONDITIONS

Regulatory Guide 1.97 calls for additional accident monitoring instruments that should have ranges covering discharge concentrations above those normally encountered and which extend to maximum values that selected parameters can attain under "worst-case" conditions. These parameters include plant radioactivity release rate through identifiable release points. General guidance as to the ranges, as well as to performance criteria suitable to worst-case conditions may be found in proposed ANSI Standard N320/D4.(2)

The identifiable points of this station, from which under accident conditions unusual amounts and/or concentrations of airborne radioactivity might be released, include the plant stack and reactor building roof vents (see Figures 1 and 2). There are no installed special high-range monitors at either release point. The capabilities of the existing monitors, with regard to the concentration ranges and parameters indicated in the ANSI Guide, are set forth in Table 4.

An area atmosphere monitor is also provided for the primary containment (drywell). It is essentially comparable in range and performance to the off-line duct monitors for the reactor, refueling and turbine building ventilation. Since this monitor is located outside the primary containment, it should be accessible during an incident. The proposed ANSI Standard does not indicate criteria for liquid effluent monitors under accident conditions, and we do not see the relevance of such criteria. Accordingly, they are not considered herein in this light.

The off-gas monitoring system is provided with redundant channels. Those for the building ventilation are not, since they are not deemed essential to safety in the event of transients or accidents (Plant Final Safety Analysis Report).

To evaluate any unusual particulate or iodine releases from the stack, it would be necessary for someone to physically retrieve these samples from their location at the base of the stack and take them to the station counting room. In view of the limited range capability of the building ventilation continuous particulate and radioiodine monitors, the same would probably be true for any consequential radioiodine releases in these air effluent streams.

V. EVALUATIONS AND RECOMMENDATIONS

1. General Evaluation

General considerations, which apply to monitoring and/or sampling under both routine and abnormal conditions, include: a) Comprehensiveness (are all identifiable effluent paths included?); b) Representativeness of sample -- includes accuracy of stack or conduit flow rate measurements and capability of probes to obtain a representative sample; c) Sampler -- includes accuracy of sampler flow rate measurement and ability of monitor to collect the medium (particulate or halogen); d) Appropriateness and response of detector; e) Presentation of information; f) Reliability; g) Capability for off-line analysis of collected samples; and h) Comparability to state-of-the-art.

a) Comprehensiveness: All identifiable release locations appear to be sampled and/or monitored, with the possible exception of the decontamination room. The plant operator states that it is ventilated through a HEPA filter, and that it is not considered a significant potential source of airborne activity, since it is used only intermittently and only for small potential sources of airborne activity, which contain no gases or radioiodines. Considering the significance of the stack as a potential

release point, we note that it is not provided with continuous monitoring for particulates and radioiodines.

b) Representativeness of Samples: The off-gas and stack air flow rates are measured continuously, with indicated accuracies of ± 20% and ± 10%, respectively. All building ventilation flow rates are established on the basis of periodic measurements. Liquid waste discharges are on the basis of measured volumes and controllable pump discharge rates. Service water effluents are essentially limited on the basis of concentration. However, amounts can be estimated from these data and indicated pumping rates. Single point probes sized for isokinetic velocities at maximum flow rates are installed for all air samples. Air sampler flow rates are not varied when duct flow rates are less than maximum, such as in the heating season when building fan operation is reduced to 50% of normal. However, this appears conservative, in that it should result in overestimates of actual releases. Additionally, this should not significantly affect radiogases or radioiodine (which should be principally in a vapor phase).

Most of the ventilation air monitors are installed at locations necessitating long vertical sampling lines (see Figure 12). While this is contrary to ANSI Standard "preferred practice",(4) it does not appear practicable to install monitors adjacent to roof vents of high bay buildings. From the information accompanying the ANSI Standard and considering the flow rates and sampling line size, significant line losses of particulates would not be anticipated. However, the plant radio-chemistry group assumes a 20% line loss for particulates in their calculations of release concentrations and amounts.

With regard to radioiodine, significant line losses would not be anticipated under normal conditions, since the stack line is heat traced and the other lines entirely inside heated buildings. The plant operator indicates that possible stack sampling line losses have recently been evaluated by comparing the daily measurements of charcoal samplers installed on alternate days immediately outboard of the sampling probe (75' elevation) and at the normal location at the base of the stack. No indication of line losses of ^{131}I was found. However, a 20% line loss is assumed in the calculations of release concentrations and amounts of radioiodines throughout the plant.

c) Samplers: The off-line samplers in the post-treatment and stack gas monitors employ standard gas rotameters. The building ventilation system samplers employ a fixed orifice and magnahelic (vacuum) gauge. A proprietary filter medium is used for particulate collection, which the vendor (NMC) states has a cellulose base. The retention efficiency of this paper should be satisfactory at the face velocity employed (∿ 50 cm/sec).[5]

At the time of the site visit, the plant employed a KI loaded charcoal (Barnaby-Cheney Type 727) in a 2½" diameter x 1" deep canister for the sampling of radioiodines. A sampling flow rate of about 2.3 cfm is employed throughout the plant. This affords a residence time in the charcoal canister of 0.075 sec. This is less than the optimum residence time of 0.25 sec per two inches of bed established for similar charcoal absorbers used in ESF systems,[6] or that of 0.4 sec recommended for radioiodine sampling by a knowledgeable investigator.[7] The authors of a previous survey found that the use of continuous air monitors designed for room monitoring, for duct and stack monitoring is not uncommon at nuclear facilities.[8]

However, they observed that it may be difficult to assure the collection of a representative sample with them due to leakage of room air into sample chambers. This would be difficult to detect when these units are used as duct or stack monitors. In this instance, efforts have been made by plant personnel to suppress obvious in-leakage by the use of welded lines, the employment of O-rings on doors and the closure of the original opening for the installed check source.

d) Appropriateness and Response of Detectors: All detectors in both the on- and off-line monitors appear appropriate to their use.

e) Presentation of Information: As is customary at currently operating stations, monitoring information is presented in the control room to plant operators, or to radiation chemistry personnel at instrument locations, in units of mR/hr, cps or cpm. We note that these are not the units of direct interest in the evaluation of either release rate (in Ci/sec) or concentration ($\mu Ci/m^3$).

f) Reliability: This reliability of the isolation function of the pertinent instruments is checked on a monthly basis. The circuit of the reactor zone exhaust GM detector contains a feature whereby it would remain upscale when saturated. Thus, this monitor should be capable of performing its intended function under abnormal conditions.

All of the plant safety-related monitors are connected to the 115 Volt a-c plant preferred circuit (see Tables 1-3), which would be powered by plant standby diesel fueled motor generators, in the event of a failure of the regular power supplies, plant or out-of-plant generated. The non-safety related building ventilation monitors are connected to redundant 115V a-c instrument and control busses. These do not derive power from the plant diesel motor generators.

g) Capability of Off-Line Analysis: The plant has a well equipped counting room with a modern Ge-Li system, including two 4096 channel multichannel analyzers and a programmable calculator (HP-9830). The recommendations of Regulatory Guide 1.21[9] on quality control are implemented, including the making of monthly cross-checks with the operator's central environmental laboratory.

The operator's counting room staff consists of seven authorized positions for supervised technicians (with a minimum of high school laboratory experience) and seven authorized positions for unsupervised technicians (with a minimum of 18 months training, including 3 months of "in plant" experience). There is one experienced Laboratory Foreman, two engineers (with a degree or equivalent experience), and a plant Chemical Engineer who must have a degree and at least one year of power reactor experience.

h) Comparability to "State-of-the-Art": The effluent monitoring instrumentation at the plant appears generally comparable to current development of what is commercially available.

2. Specific Evaluation

a) Capability Under Accident Conditions: As is apparent from Table 4, the capability of installed air effluent monitoring instrumentation at the plant is limited to relatively small excesses, above the concentrations normally encountered. Additionally, should an incident produce a large release within the containment, since the fixed particulates and iodine filters are within the secondary containment, their retrieval could occasion a considerable exposure. Similarly, a large release to the stack, particularly through the off-gas pathway, could occasion high radiation fields in the route to retrieve the fixed filters from the second level at

the base of the stack. However, this pathway consists of a shielded, concrete duct to the mid-stack, so that although large, the potential fields would not appear to be so great as to prevent access to the filters.

The radiochemistry counting room is located next to a turbine building, about 30' from the main stream line of one of the plant units. However, there are two intervening concrete walls, each about 6' thick. Thus, the counting room should not be affected in an obvious manner by a plant accident, even a major release of activity to the primary of this nearest unit.

In the event that an incident did contaminate or otherwise disable the in-plant counting room, the nearest alternate facilities are located at the operator's environmental laboratory, about 30 miles distant. This would necessitate a several hour turnaround time in the event that samples could not be analyzed on-site.

b) Sampling for Radioiodines: It has been previously noted that the residence time in the charcoal canisters, at the typical sampling rate of 2.3 cfm employed at the plant, is less than that generally recommended. However, this does not appear to occasion significant sampling losses under routine monitoring conditions. A review of some of the literature suggests that this recommendation is intended principally to assure > 90% retention of methyl iodide by impregnated charcoals under conditions of high temperature and high relative humidity.[10]

3. Recommendations

Although the radioactivity monitoring instrumentation and practices at this station appear adequate for routine effluent evaluations, we find several respects in which they could be improved. We also recommend the provision of

additional instrumentation with a high range capability appropriate to those which might be encountered during an accident. There are also some respects in which the ability of the station monitoring practices to provide information under accident conditions could be enhanced.

Our recommendations, with regard to routine monitoring are:

a) Stack Monitoring: Considering the importance of the stack as a potential release point, especially in the event of the malfunction of the gaseous waste or the standby gas treatment systems, it should be provided with continuous on-line particulate and radioiodine monitors.

b) Sampling Line Losses: Although the plant radiochemistry group appears to have taken a conservative position with regard to sampling line losses, it is not based on empirical data (aside from one comparison for radioiodine at the stack). In the literature, we have encountered a study made at a pressurized water reactor in which one set of particulate and charcoal filters was placed at the stack and another 66' downstream in a 2" sampling line, at a flow rate of 1 cfm. For a weekly sample, the line losses were: Gross Beta 46%, ^{58}Co 40%, and ^{131}I 74%.[11] This suggests that an assumed line "loss" factor of 20% may not be sufficiently conservative. It appears that most of the ^{131}I in a BWR stack effluent should be in the form of methyl iodide, with a low deposition velocity (particularly at a BWR with an advanced off-gas treatment system). However, most of the radioiodine in the building ventilation should be in the elemental form,[12] which would be most prone to line losses. Since long sampling lines are more the rule than the exception at operating nuclear power stations, we recommend that a general study of such losses be made so as to better define their extent under various plant operating conditions.

c) Samplers and Sampling Media: The indicated flow rates of off-line air samplers should be checked periodically (once or twice a year) against an integrating volume meter.

The efficiency of the type of charcoal adsorbers employed at this plant at the time of our site visit, for residence times comparable to or less than those in use, has been questioned by NRC.[13] We have been advised more recently that the plant has changed to the SAI CP-100 iodine filter. The vendor claims that this filter will maintain high collection efficiency, even at high flow rates (small residence times). We are informed that this is accomplished by the use of a finer grain size than has been customary heretofore (40-50 mesh vs. 8-16 mesh). We also note that another vendor, Hi-Q Products Company, can supply standard size (2½" x 1") iodine sampling cartridges in both the heretofore customary grain size (8-16 mesh) and in a fine grain size (40-50 mesh). Both the SAI and Hi-Q cartridges are impregnated with TEDA, which is reported to be superior as an impregnant to KI, particularly for the retention of hypiodus acid.[7]

We recommend that NRC make an independent assessment of the capability of these cartridges under a range of possible flow rates, temperatures and humidities comparable with those which might occur during their use at operating stations under normal and incident conditions. Once its apparent superiority is demonstrated, the use of this type of cartridge should be required.

d) Presentation of Information: We recognize that the variable nature of calibration factors makes it impracticable for instrument vendors to provide for a direct analog readout, using hard-wired circuits, in units

of concentration ($\mu Ci/cm^3$) or release rate (Ci/sec). Nevertheless, the provision of such supplementary scales, which could be changed readily as calibration factors change, would facilitate the prompt interpretation of the approximate significance of unusual conditions. The cumbersomeness of making the conversion will be somewhat alleviated at this station when a teletype input mini-computer, which the plant operator is installing, becomes available (in May 1978) insofar as it should facilitate computation of effluent amounts by control room and/or radiochemistry personnel.

e) Reliability of Isolation Function: At many, if not most operating BWRs, the isolation of the reactor containment ventilation exhaust air stream and the activation of the standby gas treatment system depends on a signal from a GM detector mounted on the wall of the exhaust duct. Such a detector would be responding principally to an increase in the concentration of radiogases, even though the radioiodines are of principal concern. Since the concentrations of noble gases and radioiodine in exhaust air may show great relative differences, for example between steam and water leakages of the coolant[7] the addition of an iodine monitor with alarm activation of the isolation and standby gas treatment system is recommended.

f) Comparability to "State-of-the-Art": Effluent monitoring systems featuring distributed micro-processor generated data and digital displays are now becoming available.[14] With such a system, data on the rate of collection and total accumulated activity for "flow through" streams (gaseous or liquid) or of accumulation rate and rate of change for integrated samples (particulates and ^{131}I) are stored in the micro-processor memory. Such data may be readily compared to preset activity levels with fail-safe, warning and high-level alarms. These systems offer much greater

flexibility than conventional analog systems, as well as having an ability to display a variety of data in a readily comprehensive form. Their mandatory utilization in future nuclear power stations is recommended.

g) Capability Under Accident Conditions: To facilitate the expeditious evaluation of abnormal concentrations and/or amounts, high range continuous monitors for both radiogases and radioiodines should be provided for the containment, the stack, and for the reactor building ventilation duct. We note that the proposed ANSI Guide calls only for the continuous monitoring of radiogases in high concentrations, but find it deficient in this respect in view of the significance of releases of radioiodines. These monitors need not operate continuously, but could be activated by the high level alarms of routine monitors, as long as their availability when needed was assured by regular function checks.

An elementary standby counting facility should be provided for the expeditious evaluation of effluent samples (particularly for radioiodines) in the event that the counting room became grossly contaminated or otherwise disabled. This station is provided with a whole body counter, which is located in an adjacent parking lot. It should be adaptable for this purpose. Such an effort should include the provision of an assured power supply.

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TABLE 1

Nuclear Power Station "A"
Off-Gas Treatment System and Stack Monitors

Sampled Medium	Pre-Treatment Off-Gas Monitor (Figs. 4,5) Off-Line	Post-Treatment Monitor (Fig. 6) Gas	Stack Monitor and Samplers (Figs. 7,8) Gas
Detector			
Type	Ion Chamber	NaI-Scint.	NaI-Scint.
Manufacturer	GE	GE	GE
Model	237X731G1	197E844G1	197E844G1
Ratemeter			
Type	LRM Linear	LRM	LRM
Manufacturer	GE GE	GE	GE
No. of Channels	1 1	2	2
System Sensitivity*	1.0 mR/hr = 56 μCi/sec	6.45 cps/μCi/sec	0.084 cps/μCi/sec
Accuracy	± 20%	N.A.	N.A.
Power Supply	Plant Preferred	Plant Preferred	Plant Preferred
Readout Range	$1-10^6$ mR/hr	$10^{-1} - 10^6$ cps	$10^{-1} - 10^6$ cps
Background	75 mR/hr	< 0.1 mR/hr	< 0.1 mR/hr
Alarm Set Points			
High	2,500 mR/hr($1.4x10^5$ μCi/sec)	$4.7x10^4$ cps(7,300 μCi/sec) 0.5% Tech. Spec.	$1.23x10^4$ cps(0.146 Ci/sec) 10% Tech. Spec.
High-High	5,000 mR/hr($2.8x10^5$ μCi/sec)	$1.4x10^5$ cps($2.19x10^4$μCi/sec) 1.5% Tech. Spec.	$2.45x10^4$ cps(0.292 Ci/sec) 20% Tech. Spec.
High-High-High	-- --	$9.4x10^5$ cps(0.146 Ci/sec) 10% Tech. Spec.	-- --
Isolation Function	None	Off-Gas System	None
Maximum Detectable Release Rate	56 Ci/sec	0.155 Ci/sec	0.73 Ci/sec
Sampler			
Manufacturer	None	Metal Bellows	Gast
Model	(ΔP-to SJAE inlet)	MB-21	2056V2
Flow Rate	0.7 SCFM	0.11 SCFM	2.3 SCFM
Accuracy	--	N.A.	N.A.
Meas. Method	Rotameter	Rotameter	Rotameter
Power Supply	--	Plant Preferred	Plant Preferred
Sample Line			
Size	4"	1"	1"
Length	30'	50'	75'
Material	SS	SS	SS
Ambient Condition	Building	Building	Heated (110-134°F)
Sampling Medium			Paper Charcoal
Manufacturer	None	None	NMC CESCO
Type	--	--	GVB 8170SC727
Residence Time	--	--	0.075 sec
Stack/Duct			
Flow Rate	60 cfm	60 cfm	24,828 cfm
Meas. Method	Hot Wire	N.A.	Pitot
Accuracy	± 20%	N.A.	N.A.

*Data supplied by plant operator, based on actual off-gas mixtures.

TABLE 2

Nuclear Power Station "A"

Building Ventilation Air Effluent Monitors
(Gaseous, Particulate and Iodine)

Sampled Medium	Reactor Zone Exhaust (Fig. 9) On-Line	Reactor, Refueling & Turbine Bldgs. (Fig. 10) Gas	Particulate	Iodine	Turbine Building (Fig. 11) Gas	Particulate	Iodine	Exhaust Gas	Particulate	Iodine
Detector										
Type	GM	GM	β-Scint.	NaI	GM	β-Scint.	NaI	GM	β-Scint.	NaI
Manufacturer	GE	NMC	NMC	NMC	NMC	NMC	NMC	NMC	NMC	NMC
Model	1968927C12	912	SC-2-8	SC-2-1-8	912	SC-2-8	SC-2-1-8	912	SC-2-6	SC-2-1-8
Ratemeter										
Type	LRM	LRM	LRM	LRM	LRM	LRM	LRM	LRM	LRM	LRM
Manufacturer	GE	NMC	NMC	NMC	NMC	NMC	NMC	NMC	NMC	NMC
No. Channels	2	1	1	1	1	1	1	1	1	1
System Sensitivity*	1 mR/hr =	90 cpm =	100 cpm/hr/cfm =	10 cpm/hr/cfm =	90 cpm =	100 cpm/hr/cfm =	10 cpm/hr/cfm =	90 cpm =	100 cpm/hr/cfm =	10 cpm/hr/cfm =
Concentration	≈ 3x10⁻⁶ µCi/cm³	1x10⁻⁶ µCi/cm³	1x10⁻¹⁰ µCi/cm³	1x10⁻¹⁰ µCi/cm³	1x10⁻⁶ µCi/cm³	1x10⁻¹⁰ µCi/cm³	1x10⁻¹⁰ µCi/cm³	1x10⁻⁶ µCi/cm³	1x10⁻¹⁵ µCi/cm³	1x10⁻¹⁰ µCi/cm³
Accuracy	—	± 10%	± 10%	± 10%	± 10%	± 10%	± 10%	± 10%	± 10%	± 10%
Power Supply	Plant Preferred	← 120V Inst & Control →			← 120V Inst & Control →			← 120V Inst & Control →		
Readout Range	0.1-10³ mR/hr	10-10⁶ cpm	10-10⁶ cpm	10-10⁶ cpm	10-10⁶ cpm	10-10⁶ cpm	10-10⁶ cpm	10-10⁶ cpm	10-10⁶ cpm	10-10⁶ cpm
Background	1-7 mR/hr		0.1-0.3 mR/hr			0.1-0.3 mR/hr			0.1-0.3 mR/hr	
Alarm Set Point	100 mR/hr**	9,375 cpm	1,275 cpm/hr	128 cpm/hr	35,086 cpm	5,748 cpm/hr	519 cpm/hr	88,120 cpm	12,474 cpm/hr	1,262 cpm/hr
Equiv. Release Rate	≈ 1.3 Ci/sec	0.013 Ci/sec	0.066 µCi/sec	0.066 µCi/sec	0.013 Ci/sec	0.066 µCi/sec	0.066 µCi/sec	0.013 Ci/sec	0.066 µCi/sec	0.066 µCi/sec
% F.S.	≈ 100%	10	20	20	20	20	20			
Isolation Function	Reactor Bldg. to SBGT	None	None	None	None	None	None	None	None	None
Min. Detectable Release Rate	13 Ci/sec	1.39 Ci/sec	51.8 µCi/sec	516 µCi/sec	0.23 Ci/sec	30.7 µCi/sec	206 µCi/sec	0.149 µCi/sec	4.80 µCi/sec	47.8 µCi/sec
Sampler Mfr.	—	← Route →			← Route →			← Route →		
Model	—		NA			NA			NA	
Flow Rate	—		2.5 SCFM			2.3 SCFM			2.3 SCFM	
Accuracy	—		±0.2 SCFM			± 0.2 SCFM			± 0.2 SCFM	
Meas. Method	—		ΔP Orifice			ΔP Orifice			ΔP Orifice	
Power Supply	—		120V-Inst & Control			120V-Inst & Control			120V Inst & Control	
Sample Line										
Size	—		1"			1"			1"	
Length	—		40'			≈ 100'			15'	
Material	—		SS			SS			SS	
Ambient Conditions	—		Bldg.			Bldg.			Bldg.	
Sample Medium										
Manufacturer	—	—	NMC	CESCO		NMC	CESCO		NMC	CESCO
Type	—	—	GVB-60	B170-SC-727		GVB-60	B170-SC-727		GVB-60	B170-SC-727
Res. Time (sec)	—	—	—	0.075			0.075		—	0.075
Stack/Duct										
Flow Rate (cfm)	96,944		251,853			148,869			23,373	
Meas. Method	***		***			***			***	
Accuracy	± 10%		± 10%			± 10%			± 10%	

*Reactor Zone Exhaust Monitor efficiency calculated for $\bar{E}$ = 1 MeV. Vendor's efficiency shown for particulate and iodine channels. Operator's initial calibration indicates a 15% lower efficiency for particulates and a 10% lower efficiency for radioiodine [13][1].

**Closing at 10 mR/hr

***Periodic in-duct measurement

TABLE 3

Nuclear Power Station "A"
Liquid Waste and Service Water Effluent Monitors

Location	Radwaste (Fig. 13) On-Line	Reactor Building Closed Cooling Water Service Water On-Line	Reactor Heat Removal Fig. 14 Service Water On-Line
Detector			
Type	γ-Scint	γ-Scint.	γ-Scint.
Manufacturer	GE	GE	GE
Model	117B1681G1	117B1681G1	117B1681G1
Ratemeter			
Type	LRM	LRM	LRM
Manufacturer	GE	GE	GE
No. Channels	1	1	1
System Sensitivity*	10 cps =	10 cps =	10 cps =
Concentration	$2x10^{-6}$ μCi/ml	$1x10^{-6}$ μCi/ml	$1x10^{-6}$ μCi/ml
Accuracy	± 10%	± 10%	± 10%
Power Supply	Plant Preferred	Plant Preferred	Plant Preferred
Readout Range	$10^{-1} - 10^{6}$ cps	$10^{-1} - 10^{6}$ cps	$10^{-1} - 10^{6}$ cps
Background	< 0.1 mR/hr	< 0.1 mR/hr	< 0.1 mR/hr
Alarm Set Point			
High	2000 cps=($2x10^{-4}$μCi/ml)	130 cps ($1.3x10^{-5}$ μCi/ml)	100 cps ($1.6x10^{-5}$ μCi/ml)
$High^2$		195 cps ($2.0x10^{-5}$ μCi/ml)	150 cps ($1.5x10^{-5}$ μCi/ml)
Isolation Function	Discharge Flow	None	None
Maximum Detectable Release Concentration	$2x10^{-1}$ μCi/ml	$2x10^{-1}$ μCi/ml	$2x10^{-1}$ μCi/ml
Line Flow Rate	24-80 gpm	2,500 gpm/unit	20,000 gpm/unit**

* Typical sensitivity, which plant radiochemistry group states is relatively invariant for nuclides normally encountered.

** Maximum

TABLE 4

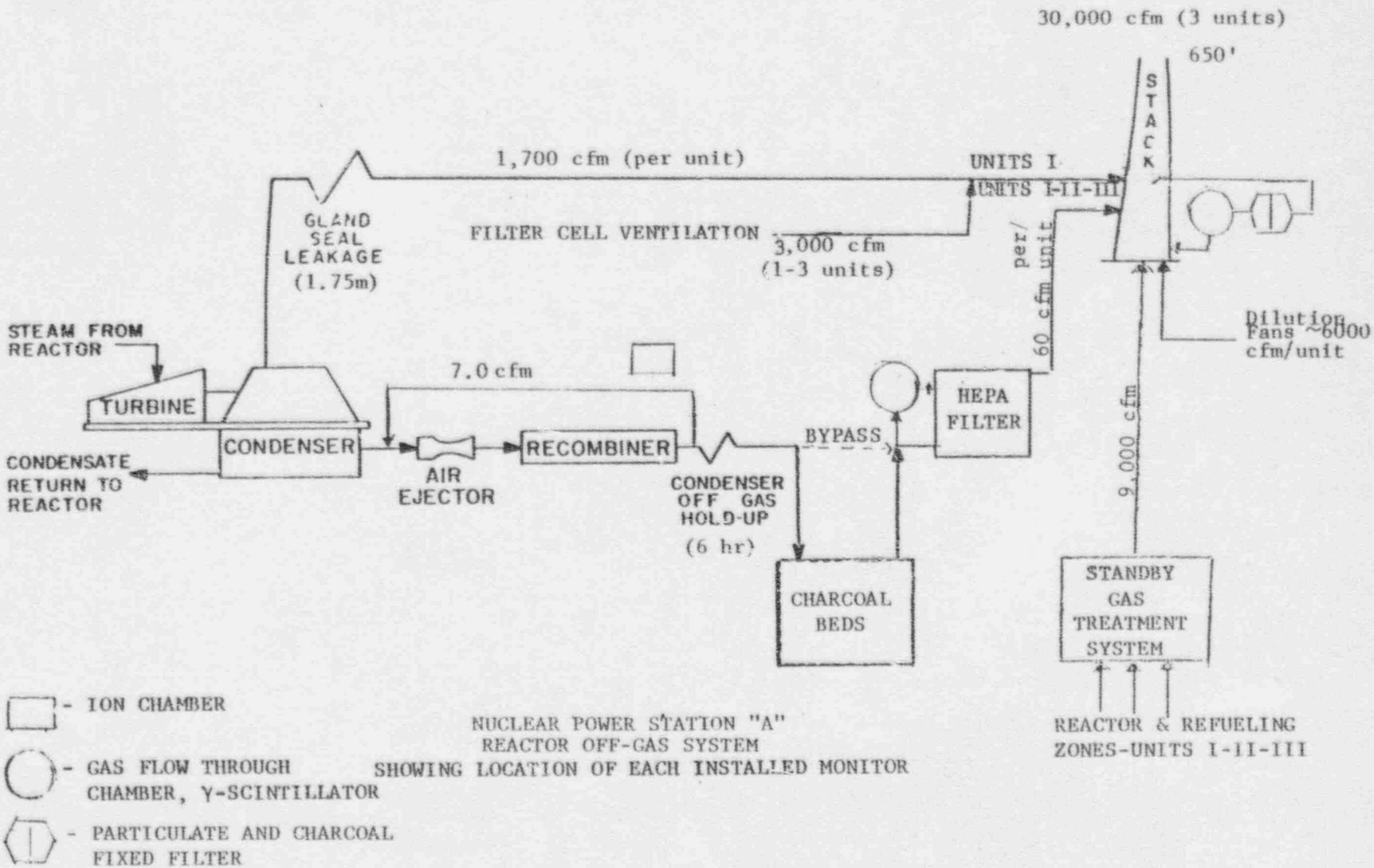
Nuclear Power Station "A"

Air Effluent Monitors at Identifiable Release Points:
Comparison of Range and Performance with ANSI N13/42 WG6 Standards

Location: Sampled Medium	Stack: Gas	Stack: Particulate	Stack: Iodine	Reactor, Refueling and Turbine Building: Gas	Reactor, Refueling and Turbine Building: Particulate	Reactor, Refueling and Turbine Building: Iodine
Type	Na-I	Fixed	Fixed	GM	β-Scint.	Na-I
Range (Conc-Ci/m^3)						
Inst. Lower	1×10^{-7}	-	-	1×10^{-7}	3×10^{-10}	2×10^{-9}
ANSI Lower*	1×10^{-2}	1×10^{-3}	1×10^{-3}	1×10^{-2}	1×10^{-3}	1×10^{-3}
Inst. Upper	1×10^{0}	-	-	1×10^{-3}	3×10^{-5}**	2×10^{-4}**
ANSI Upper*	1×10^{5}	1×10^{4}	1×10^{4}	1×10^{5}	1×10^{4}	1×10^{4}
Time Constant (sec)						
Inst.	<0.01			0.1 @ 10^6 cpm	0.1 @ 10^6 cpm	0.1 @ 10^6 cpm
ANSI	< 3			< 3	< 3	< 3
Temp. Coeff. (%/°C)	NA					
Inst.	<0.05			0.06	0.06	0.06
ANSI				< 0.5	< 0.5	< 0.5
Operational Range Temperature (°C)						
Inst.	0 to +60				-18 to +66	
ANSI	Anticipated				Anticipated	
Relative Humidity (%)						
Inst.	20 - 98				NA	
ANSI	20 - 95				20 - 95	
Max. Pressure (psi Overpressure)						
Inst.	NA				NA	
ANSI	15				15	
Seismic Design						
Inst.	NA				NA	
ANSI		"Facility Requirement"			"Facility Requirement"	
Overload Characteristics						
Inst.	Full Upscale	Full Upscale	Full Upscale	Full Upscale	Full Upscale	Full Upscale
ANSI	Full Upscale	Full Upscale	Full Upscale	Full Upscale	Full Upscale	Full Upscale

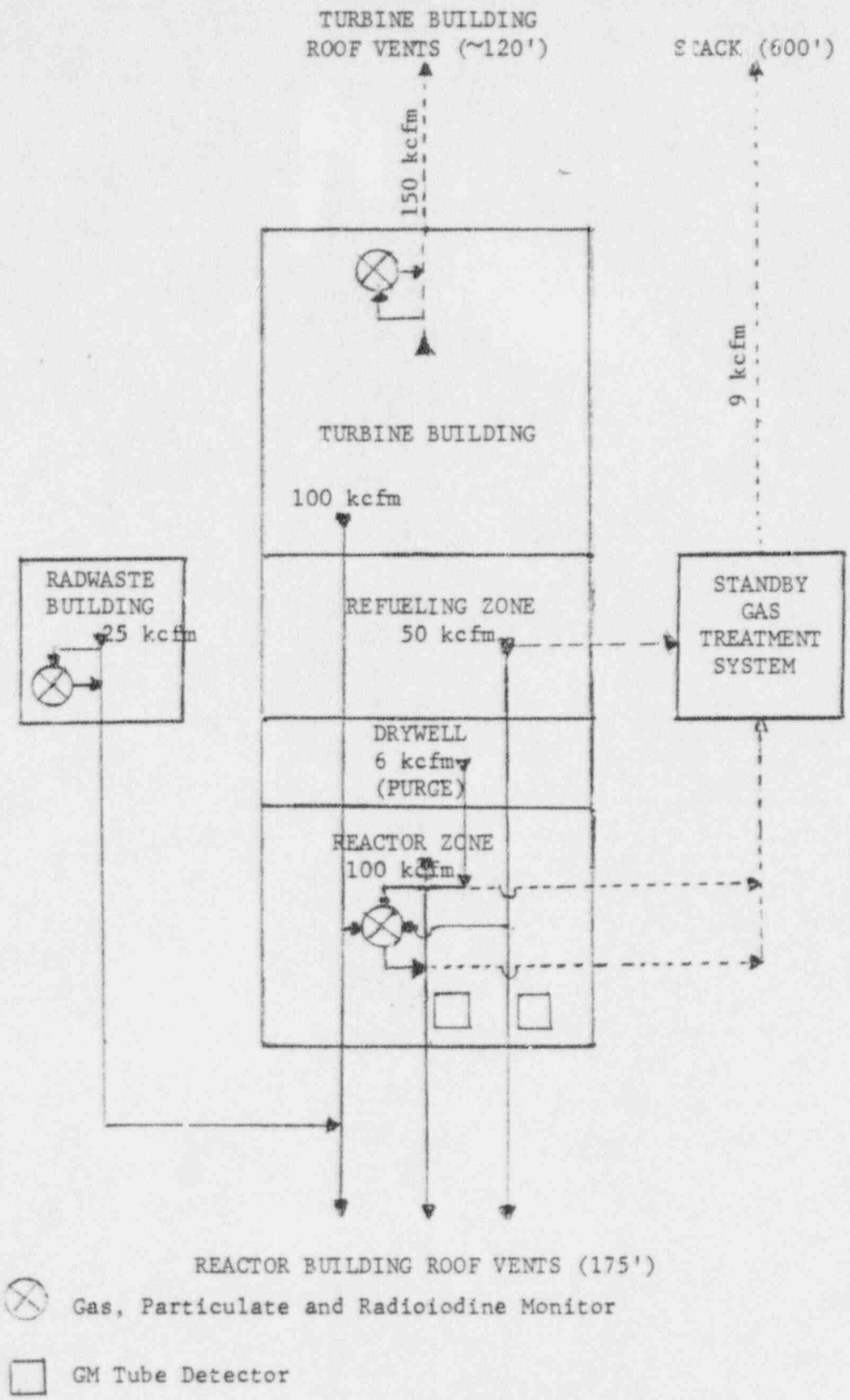
*Note: Proposed ANSI Standard N320/D5 would not require continuous monitor for particulates and/or radioiodines

**For one-minute collection time



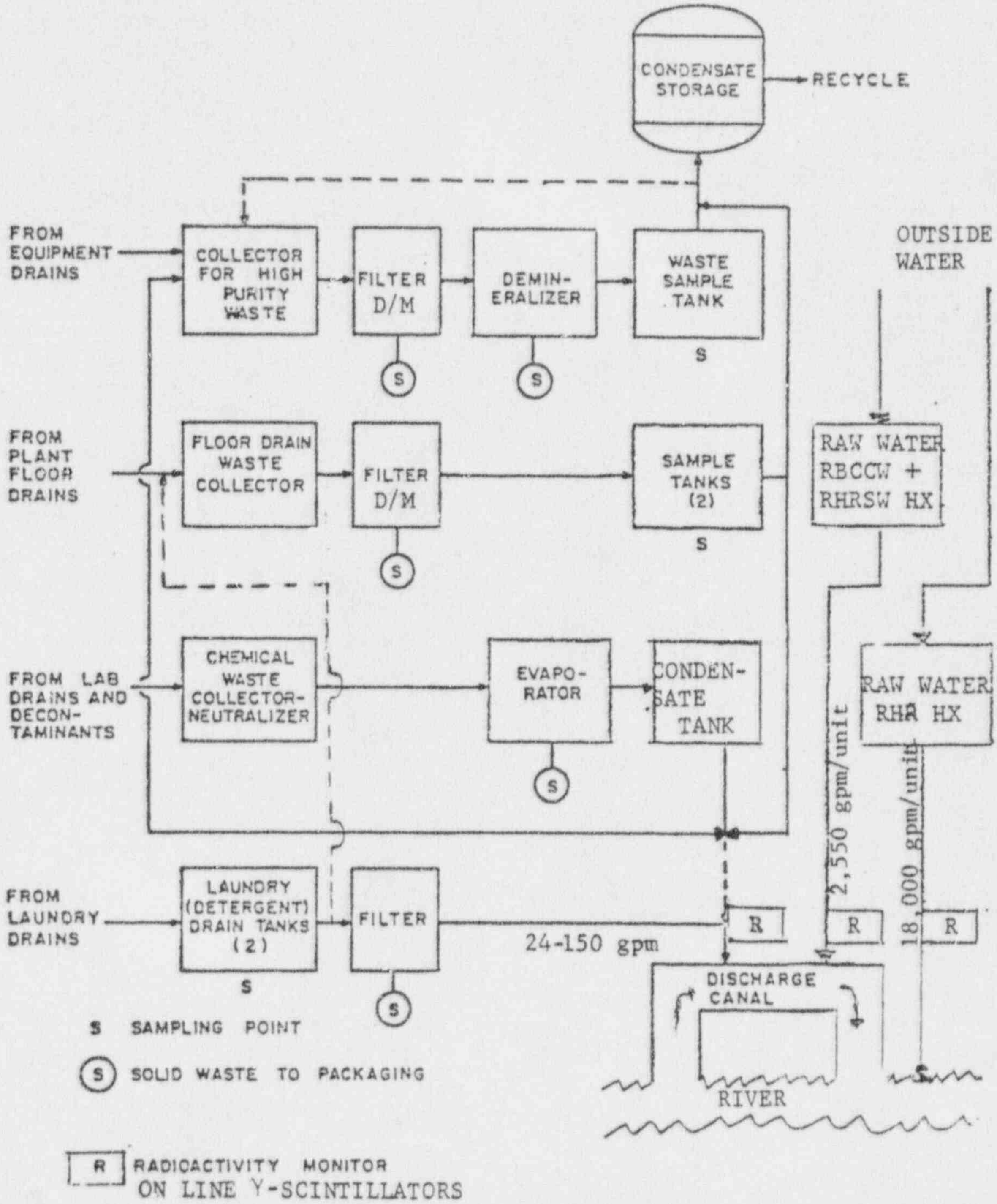
NUCLEAR POWER STATION "A"
REACTOR OFF-GAS SYSTEM
SHOWING LOCATION OF EACH INSTALLED MONITOR

Fig. 1



NUCLEAR POWER STATION "A"
REACTOR AND TURBINE BUILDING
VENTILATION AIR MONITORING SYSTEMS

Fig. 2



NUCLEAR POWER STATION "A"
LIQUID WASTE SYSTEM
(SHOWING LOCATION OF EACH INSTALLED MONITOR)

Fig. 3

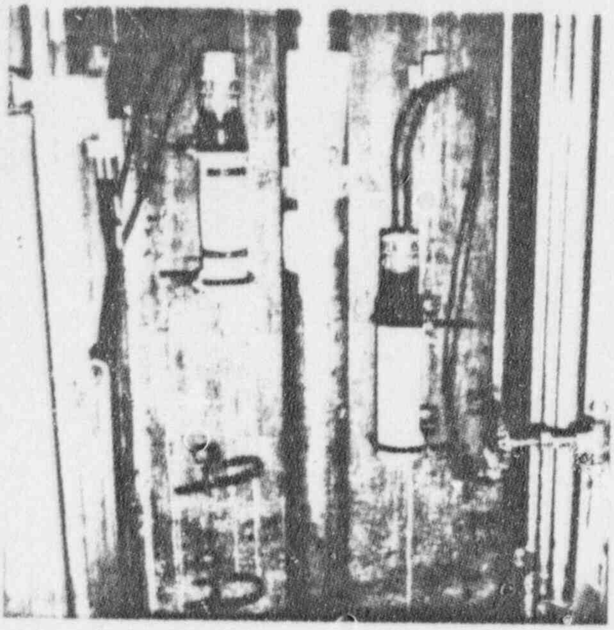


Figure 4 - Air Ejector Off-Gas Monitor

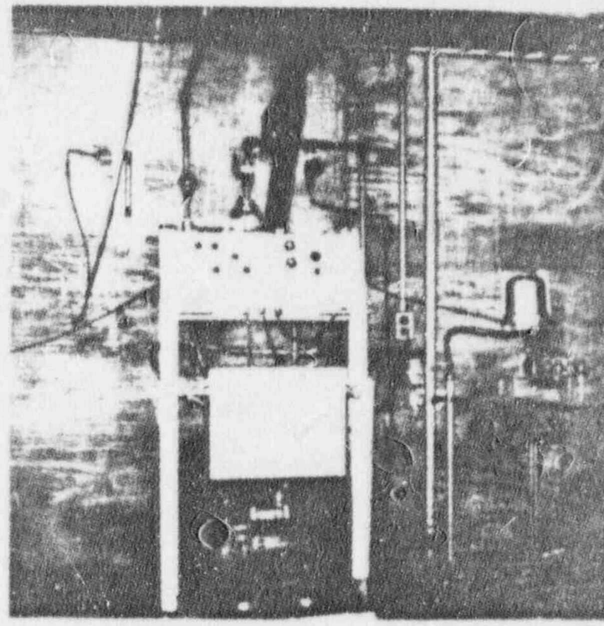


Figure 5 - Air Ejector Off-Gas Rack

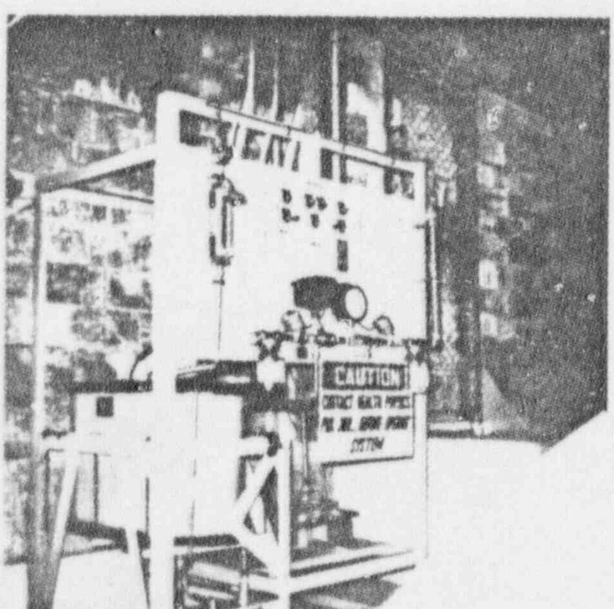


Figure 6 - Charcoal Holdup Bed Effluent Monitor

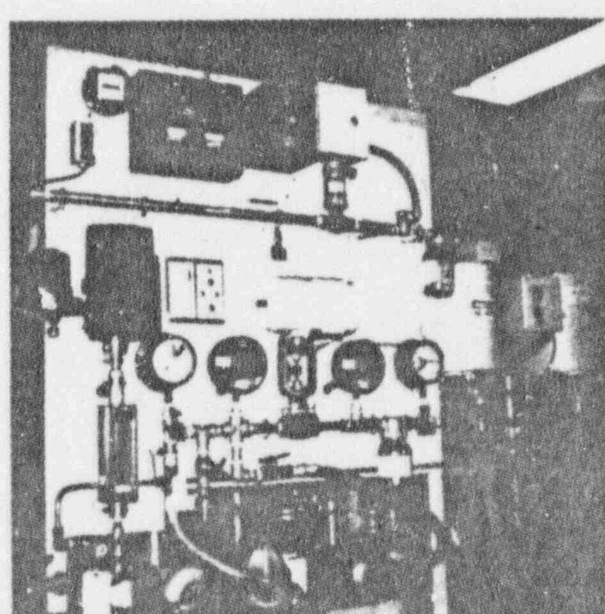


Figure 7 - Stack Radiation Monitor

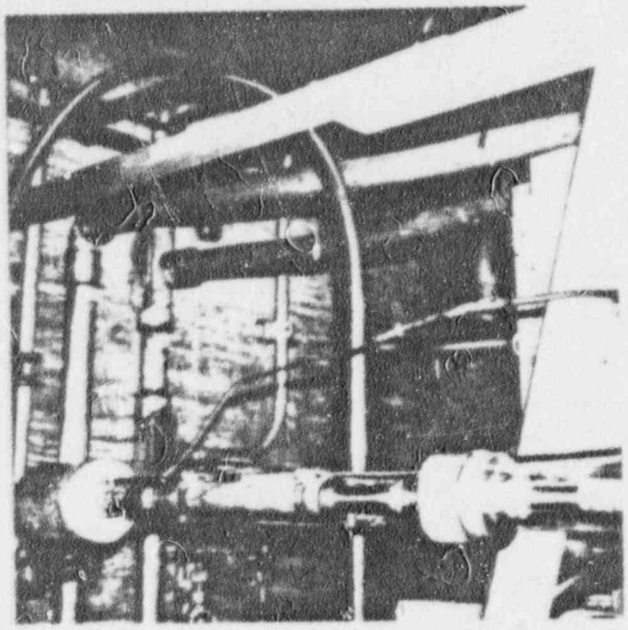


Figure 8 - Stack Halogen and Particulate Sampler Holder

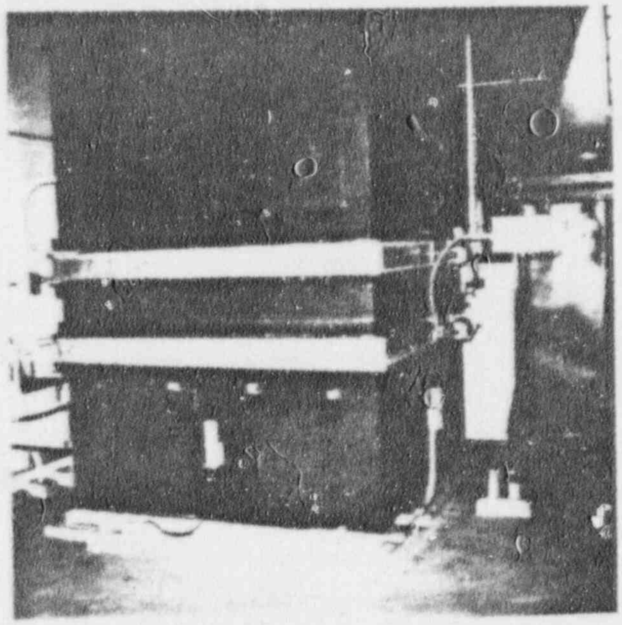


Figure 9 - Reactor Zone Ventilation Monitor

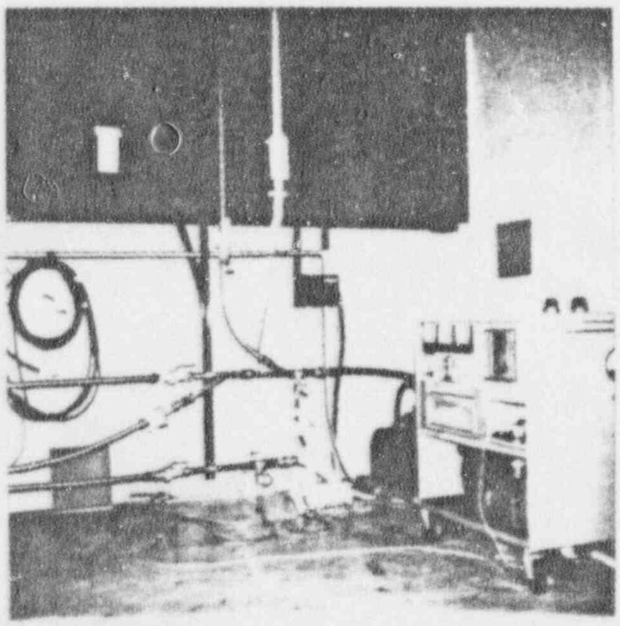


Figure 10 - Reactor Refueling and Turbine Bldg. Air Effluent Monitor

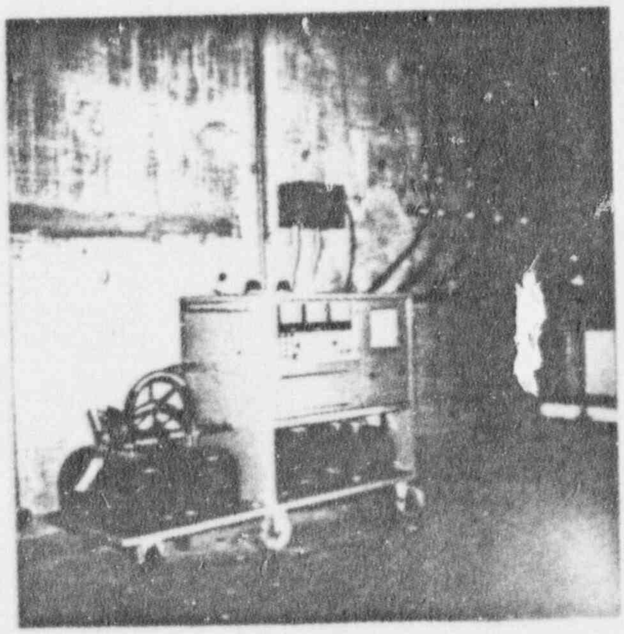


Figure 11 - Turbine Bldg. Roof Vent Monitor

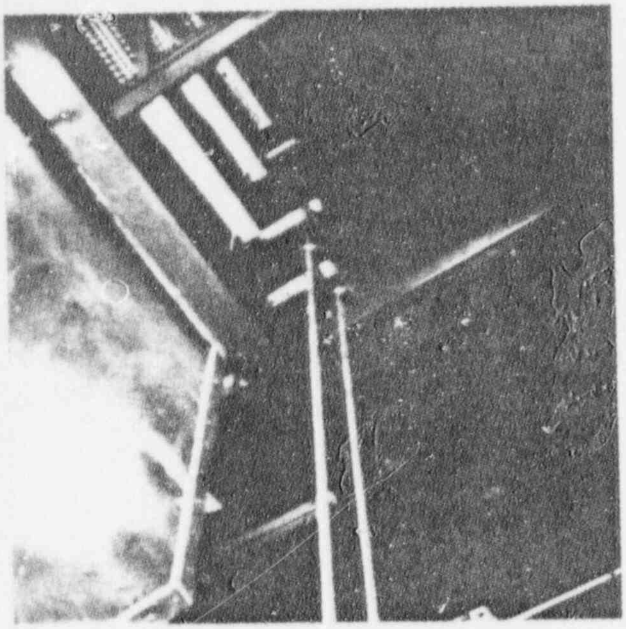


Figure 12 - Secondary Containment Exhaust Monitor Line

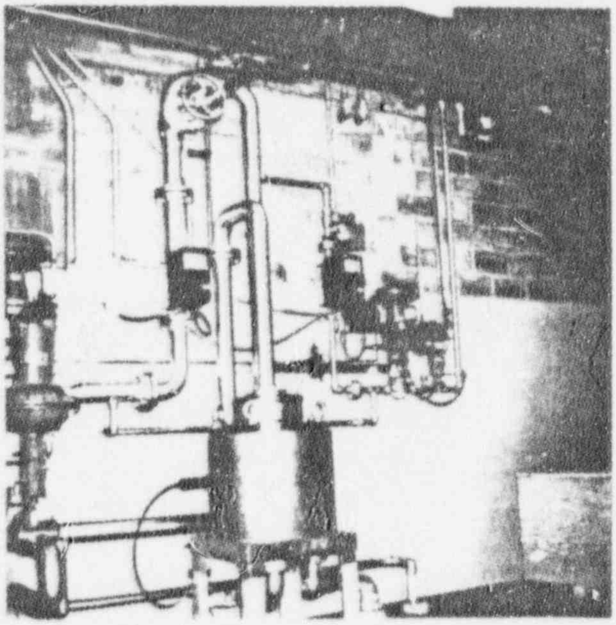


Figure 13 - Liquid Radwaste Effluent Monitor

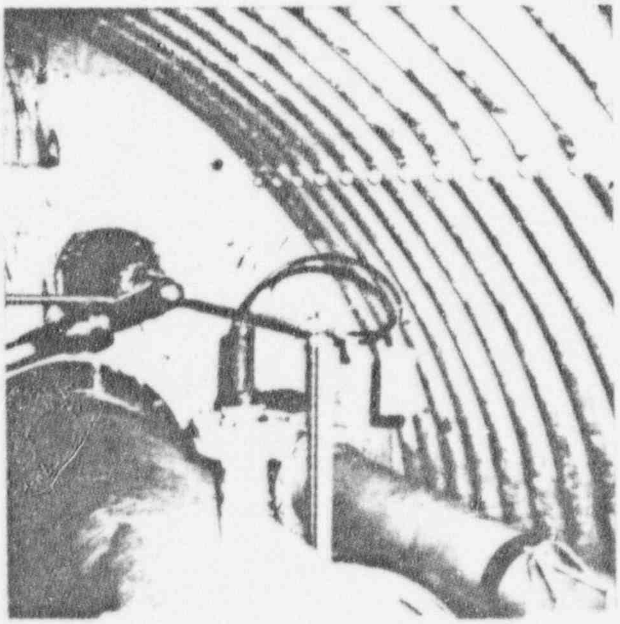


Figure 14 - RHRSW Discharge Monitor

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